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Soil Organic Matter of a Sandy Soil Influenced by Agronomy and Climate

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ABSTRACT

Long term field experiments are being conducted at Humboldt University of Berlin (Germany) to obtain information regarding sustainable management of arable land with sandy soils. In Thyrow, a location in the south of Berlin with silty and sandy soil (85 % sand, 12 % silt, 3 % clay, 0.5 % C_{org}, pH 5.5) several experiments have been–carried out since 1937. They include the study of the long-term effects of the agronomic factors of: crop rotation; organic fertilization; mineral fertilization and irrigation on soil and crops.

The results of annual C_{org} measurements make it possible to describe the influence of agronomic management and climate on the development of soil organic matter (SOM). The following ranking of agronomic factors was observed from greatest to lowest influence: Organic fertilization > crop rotation > mineral N-fertilization > irrigation. Organic fertilization with Farm Yard Manure (FYM) increases the content of Organic Carbon by 53 % compared with the control. A crop rotation consisting of cereals only leads to 34 % higher carbon contents than crop rotations including cereals and maize or potatoes respectively. Mineral nitrogen fertilization increases the C_{org} content from between 19 to 32 % but only a minor effect of 2 to 8 % was detected with irrigation treatments. At the Nutrient Deficiency Experiment Thyrow, contents of SOM have been analysed since 1965. In general, the results show a decreasing level of SOM contents with all treatments of fertilization. Over a period of 40 years the organic carbon content lost 10 to 13 % while the average air temperature rose by 1.2 °C.

Key words: Sandy soil, long-term experiments, soil organic matter, climatic change

INTRODUCTION

Soil organic matter is the most important basis for the soil fertility. It is also a sensitive indicator of different kinds of external influences on the ecosystem soil. In order to study the development of SOM contents in different soils, long-term field experiments are necessary (Körschens 2002). In sandy soils SOM shows a greater dynamic than in better-buffered soils. At the Humboldt University of Berlin (Germany) a number of long-term field experiments are being conducted to investigate the effects of agronomic factors on soil, crops and the environment. The agronomic questions include aspects of crop rotation, soil tillage, organic and mineral fertilization as well as irrigation. The results of the investigations allow a ranking of the importance of the different agronomic factors for the reproduction of soil fertility.

MATERIALS and METHODS

The experiments are being conducted in a region strongly influenced by the last ice age, approximately 15000 years ago. In this region about 70 % of the soil is typically sandy. Long-term experiments are being carried out at the experimental station Thyrow, 25 km south of Berlin (Ellmer et al. 2000).

The soil is sand that is low in silt with 83 % sand, 14 % silt and only 3 % clay. There is a low usable field capacity and the soil fertility status is also low (Ellmer and Baumecker 2005). The climatic conditions are limited by mean precipitations (Tab. 1).

Table 1. Site characteristics of Thyrow

Parameter	**Data**
Usable field capacity	11 mm dm^{-1}
pH value	5,4 … 5,8
C_{org}	5500 … 6000 mg kg^{-1}
P	56 … 80 mg kg^{-1}
K	60 … 90 mg kg^{-1}
Mean precipitation	495 mm
Mean air temperature	8,9 °C

This paper will present the current results from the long-term experiments in the agronomic factors of crop rotation, organic fertilization, mineral N-fertilization and irrigation.

Crop Rotation

In 1976 the Static Crop Rotation Experiment was established. The aim of this experiment is to investigate the effects of increasing the concentrations of cereals in the rotation on the soil status and the yield development. In three different crop rotations the cereal concentration increases from 50 %, 75 % up to 100 % (Tab. 2).

Table 2. Treatments of the Static Crop Rotation Experiment Thyrow (1976)

Cereals concentration in crop rotation		
50 % cereals	**75 % cereals**	**100 % cereals**
Potatoes	Silage maize	Oats
Winter rye	Spring barley	Winter rye
Silage maize	Winter rye	Winter barley
Spring barley	Winter rye	Spring barley

Organic and Mineral Fertilization

The important international trial The Static Nutrient Deficiency Experiment, which was established in 1937, is being carried out at Thyrow. Here the effects of organic fertilization using FYM as well as mineral fertilization, are being investigated (Tab. 3).

Table 3. Selected treatments of the Static Nutrient Deficiency Experiment Thyrow (1937)

Number	Treatments
1	Control (unfertilised)
2	FYM (15 t ha^{-1} a^{-1})
3	FYM + NPK + Lime
4	NPK + Lime

Along with a permanent unfertilised treatment there is a variant with 30 t ha^{-1} FYM in every second year. The third treatment includes additional mineral fertilization with 60 (spring barley) or 90 kg ha^{-1} N (potatoes, silage maize), 24 kg ha^{-1} P and 100 kg ha^{-1} K. The fourth treatment is the exclusive mineral fertilization.

Mineral N Fertilization

The effect of mineral N fertilization can be quantified in the Static Soil Fertility Experiment which was established in 1938. In this experiment, different treatments of organic fertilization are investigated with and without mineral N fertilization, in that case 120 kg ha^{-1} (Tab. 4).

Table 4. Selected treatments of Static Soil Fertility Experiment Thyrow (1938)

Number	Treatments
1	PK
2	PK + 120 kg ha^{-1} N
3	FYM + PK
4	FYM + PK + 120 kg ha^{-1} N

Irrigation

The only long-term experiment in Germany involving irrigation is at Thyrow and this was established in 1969. This experiment is investigating the effects of permanent additional water supply on soil and crops. It is also investigating the influence of mineral fertilization in combination with irrigation on potatoes, field grass, winter rye, winter barley and oil seed crops. (Tab. 5).

Table 5. Selected treatments of the Static Fertilization and Irrigation Experiment (1969)

Unirrigated	Irrigated
0 kg ha^{-1} N	0 kg ha^{-1} N
120 kg ha^{-1} N	120 kg ha^{-1} N

In all of the above experiments the soil organic carbon content was analysed annually in autumn to a depth of 0 – 20 cm. Analyses were carried out by the method of wet burning after Springer and Klee (1955). The long-term dataset makes it possible to analyse the development of soil organic matter content over more than 40 years in relation to environmental and agronomic conditions.

Meteorological standard data are permanently collected with an automatically working measurement station nearby the experimental field.

RESULTS and DISCUSSION

Long-term agricultural field experiments are living laboratories providing opportunities for experimentation in which the effects of manipulation may be separated from other variables (Southwood 1994, Merbach and Deubel 2007). The results from long-term investigation at Humboldt-University of Berlin into soil organic carbon show that agronomic factors as well as climatic inputs are important for the increase and decrease in development.

Agronomic Effects on Soil Organic Carbon

Soil organic matter is the basis for soil formation and soil functions (Körschens et al. 1997). In the long-term experiments different effects of crop rotation, organic manure, mineral nitrogen fertilization as well as irrigation were measured.

Pure cereal cultivation from the point of view of agronomy is problematical, because at first the yields decrease. However, this cropping system is favourable for the soil organic carbon content. Without root crops or maize in the crop rotation the C_{org} content increases because of the higher amount of cereal crop and root residues (Fig. 1).

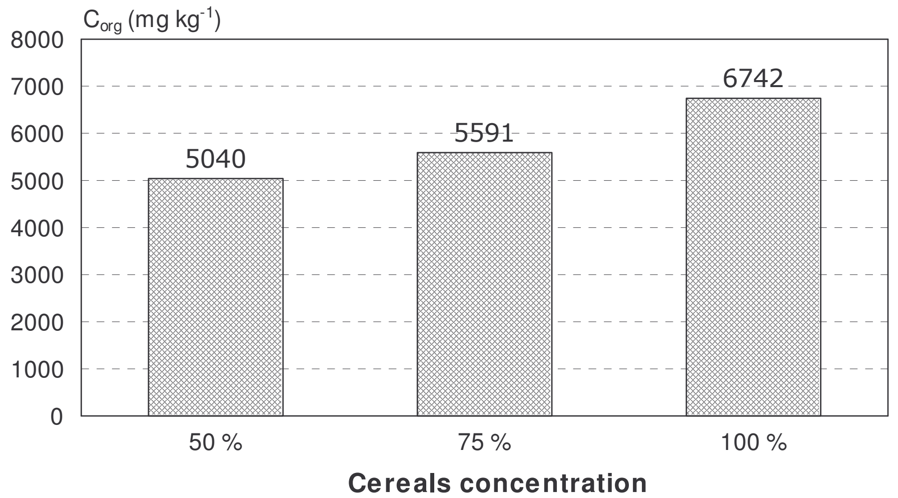

Figure 1. C_{org} content of the soil in different crop rotations with 50 %, 75 % and 100 % cereals; average 2002 - 2006

After thirty years of experimentation the C_{org} content in total cereal rotation is one third higher than in the rotation with half of the concentration.

The effects of organic manure are higher than with crop rotations. With no fertilization the SOM content shows a very low level of less than 0.37 %. Mineral fertilization with NPK and lime results in an increase of only 12 %. With organic fertilization the C_{org} content is 53 % higher than in the control treatment. In the combination treatment of mineral and organic fertilization we find the highest SOM content with 0.67 % C_{org} on average, 81 % more than in the control treatment (Fig. 2).

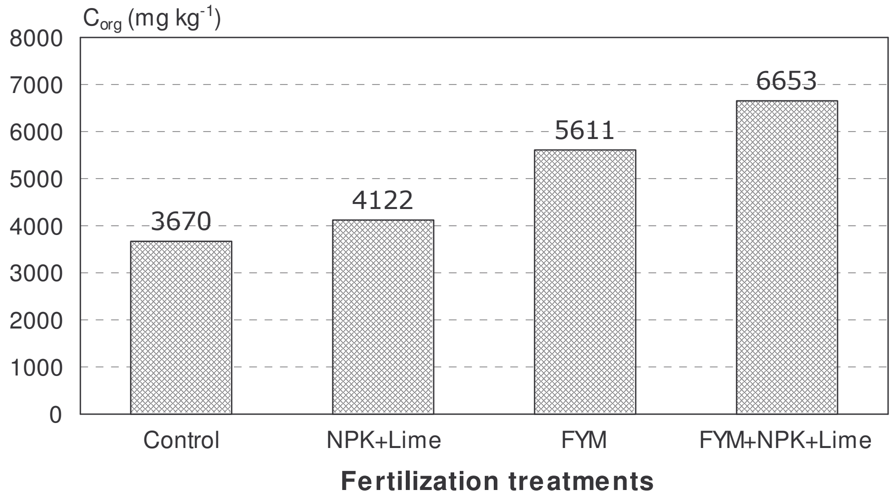

Figure 2. C_{org} content of the soil as result of different fertilization; average 2002 - 2006

These results show that for the sufficient reproduction of soil organic matter in sandy soils organic fertilization is necessary. Similar results were obtained by Zimmer et al. (2005) in a long-term experiment in sandy soil (*Albic Luvisol*) at experimental station Groß Kreuz, near Berlin. FYM fertilization (42 t ha^{-1} every third year) increased the soil organic carbon content in that case from 4370 mg kg^{-1} to 6000 mg kg^{-1}; an increase of 37 %. Under the climatic and soil conditions of Estonia, Teesalu et al. (2006) also found a significant increase in soil organic carbon content after long-term FYM fertilization in relation to mineral treatment.

With sandy soil the mineral nitrogen fertilization has a significant effect on the level of soil organic matter. In the treatment without manure 120 kg ha^{-1} mineral N resulted in an increased C_{org} content of 1031 mg kg^{-1} (+32 %). FYM without mineral N increases the C_{org} content to 5415 mg kg^{-1} (+69 %). At this level the additional mineral N fertilization has an effect of 1051 mg 1000 g^{-1}, 102 % more than in the control (Fig. 3).

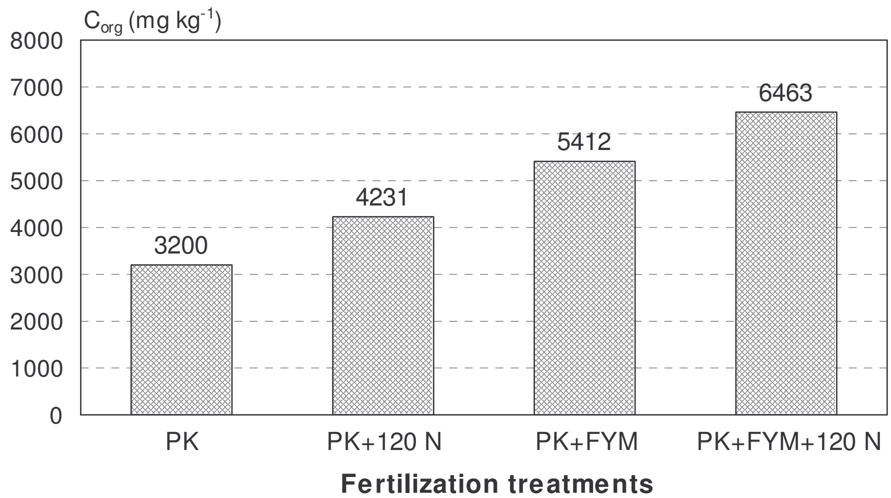

Figure 3. C_{org} content of the soil as result of different organic and mineral N fertilization; average 2002 - 2006

The increasing effect of mineral N on the C_{org} content is on the higher level of SOM content more distinct than on the lower level. Similar results were reported by Antil and Singh (2007), who, after 10 years of fertilization with 150 t ha^{-1} FYM and 150 kg ha^{-1} mineral nitrogen achieved an increase of organic C from 0.38 % up to 0,99 %.

In the long-term experiment, results show that the influence of irrigation on soil organic matter is extremely low (Fig. 4). Without mineral N a 7% increase of C_{org} content and the treatment with 120 kg ha^{-1} mineral N fertilization produced a 2% increase. Compared with this the N fertilization increased the C_{org} content by 17 % without irrigation and by 12 % with irrigation.

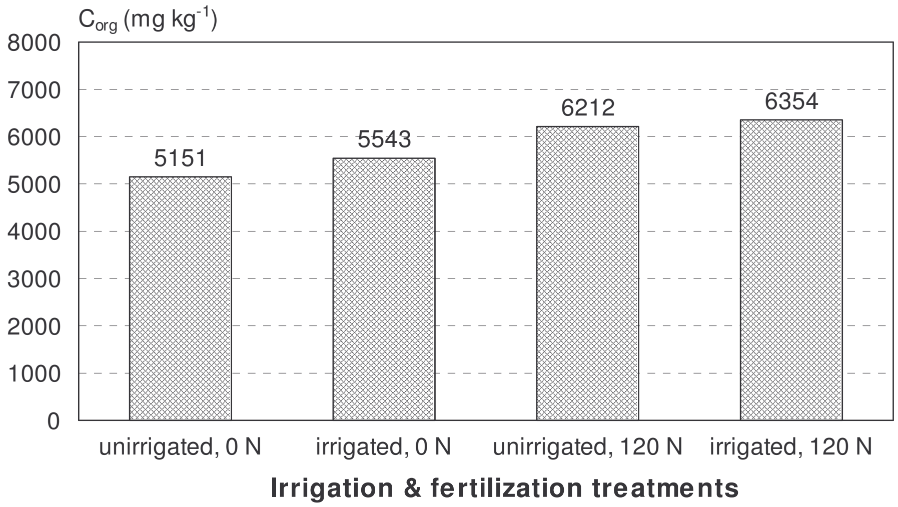

Figure 4. C_{org} content of the soil as result of irrigation and N fertilization; average 2002 – 2006

Based on the results of these four long-term experiments it is possible to deduce a ranking of agronomic factors influencing the soil organic matter content in sandy soil:
Organic fertilization (+53 %) > Crop rotation (+34 %) > Mineral N fertilization (+19 … 32 %) > Irrigation (+2 … 8 %).

Effects of Climate on Soil Organic Carbon

After four decades of experimentation the dataset can now be used to evaluate external influences on the development of SOM (Ellmer 2008). A look at the air temperature at this site shows two phenomena:

- Great variations in the mean temperature between the years with a maximum of 3.1 °C (1996 vs. 2000). The greatest variations were observed in the last decade.
- A trend of increasing mean air temperature. A simple linear regression shows an increase of 1.2 °C over the four decades (Fig. 5).

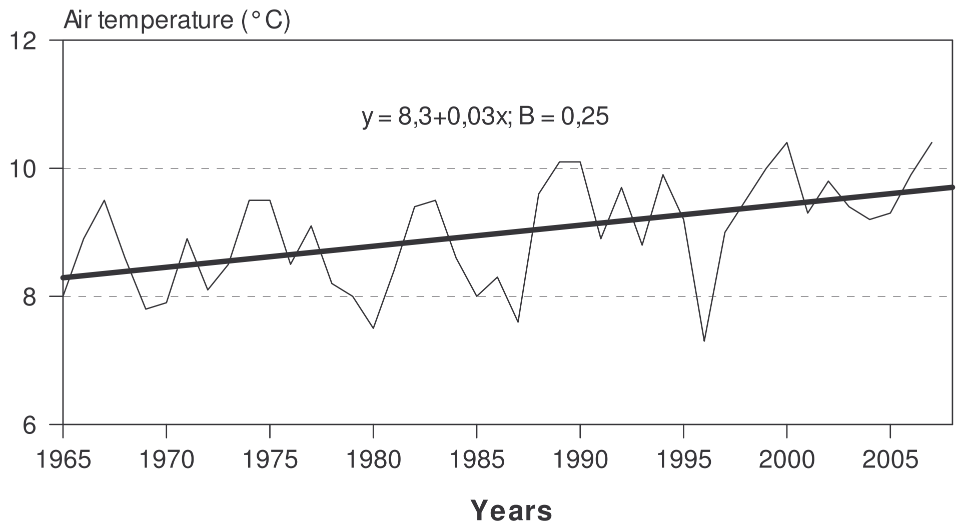

Figure 5. Development of mean air temperature at experimental station Thyrow; 1965 - 2006

More important for the dynamic of SOM is the soil temperature. It shows a similar picture:

- The variation between the years is slightly lower (maximum 2.9 °C)
- The linear trend also increased by 0.8 °C over four decades (Fig. 6).

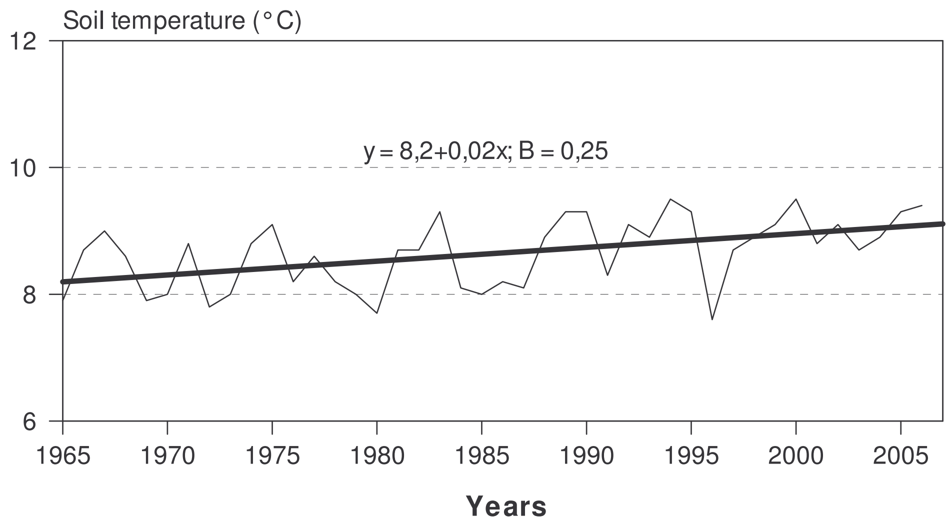

Figure 6. Development of soil temperature (10 – 20 cm) at experimental station Thyrow; 1965 - 2006

The climatic development with increasing air and soil temperatures is to be seen in connection with the development of soil organic carbon contents. In the Static Nutrient Deficiency Experiment this can be shown at two selected different treatments – mineral fertilization (NPK+lime) and organic-mineral fertilization (FYM+NPK+lime) (Fig. 7).

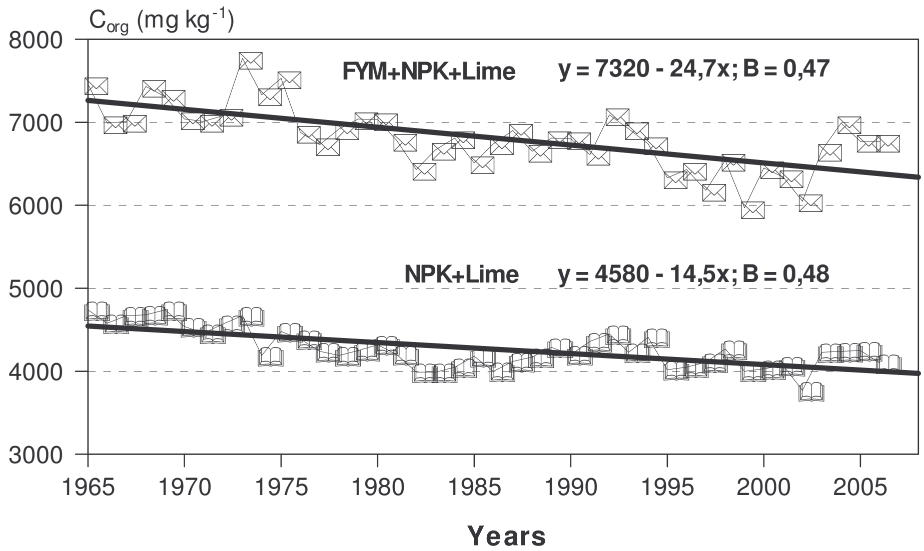

Figure 7. Development of C_{org} content in the soil in two selected treatments of the Nutrient Deficiency Experiment Thyrow

The treatment with organic and mineral fertilization over four decades results in a decreasing trend with an annual loss of about 25 mg kg^{-1} C_{org}. Over the entire period, a total loss of about 700 mg kg^{-1} was quantified. This amounts to 10 % of SOM compared to the status at the beginning of the measurements. With the other non organic fertilised treatments the results are similar. At a lower level of SOM the total loss amounts to 13 % of the initial value. Similar results were reported by Giram et al. (2007). In their long-term experiment founded in 1832 at „Magruder plots" at Oklahoma/USA they reported losses in the soil organic matter of more than 50% of the starting values. Christensen (1997) reported the same phenomena from the Askov long-term field experiments in Denmark.

These results show that soil organic carbon content is a very sensitive matter in the soil ecosystem. Its long-term development is influenced by the climatic conditions. At the investigated sandy soil it causes a negative effect on the sink function of soil for carbon. However, humus stocks and their dynamics are of special importance in connection with current environmentally relevant problems: As a sink for or a source of emissions of atmospheric carbon dioxide, which is a cause of the greenhouse effect (Reuter et al. 2007, Stevens et al. 2006).

CONCLUSIONS

1. As the most important basis of soil fertility the soil organic carbon content on sandy soils shows a distinct dynamic development over the time.
2. In arable farming organic fertilization and crop rotation have the largest effects on soil organic carbon. Mineral N fertilization is of secondary importantance and the effect of irrigation is only marginal.

3. Climatic changes have a significant influence on the organic carbon content of sandy soil. A mean increase in air temperature of 1 °C causes a decrease of carbon content of between 0.05 and 0.1 %.

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Evaluation of the Effects of Global Climate Change on Agriculture and Water Sources in the Gediz River Basin

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ABSTRACT

Global climate change is very likely to have a major impact on the hydrological cycle, and consequently on available water resources, flood and drought potentials, and agricultural productivity. As the largest user of water, the agricultural sector is expected to be affected by global climate change to an even greater extent than other sectors.

Sufficiency of water resources is generally evaluated in terms of total water potential for total population. According to this evaluation, the beginning of water stress is accepted as 1700 m^3 per capita per year. In Turkey, total water potential per capita per year was 2900 m^3 in 2000, but this value is estimated to fall to 2200 m^3 by 2025.

Rapid population growth, industrialization, and rising standards of living will decrease the annual per capita renewable water potential in Turkey, and in general, Turkey's water resources are set to decrease to critical levels. We took as an example the Gediz Basin in western Turkey, which has a total area of some 17 310 ha, and supplies water for domestic and industrial purposes. The water resources in the basin support wildlife, and are used to produce energy.

The objectives of this study are to examine the effects of global climate change on agriculture and water sources in the Gediz River Basin, to discuss the difficulties of management of the basin, and the measures which should be taken from today.

Keywords: Climate Change, water sources, irrigation, Gediz, Turkey

INTRODUCTION

Many scientists are concerned about possible climate change induced by anthropogenically caused increases in greenhouse gases. Such a climate change would have major impacts on water resources and irrigated agriculture. Predictions of climate change for the latitudes in which Turkey is situated indicate the possibility of a reduction in rainfall. Also, an analysis of rainfall data collected over many years shows a trend towards a reduction in winter precipitation, especially in the west of Turkey (Saylan and Çaldağ, 2007; Kukul et al, 2007).

The agricultural sector in Turkey is the largest consumer of water, and irrigation accounts for some 75% of water use. In 2003, the average amount of water used for agricultural purposes was 29.6 km^3 out of a total use of 40.1 km^3 of water (DSI, 2008). Sufficiency of water resources is usually evaluated in terms of water stress index. In this index, the beginning of water stress is accepted as 1700 cubic meters per capita per year. If this value decreases to 1000m^3/yr, this is called chronic water stress, and if it decreases to 500 m^3/yr, this is known as absolute water stress. In Turkey, total water potential per capita per year was 2900 m3 in the year 2000. However, this value is estimated to fall to 2200 m^3 by 2025, and by 2050 it is expected to be near the critical value (Onder and Onder, 2007). The advance of population growth, industrialisation and climate change will have their greatest effect on agriculture as the largest water user.

In this work, we consider the changes in water resources and the resulting effects on agriculture in the Gediz Basin, which is an important agricultural and industrial area in the west of Turkey.

Characteristics of the Gediz Basin

The Gediz river, at around 275 km in length, drains an area of 17 220 km^2, and flows from east to west into the Aegean Sea just north of Izmir, in western Turkey. Precipitation in the basin ranges from over 1 000 mm per year in the mountains to 500 mm per year near the Aegean coast. The total irrigated area in the basin is about 150 000 hectares (Kite et al, 2001).

Climatically the basin is ideally suited for irrigation development. During the winter months precipitation exceeds 700 mm, falling as snow at elevations above 1000 m. Since 1945, large-scale irrigation systems totaling some 105 000 ha have been constructed in the main valley. Crop production within the basin includes cotton, grapes, fruits, cereals, olives and vegetables.

The basin also serves as the source of much of the drinking water for the city of Izmir, now the third largest city in Turkey and an important harbour on the Aegean. The continuously growing metropolitan area of Izmir consumes a significant portion of the groundwater resources of the Gediz Basin (Murray-rust et al, 2003).

The hydrology of the Gediz Basin is typically Mediterranean. Precipitation falls between November and April, and peak river flows occur in February or March. After the construction of the Demirkoprü Dam and before the current drought, net annual surface water availability in the main basin and the delta is estimated to have been approximately 1 900 million $m^3 year^{-1}$. Since 1990, however, there has been a persistent decline in surface water flow into the dam, and water availability has only averaged some 940 million cubic meters (Harmancıoğlu and Onusluel, 2001). This decreasing trend in mean annual stream-flow is most likely explained by the downward trend in annual precipitation, and to some extent by a trend to an increase in temperatures. These changes in annual precipitation trends can be traced back to the 1980s (Kukul et al, 2007).

Groundwater resources are able to make up some of the potential shortfall in overall water availability. The central part of the Basin is an alluvial plain whose groundwater reserve is replenished in most years. Only during the peak of the drought, from 1991 to 1993, were there reports of declining year-to-year water tables, and these have since recovered. However, the estimated safe annual yield for groundwater in the main part of the valley is estimated to be 160 million cubic meters per year, which is about one-third less than the 219 million cubic meters estimated as being extracted from the main and Nif valleys. Despite the absence of definitive figures, it appears that groundwater use presently exceeds, by a sizeable margin, the sustainable limit (Harmancıoğlu and Onusluel, 2001; Harmancıoğlu et al, 2007).

Effects of Drought on Agricultural Irrigation in the Gediz Basin and Measures which Need to Be Taken

The river network is controlled by four main reservoirs and three regulators, which serve thirteen water users' associations (Fig 1). River flow from winter precipitation is stored in the main Demirkopru reservoir for release over the summer irrigation period.

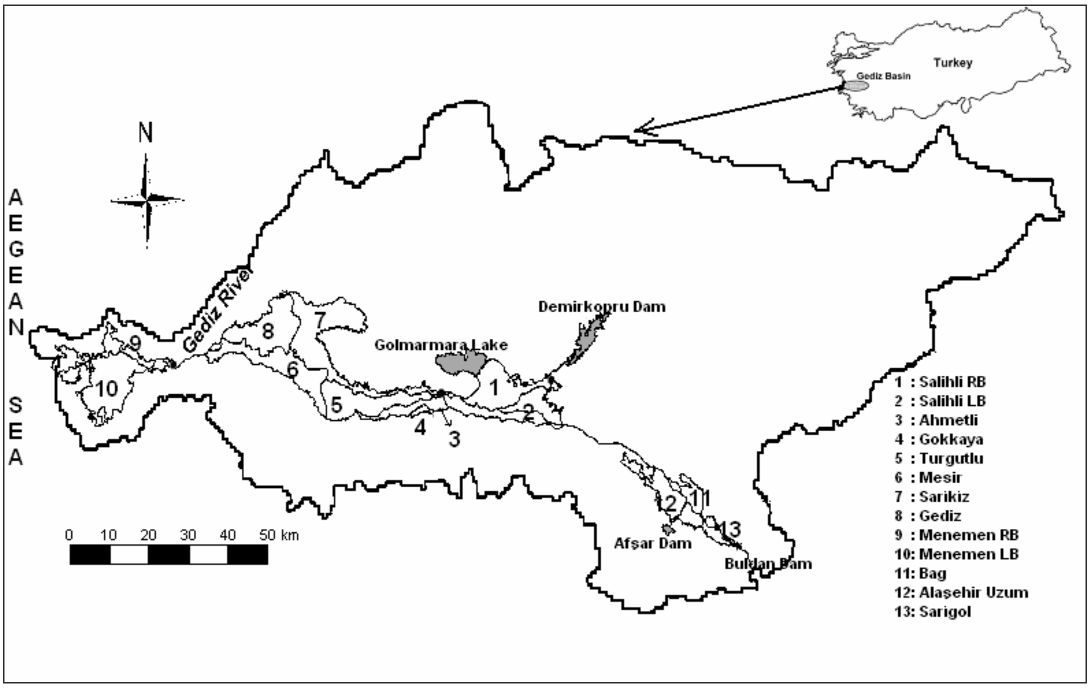

Figure 1. Gediz Basin Irrigation System

Irrigation currently uses a large share of the surface water resources of the basin (Table 1). From 1972 until 1988 there were no serious problems with water availability at basin level. The Demirkopru reservoir overflowed on several occasions, power generation continued throughout the winter months so as to maintain sufficient spare storage capacity for flood control, and irrigation water was available throughout the growing season. In 1989, however, the situation changed dramatically with the onset of a four-year drought (Turkeş, 1997). The drought had two major impacts: the start of disputes between sectors (power, irrigation, flood control, and urban and domestic supply) and the onset of significant groundwater exploitation (Murray-Rust et al, 2003). In the drought period and afterwards, the amount of water available for agriculture fell considerably (Figure 2). It can be seen from Figure 2, which shows the amounts of water diverted to the Menemen irrigation system between 1981 and 2005, that there were significant changes between before and after the drought. Figure 3 shows irrigation rates, which were very low in the drought period, but which rose again later to approach pre-drought levels. However, amounts of water supplied per unit of land area are much lower than previously. This would be expected to result in a fall in productivity, but the International

Water Management Institute (IWMI) examined the performance of the Gediz Basin irrigation systems and compared pre- and post-drought productivity, and found that in the period after the drought, productivity figures were higher, even though less water was being supplied to the system (Table 2). It was found that this increase resulted from such factors as the use of more productive crop varieties, and from the use of water from underground sources as well as from the irrigation network.

It has been pointed out in various studies of the irrigation system's performance at different levels that there are operational and structural problems in the basin: for example, water sources are insufficient and are not used efficiently, irrigation water is not distributed equitably either between irrigation systems or between users, and seepage losses are high in the systems' open canal water distribution networks.

Similar problems relating to the efficient use of water are to be found in all river basins where irrigated agriculture is practiced. In order to solve these problems, basic changes must be effected in irrigation water management. It is necessary to change from a traditional water management concept which cannot provide for measured and controlled water use, to an integrated water management concept which will maintain the sustainability of water sources and make use of water in an efficient and workable way. A management structure must be formed which takes account of the human factor, which ensures the long-term protection of water sources, which makes use of water in the most economic way without damaging the environment, and which aims at the integration of water resources.

Table 1. Estimated Water Use by Sector in the Gediz Basin (Harmancıoğlu et al, 2007).

Water User	**Estimated Consumption**		**Notes**
	[million m^3]	**Share**	
Surface Water			
Large Scale Irrigation	550	62%	From Demirkopru and Gol Marmara
	60	7%	Alasehir Valley
Small Scale Irrigation	50	6%	
Hydropower	0	-	No priority for hydropower
Bird Reserve	4	-	Current releases only; needs more
Groundwater			
Pump Irrigation Groups	30	3%	Only those outside surface irrigation area
Private Irrigators	5	1%	
Urban within the Basin	26	2%	18% of extraction, remainder is return flow
Transfer to Izmir City	108	12%	Trans-basin transfer, no return flow
Industry	50	6%	Estimated by DSI
Totals			
Annual	833	100%	
Summer (4 months)	760		

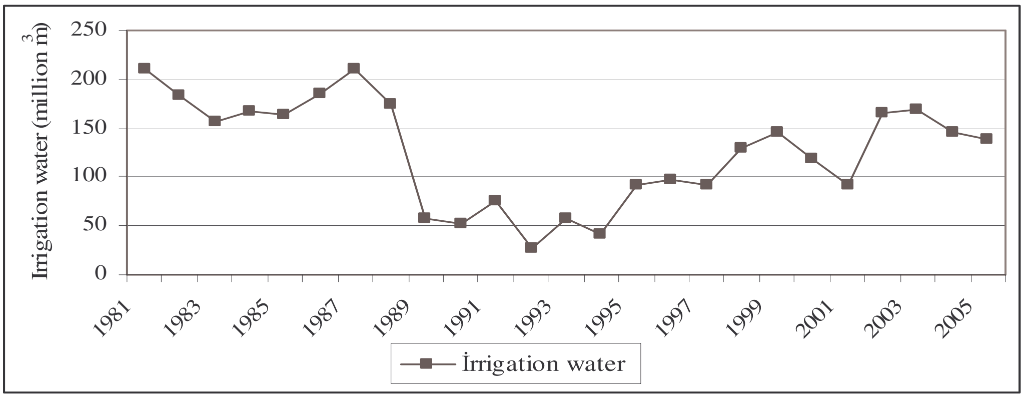

Figure 2. Amounts of Water Supplied to the Menemen Irrigation System between 1981 and 2005

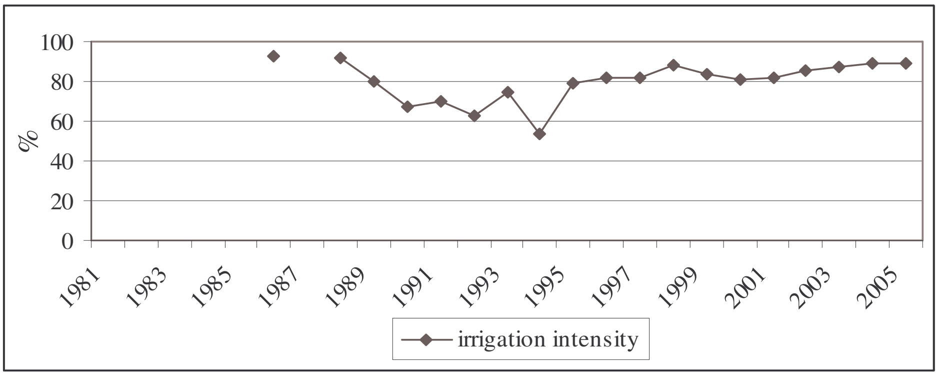

Figure 3. Irrigation Ratio in the Menemen Irrigation System for the Years 1987-2005

Table 2. Yields and Productivity of Water Before and After the Drought (KHGM-IWMI, 1999)

Year	**Average Yields (kg ha^{-1})**		**Productivity of Water**	
	Cotton	**Grapes**	**(kg m^{-3})**	**(\$ m^{-3})**
1988	2640	4830	0.42	0.29
1996	3060	5310	0.71	0.57

In the Gediz Basin, the greatest need is for a physical infrastructure which will enable more efficient use of water in the irrigation systems. Water losses and excessive use in the distribution networks must be prevented, and water must be used in a more productive way.

In order to prevent transmission losses and to achieve savings in the use of water in the basin's irrigation networks, surface irrigation methods need to be replaced by pressurised irrigation systems. This however necessitates the conversion of the current open canal distribution networks to a piped system, which is seen as difficult economically. Therefore, priority must first be placed on repair and maintenance of the open canal systems in order to prevent seepage losses, and on ensuring measured and controlled distribution of water in the networks. For this purpose, diverted water must first of all be measured and monitored in real time at main and secondary canal level. This could be achieved by a telemetric system, with such a system, irrigation associations responsible for system operation all along the Gediz River could keep a check on each other so that each association could use the water more efficiently. In this way, a self-regulating system of irrigation management would be created in the basin, and a more equitable distribution of water between systems would be possible.

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Agricultural Applications of North Dakota Agricultural Weather Network

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ABSTRACT

The North Dakota Agricultural Weather Network (NDAWN) consists of 70 automated weather stations distributed among prime agricultural locations across North Dakota, the Red River Valley, and border regions of surrounding states. The NDAWN Center is a part of the Department of Soil Science, North Dakota State University. The NDAWN stations measure wind speed and direction, air temperature, rainfall, solar radiation, pressure (32 stations), atmospheric moisture and soil temperatures under bare and turf at 10 cm (4 inch) depth. The center provides daily summaries consisting of maximums and minimums as well as time of occurrence, and various totals or averages for all variables in English or metric units. Measured and calculated variables along with complete descriptions are available. The NDAWN Center web site: http://ndawn.ndsu.nodak.edu/ allows direct access to NDAWN data in various special and temporal scales. The voice modem accommodates those who do not have internet access. The NDAWN Center has assisted many North Dakotans in making weather critical decisions concerning their crops, livestock, and livelihood. One direct benefit of NDAWN data was helping to save the 1993-94 potato crops in North Dakota. The stations provide weather data, which was instrumental in developing an agricultural model called the late blight model. This model predicts when leaf disease can occur in potato plants. Late blight doesn't occur in North Dakota every year and is prevalent during cool and moist periods of weather. In 1993-94, this model predicted that late blight would occur and growers were able to use fungicide applications to prevent the disease. Another direct benefit of NDAWN data is that it provides universities and the National Weather Service with an additional database for research and forecasting applications. Agriculture remains the number one industry in North Dakota and its success will always be dependent on the weather.

Keywords: Agricultural Weather, Automated Weather Monitoring, Agro-Climate, NDAWN , North Dakota, Weather.

INTRODUCTION

Measurement systems for agricultural applications have been implemented in many parts of the world (Sivakumar, 1994), whereas automated weather monitoring was widely published (Akyuz et. al., 2000, Snyder et. al. 1996, Sivakumar, 1994, Hubbard et al. 2000). Agriculture is the leading industry in North Dakota. Twenty-five percent of North Dakota's economic base is production

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NDAWN: North Dakota Agricultural Weather Network agriculture with close to 24% of its population employed in agriculturally related fields. The North Dakota Agricultural Weather Network (NDAWN) was developed as a valuable tool for agriculture. The primary benefit of this weather station network is to use the data to develop an array of agricultural models. The models help producers make timely decisions to keep crops healthy and increase their yield. These decisions save producers both time and money.

The NDAWN was established through a grant from, and in cooperation with, the High Plains Regional Climate Center (HPRCC) , Lincoln, Nebraska in 1989. Originally the network consisted of 6 automated weather stations located at North Dakota State University (NDSU) Research and Extension Centers. Our objective was, and still is, to provide current weather data (yesterday's data today) necessary for the development of, and operational use of various crop, insect, and disease development models. However, before agricultural models could be developed detailed hourly weather data were necessary. In the early 1990s numerous Red River Valley Potato growers and some agribusinesses associated with the potato industry were the first to invest in this venture. They collectively provided grants to purchase and operate 7 more stations in the northern Red River Valley. During the mid 1990s more stations were also added to all NDSU Research and Extension Centers and other state and federal research sites. Today there are 70 identical automated weather stations distributed throughout North Dakota and its neighboring states. Figure 1 shows the location of the stations in the network as of August 2008. Station names coincide with the nearest town and are labeled with its distance and direction from the nearest town. For example, Rolla 2S is the NDAWN weather station located 2 miles (3.2km) south of Rolla, North Dakota, USA.

Since its inception in 1989, all equipment, non-labor operational costs, and some labor costs have been funded through gifts and grants from various federal and state agencies, commodity organizations, agricultural clubs, businesses, and individuals. In addition, current web site development which allows us to disseminate these valuable data free of charge was funded through a federal agency grant. North Dakota State University funds 4 full-time employees operating the NDAWN Center; the director, a network engineer, a data manager and a computer programmer.

The stations measure air temperature, relative humidity, wind speed, wind direction, solar radiation, station air pressure at 32 stations (not adjusted to sea level), rainfall, and soil temperature under a bare soil surface and under a turf covered surface. The stations also keep track of maximum and minimum air temperature, maximum wind speed, and the times they occur. Calculated variables include potential evapotranspiration, dew point temperature, wind chill temperature, heating and cooling degree days, and numerous growing degree days. Departure from normal (1971-2000 average) temperature or rainfall data are also available. The normal temperature and precipitation values were

HPRCC: High Plains Regional Climate Center
NDSU: North Dakota State University

interpolated from National Weather Service (NWS) Cooperative stations. A complete list of variables can be seen from the following link: http://ndawn.ndsu.nodak.edu/help.html?topic=datainfo#vardefs

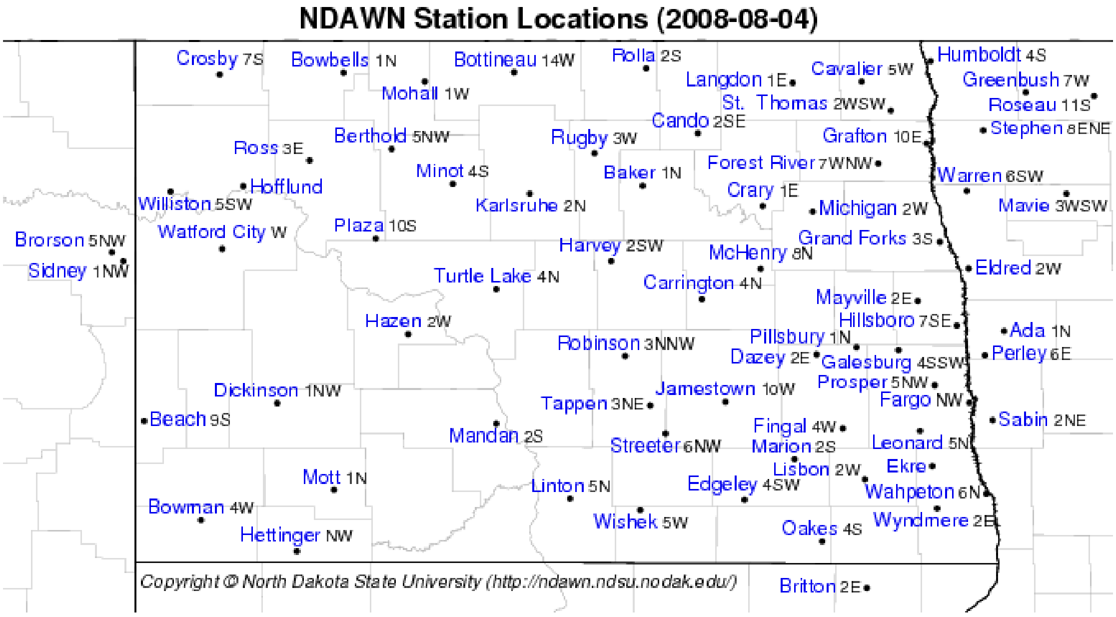

Figure 1. North Dakota Agricultural Weather Network (NDAWN) station locations in North Dakota, USA.

MATERIALS and METHODS

Data Access: The data is accessed each morning daily by a central computing system in the High Plains Regional Climate Center (HPRCC), Lincoln, Nebraska via telephone line. Each weather station has its unique telephone number. In addition to daily downloading of the data, users can call the weather station via dedicated number to get latest (last 10-min) weather conditions from the station's voice modem. The voice modem converts the data in text format into speech format for the end-user to hear.

Quality Assurance: Data quality has the highest priority in the operation of the North Dakota Agricultural Weather Network. In order to prevent erroneous data from being released to the public, two data quality control procedures are completed daily. There are several ways the data from an automated weather network can be checked in an automated fashion (Akyuz et. al. 2001).

Once the daily data is downloaded by the HPRCC computing system, it goes through a series of automated Quality Checking (QC) algorithm (Hubbard et. al., 2005). If erroneous data is detected, it is flagged for further action. The data manager can decide whether to accept the data or replace it with an estimated value. If the data is estimated, its value is displayed preceding a letter "E" indicating that

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NWS: National Weather Service
QC: Quality Checking

the value is estimated. After the data is QC'd in HPRCC, it is transferred to the NDAWN Center for a secondary QC and eventually to input for agricultural applications.

The secondary QC occurs every Monday through Friday morning, except holidays. The NDAWN data manager compares all estimated data to the original erroneous or dubious data to determine the cause of the problem so it can be fixed as soon as possible. At the same time data from all stations are visually compared to those from nearby stations in order to identify suspicious or erroneous data that the computer program cannot detect. In addition, average weekly and monthly data are similarly compared to identify possible calibration or other problems. If these checks identify erroneous or dubious data, they are estimated.

NDAWN stations are visited at least once each year for preventive maintenance, inspection, and calibration. All sensors are checked and/or replaced for refurbishment or recalibration according to manufacturer specifications and/or our strict preventive maintenance schedule. When daily quality control identifies a malfunctioning sensor the station is visited as soon as possible to repair or replace it.

Agricultural Applications: NDAWN was developed to collect weather data to be used in the development and implementation of certain agricultural applications such as; crop, insect, disease, irrigation scheduler and other models. Many models are currently available on the NDAWN web site: http://ndawn.ndsu.nodak.edu/help.html?topic=homepage.The crop related models include applications for barley, canola, corn, potato, sugarbeet, sunflower, wheat, and small grains. General agricultural and other applications available on the web site are crop water use, insect development, heating/cooling degree day, and the irrigation scheduler. As research continues, more models will be developed and added as a valuable resource for all.

Specific Applications:

Canola: Menu expands to "Sclerotinia Risk" and "Degree Days" and "Growth Stage".

Sclerotinia Risk: Link to web site for sclerotinia risk maps and more;

Degree Days & Growth Stage: Displays data request page for a "Table" or "Map" of canola growing degree days and estimated growth stages.

Corn Degree Days: Displays data request page for a "Table" or "Map" of corn growing degree days.

Potato Late Blight: Displays maps or tables of potato late blight severity values, favorable days, or "P-Days".

Sugarbeet: Expands to "Degree Days" and "Growth Stage" and "Cercospora Infection Values".

Degree Days & Growth Stage: Displays data request page for a “Table” or “Map” of sugarbeet degree days and estimated leaf stage.

Cercospora Infection Values: Displays data request page for “Map” of “Cercospora Infection Values” or “Tables” of “Favorable Days” and “Cercospora Infection Values”.

Sunflower Degree Days: Displays data request page for a “Table” or “Map” of sunflower degree days and/or estimated growth stage.

Wheat: Menu expands to “Degree Days” and “Growth Stages”, “Disease Forecaster”, and “Wheat Midge Degree Days”.

Degree Days & Growth Stages: Displays data request page for “Tables” or “Maps of “Wheat Degree Days”, and “Estimated Haun Growth Stages”.

Disease Forecaster: Link to “Small Grain Disease Forecast” system for scab, septoria, rust, and tan-spot diseases.

Midge: Displays data request page for a “Table” or “Map of “Midge Growing Degree Days”, “Wheat Growing Degree Days”, or “Estimated Haun Growth Stage”.

Small Grains: Link to “Small Grain Disease Forecast” system for scab, septoria, rust, and tan-spot diseases.

Crop Water Use: Provides options to view maps or tables of crop water use for potato, corn, dry beans, wheat, barley, sugarbeets, soybeans, sunflower, alfalfa, and turf grass for a number of preset emergence dates. Other page options include a total rainfall map since April 15th and a crop water deficit map.

Insect Degree Days: Displays data request page for an Insect degree day table with base temperatures of 40, 45, 50, 55, 60, and 65°F (4, 7, 10, 13, 16, and 18°C).

Heating/Cooling Degree Days: Displays data request page for a Table of heating and cooling degree days with base temperature of 65°F (18°C).

CONCLUSION

NDAWN has become a valuable regional resource and so far only a fraction of its potential has been realized. These data have become part of the North Dakota climatological archive and will become more valuable as the period of record grows and/or new applications are discovered by scientists in all fields. Timing of these applications is a direct economic gain and environmentally friendly. The authors encourages adaptation of networks with similar applications be implemented to assist farmers and decision makers throughout the world so that agricultural applications are all scientific and not guess-work.

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Simulation Study of Past Climate Change Effect on Chickpea Phenology at Different Sowing Dates in Gorgan, Iran

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ABSTRACT

The evaluation of past climate change is needed for selecting appropriate adapting strategy for future. This simulation study was mainly aimed to find the probable difference between sowing dates for response of four chickpea cultivars to past climate change. Firstly, the model CYRUS was recoded in QBASIC programming. Then phenology of cultivars Jam, Hashem, Arman and Beauvanij, seeded at day of year 50, 70 and 90, was evaluated during years 1961 to 2003 in Gorgan, Iran. The changes in some climatic variables were also studied. Results revealed that the solar radiation has been decreased for month December. Although the value of maximum temperature appeared to be the same across years 1961 to 2003 for all months, that of minimum temperature tended to show increasing trend for May and August. The increase in number of days with temperature higher than 35 ^{o}C was considerable for April and October, but negligible for other months. The warming of night temperature was significant only for May and August. It found about 34 mm per 43 years decrease in monthly rainfall for March. The rate of increase in number of days with rainfall was 0.0737 day year^{-1} for December. Nearly similar situation was found for number of days with rainfall lower than and/or equal to 10 mm. The change in number of days with rainfall higher than 10 mm and lower and/or equal to 30 mm was in decreasing manner (March, October and December). The length of time from sowing to emergence appeared to be constant across past years. The advance in flowering (R1) was true only for cultivar Jam seeded at day of year 70. The length of period from R1 to pod initiation (R3) has been diminished for sowing at day of year 70 (Jam and Arman). Only cultivar Hashem seeded at day of year 90 tended to have decreasing trend for length of period between R3 and pod filling. It found one day (per 43 years) decreases from pod yellowing to maturity for cultivar Beauvanij seeded at day of year 70. Based on these findings, and on the fact that future climate change is predicted using past changes, it seems that the adaptation strategies for future, including agronomy and/or breeding programs, may be not the same for different sowing dates of chickpea.

Key words: Phenology; chickpea; climate change; CYRUS; sowing date

INTRODUCTION

There has been considerable concern in recent years about climatic changes caused by human activities and their effects on agriculture (Olfert and Weiss, 2006). Surface climate is always changing, but at the beginning of industrial revolution these changes have been more noticeable due to interference of human beings activity (Cutforth *et al.*, 1999). Studies of climate change impacts on agriculture initially focused on rising CO_2 levels (Curry *et al.*, 1990). Many researchers, including Pielke *et al.* (2002) reported that changes in temperature, radiation and precipitation need to be studied in order to evaluate the impact of climate change, beyond the CO_2 increase, on crops.

Although, there is general agreement for global warming, the rate of increase in temperature has been different across the seasons and various regions. For example, the reports for Australia indicate that during the period between 1910 and 2000, average temperature has been increased by 0.76 ^{o}C (McInnes *et al.*, 2002). In Iran, results regarding Kermanshah showed that except for January, February and March, the increase in temperature is considerable for all other months, especially June (Gholipoor *et al.*, 2006a). Lu *et al.* (2006) reported that the increasing trend of temperature has been most considerable in the winter and early spring.

Temperature changes can affect crop productivity. Higher temperatures may increase plant carboxilation and stimulate higher photosynthesis, respiration, and transpiration rates. Meanwhile, flowering may also be partially triggered by higher temperatures, while low temperatures may reduce energy use and increased sugar storage (Fiscus *et al.*, 1997). Reddy *et al.* (2002) concluded that the rates of plant growth and development would continue to increase in the southern U.S. because of enhanced metabolic rates at higher temperatures, combined with increased carbon availability. Changes in temperature can also affect air vapor pressure deficits, thus impacting the water use in agricultural landscapes (Kirschbaum, 2004). This coupling affects transpiration and can cause significant shifts in temperature and water loss. These feedbacks contribute to regional changes in precipitation and cloudiness, leading to changes in radiation (Pielke *et al.*, 2002).

The radiation has an important role in photosynthesis and crop productivity. There are more evidences for decreasing trend in solar radiation. For instance, Stanhill and Moreshet (1992) after analyzing data of 45 actinometrical stations for the years 1958, 1965, 1975, and 1985 indeed found a statistically significant worldwide decrease of global solar radiation averaging 5.3%. The decline was largest between 45 and 30^{o} N. Regional declines have been also reported for the western as well as eastern sections of the former Soviet Union (Abakumova *et al.*, 1996).

It is globally accepted that precipitation is a leading factor affecting, especially, rainfed crops yield (Izaurralde *et al.*, 2003). There are conflicting reports for change in precipitation during last century in different parts of the world. For example, in long-term mean precipitation, a decreasing trend of about -4.1 mm/month/100 years has been reported in boreal Asia. The largest and most statistically significant change has been a decline in rainfall in the winter–rainfall-dominated region of the far southwest of western Australia, where during the period of 1910–1995, winter (June–July–August) rainfall declined by 25%, mainly during the 1960s and 1970s (Smith *et al.*, 2000). In Central America, for much of the period from the early 1940s to 1995, western Mexico has experienced an increasingly erratic monsoonal rainfall

(Douglas and Englehart, 1999). Annual precipitation trends in past century are characterized essentially by enhanced precipitation in the northern half of Europe, with increases ranging from 10 to close 50% (Dore, 2005).

Generally, most studies are on fruit trees or trees and there are limited information on crop plant (See references in Gholipoor *et al.* (2006b) for more detail); there is one published report regarding effect of past climate change on chickpea phenology (in Kermanshah, Iran) which has been based only on one sowing date (Gholipoor *et al.*, 2006b).This simulation study was mainly aimed to find the probable difference between sowing dates for response of four chickpea cultivars to past climate change; the changes in some climatic variables were also considered to be evaluated. The result of this study may be useful for selecting appropriate adapting strategy for sustaining the chickpea yield in future.

MATERIALS and METHODS

The weather data from 1961 to 2003 for Gorgan (36^o 85' N, 54^o 27' E and 100 m asl) Iran, was used for calculating the probable change in monthly values of some climatic variables. Data set contained daily values for sunshine hours, maximum temperature, minimum temperature and rainfall. Solar radiation data were calculated from sunshine hours and extraterrestrial solar radiation as outlined by Doorenbos and Pruitt (1977). A simple QBASIC program was written for calculating monthly values of some climatic variables including solar radiation, maximum and minimum temperatures, number of days with temperature greater than 35 ^oC, number of days with temperature lower than 0 ^oC, night temperature, day temperature, rainfall, number of days with rainfall, number of days with rainfall lower than and/or equal to 10 mm, number of days with rainfall greater than 10 and lower than and/or equal to 30 mm, and number of days with rainfall greater than 30 mm. For calculating the rate of change in each climatic variable for period 1961-2003, the parameters "a" (intercept) and "b" (slope) in linear regression equation (Y=a+bX) were calculated, using the Statistical Analysis System (SAS Institute, 1989). The value of "b" was considered as rate of change.

We used the model CYRUS (see following paragraphs) for investigating the phenological response of chickpea to past climate change in Gorgan, Iran. Firstly, it was recoded in QBASIC programming language, and then run for above named weather data set. The cultivars were Hashem, Jam, Beauvanij and Arman, and the sowing dates were 50, 70 and 90 day of year. In each year, the phenological phases including periods from sowing to emergence (sowing-E), from emergence to flowering (E-R1), from flowering to pod initiation (R1-R3), from pod initiation to pod filling (R3-R5), from pod filling to pod yellowing (R5-R7) and from pod yellowing to physiological maturity (R7-R8) were calculated. Like climatic variables, the value of "b" considered as rate of change in each phenological phase.

The model CYRUS was initially designed in 1999 by Soltani *et al.* (1999). Then it was developed for seedling emergence (Soltani *et al.*, 2006e), for leaf expansion and senescence (Soltani *et al.*, 2006d), for response of leaf expansion and transpiration to soil water deficit (Soltani *et al.*, 2000), for response to photoperiod (Soltani *et al.*, 2004a), for harvest index (Soltani *et al.*, 2005), for phenological development (Soltani *et al.*, 2006c), and for nitrogen accumulation and partitioning (Soltani *et al.*, 2006b). This model has been used for some simulation studies/investigations (Gholipoor and Soltani, 2005a, b; 2006; Gholipoor *et al.*, 2006a, b).

Briefly, in seedling emergence sub model of CYRUS, emergence response to temperature is described by a dent-like function with cardinal temperatures of 4.5 (base), 20.2 (lower optimum), 29.3 (upper optimum) and 40 ^{o}C (ceiling temperature). Six physiological days (i.e. number of days under optimum temperature conditions) (equivalent to thermal time of 94 ^{o}C days) are required from sowing to emergence at a sowing depth of 5cm. The physiological days requirement is increased by 0.9 days for each centimeter increase in sowing depth. Snow cover effect is considered on the basis of daily maximum and minimum temperatures, as presented in Ritchie (1991).

In leaf sub model, cardinal temperatures for nod appearance are 6.0 ^{o}C for base, 22.2 ^{o}C for optimum and 31.0 ^{o}C for ceiling temperature. Leaf senescence on the main stem starts when the main stem has about 12 nodes and proceeds at a rate of 1.67% per each day increase in physiological day (a day with non-limiting temperature and photoperiod). Leaf production per plant versus main stem node number occurs in two phases; phase 1 when plant leaf number increases with a slower and density-independent rate (three leaves per node), and phase 2 with a higher and density-dependent rate of leaf production (8–15 leaves per node).

Phenological development is calculated using multiplicative model that include a dent-like function for response to temperature, and a quadratic function for response to photoperiod. Photoperiod-sensitivity is considered to be different in various cultivars, and cardinal temperatures for phenological development are 0 ^{o}C for base, 21 ^{o}C for lower optimum, 32 ^{o}C for upper optimum and 40 ^{o}C for ceiling temperature. The cultivars require 25-31 physiological days from E to R_1, 8-12 from R1 to R3, 3-5 from R3 to R5, 17-18 from R5 to R7, and 6 from R7 to R8 (See Soltani *et al.* (2006d)).

The biomass production is calculated based on extinction coefficient (KS) and radiation use efficiency (RUE). It assumes that KS is not radiation- and plant density-dependent. The RUE assumes to be constant (1 g MJ^{-1}) across plant densities, but not across temperatures. After correction of RUE for temperature, it is not affected by either solar radiation or vapor pressure deficit (VPD). The partitioning of biomass between leaves and stems is achieved in a biphasic pattern before first-seed stage. After this stage, the fixed partitioning coefficients are used for calculating biomass allocation.

Despite of many simulation models in which the linearity of harvest index increases has been used as a simple means to analyze and predict crop yield in experimental and simulation studies (see Soltani *et al.* (2005) and related references for more detail), the CYRUS model assumes that its increase is biphasic with turning point temperature equal to 17 ^{o}C. The similar approach has been proved to be appropriate for application in wheat (Soltani *et al.*, 2004b).

The relation between total N and total biomass throughout the growth period is based on non-linear segmented model (with two segments/phases). Therefore, the rates of N accumulation during phase 1 and 2 are different, and the turning point between two phases of N accumulation is considered 218.3 g biomass per m^2. The distribution of N to different parts of plant is calculated using appropriate functions and coefficients.

In soil water balance sub model, daily soil water content is estimated as fraction transpirable soil water (FTSW, which ranges from 0 to 1) to calculate the degree of water limitation experienced by the crop. Similar to that described by Amir and Sinclair (1991), it accounted for additions from infiltration, and losses from soil evaporation, transpiration and drainage. Infiltration is calculated from daily rainfall less any run-off. Run-off is estimated using the curve number technique (Knisel, 1980). Soil evaporation (Ev.) is calculated using the two-stage model as implemented in spring wheat model developed by Amir and Sinclair (1991). Stage I Ev. occurs when water present in the top 200 mm of soil, and FTSW for the total profile is greater than 0.5. Stage II Ev. occurs when the water in the top layer is exhausted or the FTSW for the total soil profile reaches to less than 0.5. In stage II, Ev. is decreased substantially as a function of the square root of time since the start of stage II. The calculation of Ev. is returned to stage I only when rain or irrigation of greater than 10 mm occurs. Like procedure of Tanner and Sinclair (1983) and Sinclair (1994), the daily transpiration rate is calculated directly from the daily rate of biomass production, transpiration efficiency coefficient (=5 Pa) and VPD. The calculation of VPD is based on suggestion of Tanner and Sinclair (1983) that it to be approximately 0.75 of the difference between saturated vapor pressure calculated from daily maximum and minimum temperatures.

RESULTS and DISCUSSION

The rate of change in solar radiation within the 43 years in Gorgan, Iran presented in Table 1. As it can be seen, the changes for solar radiation ($MJm^{-2}d^{-1}$ $year^{-1}$) were negatively significant in December, but negligible in other months. The report of Stanhill and Moreshet (1992) for the years 1958 to 1985 indicates a statistically significant worldwide decrease of global solar radiation averaging 5.3% especially in north hemisphere. Similar results have been also reported for the western as well as eastern sections of the former Soviet Union (Abakumova *et al.*, 1996). The natural and anthropogenic aerosols absorb solar radiation, and this solar absorption within the atmosphere, together with the reflection of solar radiation to space, leads to a reduction in the solar radiation absorbed by the Earth's surface.

Although the changes in maximum temperature were not significant, but the trend was in increasing manner for February, March, April, August, September and October. Lu *et al.* (2006) and Fiscus *et al.* (1997) found the warming trend for the named temperature, and demonstrated that, this can affect productivity of crops. The upwardly changes of minimum temperature appeared to be significant only for May (1.45 ^{o}C per 43 years) and August (1.48 ^{o}C per 43 years). Generally, reports indicating that globally averaged minimum temperatures continue to increase at a faster rate than the maximum temperatures, resulting in a narrowing of the diurnal temperature range (Karl *et al.*, 1993; Vose *et al.*, 2005). In Beiging, China it has been shown that the linear rate of increase in minimum temperature is 4.08 °C/100 year; whereas the maximum temperature increases with a linear rate of 2.45 °C/100 years (Karl *et al.*, 1993; Xie and Cao, 1996). Other reports for China indicating that in north regions, increasing trend of minimum temperature for period 1951-1990 has been more sensible, when compared to maximum temperature (Tao *et al.*, 2003). Analyzing daily and monthly maximum and minimum surface air temperatures at 66 weather stations over the eastern and central Tibetan Plateau for temporal trends also confirmed the asymmetric pattern of greater warming trends in minimum temperature or nighttime temperatures as compared to the daytime temperatures (Lu *et al.*, 2006). In central Europe, despite of low-lying stations for which the above named behavior has been found, data from mountain top stations show a similar increase for both minimum temperature and maximum temperature (Weber *et al.*, 1994). In Iran, results regarding Kermanshah showed that except for January, February and March, the increase in minimum temperature is considerable for all other months, especially June (Gholipoor *et al.*, 2006a); whereas maximum temperature appears to show increasing trend only for April, May, June and August; the increasing trend of temperature in Tabriz has tended to have asymmetric pattern too (Gholipoor, 2008). Asymmetric change has been also reported for many other regions/countries, including southeastern Europe (Brázdil *et al.*, 1996), United States and Canada (Karl *et al.*, 1984). There are a number of possible factors, such as an increase in cloud cover, contributing to decreases in the diurnal temperature range (Easterling *et al.*, 1997; Lu *et al.*, 2006).

It found an increasing trend for number of days with temperature greater than 35 ^{o}C in April and October, but statistically no change in other months (Table 1). The slope of this trend was more considerable for October as compared to April. The rate of change for number of days with temperature lower than 0 ^{o}C, and for night and day temperatures was presented in Table 2. Number of days with temperature less than 0 ^{o}C tended to have no change across years 1961 to 2003. The rate of upwardly changes in night temperature (^{o}C year^{-1}) was statistically considerable for May (1.37 ^{o}C per 43 years) and

August (1.12 °C per 43 years), but negligible for others. The probability level for changes in day temperature tended to be higher than 0.05, suggesting no statistically changes in it.

The climate change has resulted in that the value of rainfall to be decreased only in March (Table 2); this is in agreement with Smith *et al.* (2000) who reported about 4.1 mm $year^{-1}$ decrease in rainfall for years 1910 to 1995. The rate of increase in number of days with rainfall, say wet and/or rainy days, appeared to be 0.0737 day $year^{-1}$ for December, but statistically zero for other months (Table 3); this increase in rainy days is contrary to report of Zhai *et al.* (1999). As seen in this Table, there is similar situation for number of days with rainfall lower than and/or equal to 10 mm ($R \leq 10$ mm). Despite of these two variables, number of days with $10 < R \leq 30$ appeared to show decreasing trend (March: 2.45 days per 43 years; October: 1.17; December: 1.35), and that of days with R>30 showed no change (Table 3).

Across the period 1961 to 2003, the time from sowing to emergence was statistically the same for all treatment combinations (i.e. sowing date × cultivar) (Table 4). As it was presented in this Table, the time from emergence to flowering (R1) has considerably been decreased for cultivar Jam sown at day of year 70 (4.0506 days per 43 years); the advancing of flowering is in agreement with repots of the Menzel and Fabian (1999) and Lu *et al*. (2006) for other species; the change in length of this period was statistically negligible for other treatment combinations. The length of period between flowering and pod initiation (R3) appeared to show decreasing trend only for sowing at day of year 70 (cultivar Jam: 0.8213 day par 43 years; cultivar Arman: 1.6469 day par 43 years). The decreasing rate of time from pod initiation to pod filling (R5) was 0.0377 day per year (1.6211 day per 43 years) for cultivar Hashem sown at day of year 90, but statistically zero for other cultivars sown at this date and at other dates (Table 5). The length of period between pod filling and pod yellowing (R7) appeared to be the same across 43 years for all sowing dates and cultivars (Table 5). As it was shown in this Table, the decreasing trend regarding length of stage pod yellowing to stage physiological maturity (R8) appeared to be considerable for cultivar Beauvanij which seeded at day of year 70, but negligible for other treatment combinations. The climate-change-related advance in some phenophases of chickpea is in agreement with reports for other plants/crops (Fitter *et al.*, 1995; Sparks *et al.*, 2000; Lu *et al.*, 2006). As it was speculated by Menzel and Fabian (1999) the decrease in length of phenophases, and consequently increasing the rest of growing season, may improve the opportunity for sowing the succession crop(s).

CONCLUSION

Generally, the result of this study revealed that the solar radiation has been decreased for month December. Although the value of maximum temperature appeared to be the same across years 1961 to 2003 for all months, that of minimum temperature tended to show increasing trend for May and August. The increase in number of days with temperature higher than 35 °C was considerable for April and

October, but negligible for other months. The warming of night temperature was significant only for May and August. It found about 34 mm per 43 years decrease in monthly rainfall for March. The rate of increase in number of days with rainfall was 0.0737 day year^{-1} for December. Nearly similar situation was found for number of days with rainfall lower than and/or equal to 10 mm. The change in number of days with rainfall higher than 10 mm and lower than and/or equal to 30 mm was in decreasing manner (March, October and December).

The length of time from sowing to emergence appeared to be constant across past years. The advance in flowering (R1) was true only for cultivar Jam seeded at day of year 70. The length of period from R1 to pod initiation (R3) has been diminished for sowing at day of year 70 (Jam and Arman). Only cultivar Hashem seeded at day of year 90 tended to have decreasing trend for length of period between R3 and pod filling. It found one day per 43 years decrease from pod yellowing to maturity for cultivar Beauvanij seeded at day of year 70.

Because of highly difference between months for climate change, the difference between sowing dates for climate-related hastening in chickpea phenophases appeared to be considerable. Based on this finding, and on the fact that future climate change is predicted using past changes, it seems that the adaptation strategies for future, including agronomy and/or breeding programs, may be not the same for different sowing dates of chickpea.

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Table 1. The rate of change (value of b in equation Y=a+bX) and its probability level (*P*) for solar radiation ($MJm^{-2}d^{-1}$ $year^{-1}$), maximum temperature (T_{max}; ^oC yea^{-1}), minimum temperature (T_{min}; ^oC $year^{-1}$) and number of days with temperature greater than 35^oC (T>35; day $year^{-1}$) during 1961-2003.

Month	Solar radiation		T_{max}		T_{min}		T > 35	
	B	*P*	b	*P*	b	*P*	b	*P*
January	-0.0168	0.138	-0.0004	0.991	0.0024	0.917	------	------
February	-0.0155	0.198	0.0050	0.873	-0.0100	0.658	------	------
March	-0.0082	0.561	0.0028	0.922	-0.0125	0.502	------	------
April	-0.0233	0.270	0.0381	0.150	0.0079	0.672	**0.0115**	**0.011**
May	-0.0194	0.183	-0.0232	0.323	**0.0338**	**0.033**	-0.0281	0.106
June	0.0083	0.612	-0.0120	0.565	0.0012	0.926	-0.0424	0.255
July	-0.0261	0.178	-0.0127	0.494	0.0204	0.068	-0.0381	0.520
August	-0.0037	0.774	0.0017	0.923	**0.0345**	**0.009**	0.0252	0.666
September	-0.0041	0.727	0.0110	0.541	0.0188	0.204	0.0205	0.268
October	0.0094	0.396	0.0297	0.189	0.0106	0.594	**0.0165**	**0.003**
November	-0.0101	0.342	-0.0238	0.343	0.0043	0.823	-0.0005	0.812
December	**-0.0219**	**0.011**	-0.0248	0.301	-0.0167	0.484	------	------

The bold values are statistically significant.

Table 2. The rate of change (value of b in equation Y=a+bX) and its probability level (*P*) for number of days with temperature lower than 0 ^oC (T<0; day $year^{-1}$), night temperature (^oC $year^{-1}$), day temperature (^oC $year^{-1}$) and rainfall (mm $year^{-1}$) during 1961-2003.

Month	T < 0		Night T		Day T		Rainfall	
	b	*P*	b	*P*	b	*P*	b	*P*
January	-0.0169	0.784	0.0016	0.948	0.0007	0.981	-0.3379	0.302
February	0.0083	0.866	-0.0063	0.790	0.0013	0.964	-0.1033	0.733
March	0.0257	0.211	-0.0081	0.683	-0.0011	0.964	**-0.7892**	**0.014**
April	------	------	0.0162	0.404	0.0309	0.191	-0.3563	0.250
May	------	------	**0.0319**	**0.050**	-0.0259	0.203	-0.2561	0.530
June	------	------	-0.0018	0.893	-0.0082	0.648	-0.2855	0.412
July	------	------	0.0120	0.312	-0.0042	0.790	-0.2619	0.320
August	------	------	**0.0260**	**0.042**	0.0098	0.520	-0.1022	0.733
September	------	------	0.0166	0.250	0.0135	0.403	0.1323	0.664
October	------	------	0.0157	0.425	0.0246	0.242	-0.7885	0.063
November	-0.0057	0.127	-0.0020	0.917	-0.0170	0.442	0.1945	0.694
December	0.0294	0.436	-0.0182	0.428	-0.0223	0.335	-0.5896	0.084

The bold values are statistically significant.

Table 3. The rate of change (value of b in equation Y=a+bX) and its probability level (*P*) for number of days with rainfall (Wet days; day year^{-1}), number of days with rainfall lower than and/or equal to 10 mm (R≤10 mm; day year^{-1}), number of days with rainfall greater than 10 and lower than and/or equal to 30 mm (10<R≤30 mm; day year^{-1}) and number of days with rainfall greater than 30 mm (R>30mm; day year^{-1}) during 1961-2003.

Month	Wet days		R ≤ 10 mm		10 <R ≤ 30 mm		R > 30 mm	
	b	*P*	b	*P*	b	*P*	b	*P*
January	0.0039	0.927	0.0169	0.665	-0.0151	0.337	0.0021	0.426
February	0.0104	0.785	0.0142	0.693	-0.0047	0.774	0.0009	0.734
March	-0.0071	0.863	0.0500	0.298	**-0.0571**	**0.003**	0.0000	1.000
April	-0.0142	0.752	-0.0088	0.839	-0.0076	0.551	0.0021	0.602
May	0.0403	0.304	0.0405	0.234	-0.0002	0.993	0.0000	1.000
June	0.0080	0.857	0.0044	0.918	0.0062	0.361	-0.0026	0.659
July	-0.0159	0.700	-0.0020	0.958	-0.0127	0.114	-0.0012	0.742
August	0.0051	0.886	0.0039	0.903	0.0027	0.784	-0.0015	0.731
September	-0.0148	0.690	-0.0308	0.387	0.0104	0.371	0.0056	0.253
October	-0.0026	0.948	0.0343	0.298	**-0.0272**	**0.050**	-0.0097	0.243
November	0.0455	0.251	0.0388	0.286	0.0023	0.886	0.0044	0.633
December	**0.0737**	**0.045**	**0.1108**	**0.005**	**-0.0314**	**0.041**	-0.0057	0.215

The bold values are statistically significant.

Table 4. The rate of change (value of b in equation Y=a+bX) and its probability level (*P*) for periods from sowing to emergence (sowing-E; day year^{1}), from emergence to flowering (E-R1; day year^{1}) and from flowering to pod initiation (R1-R3; day year^{1}) for different cultivars and sowing dates during 1961-2003.

Sowing date (day of year)	Cultivar	Sowing-E		E-R1		R1-R3	
		b	*P*	B	*P*	b	*P*
50	Hashem	-0.0316	0.572	0.0787	0.392	-0.0003	0.951
	Jam	-0.0316	0.572	0.0735	0.415	0.0030	0.659
	Beauvanij	-0.0316	0.572	0.0711	0.435	0.0020	0.757
	Arman	-0.0316	0.572	0.0705	0.424	0.0032	0.551
70	Hashem	0.0008	0.972	-0.0575	0.363	-0.0042	0.385
	Jam	0.0008	0.972	**-0.0942**	**0.0318**	**-0.0191**	**0.050**
	Beauvanij	0.0008	0.972	-0.0584	0.357	-0.0015	0.809
	Arman	0.0008	0.972	-0.0569	0.365	**-0.0383**	**0.020**
90	Hashem	0.0038	0.785	0.0015	0.962	-0.0051	0.174
	Jam	0.0038	0.785	-0.0039	0.906	-0.0005	0.918
	Beauvanij	0.0038	0.785	0.0008	0.982	-0.0014	0.822
	Arman	0.0038	0.785	0.0035	0.910	-0.0009	0.853

The bold values are statistically significant.

Table 5. The rate of change (value of b in equation Y=a+bX) and its probability level (*P*) for periods from pod initiation to pod filling (R3-R5; day year[1]), from pod filling to pod yellowing (R5-R7; day year[1]) and from pod yellowing to physiological maturity (R7-R8; day year[1]) for different cultivars and sowing dates during 1961-2003.

Sowing date (day of year)	Cultivar	R3-R5		R5-R7		R7-R8	
		b	*P*	B	*P*	b	*P*
50	Hashem	-0.0045	0.395	-0.0074	0.372	0.0080	0.642
	Jam	-0.0023	0.702	0.0038	0.570	0.0005	0.985
	Beauvanij	0.0020	0.753	0.0002	0.984	0.0068	0.562
	Arman	-0.0029	0.478	0.0003	0.961	0.0063	0.641
70	Hashem	0.0011	0.794	0.0041	0.513	0.0118	0.582
	Jam	-0.0062	0.302	0.0082	0.214	-0.0039	0.845
	Beauvanij	0.0033	0.587	-0.0017	0.787	**-0.0234**	**0.0358**
	Arman	-0.0060	0.192	-0.0086	0.159	0.0051	0.775
90	Hashem	**-0.0377**	**0.040**	-0.0023	0.717	-0.0130	0.515
	Jam	0.0085	0.171	-0.0009	0.895	-0.0124	0.466
	Beauvanij	0.0030	0.616	0.0018	0.784	-0.0069	0.647
	Arman	-0.0038	0.369	0.0030	0.628	-0.0159	0.359

The bold values are statistically significant.

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Estimation of Predictability of Agrophytocenoses Productivity on the Basis of Mathematical Modeling, Field Experiments and Satellite Measurements

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ABSTRACT

Estimation of predictability of agrophytocenoses productivity was made by comparing the results of investigation of a mathematical model, field experiments and satellite measurements. The mathematical model of the seasonal dynamics of agrophytocenoses productivity was built with account of air temperature. For model investigation the coefficients were used that were calculated on the basis of the results of field experiments conducted in the Republic of Khakassia. The objects of the research were agricultural crops (wheat, oats). The results of satellite measurements (NDVI dynamics), and theoretical and experimental results of the seasonal dynamics of plant total biomass proved to be quantitatively consistent.

Key words: mathematical model, agrophytocenoses productivity, satellite measurements.

INTRODUCTION

Satellite sensing techniques are becoming more and more important for optimization of land use, rehabilitation of degraded territories, and prediction of changes in agrophytocenoses (Savin, 2003). These techniques make it possible to cover large territories at a time and possess an information value, reliability and periodicity necessary to solve the above mentioned tasks. For a reliable interpretation of the images, it is necessary to use ground-based observation data on the state of crops for referencing satellite images to the territory. However, in the process of comparison of ground-based and satellite data there can be uncertainty because of agrophytocenoses pollution, changes in climatic conditions etc. A mathematical model of seasonal dynamics of agrophytocenoses production was built and investigated, and the modeling results were compared with ground-based and satellite data, with the aim of searching for the method of estimation of phytocenoses productivity.

MATERIALS and METHODS

Ground-truth observations of agricultural land vegetation were made for interpretation of satellite images. The objects of investigation were the agricultural crops and fallow lands in Krasnoyarsk Territory (Minusinsk Region) (Shevyrnogov et al., 2007)

During the vegetation season of 2006, the agrophytocenoses of wheat, oat and buckwheat (with a total area of 5.3. thousands of hectares) were studied using standard geobotanical methods, on permanent plots, on such days (or several days before or after) when the Modis/Terra satellite was passing (Shevyrnogov et al., 2007). The coordinates of the plots were registered using a GPS-navigator.

Samples for weighing aboveground raw biomass were taken during the vegetation season from 1×1 m^2 plots, number of replications being 3-5.

To estimate the photosynthetic active biomass we used the Normalized Difference Vegetation Index (NDVI) which is calculated by the following formula:

$$NDVI = \frac{NIR - RED}{NIR + RED}, \qquad (1)$$

where NIR is reflection in the near infrared region;

RED – reflection in the red region.

According to this formula, NDVI in a certain image point is equal to a difference between the reflected light intensities in the red and near infrared bands divided by the sum of the intensities.

RESULTS and DISCUSSION

Figure 1 shows the results of field investigations – the results of the seasonal dynamics of wheat total aboveground raw biomass, including weeds, and net phytomass (the sum of vegetative and generative parts); the values of phytomass vegetative and generative parts are given separately.

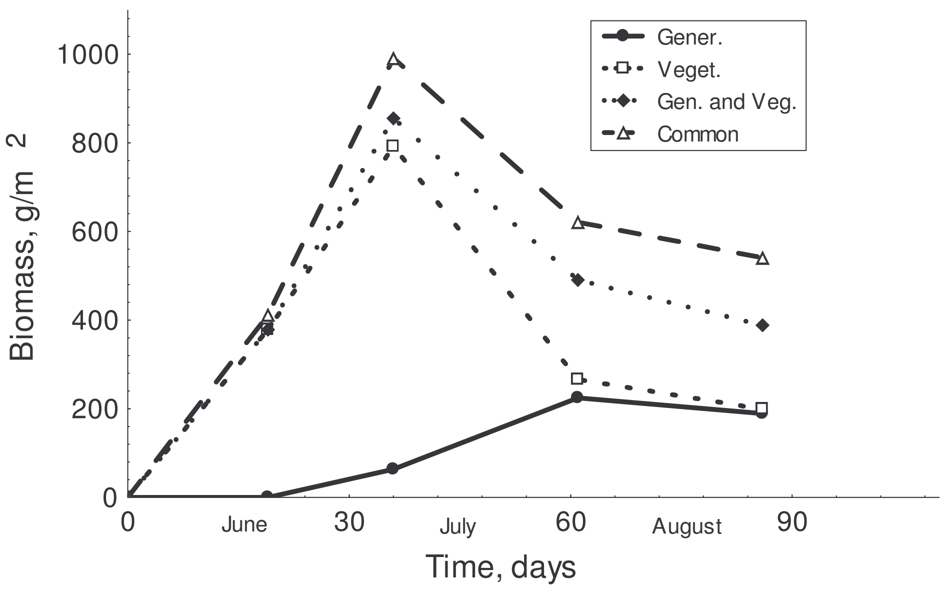

Fig.1. Dynamics of wheat aboveground raw phytomass in 2006.

The data of satellite images are presented on Fig. 2. The dynamics of NDVI values during the field season (June - August) allows one to fully trace the dynamics of the seasonal production of aboveground raw phytomass of wheat agrophytocenosis, that is, its total biomass. However, it is rather difficult to study the production dynamics of vegetative and reproductive phytocenosis parts separately. Scientists are trying to isolate these growth stages by calculation of vegetation rates (based on NDVI changes) according to satellite data (Pugacheva, 2007). It is necessary to find connection between the total phytocenosis phytomass and its components (biomass of vegetative and reproductive organs) to predict phytocenoses productivity.

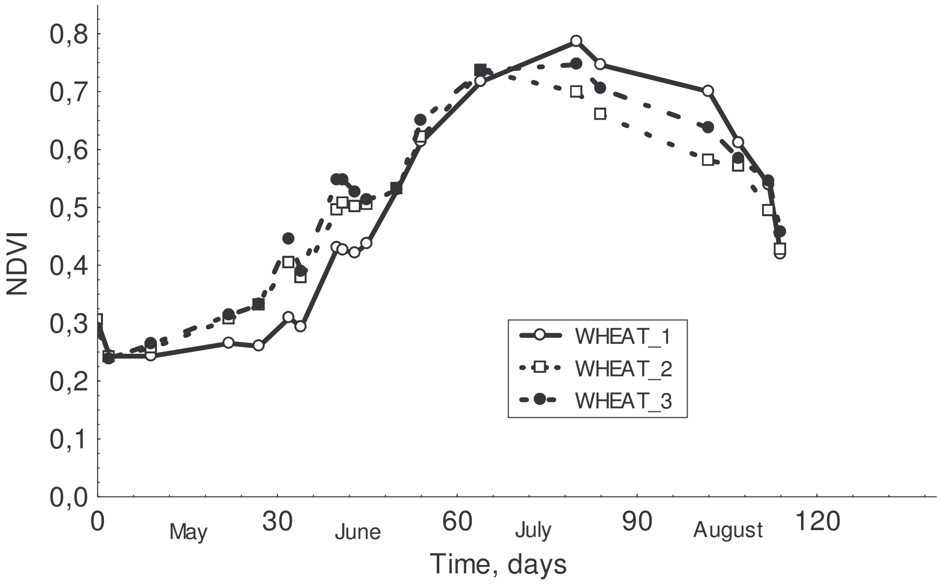

Fig. 2. Dynamics of NDVI values at the territory of Minusinsk Region sown with wheat, in 2006.

The mathematical model of phytocenosis production seasonal dynamics is based on a common differential equation limited in terms of growth in the end of field season.

$$dX/dt = \mu(T, W, N)\,X - \mu(T, W, N)\,X^2/X_{max}\text{, where} \qquad (2)$$

X is the biomass of the sum of agrophytocenosis vegetative and reproductive parts;

$\mu(T, W, N)$ – phytocenosis specific growth rate;

X_{max} – the maximum biomass of the sum of agrophytocenosis vegetative and reproductive parts;

Since the phytocenosis seasonal growth was observed for one year, the limitation of phytocenosis growth was simplified: it was supposed that the limiting factor is the biogenous element nitrogen.

The solved equation demonstrates a quantitative coincidence with the results of full-scale experiments and data calculated on the basis of satellite images. The maximum total production of phytocenosis falls on July. NDVI dynamics has a more smoothed form, as there are more points than in case of field investigations, which is connected with the difficulty to measure the production of aboveground raw biomass in the field.

Modeling of the production of phytomass reproductive part has its characteristic features – delay in new production of reproductive organs as compared to the new production of vegetative organs. In this case, apparently, it is necessary to use delay time or the dependence of the production rate of the phytocenosis reproductive part on the biomass of the vegetative part according to Mono. Then the equation for calculation of the specific rate of reproduction will look as follows:

$$\mu_{repr.} = \mu_{max\ repr.}\ X_{veg.} / (K_{X\ veg.} + X_{veg.}) \qquad (3)$$

Fig. 3 shows the results obtained during the investigation of the model of wheat phytocenosis seasonal growth: production of total (vegetative and reproductive) biomass and production of reproductive organs biomass. Once the delay time was introduced, a more complete coincidence with the results of field investigations was obtained. In June the total biomass of phytocenosis increased due to the new production of vegetative organs, and in June it decreased as a result of vegetative organs drying.

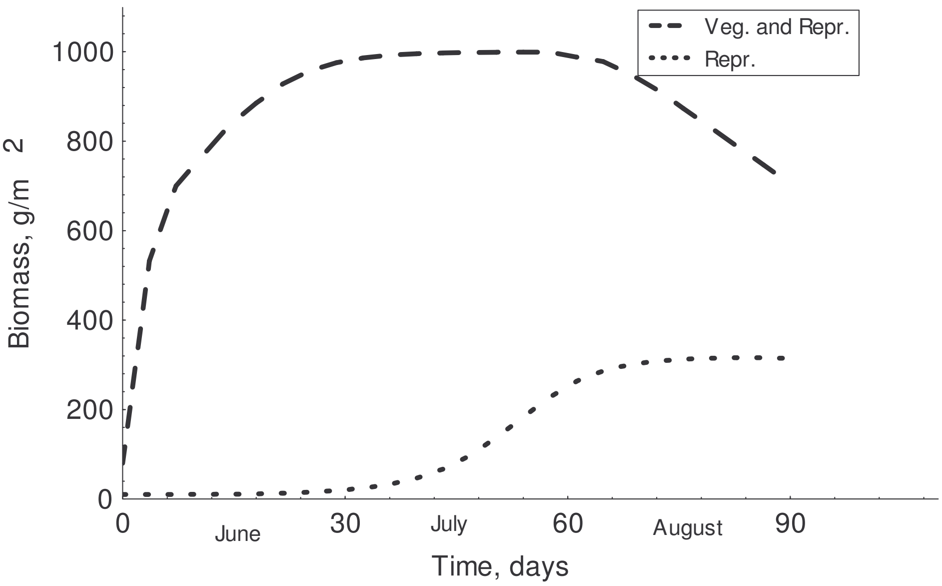

Fig. 3. Dynamics of the seasonal growth of wheat phytocenosis (results of model investigations).

Thus, investigation of the mathematical model of wheat phytocenosis seasonal growth showed that it is possible to make satellite measurements more complete and precise. Combination of the results of mathematical modeling, satellite sensing and field experiments will allow scientists to obtain complete information on the state of crops and their productivity more quickly.

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Mathematical Model of Seasonal Growth of Halophytic Plant Community with Account of Environmental Factors

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ABSTRACT
Field investigations of yields of halophytic meadow plant communities were performed near of Lake Kurinka in the central part of the Republic of Khakasia in 2004 - 2006. A mathematical model has been constructed to describe the growth dynamics of different plant communities of halophytic meadows as dependent upon the temperature factor and the salinity level of the soil. Results of field investigations and model studies show that there is a correlation between plant growth and the temperature of the air for plant communities growing on soils containing the lowest (0.1%) and medium (1.84%) salinity levels. It has been proven in model studies that for plant communities growing on high-salinity (3.58%) soils, not only the temperature of the air but also the salinity level of the soil should be taken into account.

Keywords: halophytes, plant communities, temperature, salinity level of the soil.

INTRODUCTION

Mathematical methods are widely used to study plant growth and production (Apchevskii, 1990; Kul K.and Kul O., 1989). Construction of dynamic models of biological production is currently considered to be the most efficient method in mathematical modeling. These models take into account as many basic processes and parameters influencing plant growth as possible.

Models showing the influence of climate and climate change on plant growth, which would also involve soil site parameters, could be of both practical and theoretical interest.

A computer simulation model of regional vegetation dynamics was applied to the terrestrial ecosystems of China to study the responses of vegetation to elevated CO_2 and global climatic change. The primary production processes were coupled with vegetation structure in the model. Simulation results were obtained for each of the climatic scenarios with the model running toward equilibrium solutions at a time step of 1 month. Preliminary validation indicated that the model wascapable of simulating the net primary productivity of most vegetation classes and the potential vegetation structure in China under present climatic conditions. (Gao et al., 2000).

A mathematical model of the processes involved in carbon metabolism is described that predicts the influence of temperature on the growth of plants (Gent Martin and Enoch Herbert, 1983). The model assumes that the rate of production of dry matter depends both on the temperature and the level of nonstructural carbohydrate. The level of nonstructural carbohydrate is determined by the rates of photosynthesis, growth, and maintenance respiration. The model describes the rate of growth and dark respiration, and the levels of carbohydrate seen in vegetative growth of carnation and tomato.

Lopatin and his co-authors (Lopatin et al., 2006) performed mathematical analysis of the effect of solar radiation on the structure and productivity of plants. The author of another study determined the main properties of saline soils that are responsible for the level of the crop yield and developed models of their fertility (Kursakova, 2005). Models could be used to describe natural processes and to make a quantitative prediction of their development. An aim of crop modelers is to develop a dynamic model of plant growth that takes account of the varying environmental conditions imposed upon the crop, and of the competition occurring between plants within the crop (Aikman and Scafe, 1993).

Halophytic plants are capable to exist on soil with high salt concentration. Different researchers observed beneficial effects of moderate salinization on life processes of halophytic plants. Particularly, increasing of ferments strength, responsible for a salt exchange, maximal growth, etc was observed. However, high concentrations of soluble salts in the soils had negatively impact on plants. In addition, toxic salts action depends on chemical compound of salts and depends on salt tolerance of plant (Prokop'ev, 2001).

Influence of the temperature and a soil salinity degree on growth of halophyties also is insufficiently studied now. The purpose of this work was to construct and study a mathematical model describing the dynamics of seasonal growth of different plant communities in halophytic meadows, depending upon the air temperature and soil salinity level, which could be further used to predict yields of these plant communities.

MATERIAL and METHODS

The study was performed on plants of halophytic meadows in the coastal area of Lake Kurinka in the Altaiskii District of the Republic of Khakasia. The common mineralization is changing from 72 to 108 g/l (Krivosheev, 1991). Field investigations were conducted during 2004–2006. The mathematical model was analyzed using field data of 2004 and 2006, the years of contrasting air temperatures. Harvest was gathered during the time period of May to September, on the same days of every month. Three plant communities were studied: meadow fescue-couch grass (*Festuca pratensis* Huds., *Elytrigia repens* (L.) Nevski) – PC.1, sagebrush-puccinellia (*Artemisia nitrosa* Web., *Puccinellia tenuissima* Litv. ex V. Krecz.) – PC.2, and seablite (*Suaeda linifolia* Pall.) – PC.3. Every plant community grew on the soil of a different level of salinity – the amount of the solid residue of the saline soil aqueous extract (Table 1). The type of salinity is sulfate-sodic. Theoretical results are compared with the field data of the first three months of active growth of plant communities (May, June, and July). The field data were processed statistically (Dospekhov, 1973).

Table 1. Structure of plant communities and soil salinity level

Plant community	Plant community structure	Soil salinity, %
PC.1	*Elytrigia repens* (L.) Nevski *Elymus junceus* Fish	0.1
PC.2	*Puccinellia tenuissima* Litv. ex V. Krecz. *Artemisia nitrosa* Web.	1.84
PC.3	*Puccinellia tenuissima* Litv. ex V. Krecz. *Suaeda linifolia* Pall.	3.58

Plant productivity was determined in the growth period in 2004-2006 year. Three permanent study plots (10×10 m^2) were located on soil with different degree of salinity. The occurrence of each vascular species, its coverage, density and mean height was recorded in each plot. Plant productivity calculations were based on alive aboveground biomass from samples that were harvest from a 1 × 1m area in four replications in the center of each plot. Raw material was separated into five botanical-functional groups: gramineous plants, sedges, beans, sagebrush, herbs. All reproductive shoots were weighed, dried from air-dry state (at 80°C) and weighed again (Voronov, 1973).

For determination of the solid residue of the saline soil aqueous extract was measured 30 g of soil samples and scooped of soil into a 300-ml conic flasks. Then, in conical vessel was added 150 ml of distilled water. The soil samples and water was stirred in during 3 min and was leave the solution to settle for at least 5 min. After that an extract filter, using double folded filters, and place in porcelain cup. Previously, porcelain cup was dried up and weighed with a margin error no more 0,001g. After that porcelain cup was put up on a water-bath for evaporation of a filtrate. Then a cup was weighed again (with a margin error no more than 0,001g). The mass fraction of solid residue of the saline soil aqueous extract (total dissolved solid (TDS)) was calculated under the formula:

$$TDS = (A - B)*1000 / V$$

where:

A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

V= sample volume, ml (Schukin, 1985).

The mathematical model was studied using Mathcad software.

RESULTS

Temperature is one of the main ecological factors determining whether a plant species can grow in a certain climate zone and perform its primary biological production.

Variations in the mean daily air temperature in 2004 and 2006 are shown in Figure 1 (based on the data obtained from Meteorological Station "Khakasskaya").

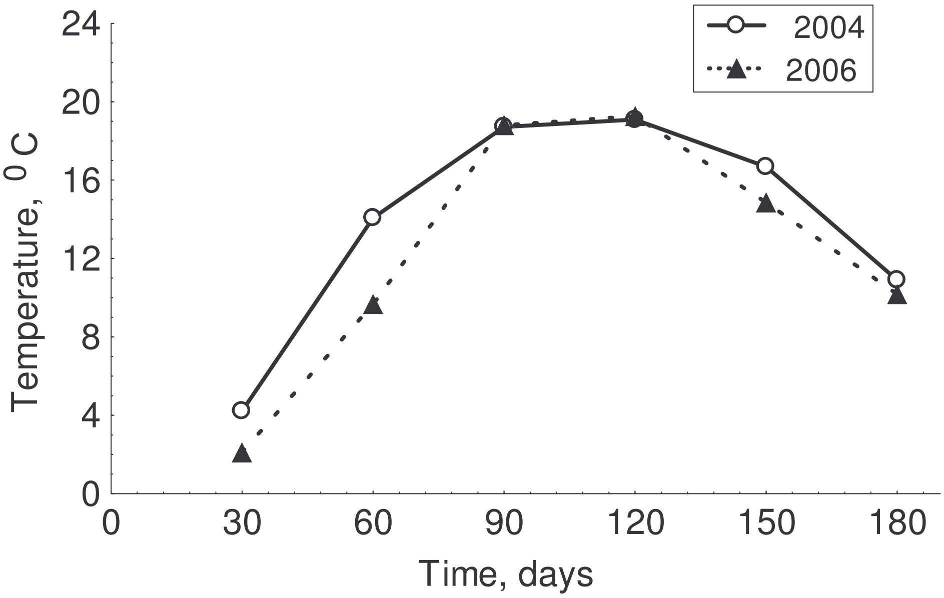

Fig. 1. Daily mean air temperature

In 2004, plant growth conditions (temperature and moisture) were optimal – it was warm and humid; 2006 was cold and humid. The mean daily air temperature of the first three months of active plant growth was higher in 2004 than in 2006

Results of Field Investigations. The graphs of Figures 2 and 3show the crop yields of PC.1and PC.3 in 2004 and 2006 (field data) (Pisman and Slyusar, 2007). For PC.1 there is a correlation between the crop yield and air temperature. The crop yield of PC.1 on the soil with the lowest salinity level (0.1%) was 12-14% higher during the first three months of active plant growth in 2004 than in 2006 (Fig. 2). The temperature-dependent crop yield dynamics of PC.2 growing on the medium-salinity soil (1.84%) was similar to the crop yield dynamics of PC.1. The only parameter in which they differed was the maximum crop yield.

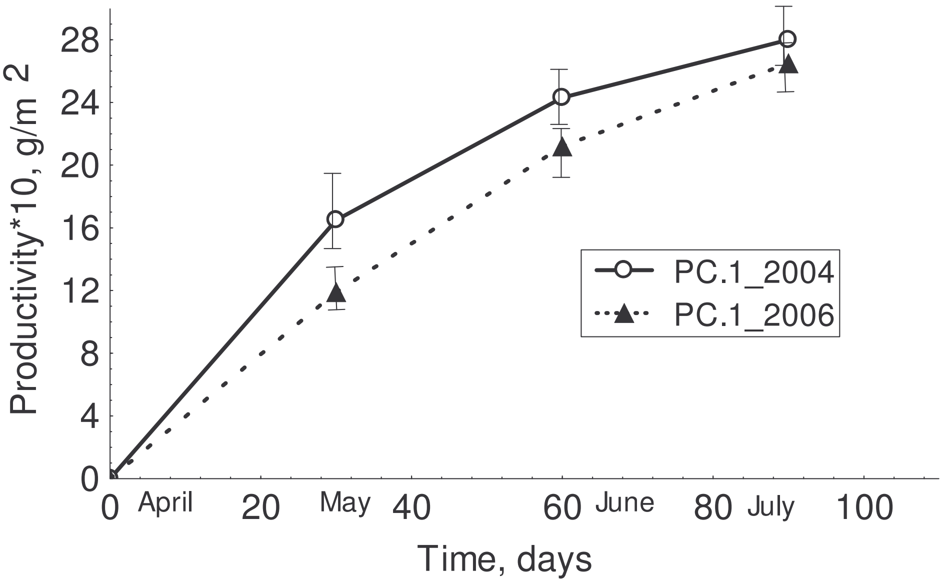

Fig. 2. Seasonal crop yield of PC.1 in 2004 and 2006 (field data).

However, no correlation was found between the crop yield of PC.3, growing on the high-salinity soil (3.58%), and the air temperature (Fig. 3). Moreover, the crop yield of PC.3 during the active plant growth was much lower than the crop yields of PC.1 and PC.3, reaching just 140 g/m^2 in 2004 and 2006.

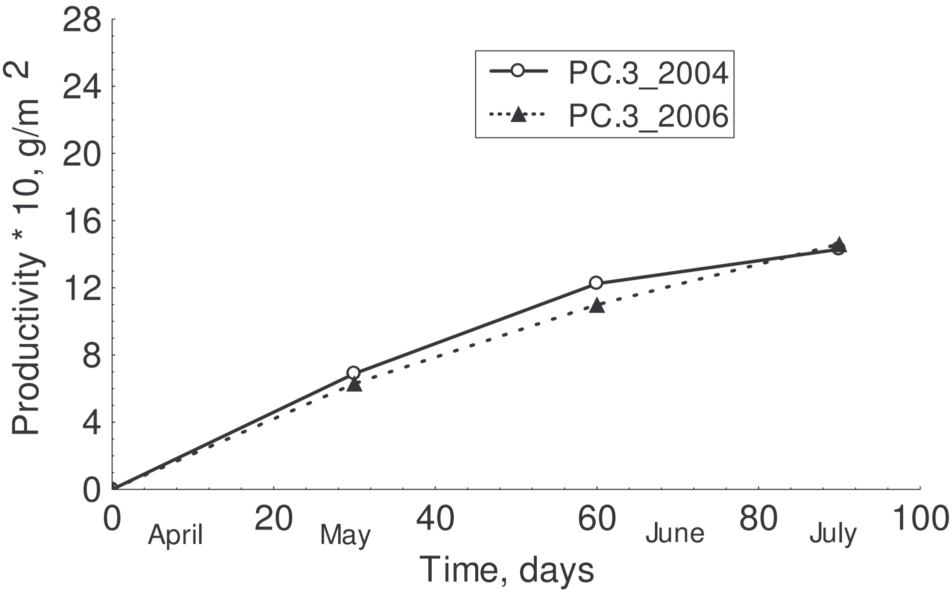

Fig. 3. Seasonal crop yield of PC.3 in 2004 and 2006 (field data).

Theoretical Results. A mathematical model of temperature-dependent seasonal dynamics of the yield produced by plant communities of halophytic meadows was constructed to account for the abovementioned differences in the functioning of the plant communities (PC.1and PC.3) of halophytic meadows and the relationship of their yields to climate factors (temperature) and ecological factors of their environments (soil salinity level). The model is represented by a system of two differential equations (1), using the coefficients preliminarily obtained from field experiments.

$$dP/dt = \mu(T)P - \mu(T)P^2/P_{max}$$
$$dT/dt = \alpha T - \alpha T^2/T_{max} \quad (1)$$
$$\mu(T) = \mu_{max}[(T_{max} - T)/(T_{max} - T_{opt})]\,[(T - T_{min})/(T_{opt} - T_{min})]$$

where P is crop yield, g/m^2; T – temperature, °C; $\mu(T)$ – specific growth rate of a plant community, d^{-1}; P_{max} = 280 g/m^2 – maximum crop yield of a plant community; μ_{max} = 0.07 d^{-1} – maximum specific growth rate of plants; T_{min} = 5°C – minimum air temperature at which plants begin growing; T_{opt} = 25°C – optimum air temperature; T_{max} = 40°C – maximum air temperature;
α = 0.01– rate of temperature change, d^{-1}.
The equation for the specific growth rate of a plant community – $\mu(T)$ – contains 4 parameters: 3 basic parameters for the temperature (T_{opt}, T_{max} and T_{min}) and μ_{max} – the maximum specific growth rate of plants at T_{opt}. Specific growth rate will be equal to 0 (μ = 0) if T = T_{min} or if T = T_{max}, and it will be maximal ($\mu = \mu_{max}$) if T = T_{opt}.
Figure 4 show results of theoretical calculations of the dynamics of PC.1 crop yields in 2004 and 2006. Investigation of the model showed a qualitative agreement between the field data and the theoretical results: the crop yields of PC.1 and PC.2 are temperature dependent on soils with low (0.1%) and medium salinity levels (1.84%). The crop yield of these plant communities is higher in 2004, at the optimal air temperature, than in 2006, at a low temperature.

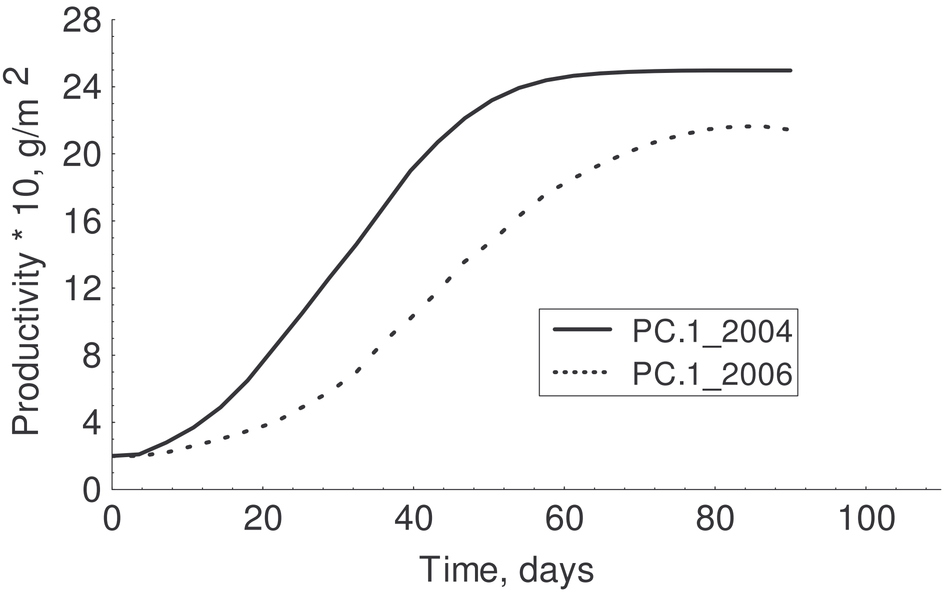

Fig. 4. Crop yield of PC.1 in 2004 and 2006 (theoretical results).

However, no qualitative agreement between experimental and theoretical results for the temperature dependence of the crop yield of the plant community was obtained for PC.3, the plant community growing on the high-salinity (3.58%) soil. It was assumed that the crop yield of PC.3 is affected not only by the temperature but also by soil salinity.

To check this assumption, we used our field results to calculate soil salinity dependence of the maximum specific growth rate of the puccinellia, the plant representing most of the plant communities. It had a shape of a classical curve showing inhibitor dependence of specific growth rate (Fig. 5).

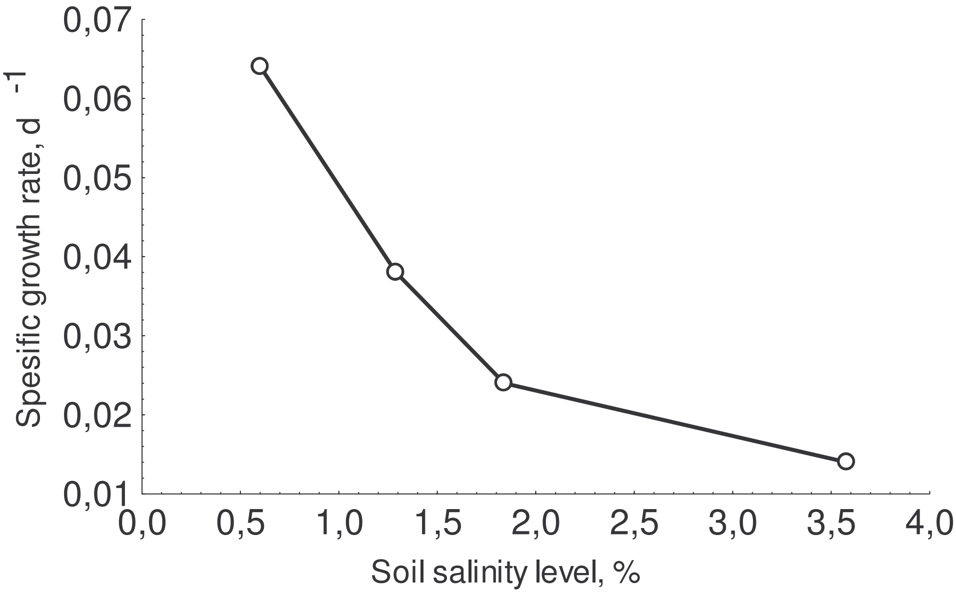

Fig. 5. Puccinellia growth depending upon soil salinity level.

To confirm the assumption that soil salinity affects the crop yield of PC.3, we modified the equation for the specific growth rate (2), taking into account inhibitor (soil salinity) dependence of PC.3 development:

$$\mu(T, I) = \mu_{max} [(T_{max} - T)/(T_{max} - T_{opt})] [(T - T_{min})/(T_{opt} - T_{min})][k_I/(k_I + I)], \quad (2)$$

where I is soil salinity level, %;

$k_I = 1.5\%$ – inhibition constant numerically equal to the soil salinity level at which specific growth rate of the plant community is equal to half maximum specific growth rate.

With the modified model we obtained a qualitative agreement between the experimental and the theoretical results (Figs. 3 and 6): the crop yields of PC.3 (soil salinity 3.58%) during the period of active plant growth (May – July) are the same in 2004 and 2006, i.e. they are temperature independent, reaching 150 g/m^2, which is much lower than the crop yields of PC.1 (soil salinity 0.1%) and PC.2 (soil salinity 1.84%).

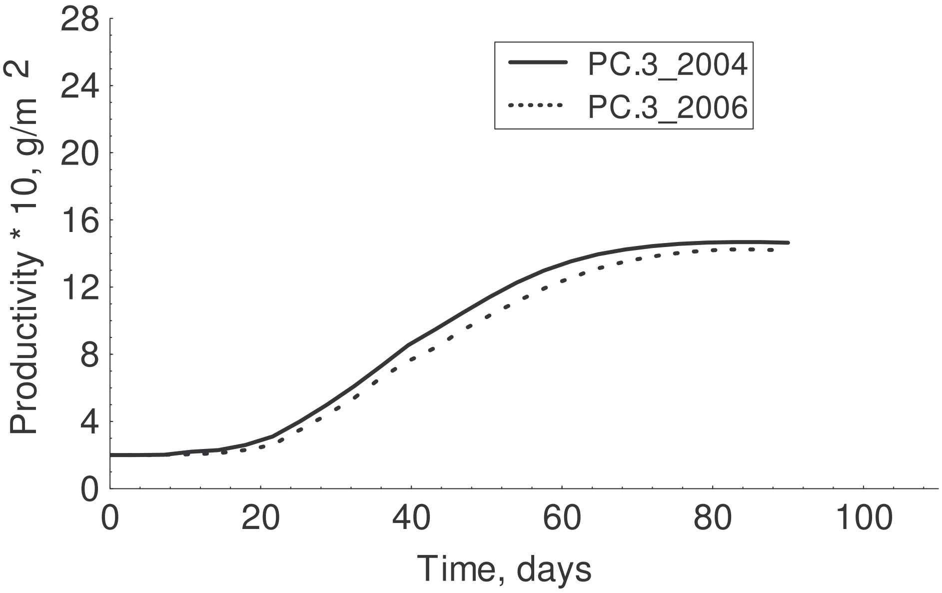

Fig. 6. Crop yield of PC.3 in 2004 and 2006 (theoretical results).

Thus, results of our study, in which we used a mathematical model describing the development of plant communities of halophytic meadows and field measurements, suggest that both climate conditions (temperature) and ecological factors of the plants' habitat (soil salinity level) should be taken into account when constructing models for predicting crop yields.

DISCUSSION

It is difficult to predict growth rates of plants because there are no accurate methods of making relatively long-term weather forecasts. So, one has to model seasonal trends in some meteorological parameters, which are clearly of periodic nature. This is true for air temperature, which is the main factor controlling plant growth rates. Therefore, attempts are made to find the way to predict the value of this factor first. Although temperature has a pronounced yearly trend, there are significant fluctuations in temperature conditions from year to year. Thus, variations in temperature conditions (and, of course, all other weather parameters) cause interseasonal variations in plant growth rates.

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Changes of Soil Properties and Flora in Natural Forest and Afforestation Areas (Çankırı-Eldivan Region)

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ABSTRACT

In this study, existing flora and its soil characteristics besides the silvicultural features of natural and cultured forest areas having ecological and topographic qualities alike were compared. Due to the fact that Turkey has so many different growing conditions, it is one of the most important geographical regions in terms of richness of plant species. The fact that diversity of these plant species are known, conserved and conducted in accordance with the complex relations among climate-soil and plant must be necessary. In the field of our research, the richest families are *Fabaceae*, *Asteraceae*, *Lamiaceae*, *Brassicaceae*, *Poaceae, Scrophulariaceae, Boraginaceae Caryophyllaceae*, *Apiaceae* and *Rosaceae. The ratio of the richest ten families in total species 73.83%, and also the ratio of the rest 22 families is 26.17%. At the end of the afforestation efforts of 46 years, In spite of all negative characteristics, it's shown that afforestation makes the soil approach to the natural forest soil.*

Key Words: Afforestation, Soil, Flora, Watershed restoration, Çankırı-Eldivan

INTRODUCTION

As being considered of topographic, climate and soil characteristics of Turkey, erosion has been as a basic result of decaying land covering. In addition to this, many natural and socio-economic problems such as flood, overflow, avalanche, calamity, decrease of biological diversity, rural indigence, and emigration have been met. Decline on forest in the region of The Central Anatolia having arid and semiarid climate and decaying of its land covering have been more extremely acute. As the district of Çankırı Eldivan where the research has been done and considered in terms of ecological conditions, it's a region similar problem experienced. The problems such as illegal cutting, overuse pasturage, layout, fire and beetle cause it to decrease of agricultural areas and also to decline yield.

The basic purpose on the afforestation efforts during the last periods has been wood production. Newly, in addition to this aim, some different purposes such as recreation, land save, watershed restoration, and tourism have been considered. Furthermore, biological diversity one of the current subjects of the last years has a vital effect on the afforestation efforts. This topic has appeared as two different forms. The first one is that domestic breed of its region in the selection of species which will be used in the afforestation must be employed. So these existent species having been accorded for years will be saved and make the chance of success of afforestation increase. The other topic is a change appeared with the combination of bush, weed and other species by reason of afforestation. In forests composing the major portion of biological diversity, above all to save this richness is critically important. Afforestation is defined as problematic works on the regions having arid and semiarid climate in Turkey. Human effect and soil shallow together with climate make the trouble increase much more. On this head, the studying of watershed restoration and afforestation in Eldivan constitutes a good example. The main purpose of our study is to display how the studies of watershed restoration which were done 46 years ago effects to the flora and basic soil characteristics under the natural forest and afforestation.

MATERIAL and METHODS

Description of Study Area

Study area is in 2078.7 hectares of land and within the limitseonfines of the town Eldivan of the province Çankırı in the Central Anatolia. Its location is between the north latitude 40° 34' 41" - 40° 20' 38" and east longitude 33° 36' 00" - 33° 25' 10" (Figure 1).

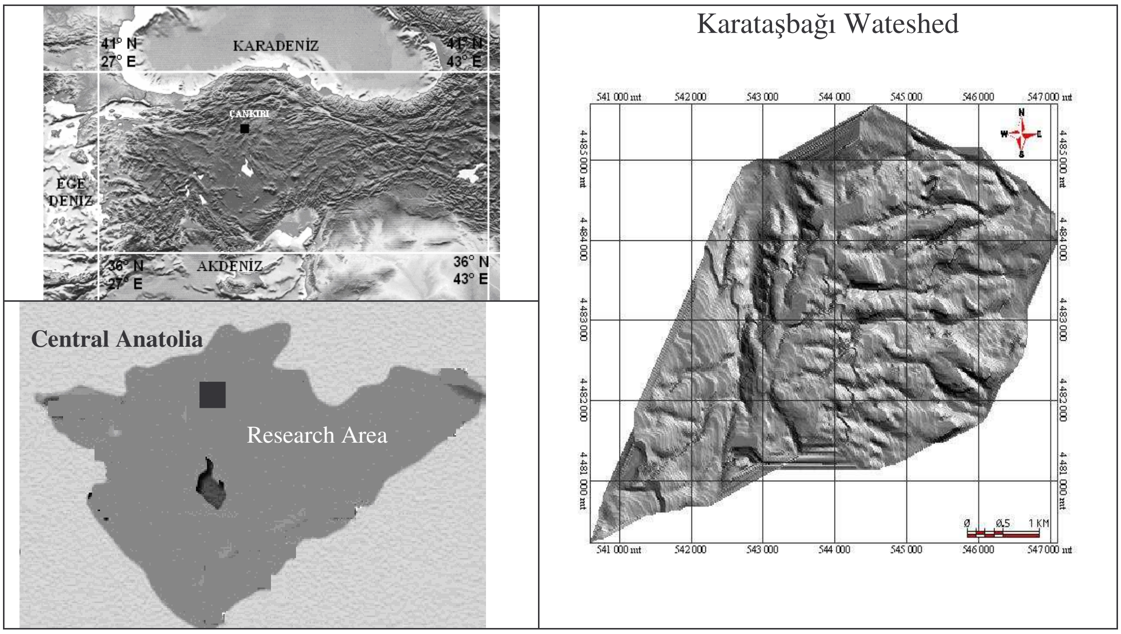

Figure 1. Location of Study Area

Study area is on the twilight area between the step climate of Central Anatolia and the climate of West Black Sea, which are macro climate regions of Turkey. By using the measurement reading (Anonymous, 2001) of Meteorological Station in Eldivan, the method of Thornthwaite was used to determine the climate type of research area (Özyuvacı 1999). According to this, Eldivan has a type of climate which is arid-semi humid, mesothermic, having surplus water in winter and pretty nearly the same effect of maritime climate (Göl, 2002). Geological formations of research area consist of metamorphic and volcanic fasiers belonging to Neogene and Cretaceous. Eldivan Ophiolitic Complex detected by Akyürek (1979) is a material of oceanic-crust which initial arrangement has been saved in spread of ophiolitic melange observed in Central Anatolia (Anonymous, 1988). In respect of Soil

Taxonomy (1999), the soils of Çankırı-Eldivan Karataşbağı watershed have been included to the classifications of Lithic Xerorthent, Typic Xerorthent, Typic Calcicxerept, Typic Haploxerept, Lithic Calcicxerept ve Lithic Haploxerept (Göl and Dengiz 2007).

Methods

By using the Digital Elevation Model (DEM) belonging to Göl and Dengiz (2007), which was made previously on research area and observing topographical maps drawn to a scale 1:25.000, sampling dots and places of land cavities has been determined. Two-number sample regions which are similar alike in terms of the characteristics of slope, aspect, height in natural forest and afforestation areas. Sample areas were limited as 20x20=400 m^2. Heights and diameters of all the trees and age of three ones of supreme trees were measured (Kantarcı 1979). In the study, it was used clizimeter, altimeter, calipers, heightmeter, increment borer and compass.

Soil profile was digged in each sample area. In the soil profile, condition of outer-soil, absolute and physiological depth, drainage state, skeleton, root distribution, humidity, structure, stoniness and carbonates were assessed according to Çepel (1998) and Kantarcı (2000). From soil profiles, natural distorted soil samples in respect of the genetic horizon base were taken. On these samples, grain distribution was determined by using hydro-meter method (Bouyoucos, 1951), saturation % (Richards, 1954) besides, organic matter were designated by the newly version of the method Walkley-Black, which was modified by Jackson (Nelson and Sommers 1996). The total nitrogene were determined according to the method Micro Kjeldahl (Bremner, 1996) pH, EC and salt in the soil samples were analyzed in respect of (Rhoades, 1996; U.S. Salinity Lab. Staff, 1954) and lime ($CaCO_3$) was analyzed by Richard and Donald (1996). Plant materials in the region were collected as a result of land-studies during the periods of vegetation development (bloom, bearing, seed etc.) in 2008. These plants collected have been put into herbarium material in accordance with its modern systematic rules. Minimum 2 samples of each plant species were prepared and after identifying these species, they were preserved in the Herbarium of Forestry Faculty of Çankırı Karatekin University.

RESULTS

Watershed Rehabilitation Studies (Since 1962)

"The Directorate of the Soil Protection and Pasture Rehabilitation" was established within the forest organization in order to carry out watershed rehabilitation studies in the 1950s. While the forest organization started to afforest slope areas, The General Directorate State Hydraulic Works started the rehabilitation project of Dümeli (Eldivan) Karadere watershed and stream improvement studies. There were great changes in the use of land and the cover of the land as a result of these studies. It was reported as a result of these studies carried out between 1955 and 1961 that there were strong erosions in the 42% of the watershed. It was stated that there were floods that caused deaths and loss of goods in the years of 1913, 1949, 1952, 1961 and 1962. Between 1964 and 1967, the State Hydraulic Works built tree little dam, six rehabilitation benches, twelve mixed-benches, 121 dry wall benches and a terrace which is 3700 m in length reinforced with bush bunch (Anonymous 1967).

The afforestation studies were started in 1962. Plantation was made with naked-rooted saplings black pine aged 2+0. In 1983, Çankırı Directorate of Forest Enterprise applied "The Project of Eldivan Gölez Erosion Control and Afforestation Inside-Forest Application". Within the project, black pine saplings aged 2+0 were planted. It was stated that the features of the flora changed depending on the slope. It was reported that juniper, the species of oak in the form of bush, the species of milk-vetch, wild sainfoin, vitch grass, mullein etc., single or multi-years herbaceous species were common (Anonymous 1983). According to the use of the land and the distribution of the cover of the land in 2006, it was provided that a decrease in the area of the degraded black pine and degraded coppice (-5.7 %) along with the farm areas produced from forests (-15.8 %), but an increase in the forests of black pine (21.3 %) (Göl and Dengiz 2007).

Silvicultural and Flora Properties of Study Area

The findings related to the stand constitutions of natural forest and afforestation areas chosen in the watershed of The Karataşbağı Stream and the four sample areas (1^{st} and 2^{nd} samples are in the natural forest, 3^{rd} and 4^{th} samples are in plantation) that were taken to determine various silvicultural features of them are given below. While evaluating the findings, the sample areas of natural and afforestation forest are consolidated together.

The sample areas chosen in natural forests take place in the altitudes of 1200 m and 1250 m. the stand canopy in the areas are valued as full (80-100 %). In the natural forests, the dominating species is the black pine *(Pinus nigra* Arn. subsp. *nigra* var. *caramanica* (Loudon) Rehder). Oak (*Quercus cerris* L., *Q. pubescens* Willd,) joins the mixture on the below tree floor. On the bush floor, *Quercus cerris* L., *Q. pubescens* Willd, *Crataegus monogyna* Jacq., *Colutea cilicica* Boiss.et Bal., and *Rosa canina* L**.** join the mixture. The canopy of the A1 floor is 90-100 %, the canopy of the A2 floor is 80% and the canopy of the A3 floor is 10 %. It was determined that the canopy of the bush floor is 10-30 % and the canopy of grass floor is 10 %. Thirty-two trees were counted in the first sample area (400 m^2). The highest is 26 m, the largest is 55 cm and the oldest is 79 years old of the trees that are all black pines. Sixty-six trees were counted in the second sample area. Although the main species of the A1 floor in this area is black pine, oak joins the mixture at a high rate (50%). The highest of the black pines is 15 m, the largest one is 32 cm ($d_{1.30}$) and the oldest is 70 years old. The highest of the oaks is 7 m, the largest one is 8 cm ($d_{1.30}$) and the oldest is 36 years old.

The third and the fourth sample areas were chosen in the afforestation areas were chosen in the altitudes of 1105 m and 1285 m in the west. At the afforestation studies, the slopes were chosen different from each other in order to see the effect of the depth of the soil and the slope. Slope of the third sample area is 45 % and slope of the fourth sample area is 0-5 %. The saplings of black pine aged 2+0 which were forested mono-culturally were used. Stand canopy on the above-tree floor was provided by 80-100% in both areas. Moreover, it was seen that the forest started to regeneration in the below-tree floor and in the bush floor. The stand canopy of the A1 floor was valued as 70-80%, the canopy of the A2 floor was valued as 70-80%, and the canopy of the below-tree floor was valued as 10-20% in the third sample area where the slope is high and the erosion is strong. Because the stand canopy didn't occur entirely in this sample area, the canopy in the bush and grass floor was valued as high (60-70 %). In the bush floor, lots of species of oaks, azarole, (*Colutea cilicica* Boiss.et Bal.), rose hip, juniper, plum, filix mas and (*Astragalus angustifolius* Lam. subsp. *pungens* (Willd.) Hayek) were encountered. The sample area was separated by gullies, and it was seen that the stream rehabilitation study was done with dry wall benches during the watershed rehabilitation studies. The A1 floor canopy was valued as 90-100 %, A2 was valued as 70-80%, in the fourth sample area where the slope is low. Stand canopy was valued as 60-70% due to the oaks that join the mixture at a rate of 50% in the A3 floor. The species similar to grass that were encountered in the third sample area were also seen in the bush floor. Thirty-two trees were counted in the third sample area (400 m^2). Although 2500 saplings were planted, it was seen that there were 800 trees in hectare. The highest is 19 m, the largest is 29 cm ($d_{1.30}$) and the oldest is 42. The main species of the A1 floor is the black pine in the fourth sample area. Thirty-five trees were counted totally. Although the slope was low in this sampling area, that the depth of the soil was low affected the development of the height and the width of the trees badly. In this sampling area, the highest is 12 m , the largest is 24 cm ($d_{1.30}$) and the oldest is 41 in the A1 floor.

Research area is in the A4 square according to P.H. Davis's Grid system. 118 genus and 172 taxons belonging to 32 families (including species and subspecies) were determined as a result of the evaluation of the samples of nearly 500 plants that we collected during the area studies that we carried out between April and September in order to determine the flora of the area. The richest family in our research area is *Fabaceae*, *Asteraceae*, *Lamiaceae*, *Brassicaceae*, *Poaceae, Scrophulariaceae, Boraginaceae Caryophyllaceae*, *Apiaceae* and *Rosaceae.* The rate of the ten richest families to the total species is 73.83 %, the rate of the species that separated to the remaining 22 families is 26.17 % (Table 2).

Some Soil Physical and Chemical Properties of Study Area

It was determined that there was dry-mull-type humus, litter heaping which was 4 cm wide in the first sample area and 5.5 cm wide in the second sample area which were chosen in the natural forests. It was seen that in the opened soil profile, there was a deep physiological depth in the first sample area (130+ cm) and there was a medium-deep physiological depth in the second sample area (60+ cm). Stoniness was valued as medium (0-15 cm) in above soils due to strong surface erosion, and it was valued as high amount in the below soils due to the main material. Although stoniness is high and the main material is close to the surface, a cracked main rock structure let the tree seeds go deep. It was determined that it couldn't be provided for enough litter heaping (3-4 cm) in the third and the fourth sample areas which were chosen in the afforestation area and it was seen that the mixture of the soil and the litter was not good. Stoniness was valued as medium (15-30 %) on the surface and as high (50-60 %) on the below soils in both sample areas. Absolute depth of the soil is low (25-40 cm) due to the strong erosion, and the physiological depth is high (130 cm) due to the cracked main rock structure.

The results of the analyses of the natural and the afforestation area soils are given at Table 1. These soils have a sandy, with clay, loam structure. In the afforestation areas stand canopy didn't occur entirely, there are problems in litter accumulation. The amount of coarse fragments is high in natural forest soils. Soil reactions (pH) vary among very light acid (pH 6.1), light acid (pH 6.7), and strong alkali (pH 8.1). The content of lime and organic matter of soils affected the reaction of the soil directly. pH is low in the above horizon soils where the amount of organic material is high, and the pHs of the below horizon soils whose amount of lime is high are valued as high. The amount of lime of the soils that belong to third sampling area decreases with the depth. The lowest pH was valued in the fourth sample area. Also, the amount of lime of the soils of this area is low. When the soils are evaluated in the view of saltiness, the results are like this: The soils that belong to the first, the second and the third sampling areas are saltless or very little salty. They are medium-salty or too salty in the fourth sampling area. The electrical conductivity of the soils of this area is EC=6.81dS/m. That the amount of the salt is high and the depth of the soil is insufficient affected the development of the height and with of the trees badly. Depending on the amount of the dead cover which heaped on the soil and soil dampness, the amount of organic material and total nitrogen changed. It was seen that the heap of organic material of the soils approximated the soils of the natural forests as a result of the afforestations which were made 46 years ago. The amount of organic material in the above horizon soils of the natural forests is rich and very rich. The above horizon soils of the artificial forests are rich (Table 1).

As a result of the afforestation studies of 46 years, the soils of afforestation forest approximated the features of natural forest soil in spite of all the bad features.

DISCUSSION

When the old and the present maps of land use are evaluated together, it is seen that afforestation has been made in the agriculture and the pasture land in the study area and around it. The borders of the natural forests have expanded. In the forest areas, the unproductive coppice stands turned into coppice forest, and the open areas turned into afforestation areas. The increase in black pine forests is 21.3 %. The afforestation studies must be continued in the high-slope places where there is a risk of erosion. Afforestation must be as a mixed species forest building instead of the single one. In the places where afforestation isn't done and where there is a risk of erosion, protective herbaceous species must be encouraged. Maintenance studies must be attached importance in the natural forest and afforestation areas. With the watershed rehabilitation studies which were made after 1960-1962, 27 % of the watershed was forested and studies were successful. But wrong agricultural activities and wrong pasturing still continues. Dense forestry activities and that people support these activities increase the success in the area where the drought is the biggest problem. As a result of this success, Bülbülpınarı zone of the watershed has been opened to be used as recreation. The rehabilitation studies were successful; the risk of flood was decreased to the minimum level. The flood control structures which were built in the Karataşbağı Stream zone have stopped the erosion entirely. The stress continues in the forest areas because the people who live under rural poverty aren't aware of the protection of nature sufficiently. Consequently, when determining the targets in the watershed rehabilitation studies, economical and ecological criteria must be evaluated together.

Authorities who have the right to make decisions must take benefit from the scientific findings of earlier studies while deciding the policies of land use. So, country lands will be used more productive and sustainable.

Table 1 Some soil physical and chemical properties of Research area

Land Use	Coordinate	Horizon	Depth (cm)	Texture (%)			Soil Type	Coarse Fragments (%)	pH 1/5 water	Saturation (%)	Salt (%)	EC (dS/m)	Lime ($CaCO_3$) (%)	Organic Matter (%)	Total Nitrogene (%)
				Clay	Loam	Sand									
Natural Forest	542 941 N	Ah	0-4	31	23	46	SCL	55	7.1	80	0.12	2.69	7	7.04	0.36
		Ael	4-22	19	33	48	SL	41	6.7	64	0.12	2.61	17	5.54	0.32
		AB	22-33	30	23	47	SCL	46	7.7	56	0.11	2.38	27	3.14	0.15
		Bst	33-46	29	21	50	SCL	25	7.5	52	0.13	2.90	25	2.02	0.10
	4 483 338 E	BC	46-62	28	25	47	SCL	71	7.6	52	0.08	2.00	21	1.89	0.09
		Cv_1	62-80	27	26	47	SCL	81	7.7	44	0.09	2.08	27	0.88	0.04
		Cv_2	80+	27	27	46	SCL	75	7.7	47	0.07	1.64	24	0.77	0.03
Natural Forest	542 985 N	Ah	0-5	22	20	58	SCL	43	7.1	65	0.11	2.35	17	5.29	0.26
		Ael	5-17	14	36	50	SL	52	7.6	50	0.09	2.05	24	3.89	0.19
	4 483 747 E	AC	17-25	13	27	60	SL	52	7.5	47	0.09	2.03	22	2.02	0.10
		Cv	25+	34	31	35	SCL	55	7.7	41	0.07	1.62	26	0.88	0.04
Plantation Forest	543 539 N	Ael	0-10	33	32	35	SCL	44	7.7	47	0.09	2.22	21	2.39	0.11
		Bst	10-26	28	38	34	SCL	44	7.7	42	0.11	2.41	22	2.77	0.13
		BC	26-40	34	29	37	SCL	49	7.8	43	0.13	2.81	16	0.90	0.04
	4 484 863 E	Cv_1	40-63	20	31	49	SCL	58	7.9	39	0.07	1.70	19	0.63	0.03
		Cv_2	63-78	32	29	39	SCL	66	7.9	43	0.07	1.67	18	0.63	0.03
		Cv_3	78+	22	23	55	SCL	52	8.1	35	0.06	1.41	5	0.51	0.02
Plantation Forest	543 812 N	Ah	0-2	35	23	42	SCL	13	6.7	70	0.07	1.71	2	5.67	0.32
		Ael	2-20	34	38	28	SCL	17	6.5	51	0.19	4.08	2	3.89	0.19
		Bst	20-36	34	23	43	SCL	38	6.2	62	0.26	5.61	1	2.02	0.10
	4 484 263 E	BC	36-52	14	16	70	SL	32	7.0	50	0.14	3.11	2	1.40	0.07
		Cv	52+	28	21	51	SCL	25	6.2	58	0.33	6.81	2	1.01	0.05

Note: SCL: Sandy clay loam, SL: sandy loam,

Table 2. Floristic list of different land use of Karataşbağı Watershed

Plant Family	Genus	Natural Forest	Plantation	Grassland
Ranunculaceae	*Ceratocephalus falcatus*			x
	Clematis vitalba L.	x		
	Consolida orientalis (Gay) Schröd.		x	
	Ranunculus arvensis L.			
Berberidaceae	*Berberis crataegina* DC.	x	x	x
	B. vulgaris L.			x
Papaveraceae	*Fumaria asepala* Boiss.	x		x
	F. parviflora Lam.	x		
	Papaver dubium L.			x
Brassicaceae	*Aethionema arabicum* (L.) Andrz. ex DC.			x
	Alyssum desertorum Stapf. var. *desertorum* Stapf.		x	
	A. minutum Schlecht. ex DC.		x	
	A. minus (L.) Rothm. var. *micranthum* (Meyer) Dudley	x		
	A. murale Waldst. & Kit. var. *murale* Waldst. & Kit.		x	
	A. pateri Nyar. subsp. *pateri* Nyar.			x
	Arabis caucasica Willd. subsp. *caucasica* Willd.			x
	Camelina rumelica Velen.	x		x
	Cardaria draba (L.) Desv. subsp. *chalepensis* (L.) O. E. Schulz	x	x	
	Erysimum crassipes Fisch. & Mey.	x		
	Fibigia clypeata (L.) Medik.	x		
	Thlaspi perfoliatum L.			x
Resedaceae	*Reseda lutea* L. var. *lutea* L.	x	x	
Cistaceae	*Helianthemum nummularium* subsp. *lycaonicum* Coode & Cullen	x	x	
	H. nummularium subsp. *ovatum* (Viv.) Schinz & Thellung		x	
Polygalaceae	*Polygala anatolica* Boiss. & Heldr		x	
	P. supina Schreb.		x	
Caryophyllaceae	*Arenaria serpyllifolia* L.	x		
	Cerastium brachypetalum Pers. subsp. *roeseri* (Boiss. & Heldr.) Nyman	x		
	Saponaria prostrata Willd. subsp. *prostrata* Willd.	x		
	Silene alba (Miller) Krause subsp. *eriocalycina* (Boiss.) Walters	x	x	x
	S. chlorifolia Sm.			x
	S. italica (L.) Pers.			x
	S. vulgaris (Moench) Garcke var. *vulgaris* (Moench) Garcke		x	
	Stellaria holostea L			x
Illecebraceae	*Herniaria incana* Lam.	x		x
Polygonaceae	*Rumex acetosella* L			x
	R. crispus L.			
Chenopodiaceae	*Chenopodium album* L. subsp. *album* L. var. *album* L.	x		
	C. botrys L.	x		
Clusiaceae	*Hypericum linarioides* Bosse		x	x
	H. lydium Boiss.			x
	H. origanifolium Willd.			
	H. perforatum L.	x		x
Malvaceae	*Alcea pallida* Waldst. & Kit			x
	Malva neglecta Walh			x
Linaceae	*Linum tenuifolium* L.			x
Geraniaceae	*Geranium asphodeloides* subsp. asphodeloides Burm. Fil.		x	
Fabaceae	*Astragalus angustifolius* Lam. subsp. *pungens* (Willd.) Hayek	x		
	A. anthylloides Lam.	x	x	
	A. dipsaceus Bunge	x		
	A. karamasicus Boiss. & Bal.	x	x	
	A. lycius Boiss.	x		
	A. sigmoideus Bunge			x
	Colutea cilicica Boiss. & Bal.	x	x	
	Coronilla orientalis Miller var. *orientalis* Miller	x		
	C. varia L. subsp. varia L.	x		
	Dorycnium graecum (L.) Ser.			x
	Genista lydia Boiss. var. *lydia* Griseb.			x
	Lathyrus tukhtensis Czecz.			x
	Lotus aegaeus (Gris.) Boiss.		x	
	Medicago falcata L.		x	

Plant Family	Genus	Natural Forest	Plantation	Grassland
Fabaceae	*Medicago lupulina* L.		x	
	M. minima (L.) Bart. var. *minima* (L.) Bart.	x		
	Melilotus alba Desr.			x
	M. officinalis (L.) Desr.			x
	Onobrychis armena Boiss. & Huet		x	
	Ononis spinosa L. subsp. *leiosperma* (Boiss.) Sirj.		x	
	Trifolium caudatum Boiss.			x
	T. medium L. var. *medium* L.			x
	T. pannonicum Jacq. subsp. *elongatum* (Willd.) Zoh.			x
	T. repens L. var. *repens* L.			x
	Trigonella fischeriana Ser.	x		
	Vicia cracca L. subsp. *cracca* L.		x	
	V. cracca L. subsp. *stenophylla* Vel.		x	
Rosaceae	*Alchemilla mollis* (Buser) Rothm			x
	Geum urbanum L.			x
	Potentilla recta L.			x
	Rosa canina L.	x	x	
	Sanguisorba minor Scop. subsp. *muricata* (Spach) Brip.			x
Apiaceae	*Bifora radians* Bieb.			x
	Bunium microcarpum subsp. *bourgaei* (Boiss.) Hedge & Lamond			x
	Caucalis platycarpos L.	x		
	Echinophora tenuifolia L. subsp. *sibthorpiana* (Guss.) Tutin		x	
	Laserpitum hispidum Bieb.		x	
	Turgenia latifolia (L.) Hoffmann			x
	Zosima absinthifolia (Vent.) Link			x
Rubiaceae	*Cruciata taurica* (Pallas ex Willd.) Ehrend.			x
	Galium incanum Sm. subsp. *elatius* (Boiss.) Ehrend.			x
Morinaceae	*Morina persica* L. var. *persica* L.			x
Dipsacaceae	*Scabiosa argentea* L.		x	
Asteraceae	*Achillea biebersteinii* Afan.			x
	Acroptilon repens (L.) DC.		x	
	Anthemis tinctoria L. var. *pallida* DC.			x
	A. triumfetti (L.) All.		x	
	Carduus nutans sensu lato			x
	Centaurea depressa Bieb.			x
	C. virgata Lam.		x	
	Chondrilla juncea L. var. *juncea* L			x
	Cichorium intybus L			x
	Cirsium arvense subsp. *vestitum* (Wimmer & Grab.) Petrak			x
	Crepis foetida L. subsp. *rhoeadifolia* (Bieb.) Celak	x	x	
	Crupina vulgaris Cass.		x	
	Doronicum orientale Hoffmann			x
	Inula montbretiana DC.			x
	Jurinea pontica Hausskn. & Freyn ex Hausskn.		x	x
	Pilosella piloselloides subsp. *piloselloides* (Vill.) Sojak			x
	Senecio vernalis Waldst. & Kit			x
	Tanacetum vulgare L.			x
	Taraxacum macrolepium Schischkin		x	
	T. serotinum (Waldst. & Kit.) Poriet	x	x	x
Campanulaceae	*Asyneuma amplexicaule* subsp. *amplexicaule* var. *amplexicaule* (Willd.) Hand.-Mazz.			x
	Campanula glomerata L. subsp. *hispida* (Witasek) Hayek			x
	C. rapunculoides L. subsp. *rapunculoides* L			
Primulaceae	*Androsace maxima* L.			x
Boraginaceae	*Alkanna orientalis* (L.) Boiss. var. *orientalis* (L.) Boiss.	x	x	
	Anchusa azurea Miller var. *azurea* Miller	x		
	A. leptophylla subsp. *incana* (Ledeb.) Chamb.	x	x	x
	A. leptophylla subsp. *leptophylla* Roemer & Schultes			x
	Echium vulgare L.			
	Lappula barbata (Bieb.) Gürke	x		x
	Myosotis alpestris subsp. *alpestris* F.W.Schmidt		x	
Boraginaceae	*Onosma isauricum* Boiss. & Heldr.		x	
	O. stenolobum Hausskn. ex H. Riedl		x	x
Scrophulariaceae	*Linaria corifolia* Desf.			x
	L. simplex (Willd.) DC.	x		
	Odontites verna subsp. *serotina* (Dumort.) Corb.	x		
	Scrophularia canina L. subsp. *bicolor* (Sm.) Greuter			x
	Verbascum cheiranthifolium var. *asperulum* (Boiss.) Murb.			x
	V. cheiranthifolium Boiss. var. *cheiranthifolium* Boiss			x
	V. lasianthum Boiss. ex Bentham			x
	Veronica multifida L	x	x	
	V. officinalis L.	x		
	V. triphyllos L.	x		
Lamiaceae	*Acinos rotundifolius* Pers.		x	x
	Ajuga chamaepitys subsp. *chia* var. *chia* (Schreber) Arcangeli			x
	A. orientalis L			x
	Lamium purpureum L. var. *purpureum* L.			x
	Marrubium astracanicum Jacq. subsp. *astracanicum* Jacq.		x	
	Mentha longifolia (L.) Hudson subsp. *longifolia* (L.) Hudson		x	
	Phlomis armeniaca Willd.			x
	P. pungens Willd. var. *pungens* Willd.			
	Salvia candidissima Vahl subsp. *candidissima* Vahl	x	x	
	S. dichroantha Stapf		x	x
	Scutellaria orientalis L. subsp. *pinnatifida* Edmondson			x
	S. salviifolia Bentham			x
	Sideritis montana L. subsp. *montana* L.		x	
	Stachys annua subsp. *annua* var. *lycaonica* Bhattacharjee	x	x	
	Teucrium chamaedrys L. subsp. *chamaedrys* L.			x
	Thymus longicaulis subsp. *longicaulis* var. *longicaulis* C. Presl	x	x	
	T. longicaulis subsp. *longicaulis* var. *subisophyllus* (Borbas) Jalas	x	x	
	T. sipyleus subsp. *sipyleus* Boiss. var. *sipyleus* Boiss			x
Euphorbiaceae	*Euphorbia macroclada* Boiss.	x	x	x
	E. myrsinites L.			x
	E. stricta L.			x
Fagaceae	*Quercus petraea* subsp. *iberica* (Steven ex Bieb.) Krassiln	x	x	
	Quercus pubescens Willd.	x	x	
Liliaceae	*Allium. scorodoprasum* L. subsp. *rotundum* (L.) Stearn			x
	Muscari armeniacum Leichtl. ex Baker	x	x	
	M. neglectum Guss.	x	x	x
	Ornithogalum oligophyllum E. D. Clarke			x
Iridaceae	*Crocus ancyrensis* (Herbert) Maw	x	x	x
Poaceae	*Aegilops umbellulata* subsp. *umbellulata* Zhukovsky	x	x	
	Agrostis stolonifera L.			x
	Alopecurus arundinaceus Poiret			x
	Bromus danthoniae Trin.			x
	B. japonicus Thunb. subsp. *japonicus* Thunb.			x
	B. squarrosus L.	x	x	x
	B. tectorum L. subsp. *tectorum* L.	x	x	x
	Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman	x	x	x
	Festuca valesiaca Schleich. ex Gaudin		x	
	Poa bulbosa L.	x	x	x
	Stipa joannis Celak.		x	x

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Time-Dependent Changes in Distribution Patterns of Soil Penetration Resistance in a Rangeland under Overgrazing

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ABSTRACT
Soil penetration resistance as an indication of soil compaction affects on soil infiltration and runoff. Overgrazed rangelands are under severe erosion risk because of compaction. The objective of this study was to determine changes in soil penetration resistance with time in a high altitude rangeland. A 5 ha rangeland (200x250 m) was transected with 25 m intervals, and soil penetration resistance was measured at every 5 m in each transect for 20 cm surface soil layer in three different time periods (15th of July, August and September). Undisturbed soil samples were taken for determining soil bulk density and soil moisture-penetration calibration tests, and these samples also were used to obtain fundamental soil characteristics. Exponential semivariogram models were fit to explain spatial variance in soil penetration resistance values. Distribution patterns of soil penetration resistance were defined using kriging values produced by the punctual kriging. Results indicated that soil penetration resistance was higher than the critical penetration resistance (3 MPa) for root growth in all measurement points. The mean soil penetration resistance increased about 9 % in August as compared with July and it was more or less constant in the following month. There were good agreements among the distribution patterns of soil penetration resistance obtained for different time periods.
Key Words: *penetration resistance, spatial variability, overgrazing, rangeland.*

INTRODUCTION

Overgrazing is one of the main factors causing range degradation by leading erosion, reducing biodiversity, and altering soil properties (Özgül & Öztaş, 2004). Zhao et al. (2007) reported that grazing decreased soil water content and soil organic C, but increased bulk density and shear strength. Greenwood (1997) compared hydraulic conductivity, bulk density and soil strength in grazed and ungrazed pastures and found statistically significant differences among the measured properties between two sites.

Soil compaction due to animal trampling is one of the factors responsible for the degradation of the physical quality of soils under pasture (da Silva et al., 2003). Warren et al. (1986) reported that trampling animals caused soil deformation by exerting high ground contact pressures under their hooves. The soil compaction caused by cattle grazing generally leads to reduction of porosity and water infiltration rates (Dadkhah and Gifford, 1981), impeded root growth, and increased losses of nitrogen due to runoff and erosion (Wood et al., 1989).

Spatial variability patterns of soil properties within an agricultural field or a pasture are useful tools for making effective management practices, defining relations among soil properties and also for evaluating disruptive factors affecting on these properties. Imhoff et al. (2000) used penetration resistance (PR) for determining spatial variability in soil properties induced by animal trampling in grazing systems, and emphasized the usefullness of PR curves for the evaluation of the physical quality of soils under pasture.

The objective of this study was to determine changes in soil penetration resistance with time in a high altitude rangeland under uncontrolled grazing.

MATERIAL and METHODS

The study area is located in a high altitude of the Palandoken Mountains. A 5 ha rangeland (200x250 m) was transected with 25 m intervals, and soil penetration resistance was measured at every 5 m in each transect for 20 cm surface soil layer in three different time periods (15^{th} of July, August and September). About 400 cattles were grazed in the research site during the whole grazing season.

Undisturbed soil samples were taken for determining soil bulk density and soil moisture-penetration calibration tests, and these samples also were used to obtain soil physical and chemical properties. Particle size fraction was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986), soil reaction using a glass electrote pH-meter (McLean, 1982), $CaCO_3$ by the Scheibler calcimeter (Nelson, 1982), organic matter by the Smith-Weldon method (Nelson and Sommers, 1982), electrical conductivity using a conductivity meter in saturation extract (Rhoades, 1982a), cation exchange capacity by the ammonium acetate method (Rhoades, 1982b), and aggregate stability using a Yoder type wet sieving analysis (Kemper and Rosenau 1986). Penetration resistance was measured using an Eijkelkamp type hand penetrometer (Herrick and Jones 2002).

Three undisturbed soil cores (30 cm in diameter and 30 cm in depth) were also taken for penetration resistance (PR) moisture calibration test. Soil cores were saturated and PR measurements were taken with approximately 5 days intervals and soil moisture content was determined at the time of PR measurements in laboratory.

Penetration resistance measurements were standardized for moisture changes using the relationship given in Figure 1.

$$\mathbf{PR_a = PR_o \exp((x-0,1)/0,716)}$$

in where;

PR_a : Adjusted penetration resistance, (kPa)

PR_o : Measured penetration resistance, (kPa)

X : Moisture content at measurement taken, (kg/kg)

0.1 : Selected moisture content for standardization, (0.1 kg/kg)

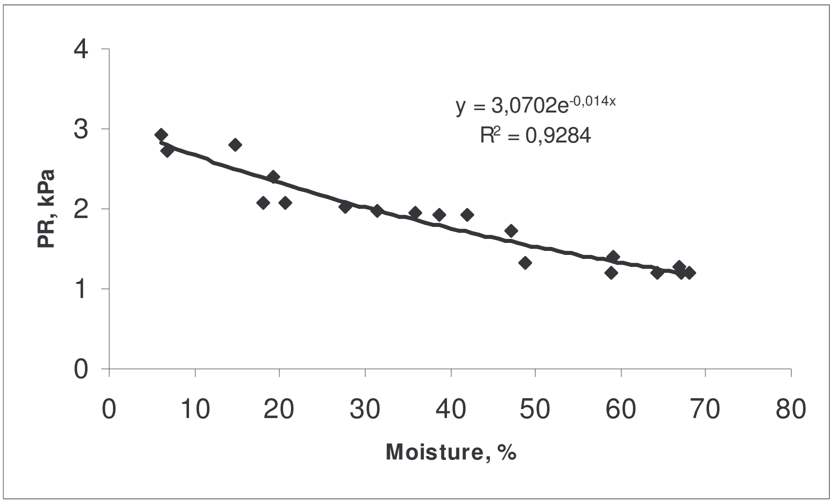

Figure 1. Relationship between soil moisture and penetration resistance for the soil studied.

Semivariogram and punctual kriging analyses were performed for preparing the distribution patterns of spatial variability of penetration resistance within the study field using GS+ geostatistical software.

RESULTS and DISCUSSION

Some physical and chemical properties of soil in the rangeland site were given in Table 1. The soil in the study site is loamy-textured, containing, on the average, 6.7 % organic matter and 0.2 % $CaC0_3$. Although the bulk density in the early grazing period was 0.88 g cm^{-3}, it slightly increased with increasing animal trampling due to compaction in August and decreased in September because of autum rainfall. The average soil wet aggregate stability (WAS) was 96 %. Although it decreased slightly in August as compared to the July, there was no significant differences among the WAS values.

Table 1. Some physical and chemical properties of soil in the study site.

Soil property	Time of sampling		
	June 15th	August 15th	September 15th
Sand, %	43.52		
Silt, %	33.54		
Clay, %	22.94		
Textural class	Loamy (L)		
Bulk density, g cm^{-3}	0.88	0.93	0.82
pH (1:2.5)	5.60	5.85	5.72
Organic matter, %	6.37	6.65	7.08
EC, dS cm^{-1}	450		
$CaCO_3$, %	0.21	0.20	0.20
Wet aggregate stability, %	95.88	94.52	97.71
Cation Exchange capacity, cmol kg^{-1}	38.6		

Spatial Variability Patterns of PR with Time

Descriptive statistics of the data are given in Table 2. The mean penetration resistance was 3.88, 4.21 and 4.16 MPa for July, August and September measurements, respectively. There was statistically significant increase (9%) in the PR measurements between the July and August values, but it was almost constant in September. The coefficient of variation of PR measurements was considerable low (5.16, 3.33 and 3.73 % for July, August and September, respectively) in all time periods, but it was the highest in July. This result indicated that the variability of PR get almost constant with grazing after July.

Table 2. Descriptive statistics for PR (MPa) measurements.

Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
July 15th					
3.41	4.47	3.88	0.20	-0.14	-0.34
August 15th					
3.63	4.54	4.21	0.14	-0.62	1.65
September 15th					
3.70	4.52	4.16	0.02	-0.37	-0.15

The experimental semivariograms were developed for different directions at the angles of 0^0, 45^0, 90^0, and 135^0 for soil penetration resistance values to determine directional variability within the research site. There were no distinct differences among the structures of the directional semivariogram models. Therefore, isotropy was assumed and a uni-directional semivariogram was fitted for characterizing spatial variability. Exponential semivariogram models were fit to explain spatial variance in soil penetration resistance values. The best fit model for the last period of grazing was only given here because of limited pages, (Figure 2). The range of influence was 122 m. This means that PR measurements within a circle area with a diameter of 122 m are correlated to each other.

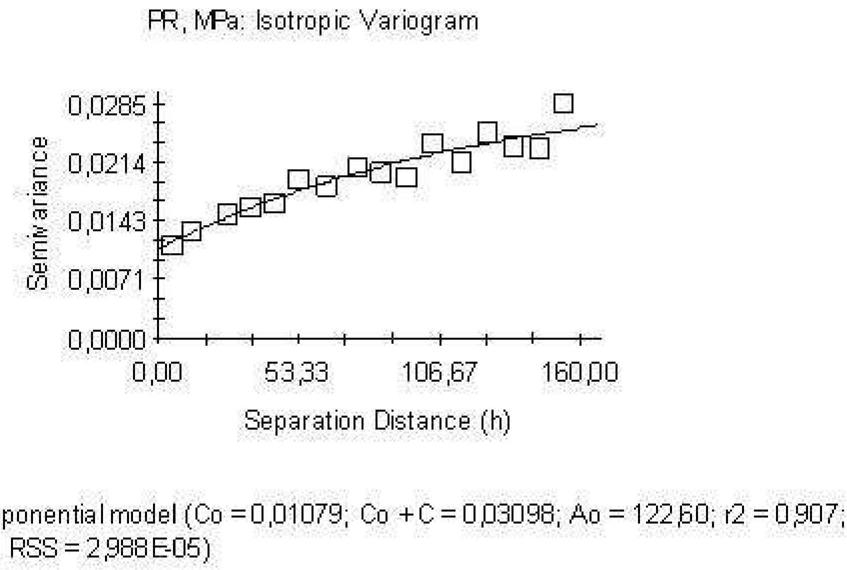

Figure 2. Semivariogram model fitted to explain variability in PR measurements (September).

Punctual kriging procedure was applied for estimating penetration resistance values at unsampled points with 1 m intervals using 6 to 10 measured values. The kriged estimation values were mapped to produce spatial variability patterns of PR in three different measurement periods (Figure 3). The patterns of variation in soil penetration resistance showed remarkable differences in different measurement periods. In July, higher PR values (>4.2 MPa) were recorded only in several points within the rangeland area, and total area with PR value of 4.0 MPa or more was only 14 % of the whole research area. However, in August the PR value was higher than 4.0 MPa in almost whole area (99.2 %). The rate of the most severe compacted area with PR value more than 4.2 MPa within the whole site was 65 %. On the other hand, in September the rate of the most severe compacted area with PR value more than 4.2 MPa within the whole site decreased down to 42 % and the rate of relatively less compacted area with PR value lower than 4.0 MPa within the whole site was almost 10 %. These results clearly indicated that grazing caused significant soil compaction during summer period, but autum rainfalls helped to slightly lower PR values in September. As reported by the Zhao et al. (2007) soil compaction induced by animal trampling inclined to a homogeneous spatial distribution of penetration values.

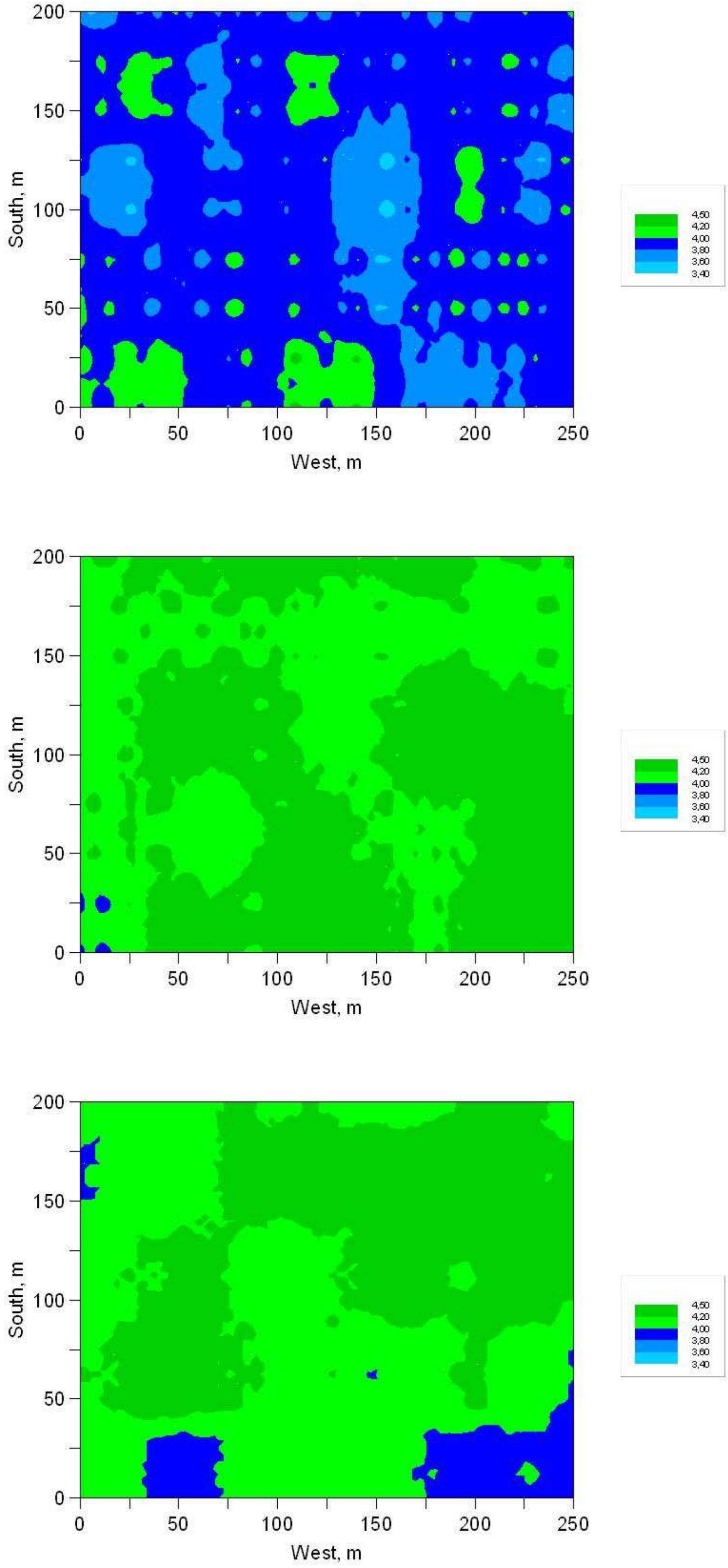

Figure 3. Spatial distribution patterns of PR in different time periods.
(from top to bottom; July, August and September).

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Fire Induced Changes in Soil Characteristics in Keşan, Turkey

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ABSTRACT

This research was conducted in Keşan (Çınarlıdere) area (1689 ha) of Thrace region, Turkey. The forest area was burned naturally in 2000. The aim of this research was to determine the effects of forest fire on some soil characteristics two year after the fire. Soil samples were collected from three locations as replicates from both burned and nearby unburnt sites. According to the study results, urease activity and soil organic carbon values ($P<0.001$), organic nitrogen and total porosity ($P<0.01$), aggregate stability, microbial biomass carbon values ($P<0.05$) were lower in burned soils than those of unburned soils. On the other hand, hydraulic conductivity and available phosphorus in unburned soil was not significantly higher than that of burned soils. This research showed negative effects of fire on some soil characteristics after two years.

Keywords: forest fire, soil, soil organic carbon; total organic nitrogen; porosity

INTRODUCTION

Forest fires are common problem in western and southern parts of Turkey. Fire is an important natural disaster in most forest ecosystems and can lead to rapid changes in physical, chemical and biological properties of soil. Fire effects on these characteristics of forest soils vary from minimal to profound. Depending on factors such as intensity and duration of the fire, soil type, soil moisture content at the time of the fire (Chandler et al. 1983, Pyne et al. 1996). Fire can substantially change surface soil characteristics and erosion rates and can influence patterns of vegetation on the landscape. Fire can have consequences on soil productivity by consuming organic matter and vegetation.

Previous studies on burned forest soils, illustrated that burning could influence the enzyme activities of soil not only of topsoil but also lower layers of soil profile. Zhang Yong-Mei et al. investigated invertase, acid phosphatase, proteinase, catalase, peroxidase and polyphenoloxidase activities in burned soils. It was found that the activities of invertase and proteinase were reduced by burning, but the activities of acid phosphatase, polyphenoloxidase and peroxidase increased.

The extent of fire effects on soil physical properties varies considerably depending on fire intensity, fire severity, and fire frequency. In general, most fires do not cause enough soil heating to produce significant changes to soil physical properties (Hungerford et al. 1990).

Loss of soil organic matter results in a loss of soil structure. By altering soil structure, severe fires can increase soil bulk density (DeByle 1981), and reduce soil porosity (Wells et al. 1979), mostly through the loss of macropores. Soil porosity can also be reduced by the loss of soil invertebrates that channel in the soil (Kettredge 1938). When fire exposes mineral soils, the impact of raindrops on bare soil can disperse soil aggregates and clog pores, further reducing soil porosity (Ralston and Hatchell 1971).

Intense fires may also induce the formation of a water repellent soil layer by forcing hydrophobic substances in litter downward through the soil profile (DeBano 1969). These hydrophobic organic compounds coat soil aggregates or minerals creating a discrete layer of water repellent soil parallel to the surface. Water repellent soil layers are reportedly formed at temperatures of 176-288 ^{0}C and destroyed at >288 ^{o}C (Neary et al. 1999). Extensive water repellent layers can block water infiltration and contribute to runoff and erosion.

There are not enough studies in literature on wildfire effects on carbon and nitrogen content in the soil. Groeschl et al. (1991) reported that, one year after a lightning-caused wildfire in Shenandoah National Park- Virginia, measured C and N amounts in low- and high-intensity areas of the wildfire area as well as in an adjacent unburned area. About the soil nutrients, P as phosphate is a nutrient released by burning. Schripsema (1977) found the availability of P to vary by site. Others have found availability to increase (Raison 1979, Kramer 1973, Smith and Owensby 1973, White and Gartner 1975, Christensen 1976). Some studies discuss nutrients other than N and P. Availability of K may increase after fire (Christensen 1976; Raison 1979).

Kavdir et. al. (2005) investigated the influences of forest wild fires that occurred 12, 8, 2 years and 2 weeks before the time of sampling on the composition of the forest floor organic matter by comparing total carbon (C) and total nitrogen (TN), composition of organic functional groups as determined by ^{13}C CP/MAS-NMR and soil aggregate stability of unburned and burned forest floor in four locations in Çanakkale, Turkey. Soil organic carbon values of three field replicates of burned soils, there was 20% decrease in 1990, 52% in 1994, 43% in 2000 and 11% in 2002 compared to unburned forest floor. Differences between burned and unburned soil organic C values were found to be significant at Kesan and Gelibolu sites. No significant decrease or increase in soil organic C was observed for samples taken from Lapseki and Cumali sites.

This work is aimed to the effects of forest fire, which occurred two years before sampling in Keşan-Edirne, on some soil physical chemical and biological properties. The soil chemical quality indicators are soil pH, electrical conductivity, organic nitrogen, soil organic carbon, cation exchange capacity, and available K and P. The soil biological indicators are urease activity, microbial biomass C. The soil physical quality indicators are aggregate stability, hydraulic conductivity, soil bulk density and soil water content.

MATERIALS and METHODS

Study Area

This research was conducted in Keşan (Çınarlıdere) area (1689 ha) of Thrace region, Turkey (Figure 1). The forest area (1689 ha) was burned naturally in 2000. Annual average temperature is 13,55 ^{0}C and rainfall is 585 mm in the area. The fire type was classified as medium to high intensity.

Figure1. Location of Research Area

Soil Sampling

Soil samples were taken from three different locations with three replicates in study area which burned in 2000. Each of the replicates was 1 m apart from each other. Burned and unburned sites were approximately 20–30 m apart from each other depending on the site. Burned and unburned disturbed, undisturbed soil samples were taken from 0–5 cm soil depth. Some samples were kept in at 4 °C for biological analysis.

Laboratory Analysis

Soil organic C was analyzed using the dichromate oxidation technique (Nelson and Sommers, 1996); total N was determined by steam distillation by Kjeldahl automatic analyzer using the Bremner method (Bremner, 1996); pH, EC, and CEC using the methods described in Soil Survey Staff (Soil Survey Staff. 1996), Soil aggregates were separated into their size fractions by sieving them through a 3.3-mm screen. Aggregate stability was determined by the Youder's wet sieving method (Kemper and Rosenau, 1986).

Dry soil samples were extracted with Mehlich I extraction solution. Available phosphorus (P) and potassium (K) were determined by ICP-AES. The method by Tabatabai (1994) was used for determining urease activity. Microbial biomass carbon of soil samples was determined by using the chloroform fumigation method (Howarth W. R., Paul E. A. 1994). Total organic carbon loads in Kg.ha-1 (0-5 cm) were calculated from the soil volume (V), soil bulk density (BD), percentage or concentration of SOC (Con), according to the equations 1 and 2 (Morley, et al. 2004).

$V=10{,}000\ m^2 \times 0.05\ m$ (1)

$C\ (kg.ha^{-1}) = (V \times BD\ (g/cm^3)) \times (Con\ (\%))/100$ (2)

Statistical Analysis

Collected data were analyzed by a PROC GLM procedure using Statistical Analysis System (SAS) (SAS Institute, 1997). Duncan's LSD test was used to separate means of measured values.

RESULTS

Variance analysis results in burned and unburned soils presented in Table 1. Means of physical, chemical and biological properties of samples, shown in Table 2.

Table 1. Variance Analysis of the Analyzed Biological-Chemical and Physical Properties

Parameters	Mean Squares		
	Fire (df=1)	Replication (df=2)	Error (df=2)
pH	0.48*	0.04	0.06
EC	10034.72*	567.39	1702.00
Total Organic N	0.17**	0.01	0.01
Urease Activity	71849.56***	648.45	2618.26
Microbial Biomass Carbon	2.77*	0.21	0.34
Available K	8683.86*	173.88	1151.29
Available P	121.47	36.96	30.19
Total Organic Carbon	48.05***	0.05	2.19
Cation Exchange Capacity	84.76	8.82	18.86
Aggregate Stability	1063.37*	26.92	170.22
Total Porosity	758.42**	4.20	51.95
Hydraulic Conductivity	10.19	6.68	8.51
Soil Water Content	86.68*	11.98	18.69
Soil Bulk Density	0.09**	0.00	0.00

*, ** and ***: Significant at 0.05, 0.01 and 0.001, respectively.

Table 2. Mean Values of Soil Physical, Chemical and Biological Properties of Burned and Unburned Forest Soils (n=9)

Parameters	**Burned**	**Unburned**	**LSD (0.05)**
pH	5.60b	5.93a	0.25
EC (µS.m^{-1})	85.11b	132.33a	42.37
Total Organic N (%)	0.20b	0.39a	0.11
Urease Activity (mg.Kg-1.2h^{-1})	88.57b	214.93a	52.56
Microbial Biomass Carbon (mg.C g Soil^{-1})	0.71b	1.49a	0.60
Available K (mg.Kg^{-1})	143.13b	187.06a	34.85
Available P (mg.Kg^{-1})	13.94	19.13	-
Total Organic Carbon (%)	3.80b	7.07a	1.52
Cation Exchange Capacity	14.84	19.18	-
Aggregate Stability (%)	75.24b	90.61a	13.50
Total Porosity (%)	46.28b	59.27a	7.40
Hydraulic Conductivity	3.33	4.84	-
Soil Water Content %	15.09	19.48	-
Bulk Density (g.cm^{3})	1.19b	1.33a	0.09

Total Organic Nitrogen

One effect of fire on N is volatilization (DeBell and Ralston 1970; Sharrow and Wright 1977; Tiedmann and Anderson 1980). Fire intensity, amount of green material, and moisture has been reported to influence the amount of N lost through volatilization (Dunn and DeBano 1977). However in some researches fire increased soil N due to stimulation of legumes (Mayland 1967), the washing of charred surface material into the soil (Metz et al 1961) and formation of ash which increases growth of nitrifying bacteria (Burns 1952). Nitrifying bacteria are protected from heat and recover quickly to produce nitrates from organic matter (Sharrow and Wright 1977). Organic N contents of both burned and unburned soils are presented in Table 2. Organic N contents of burned soils (0.20%) were found to be lower than unburned soils (0.39%) and this was statistically significant at 0.01 ($P < 0.01$).

Total Organic Carbon (TOC)

Volatilization causes carbon, hydrogen, and oxygen, (C, H, and 0) release to the atmosphere, along with varying amounts of sulfur (S), and phosphorus (P) depending on the composition of the organic matter burned and the degree of combustion (Raison 1979). As it is seen from the Table 2, negative effects of forest fire on topsoil soil carbon contents were observed two years after the fire. Mean values are, 3.80% and 7.07% for burned and unburned soils, respectively. Difference between mean values is statistically significant ($P < 0.001$).

Microbial Biomass Carbon (MBC).

Microbial organisms are an extremely important component of the biologically active portion of soil ecosystems. Soil microbial diversity and bio-mass are very important properties in terms of soil health and quality. According to Table 2, difference is statistically significant ($p < 0.05$). Microbial biomass carbon (MBC) of burned soils (0.71%) was found to be lower than unburned soils (1.49%).

Urease Activity

Urease catalyzes the hydrolysis of urea to carbon dioxide and ammonia. It acts on carbon-nitrogen (C-N) bonds other than the peptide linkage. Urease is important in organic N mineralization (Tabatabai, 1982). Urease activity of burned soil was lower (88.57 mg $kg^{-1}2h^{-1}$) than unburned (214.93 mg $kg^{-1}2h^{-1}$) soils. This difference was statistically significant ($p < 0.001$).

Electrical Conductivity (EC)

The EC after high-severity fire increased immediately and then decreases to relatively low values, for a relatively long period, due to the quick erosion of the ash layer as well as by the fast wash into subsoil (Tessler et al. 2008). In this research, soil changes persisted for 2 years following fire (Table 2). At the study site soil differences of EC values are statistically significant ($p < 0.05$) (Table 1).

Phosphorus (P) and Potassium (K)

White and Gartner (1975) found an increase in available P only if temperatures did not exceed 392 F (200 ^{o}C). They also speculated that, as in the case of ammonia, soil moisture and heat determine the extent of the increase in P availability. Soluble K will increase in the litter, and A-1 horizon if temperatures do not exceed 392 F (200 ^{o}C) (White et al 1973). Available soil P values of burned soils were lower than unburned soils after 2 years following fire, but this difference was not statistically significant (Tables 1 & 2). Available K values of burned (143.13 $mg.Kg^{-1}$) soils were lower than unburned (187.08 $mg.Kg^{-1}$) soils, and this was statistically significant ($p < 0.05$).

Cation Exchange Capacity (CEC)

Fire should not affect the CEC of mineral soils but may change CEC of soils rich with organic carbon,

This was also observed in this study. CEC values of burned soils and un-burned soil were 14.84 $cmol.kg^{-1}$ and 19.18 $cmol.kg^{-1}$, respectively. This difference was not statistically significant.

Soil Water Content

Fire induced changes in soil structure and texture can potentially impair soil hydrology**.** Decreased soil porosity and the formation of water repellent layers decrease water infiltration rates (DeBano 1971). Loss of soil organic matter and increased bulk density can decrease the water storage capacity of soils. In this Research, soil water content of burned and unburned soil samples were 15.09% and 19.48%, respectively, and this difference was not statistically significant.

Aggregate Stability (AS)

In areas affected by severe fires, organic matter content in soil was reduces, thus causing reduced aggregate stability. Aggregate stability values of burned and unburned soils are different and this difference is statistically significant ($p < 0.05$).

Hydraulic Conductivity, Porosity and Bulk Density

The strong water repellency of burned soils and reduced hydraulic conductivity, together with the loss of plant cover, can be assumed to be the main sources of the increased surface runoff and soil erosion. Difference of Hydraulic Conductivity values was not statistically significant in this study. Soil organic matter holds sand, silt, and clay particles into aggregates, therefore a loss of soil organic matter results in a loss of soil structure. By altering soil structure, severe fires can increase soil bulk density (DeByle 1981), and reduce soil porosity (Wells et al. 1979), mostly through the loss of macropores (>0.6 mm diameter). Soil porosity values of both burned and un-burned soils are presented in Table2. This difference was statistically significant ($p< 0.01$). Soil bulk density values of burned and unburned soils were statistically significant ($p < 0.01$).

CONCLUSION

Forest fires affect physical, chemical, and biological soil properties directly by transferring heat into soil and indirectly by destroying vegetation and the dynamics of plant nutrients and organic matter. High soil temperatures can kill soil microbes and plant roots; destroy soil organic matter; and alter soil nutrient and water status. The degree of soil heating during fire depends on a variety of factors, including fuel characteristics, fire intensity and residence time, and properties of the soil and litter layer. As a conclusion, the fire after two years reduced soil EC, available P and K, organic N content, CEC, porosity, hydraulic conductivity, urease activity, TOC and soil water content. This study showed that the forest fires do not only cause air pollution but also cause losses in soil properties. Also, negative effects of fire on soils still could be found after 8 years.

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An Investigation on the Relationship between Saline Soil and Halophytic Plants in Semi Arid Region (Acıçay Stream)

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ABSTRACT

The main objectives of this study were to compare soil properties and plants of both sides of the Acıçay River and evaluate relationships between salinity and landscape positions under the condition of semi-arid climate. Right side of the Acıçay River lands has been generally used for agriculture crops, while left side lands used for grassland. Soil properties and plant composition differentiate in the right and left sides of Acıçay River in Çankırı city which is chosen for a research area. The change on salinity and topography affect directly vegetation and variety of land use. With the aim of determining soil-plant interaction ,salinity has been determined in the plant-root area from two different depths (0-20cm-20-40cm) in the right and and left sides of Acıçay River and floristic composition is introduced in this region. Salt ratio in upper soil increases when you go near to the watershed. Salt and EC values of soils are measured high in left sides. Besides salt and EC values decline as you come up the slope through the stream. As a result of assessing plant samples which are collected at the time of land study, belonging 26 family 70 species and 110 taxon (including species and sub-species) have been ascertained.The richest families in the research area are *Asteraceae, Fabaceae, Lamiaceae, Poaceae* ve *Chenopodiaceae*. The ratio of the five of the richest family to the total species is 56.37. The ratio of the species dispersed in the rest 21 family is 43.63%.

Key Words: Salin Soil, Plants, Halophytic, Semi Arid, Çankırı

INTRODUCTION

The soils that are affected by salt are about 1 billion ha.in the world, although there is not any definite figure in Turkey, it is cited that it is about 2.5 million ha (Munsuz *et al.*, 2001). The increase on the world population and consumption necessitate gaining new production areas. When it is said new production area, one must think about bringing in economic support by rehabilitating problematic areas. Rehabilitation and development of production of salty and alkaline soils are quite complicated and it changes according with the region's climate, soil and plant features.

It is appeared that salt, gypsium and erosion are the most important soil problems in Turkey's arid and semi-arid regions. Slope areas of this region are used as a meadow and base lands are used for agricultural purposes. Great plant diversity does not exist in the areas which have salty soil condition except halophytic. The most important effect of salt on plant is to decrease taking in water and nutrients. Plants can not get enough water because of high osmotic potential. Toxic effect which is caused by excessive amounts of Na^+ and Cl^- poisons the plant (Flowers and Yeo, 1981). Na^+ that is accumulated in excessive amounts in the salt stressed plants causes a corruption of ion balance of plants by preventing K (Siegel *et al*., 1980), and Cl^- especially (NO_3^-) (Güneş *et al*., 1994) intake. In the salty and gypsium regions, existent plants should be analysed accurately in the rehabilitation and afforestation practices and plant species that have adapted should be preferred (Sönmez, 1990). The objectives of this study were to characterize the soil properties of the both sides of the Çankırı-Acıçay River and identifiy soil salinity and compare effects of soil properties on plant community of Acıçay River.

MATERIALS and METHODS

Description of the Study Field

The study was carried out transect along both sides of the Çankırı-Acıçay stream which is a prominent land form, parent material and vegetation. The study area is located approximately between 557 733 E-4 497 924 N, 557 751 E-4 4978 89 N and situated in vicinity of Çankırı province. It ranges in relief from 740 m to 800 m and four landscape positions (in river, flat-terrace, backslope, shoulder), representing changes in geomorphology, topographic gradients and soil characteristics, were selected. The underlying bedrocks within the study area consist of primarily that while right side soils of the Acıçay stream are formed on quaternary alluvial deposits that find on young and old terraces, left side soils are formed on quaternary alluvium, alluvial-collivial material spotted on and floodplain and old terrace oligomiocene gypsium and rock salt strata located on mid-slope and steep lands. According to meteorological data (Anonymous, 2008), the mean annual temperature and rainfall are 11.1 ºC and 417.7 mm, respectivly. According to the Thornthwaite water-balance model, the prevailing climate is arid-semiarid, mezo-thermal, arid-semi arid climate that has intensive water absence in summer and that was coded with D B'_1 d b'_3

Sampling and Analysis

Climate, topography and soil properties might be the main controlling factor in plant community. Soil and plant samples were collected from different topography and parent material at right and left sides of stream (Figure 1). Soils have been studied on along transect (crosswise from East to West direction) at 0-20 cm and 20-40 cm depths. Soil samples were taken to investigate for their chemical properties at the laboratory. The soil samples were then air-dried and passed through a 2 mm sieve to prepare for laboratory analysis. Soil pH and electrical conductivity (EC) were measured by a pH/conductivity meter (Rhoades, 1996). Carbonate ($CaCO_3$) was determined by pressure calcimeter method (Richard and Donald, 1996). Ca^{++}, Mg^{++}, Na^+, K^+ were determined with flame photometer (Helmke and Sparks, 1996)

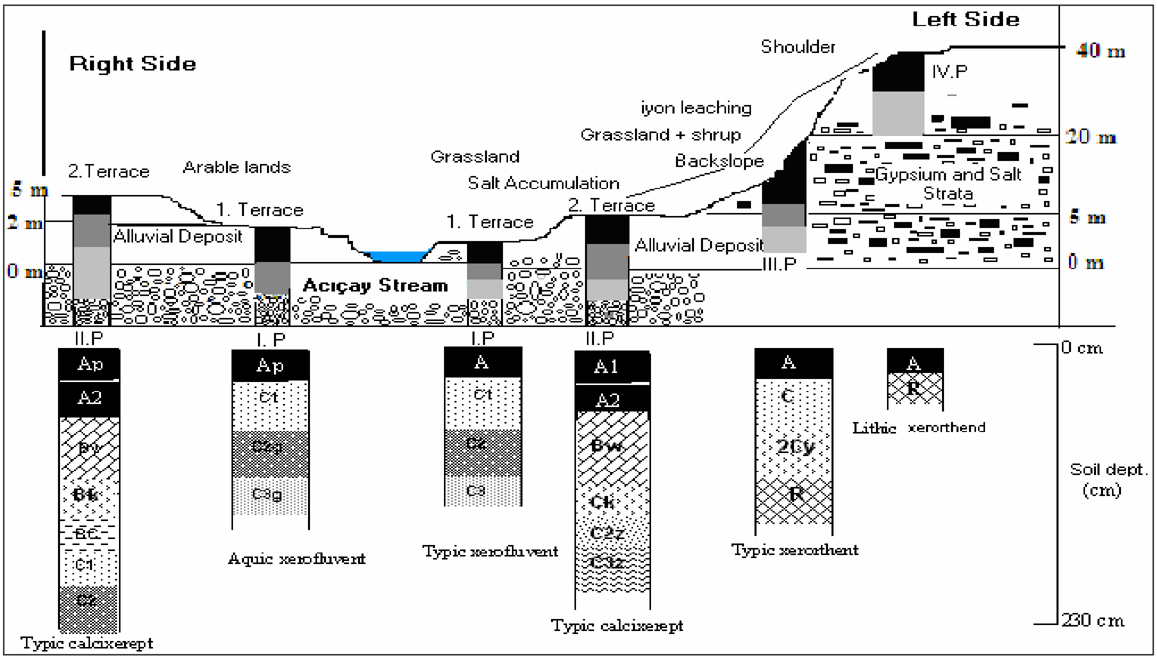

Figure 1. Different soil formations on various parent materials, slopes and land covers along the transect of both sides of the Acıçay stream (Dengiz *et al*., 2007)

The Acıçay stream is situated in the A4 square according to the Grid system of Davis (1965). The material of plant which forms the subject of the study was collected as a consequence of the estate studies during the term of the developing of vegetation in the years of 2007 and 2008. Plant samples have been studied on along transect (crosswise from East to West direction) like soil samples. The estate studies was conducted in various developing periods such as the aspect of Spring, Summer and Autumn of the vegetation. At least two pairs of sample were taken and these samples were put in the Herbarium of Forest Faculty, Çankırı Karatekin University after being defined. Boissier (1867-88), Harringion (1957), Polunin (1972) and particularly the work of "The Flora of Turkey and East Eagen Islands (Davis, 1965-85)" were used for recognition of the samples of the plants.

RESULTS and DISCUSSION

Soil chemical properties considered in this study are pH, salt, EC (Electrical Conductivity), exchangeable cations, total phosphorus and calcium carbonate. Right side soils of the Acıçay River are formed on quaternary alluvial deposits that are found on terrace and floodplain, alluvial-collivial deposits, left side soils formed from quaternary alluvium, alluvial-collivial material and oligomiocene gypsium and salt strata located on floodplain, terrace and steep lands respectively. In addition, right side lands have been generally used for agriculture crops, while left side lands have covered three major plant community types (herb, shrub-grass, and grass) and upper lands is generally barren due to overgrazing.

Soil chemical properties that have been taken into consideration in this study showed variability as a result of dynamic interactions among natural environmental factors such as climate, parent material, ground water, surface water, erosion and topography. Soil chemical properties on different slope position and parent material were significantly affected by ground water, river and leaching processing (Table 1-3)

In left side soils, salt percentage of surface soils in low slope sides is more than on higher slope except floodplain top soil that is almost salt recently alluvial deposits and the sand and gypsium content for slopes with high gradient is lower than for low slopes. The same properties are in right soils. This case is similar to the EC. While the lowest value (0.06 %) of salt is for slopes ranging from 30-40 %, the highest values of salt that are steadily increased with increasing slope gradient are 1-2 %. On the other hand, the salt ratios on the top soils increase as you come down area of the watershed. Accumulation of salt and gypsium which dissolve in the drainage area of the watershed increases as it gets down to the watershed. The highest salt is measured %0.26 from the 3 samples that are taken from the above of the watershed. But the highest salt is measured %4.09 in the 1.sample that are taken from the lower watershed. The ECs of top soils decrease as you go upward the watershed. Salt and EC amounts of soils are measured higher in the left sides of river. The reason of this is that left side's main material shows salty and gypsium properties. Besides salt and EC figures decrease as you go upward the slope through the stream.

Soils on shoulder position contain less exchangeable Na^+, K^+, and Mg^{++} due to stronger leaching. Soils can significantly accumulate these soluble ions such as Ca^{++}, Na^+, K^+, Mg^{++} from the upper slope and deposite on the floodplain and terrace soils where leaching is weaker. On the other hand exchangeable Na^+, K^+, and Mg^{++} which are carried from high slope to low slope, are moved away lower watershed by base water and stream flow. Therefore, the highest values (Na^+: 220 cmol kg^{-1}, K^+: 0.78 cmol kg^{-1} and Mg^{++}: 75.24 cmol kg^{-1}) are measured in the top soils in the lower watershed. The distribution of Ca^{++} among slope positions was the reverse of exchangeable Na^+, K^+ and Mg^{++} In spite of the leaching process, upper slope soils contain higher Ca^{++} concentration than low slope soils due to their parent materials which are gypsiferous rocks. On the other hand, Ca^{++} amount of top soils is higher in the first transect that is taken from the lower awatershed. Ca movement that is occurred by groundwater and steram flows has continued. Soil pH is generally greater at soil surface than at the depth. This case positively correlated with accumulation of cation concentration such as Na^+ and K^+. Cations that dissolve in subsoils by reason of arid and semi-arid climate are carried to the surface.

Soil chemical properties undergo great variations as you go upward from starting the first transect (Table 1-3). There is the effect of accumulation of soils that are carried by groundwater and surface flow in the lower watershed. The ratio of salinity, EC and cations decrease as you go upward the watershed.

70 genus belonging to 26 families and 110 taxons (including species and sub-species) have been determinede as a result of assessing plant samples being collected at the time of the land study (Table 4).

The richest families are *Asteraceae, Fabaceae, Lamiaceae, Poaceae* ve *Chenopodiaceae*. The ratio of the five of the richest family to the total speceis is 56.37%. The ratio of the species dispersed in the rest 21 species is 43.63%.

Research area is in Iran-Turan floristic region. According to this, regions' dominant vegetation constitute step formations in which trees and shrubs are found locally and sporadically. Regarding this, while step characteristic plants have been encountered in the third and fourth transect in the reserach area, salty characteristic (halophytic) plants have been especially encountered in the first and second transect and humid characteristic plants are in the stream.

Research area is quite close to setting areas in which antropojen effect is intense. In river and first terrace (flat-terrace) areas are used as a meadow land. Oleaster (*Elaeagnus angustifolia*), *Tamarix smyrnensis*, willow (S*alix alba, S. amplexicaulis*), poplar (P*opulus alba*) together with herbal species that are humid and salty characteristic spread in this regions. Over-grass has caused a destruction to the vegetation. 2-3and 4.terraces in right sides of river are used as a orchard and cültivated area throughout the research region. There is only an orchard in the second terrace of the first transect that is taken from the lowest point of the watershed. There is an orchard in the 2. and 3. terrace of third transect that is taken from the upward watershed (Figure 1). Being less salty as going upward the watershed provides production of fruit and vegetable.

CONCLUSION

Soil properties data of these both sides of Acıçay River soils indicated significant differences each other in terms of leaching processes which have been shaped by landscape position and parent material. In addition, the relationships between chemical properties of the soils and landscape positions determined by this research affect plant growth. Study of the variations in soil properties is important for soil management and selection that plant species. Therefore, in this study it is explained that parent material, salt, EC and pH and field slope factors affect plant variability through by how nutrients are retained. In addition, Gerrard (1981) also indicated that the movement and distribution of salt on slopes and floodplain is one of the primary reasons for plant variability. While plant variability at lower slope positions is worse due to high salt and gypsium. Nutrient elements transported from upper slope by overland erosion and subsurface flow to floodplain.

As a result of the research, it is understood that surfacel water carries the salt that can be dissolved by melting them to the accumulation subwatershed. On the other hand soil water under the great temperature has vapoured and rised to the surface together with capilarity and while rising up, it has carried salts along with.

Choice of species becomes important in arid and semi arid region's agricultural areas and afforestation pratices. The amaount of pH, salinity and lime of the soil should be taken into account. The amount of salt is higher in the first terrace (alluvial deposits) of the both sides of the stream in the research area. Therefore species that are resistant to salt should be supported in these regions. Growth of crops that are resistant to salt in the agricultural activities will incerease the output. The first terraces are directly used as a meadow land. As from the second terraces arid-watery agriculture and orchards have come into being. Salt is transmitted into the depths by irrigating abundantly with the water from the stream. In this way the chance of lifetime of the plant is increased.Meadow lands have been destructed as a result of over and faulty pasturage .Meadow improvement measures should be taken and also supported in these regions. Species that are resistant to salt should be prefered in afforestation practices and young plants should be supported with additional soils.

Table 1. Selected chemical properties for 1st Transect Soil

		Right Side					Left Side			
	Terrace No	4	3	2	1	0	1	2	3	4
Soil Properties	Soil Depth (cm)	Shoulder (P. M.)	Backslope (C.M.)	Old River Terrace (A.-C. M)	New River Terrace (A.M.)	In River (N.S)	New River Terrace (A.M.)	Old River Terrace (A.-C. M)	Backslope (C.M.)	Shoulder (P.M.)
Tuz (%)	0-20	0.23	0.24	0.31	4.09	1.26	2.59	0.68	0.21	--
	20-40	0.20	0.19	0.47	1.67	0.17	0.96	1.48	0.19	--
EC ($dS\ m^{-1}$)	0-20	4.92	5.46	6.63	72.88	24.44	47.86	13.68	4.46	--
	20-40	4.22	4.37	9.78	31.90	3.70	19.04	28.50	4.07	--
pH (1/5 D. W.)	0-20	7.6	7.6	7.5	6.9	8.1	6.9	7.5	7.5	--
	20-40	7.5	7.7	7.4	7.3	8.0	7.6	6.6	7.6	--
Calcium Carbonate (%)	0-20	15.56	14.88	18.06	20.42	18.76	16.67	24.32	15.28	--
	20-40	15.98	15.41	15.70	15.84	15.70	15.84	19.59	20.01	--
P ($kg.da^{-1}$)	0-20	4.73	5.56	7.30	4.04	0.39	1.32	7.72	0.78	--
	20-40	0.16	1.13	2.33	0.39	0.08	0.23	1.24	0.31	--
Exchangeable cations ($cmol\ kg^{-1}$) Ca	0-20	30.35	31.16	40.74	59.75	28.35	31.92	51.03	22.68	--
	20-40	28.35	23.44	27.09	37.28	2.31	31.92	63.63	27.09	--
Mg	0-20	1.56	3.22	7.57	75.24	19.36	43.03	4.34	6.74	--
	20-40	0.38	4.98	9.18	20.57	9.42	20.86	40.14	4.22	--
Na	0-20	0.56	0.39	0.94	178.00	66.00	220.00	7.00	0.50	--
	20-40	0.42	0.51	6.00	78.00	13.00	94.00	120.00	0.76	--
K	0-20	0.36	0.41	0.36	0.78	0.68	4.00	0.63	0.28	--
	20-40	0.16	0.27	0.22	0.42	0.14	0.70	0.44	0.22	--

Note: P.M.; Parent materyal, C. M.; Collivial metaryal, A.-C. M.; Alluvial-collivial material, A. M.; Alluvial materia, N. S.; New sedimentation.

Table 2. Selected chemical properties for 2nd Transect Soil

		Right Side					Left Side			
	Terrace No	4	3	2	1	0	1	2	3	4
Soil Properties	Soil Depth (cm)	Shoulder (P. M.)	Backslope (C.M.)	Old River Terrace (A.-C. M)	New River Terrace (A.M.)	In River (N.S)	New River Terrace (A.M.)	Old River Terrace (A.-C. M)	Backslope (C.M.)	Shoulder (P.M.)
Tuz (%)	0-20	0,12	0,16	0.18	0.17	0.24	0.12	0.23	0.26	--
	20-40	0.16	0.15	0.19	0.15	--	0.73	0.23	0.23	--
EC ($dS.\ m^{-1}$)	0-20	2.74	2.84	3.83	3.62	5.12	3.71	5.03	5.45	--
	20-40	3.46	2.69	4.04	3.31	--	14.72	4.87	5.00	--
pH (1/5 D. W.)	0-20	8.2	7.7	7.7	7.8	8.4	8.1	7.7	7.7	--
	20-40	7.6	7.6	7.6	7.7	--	7.9	7.6	7.6	--
Calcium Carbonate (%)	0-20	10.16	12.92	13.09	14.69	11.78	17.45	14.69	19.05	--
	20-40	12.94	13.07	15.85	9.16	--	5.81	15.56	14.25	--
P ($kg.da^{-1}$)	0-20	0.85	5.15	6.21	7.84	0.62	4.58	1.55	2.41	--
	20-40	0.47	--	5.20	1.86	--	0.47	1.01	0.62	--
Exchangeable cations ($cmol.\ kg^{-1}$) Ca	0-20	22.05	23.60	27.09	28.04	11.76	25.83	32.76	29.72	--
	20-40	28.35	28.62	31.82	27.93	--	32.34	23.52	29.19	--
Mg	0-20	2.50	1.96	1.42	10.76	13.29	4.68	1.73	3.18	--
	20-40	3.16	3.71	4.36	5.17	--	45.49	12.07	6.00	--
Na	0-20	0.78	0.72	1.24	1.20	14.01	2.14	0.24	0.66	--
	20-40	0.90	--	0.94	0.88	--	64.00	0.50	0.46	--
K	0-20	0.16	0.28	0.36	0.42	0.20	0.22	0.70	0.52	--
	20-40	0.10	0.32	0.36	0.32	--	0.28	0.90	0.34	--

Table 3. Selected chemical properties for 3rd Transect Soil

		Right Side					Left Side			
	Terrace No	4	3	2	1	0	1	2	3	4
Soil Properties	Soil Depth (cm)	Shoulder (P. M.)	Backslope (C.M.)	Old River Terrace (A.-C. M)	New River Terrace (A.M.)	In River (N.S)	New River Terrace (A.M.)	Old River Terrace (A.-C. M)	Backslope (C.M.)	Shoulder (P.M.)
Tuz (%)	0-20	0.21	0.12	0.06	0.17	0.04	0.14	0.13	0.20	015
	20-40	0.26	0.17	0.04	0.21	0.05	0.16	0.04	0.25	0.15
EC ($dS.\ m^{-1}$)	0-20	4.49	2.60	1.48	3.78	1.12	3.18	2.95	4.32	3.30
	20-40	5.65	3.32	9.57	4.58	1.18	3.46	1.10	5.23	3.32
pH (1/5 D. W.)	0-20	8.0	7.9	8.4	7.7	8.5	8.3	8.5	7.7	7.7
	20-40	7.7	7.7	8.5	7.7	8.5	8.1	8.7	7.6	7.6
Calcium Carbonate (%)	0-20	31.11	14.25	11.05	1.63	10.18	13.09	11.63	12.36	8.43
	20-40	20.21	7.56	9.16	10.90	7.56	6.39	4.36	12.50	10.61
P ($kg.da^{-1}$)	0-20	1.32	2.79	1.32	0.93	0.85	0.70	0.70	1.24	0.39
	20-40	1.55	0.31	0.47	0.62	0.62	0.47	0.23	0.85	0.47
Exchangeable cations ($cmol.\ kg^{-1}$) Ca	0-20	26.99	5.25	8.61	24.47	3.15	11.03	13.44	27.51	26.67
	20-40	31.50	8.40	0.95	25.73	11.76	17.75	2.63	24.26	26.15
Mg	0-20	6.31	3.91	2.22	5.65	3.51	6.17	5.84	1.32	1.96
	20-40	3.49	2.78	1.73	6.58	5.83	8.30	4.13	9.24	2.18
Na	0-20	0.50	0.18	0.44	4.50	1.52	10.50	8.00	0.46	0.24
	20-40	0.18	0.44	0.64	3.00	6.00	6.00	1.52	0.66	0.34
K	0-20	1.02	0.30	0.16	0.26	0.10	0.18	0.18	0.50	0.22
	20-40	1.28	0.36	0.06	0.10	0.10	0.20	0.10	0.30	0.22

Table 4. Floristic list of various parent materials, slopes and terrace along the transect of both sides of the Acıçay stream

Plant Family	Genus	Rigt side					Left side			
		Terrace No								
		4	3	2	1	0	1	2	3	4
Apiaceae	*Heracleum platytaenium*								▲●	
	Bupleurum falcatum subsp. cernuum	●	●							
Asteraceae	*Achillea millefolium*				●▲					
	A. wilhelmsii		X	●	▲		X		X▲	X
	Anthemis tinctoria				●▲		X		▲	●
	A. sintenisii		X	X●		X				
	*Artemisia absinthium**								X	X
	A. santonicum	●							●▲	▲
	Carduus nutans	▲								
	Centaurea urvillei		▲							X●
	C. solstitialis		X						▲	▲
	C. virgata		X							▲
	C. depressa		X	X●	●▲	X			▲	
	C. drabifolia subsp. *detonsa*			X		X				
	C. carduiformis								▲	
	Cirsium vulgare	X								X●▲
	C. hypoleucum				▲					
	C. arvense								▲	▲
	C. elodes									▲
	Crepis macropus									X▲
	Crupina crupinastrum		X		●					X

	Echinops orientalis		X							
	*Inula aucherana**			●	●					
	*Koelpinia linearis**			X●	▲					
	Senecio vernalis	X▲								▲●
Boraginaceaea	*Alkanna orientalis*	▲		X	●	X●	X			
	Echium italicum				●					
	Onosma briquetii				●					
	Onosma tauricum subsp. *brevifolium*			X		X				
Brassicaceae	*Alyssum pateri*			X		X			▲	
	Brassica elongata				●					
	Cardaria draba			●		●				
	Crambe orientalis			●	▲					
	Lepidium campestre					●				
Caryophyllaceae	*Minuartia anatolica* var. *arachnoidea*				X▲		X		▲	
	Silene cappadocica				●					
	Spergularia rubra			●			X			
*Chenopodiaceae**	*Atriplex laevis*				▲●					
	A. lasiantha							●		
	A. rosea			X						
	Chenopodium botyrs							X	▲	
	C. foliosum						●▲			
Convolvulaceae	*Convolvulus arvensis*			X●		X				
Cyperaceae	*Bolboschoenus maritimus*					X●		X		
	Eleocharis palustris					X		X		▲
	Scirpoides holoschoenus					X		X		
Dipsaceae	*Scabiosa rotata*		X		▲				▲	X
	S. argentea			X		X				
Euphorbiaceae	*Euphorbia macroclada*						X			X
	E. orientalis		X							
	E. myrsinites	▲							▲	
Fabaceaea	*Astragalus plumosus*	▲							X	
	A. lineatus								X	
	A. macrocephalus			X		X			▲	
	A. elongatus									●
	A. lycius								▲	
	Dorycnium graecum	▲				●				●
	Genista sessilifolia								▲	
	Lotus corniculatus				●	X		X	X	
	Medicago falcata						X			
	Melilotus alba				●					
	M. officinalis		X		●					
	Onobrychis armena	▲								
	Vicia cracca	▲		●						
Frankeniaceae	*Frankenia hirsuta**				▲					▲
Geraniaceae	*Erodium hoefftianum*								▲	
Hypericaceae	*Hypericum lydium*		X●						●▲	
	H. linarioides									X
	H. perforatum	●	▲							

Table 4 continue

Juncaceae	*Juncus inflexus*					●▲				
	J. orticulatus					X				
Labiatae	*Ajuga chamaepitys*		X		●				▲	▲
	Marrubium parviflorum subsp. *parviflorum*						X			▲
	Mentha pulegium		X	●						
	Nepeta nuda						X			X
	Salvia cryptantha									●
	S. syriaca				●					
	S. forskahlei					●				
	Sideritis montana			X		X				
	Phlomis pungens		X						▲	
	Thymus leucostamus					●	X		X	X●
	T. praceox subsp. *jankae* var. *jankae*								▲	
	Ziziphora persica								▲	
Liliaceae	*Allium atroviolaceum*	▲			●		X		X	
	A. jubatum	▲								
	Ornithogalum narbonense									●
Papaveraceae	*Papaver dubium*			X		X				
Plantaginaceae	*Plantago maritima*					X		X		
	P. lanceolata		X		●					
Plumbaginaceae	*Limonium gmelinii*								▲	
Primulaceae	*Anagallis arvensis*			●						
Poaceae	*Aegilops triuncialis* subsp. *triuncialis*		X						X▲	
	Avena barbata		X			●			▲	▲
	Bothriochloa ischaemum	▲							X	
	Bromus tectorum						X			
	B. arvensis	▲			●					
	Calamagrostis epigejos					X●		X		
	Hordeum geniculatum				▲					
	H. bulbosum	▲								▲
	Stipa arabica	▲								
Ranunculaceae	*Adonis aestivalis*		X		●▲					
	A. flammae								▲	
	Consolida orientalis	▲	X		●▲					
	C. regalis	▲	X	●	▲					
Rubiaceae	*Galium aparine*		X						X	X
	G. verum			●						●
Scrophulariaceae	*Verbascum cheiranthifolium* var. *asperulum*				●					
Tamaricaceae	*Myricaria germanica*					X●▲		X		
	Tamarix smyrnensis					X●▲				

*Halophytic plant
▲: 1. transect, X: 2. transect, ●: 3. transect
Terrace no; 0: in river (water course), 1: flat-terrace (alluvial deposits), 2: flat-terrace (alluvial-collivial deposits), 3: backslope, 4: shoulder

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Vertical Transport of Water and Chemicals as Affected by Soil Layering: A Model Study

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ABSTRACT

Transport of water and chemicals in soils is controlled by soil properties and processes. Advection, adsorption, diffusion, and dispersion of the chemical are the main processes controlling the extent of transport of a chemical. Soil porosity and pore size distribution are the key factors controlling the water and solute flow by advection and dispersion, soil adsorption phenomena are the main factors controlling the retention of the chemical in soils. All these processes are highly variable by depth due to differences in soil characteristics of different soil horizons. This study was conducted to analyze interactions between soil layering and vertical transport of solutes and water at 2-m wide, 4-m long, and 0.5-m deep lysimeters constructed as field plots. Zero, five, ten, fifteen, and twenty cm thick sand layers (as treatments) were placed over a level alkaline surface, then 30 cm thick non-alkaline soil layers were packed over the sand layers. To represent plant effect, alfalfa was grown at each plot since it has a dense canopy. Changes in pH, EC, and in concentrations of Na, K, HCO_3, and B in topsoil were monitored, measuring these variables in water extracts collected by vacuum samplers following rainfall and/or irrigation events. Water content of both repacked topsoil and alkali subsoil were measured in October, 2004 when soil was dry. At the final sampling, a representative profile was open in each research plot and morphological observations were made in these profiles. Soil pH decreased and then increased sharply irrespective to sand layer thickness, and concentrations of HCO_3 and B showed a similar behavior. The EC of repacked topsoil decreased continuously probably due to the leaching of salts by application of excess amount of irrigation water, and Na concentration of soil solution increased continuously, which was attributed to sodium transported by capillary rising water from the blow alkali soil. Greater values for water content occurred at final sampling in alkali soil below 5- and 0-cm sand layers, indicating that sand layer with 10 cm thickness obscured percolation of excess water from irrigation and precipitation as observed in layered soil profiles. Roots of alfalfa concentrated in the zone of sand layers, and almost no roots of alfalfa penetrated into the alkali zone in search of water and nutrients. As morphological observations revealed, channels of decayed roots in the alkali soil served as preferential pathways of water and chemical from upper layers.

Keywords: Soil layering, chemical transport, water flow, sand layer, alfalfa

INTRODUCTION

Soil layering greatly affects water and chemical transport in downward and upward directions due to differences in hydraulic characteristics of soil layers. The soil layer with lowest conductivity attains the magnitude of water and chemical transport in layered soil profiles (Hillel, 1980). While downward transport is important for transport of agrochemicals and their derivatives toward groundwater, upward transport is important in the case of transport of salts from water table to root zone, resulting in salinity and alkalinity of the soils. Preferential flow may contribute significantly the downward movement of water and chemicals in saturated conditions (Jarvis, 2007; Clothier et al., 2008). The extent of preferential flow is controlled by structural formations such as soil cracks, inter-aggregate spaces, and biological features such as root channels and wormholes. All these may differ significantly by layers (Vanclooster, et al., 1995). Ersahin et al. (2002) related preferential flow in A and B_w horizons with a well-developed macroporosity and equilibrium transport in E horizon that lacked macropores.

Characteristics of water flow and chemical transport in layered soils have been studied extensively. Majority of these studies have been conducted in controlled conditions of laboratory column studies and lysimeters in relatively short time scales. The purpose of this study was to assess soil layering influence on vertical transport of matter in plot scale in relatively longer time. This paper reports the data collected and observations made in the first two years of this long-term experiment.

MATERIAL and METHODS

A field trial, as complete randomized blocks with five treatments and three replicates, was designed (Fig.1a). Each parcel in the Fig.1a was a 4-m by 2-m by 0.5 m lysimeter supported by metal frames around (Fig. 1b). The parcels in the Fig.1a were built on level surface of alkali soil. The purpose of using alkali soil was to evaluate the vertical transport of sodium and other substances by capillary ascent from alkali soil to the non-alkali soil repacked over the sand layer. Sand, screened with a 2-mm sieve, was located over the alkaline surface. Finally, soil provided from a nearby river bed was located over the sand layer (Fig. 1c). The sand layers with 0, 5, 10, 15, and 20 cm were the treatments of the complete randomized block design. To account for plant effect, alfalfa was grown at the plots (Fig. 2).

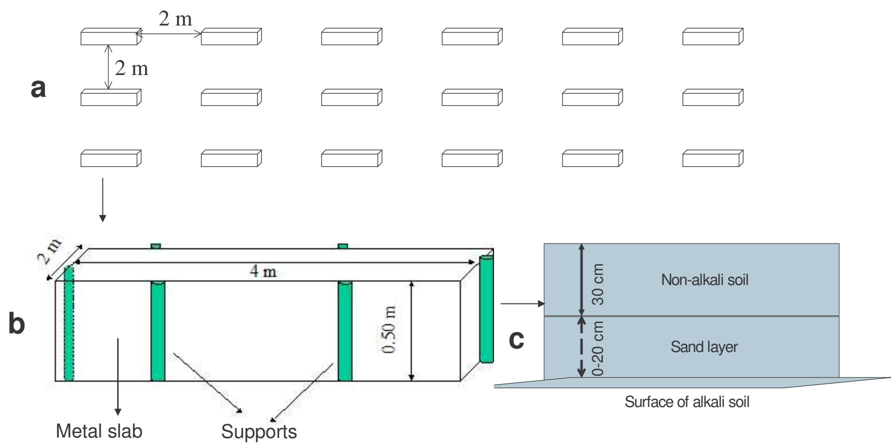

Fig 1. Layout of field trial with details of plots.

Fig 2. View of field trial with alfalfa grown at the plots.

To determine the initial conditions, soil samples were taken from below alkali soil and non-alkali soil in each parcel. The soil sampling was repeated in the fall of 2003 and 2004. The parcels were irrigated when needed. At the soil sampling, observation for plant root development and other visual features were made in representative profiles of parcels. The soil samples were transported to laboratory and analyzed for soil texture with a Bouyoucos hydrometer (Gee and Bouder, 1982), soil pH and EC with a glass electrode (McLean 1982) Na, Ca, and Mg with a flame photometer. Cation exchange capacity of the soils were measured by the method given by Rhoades (1982). Bulk density was measured in non-alkali soil, after repacking, with undisturbed soil samples taken with 100 cm^3 steel cores (Blake and Hartge, 1986). Soil particle size distribution was measured once, while other properties were measured at each sampling. The data were evaluated by ANOVA.

Vacuum soil samplers were installed in 20 cm depth of non-alkaline soil (Fig. 3). Concentration of soil solution Na, K, B, HCO3 and values of EC and pH were measured in water samples taken by porous samplers to monitor changes the soil solution concentration of these chemicals.

Fig 3. Vacuum soil water samplers at the plots

RESULTS and DISCUSSION

Initial conditions for alkali soil and non-alkali soil over the sand layers are given in Table 1. The alkali soil is clay with considerably high pH. The EC of alkali soil is not high enough to designate it as a saline-alkali soil. The silty loam soil placed over sand layers is slightly salty (Table 1).

Table 1. Properties of alkali soil and non-alkali soil repacked at the plots

Soil property	**Non-alkali soil**	**Alkali soil**
CEC (cmol kg^{-1})	22.00#	30.40
Na (cmol kg^{-1})	3.80	18.40
K (cmol kg^{-1})	1.28	1.02
Ca+Mg (cmol kg^{-1})	17.18	11.6
pH	8.3	9.4
EC dS cm^{-1}	700	2270
CO_3^{-2} meq/L	1.0	10
HCO_3^- meq/L	9.9	90
Sand (%)	26	20
Silt (%)	53	23
Clay (%)	21	57
Texture class (USDA)	Silty loam	Clay

#The values are mean of 15 samples.

The values of bulk density (Mg m^{-3}) of the repacked topsoil achieved in each plot, after repacking, are shown in Table 2. Bulk density values are highly similar one to another, indicating that a uniform repacking was achieved.

Table 2. Bulk density (Mg m-3) of the topsoil after repacking

Replicates	Treatment (thickness of sand layer placed between alkali soil and repacked topsoil)				
	0	5	10	15	20
1	1.20	1.08	1.20	1.08	1.09
2	1.11	1.24	1.14	1.07	1.12
3	1.07	1.02	1.12	1.14	1.18
Mean	**1.13**	**1.11**	**1.15**	**1.10**	**1.13**

Changes in Soil Solution Composition in Non-alkali Soil

During the experimentation, soil water samples, taken from repacked topsoil using vacuum samplers, were analyzed for pH, EC, HCO_3, Na, K, and B. The results are given in a series of figures (Figs 4 and 5). Soil pH decreased and then increased sharply in all the treatments. Concentrations of HCO_3 and B followed a similar trend but their final increase was not as sharp as of pH. The effect of sand layer thickness between alkali soil and repacked non-alkali topsoil was insignificant. The EC of non-alkali topsoil decreased gradually, which was attributed to the continuous leaching of salts as alfalfa in the plots (Fig.2) was irrigated excessively.

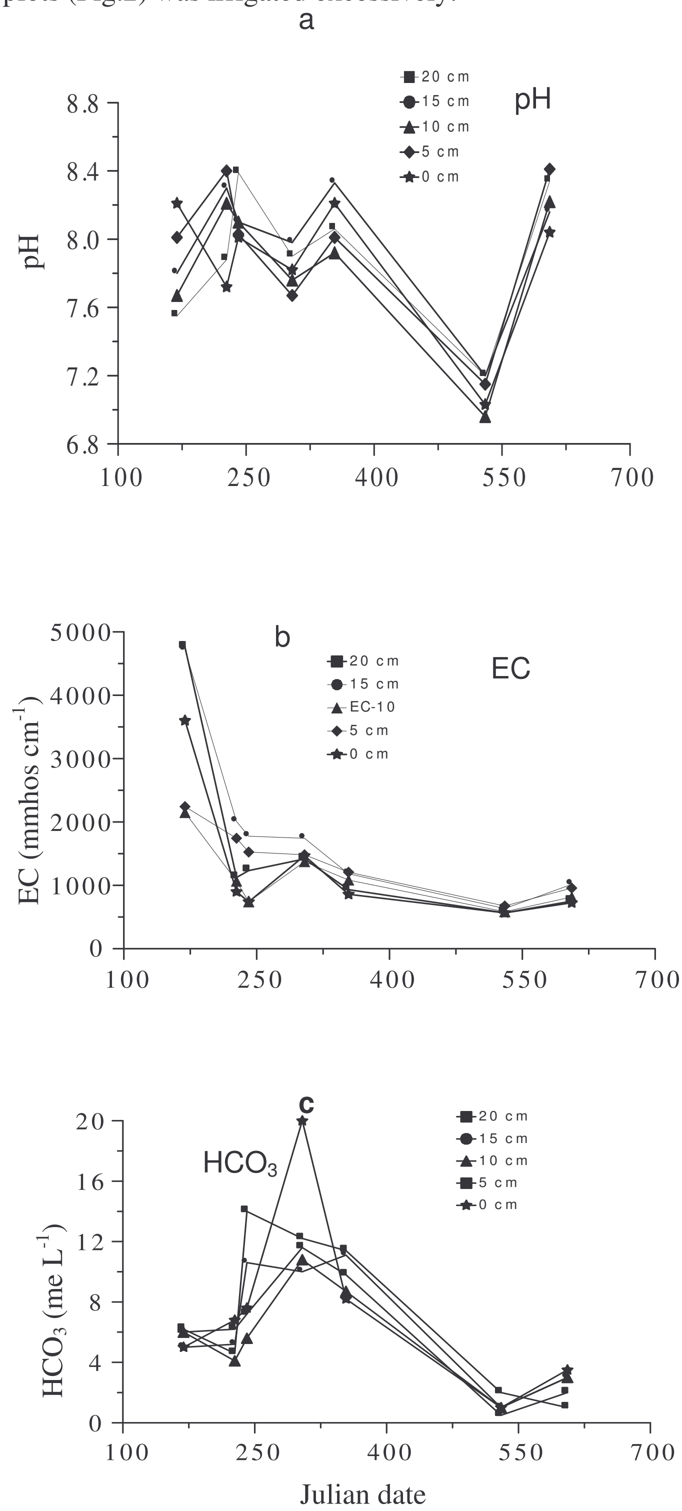

Fig 4. Changes in (a) pH, (b) EC, and c) HCO_3 in solution of repacked topsoil, located over 0, 5, 10, 15, and 20 cm thick sand layers on an alkali soil surface. The observation starts on the 100th day of the year 2003.

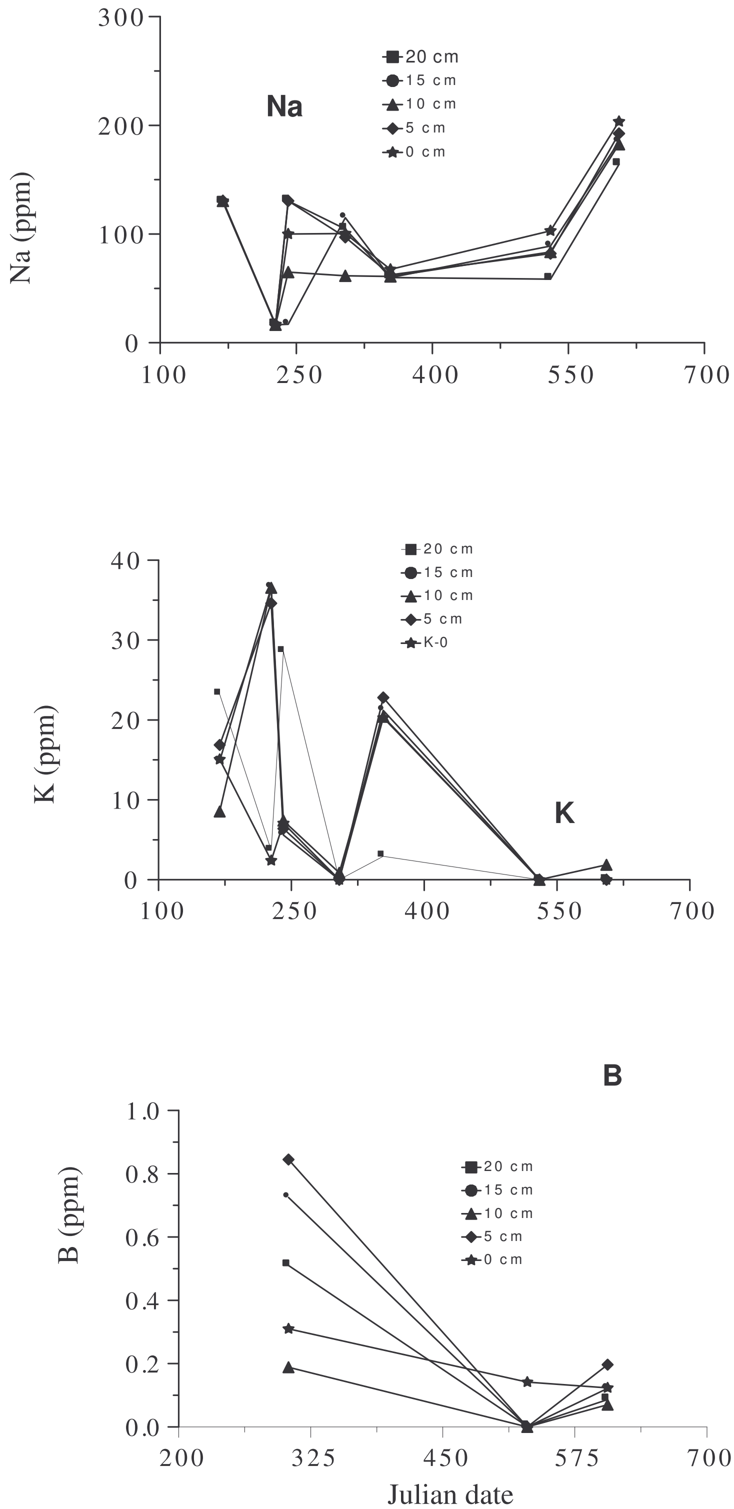

Fig 5. Changes in (a) sodium, (b) potassium, and c) boron concentration of solution of repacked topsoil, located over 0, 5, 10, 15, and 20 cm thick sand layers on an alkali soil surface. The observation starts on the 100th day of the year 2003.

Sodium concentration of soil solution increased continuously, which was attributed to the fact that some sodium was transported by capillary rising water from the blow alkali soil. The greatest increase in Na concentration occurred in 0 cm sand layer, while lowest occurred in 20 cm sand layer, indicating that the sand obscured transport of Na by capillary rising. Potassium does not leach in the soils with medium texture. However, the Fig.5 shows that K concentration of soil solution in the repacked topsoil generally decreased. This was attributed to that alfalfa would consume readily available K in the soil solution as no fertilizer was used in the second year of experiment.

Water Content of Repacked Topsoil and Alkali Soil

Water content of both repacked topsoil and alkali soil below the plots were measured on the last day (in October, 2005) of the two-year experimentation. Results are shown in Table 3. Expectedly, water content vales obtained for repacked topsoil were highly similar. However, interestingly, the greater values for water content were obtained for alkali soil under 5- and 0-cm sand layers.

Table 3. Water content (on the weight basis) of repacked topsoil and alkali soil under sand layers with different thickness

Treatment	**Water content (%)**	
	Repacked topsoil	**Alkali soil**
B1-0#	10.15	27.81
B2-0	8.75	28.01
B3-0	10.84	na
Mean	**9.91**	**27.91**
B1-5	9.60	31.48
B2-5	8.98	30.53
B3-5	10.57	na
Mean	**9.72**	**31.01**
B1-10	7.88	14.76
B2-10	7.23	na
B3-10	10.24	14.93
Mean	**8.45**	**14.84**
B1-15	10.22	na
B2-15	8.32	15.56
B3-15	10.20	16.31
Mean	**9.58**	**15.94**
B1-20	10.88	15.54
B2-20	8.08	16.68
B3-20	10.02	na
Mean	**9.66**	**16.31**

#The notation B1-0 indicates the first replicate of treatment 0-cm thick sand layer.

na: Not available

As reported by Jury et al. (1992), Gardner demonstrated how a sand layer located below a clay layer impeded water flow from the clay layer to the sand layer, showing that water could not penetrate into the sand layer unless some positive pressure to form over the sand layer. Hillel and Baker (1988) proposed that instabilities arise whenever difference in hydraulic conductivity at the water supply suction occurs between soil layers. Therefore, we suspected a similar effect of sand layer in the plots. Similar proposals were made earlier by Saffman and Taylor (1958). That 5-cm thick sand layer behaved similar to 0-cm one would be attributed that the thickness of sand layer would be critical in obscuring the vertical flow of water in layered soils.

Morphological Observations

At the final soil sampling, representative profiles were open in plots for morphological observation and photographing. Interestingly, the roots of alfalfa concentrated in sand layers, which is poor in nutrients (Fig. 6).

Fig 6. Roots of alfalfa considerably proliferated and concentrated in the sand layers located under non-alkali soil.

Almost no roots of alfalfa detected in the alkali zone in search of water and nutrients. However, water and other substances from the upper zone penetrated into the alkali zone through channels of decayed roots from the weeds that died as they were covered by the overlying material (Fig.7).

Fig 7. Decayed roots of weeds previously grown in the alkali soil. The roots decayed after the soil surface had been covered with sand and non-alkali soil. The decayed root channels served as preferential pathways for the water and solutes transported from overlying non-alkali soil.

CONCLUSIONS

This model study was conducted to investigate vertical transport of water and chemicals in artificially layered soil profiles. The sand layer located between alkali and non-alkali soil over the sand layer obscured both upward and downward flow of water as expected. Also, decayed root channels in alkali soil served as preferential pathways for water and chemicals from the upper zone. Localities around the decayed roots were colored differently, indicating improvements in the alkali soil. This may be an alternative way of remediation of strongly alkali soils. Interestingly, the roots of alfalfa concentrated in the sand layer, which is poor in nutrients. The time duration of the experiment was insufficient for an adequate investigation of the effect of treatments. Therefore, the experiment still continues for future investigations.

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Increasing Soil Organic Matter Content in Mine Soil through Pig Manure Addition

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ABSTRACT

Mine soils in southeast Spain have scarce vegetation due to very poor properties such as extremely low soil organic matter (SOM) (< 0.6 g carbon kg-1 soil), low pH, high salinity and metal contents. Also in southeast Spain, there is an economically-important pig husbandry faced with challenges to manage the large volumes of industry-generated animal wastes. This study will present the results of a leaching experiment to assess the retention and release of nitrogen and carbon from pig manure added to undisturbed column of mine soil. We excavated three columns (15-cm diameter and 30-cm length) from a representative mined site. The columns were amended with single (7 % by mass) and double doses of pig manure, and leached weekly with distilled water for 10 weeks to simulate annual rainfall events in the study area. Leachates were collected and analyzed for pH, electrical conductivity, redox potential, and contents of selected anions and metals. However, we will limit this presentation to carbon and nitrogen to quantify the potential contribution of pig manure addition to the build up soil organic matter in mine soils. Results showed that after addition of pig manure in the soil surface, soil pH increased from 2.2 to 4.0 after 11 weeks (single dose) and to 5.2 at week 21 (double doses). Significant increased were observed in total nitrogen contents in both single and double doses, 1.14 g kg-1 (900 %) and 1.40 g kg-1 (1100 %), respectively. Total carbon contents increased to 18.6 g kg-1 (3200%) in single dose and to 16.4 g kg-1 (2800%) in double doses. Nitrogen and carbon in soils had weekly rate of increases of 0.1 and 2.0 g kg-1, respectively. Moreover, C/N ratio increased from 5 to 12 at the end of the experiment. Leachates had significantly higher weekly release of NO3- than total dissolved organic carbon (DOC) during the first 6 weeks of leaching. Weekly rate of releases (mg L-1) were 127 (NO3-) and 5.2 (DOC) in single dose, and 35 (NO3-) and 2.8 (DOC) for double doses. Leachates contained NO3- less than the 50 mg L-1 threshold established by FAO. These results suggest that addition of pig manure may significantly accelerate the build up of SOM in mine soils without endangering the release of NO3- into sub-soil or groundwater in semiarid regions. Once there is sufficient SOM, mine soils will have an environment hospitable to various ecosystems including plant colonization and microbial community needed for its physical stability. Pig manure amendment of mine soils can be an ecologically-sound means of managing the large volume of wastes generated by the pig industry in southeast Spain

Keywords: Mine soils, TOC mine soil, nitrogen, leaching columns experiment

INTRODUCTION

Mine tailings stored in mine tailing pond are residues from the extraction of lead/zinc (Pb/Zn) generated during the long history of mining activities in Murcia - southeast Spain. Surficial storage of these materials poses environmental risks from wind and water erosions, runoff and potential leaching of metals into the groundwater. An effective method to stabilize these materials is to establish a permanent plant cover. However, soils in mine tailings are difficult to revegetate due to nutrient deficiencies and metal toxicities (Bradshaw and Johnson, 1992). Due to the lack of organic matter and severe nutrient limitations of mine tailings, an amendment of pig manure could ameliorate mine soil by providing available nutrients (e.g., nitrogen), improve physical properties and possibly lower the availability of toxic metals through complexation with the organic matter (Ye et al, 2002).

Organic matter improves retention of nutrients by increasing cation exchange capacity, enhances the availability of nutrients (e.g., NH4+, NO3-, PO43-, SO4=) and trace elements by mineralization, improves soil buffering capacity, chelates metallic ions increasing the availability of some nutrients, and decreases the toxicity of other ions. (McBride, 1994). Organic amendments are commonly added to disturbed sites to provide a source of N and encourage mineralization for crop growth. Nitrogen is frequently the most limiting nutrient for crop production on mine soils (Roberts et al., 1988), so the nitrogen mineralization potential of a soil is an indicator of fertility and site productivity. Nitrogen is usually deficient in mine soils and limits vegetation establishment and sustained productivity. Organic amendments are used as a source of mineralizable material to enhance N levels and extend N availability through cycling (Bradshaw, 1987).

Nitrogen is very mobile and easily leached in soil. Nitrogen undergoes many changes that are facilitated by soil biological, physical, and chemical processes (Brady and Weil, 1996). Total organic N added from organic amendments may be substantial to increase soil organic matter. However, a high percentage of potentially mineralizable N can be mineralized within the first year after application and continue to decline through time resulting in a rather short-term (1 to 5 yr) benefit to the N cycle (Barber, 1995).

The use of pig manure to reclaim mine soils in southeast Spain is promising because the region includes the province of Murcia where more than 10% of pig production in Spain is located. Annually, Murcia province generates an estimated 3.5 millions m3 of waste residues from the pork industry (CAAMA, 2007). This generation of large volume of pig slurry continuously increases with high demands for pork, and consequently creates disposal problem for many pig producers. Earlier studies (Núñez-Delgado et al., 2002; Carmona et al., 2005) had shown that the organic matter content in pig manure (or dried slurry) can effectively increase soil organic matter and prevents migration of metals out of the soil. Using pig manure as soil amendment will address two environmental problems in southeast Spain – disposal of industrial wastes from pig production and reclamation of mine soils.

In this study, column leaching experiments were used to understand the dynamics of soil organic matter (SOM), particularly nitrogen in soils amended with pig manure to evaluate the potential use of organic waste residues for the remediation of mine soils.

MATERIAL and METHODS

Undisturbed Column Mine Soil

Three undisturbed soil columns were extracted using an apparatus designed based on Gavaskar (1999), Powell et al., (1998) and Park et al., (2002), and recent modifications by Carmona and Faz (2004) (Fig. 1A.). These columns were made of transparent methacrylate tubes (15-cm diameter and 60-cm length) with a base for plastic rings filter and an artificial rain system at the top. Soil columns were taken from surface to a depth of 35 cm of three representative soils affected by mining activities in the Mazarron District mining areas in Murcia, SE Spain.

Column Leaching Experiment

The leaching column experiment was based on the studies by Mihaljevic et al., (2004), Ashworth and Alloway (2004), Doye and Duchesne (2003), Ciccu et al., (2003), Camobreco et al., (1996), and recommended by ISO/DIS 18772, (2006). Three columns were amended with single (3,750 kg N ha-1 yr-1) and double doses of pig manure, incorporated with the mine soil in the first 10 cm of the column. The applied dose was obtained from the 3,580 kg N ha-1 yr-1which is the mean nitrogen (N) content of soils in the study area, and the agronomic rate of N-requirement estimated at 170 kg N ha-1 yr-1 (Directiva 91/676/CEE). The pig manure amendment used in the study came from a farm located in Fuente Álamo-Murcia, and was taken from a dry pond.

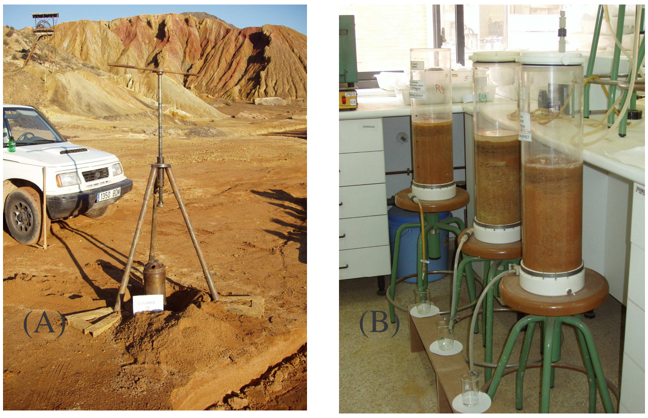


Figure 1. (A) Apparatus used to extract undisturbed soil columns. (B) Set-up of column leaching experiment.

Prior to leaching, mine soil column was saturated from the bottom using distilled water at a rate of 8 mL h-1 applied using a peristaltic pump; the column remained saturated for 24 h to keep the oxygen content at minimum, silica sand was used as drainage material for efficient flow distribution. Leaching was carried out weekly with 1,000 mL (50 L m-2) distilled water for 10 weeks to simulate annual critical rainfall events. At the end of week 7, we applied a 350 mm H2O corresponding to annual precipitation in the region. Experiment was carried out for 21 weeks (Fig. 1B.) for double doses. Leachates were collected as a function of time, for each week of experiment, and analyzed for pH, electrical conductivity (EC), redox potential (Eh), and soluble metals and ion contents. Results presented in this paper will be limited to total disolved organic carbon (DOC), and nitrate (NO3-) for leachates and total organic carbon (TOC) and total nitrogen for soils.

Analytical Methods

Selected chemical properties of soils and pig manure were determined following the routine methods for soil and pig manure analyses. Soil pH and redox potential (Eh) were measured in 1:1 water extracts (Peech, 1965), electrical conductivity (EC) in 1:5 water extracts (Bower and Wilcox, 1965), Total organic carbon was measured using a TOC – SSM-5000A Shimadzu (Kyoto-Japan), and total nitrogen was determined by the Kjeldahl digestion-distillation method (Bremner, 1996). The chemical compositions of leachates were determined following analytical techniques suggested in APHA (1998), total DOC was measured using a TOC – V-CSH Shimadzu (Kyoto-Japan), and NO3-– N by ion chromatograph (Dionex DX500-ED40) Soil columns leachates were filtered with a Whatman nº 42 paper, and filtrate were refrigerated at 5 ºC while awaiting chemical analysis. We determined the following metals in soil and pig manure samples: Cd, Cu, Pb, Zn, and for leachates metals and ions were determined: Cd, Cu, Pb, Zn, iron (Fe), manganese (Mn), nitrate (NO3-), sulphate (SO42-), chloride (Cl-), sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg).

Statistical comparison of the chemical composition of soils and leachates from columns subjected to single and double doses of pig manure was conducted using ANOVA.

RESULTS and DISCUSSION

Selected properties of pig manure and soils before and after the leaching experiment

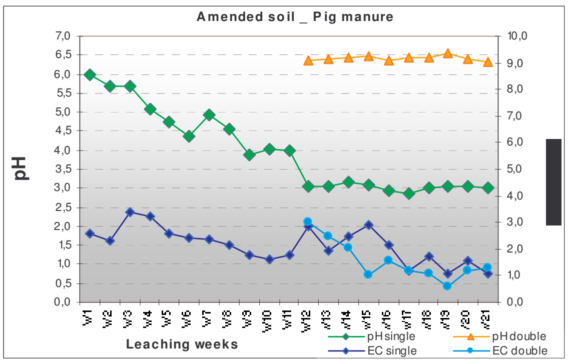
Pig manure had higher pH, and content nitrogen and carbon, and lower EC, Eh (Table 1). Textural class of mine soil is silt loam, (FAO-ISRIC-ISSS, 1990), with a content of 5.9% clay; 29.3% fine silt; 30.8% coarse silt and 33.9% sand. The low pH of mine soil is often attributed to the oxidation of pyritic materials in mine wastes also known as acid mine drainage (Evangelou, 1995). Low content nitrogen and TOC indicate that mine soil are poor soil fertility and limit of grown plant. Addition of pig manure may help pH increase the low pH of mine soil. Similarly, the NO3- in pig manure can potentially increase soil organic matter.

Table 1. pH, EC, Eh, N total, TOC (mean and standard error) in soils from column experiments.

	pH	EC dS m-1	Eh mV	Ntot g kg-1	TOC g kg-1	C/N
Pig manure	7.79	9.31	126	28.10	340.5	12.1
Initial mine soil	2.21 (0.07)	14.32 (2.25)	520 (30)	0.11 (0.03)	0.75 (0.17)	5.1
W1	5.99 (0.29)	2.57 (0.07)a	261 (35)	1.72 (0.29)	16.64 (0.35)	9.7
W11	3.98 (1.53)	1.78 (0.14)b	292 (136)	1.14 (0.24)	18.94 (6.90)	16.6
W21	6.34 (0.08)	1.30 (1.21)ba	173 (52)	1.40 (0.34)	16.65 (1.87)	11.9

n: number of observations in a group, w1 (n=3), w11 (n=3), w21 (n=2). Means followed by similar letter are not significantly differences

Amended soil columns showed that pig manure increased soil pH in single dose (W1 to W11) from 2.2 to around 4.0, 11 weeks after the addition of pig manure. The increase in soil pH was especially evident in soils amended with double doses where soil pH was 6.3 after week 21. The change in pH might indicate the "liming effect" of pig manure when added to the surface of mine soils. Soil EC values for both single and double doses progressively decreased from 14.3 to around 1.0 dS m-1 perhaps, due to the removal of soluble salts from mine soil and pig manure through leaching. Eh was maintained at reducing conditions (290 and 170 mV, respectively for 11 and 21 weeks) (Figure. 1a). After addition of pig manure-amendment in top 10-cm of the column, significant increased were observed in total nitrogen contents in both single and double doses, 1.14 g kg-1 (900%) and 1.40 g kg-1 (1100%), respectively. Total carbon contents improved to 18.9 g kg-1 (2400%) in single dose and to 16.6 g kg-1 (2100%) in double doses. Nitrogen and carbon in soils had weekly rate of increases of 0.1 and 2.0 g kg-1, respectively. Moreover C/N ratio increased from 5 to 12 at the end of the experiment, this is quite significant because mine soil has almost negligible amount of N and TOC (0.11and 0.75 g kg-1 soil, respectively). Mine soil amended with pig manure can increase SOM and might initiate increase in microbiological population. Soil organic matter will also lead to increase in cation exchange capacity (CEC) and water holding capacity (Stevenson, 1994).

a) 

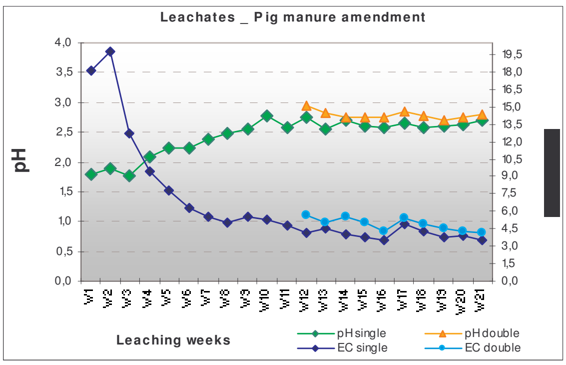
b) 

Figure 1. Dynamic changes of leachates pH and EC in the leaching experiment: (a) amended soil, (b) leachates

Leachates chemistry at the end of experiment (21 weeks)

The composition of leachates obtained in soil columns amended with pig manure subjected to single and double doses are presented in Table 2. The results showed that initial acidity was very high due to the oxidation of pyritic minerals as mentioned before. pH in leachates slightly increased from 1.8 to 2.6 after week 11 and to pH 2.9 at the end of the experiment. Leaching caused a significant reduction ($p<0.05$) in EC in single dose (W1-W11). EC values was highest in the first leaching events due to the washing of soluble salts from pig manure amendment and soil but declined from 18.1 to ~ 4.5 dS m-1 in single and double doses (Fig. 1b). The redox potential in leachates remained in the range 400 to 450 mV for columns amended with single and double doses.

Table 2. Characteristics of leachates in single and double doses of pig manure-amendment

Leaching, week	pH	EC dS m^{-1}	Eh mV	NO_3^- mg L^{-1}	DOC mg L^{-1}
W1	1.80 (0.08)a	18.13 (2.15)a	583 (24.9)a	42.1 (36.2)	25.25 (1.3)a
W11	2.57 (0.14)b	4.79 (0.33)b	412 (47)b	3.88 (1.24)	15.34 (1.6)b
W21	2.87 (0.19)ba	4.26 (0.49)b	448 (59)b	22.1 (27.4)	15.00 (2.9)ba

n: number of observations in a group, w1 (n=3), w11 (n=3), w21 (n=2). Means followed by similar letter are not significantly differences

Leaching of the nitrate and total DOC from the different doses of pig manure amendment is presented both as concentration in the leachate (Table 2) and as a rate of release (Fig. 2). Soil organic matter in this long-term experiment showed that significant changes had taken place during first 7 weeks, leachates had significantly higher weekly release of NO3- than DOC during the first 7 weeks of leaching. Weekly rate of releases showed significantly defferences, the slopes founded were 127 mgNO3- L-1 (or 10.6 mg kg-1soil) and 5.2 mgDOC L-1 (or 0.3 mg kg-1soil) in single dose, and 35 mgNO3- L-1 (or 2.1 mg kg-1soil) and 2.8 (mgDOC L-1 (or 0.2 mg kg-1soil) for double doses.

This results suggest low losses of nitrate and DOC through soil washing processes especially at the initial application of pig manure. DOC concentration was highest in the first leachate and decreased during the experiment due to the removal of the most soluble disolved organic matter (DOM) fractions. DOC release should be controlled by the decomposition of organic substances from pig manure. The increased in SOM of mine soil reduced the release of added NO3- from the double doses addition perhaps due to increase microbiological activity that can consume the freshly-added NO3-.

After 7 weeks, we estimated for single dose a total release of 74 mg NO3- kg-1 soil (17 mg N kg-1soil) and 15 mg NO3- kg-1 soil (3.3 mg N kg-1soil) for double dose, wich is very low compared to initial content in amended soil (1.7 g N kg-1 soil).This result suggests that losses of N through leaching is very low and in a long-term (3 year) period, nitrogen content will stabilize at acceptable level that is conducive for plant growth.

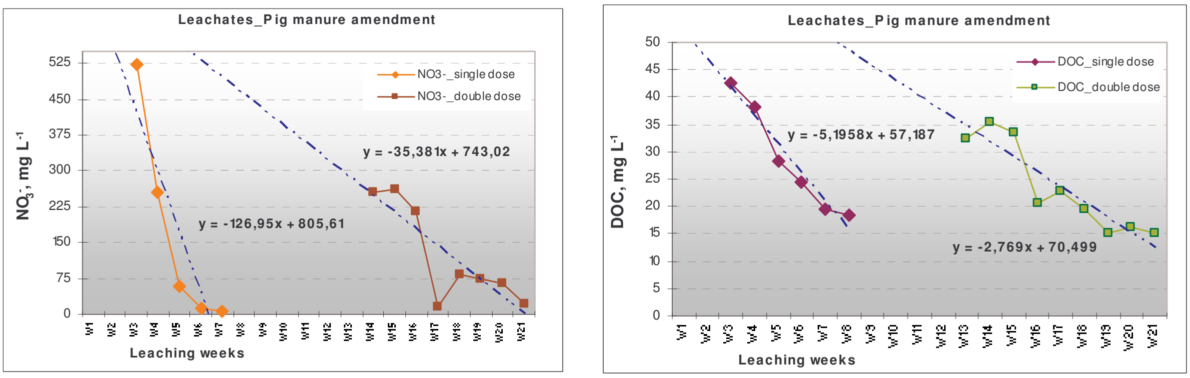


Figure 2. Rate release (mean) to NO_3^- and DOC in leachates for single and double doses.

In general, the changes in leachate NO3- concentration vs. leaching events had similar trends to those of DOC concentrations. However, there were evident differences between the contents for NO3- and DOC for both single and double doses. First, higher concentrations were noted for NO3- than the DOC, the maximum concentrations was obtained at week 5 given 520 mg L-1 for NO3- and 43 mg L-1 in single dose (W1-W11) (data not shown). Secondly, NO3- losses were relatively fast after pig manure application both in single and double doses; NO3- in leachates reached a minimum value (22 mg L-1) at week 21. After week 6, leachates NO3- values were 3.9 and 22.0 mg L-1 for single and double doses, respectively. These NO3- contents remained less than the 50 mg L-1 threshold value established for irrigation water by FAO guideline (FAO, 1985). These results suggest that addition of pig manure may significantly accelerate the build up of SOM in mine soils without significant release of NO3- into sub-soil or groundwater in semiarid regions. Once there is sufficient SOM, mine soils will have an environment hospitable to various ecosystems including plant colonization and microbial community needed for its physical and chemical stability.

The long-term restoration of soil quality and permanent re-establishment of vegetation depends on the continuous N mineralization. Due to the decay in mineralizable N through time, the N content should be monitored especially on soils that have received a one-time application of pig manure. Marrs et al. (1983) explain that N accumulation is very slow in new ecosystems and that total soil N capital should be maintained at least 10 to 20 times the annual plant uptake.

CONCLUSIONS

The results obtained from laboratory column experiment with additions of 7 % and 14 % (weight basis) of pig manure as amendment in mine soils show some potential benefits of pig manure as an agricultural amendment. Although, the high pH of pig manure was insufficient to neutralize the acidic pH in soil and leachates, pig manure amendment increased the total N, TOC and C:N ratio of mine soils. This is important because increases in SOM can initiate several important biochemical processes in soils. Increased soil organic matter can potentially increase soil pH, nitrogen content and diminish metal mobility in mine soils. The low rates of NO3- and DOC releases are additional findings to support the potential use of pig manure as an agricultural amendment to reclaim unproductive soils in several mining districts in southeast Spain. Our results suggest that mine soil amended with pig manure in double doses will not result to the migration through leaching of NO3- to surface and ground water in semiarid conditions similar to the study areas.

Our results imply that using pig manure will help solve the problem of waste disposal simultaneously with the rehabilitation of unproductive soils in mined areas. The potential use of wastes from the ever growing large pig industry in Spain would help transform unhealthy soils left behind by more than 2,500 years history of mining in southeast Spain into land with functional ecosystems. Pig manure amendment of mine soils can be an ecologically-sound means of managing the large volume of wastes generated by the pig industry in southeast Spain. We propose that the use of pig manure as soil amendment is an environmentally-friendly approach to waste disposal at the same time might help reclaim long-time remediation program for mine soils.

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Effect of Mycorrhizal Fungi on the Absorption of Phosphorus and Zinc by two Alfalfa Varieties in Cadmium Contaminated Soils

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ABSTRACT

Some agricultural and industrial practices such as mining activities, waste materials of industrial factories, other pollutants and the application of wastewater on farmlands contaminate the agricultural soils. Cadmium is one of the most common heavy metals which accumulates in agricultural soils as a result of the application of phosphorus fertilizers and can easily be absorbed by plants even at very low concentrations with detrimental effects on the living systems. Alfalfa requires high rates of phosphorus fertilizer and therefore the soils under alfalfa are more prone to contamination of cadmium. Arbuscular Mycorrhizal fungi exist as obligate symbiotic organisms on roots of more than 80% of plant families and enhance the growth of the host plant by providing water and nutrients when the plant growth limited by environmental stresses. In order to evaluate the effect of Mycorrhiza symbiosis on nutrient absorption by alfalfa under the cadmium pollution, a factorial experiment base on completely randomized design conducted by using two alfalfa varieties (2122 and Hamadani cultivars); Glomus intraradices fungi; and four levels of cadmium (0, 5, 10 and 20 mg kg $^{-1}$ soil) with four replications in green house on 2005. The plants cut at 50% bloom to determine root and shoot dry matter as well as mineral nutrient absorption by using standard laboratory procedures. The soil material rhyzosphere collected to determine colonization percent. Results showed that phosphorus and iron absorption of 2122 was superior under normal growing conditions. However, under cadmium stress Hamadani performed superior where it also proved none suitable as a host plant for symbiosis with Mycorrhiza. Fungi significantly $(\alpha = \%1)$ increased the absorption of nitrogen, phosphorus and zinc by shoots and phosphorus even in the presence of cadmium adverse effects. Time of harvest also significantly improved the uptake of all the nutrients by the shoots as well as the dry matter production by shoots.

Key words: Alfalfa, Arbuscular mycorrhiza, Cadmium, Symbiosis, Yield

INTRODUCTION

Some human efforts such as industrial, agricultural, mining and use of wastewater in irrigation caused soil contamination. The main source of soil contamination to Cadmium is phosphorous fertilizers (Sheila 1996). Short term effects of Cadmium on human health is mainly respiration disorders (Merian 1991). It accumulates in kidney and liver (Davies 1980), so long term effects have been on kidney and bon hallow (Friberg et al 1986). Some plant species such as alfalfa (Peralta et al 2001) have the ability to accumulate heavy metals and soil detoxification (Bert et al 2003). The main effect of cadmium is on alkaline and acidic phosphatase enzymes in soil (Alloway 1990). Over 40 % of world cultivated lands have lower phosphorous (Igul and

Rodriguez 2002). Phosphorous fertilizers applied to overcome the P deficiency but it cause Cadmium contamination in arable lands. Mycorrhiza can aid plants to absorb P even though p is insufficient in soil, and can replace for parts of chemical fertilizers (Mukerji and Chen et al 2003).

MATERIALS and METHODS

The selected soil for this study had P lower than 10 mg kg^{-1}. Soil sterilized three times before use (Dodd 2000). Seeds treated with ethanol 96% for 30 seconds and Hg Cl_2 for two minutes. Soil autoclaved 24 hr for three times. Fungi of VAM (Glomus intraradices) provided as Adholeya et al (1997) method. Four Kg sterilized soil used in ach pot. A split plot design used with four replications based on CRD. Cadmium used as $CdCl_2$, H_2O at 0, 5, 10 and 20 mg Cd per kg soil. Two alfalfa cultivars of 2122 and Hamedani and soil inoculation or non-inoculation with VAM fungi were used. Plants (4 seedlings in each pot) grown in growth chamber at 16:8 H day-night and 26-28$^{\circ C}$ at 10000 lx PPFD. In 50% bloom shoot were cut and oven dried at 65-70$^{\circ C}$ for 48 hr. Dry mater grounded and P, Zn, Cu, Fe and Mn were determined (Cottenie 1980). Root removed from soil and dried at 65-70$^{\circ C}$ for 72 hr and used colonization assays (Philips and Hayman 1970). Data's were analyzed with SAS, MSTATC, Minitab and SPSS and figures by Excel soft ware.

RESULTS and DISCUSSION

There were significantly effects between alfalfa cultivars and 2122 had superiority in P and Fe absorption (Fig: 1). Higher root dry mass and roots development of 2122 may caused this superiority. Inoculation of soil with VAM caused that N, P and Zn absorption increased 61.4, 28.09 and 4.7 per cent respectively (Fig. 2). Kaya et al. (2003) also obtained such results on water melon.

Mineral absorption decreased by increasing Cd concentration in soil (Fig. 3). Some disorders effects of cadmium such as toxicity, ion imbalance in plant, reduction in photosynthesis and turgor potential cause growth and yield reduction (Gupta et al. 1990).

Root colonization reduced by increasing in cadmium concentration (Fig.4). Cadmium decreased shoot dry weight (Fig. 5). Nutrient absorption disorders, reduction in chlorophyll content, leaf chlorosis are some cadmium effects on plants (Alloway 1990). Our results showed that we can decrease P fertilizer application and so decrease soil contamination by using biofertilizers (such as VAM).

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Figures:

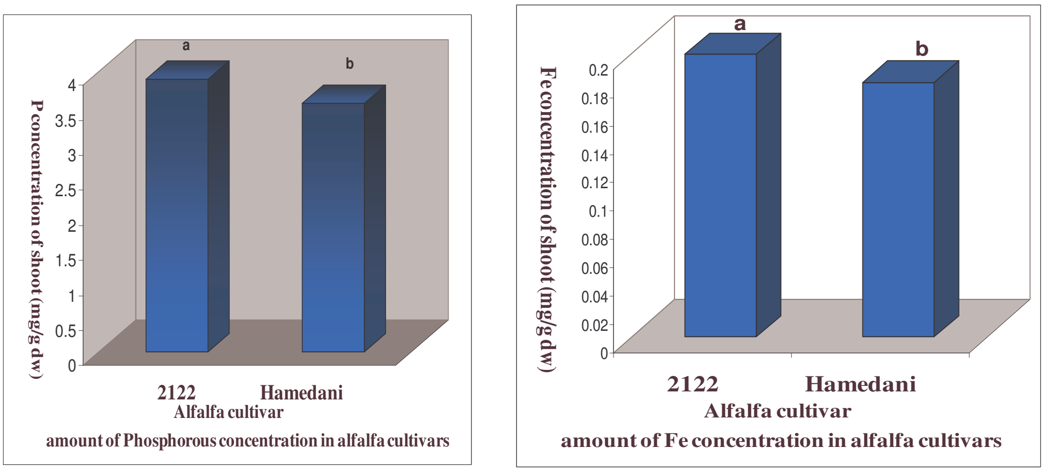

Figure: 1 - P and Fe absorption in two alfalfa cultivars

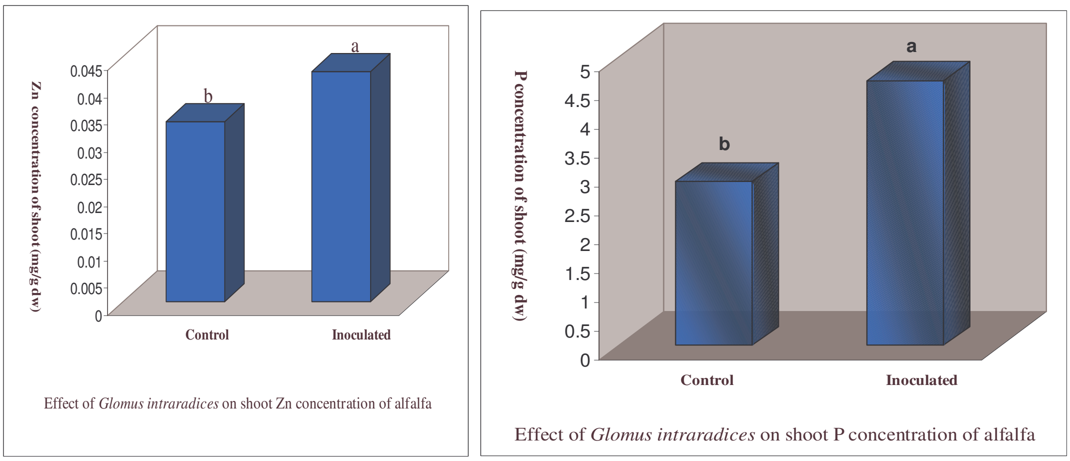

Fig. 2 : Effect of VAM inoculation on P and Zn absorption of alfalfa

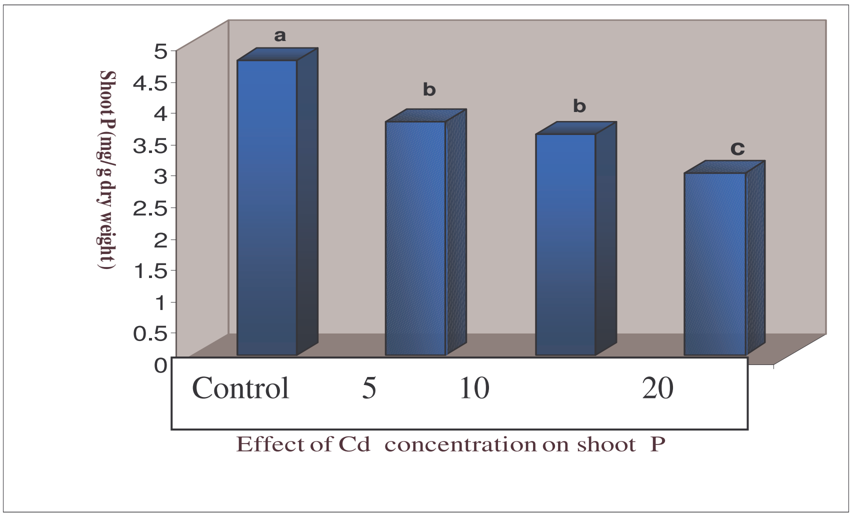

Fig. 3 : Effect of cadmium contamination of soil on phosphorous content of alfalfa shoot

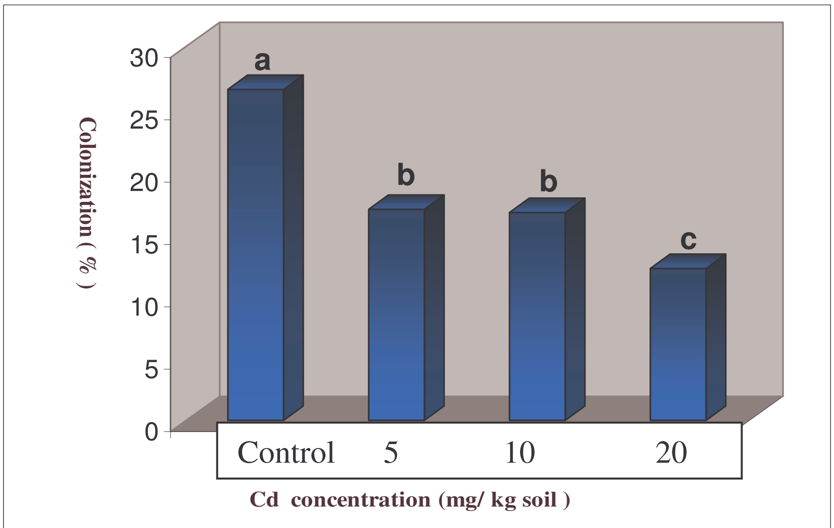

Fig.4: Effect of Cd conc. on alfalfa root colonization

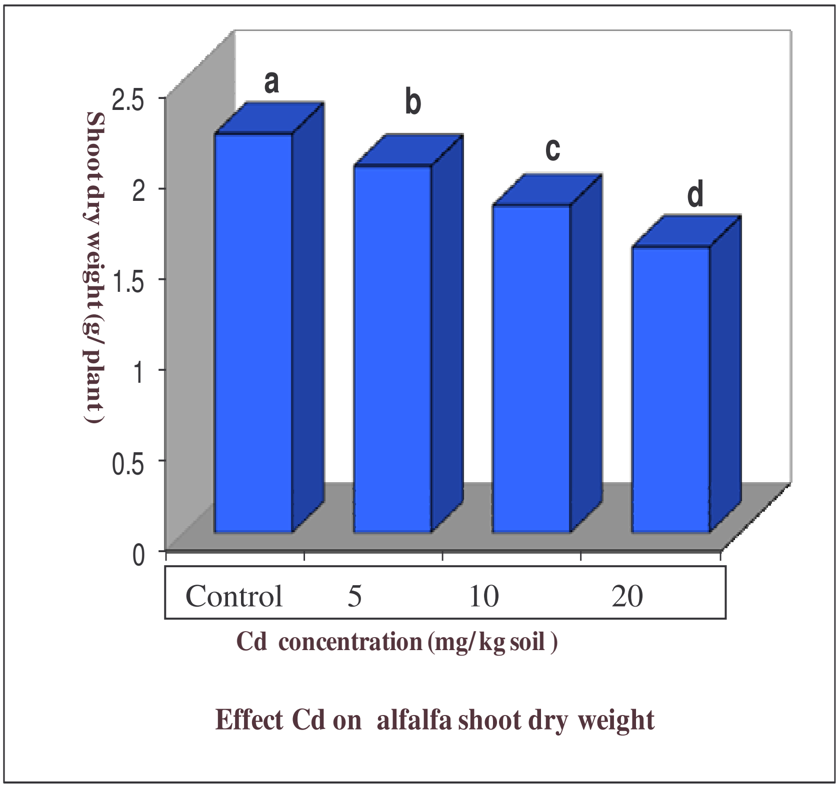

Fig. 5: Effect of cadmium contamination of soil on alfalfa shoot dry mass

The Effect of Plant Residual on Establishment of Crops

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ABSTRACT

In order to evaluation of plant residual on establishment of crops an experiment was conducted during 2006-2007 in Sharood Universiy of Technology in Iran. The experiment was as factorial in Completely Randomized Design with 4 replications. The residual of Triticum aestivum, Beta vulgaris, Zea mays and Brassica napus and distilled water as check were tested on themselves and other crops. The results showed residual of crops had different effect on growth of themselves and other crops. Germination percentage, speed of germination, root dry weight, stem dry eight, root length, stem length, root/shoot ratio and plant growth traits were significantly affected by residual of Beta vulgaris, Zea mays, Triticum aestivum and Brassica napus respectively.

Keywords: Residual plants, growth, growth

INTRODUCTION

Plant growth and development are influenced by a wide rang of fluctuating abiotic and biotic conditions that usually create less than an optimal cropproduction evironment. Allelochemicals produced and released by certain plants and microorganisms are only one component of the stresses that influence plant growth. The complexities of ecological processes mandate that the effect of an allelochemical must be recognized and evaluated in a context where interdependence with other growth conditions is the rule.

Several basic facts about the science of allelopathy provide a prelude to amplifying these objectives. First, a diverse array of more than 300 secondary plant and microbial compounds representing many chemical classes have been implicated as the agents of allelopathy (Rice, 1984; Gross and Parthier, 1994; Einhellig, 1995a), and additional allelochemical are being recognized as studies of allelopathy continue. This diversity among allelochemical structures is a major hindrance to predicting their action in allelopathy (Einhellig, 1995b). Another complication is that the origin of an allelochemical often is obscure, and its biological activity may be reduced or enhanced by microbial action, oxidation, and other transformations. It is an error to assume that there must be enough of a single compound present in a field situation to affect growth of a receiving plant. Investigations of allelopathy consistently isolate several chemicals, often representing different families of compounds, from the allelopathic plant or associated soil. A variety of experiments have established that combinations of allelochemicals act additively or synergistically to inhibit growth (Table 1). This joint action is especially important because the concentration of a single substance in field situations is generally below its inhibition threshold.

Various combinations of allelochemicals may be encountered through the aqueous medium or vapor phase. Bradow and Connick (1990) reported that residues of several weeds and legume cover crops caused allelopathic interference by emissions of volatile hydrocarbons, alcohols, aldehydes, ketones, esters, furans, and monoterpenes into the soil atmosphere. They identified an array of methyl ketones and aliphatic alcohols and aldehydes in volatiles released from residues of Palmer amaranth (Amaranthus palmeri S. Wats.) and concluded that the inhibitory activity of these compounds was additive (Bradow and Connick, 1988a, b).

Possible sources of allelochemicals in the crop environment include numerous microorganisms, certain weeds, a previous crop, or the current crop. Similarity, the affected species could be microorganisms, weeds, or the crop. Bhowmik and Doll (1983) found that inhibition of corn by residues of redroot pigweed and yellow foxtail [Setaria glauca(L.) Beauv.] was influenced by photosynthetic photon flux densities (PPFD) and temperature. Residues of the weeds were less inhibitory when corn was grown under 30/20 C day/ night conditions and moderate PPFD (380-570 mol photons), as compared with lower temperature and irradiance. In contrast, inhibitory effects of the weed residues on soybean showed little response to temperature or PPFD. The higher temperature and irradiance are cloer to optimal conditions pected to minimize allelopathy. Interactive effects between irradiance and response to allelochemicals need further investigation.

MATERIALS and METHODS

In order to evaluation of the effect of plant residual on establishment of rotate crops an experiment was carried out as factorial in compeletly randomized design with 4 replications in shahrood university of technology. First factor included wheat, sugerbeet, corn and water distilled(chek) and second factor included rotate crops: wheat, corn, barly and rapeseed.The senescent residual plant of wheet, sugerbeet and corn were gently sprayed with distilled water and the leached water passing through the plants gathered. The plant residual allowed to decay for 24h in distilled water in the ratio of 1:10 w/v (plant residual : water). The extract were allowed to decay at room temperature (25 c) following which the extract . Seeds were transferred to Petri dishes containing two layers of Whatman filter paper. Germination measured from secondary days and continued until 10 days. In order to avoid water losses, edges of Petri dishes were tightly sealed with an impermeable colorless Para film. Seed were germinated when radical was 2 mm long (ISTA 1996). Germination rate was measured from Agarval method. Germination percentage was measured conforming according to International Seed Test Association (ISTA). Radical dry weight, (my plant) stem dry weight (mg plant), Root to shoot length ratio were estimated by dividing root length to shoot length . Radical length, stem length, was measured. Dry weight of seeds and seedling Parts were measured after drying samples at 70 in an oven until a constant weight is achieved. Transformation of data (Arc sin $\sqrt{x}$)

carried out with Minitab program. The data were statistically analyzed by MSTAT-C computer program..

RESULTS

Analysis of variance results are shown in table 1. Seed germination time delayed when allelochemicals added to Petri dishes and allelochemical extracted from different plants had different effects on germination of seeds. Germination percentage(%) according to Agarval method(1982) declined when allelochemicals added to petri dishes. Therefore germination process started at different times in various allelochemical solution. Sugarbeet allelochemicals declined seed germination, germination percentage, root length, shoot length, root to shoot length, root dry weight, shoot dry weight more than other plants allelochemicals and corn, wheat and distilled water were respectively. The visible effects of allelochemicals on plant processes are only secondary signs of primary changes. Therefore, studies on the effects of allelochemical on germination and/ or growth are only the manifestation of primary effects occurring at the molecular level. Although a strong tendency is being developed to look into the actual mechanism of action, the experimental work is in its infancy. The mode of action of allelochemical can broadly be divided into indirect and direct action. Indirect action may include effects through alteration of soil property, its nutritional status and an altered population and/ or activity of harmful/ beneficial organisms like microorganisms , insects, nematodes, etc. This is relatively a less studied aspect. On the other hand, the direct mode of action, which includes effects of allelochemicals on various aspects of plant growth and metabolism, has received fairly wide attention. Rotate crops had different reactions to allelochemicals and wheat had minimum reaction to allelochemicals and barely had maximum reaction.

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Table 1- Analysis of Variance

S.O.V	G.P.	G.R.	R.L.	S.L.	S.F.W.	S.D.W.	R:S
Plant allelochemical (A)	**	**	*	*	**	*	*
crops (B)	**	*	*	**	**	*	*
(A*B)	**	*	*	*	*	*	**

*, ** Significant at 5 and 1%
G.P. Germination Percentage
G.R. Germination Rate
R.L. Root Length
S. L. Stem Length
S.F.L. Seedling Fresh Weight
S.D.W. Seedling Dry Weight
Root : Shoot

Physical and Chemical Properties in Soils in Conversion to Organic Management

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ABSTRACT

Interest in organic soil management has grown appreciably in recent years. The transition from conventional to organic farming is accompanied by changes in soil physical and chemical properties and processes that could affect soil fertility. Nevertheless, the organic systems is very complex and very few studies has been studied this process. Understanding of physical and chemical processes involved in the transition process is important for ameliorating the management of the organic farming systems.

This work studies the effect of the transition conventional to organic farming on physical and chemical properties of a loam soil (Xerofluvent) located in the Guadalquivir River Valley, Sevilla, through a succession of six crops cycles over a three year period. Two mature composts (plant and animal compost) were used for the organic fertilization. Crop rotation and varieties were identical in the two systems.

At the end of the study, the organic farming management resulted in a higher soil organic carbon, N and P, K and Mg available. Electrical conductivity and pH are not significant differences between treatments. The use of organic farming resulted in higher available Fe, and Zn. The available Mn and fundamentally Cu do not show significant differences. The organic treatment also showed lower bulk density and higher available water content.

This study demonstrated that the use of organic compost results in an increase of soil organic matter, storage of nutrients, and produce positively effect in physical soil properties than with conventional management , which can provide long-term fertility benefits.

Keywords: organic farming; compost; nutrients

INTRODUCTION

The soil quality determines the sustainability and productivity of agroecosystems. The excessive use of mineral fertilizers in intensive agriculture has reduced the soil organic matter in most of the Mediterranean soils leading to an increase of erosion risk and fertility losses (Nachtergaele et al., 2002). One of the most important ways of soil regeneration involves the addition of organic materials to conserve organic matter and maintain or enhance soil fertility (Lampkin, 1998).

Organic farming is an alternative to conventional farming and has been adopted in a wide range of climate and soil types (Altieri, 1995). The transition from conventional to organic farming is accompanied by changes in an array of soil chemical properties and processes that affect soil fertility (Clark et al., 1998). These changes affect nutrient availability to crops either directly by contributing to nutrient pools, or indirectly by influencing the chemical and physical environment of the soil (Bulluck et al., 2002). Studies that compare organic and mineral fertilization in soils show higher SOC, total N and macronutrients content for organic-amended soils (Edmeades, 2003; Herencia et al., 2007). On the other hand, although studies showed the influence of organic amendment on availability of micronutrients (Kabata Pendias and Pendias, 2000) very little information exists in organic agriculture (Herencia et al., 2008).

It is well established that the addition of OM improves physical properties (Celik et al., 2004). The intensive cropping systems based on mineral fertilization and elimination of residues of crops frequently lead to a diminution of SOM which adversely affects the soil physical properties. (Haynes et al., 1991). Nevertheless, as well as chemical parameters, the effects of organic matter additions on physical properties of soils depend on climate, soil characteristics and rate and type of organic amendments.

In addition, many studies show the effect of additions of sewage sludge, urban waste compost, or manure in soil fertility, but very few agronomic studies are available with application of vegetal compost (Herencia et al,. 2007).

The aim of this work is to determine the influence of organic versus conventional farming on the physical, physicochemical and chemical properties of a calcareous soil during the three years of the transition period with two different organic amendment.

MATERIALS and METHODS

The field study was carried out on a loamy soil classified as a Xerofluvent (Soil Survey Staff 1999). The study site (latitude: 37º 8´ 33´´ N and longitude: 5º 16´ 4´´ W) was located in the Guadalquivir River Valley (SW Spain), at the CIFA "Las Torres-Tomejil" farm in Alcalá del Río (Seville).

A crop rotation was conducted in plots of 10m x 20m. The data reported in this study include the results from 2001 to 2003. The following crops were grown: potato (*Solanum tuberosum* var. spunta) (spring 2001), lettuce (*Lactuca sativa* var. oreja de mulo) (autumn 2001); carrot (*Daucus carota* var. nantesa) (spring 2002); spinach (*Spinacia oleracea* var. gigante de invierno) (autumn 2002); tomatoes (*Lycopersicon lycopersicum* var. plato de Egipto) (spring 2003); and vetch-oat (*Vicia sativa* L. - *Avena sativa* L) as a cover crop (autumn 2003).

Three treatments were tested: one conventional treatment (CN), and two organics treatments (VT) and (MT). Four replicates per treatment were established randomly.

The organic treatment VT was vegetal compost (pruning waste and crop residues) and MT was manure compost (stables and cow barns), both applied by superficial tillage each crop cycle (30 t ha^{-1}). The CN was managed with normal doses of chemical fertilizers and pesticides used for these crops (Maroto 1995). The organic system was managed organically (Regulation (EEC) No. 2092/91). The soil and compost characteristics are show in Table 1. The soil was mouldboard ploughed to a depth of 20-25 cm after each crop harvest. In general, all crops were irrigated by surface irrigation each crop cycle.

Table 1. Soil (0.0-0.15 m depth) characteristics at the beginning of the experiment (n=12), and elemental analysis of vegetal and manure composts (dry wt. basis) used during the study (n=18*)

		Soil**		Vegetal Compost		Manure Compost	
Parameter	Units	Means	±SD	Means	±SD	Means	±SD
Moisture	g kg^{-1}	-	-	245.8	24.3	295.6	96.9
pH (1: 2.5)		8.04	0.06	7.7	0.3	7.9	0.6
EC (1: 2.5)	dS m^{-1}	0.19	0.04	2.2	1.0	6.6	2.0
TOC	g kg^{-1}	7.56	0.40	168.0	35.8	175.4	54.9
TN	g kg^{-1}	0.88	0.07	9.0	2.4	11.9	4.9
P	g kg^{-1}	19.51	2.10	3.7	1.3	5.1	1.6
Mg	g kg^{-1}	0.29	0.03	5.2	1.9	6.4	0.9
K	g kg^{-1}	0.38	0.03	4.6	0.7	9.9	3.8
Fe	mg kg^{-1}	5.62	0.79	8184.8	371.6	8522.6	903.5
Cu	mg kg^{-1}	1.56	0.18	21.2	2.2	36.3	6.2
Mn	mg kg^{-1}	7.11	2.04	289.8	59.1	345.8	61.8
Zn	mg kg^{-1}	0.88	0.12	48.8	4.7	73.2	25.7

S.D.: Standard Deviations; EC: electrical conductivity; TOC: total organic carbon.
*Data are the mean of three samples by each crop (six crop cycles).
** Soil P is available content (mg kg^{-1}); soil K is available content in ammonium acetate and soil Fe. Cu. Mn and Zn are available content in DTPA.

Soil samples (0.0-0.15 m deep) were taken for analysis at the beginning of each new crop. Soil samples were air-dried, sieved to 2 mm, and stored in plastic containers before analysis. The compost characteristics and soil nutrients content (pH, EC, OC, Kheldahl N, P olsen, available K, Mg, Fe, Cu, Mn and Zn) were determined by the methods of MAPA (1994). For Bulk density (Bd), undisturbed soil cores from the upper horizon (0-15 cm) were collected from the subplots in rings of known volume (Henin et al., 1972). Soil water content were determined in undisturbed samples placed in a 5.5 cm ring on 33 kPa (FC, field capacity) and and 1500 kPa (PWP, wilting point) pressure plates, respectively (Klute, 1986). Available water content (AWC) was calculated as percentage by find the differences between moisture % at field capacity and wilting point.

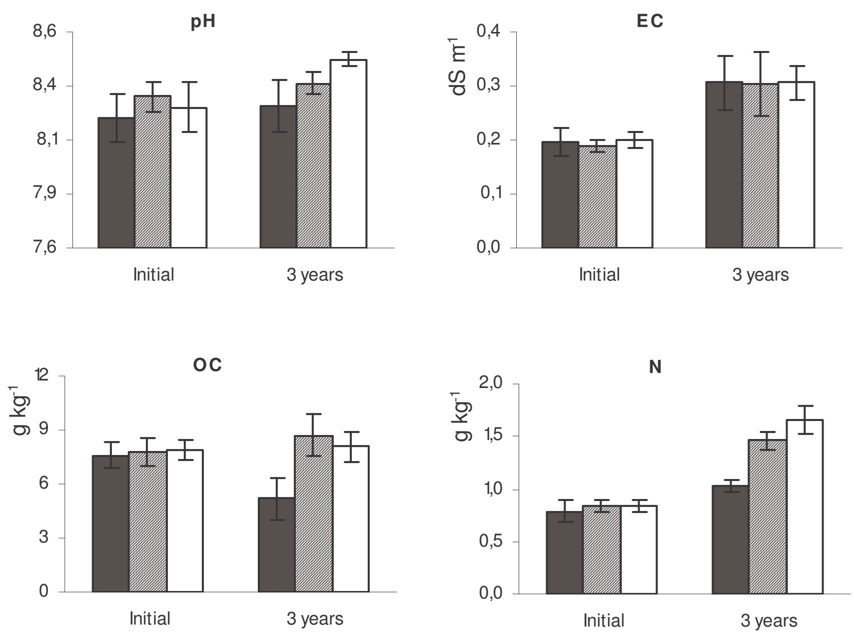
The results were analysed by ANOVA, considering the treatments as the independent variable. All statistical analyses were carried out with the program SPPS 11.0 for Windows. All values are expressed as mean values. Significant statistical differences of all variables between the different treatments were established by the Tukey`s test at P<0.05.

RESULTS and DISCUSSION

Soil pH and Electrical Conductivity (EC)

The pH values in organic amended soils were slightly higher than values in conventional fertilized soils (Fig. 1). The values showed an increase in all treatment in the last cycle although significant differences were only observed between MT and CN treatments. The slightly increase in pH in organically fertilized soils is due to basic cations in compost. Bulluck et al. (2002) showed an increase in pH in soils amended organically due to the complexation of Al and increases of basic cation in the soil solution. However, this pH increase is small due to the buffer character of the SOM and the high carbonate content of these soils.

No significant differences in electrical conductivity (EC) values were found between the organic and conventional treatments (Fig. 1). It is interesting to observe that, at the end of study, the EC values increased in all treatment and they were higher than from the beginning of the study, independently of the type of fertilization. Organic fertilization does not appear to cause soil salinization. The slightly increase is probably due to the fertilization rates. However neither inorganic nor organic fertilization appeared to cause soil salinization at the end of study.



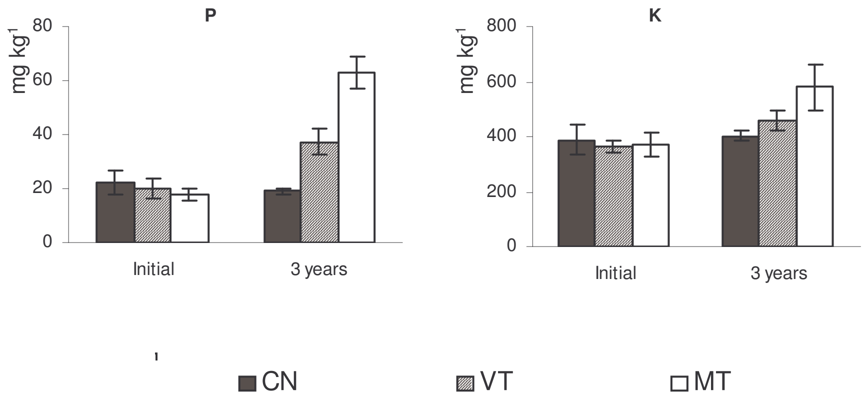


Fig 1. Values of pH. electrical conductivity (EC). organic carbon (OC). Kjeldahl nitrogen (N). available phosphorus (P) and potassium (K) to the beginning (Initial) and at the end of the experiment (3 years). Conventional management plots (CN); organic management plots fertilized with vegetal compost (VT) or manure compost (MT). Error bars indicate standard deviations of means.

Organic Carbon

At the three years, the Organic carbon content (OC) was found to be considerably greater in organic plots compared with those receiving mineral fertilizer (Fig. 1)

The addition of organic amendment in continuous cycles increases slightly the OC content in the soil. On the contrary, the mineral fertilization cycles (no addition of OM), showed a decrease of OC in the last cycle. The continuous addition of organic matter is important to maintain the content of SOM, which can be easily oxidized under the climatic conditions of our soils, located in the Mediterranean region.

This increase is particularly important in Andalusia, the region of our study, where the levels of organic matter in agricultural soils are normally <10 g kg^{-1} (Costa et al., 1991). Organic management systems have been shown to maintain SOM at higher levels than inorganic fertilization (Edmeades, 2003).

Soil Nitrogen

In all cases, comparing to the initial content in soil, significant increases in N content was observed in the last cycle and specially in the organically amended plots. Significant differences between CN and organic treatments were observed. The N content of organic plots is about twice the N content of the mineral fertilized plots.

Although inputs of N were very similar in organic and conventional treatment (CT=959 kg ha^{-1}; VT=1025 kg ha^{-1}; MT=1190 kg ha^{-1}), the addition of organic N favoured the increase of the N reserves in soils.

Available Soil phosphorus

The available phosphorus (P) in the organically fertilized plots was significantly higher compared with the mineral ones, on the order of 2 to 3 times in VT and MT respectively (Fig.1). At the end of the experiment, P values showed statistical differences between all treatments, according to the following order: MT > VT > CT.

The addition of OM to calcareous soils can increase available-P and decrease P-insolubilisation (Braschi et al., 2003). Tan (1998) indicated that P can be fixed in calcareous soils; however, the organic anions from organic amendments decrease the fixation of P. In calcareous soils it seems to be more advantageous to apply these organic amendment rather than mineral fertilizer to improve the availability of P to plants, due to the high retention of P in this soil type.

In addition, the higher availability of P in MT than in VT treatment could be explained by the higher amounts of P added through the manure compost (Table 1).

Available Soil Potassium and Magnesium

We are represented only available Potassium (K) because available Magnesium (Mg) showed very similar results. The K and Mg content in the organically fertilized plots was significantly higher compared with the conventional ones (Fig.1) the MC treatment showed the highest values. The higher availability of K and Mg in MC than in VC treatment could be explained by the higher amounts of Mg and, fundamentally K, added through the manure compost (Table 1)

It is interesting to denote that although the supply of K is very similar or lower with organic fertilization (CT=870 kg ha^{-1}; VT=525 kg ha^{-1}; MT=997 kg ha^{-1}), K availability is higher in the soil organically fertilized. The results obtained indicate that the increase of K comes both from the K released from organic amendment and increasing of K availability after addition of this organic amendment. Some authors have also shown an increase in K and Mg after organic amendment (Bulluck et al., 2002; Edmeades, 2003) They attributed the result to the high nutrients content of the compost and the increase of exchange sites due to organic matter added.

Available Micronutrients

The available Cu and Mn were similar among treatment (Table 2). The Mn in the organic plots, fundamentally in VT was slightly higher than in CT, but the differences were not significant. It is interesting to observe that in the last cycles the Cu and Mn values were lower than the beginning in all treatments.

The higher values of Fe and Zn in MT are in agreement with other authors that indicate that OM exerts a significant and direct effect on micronutrients availability (Wei et al., 2006) The Zn content in the organically fertilized plots was higher than in mineral plots for both organic treatments. The Fe were statistically higher in the MT treatment (Table 2).

The OM can interact with heavy metals in two contrasting ways, either increasing the solubility of the former or contributing to their immobilization (Madrid, 1999). The amendment of our soils with compost resulted in an increase of TOC and Cu that can form stable complexes with humic acids, which would give rise to metal immobilization.

The addition of OM with functional groups with the ability to form complexes promotes Zn availability in soils (Almas et al., 2000). In addition, the higher amount of Zn in MT could be due to the higher Zn concentration in the manure compost (Table 1).

The higher values of Fe obtained in MT are in agreement with the those of other authors, which indicate that OM is the main source of the plant available form (Kabata-Pendias and Pendias, 1992). The amount of Fe added with either compost (Table 1) was similar; nevertheless, the Fe was higher in MT (Table 2), indicating the importance of the composition of the compost.

Table 2. Mean values of soil available micronutrients (mg kg^{-1}) to the beginning (Initial) and at the end of the experiment (3 years)

	Fe		Cu		Mn		Zn	
Treatment	Initial	3 years	Initial	3 years	Initial	3 years	Initial	3 years
CN	5.25 a	4.27 b	1.53 a	1.02 b	7.25 a	4.69 b	0.88 a	0.88 a
VT	5.91 a	3.55 b	1.59 a	1.04 b	7.05 a	5.90 abc	0.89 a	1.33 b
MT	5.50 a	7.41 c	1.51 a	1.08 b	6.99 a	5.20 bc	0.86 a	2.22 c

CN=Conventional treatment; VT= vegetal compost treatment; MT=manure compost treatment. Values of different elements followed by the same letter do not differ significantly ($p < 0.05$).

Bulk Density (Bd) and Available Water Content (AWC)

The Bd values was found to be lower in organically fertilized plots compared to plots receiving mineral fertilizer but the differences are statically different only with MT (Table 3).

The values of AWC in the plots managed organically were higher (Table 3), than the corresponding values of the plots with conventional nutrition, but the differences were not significant except for VT; therefore, it is evident that the porosity of organically fertilized plots was significantly higher than in the plots fertilized with synthetic fertilizers, as evidenced by the differences in the Bd. An increase of the water retention at tensions of FC mainly is due to the augmentation of the number of small pores. At higher tensions, near PWP, almost all the pores are full of air and water retention is determined by the surface area and the water pellicle thickness on these surfaces (Khaleel et al., 1981). After OM addition, the number of pores and the area of specific surface enlarges, resulting in an increase of AWC.

Table 3. Bulk density (Bd). water content at field capacity (Fc). permanent wilting point (PWP). and available water content (AWC) after three years of different treatment

Treatment	Bd (g cm^{-3})	Fc (%)	PWP (%)	AWC
CN	1.49 a	27.9 a	12.2 b	15.6 a
VT	1.42 ab	29.6 b	12.4 b	17.3 b
MT	1.30 b	28.7 ab	12.4 b	16.3 ab

CN=Conventional treatment; VT=vegetal compost treatment; MT=manure compost treatment. Values of different parameters at the same column followed by the same letter do not differ significantly ($p < 0.05$).

The main conclusions from this work are that the organic management (Regulation [EEC] No 2092/91) characterized by the incorporation of organic matter through compost (animal, vegetal), crop rotation, weed control by mechanical tillage maintain soil organic matter at higher levels than inorganic fertilization.

The type and amount of organic amendment described in this research is suitable to maintain an adequate level of SOM, Kjeldahl N and available P, K and Mg in soil, even higher than that obtained by application of the mineral fertilizer. The use of organic farming resulted in higher available Zn but, available Fe were higher only with manure compost and the available Mn and fundamentally Cu do not show significant differences, indicating the importance of the composition of the compost. No clear differences were found in pH and electrical conductivity for both fertilization types. The results after three years of organic fertilization indicate that the use of organic amendment produced a decrease of bulk density and an increase of available water content.

Soils under organic fertilization showed an improvement in soil fertility. However, further studies must be carried out in the next years to confirm the positive long-term effect of organic fertilization in order to maintain or improve soil quality.

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Effects of Different Long-Term Soil Management Systems on Some Physical and Chemical Properties and Crop Production in Soils in Berlin-Dahlem and Dedelow- ZALF Müncheberg (Germany)

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ABSTRACT

Soil management systems influence the agricultural system as they have in short- and long term period different effects on soil physical and chemical properties, therefore influencing the efficiency of production as well. A well directed choice of tillage equipments leads to a better soil protection and enables a higher fertility which is an important requirement for sustainable agriculture. The aim of this study is to investigate the effects of different soil management systems on some physical and chemical properties and the crop production of these sandy soils. This study demonstrates the first results obtained from the year 2006, performed on the long-term land use experiment with the effects of three different factors (deep and shallow tillage; 17 and 28 cm, lime application; +Ca and –Ca and Farmyard manure; +FYM and –FYM) in Berlin-Dahlem (Germany), Humboldt University of Berlin and the ZALF experimental station at Dedelow (Germany) in 5 different tillage systems (no-tillage, mulch; 10 cm, cultivator; 15 cm, plough; 15 cm and plough; 25 cm).

The soil heterogeneity were determined and evaluated with the computer program “Surfer” depending on the different depths of the sand and loam layers. The penetration resistances of both experimental fields showed that the deep tillage systems caused a higher compacted zone in deeper soil layers. It was found that there are significant differences in the soil aggregate stability and pH values between the shallow and deep tillage systems in Berlin-Dahlem. The pH values were significantly higher in the deep tillage systems. The soil organic matter contents were found higher in the deep tillage systems but there were no significant differences. There were also no significant differences in grain yield between these two tillage systems in Berlin-Dahlem.

Key words: Penetration resistance, soil compaction, pH, aggregate stability, soil organic matter, crop production

INTRODUCTION

Long-term tillage experiments are needed to understand soil chemical and biochemical processes and provide consistent experimental results. Long-term experiments require considerable resources, time and labour input, but they offer the best practical means of understanding many of the problems of farmers, ecologists and policy makers have to deal with (Poulton, 1996).

Tillage management and manure application are among the important factors affecting soil physical properties and crop yield. Still today, farmers continue to use intensive conventional tillage for plant production in some European areas. However, the European Community agricultural policy has strongly encouraged conservation tillage practices in order to decrease soil loss (European Union, 2000).

Benefits of long-term no-tillage over conventional tillage include: reduced soil erosion, increased organic carbon, higher infiltration, more soil biological activity, reduced evaporation, reduced labour requirements and greater profits (Lal et al., 2003; Souza Andrade et al., 2003). Many farmers are taking advantage of the economic and environmental benefits of no-tillage, by the increased adoption in many parts of the world (Towery, 2002).

According to the soil physical characteristics, farm yard manure application is very important because it changes the structure which has a positive effect on soil and crop yield. Manures have traditionally been accepted as a source of plant nutrients; however, the beneficial soil physical effects have received little attention. The maintenance of optimum soil physical fertility is an important component of soil management, which has only recently been accepted (Haynes and Naidu, 1998). Manure application significantly increased soil organic matter content on row and inter-row positions.

In addition to tillage and farm yard manure application benefits, calcium improves the soil physical properties and is one of the most important nutrition elements for plant growth.

The objective of this study was to determine the effects of different long-term soil management systems on some physical and chemical properties and crop production in soils in Berlin-Dahlem and Dedelow- ZALF Müncheberg (Germany).

MATERIALS and METHODS:

The field experiment were conducted by the Experimental Station in Berlin Dahlem (52° 28'' N, 13° 18'' E) which is located between oceanic and continental climate conditions. This experiment was created by Kurt Opitz in 1923. Thus it is the oldest long-term field experiment on sandy soils in Germany.

The soil of the area is an Albic Luvisol (FAO). The soil properties are: Approximate water holding capacity 21 mm per 100 mm; approximate soil organic matter content: 1.2 %; approximate carbon content: 0.7 %; approximate carbon: nitrogen ratio:10:1; approximate soil bulk density: 1.7 g cm^{-3}; clay (i.e. particles smaller than 2 µm): 4 %; silt (i.e. particles between 2 µm and 63 µm): 23 %; sand (i.e. particles between 63 µm and 2000 µm): 73 %; approximate soil pH: 5.5.

This experimental design consists of three different factors which has different tillage depths (17 cm and 28 cm), farm yard manure application (with or without) and lime application (with or without) with 6 replications. Each main plot has acreage of 20 m² and harvest acreage of 10.08 m². According to these factors, the disturbed and undisturbed soil samples where taken from totally 48 plots from 10-15 cm and 20-25 cm soil depths. The penetration resistance values were taken from all these 48 plots in spring 2006.

Geographically the research area Leibniz Centre for Agricultural Landscape Research (ZALF) Müncheberg is situated in Northeast Germany which was established in 1985. The approximately soil properties are: Soil organic matter content 0.9 %, carbon content 0.98 %, carbon: nitrogen ratio 7-10:1, soil bulk density: 1.7 g cm^{-3}, clay (i.e. particles smaller than 2 µm): 10 %; silt (i.e. particles between 2 µm and 63 µm): 30 %; sand (i.e. particles between 63 µm and 2000 µm): 60 %, pH: 7.5-8.2.

The experimental design consists of 5 different tillage depths (No-tillage, mulch: 10cm, cultivator: 15 cm, plough: 15 cm and plough: 25 cm) from where the soil samples were taken from 10-15 cm and 20-25 cm depths.

RESULTS and DISCUSSION:

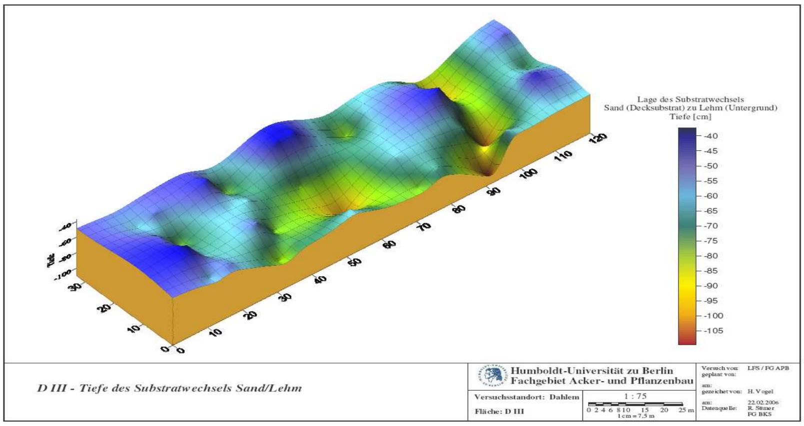

Figure 1: Display of Substrat- Change in the Long-Term Field Experiment DIII at Berlin Dahlem via Software „Surfer“.

The spatial variability of soils plays in important role in plant growth. Therefore it's important to know the heterogeneity which affects the root elongation for a healthy plant growth. This field experiment showed that the sand layer varies between the depths of 35 cm and 110 cm. The spatial variability showed a wide heterogeneity.

Table 1: Results from some physical and chemical properties and crop production in soils in Berlin-Dahlem

Factors		pH 10-15 cm	pH 20-25 cm	Humus (%) 10-15 cm	Humus (%) 20-25 cm	Aggregat St. (%) 10-15 cm	Aggregat St. (%) 20-25 cm	C/N 10-15 cm	C/N 20-25 cm	Grainyield (dt/ha)
deep (28 cm)	(+) FYM, (+) lime	5,8 de	5,9 c	1,27 cd	1,25 cd	13,30 ab	13,05 ab	13,94 a	13,64 bcd	27,79 b
	(+) FYM, (-) lime	4,4 c	4,3 b	1,16 bc	1,06 abc	13,06 ab	13,14 ab	14,33 a	13,30 abc	29,24 b
	(-) FYM, (+) lime	6,0 e	6,0 c	1,09 ab	1,01 ab	13,32 ab	13,24 ab	14,38 a	14,07 cd	25,89 b
	(-) FYM, (-) lime	4,0 bc	4,0 b	0,98 a	0,94 a	11,62 a	12,71 a	14,32 a	14,34 d	23,70 b
shallow (17 cm)	(+) FYM, (+) lime	5,5 de	5,6 c	1,78 e	1,28 d	18,76 d	15,61 abc	14,49 a	12,45 a	24,96 b
	(+) FYM, (-) lime	3,9 ab	3,9 ab	1,68 e	1,11 abcd	18,03 cd	16,15 c	14,57 ab	13,09 ab	28,74 b
	(-) FYM, (+) lime	5,4 d	5,6 c	1,40 d	1,14 bcd	15,51 bc	15,61 bc	14,73 ab	13,28 abc	23,75 b
	(-) FYM, (-) lime	3,5 a	3,5 a	1,38 d	1,11 abcd	15,41 bc	17,60 c	15,63 b	13,94 bcd	15,32 a
	LSD_{A*B*C} (a= 5 %)	0,45	0,42	0,16	0,18	3,05	2,89	1,13	0,95	6,40
	* significant in multipler T- Test									*

According to this one year experiment in Berlin Dahlem 2006, results show that there was a positive effect between three treatments (lime, FYM and tillage depth) on Humus- Aggregate Stability relation. Each tillage system shows higher Humus and Aggregate Stability results in contrast to none FYM applications in itself. The humus content is closely related to soil aggregate stability Furthermore, the Humus and Aggregate Stability results are higher in shallow tillage in contrast to deep tillage system. A relatively higher Humus content in the shallow tillage system shows that deep tillage went to a reduction in soil organic carbon in the deep tillage system.

The soil C/N ratio (10-15 cm and 20-25 cm) were between 12.45 and 15.63 for both soil depths in all tillage systems. The pH values were between 3.5 and 6.0 and show higher results in deep tillage system. There was found no significant differences between the grain yield in both tillage systems except of the (-) FYM and (-) lime application in shallow tillage.

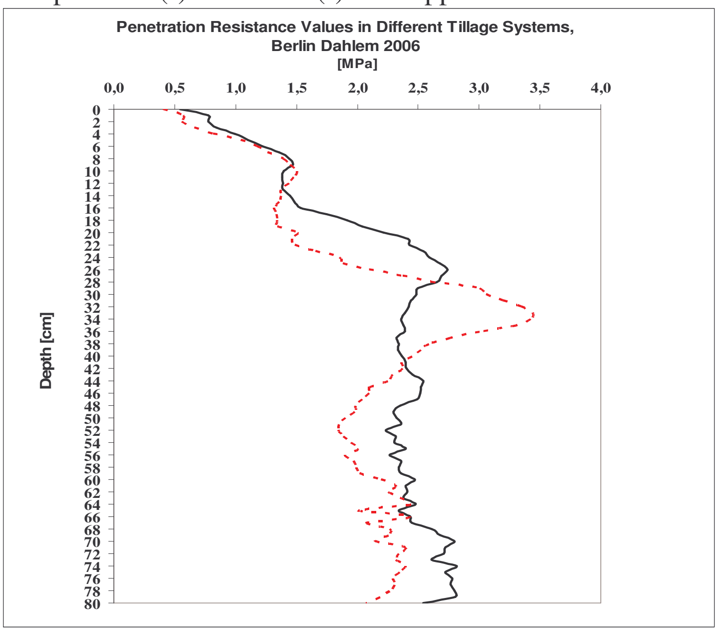

Figure 2: Penetration Resistance Values in Different Tillage Systems,Berlin Dahlem 2006

The penetration resistance begins with nearly the same value at the surface of both deep tillage systems. Until reaching the 10 cm soil depth, both systems show nearly the same resistance effects. Between 10- 26 cm soil layer there is a more compacted soil layer in shallow tillage. The deep tillage system shows a maximum compacted soil layer with a value of 3.5 MPa in 32 cm depth whereas in shallow tillage this value is only 2.7 MP in 26 cm soil depth. The penetration resistances of both experimental fields showed that the deep tillage systems caused a higher compacted zone in deeper soil layers.

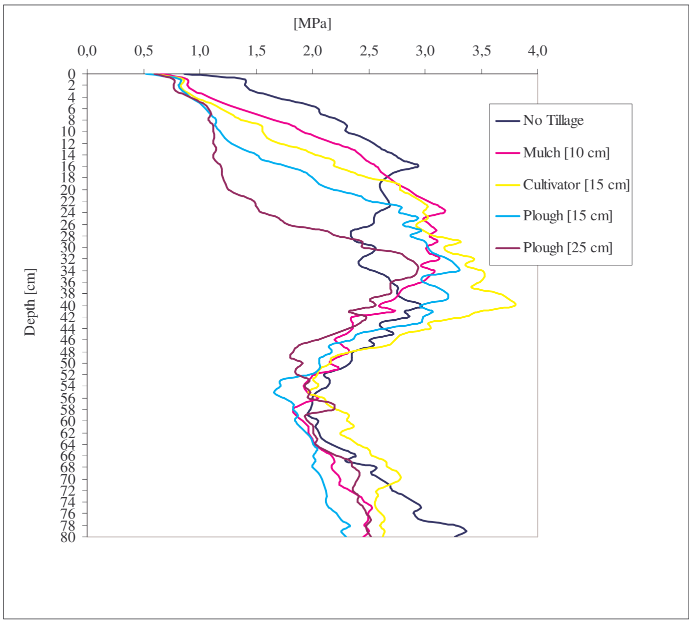

Figure 3: Penetration Resistance Values in Different Tillage

Systems, ZALF 2007

The penetration resistance values in ZALF show the most compacted zone between 0-16 cm soil depths belonging to No- Tillage system. The lowest compacted soil zone between 0-25 cm can be seen at plough (25 cm).

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Mineralization of Five Biosolids in Two Tropical Soils

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ABSTRACT

This work aimed to evaluate mineralization rates of the five most common biosolids (digested sludge, composted sludge, limed sludge, heat-dried sludge, and solar-irradiated sludge) when incubated to two tropical soils - a Spodosol and an Oxisol soil. Fresh sludge and stabilized biosolids were mixed with soil samples at 0.5, 1.0, 2.0, 4.0, 6.0 and 8.0 dry t biosolids/ha and incubated at 25°C in a high humidity chamber (95% air moisture), at 12 hours light/day, during 23 weeks for a non-leaching experiment. Results have showed that all the stabilization processes altered the capacity of the fresh sludge to release mineral-N. Except solar-irradiated sludge, the stabilization processes hindered the release and accumulation of mineral-N in soils. Composting and CaO-liming were the processes that most reduced the release of mineral-N. Mineralization rates and mineral-N release from biosolids were always higher in the Ferrosol compared to Spodosol soil.

INTRODUCTION

The idea of applying organic matter, primarily containing nitrogen (N) and phosphorus (P), back into the natural cycle forms the basis of using sludge on land (Frank, 1998). There is actually a wide spectrum of sewage products internationally referred as biosolids that have been reported to improve soil physical and chemical conditions and increase plant yield (Cameron *et al.*, 1996).

Besides the significant agronomic benefits that biosolids can provide when applied to land, its use frequently encounters apprehension and even strong opposition from the general public (Forste, 1996). The reasons according to Sparkes (1990) are not only due to nuisance problems and pathogenic contents in sewage materials, but also to concerns on environmental hazards from high biosolids N and P concentrations. For such reasons, the United States Environmental Protection Agency (USEPA) has addressed potential hazards represented by disposal and beneficial use of sewage materials in its Title 40 of the Code of Federal Regulations (CFR), Part 503. It is a risk-based rule to protect public health and the environment, which describes sludge stabilization processes (sludge digestion, composting, lime stabilization, heat treatment, and solar irradiation). Stabilization processes can make biosolids safe enough for their beneficial use, and for the sake of groundwater protection, land application rates are based on matching biosolids-N with crop N-needs, namely N-agronomic rate (USEPA, 1995).

Policies worldwide will require in the next years a more intensive management of biosolids-N to ovoid deleterious impacts of on the environment (Maguire *et al*., 2000). The release of nutrients from mineralization of biosolids is therefore an important issue in plant nutrition and environmental management. Several authors stress the importance of matching the amount of nutrients available and delivered through time with crop demands in order to avoid either limitations on plant growth or losses of excess nutrient to surface and groundwater (Sims, 1990; Reed *et al.* 1995; Epstein 1997).

Laboratory incubation experiments have showed sewage sludge to be highly mineralizable (Willett *et al.* 1984). But sewage sludge stabilization processes aim to make it less putrescible, and mineralization of different stabilized biosolids probably present different capacities to release nutrients. Even mineralization rates of aerobically digested sludge are higher than of anaerobically digested sludge as the latter is more stable (Munn 1995).

When biosolids are applied to land, mineralization and nutrient transformations occur in combination with other soil processes. Mineralization rate and fate of nutrients will then depend on the soil type and site conditions. O'Dowd *et al.* (1999) stated that mineralization is a major process influencing the supply of N to plants and for leaching. Procedures involving the determination of N mineralized during incubation are considered the most satisfactory method used to estimate mineralization of organic materials in soils (Serna & Pomares 1991; van Kessel *et al.* 2000). The potential mineralization rates of different stabilized biosolids and their behavior after mixing with different soils have to be investigated for their appropriate beneficial use (Maguire *et al*., 2000).

Thus, this work aimed to evaluate mineralization rates of the five most common biosolids (digested sludge, composted sludge, limed sludge, heat-dried sludge, and solar-irradiated sludge) when incubated to two tropical soils – a Spodosol and an Ferrosol soil.

MATERIALS and METHODS

Sludge Stabilization

A 500 kg sample of tertiary biological domestic sewage sludge was collected from a wastewater treatment plant at Bendigo shire, Victoria – Australia. The sewage sludge was analyzed in triplicate for gravimetric water content (105°C for 48 hours), bulk density (BD) (Rayment & Higginson, 1992), total carbon (total-C), total nitrogen (total-N), mineral nitrogen (mineral-N), total phosphorus (total-P), and available phosphorus (available-P). The fresh sewage sludge (Table 1) presenting 878 g kg^{-1} moisture, BD = 1.2 Mg m^{-3}, and C/N ratio = 6.2 was mixed with hardwood sawdust (96 g kg^{-1} moisture, BD = 0.3 Mg m^{-3}, and C/N ratio = 668) and woodchips (bulk agent) to achieve a C/N ratio = 25:1. Three 450 L composting piles were pitched on a sheltered cement pavement, run at 35°C - 65°C for 34 days, let to mature for another 60 days and sieved at 2 mm. Lime treatment used CaO at 30% rate to sludge dry solids (weight/weight). Heat drying was performed in a furnace at 250°C until constant weight. The heat-dried sludge was ground and passed through a 2 mm sieve. For the solar irradiation process, three 10 kg fresh sludge samples were stored in freely drained plastic bowls under transparent plastic-covers and sunny conditions for 14 days during Melbourne's summer, with daily temperatures ranging from 12.8°C to 26.5°C. The stabilization criteria established in USEPA (1995) were achieved in all the employed processes. All stabilized biosolids were analyzed in triplicate for total-C, total-N, mineral-N, total-P and available-P using the same analytical methods for the fresh sewage sludge. Results are showed in Table 1. Analysis of variance and Tukey test were performed in GenStat® for Windows 5th edition.

Soils

Two contrasting Australian soils were selected to be amended with the biosolids: a humosesquic, aeric Podosol and an acidic, mesotrophic Ferrosol (Isbell, 1996). The soils are respectively an Orthod Spodosol and an Ustox Oxisol according to USDA (1999). A 200 kg sample of each soil was collected from nearby Melbourne, allowed to air dry for 2 weeks, and passed through a 4 mm sieve.

Mineralization Experiment

Fresh sludge and stabilized biosolids were mixed with soil samples of 1.5 kg amended at 0.5, 1.0, 2.0, 4.0, 6.0 and 8.0 dry t biosolids/ha and placed in triplicate in 1.7 L free-draining pots. Amended-soils were wetted with deionized water to their pot capacity, as described in Cassel & Nielsen (1986), and covered with plastic lids containing three 4-mm holes. Pots were incubated at 25°C (±1°C) in a high humidity chamber (95% air moisture), at 12 hours light/day, during 23 weeks for a non-leaching experiment. Three pots containing 1.5 kg blank-Podosol soil and three with blank-Ferrosol soil were placed together with the others for control purposes. Soils were mixed prior to each sampling, which occurred on day 0 and in the 1st, 3rd, 7th, 15th and 23rd weeks after the experiment started. Pots were randomized weekly and samples were sprayed on surface with deionized water every second week to replace moisture losses.

Laboratory Analysis

Blank and amended soil samples were collected and placed in a 5 °C cold room (±1°C) for the analysis of mineral-N within 48 hours after sampling. A Carbo-Erba NA 1500 analyzer was used to measure total-C and total-N by the dry combustion method. Mineral-N was analyzed by the Kjeldahl steam distillation method for ammonium-N (NH_4^+-N) and nitrate-N (NO_3^--N) (Rayment & Higginson, 1992). Mineralization rates were accounted based on mineral-N released in the amended soils.

Analysis of Data

Data on mineral-N concentrations during soil incubation were set on graphics and regressions were drawn for accounting mineralization rates. N-mineralized throughout 23 weeks was summed up to determine the potentially available-N (PAN). PAN can be used by plant or leached down into soil profile was calculated according to Pierzynski (1994) and Barbarick & Ippolito (2000):

$$PAN = NO_3^- \text{-N} + X\ NH_4^+ \text{- N} + Y\ \text{Organic-N} \qquad \text{Equation 1}$$

where X is fraction of NH_4^+-N that does not volatilize (often assumed to be 1) and Y is the fraction of organic-N that mineralizes. Organic-N was calculated according to Pierzynski (1994):

$$\text{Organic-N} = \text{total-N} - (NO_3^- \text{-N} + NH_4^+ \text{-N}) \qquad \text{Equation 2}$$

All data were converted to oven-dry basis and statistical analyses were done in Minitab 12.1 and Systat for Windows software.

Table 1: Some agronomic characteristics of the biosolids.

Parameter	Fresh Sludge	Composted sludge	30%-CaO Sludge	250°C-dried sludge	Solar-dried sludge
		dry weight basis			
Total-C (g kg^{-1})	404c	283a	303b	389c	406c
Total-N (g kg^{-1})	65.1c	15.9a	40.1b	64.8c	65.3c
C/N ratio (w/w)	6.2a	17.8c	7.5b	6.0a	6.2a
Total-P (g kg^{-1})	72.1c	24.2a	50.6b	72.5c	72.6c
Mineral-N (mg kg^{-1})	624d	277b	93.8a	356c	803e
Available-P (mg kg^{-1})	268c	377d	11.9a	678e	199b
Bulk density (Mg m^{-3})	1.2c	0.4a	1.4d	0.6b	1.3cd
		wet weight basis			
Gravimetric water (g kg^{-1})	878e	551b	754c	101a	819d
pH [1:5 water $_{(w/v)}$]	6.4b	6.1ab	11.9d	5.8a	7.4c

Means (n = 3) with same letter within rows are not statistically different by the Tukey test ($p < 0.05$)

Table 2: Total-N applied to air-dry soils, based on their contents in biosolids

Equivalent dry t/ha	Fresh sludge	Composted sludge	30%-CaO sludge	250°C-dried sludge	Irradiated sludge
		Total-N applied to soils as biosolids (mgN kg^{-1} soil)			
0.25	8.1	2.0	5.0	8.1	8.2
0.50	16.3	4.0	10.0	16.2	16.3
1.0	32.6	8.0	20.1	32.4	32.7
2.0	65.1	15.9	40.1	64.8	65.3
3.0	97.7	23.9	60.2	97.2	98.0
4.0	130.2	31.8	80.2	129.6	130.6
5.0	162.8	39.8	100.3	162.0	163.3
6.0	195.3	47.7	120.3	194.4	195.9
7.0	227.9	55.7	140.4	226.8	228.6
8.0	260.4	63.6	160.4	259.2	261.2

RESULTS and DISCUSSION

Soils amended with organic wastes are usually reported to increase mineralization rates due to the increase of available organic components and inoculation with saprophytic microorganisms (Siegenthaler & Stauffer 1991; Pascual *et al.* 1997a; Fliessbach *et al.* 2000). Mineralization rates in both soils were boosted after application of biosolids (Figures 1 - 5).

The primary factors likely to control decomposition and release of nutrients from incorporated biosolids are application rate, substrate quality and interactions with bacteria, fungi and climate (Mary *et al.* 1996; Robinson & Polgase, 1996). In that respect, the mineralization of all biosolids in Podosol and Ferrosol soils was highly influenced by the two different soils. Such a soil dependency was studied by Soni & Singh (1994) who evaluated the capacity of different soils to mineralize sewage sludge.

Concentrations of mineral-N in the Podosol soil treated with fresh sludge never reached treated-Ferrosol soil's N-concentrations during the 23 weeks of incubation, despite the equivalent rates of biosolids-N applied to both soils (Table 2). Incorporation of different rates of fresh sludge in the Podosol and subsequent mineralization brought mineral-N concentrations to 6.6 - 15.7 mg mineral-N/kg soil which accounts for a 5 - 6 fold increment in mineral-N concentrations relative to control-soil. The higher value is similar to 14.7 mg mineral-N/kg soil present in the unamended-Ferrosol soil (Figure 1b). Therefore, Podosol soil presented a limited potential for sewage sludge mineralization compared to the Ferrosol soil (Figures 1a and 1b).

Mineral-N concentrations in the Podosol treated with fresh sludge increased in a linear fashion (Figura 1a), but there was no significant difference of applying 0.5 or 1.0 dry t/ha to Podosol soils after 23 weeks of trial as both rates ended at mineral-N concentration of 6.7 mg kg^{-1}. The same applies to the range 2.0 - 6.0 dry t/ha (11.8 mg kg^{-1}) but the 8.0 dry t/ha rate finished the trial at mineral-N concentrations significantly higher than the 2 - 6 dry t/ha range. However, for a 16 times increasing in application rate (0.5 → 8.0 dry t/ha), mineral-N concentration increased only 2.4 times (6.6 mg kg^{-1} → 15.7 mg kg^{-1} soil). Fresh sludge proportionally mineralized more in Podosol at low application rates (0.5 - 2 dry t/ha) than at the highest ones (6 - 8 dry t/ha). Mary *et al.* (1996) also reported relatively higher mineralization rates for the lower application rates in their work.

Ferrosol soil samples treated with fresh sludge increased N-concentrations 3 - 5 fold during incubation (Figure 1b). The 4.0 - 8.0 dry t/ha range delivered enough mineral-N to increase concentrations high enough to support crops (Rashid & Memon, 1996) yet from the 7th week. Thus, this biosolid may be able to totally substitute N-fertilizer in this soil. The highest 8.0 dry t/ha ended the trial at 58.9 (±4.1) mg mineral-N kg^{-1} soil, which is a level suitable for most of the crops. Even the two lowest rates (0.5 - 1.0 dry t/ha) ended the trial at mineral-N concentrations (19.8 mg kg^{-1}) that Rashid & Memon (1996) heeds as suitable for most crops.

A common aspect of organic matter mineralization curves is the stabilization of cumulative mineral-N showing either mineralization stopped or significantly reduced after a certain period (Dendooven *et al.* 1995). As curves on Figures 1a and 1b are rather linear, the mineralization of the fresh sludge would probably continue in both soils if a longer time was given. The long-term mineralization of sewage sludge in soils was demonstrated by Cox & Whelan (2000) who reported N from sewage sludge incorporated to a loamy clay soil still present after five years.

The regression of mineral-N concentrations on time showed an increasing of 0.6 mg mineral-N/kg soil/week for each tone of fresh sludge dry solids applied to Ferrosol soil (R^2 = 0.95). For Podosol soil there was an increasing rate of 0.2 mg mineral-N/kg soil a week at the same 1 dry t/ha application rate (R^2 = 0.92) which made fresh sludge to mineralize three times quicker in the Ferrosol than in the Podosol soil. For the highest 8.0 dry t/ha tested in this work, such difference reached 3.8 times in favor to the Ferrosol.

Podosol and Ferrosol soils showed different mineralization patterns and rates as responses to equal application rates of composted sludge (Figures 2a and 2b). Mineral-N quickly increased in Podosol soil within three weeks of incubation (Figure 2a) while it increased mostly in the Ferrosol after the fifteenth week of trial (Figure 2b). Organic matter incorporated to soils contains fractions with weekly, monthly, and annual turnover rates and it seems that the Podosol was able to mineralize only the light organic matter fraction. Whalen et al. (2000) explain that the exhaustion of the most readily available-C usually slows down organic matter degradation.

Various authors cite the two stages of composted sludge mineralization in soils as a result of its highly stabilized forms of nutrients (Rodrigues *et al*., 1995). Van Kessel *et al.* (2000) describe the compost's mineralization as biphasic because of the presence of a readily mineralizable organic pool of nutrients and a second slowly mineralizing pool. Under Podosol soil conditions, the fraction that quickly mineralized made greater contribution to inputs of mineral-N in 23 weeks, that is common in soils having low potential for organic matter mineralization (Whalen *et al.* 2000). In Ferrosol soil, mineral-N increased 1.5 times in the first 15 weeks trial and over twice from this to the 23^{rd} week.

Although mineralization rates of composted sludge in Ferrosol soil were much higher, doses 0.5 -1.0 dry t/ha did not significantly ($p = 0.05$) increase mineral-N relative to the control-Ferrosol (Figure 2b). Control-Ferrosol soil increased mineral-N from 5.0 (±0.2) to 14.7 (±1.8) mg kg^{-1} in 23 weeks of incubation, whilst 1.0 dry t/ha amended-soils departed from 5.3 mg kg^{-1} to reach 15.3 mg kg^{-1} after the same period. Thus, Ferrosol had to receive at least 2.0 dry t/ha of composted sludge to significantly increase mineral-N concentrations by approximately 30%. Doses of 6.0 and 8.0 dry t/ha could increase mineral-N by 40% and 65%, respectively, relative to the control-Ferrosol.

Mineralization rates of composted sludge in sandy soils are frequently reported as low: 10% after 160 days incubation at 25^{o}C in Smith *et al*. (1998b) and less than 20% after a year at 14^{o}C in Leifeld *et al*. (2001). Saviozzi *et al.* (1999) consider composted sludge more adequate to restore soil organic matter than sewage sludge as the former lasts longer in soil as a result of its higher degree of stabilization. Composted sludge has mineralized twice as quicker in the Ferrosol than in the Podosol soil.

The mineralization of 30%-CaO sludge in soils occurred mostly until the 7^{th} week of incubation, from which mineral-N increased little (Figure 3a and 3b). The 30%-CaO sludge showed amongst the biosolids in this work the highest mineralization rates in Podosol soil: mineral-N doubled each week until the 15^{th} week and from this mineral-N increased a further 20%. Concentrations of mineral-N in Podosol samples treated with 30%-CaO sludge increased from 4 to 6 times during incubation and reached values up to 21 times higher compared to control.

According to Sloan & Basta (1995), the liming of sewage sludge usually enhances mineralization rates when pH set within 5 - 7. But the two highest application rates (6.0 and 8.0t dry solids/ha) were exceptions as most of the mineralization occurred between the 7^{th} and 15^{th} weeks. It was probably a pH influence since soil pH increased pH to 7.0 - 7.5 while lower rates never increased pH beyond 6.5.

A high pH buffering capacity of Ferrosol soil enabled it to receive up to 8.0 dry t/ha of 30%-CaO sludge without significantly change its pH. It suggests this soil could receive higher loads of limed-sludge without major changes in pH related-chemical characteristics, such as P availability. However, Ferrosol samples amended at 0.5 dry t/ha ended the trial having mineral-N concentrations approximately 10% lower than the control-Ferrosol soil. Application rates between 1.0 - 4.0 dry t/ha could not significantly increase mineral-N relative to control. A significant 8% mineral-N increase ($p = 0.05$) started to occur from 6.0 dry t/ha rate. At 8.0 dry t/ha rate, mineral-N increased by 35% relative to the control-Ferrosol (Figure 3b). The 30%-CaO sludge´s capacity to increase mineral-N in Ferrosol remained at one-third compared to the fresh sludge.

Overall, a dry tone of 30%-CaO sludge increased mineral-N at 0.2 mg/kg soil/week in the Podosol and 0.4 mg/kg soil/week in Ferrosol soil. The former rate is similar to fresh sludge in the Podosol soil but the last one is approximately half the mineralization rate of fresh sludge in the Ferrosol Therefore, lime enhanced mineralization in the Podosol soil and delayed it in the Ferrosol soil.

The 250 ^{o}C-heat drying process certainly sterilized fresh sludge and deprived it of microorganisms. Enzymatic activities to break down organic components into available nutrients are highly dependable on microbial activity (Pascual *et al.* 1997a). Possibly due to shortage of microorganisms and lower dissolution capacity, a tone of 250^{o}C-dried pellets reached only 54% of mineral-N concentrations in the Podosol compared to the fresh sludge, despite both biosolids have similar contents of nutrients at dry matter base (Table 1). Figures were better in the Ferrosol as mineral-N reached 61% of fresh sludge's concentrations.

Despite of it, Podosol soil responded well to the incorporation of different rates of 250^{o}C-dried sludge. There was a linear increase in mineral-N through the time from application rates of 4.0 dry t/ha. Application rates ≤ 2.0 dry t/ha resulted in very gentle slopes as the release of mineral-N was very slow (Figure 4a). The highest 8.0 dry t/ha rate finished the trial at 12.3 (±0.8) mg kg^{-1}, which is approximately three times higher than the control and 30% higher than the amount released by 4.0 - 6.0 dry t/ha rate.

Mineralization of 250^{o}C-dried sludge in the Ferrosol showed a similar pattern to that shown by the composted sludge. Mineral-N increased at higher rates after 15 weeks of incubation than in the first half of trial. However, the 250 ^{o}C-dried pellets increased Ferrosol's mineral-N concentrations 46% higher than composted sludge, thta is a consequence of the pellets' higher initial mineral-N content (Table 1). Similar fact occurred in the Podosol, where mineralization rates of dried-pellets were half compared to the composted sludge, but mineral-N concentrations increased 40% higher in

Podosol treated with the former biosolid. Therefore, from the practical point of view, both of biosolids mineralize slower in soils than their raw material (fresh sewage sludge). But the 250°C-dried pellets were more effective to increase mineral-N concentrations than equivalent dry tonnage of composted sludge.

Solar-irradiated sludge at 6.0 - 8.0 dry t/ha application rates were the treatments that most increased mineral-N in the Podosol soil, especially because these two highest doses showed a distinguished increase in mineral-N concentrations relative to the lower application rates (Figure 5a). Controversially this biosolid had one of the lowest mineralization rates in this soil (Table 3) and its high mineral-N concentrations (Table 1) must be the cause of such a high mineral-N input. Mineral-N concentrations in the Podosol treated with solar-irradiated sludge reached up to 19.4 mg/kg soil against a value 36% lower for the fresh sludge at the same 8 dry t/ha application rate. Wen *et al.* (1997) also reported higher mineral-N concentrations in soils incubated with irradiated sludge than with fresh sludge.

Ferrosol soil treated with solar-irradiated sludge reached similar N-concentrations and increasing patterns to the fresh sludge (Figures 1b and 5b). Both biosolids applied to Ferrosol linearly increased mineral-N through the 23 weeks to end the trial at the highest mineral-N concentrations in this soil (57.5 mg kg^{-1}). According to Smith *et al*. (1998a), storage effectively stabilizes organic-N in sewage sludge making the organic matter more resistant to further mineralization in soil. This statement applies to the Podosol soil but for the Ferrosol, soil environment prevailed as these two biosolids showed the two highest mineralization rates in this soil.

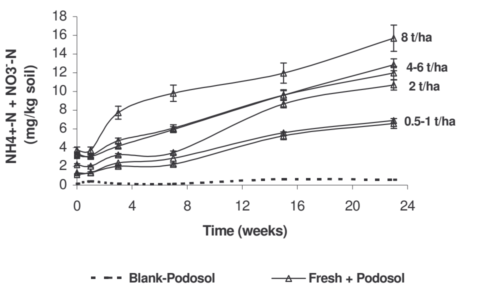

Figure 1a: Fresh sludge-amended Podosol soil in 23 weeks incubation

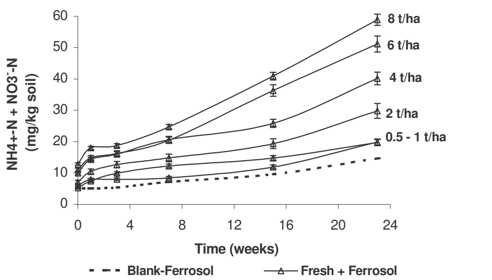

Figure 1b: Fresh sludge-amended Ferrosol soil in 23 weeks incubation

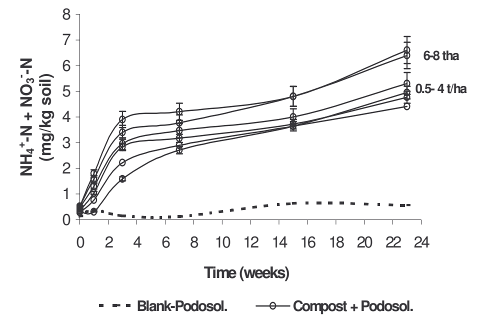

Figure 2a: Composted sludge-amended Podosol soil in 23 weeks incubation.

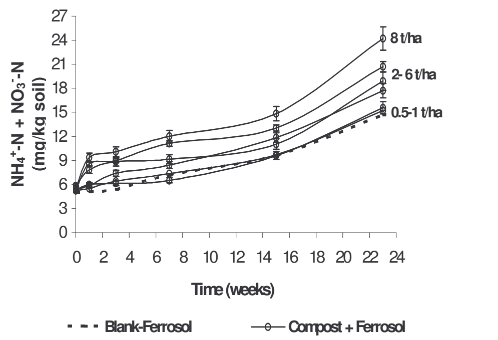

Figure 2b: Composted sludge-amended Ferrosol soil in 23 weeks incubation

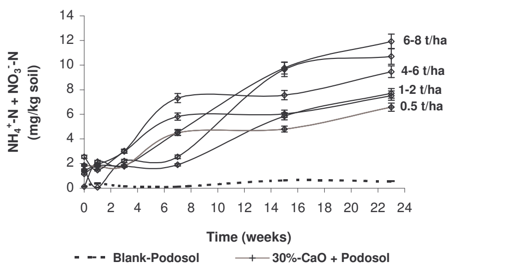

Figure 3a: 30%-CaO sludge-amended Podosol soil in 23 weeks incubation

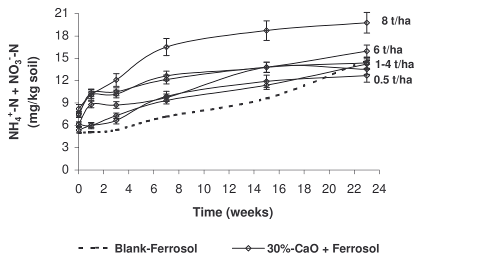

Figure 3b: 30%-CaO sludge-amended Ferrosol soil in 23 weeks incubation

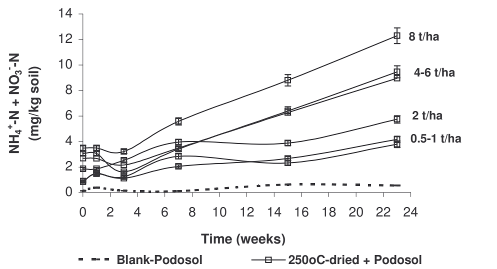

Figure 4a: 250°C-dried sludge-amended Podosol soil in 23 weeks incubation.

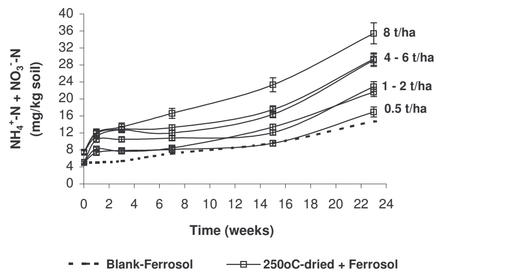

Figure 4b: 250°C-dried sludge-amended Ferrosol soil in 23 weeks incubation.

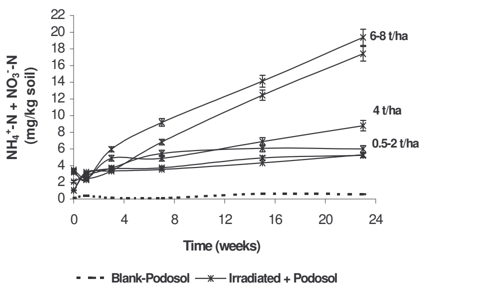

Figure 5a: Solar-irradiated sludge-amended Podosol soil in 23 weeks incubation.

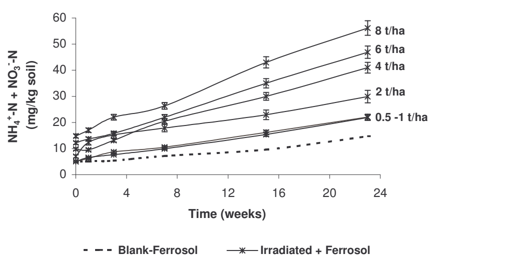

Figure 5b: Solar-irradiated sludge-amended Ferrosol soil in 23 weeks incubation

Many patterns for the mineralization of biosolids have been described in the literature, since soil type, temperature of incubation, biosolids' N content, C/N ratio, and time influence the kinetics of organic matter degradation (Dendooven *et al.* 1995; van Kessel *et al.* 2000). Zero-order and first-order functions can usually explain the biggest part of mineralization of organic materials added to soils (Dendooven *et al.* 1995; Mary *et al.* 1996; van Kessel *et al.* 2000). In this work, zero-order functions (linear equations) could explain from 71% to 99% of the mineralization of biosolids in both Podosol and Ferrosol soils.

After 23 weeks of soil incubation, between 10% and 28% of organic-N in biosolids mineralized in the Podosol and from 32% to 82% in the Ferrosol soil (Table 3). Van de Graaff (1998) considers soil the most effective medium for mineralizing decomposable substances, which could be confirmed for biosolids, particularly when applied to Ferrosol soil. High mineralization rates of organic materials are frequently reported in soils presenting higher clay content (Fliessbach *et al.* 2000), which is desirable for both the supply of nutrients to plants and degradation of hazardous organic substances.

The highest percentage of organic-N mineralized in the Podosol refereed to the composted and 30%-CaO sludge (Table 3). However, their lower N content resulted in PAN inputs inferior to that from fresh sludge. On the other hand, the high N content in 250^{o}C-dried pellets showed the lowest mineralization rate in this soils and PAN input was half of that release by the fresh sludge. Approximately 17% of fresh sludge organic-N at 1 dry t/ha application rate had mineralized after 23 weeks of incubation in the Podosol. This biosolid had the highest mineralization rate over the period and as a result, fresh sludge showed the highest PAN input in this soil. As far as a N-source is the concern, fresh and solar-irradiated sludge were the best options for the Podosol soil.

Composted sludge applied to Ferrosol soil mineralized 82% of its organic-N but the potentially available nitrogen (PAN) input was one of the lowest measured (Table 3). Considering the initial values of mineral-N in compost-amended soils, mineralization of organic-N incremented at most an extra 2 mg kg^{-1} in Podosol soil and 9.5mg kg^{-1} in Ferrosol soil. The highest mineral-N concentration achieved in composted sludge-amended Podosol soil (6.6mg kg^{-1}) is similar to the value showed by the 0.5 dry t/ha of fresh sludge in the same soil.

Fresh and solar-irradiated sludge mineralized approximately half the organic-N in Ferrosol soil and PAN inputs were the greatest ones (Table 3). Despite only 32% of dried-pellets' organic-N mineralized in Ferrosol soil, PAN input was higher than composted and 30%-CaO sludge in this soil. Pascual *et al*. (1997b) stated that different rates of mineralization amongst sewage materials are consequence of different stabilization processes. According to them, the less stable is an organic material the bigger the soil biological activity and its mineralization in soils. However, organic-N content was of greater importance in the Ferrosol for PAN input than the stabilization degree of the biosolids.

Ferrosol amended with biosolids presented a better C/N ratio range (23-30:1) than amended Podosol soils (12-20:1) for mineralization to occur. Thus, mineralization rates were correlated with C/N ratios (R^2 = 0.56) in the Ferrosol but not in the Podosol (R^2 = 0.002). Mary *et al.* (1996) pointed out the importance of appropriate soils' C/N ratios to degrade organic materials. There was not any correlation between mineralization rates and total-N concentrations in both Podosol and Ferrosol soils besides it was drawn by Cox & Whelan (2000) in their work. The mineralization of biosolids in Ferrosol soil was more predictable and efficient relative to the Podosol soil. Iakimenko *et al.* (1996) concluded that among various factors soil type was the most important for N mineralization of sewage sludge, followed by application rate.

Mary *et al*. (1996) calculated that laboratory experiments underestimate field mineralization trials by 25% under northern France environment. Zagal (1994) concluded from his incubation experiment that amounts of N-mineralized in planted soil during 43 days were comparable to N-mineralized in unplanted soils incubated for 210 days. Therefore, under planted field conditions mineralization rates will probably be higher than the results found here.

Table 3: PAN in biosolids-amended soils at 1.0 dry t/ha after 23 weeks of incubation

Biosolid	NH_4^+-N at day 0 (mg/kg soil)	NO_3^-N at day 0 (mg/kg soil)	Organic-N mineralized	Mineraliztion rate (mgN/kg soil/week)	PAN input after 23 weeks of incubation (mg/kg soil)
Podosol soil					
Fresh	1.18	0.14	17%	0.24	5.6
Composted	0.16	0.15	28%	0.20	4.6
30%-CaO	2.55	0.0	25%	0.22	4.9
250°C-Dried	1.15	0.02	10%	0.13	3.0
Irradiated	1.05	0.0	13%	0.18	4.2
Ferrosol soil					
Fresh	5.15	0.08	45%	0.63	14.5
Composted	5.09	0.18	82%	0.43	9.9
30%-CaO	6.13	0.0	40%	0.35	8.1
250°C-Dried	4.96	0.06	32%	0.52	11.9
Irradiated	5.08	0.0	52%	0.74	16.7

CONCLUSIONS

All the stabilization processes used in this worked (composting, CaO-liming, heat-drying and solar irradiation) altered the capacity of the fresh sludge to release mineral-N. Except solar-irradiation, the stabilization processes hindered the release and accumulation of mineral-N. Composting and CaO-liming were the processes that most reduced the release of mineral-N.

Potentially available-N (PAN), percentage of organic-N mineralized, and mineralization rates were always higher in Ferrosol than in Podosol soil.

Fresh and solar-irradiated sludge presented the highest PAN in Ferrosol soil. This soils treated with 250^{o}C-dried sludge came on second place, followed by composted and 30%-CaO sludge. But not only the composted sludge released more mineral-N than 30%-CaO sludge in the Ferrosol, but also the former tends to keep increasing after 23 weeks whilst 30%-CaO sludge had already peaked before the end of the experiment.

Except 30%-CaO sludge, the biosolids could not display their full mineralization potential due to the relative short-term experiment. The premature exhaustion of N from 30%-CaO sludge was a common characteristic in both soils. Despite the low capacity of composted sludge to increase mineral-N, it was the most degraded biosolid in both Podosol and Ferrosol soils. On the other hand, 250^{o}C-dried sludge mineralized little, but it has high amounts of N to be delivered on a longer-term basis.

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Evaluation of Economy and Compared Energy Efficiency on Grape in West Azerbaijan Province

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ABSTRACT

A way of estimation agriculture development and product stability agricultural location is using of energy flow method. In this consideration, energy flow at agricultural ecosystems of Grape in two cities from west Azerbaijan province was compared. The related data of inputs and outputs for evaluation of energy efficiency in these gardens are become equivalent value of input and output energy efficiency. Energy value of used factors and input in grape gardens of uremia and sardasht were respectively 6417773 and 862570 k cal/ha and output (production) energy value of the gardens were 25632600 and 10123800 k cal/ha respectively. Energy efficiency values (output: input ration) were 3.99 and 11.7 respectively. Data showed in grape gardens of uremia the most use of energy were nitrogen fertilized usage and irrigation. In grape gardens of sardasht the most use of energy was nitrogen fertilized. In general, because of the climate conditions, topography, society culture in these regions, difference in energy efficiency of these gardens almost was reasonable. The number of inputs increases; effect increases any one of input decrease. Grape garden system of sardasht hasn't any contamination and agricultural systems because of much Annual rainfall in this region are dry farming. There for, costs of irrigation and poisoning are deleted but inordinately poisoning of uremia gardens result in contamination and transformed these ecosystems.

Keywords: Energy efficiency, output, input, and grape.

INTRODUCTION

Agricultural ecosystems are related to economical and society condition widely, that there are in the world. The major of agricultural ecosystems management are maximum energy flow and human service materials. (Energy cycle is a subject of agricultural ecology and in different locations of word, input and output energy is calculated in different agricultural ecosystems (Heydar golynejad and Hassanzadeh-Gorttapeh, 2003).

Agricultural ecosystems depend on ecological energy and cultivation energy (Kuchaki, 1994), ecological energy source is sun energy that using for photosynthesis, environmental temperature control, atmosphere currents and creating rain (Hassanzadeh Gorttapeh et al, 2006). Cultivate energy is divisible in two groups biological and industrial. Amount of using energy in agriculture depends on changing degree in natural ecosystem (Kuchaki and Hoseini, 1989). Apprehension distribution energy method is very important in development agricultural design (Hassanzadeh Gorttapeh et al, 2005). Sun is greater ecological energy source . Biological analyzes and energy in agricultural ecosystem necessary to efficient yield (Tripartitie et al, 2001).

Agricultural ecosystems haven't desirable condition. Because at the time of yield harvesting, all mineral elements go out of soil and rest provisions are used to feed domesticated animals, therefore coefficient return of materials is very low.(Hassanzadeh-Gorttapeh et al., 2001.; Kuchaki et al, 1995). In this case, these ecosystems must be are reclaimed by using chemical and organic fertilizers. On the other hand using of chemical materials such as fertilizers, fungicides, herbicides, and …. Make new ecological and economical problems of environmental. These problems particularly in Iran have more importance (Dehganian, 1996 and Vlek et al, 2004). Iran country as one of the developing commercial countries the most of energy is used for agricultural productions for example insecticide, fertilizers and machinery. While human force is main energy source and machine power is used less (Vlek et al, 2004). The increase of industrial technological application in agriculture caused to increase in energy efficiency basically. Because in this condition fewer lands are released rotation, and shortage of nutrients and water is reparable mostly.

Nowadays the use of fossil fuels as energy in agriculture has specific rolls. Agriculture is depending on fossil fuels energy. Energy efficiency is increased with consumption of fossil fuels although; most energy is used in fossil fuels production. Fossil fuels energy increases amount of yields in land unit (Hassanzadeh-Gorttapeh et al, 2001, Kuchaki, 1994; Pimental et al, 1987).

Valadyani et al, (2003) express that amount of addition energy efficiency in using nitrogen depends on kind of previous yield, primary amount of nitrogen in the soil and type of weather.

In this study most of using energy related to nitrogen fertilizer, and machinery respectively. Using of nitrogen with increasing humidity or precipitation is increased.

Punti et al. (1988) in the wheat and sunflower energy efficiency and ecological evaluation comparison showed that in the modern culture available energy from straw is lower than traditional culture.

The main objective of this paper is to analyze the energy efficiencies and economic aspect of the grape in two city of west Azerbaijan province, Iran

MATERIALS and METHODS

The grape (Vitis vinifera) is from Vitaceae family. This plant almost are cultured in total Iran regions, Urmia by existence cold high winter is one of the grape plantation important region in Iran country(Aslany and Hagygat, 1989 and Shahrestany, 1998).

Grape is one of exportable important productions in this province (Aslany et al, 1989 and Shahrestany et al, 1998); on this basis the study conduct during 2006-2007 in Urmia and Sardasht areas of the west Azerbaijan province in the North West of Iran.

In this consideration the energy flow in the agricultural ecosystem of grape was evaluated by five years statistics and information derived from the local's agriculture government organization (preparation of questionnaire raises from 25 farmers of any local). Detail inventory of average different inputs (labor, fertilizer, pesticide, nitrogen, phosphorus, potassium, fungicide, irrigation water) and output (grape yield) was prepared following scrolls, 1994. Various inputs and output data's were converted as output input ratio. So calculated amount of energy efficiency (input and output ratio) (Hassanzadeh- Gorttapeh et al, 2001 and 2005 ; Riller and Upadhyay, 1994).

Energy efficiency = Input energy/ Output energy

Inputs of Urmia area include labor (to dig of under tree, winter and spring pruning, collecting of lops, repair of streamlets, irrigation, moving of chemical fertilizers, moving of manure, fertilization, poisoning, moving, to pluck, collecting, putting box, to degree, wrapping, loading and moving, chemical fertilizers, poisoning (pesticide, fungicide) and irrigation (Table 1). The inputs of Sardasht area include labor (to plough under tree in winter and spring, collecting of lops, moving of chemical fertilizers, fertilization, pruning, to pluck, collecting, putting box, sorting, wrapping, loading and moving), chemical fertilizers (N_2, P_2o_5 and K_2o).

Yield average of Urmia and Sadrasht grape gardens in 2001-2006 agricultural years were 11.900 and 4.700 tons/ha, respectively. The fix price of each kilo grape in Urmia and Sardasht were 24.8 and 13.3 cents (1 $=9000 Rails).

Table 1: Inputs energy in grape cultivation in Urmia and Sardasht areas (Iran).

Input	Urmia			Sardasht		
	Amount/ ha	energy/unit (kcal)	Kcal/ha	Amount/ ha	energy/unit (kcal)	Kcal/ha
Labor	873 hour	500	436500	320hour	500	160000
Nitrogen	180.5 kg	17600	3176800	37.2 kg	17600	654720
P2O5	62.5 kg	3190	199357	15 kg	3190	47850
K2O	250 kg	1600	4000000	-	-	-
Poisoning	13 kg	27170	353210	-	-	-
Irrigation	1600 m3	1157.43	1851888	-	-	-
Total			6417773			862570

Table 2: Grape compounds and energy produce per hectare in Urmia area.

Component	Urmia				
	Component (%)	Energy/ gram(kcal)	Aount / ha (kg)	Product energy (kg/ha)	Input /output (energy)
Hydrocarbon	20	4	2380	9520000	1.48
Protein	3.1	4	368.9	14756000	2.29
Oil	1.9	6	226.1	1356600	0.21
Total				25632600	3.99

Table 3: Grape compounds and energy produce per hectare in Sardasht area.

Component	Sardasht				
	Component (%)	Energy/ gram(kcal)	Amount/ha (kg)	Product energy (kg/ha)	Input/ output (energy)
Hydrocarbon	20	4	940	376000	2.67
Protein	3.1	4	145.7	582800	4.14
Oil	1.9	6	89.3	535800	0.38
Total				10123800	7.19

Table 4: Total costs, net revenue values and income/cost per hectare of grape cultivation (9000 Rails =1$)

	Urmia (1000 Rials)	Sardasht (1000 Rials)
Avrage cost (2001-2006)	1977.94	216.66
Gross income	2961.77	626.66
Net income	983.83	410
Net income /cost	0.5	1.9

Table 5: Input energy rate and cost per hectare in grape garden.

Input energy	Urmia		Sardasht	
	energy use/ ha (%)	cost/ha (%)	energy use/ha (%)	cost /ha (%)
Labor	6.7	26.7	18.5	99
Nitrogen	49.5	0.5	75.9	0.46
P2O5	3.1	0.27	5.5	0.46
K2o	6.2	0.27	-	-
Poisoning	5.5	42.9	-	-
Irrigation	28.8	29.2	-	-
Total	100	100	100	100

RESULT and DISCUSSION

Data showed that energy efficiency (output and input energy ratio) for grape yield in Urmia and Sardasht areas were 3.99 and 11.7 respectively (table 1). It means that for each unit of using energy 3.99 or 11.7 kcal energy is produced. When the amount of energy for each input was calculated, this result showed that, the most consumption of energy in Urmia gardens was related to nitrogen fertilizer (79.5) and irrigation (28.8) respectively. The most consumption of energy in Sardasht gardens was related to nitrogen fertilizer (75.9) and labor (18.5) respectively. Although nitrogen fertilizers have low percentage of total input cost but amount of energy use very much (table 1 and 4). N fertilizer is the most important fertilizer among other fertilizers both in consumption amount in plant and energy making N fertilizer requires a lot of energy. As for making, wrapping and moving, of each kilo N almost 77.5 MJ energy is needed (Vlek et al, 2004).Hassanzadeh-Gorttapeh et al, 2006, showed that in sugar beet culture the most consumption of energy was related to irrigation (31.6%) and machinery (23.8%) respectively. The reason is high requirement to water and the growth period is long time.

In Urmia area the most labor consumption of energy was related to plough under tree, sorting, wrapping, loading and moving, respectively (table 2), but in Sardasht it was related to plough of under tree, picking, collecting, sorting, wrapping, and fertilization respectively (table 3). Because when these are performed number of labor is determinate, so the costs that are used for these inputs are a lot (table 4), also, the number of labors in this case is more than other cases (table 5).

In Sardasht area aren't used of poisoning, potassium fertilizer and irrigation. The reason is Ribes nigrum is Native tree of Sardasht, also is resistant and adapted against undesirable conditions. This tree wildly grows in mountains slope, because in this area a lot of rainfall grape garden aren't irrigated than Using of N fertilizers should be according required amount. As humidity or precipitation increases, using of fertilizers especially N fertilizer are increased. (Rillor and Upadhyay, 1992;

Shahrestany et al, 1998). So, amount of N fertilizer that is used in Urmia garden is more than Sardasht gardens(table 1).

Sardasht gardens energy efficiency is three times as much as Urmia gardens (table 2 and 3). Using the input per hectare grape garden is very low in Sardasht area. If it can be made like this condition for Urmia gardens, energy efficiency will increase.

Although Urmia has high production but because of more fertilizer consumption, its energy efficiency is low also more using of N fertilizer will caused increase the N aggregation damaging in grape fruit. Also using it caused environment contamination (Blamy and Chapman, 1981). Hassanzadeh-Gorttapeh et al, 2005, suggested that amount using energy in potato is a lot The reason is lots of use of using potato seed that healthy seed is adequate and non-uniform dimension seeds and using much human energy.

Consumption of fossil fuels, chemical fertilizers, insecticides and... Induce to release a lot of CO2 in the atmosphere. In the mean while, chemical fertilizer (Specially N fertilizer), fossil fuels, irrigation pumps, and insecticides have the most of CO2 release respectively (Vlek et al, 2004). In Urmia there is high yield but energy efficiency is low (table 2). In Sardasht region there is low yield but energy efficiency is high (table 3), The reason is consumption of lower inputs. Agriculture in this region have performed in low yield and isn't commercial. If using the inputs is desirable, yield will be increased, on the other hand whatever using of energy increases, increasing effect of each input is lessening in yield (Kuchaki et al, 1995; Meimandy Nejad, 1974).

Among costs calculated for each area, these results obtained that net income and total cost ratio in Urmia and Sardasht grape production is 0.5 and 1.9 respectively (table 4), this means that for each Rails of input cost, the farmer benefits 0.5 or 1.9 rails. Whatever this rate is more, net income is increased. So farmers for more grape production and more benefit should use the modern and mechanization methods. Also, the chemical fertilizers should be used exactly (by testing soil).

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Assessment of Spatial Distribution Patterns of Soil Properties in the EAARI-Experimental Station (Erzurum)

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ABSTRACT

Defining spatial distribution patterns of soil properties within a field or watershed is important for site-specific soil and plant management. The objective of this study was to determine spatial distribution patterns of particle size distribution, organic matter, lime content, pH and plant-available P contents of soils in the Experimental Station of the Eastern Anatolia Agricultural Research Institution (EAARI). The research area, about 100 ha, was gridded with 100 m intervals in the north to south and east to west directions, and 68 soils samples were collected from 0-20 cm dept at each intersection. Exponential semivariogram models were fitted for clay, silt and sand contents and soil pH, Gaussion models for lime content and plant-available P, and spherical model for organic matter content. Block kriging analysis was performed to prepare distribution maps. Distribution patterns of soil properties studied showed great similarities with each other, as the patterns of yield.

Key Words: spatial variability, soil properties, EAARI

INTRODUCTION

Although soil properties show continuous changes on earth, the sample mean values for measured soil properties are commonly used to represent soil populations. There is no way to measure a property at every location within a study area. But, many soil properties produce great variations among sample values measured at several points. Therefore, classic statistical methods may not be used safely for characterizing variations in soil properties. It is assumed that samples are independent from each other and the mean value is the best representative of population mean in classical statistics. However it is well known that samples taken close together may produce more related values that those far apart. That means is that sample pairs produce values as a function of distance between them (Oztas, 1995).

Jeostatistical methods are commonly used to define spatial variability and estimations in many properties in different fields. Autocorrelation and kriging analyses are applied to soil science for defining spatial and temporal variability as a function of time and location (Warrick et al., 1986, Kutilek and Nielsen 1994, Reese and Moorhead 1996, Bourgault et al., 1997, Goovaerts 1999, Bocchi et al., 2000, Webster and Oliver 2001).

Jeostatistical methods are applied in two steps. In the first step, the degree of autocorrelation among the measured values of a soil property is defined and in the second step values of the property at unsampled points or areas are estimated using an advanced interpolation technique. Semivariograms and Kriging methods are commonly used for these purposes (Isaaks and Srivastava, 1989).

Within the last decade, jeostaistical methods are intensively used to modeling spatial variability and mapping distribution patterns of soil properties within an area (Yost et al, 1982; Trangmar et al., 1987; Miller et al., 1988; Lark 2002). Oztas and Ardahanlioglu (1998) defined spatial variability of soil texture in a deposited alluvial plain. The researchers reported that spherical model was the best-fit model for characterizing clay, silt and sand contents within the study area and the ranges of influence were 27, 16 and 18 m for the textural fractions, respectively. Mahinakbarzadeh et al. (1991) analyzed spatial variation patterns of soil organic matter throughout transects and indicated that organic matter had small variations as compared to other soil properties. On the other hand Huang et al. (2001) reported that soil total C periodically changes depending on topography other than land use type.

Degree of variation in soil properties are caused by many factors including soil forming factors and processes, land use type and soil management. Alluvial materials are recognized with higher heterogeneity because of origin of sediments deposited by water at different times and amounts (Die et al., 1989). Therefore, characterizing spatial paterns of soil properties formed on alluvial parent material are complex and always gets special interest.

The objective of this study was to determine spatial distribution patterns of particle size distribution, organic matter, lime content, pH and plant-available P contents of soils in the Experimental Station of the Eastern Anatolia Agricultural Research Institution (EAARI), which formed on alluvial parent material.

MATERIAL and METHODS

The study area, the EAARI Experimental Station is located in Pasinler-Erzurum ($39^0$58'723" N - $41^0$37'500" E). The altitude is 1680 m and average slope gradient of the experimental field is less than 1 %. Soils of the study site were formed on alluvial parent material (Anonymous 1998), having slightly alkaline soil reaction, low organic matter, moderate level of plant-available P and clay or clay-loam texture.

The EAARI-Pasinler Experimental Field was gridded with 100 m intervals in the north-south and east-west directions, and soil samples from 0-20 cm top layer were collected at 68 intersection points. Plant pattern of the experimental field is given in Figure 1.

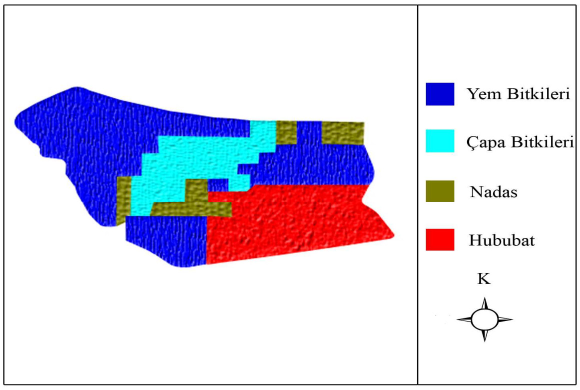

Figure 1. Plant patterns of the experimental field

Texture, pH, organic matter, lime content and plant available P contents of soil samples were determined (Klute, 1986; Page, 1982). Descriptive statisctics (mean, standard deviation, minimum and maximum values, coefficient of variation, skewness and kurtosis) were calculated for each measured soil property.

Semivariogram analysis was performed to describe spatial variation among the measured points. The best fit model was chosen based upon the maximum r^2 and minimum residual sum of squares. Each soil property was estimated for 100 m^2 cells at unsampled locations .

RESULTS and DISCUSSIONS

Descriptive statistics for the measured soil properties were given in Table 1. The highest coefficient of variation (CV = 87 %) was obtained for plant-available P, followed by organic matter and lime content, but the lowest (1.7 %) for soil pH. That means the most confident soil property for the study area is soil pH. Higher CV values may be due to land use-type and soil management strategies within the experimental field.

Table 1. Descriptive statistics of soil properties studied.

Property	Mean	sd	Min.	Max.	Skew.	Kurt.	cv %
Clay, %	40.2	11.2	10.5	59.3	-0.7	2.9	28.0
Silt, %	29.2	5.0	9.8	37.7	-1.0	5.4	17.0
Sand, %	30.6	10.8	7.8	64.4	1.1	4.4	35.5
OM. %	1.8	0.8	0.1	3.9	0.4	3.4	46.1
$CaCO_3$, %	6.3	2.5	1.6	13.8	0.1	2.8	40.4
pH, 1:2.5	7.8	0.1	7.5	8.1	-0.6	2.9	1.7
Ava.-P, ppm	29.1	25.5	0.7	93.1	0.9	2.6	87.3

In order to determine isotropy/anisotropy variation, four different directional semivariograms (N-S, NE-SW, E-W, NE-NW) were performed and they were compared for the best-fit model and model parameters (sill, nugget and range). All soil properties showed isotropic variation, therefore a single isotropic semivariogram was defined (Table 2).

Table 2. Best-fitted isotropic semivariogram models and parameters.

Soil property	Model	Co	Co+C	A_0	r2
Clay	Exponential	0,1	201,1	326	0,99
Silt	Exponential	2,06	20,6	58	0,79
Sand	Exponential	39,1	216,8	618	0,97
Organic matter	Spherical	0,45	0,9	1258	0,98
$CaCO_3$	Gaussian	0.01	8,8	153	0,99
pH	Exponential	0.01	0.02	80	0,91
Available P	Gaussian	318	776	263	0,99

Exponential semivariogram models were fitted for clay, silt and sand contents and soil pH, Gaussion model for lime content and plant-available P, and spherical model for organic matter content (Fig. 2).

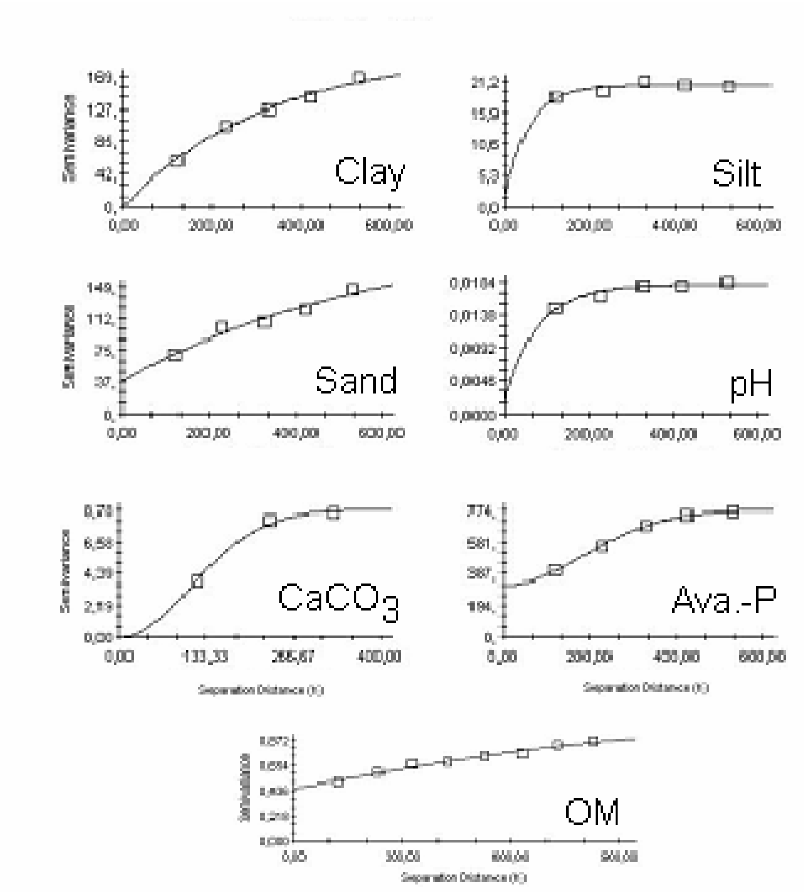

Figure 2. The best-fitted experimental semivariogram models for soil properties studied.

The range of influence, which indicates the maximum distance of spatial dependence between sample pairs, was 326, 58, 618, 1258, 153, 80 and 263 m for clay, silt, sand, organic matter and lime contents, and pH and plant-available P, respectively.

Based upon the best-fit model for each soil property, values were estimated for unsampled locations griding the experimental field with 10x10 m sub-cells using block kriging analysis.

The distribution map of soil clay content indicated that clay content was the lowest at the northern part of the experimental field in where a creek lies through causing partial leaching of clay to deeper soil layers (Fig. 3). The most complex distribution was obtained for silt content (Fig. 4). This situation was thought to be related to silt content of sediment carried in different times and flow characteristics. On the other hand, sand content was highest in the northern part of the study site as expected because of leaching of clay (Fig. 5). Sand content gradually decreased from north to south direction as a function of deposition, flow carry capacity and load.

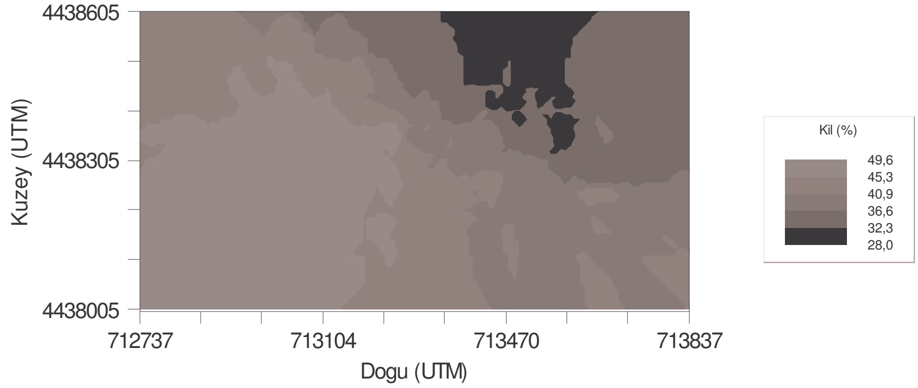

Figure 3. Spatial distribution pattern of clay within the syudy area.

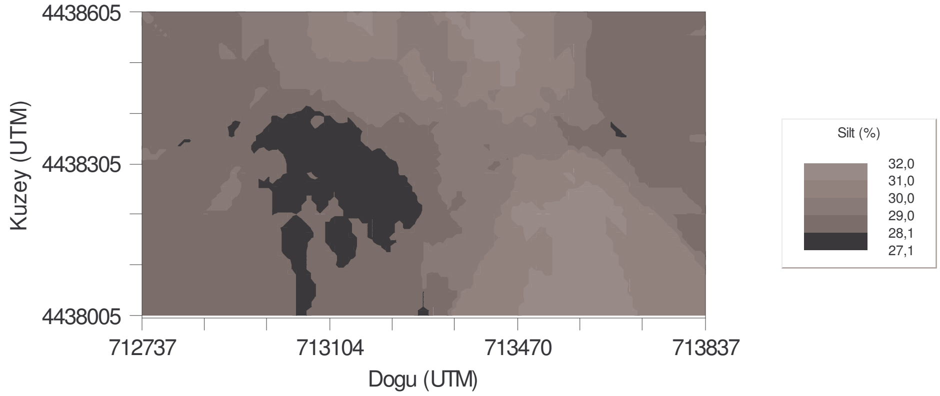

Figure 4. Spatial distribution pattern of silt within the syudy area.

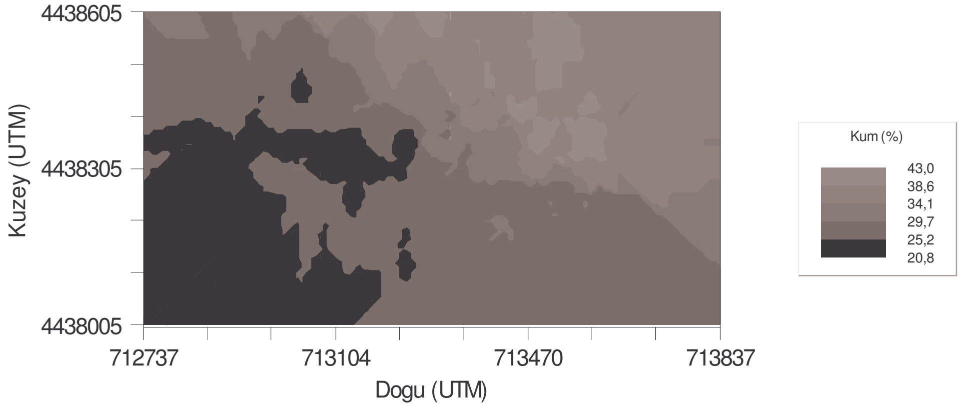

Figure 5. Spatial distribution pattern of sand within the syudy area.

As seen in Figure 6, organic matter content was highest at the southern part of the study area in where cereals was planted for long years, however, it was lowest amount in row-crop planted areas and in the northern part. High organic matter amounts were also obtained in alfa alfo and tall fescue planted areas. Organic matter content decreased in artificial rangeland areas, in where row-crops were planted in previous years. All these results were related to biomass input to soil because of plant type, and higher mineralization rate of organic matter in relatively coarse-textured areas.

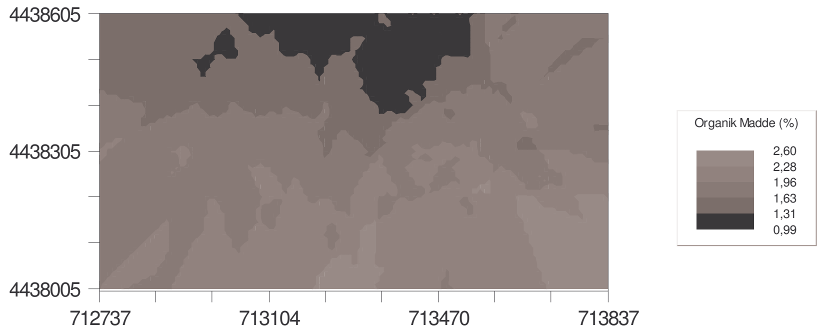

Figure 6. Spatial distribution pattern of organic matter content within the syudy area.

Lime content of soils was the highest in the center part of the experimental field in where row-crops take place (Fig. 7). But, lime content was relatively in lower amounts in cereal and hay production areas and in the lowest amount in the northern part in where a creek lies through.

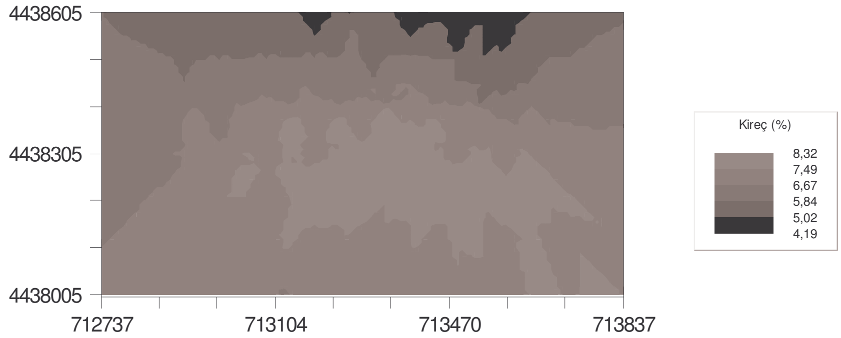

Figure 7. Spatial distribution pattern of lime content within the syudy area.

Although soil reaction has the minimum variation within the study area, small differences were still existed. Soil pH was relatively higher in hay crop production areas as compared with cereal and row-crop planted areas (Fig. 8).

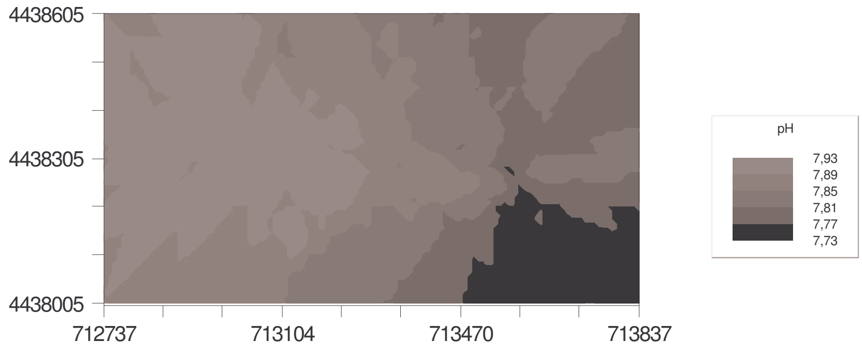

Figure 8. Spatial distribution pattern of pH within the syudy area.

The highest variation was obtained for plant-available P. It was higher in the northern site cereal-planted areas and decreased from north to south, and get the lowest values in creek sites (Fig. 9). This result may be due to P fertilizer application and cattle manure because of grazing animals.

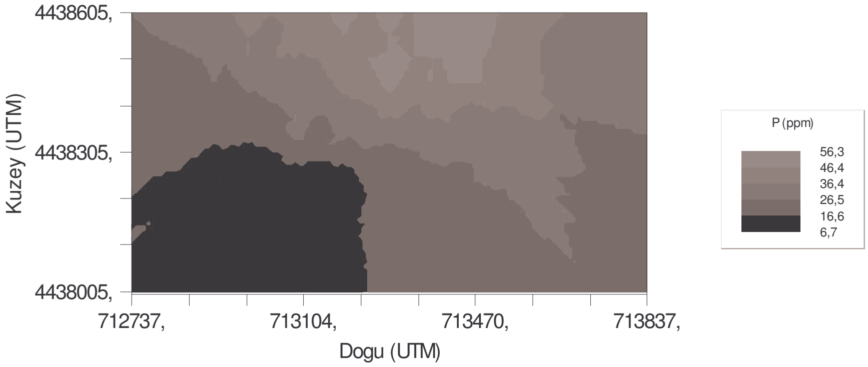

Figure 9. Spatial distribution pattern of plant-available P within the syudy area.

In conclusion, the results of this study clearly indicated that spatial distribution patterns of soil properties are closely related to each other in addition to land use type and plant patterns, even in soils formed on alluvial material.

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Calibration of van Genuchten Unsaturated Hydraulic Conductivity Parameters by Regression Technique

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ABSTRACT

Unsaturated hydraulic conductivity is the mainstay, modulating water and chemical transport in the field. Measurements of parameters take place in the processes are difficult and require time, labor and finance. Thus, correct estimation of these parameters is very important to save valuable sources. The purposes of the study was to estimate van Genuchten unsaturated hydraulic conductivity parameters with RETC-ROSETTA program and calibrating the estimations by regression technique using easily measured soil physical properties, such as components of texture, bulk density and water holding capacity. Total, 168 soil and bulk density samples were collected from 0-30 cm soil depth in an alluvial area located over young river terraces of Yesilırmak near Tokat city. The soil samples were analyzed for clay, silt, sand, and organic matter, and saturated hydraulic conductivities of each sample was measured. Soil water content of each soil sample was determined for -10, -20, -33, -50, -75, -100, -300, -500, -700 and -1000 KPa soil water pressure. van Genuchten's water retention curve parameters, α and **n**, were determined inversely using water retention data with RETC program. In addition to estimation of α and **n** parameters using RETC program, regression technique was used to develop equations to predict α and **n** parameters using basic soil parameters. Performance of regression-model was judged by correlation of estimations with observed values of validation data set.

Keywords: RETC, van Genuchten parameters, water retention curve, unsaturated hydraulic conductivity, estimation, modeling.

INTRODUCTION

Significant events such as runoff, drainage, soil reclamation, and chemical transport are related to unsaturated water transport, and this requires advanced knowledge of water flux under unsaturated conditions and spatial variation of this flux. Especially contaminant transport under unsaturated conditions is affected by soil hydraulic and chemical properties and process in soil (Thomasson and Wierenga, 2003). Numerical expression of water transport is difficult due to the variable moisture conditions through the soil profile. Hence, quantification is vitally important to model hydrological processes in soil system (Harter and Yeh, 1998; Tuli et al., 2001; Tartakovsky et al., 2003). Among soil hydraulic parameters, saturated hydraulic conductivity (Ks), and unsaturated hydraulic conductivity [Kus(θ)] or [Kus(ψ)] are most important ones. Measurement of these parameters requires time and intensive labor, and, is hence expensive. Thus, instead of measurement of soil hydraulic parameters scientist focused on the estimation of hydraulic parameters using routinely measured simple soil parameters such as textural components, bulk density, soil moisture, and saturated hydraulic conductivity (Kosugi et al., 1997; Wagner et al., 1998; Zhuang et al., 2001; Schaap and Leij 2000). Many scientist have tried to relate (θ) to (ψ) and /or (K) to (ψ) by analyzing data of water movement under unsaturated conditions. (Kosugi at al., 1997).

One of the widely used water retention equation developed by van Genuchten (1980) is,

$$Se = \frac{1}{\left[1+(\alpha h)^n\right]^{1-1/n}} = \left[1+(\alpha h)^n\right]^{-m} \tag{1}$$

Here, **h** is soil water pressure (cm); **α** (cm^{-1}), **n and m** are curve shape parameters of water retention. The parameter **α** is described as inverse of the pressure head at the point, where dθ/dh is maximum or as inverse of air entry value. The dimensionless van Genuchten's parameter n refers to the steepness of the water retention curve. **Se** is the effective saturation that relates volumetric water content for any dθ/dh to residual and saturated water content (θ, θr, θs) (cm^3 cm^{-3}) and expressed as,

$$S_e = (\theta - \theta_r)/(\theta_s - \theta_r) \tag{2}$$

Residual water content θ_r represents the soil water content at some large negative value of the soil water pressure head. Combination of Equation (1) and Muallem's (1976) particle size distribution model, results equation (3) to estimate unsaturated hydraulic conductivity (van Genuchten, 1980; Scaap, 1998);

$$K(Se) = Ks\ Se^{\lambda}\left[1-\left(1-Se^{1/m}\right)^m\right]^2 \tag{3}$$

In equation (3), *K(Se)* and *Ks* are unsaturated and saturated hydraulic conductivity, and λ is an empiric constant usually accounted as 0.5 (Muallem, 1976), and m is equal to 1-1/n. By using equation (3), van Genuchten et al., (1991) developed RETC (**RET**ention **C**urve) computer model to estimate unsaturated hydraulic conductivity using hierarchical application of soil parameters.

The aims of this study were to estimate van Genuchten's water retention parameters α and n with easily measured soil physical properties using RETC computer program, and (ii) to calibrate estimated α and n parameters to increase estimation validity.

MATERIAL and METHODS:

Sampling and Soil Analysis

For this study, total 168 soil samples taken from 0-30 cm depth were analyzed for texture components (SSiCl) (%) (Gee and Bauder, 1986), bulk densities (BD) (gr cm^{-3}) (Blake and Hartage, 1986), saturated hydraulic conductivity (K) (cm day^{-1}) (Klute and Dirksen, 1986), and water retention curve (Klute, 1986). For water retention curve, volumetric water content measured for -10, -20, -33, -50, -75, -100, -300, -500, -700, and -1000 KPa soil water pressure. Saturated water content was obtained by curve fitting of retention data. Data of texture class and components (SSiCl) (Sand, Silt and Clay), SSiCl + Bulk desity (SSiClBD), SSiClBD + Field Capacity (SSiClBDFC) were used into ROSETTA subroutine program of RETC hierarchically to estimate van Geuchten water retention parameters (**α** (cm^{-1}) and **n**). In addition to these estimations, van Genuchten's parameters were also obtained experimentally by using water retention data into inverse function of RETC computer program. New regression equations developed to estimate (**α** (cm^{-1}) and **n**) parameters for calibration of RETC estimated **α** and **n** parameters by using inverse function and basic soil parameters.

Statistical Analysis

Input parameters and estimated parameters were analyzed statistically using SPSS v13 program. Accuracy of estimations were evaluated using Corelation Coefficient (R) and Root Mean Squared Error (RMSE), expressed as,

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^{N} (\hat{y}_i - y_i)^2 \right]^{1/2} \quad (4)$$

Where y_i refers the measured value, $\hat{y}_i$ is the predicted value, and N is the total number of observations. Negative and positive values of MR indicate under and over estimation. In addition **α** and **n** parameters, estimated by ROSETTA from basic soil parameters and estimated by inverse function of RETC using measured retention curve data, were regressed.

RESULTS and DISCUSSION

Summary statistics of input parameters (Table 1), and **α** and **n** parameters (Table 2) showed that among the input parameters clay (Cl), and among the **α** and **n** parameters estimated by ROSETTA α-SSiClBDFC and n-SSiCl parameters have the greatest C.V. values.

Table 1. Summary statistics of some soil physical properties used as inputs in ROSETTA to estimate van Genuchten water retention parameters

	Minimum	**Maximum**	**Mean**	**[1]SD**	**[2]C.V. (%)**
[3]BD (gr cm^{-3})	1.13	1.78	1.45	0.13	1.15
[4]FC (%)	21.43	46.98	30.60	4.46	64.99
[5]Ks (cm gün^{-1})	41.60	154.74	93.07	24.03	620.55
Clay(%)	15.16	50.21	33.18	9.25	258.07
Silt (%)	23.44	42.50	31.81	3.63	41.50
Sand (%)	20.00	57.50	35.01	8.22	193.14

[1]: SD, standard deviation, [2]: CV, coefficient of variation, [3]: BD, bulk density, [4]: FC, filed capacity,
[5]: Ks, saturated hydraulic conductivity

Table 2 Summary statistics of α and n parameters estimated by ROSETTA and obtained by inverse function of RETC computer model

	Minimum	**Maximum**	**Mean**	**[1]SD**	**[2]C.V. (%)**
α - [3]SSiCl	8.40E-03	0.02	0.015	2.47E-03	0.04
α - [4]SSiClBD	7.40E-03	0.02	0.01	2.45E-03	0.04
α - [5]SSiClBDFC	3.70E-03	0.03	0.02	4.68E-03	0.13
α - [6]Inverse	6.27E-03	0.04	0.02	5.61E-03	0.20
n- SSiCl	1.27	1.52	1.37	0.06	0.26
n- SSiClBD	1.30	1.58	1.42	0.06	0.22
n- SSiClBDFC	1.25	1.53	1.35	0.05	0.22
n- Inverse	1.17	1.47	1.29	0.06	0.24

[1]: SD, standard deviation, [2]: CV, coefficient of variation, [3]: SSiCl; sand, silt and clay, [4]: SSiClBD; SSiCl+Bulk Density (BD), [5]: SSiClBDFC; SSiClBD+Field capacity (FC), [6]: INVERSE, inverse function

Goodness-of-fit of α and n parameters estimated from basic soil parameters using ROSETTA were evaluated (Table 3). ROSETTA showed better performance to predict **n** parameter than **α** parameter. This is because fitting α parameter to air entry point is difficult than fitting the slope parameter **n** to retention curve.

Table 3. Goodness-of-fit of the ROSETTA program in predicting α and n parameters from basic soil properties

	[1]R	[2]RMSE
α - [3]SSiCl	0.26	0.0055
α - [4]SSiClBD	0.30	0.0056
α - [5]SSiClBDFC	0.39	0.0059
n - SSiCl	0.69	0.0900
n - SSiClBD	0.53	0.1328
n - SSiClBDFC	0.61	0.0770

[1]: correlation coefficient, [2]: RMSE, root mean square error; [3]: SSiCl; sand, silt and clay, [4]: SSiClBD; SSiCl+Bulk Density (BD), [5]: SSiClBDFC; SSiClBD+Field capacity (FC)

Tomasella et al. (2000) stated these poor fits of retention points near saturation (Tomasella et al., 2000). Pachepsky and Rawls (2003) found that there is an important difference between the field and laboratory measured volumetric water contents for coarse, intermediate, and fine textured soils. As a result, poor prediction of the parameters might be due to measurement errors. Increase in the number of input variables such as organic carbon, and water contents at one or two potentials can improve the accuracy of soil hydraulic models (Schaap et al., 1998; Schaap and Leij, 1998; Minasny et al., 1999).

In addition to **α** and **n** parameters of ROSETTA, all input parameters of 100 soil sample are regressed with **α**-inverse and **n**-inverse to obtain best regression model of α and n (Eq. 5 and 6) to calibrate model for the filed studied. These regression models expressed as;

$$\alpha = 0.0086 - 0.00036 * FC + 0.000508 * clay \quad \text{(P<0.001, R2=0.54)} \quad (5)$$

$$n = 1.408 + 0.004 * FC - 0.007 * clay \quad \text{(P<0.001, R2=0.55)} \quad (6)$$

Goodness-of-fit of **α** and **n** parameters obtained using developed regressions were given in Table 4. Compared to ROSETTA subroutine of RETC program estimations, Regression model estimations were better, increasing R for α from 0.39 to 0,736 and for n from 0.69 to 0.831.

Table 4. Goodness-of-fit of **α** and **n** parameters obtained by regressing α-inverse and n-inverse parameters with basic soil properties

	[1]R	[2]RMSE
α	0.736	0.0032
n	0.831	0.0331

[1]: correlation coefficient, [2]: RMSE, root mean square error

The other 68 soil data set were used for validation. Validity of regression model tested using 68 input data used in equation 5 and 6. Estimation results of regression models (α' and n') were correlated to measured data set (α-inverse and n-inverse), and results were given in Table 5. The results showed that R values found for validation data set were greatest as much as were for the regression data set

Table 5. Correlation of α' and n' parameters, obtained using validation data set into regression equations (6) and (7), with α-inverse and n-inverse parameters of validation data set

α'	-0.988**		
α -inverse	-0.703**	0.716**	
n -inverse	0.744**	-0.745**	-0.782**
	n'	α'	**α** -inverse

** Correlation is significant at the 0.001 level.

Minasny et al. (1999) implied that there was no linear relationship between the retention curve parameters and soil properties. That's why using linear regression for prediction of these parameters is not suitable. Further more, α and n curve shape parameters are quite sensitive to variability of soil properties as in this alluvial soil. The low performance of models to estimate **α** and **n** parameters might be due to the wide spatial and temporal variability in physical and hydraulic properties of alluvial soils.

CONCLUSIONS

In this paper, calibration of van Genuchten parameters using ROSETTA computer program and developed by regression analysis was presented. General performance of estimation ROSETTA is low for **α**, and is much better for **n**. Regression model for **α** and **n** developed using soil parameters of FC and clay content increased the estimation performance by increasing R value and decreasing RMSE values. Although prediction errors of ROSETTA are large, the results may be acceptable for most applications to predict soil hydraulic properties especially where hydraulic parameters are not available, and time, labor and money are limited.

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Evaluation of Onion Cultivation Energy Balance in East Azerbaijan Province

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ABSTRACT

One of the estimating methods of agricultural development and production stability in agricultural locations is the use of energy flow method. In this consideration energy flow in agricultural ecosystems of onion in East Azerbaijan was calculated by the use of gathered information and data via questionnaire and statistics of related Province's agricultural Jihad organization and farms. The related data of inputs and outputs were altered to equal amounts of consumer and productive energy and then energy efficiency was calculated. Energy amounts of used factors and input in this type of cultivation was estimated 22307134 kcal/ha and output (production) energy amount of onion yield was 18594060 kcal/ha. Also energy efficiency value (output/input) was 0.833 percent. Data show that most of the consumer energy of onion cultivation of East Azerbaijan province is related to irrigation water use and chemical fertilizers and energy that used in machinery. In such a condition it is suggested that through precise determining of the vegetable's water need, replacing modern irrigation methods in regard to current methods, preventing irregular use of inputs specially nitrogen fertilizers, applying proper managing methods in dry regions and using fertilizer on the base of soil test and production potential by increasing usage of function, energy could be optimum.

Key words: Energy flow , Input , Output and Onion .

INTRODUCTION

Onion belongs to Alliaceae vegetables and genus, *Allium*. The most important kind of this genus is the ordinary onion, *Allium cepa* (Singh, 1990). This plant is Asia's native plant so it has various ecological groups from the shape and colour point in these regions (Blamy and Champman 1981).

Edible onion is most the important vegetable which is used in different ways. One of onion's importance is producing energy (432.42 kcal/ kg) and its effect on health of society regarding its different vitamins and minerals is noteworthy. Onion as a complementary of main food in a diet is very important. There are many various energy inputs that may lead to increase in production rate or keep that energy resulting from production. This energy in animal and vegetable products arises from planting orders. The land under cultivation of onion in east Azerbaijan was 10528.5 hectares in 2005 and yielded 43 ton per hectare. Agricultural lands are ecosystems in which energy enters as a subsidy such as chemical fertilizers, insecticides, herbicides, irrigation worker and machinery (Hassanzadeh et al. 2002). These inputs show that the use of energy input is changeable with a great degree and depends on the rate of nitrogen use and the kind of crops. Agriculture depends strongly on energy especially fossil fuels (Kouchaki and Hosseini 1998). So using of fossil energy in agriculture increases energy production (Hassanzadeh et al 2002). Energy analyses in agricultural ecosystems are necessary in order to create useful and effective production (Singh, 1990). Understanding methods of energy distribution in development and designing of agricultural management is important and the necessity of energy and environmental constant management from the ecological point related to development (Hassanzadeh and Arjmand 2006).

Agricultural ecosystem depends on two quite different energy input that is ecological energy contains solar energy which is used in order to photosynthesis, environmental temperature control, creating atmosphere flows and producing rain. All together the need to energy in agricultural cultivation depends on the rate of changes in its natural ecosystem (Heydar-golinezad and Hassanzadeh, 2003). One of the ways of estimating agricultural development and production stability in agricultural areas is the use of energy flow (Schorl, 1994). Evaluation of energy balance, calculating of energy use, determining and discriminating of kinds and rate of used energy can be received to measure of production stability in an agricultural ecosystem.

Peterson et al.(1990) suggested that irrigation and nitrogen use depends on the kind of former yield and the rate of primary nitrogen in soil. In this research the most efficiency of energy for alternation of corn, wheat and soybean was 6.1 but in planting one of these crops the quantity was 4.7. Regarding their statements energy efficiency can be corrected by having available nitrogen from previous years, crop residual and the history of yield cultivation in order getting economical income and decreasing environmental pressures caused by increasing NO3, Nitrogen leaching, water pollution or the increasing of greenhouse gases in the atmosphere. Pimentel et al (1994), by examining energy efficiency of organic and traditional in corn, wheat and potato, reported that the energy efficiency of organic order of corn and wheat as compared with traditional order 29-70 percent has increased. On the contrary potato energy efficiency in traditional fields are 70-93 percent more than organic order.

Hanson et al. (1999) Reported that the energy efficiency increases in a area by increasing use of nitrogen fertilizer up to 180 kg /hectare. They knew the kind of soil and amount of used fertilizer is an important factor because of increasing output energy. But it should be mention that in agricultural ecosystem coefficient of the nutrient cycle is very low because the important part of mineral elements comes out of ecosystem by harvesting agricultural yield and usually plant residual is used as forage. So fertility of this ecosystem is possible only by using chemical or mineral fertilizers (Pimental et al. 1994). While intensive agricultural procedures and more use of chemicals (such as fertilizers, herbicides, insecticides and other poisons) make some economical, environmental and ecological problems also wearing out of top soil, and sub soil pollution by chemicals, damaging of disorder in the wild life station and undesirable effects on the environment (Hulbergen, 2001). Therefore, pollution is one of the several harmful lateral effects of enormous use of energy in modern civilizations. In this research by using questionnaire, collecting information from onion farmers, statistics and information of Agricultural Jihad organization of east Azarbaijan province, average of onion agriculture energy in east

Azarbijan, examination of suitable solutions and their effect on providing necessary energy of human is shown.

MATERIALS and METHODS

The data is collected through making questionnaire, taking information from onion farmers, 25 area of province in which cultivation of onion is common, and use information of agricultural Jihad organization of east Azarbijan. Then using related formulas and inputs energy amount the average of data is mentioned on the base of kilocalorie per hectare and the input and output energy was defined in (table 1 and 2). Except machinery part and using gasoline quantity, the amount of each cause and using inputs in a hectare is calculated by using existed statistics, information and the questions asked farmers (table 1).

The quantity of fuels of used machinery in a hectare was calculated by formula number 1 (Kouchaki and Hosseini 1998).

1) Power in PTO (output of transferring energy) ×0.06×

73= Fergusson copper tractor fuel (a gallon in an hour)

Tractors used in East Azerbaijan Province are mostly English or Rumanian Fergosen tractors 282. These tractors have 70 horse-powers and the power in PTO is a little less than nominal power of the tractor. Here nominal power is stated 75% (Tripathi, and Sah, 2001), with regard to table 3 the whole working hour of machinery is 41. One gallon is 3.78 liter. So the amount of using fuel was calculated through formulas 2 and 3.

2) fergosen copper tractor 285 fuel =0.06 ×70 ×0.75 ×0.75×3.75=8.7 liter in a hectare (Peterson et al., 1990).

3) 8.7×41hour per hectare =356.7 liter used gasoline in a hectare.

In order to estimate weight of machinery in each hectare about one horse power of machine force is needed so tractors weight is equal to about 90000 kilocalories used energy for kilogram (Kouchaki and Hosseini 1998).

Estimating Onion Seed Energy:

On the average, an onion with 148 g weigh has 2g protein, 14g hydrocarbon and 3g fiber percentage of onion compounds which shows in table 3. Using this data, an input energy with a weight of 3000kg onion to plant for seed production is calculated. In table 1 the kind, the quantity and the percentage of compounds with energy quantity for onion defined. The used quantity of onion to produce seed in east Azarbijan province especially is in cities, Oskoo, Azarbijan. Benab, Malkan and Tabriz are about 300kg on average. According to tables 1 and 3 the energy of each kilogram onion and onion seed is calculated 432.4 and 14511.16 kilocalories respectively (Tripathi and Sah, 2001).

RESULTS and DISCUSSION

The stated results in table 2 shows the energy efficiency and the rate of used energy necessary for producing each unit of protein and hydrocarbon compounds in yield, onion (Peterson et al 1990). The existed results show that the rate of energy efficiency (ratio of output to input) for onion yield is about 0.833 % (table 3). That 0.833% energy unit is produced by using an energy unit. According to table 1-4 the rate of used energy in onion plant is high for extra use water because of farmer's knowledge lack and their expectation when have sting the yield and the soil's sandy and saline quality also using more farmhands and more chemical fertilizers (Marjani, 2001). Therefore, farmers economical, motivation to get more yield and income, their lack of attention to fertilizers commends and their not doing tests of soil analysis to determine the exact fertilizers ratio are the causes that make worse crises. It is showed that 12% of the whole agricultural using energy is used by irrigation (Hulbergen, 2001). In the inside of the farm activities that need direct energy irrigation and fertilizing has the most use of energy (Blamy and Champman, 1981). However the most use of energy belongs to the rate of irrigation 39.90% in the onion farm. Extra irrigation causes an increasing in fertilizing of onion. Irrigation energy contains making equipment, erecting the system and pump and transporting equipment or pipe (Peterson et al., 1990). Developing countries pay remarkable subsidy for commercial energy such as coal, oil, gas, electricity. As water of irrigation the effect of these subsides causes extra use of energy (Pimental, 1994).

Regarding the payment of input subsidies of agricultural Jihad organization the use of chemical fertilizers come to rising more every year as in some onion planting regions 400-1000 kg urine is used. This process makes, lessening soil's organic elements, mineralizing soil, weakening microorganism, running the environment, increasing nitrate in the yield, having undesired effects on the health of the farmer and at last imposing related costs on the farmer and pollution under ground waters. Sand usage in direct cultivation of onion causes change of the soil texture. Increasing of cost production and decreasing of keeping power of water soil (Mosavizadeh and Khodadadi, 2002). Also produced energy is few in each kilogram, onion. Because of more water that is in onion (85%). If the produced energy without considering its content for an adult is 2550 kilocalorie a day , according to table 4 produced onion in each hectare can supply the necessary energy of 7291.8 person and produced potato, wheat, and rice in every hectare can supply the need energy of 12627, 9339 and 4864 person respectively a day(Hassanzadeh and Arjmand 2006). Considering that each person needs 60gr protein daily, yields of onion, will supply the need protein of 27person. Most use of energy respectively is related to irrigation (39.9%), chemical fertilizers (19.79%), machinery (16.53%) and fuel or oil (15.31%). The main reason of low energy efficiency in this research is more use of energy to supply needed water which allows most part of the input energy to itself. One of its reasons is that the rate of rain has been decreasing during the past years and the depth of underground water has decreased in the region. So in practice, irrigation of onion is less than real need of the plant (Mosavizadeh and Khodadai, 2002).

The rate of irrigation water in onion agriculture is main increasing use of energy, despite of an increase function in a land unit, more use of fossil energy and other system of food production decrease efficiency of the use of energy comparing to traditional systems that only depend on the human force or animal. Although traditional systems can not supply food need of population as it grows rapidly stable from the ecological points. Today salinity of soil and irrigation water is between important hindrances especially onion in Iran and east Azerbaijan. According to the existed statistics land measure of saline soil used in the agricultural of the country (4 more than 32 dSm/meter) is more than 7.3 million hectare (Hanson et al., 1999). One of the reasons is low average of onion yield in Asian countries such as Iran especially East Azerbaijan province, comparing to European countries, Central and North America salt and a1kaline effected of soil. Because of low knowledge of onion farmers in using to transplanting instead of direct culturing method (Mosavizadeh and Khodadadi, 2002). So that efficiency of the output energy transformation in plants in natural condition is about 2-3 percent, in agricultural ecosystems is about 9 percent and in unfertile ecosystems is less than 1 percent (Hassanzadeh et al., 2002).

Solution to Increasing Product and Output of Onion Functions in the Province:

Planting suitable kinds of onion variety has worthy part in the average of the yield. each kind of onion is suitable for a particular region and climate of environmental effect on the agricultural plants, it can be used to formulizing fertilizer, because with less input rate, the increasing of the use of mineral fertilizers has a considerable effect on the functions of agricultural plant decrease rapidly (Astaraie, 1999). Using green and compost fertilizer and suitable management of farm in order to minimize the use of chemical fertilizers and their quantity depend on soil quality and rate of irrigation water. Efficiency of using nitrogen fertilizers is increased by suitable management. Economizing in the use of fuel through minimum plugging, transforming method of planting in onion from traditional to modern (Hassanzadeh and Arjmand, 2006) and planting in true time have the highest function in onion (Pimental et al., 1994). Following points should be considered to get maximum function and minimum use of energy:

- Not planting onion in saline soil.
- Not planting onion by direct method: because transplanting is a suitable solution to prevent use of sand to cover seed in direct method of onion cultivation and to increasing the production. Therefore the advantages of planting onion are: low used seed, no use of sand, equal planting intervals, low costs of weeding and scattering, abandoning and low use of poisons, high economical function, increasing productivity, early ripeness of the yield, harvest of the yield on time.
- Exact determining dry regions and substituting modern irrigation methods to other methods.
- Economizing in the use of water through shortening growth period in dry regions.
- Use of fertilizers on the base of soil analysis test and production potential of the region.

Table 1. Rate of energy on the base of kilocalorie to produce onion seed in east Azerbaijan (2005-2006).

Kind of energy	Quantity /ha	Energy/ unit (kcal)	Total energy(kcal/ha)
Machinery	15h	90000	1350000
Fuel	130.5 lit	9583	12505881.5
Human force	328 h	465	152520
Onion seed	300 kg	432.42	1297260
Nitrogen	250 kg	17600	2323200
Phosphorus	100kg	3190	76560
Potassium	50 kg	1600	44000
Herbicide (ronstar)	1.5 lit	99910	149865
Insecticide (dorsban)	3 lit	8610	173820
Irrigation energy	1666.67 kw/h	2004	3340006.68
Total	-----	---	10157813

Economical motivations of farmers to get more yield and income, their lack of attention to fertilizer commends and not doing tests of soil analysis to determine the exact fertilizer ratio are the causes that makes the worse (Astaraie, 1999). At last it can be said that regarding irregular use of chemical fertilizers which in this research used the most energy after irrigation (19.790 %) onion productions through traditional method pollution the air, underground water, environment and other elements in a long period of time. These fertilizers should be used in the best way. Otherwise, it causes high energy efficiency in the farm.

Table 2. Onion compounds with quantities and energy on the basis of kilocalorie

Compounds	(%)	Quantity (kg)	Energy/gram	Energy / kilogram
Protein	10.52	13.5	4	54.06
Hydrocarbon	73.68	94.59	4	378.36
Fiber	20.27	20.27	--	-----
Total	100	------	8	432.42

Table 3. Produced and used energy on the base of kilocalorie to produce onion of east Azerbaijan province during 2005-2006

Kind of used energy	Quantity/ha	Energy/unit (kcal)	Total energy (Kcal/ha)
Machinery	41h	90000	360000
Fuel	356.7 lit	9583	34182568
Human force	1567h	465	728655
Seed	15.5 kg	14511.16	224923
Nitrogen	450 kg	17600	4285600
Amino phosphate	150 kg	3190	114840
Potassium sulphate	200 kg	1600	17600
Herbicide (Nabu-s)	4 Lit	99910	399640
Insecticide (Dorseban)	6 Lit	86910	521460
Fungicide (kapetan)	2 kg	4200	8400
Irrigation water	4440 kw/h	2004	8897760
Total	-------	324761.22	23307134

Table 4. Energy efficiency of onion agriculture in East Azerbaijan Province during agricultural tear of 2005-2006

Onion production (kg/ha)	Produced energy (Kcal)	Input energy (Kcal)	Energy efficiency (input/output)
43000	18594060	22307134	0.833

Table5: Percentage of used energy of all of the causes and inputs in puts in farms of onion production in east Azerbaijan province

Kind of used energy	Percentage from the whole
Machinery	16.53
Fuel	15.31
Human force	3.26
Seed	1.04
Nitrogen	19.20
Amino phosphate	0.51
Potassium sulphate	0.08
Herbicide (Nabu-s)	1.8
Insecticide (Dorseban)	2.33
Fungicide (kapetan)	0.04
Irrigation water	39.9
Total	100

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Some Properties of Saline-Alkaline Soils of Aydin-Söke Plain and Activity of Gypsum as Amelioration Material

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ABSTRACT

The study has been carried out in two different areas; a farmer area in Söke Plain and in experimental station of Adnan Menderes University. The aims of study, are to determine of some physical and chemical properties of the soils and to search of activity of gypsum (CaSO4) used in alkaline soils having high sodium. For this purpose, 50,100 and 150 kg/da gypsum were applied to the experimental soils besides control. These applications were made in autumn after harvest period and before the winter rains. In order to determine affects of gypsum on some physical and chemical properties of the soils such as texture, pH, soluble salt content, lime, EC, organic matter content, boron, aggregate stability, dispersion ratio, suspension and dispersion percent. Disturbed and undisturbed soil samples were taken from 0-10,10-20,20-30, 30-40, 40-60, 60-90 cm depths in May after spring rain and in September when the soils are drier. The obteined data taken from the analyses were evaluated as statistically. The results showed that gypsum doses used as amelioration material are effective to lead Na into soil solution by leaving from soil colloids. However this phenomenon was not found sufficient in the soils of sesecond experimental area. Hence gypsum doses that will be used in soils having high alkalinity should be higher and the soils should be washed with high quality water after gypsum treatment because of unsufficient rains in the area.

Key words: salinity, alkalinity in soil, amelioration, gypsium.

INTRODUCTION

Estimating that the world's popolation will be approximetaly 8 billion in year 2025 there will be a minimum two time increase of nutrition need for human being in the next 50 years (Howel, at all., 2001). Salinity and alkalinity problems reduces soil fertility. Because of that reason the soils for agricultural lands become unuseful conditions. In these study, it is aimed to determine the effects of the amelioration material as gypsum on physical and chemical soil properties of salinity and alkalinity soils in Söke Plain and in Adnan Menderes Universty Resource Practice Farm.

MATERIAL

The Gypsum doses which were applied for the experimental land desing were as fallows: control, 50 kg da-1, 100 kg da-1 and 150 kg da-1. After these applications the soil samples which were taken from different soil depths in time periods were used as material for these study.

METHOD

The different gypsum doses which were applied to an experimental design of 500 m2 follows as: control, 50 kg da-1, 100 kg da-1 and 150 kg da-1 the application were carried out in November. The first soil samples were taken in May and at the same time when the spring rain become less. The disturbed and undisturbed soil samples which were taken in May and at the end of the Spring rain period from different soil depths were 0-10, 10-20, 20-30, 30-40, 40-60 and 60-90 cm.

RESULTS and DISCUSSION

Before applying the different gypsum doses, there were taken from all plots from different soil depths soil samples to make some analyses as ph, EC and Na in order to determining the soil conditions in this area (Table 1.)

Table 1. The analyse results before the gypsum applications.

GYPSUM	I. Test Area				II. Test Area			
	Depth (cm)	pH	EC (dS m^{-1})	Na (ppm)	Depth (cm)	pH	EC (dS m^{-1})	Na (ppm)
50 kg da^{-1}	0-30	8.45	0.38	33	0-30	8.73	3.06	240
	30-60	8.36	0.58	26	30-60	9.72	1.53	280
	60-90	8.33	0.99	31	60-90	9.60	4.14	300
100 kg da^{-1}	0-30	8.43	0.59	29	0-30	8.50	3.07	240
	30-60	8.33	0.71	34	30-60	9.89	1.00	170
	60-90	8.24	1.31	38	60-90	9.71	0.89	180
150 kg da^{-1}	0-30	8.31	0.54	25	0-30	8.88	2.83	320
	30-60	8.38	0.87	29	30-60	9.61	2.30	430
	60-90	8.24	0.77	32	60-90	9.80	1.16	250

According to these results, in the first test area the soils were alkaline and at the second test area the soils showed high alkaline and very high alkaline conditions. According to the EC values, none of the test fields showed a salinity problem. The Na contents showed in the first test area low contents but at the second there was a high content of Na which can lead to alkalinity problems.

The taken soil sample results before applying gypsum showed that gypsum could be a good amelioration material for the second test area. Although there were no problems at the first test area it was thought to apply gypsum to understand how many Na content will take place in soil by moving from the colloid material.

According to the statistical results for both soil sampling periods, at the first test area in the soil surface layer (0-30 cm), the Na, K, Mg and the soil organic matter content changes according to time were statistically significant ($P<0.05$) (table 2).

Table 2. The statistical results at the first test area.

I. Test Area: 0-30 cm depth

DOSES	pH (1:2,5)	EC (dSm^{-1})	Salt (%)	O.M. (%)	$CaCO_3$ (%)	Na^+	K^+	Ca^{++}	Mg^{++} (me 100 g^{-1})	B (ppm)	Dispersion Percentage (%)	Süspansion Percentage (%)	Dispersion Rate (%)	Porosity (%)	Volume Weight (g/cm^{-3})	Aggregate Stability (%)
Control	7.67	1010	0.04	0.71	9.05	0.47	0.66	10.81	6.55	3.17	54.51	30.46	56.11	43.90	1.42	1.05
50 kg da^{-1} Gypsum	7.60	1043	0.03	0.61	6.27	0.46	0.54	8.60	3.67	3.32	37.62	27.53	73.85	42.65	1.49	0.77
100 kg da^{-1} Gypsum	7.82	944	0.03	0.74	6.50	0.48	1.03	9.51	4.50	3.84	43.71	28.53	65.31	31.70	1.65	1.11
150 kg da^{-1} Gypsum	7.78	817	0.03	0.94	7.60	0.37	0.73	9.97	5.59	3.65	54.38	34.34	63.45	35.97	1.54	1.18
Mean	7.72	954	0.03	0.75	7.35	0.45	0.74	9.72	5.08	3.49	47.55	30.22	64.68	38.56	1.52	1.03
LSD dos :	0.12	ns	ns	0.34	0.9	0.13	ns	0.68	0.93	0.37	5.76	7.12	13.93	7.62	0.14	ns
LSD time	ns	ns	ns	0.14	ns	0.10	0.34	ns	0.43		ns	ns	ns			
LSD dos*time	ns	ns	ns	0.28	ns	0.21	ns	ns	0.86		ns	ns	ns			

I. Test Area: 0-90 cm depth

DOSES	pH (1:2,5)	EC (dSm^{-1})	Salt (%)	O.M. (%)	$CaCO_3$ (%)	Na^+	K^+	Ca^{++}	Mg^{++} (me 100 g^{-1})	B (ppm)	Dispersion Percentage (%)	Süspansion Percentage (%)	Dispersion Rate (%)	Porosity (%)	Volume Weight (g/cm^{-3})	Aggregate Stability (%)
Control	7.76	849	0.03	0.68	9.26	0.52	0.50	10.81	6.53	3.23	52.37	29.09	56.24	39.47	1.51	0.98
50 kg da^{-1} Gypsum	7.74	1010	0.03	0.68	5.90	0.69	0.37	9.00	4.31	3.35	40.18	27.31	69.02	39.91	1.50	0.88
100 kg da^{-1} Gypsum	7.86	1094	0.03	0.85	6.54	0.86	0.63	9.85	5.38	3.69	46.25	28.89	62.67	33.68	1.63	1.05
150 kg da^{-1} Gypsum	7.83	677	0.02	0.97	7.16	0.45	0.52	10.11	5.69	3.63	50.07	31.03	62.04	32.51	1.63	1.10
Mean	7.80	907	0.03	0.79	7.22	0.63	0.51	9.94	5.48	3.47	47.22	29.08	62.49	36.39	1.57	1.00
LSD dos :	ns	335.14	0.012	0.21	1.41	0.53	ns	0.78	1.44	0.22	6.47	4.79	10.06	6.32	ns	ns
LSD time	ns	ns	ns	0.10	ns	ns	ns	0.37	ns		ns	ns	4.83			
LSD dos*time	ns	ns	ns	0.21	ns	ns	ns	ns	ns		ns	ns	ns			

The Na, Ca, organic matter content, lime and dispersion rates at 0-30 cm soil depth were found statistically significant in the second test area ($P<0.05$). The gypsum applications have statistically significant influence on Ca, pH, Organic matter content, lime, suspension and porosity (table 3).

Table 3. The statistical results at the second test area.

II. Test Area: 0-30 cm depth

DOSES	pH (1:2,5)	EC (dSm^{-1})	Salt (%)	O.M. (%)	$CaCO_3$ (%)	Na^+	K^+	Ca^{++}	Mg^{++} (me 100 g^{-1})	B (ppm)	Dispersion Percentage (%)	Süspansion Percentage (%)	Dispersion Rate (%)	Porosity (%)	Volume Weight (g/cm^{-3})	Aggregate Stability (%)
Control	7.87	3635	0.12	1.08	13.18	6.41	0.34	9.40	5.53	7.52	60.55	52.70	87.12	47.43	1.37	0.26
50 kg da^{-1} Gypsum	8.20	3452	0.12	0.75	12.19	6.42	0.31	8.77	5.34	8.94	59.54	51.53	86.43	35.00	1.49	0.26
100 kg da^{-1} Gypsum	8.46	2372	0.08	0.59	11.54	5.78	0.30	10.01	5.07	9.09	59.91	53.29	89.00	35.40	1.51	0.17
150 kg da^{-1} Gypsum	8.10	3447	0.12	0.74	11.89	6.71	0.28	9.28	5.90	8.30	60.88	49.92	82.24	46.03	1.38	0.34
Mean	8.16	3226	0.11	0.79	12.20	6.33	0.31	9.37	5.46	8.46	60.22	51.86	86.20	40.97	1.44	0.26
LSD dos :	0.34	ns	ns	0.24	1.42	ns	ns	0.39	ns	ns	ns	7.3	ns	10.39	ns	ns
LSD time	ns	ns	ns	0.23	0.96	1.47	ns	0.87	ns		1.99	ns	ns			
LSD dos*time	ns	169.34	0,05	ns	ns	ns	ns	ns	ns		ns	7.81	12.10			

II. Test Area: 0-90 cm depth

DOSES	pH (1:2,5)	EC (dSm^{-1})	Salt (%)	O.M. (%)	$CaCO_3$ (%)	Na^+	K^+	Ca^{++}	Mg^{++} (me 100 g^{-1})	B (ppm)	Dispersion Percentage (%)	Süspansion Percentage (%)	Dispersion Rate (%)	Porosity (%)	Volume Weight (g/cm^{-3})	Aggregate Stability (%)
Control	8.38	2951	0.10	0.87	15.21	6.54	0.24	9.27	5.11	7.49	60.75	54.76	90.17	47.22	1.38	0.26
50 kg da^{-1} Gypsum	8.50	2691	0.10	0.77	15.31	5.60	0.21	9.02	4.81	6.73	60.32	53.51	88.67	39.47	1.48	0.35
100 kg da^{-1} Gypsum	8.72	1838	0.06	0.52	15.60	4.96	0.20	9.71	4.26	7.27	60.00	52.76	88.04	37.34	1.53	0.22
150 kg da^{-1} Gypsum	8.43	3131	0.11	0.88	13.30	6.71	0.20	9.30	5.20	7.88	59.81	51.63	86.49	46.62	1.35	0.30
Mean	8.51	2653	0.09	0.76	14.85	5.95	0.22	9.32	4.84	7.34	60.22	53.17	88.34	42.66	1.43	0.28
LSD dos :	ns	967.93	0.038	0.37	ns	ns	ns	ns	ns	ns	ns	ns	ns	6.72	0.13	ns
LSD time	ns	ns	ns	0.22	ns	ns	ns	0.68	ns	ns	1.68	ns	6.44			
LSD dos*time	ns	ns	ns	0.31	ns	ns	ns	ns	ns	ns	ns	ns	ns			

The Na content for 0-30 cm soil depth after gypsum application showed in both test fields important statistical results. In Mai, also after the rain period, the Na content was lower than in the summer period when the soil moisture was higher. This situation can be explained as the capillarity in soil which becomes in summer seasons higher rates that in spring while the Na transfers to the surface layer of the soil. The lack of water condition of these soils leads to a precipitation of Ca and Mg ions as carbonates. Because of that reason the Ca and Mg concentrations decrease and the Na content increases relatively (Saglam, M.T., 1997). The low soil content and the higher lime contents in the second test field can also be explained for that reason.

As the soil moisture increases, the soluble Ca replaces with the adsorbed Na so the soluble Na content becomes higher concentrations in soil. This effect is a function of the available water content in soils. Moreover according to the dilution in soil the adsorbed Na content replaces with H ions so the pH value increases. Meanwhile there can be seen an important increase at the soluble CO3 and HCO3 contents (Munsuz et. al., 2001).

RESULTS

As a result, the applied gypsum material for both test fields affects the soil positively by replacing the Na ions from the colloid material to the soil but insufficient for the soil at the second test field. Because of that reason, those soils which have high lime and alkaline content needs higher gypsum doses and the soluble Na content in soils must be removed with an additional good quality of water where the rain is not sufficient.

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In situ Monitoring of Soil Solution Nitrate in Saturated and Unsaturated Sandy Soil

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ABSTRACT

A lack of in-situ instrumentation limits continuous monitoring of soil solution concentration to evaluate environmental (contaminants) and agricultural management (plant nutrients) practices. We developed a prototype soil solution monitoring technique, to measure long-term in-situ nitrate concentration, consisting of an in-situ stainless-steel porous cup, with real time concentration measurements using a UV fiber-optic sensor and Ion Selective Electrode (ISE). The measurement technique does not require soil solution extraction, but is based on in-situ soil solution equilibration by diffusion between the porous cup and the surrounding medium. The technique is presented for nitrate solution with sandy soil using new designed of solution samplers. Analytical solutions are presented to evaluate solute diffusion coefficients, as controlled by a variety of soil water contents. The principles of operation are demonstrated for diffusion a saturated and unsaturated Oso Flaco Sand, illustrating the potential application solution samplers in a soil environment.

INTRODUCTION

In-situ solution samplers are essential tools for water quality assessment in surface water, groundwater, as well as for vadose zone monitoring of agricultural and industrial chemicals, and for ecological monitoring of soil nutrients. There is increasing interest in detailed sampling of soil water solutions for soil ecological purposes, so as to better understand nutrient limitations in natural ecosystems (Simunek and Hopmans, 2008).

Several methodologies have been developed to measure concentrations of inorganic solutes in soils. The soil solution extraction is still the preferred method when a time series of solute concentration is required. However, the soil solution extraction can affect the concentration measurement directly by way of the suction applied (Grossmann and Udluft, 1991). Also, as pointed out by Essert and Hopmans (1998) and Poss et al. (1995), the magnitude of the applied suction will determine the soil pore sizes from which solution will be extracted, thereby affecting the measured soil solution concentration. Although ceramic solution cups are generally accepted as the material of choice for soil solution extraction (Weihermuller et al., 2007), these do have limitations. On the other hand, stainless steel porous cups are strong and durable comparison to ceramic cup with fragile nature, and porous steel materials are available with a wide range of air entry pressures, thus providing for an excellent alternative to ceramic cups.

An alternative approach to monitor soil solution concentration is by applying the passive diffusion technique introduced by Moutonnet et al. (1993), allowing for ionic equilibrium between the solution inside the porous cup and the surrounding soil solution by ionic diffusion. Riga and Charpentier (1998) developed a mathematical method to estimate equilibrium time, and they showed that equilibration times for nitrate diffusion can be weeks, especially for unsaturated soils. After a field evaluation of both the diffusion and vacuum extraction method, Poss et al. (1995) concluded that both sampling devices are suitable for nitrate leaching monitoring, considering that the diffusion method provides for a much more time-integrated measurement.

Rather than by using soil solution extraction (Moutonnet et al.,1993) we present two alternative in-situ methodologies. The fiber optic measurements involved measuring ion levels in the water contained within the sampling cups with ultraviolet (UV) absorption spectroscopy techniques (Jaffe and Orchin, 1962; Knowles and Burgess, 1984). Ultraviolet spectroscopy has been employed for analysis of aqueous nitrate levels for several decades. Ultraviolet absorption spectroscopy has also been used to measure other ionic and nonionic species in water such as bromides and sucrose (Johnson and Coletti, 2002; Roig and Thomas, 2003), but has not been applied to date for in situ soil solution concentration measurements.

The other alternative in-situ methodology is to use ion-selective electrodes by inserting into solution sampler. Despite disadvantages such as electrode fouling, electrode drift, ion interference and frequent calibration requirement, and the need for temperature compensation, the ISE technology provides for a rapid and convenient method for soil nitrate concentrations after extraction of the soil solution (Dahnke, 1971).

The main objective of the study was to test the ionic diffusion method using both the ISE specific electrode and UV fiber optics technology for in-situ measurement of nitrate (NO_3^--N) concentration. We used two types of stainless steel cups with different porosity and permeability values. Moreover, we compared the measured NO_3^--N diffusion concentration inside the SS porous cups with two analytical models. We believe that in concept, the presented technology is an important step towards continuous, long-term deployment and real-time monitoring of NO_3^--N soil solution concentration in situ.

MATERIAL and METHODS

The principal objective of this study was to experimentally test the diffusion equilibration method for nitrate, and to compare results with analytical solutions of diffusion in liquid, saturated and unsaturated sand. For this purpose, we monitored diffusion of nitrate across the porous wall of a stainless steel (SS) cup by way of either an ion-selective electrode (ISE) or by a UV adsorption method using fiber-optic technology in liquid and sandy soil conditions. We tested simple analytical solutions that were fit to the diffusion data, providing for solute diffusion coefficients from solution into the porous SS cup. The experiments were conducted for liquid diffusion across a range of outside reservoir volumes, for two types of stainless steel porous cups of different grade and size, and for a saturated and unsaturated sandy soil.

The simple experimental set up consists of an inside reservoir with radius r_i (L) (excluding the porous wall) consisting of a stainless steel (SS) porous cup containing a known volume of deionized water where $C_i(r, 0) = 0$, and an outside reservoir of inside radius r_o (L), containing a known volume of NO_3^--N solution at predetermined concentration (Fig. 1). We denote the outside radius of the SS cup as r_{iw} (L), to include the thickness of the SS cup wall. At $t = 0$, the stainless steel cup filled with de-ionized water was immersed into the reservoir filled with the NO_3^--N solution. Diffusion experiments were terminated after the cup concentration was about 90 % of the final NO_3^--N equilibration concentration (Riga and Charpentier, 1998).

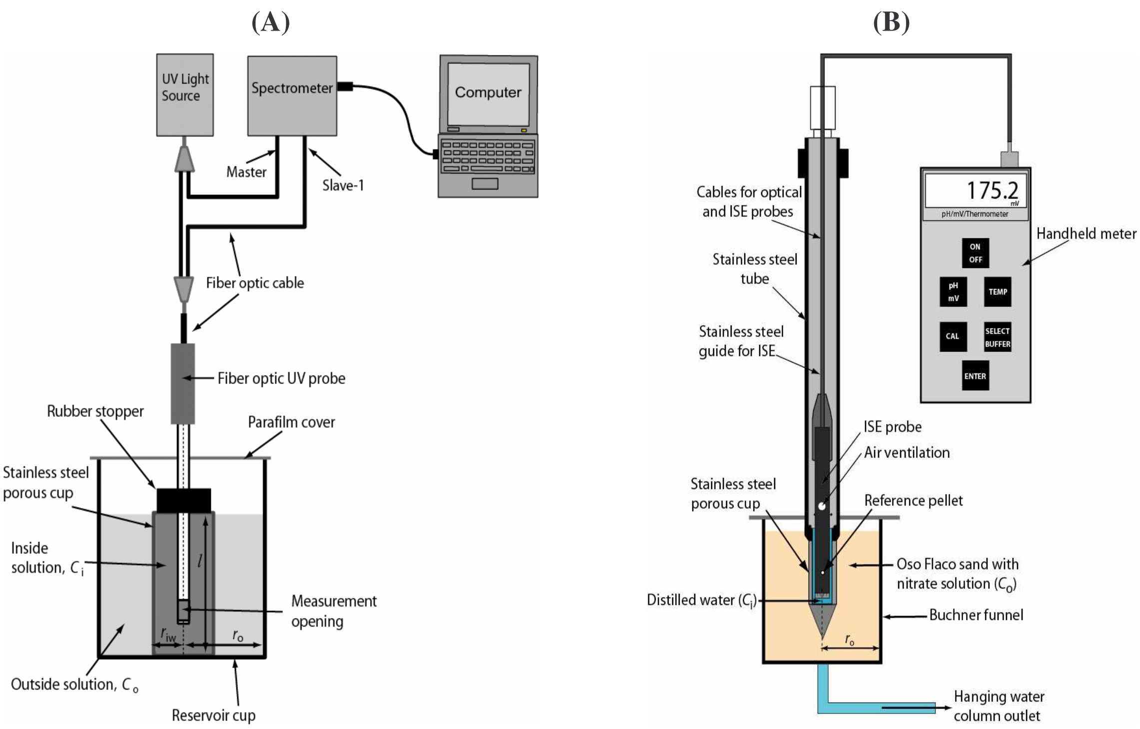

Figure 1. Schematic of the (A) fiber optic system and experimental set up in liquid and (B) ISE system with Oso Flaco Sand.

Electrical Circuit Analog (ECA) Model

A simplified model to predict the time-varying NO_3^--N concentrations can be developed by way of using a simple electric circuit analog (Tuli et al., 2008). We denote the average NO_3^--N concentrations inside and outside the porous cup as C_i (M L^{-3}) and C_o (M L^{-3}), respectively, with corresponding reservoir volumes of V_i (L^3) and V_o (L^3), respectively. For simplicity, the volume of solution within the porous wall material can reasonably be assumed to be negligible.

The NO_3^--N diffusion rate, J ($M\ T^{-1}$), is given by

$$J = \frac{C_o - C_i}{R_c}, \tag{1}$$

where R_c ($T\ L^{-3}$) is the overall resistance to diffusion through the liquids and across the porous cup. In addition, J can be identified as the time-rate-of-change of the average concentrations in the inner and outer reservoirs, or:

$$J = V_i \frac{dC_i}{dt} = -V_o \frac{dC_o}{dt}. \tag{2}$$

We require that mass is conserved, or

$$C_i V_i + C_o V_o = C_{ave} V_t, \tag{3}$$

where $V_t = V_i + V_o$ (L^3) and C_{ave} ($M\ L^{-3}$) is the average NO_3^--N concentration after full equilibration, so that NO_3^--N levels are the same everywhere. By combining Eqs. (1) - (3), an ordinary differential equation can be developed with subjecting to the initial condition $C_i(0) = 0$, leading to $C_{ave} = C_o(0)/(1 + V_i/V_o)$, where $C_i(0)$ and $C_o(0)$ are the NO_3^--N concentrations at the time $t = 0$. The solution of ordinary differential equation can then be written as:

$$\ln\left(1 - \frac{C_i}{C_{ave}}\right) = -at, \tag{4}$$

so that a plot of $\ln(1 - C_i/C_{ave})$ as a function of time, t, yields a straight line with slope $-a$. By measuring the slope of the data, which determines the variable a, the overall resistance to NO_3^--N diffusion can be computed. This overall wall resistance can be related to the effective diffusion coefficient of the porous cup to NO_3^--N by assuming that NO_3^--N diffusion through the wall is quasi-steady, and by solving Laplace's equation in cylindrical coordinates (Incropera et al., 2007).

$$R_c = \frac{\ln(r_{iw} / r_i)}{2\pi l D_E}, \tag{4}$$

where l is inside height of the SS cup. Substituting Eq. (4) into $a = (V_t / R_c\ V_i\ V_o)$, we can compute the effective diffusion coefficient, D_E, using that incorporates both liquid diffusion and diffusion through the porous cup ($L^2\ T^{-1}$). We note that r_{iw} and r_i are the outside and inside radius of the stainless steel porous cup, respectively.

Riga and Charpentier (RC) Model

The analytical solution introduced by Riga and Charpentier (1998) was used assuming a constant spatial diffusion coefficient across the inside and outside reservoir, neglecting the reduced diffusion across the porous cup wall. This analytical solution also assumes radial symmetry across the inside cup and outside reservoir. The initial uniform concentration inside the porous cup (t = 0), C_i, is brought into instantaneous contact with an infinite and homogeneous cylindrical source with concentration C_o ($C_o > C_i$). The general solution is given as Eq. (3.10) in section 3.2 of Crank (1975). With C_i = 0, the concentration change in the center of the cup can be written as (Riga and Charpentier, 1998)

$$\frac{C(0,t)}{C_o} = \exp(-r_{iw}^2/4\,D_E\,t) \qquad (10)$$

where D_E is effective diffusion coefficient ($L^2\ T^{-1}$), r_{iw} is the outside radius of the stainless steel cup (L), and $C(0,t)$ denotes the NO_3^--N concentration ($M\ L^{-3}$) as a function of time in the center of the cup, with $0 \le t \le \infty$. The effective diffusion coefficient of the experimental system with the porous cup was treated as a fitting parameter, to be estimated using the MS Excel solver (Wraith and Or, 1998), minimizing the objective function consisting of the sum of the squared error between independently-measured concentrations and model output.

Nitrate Measurements

Ultraviolet (UV) Absorption Spectroscopy

Ion concentration levels in solution were analyzed using ultraviolet (UV) absorption spectroscopy techniques (Jaffe and Orchin, 1962; Knowles and Burgess, 1984). When light passes through a sample, the light interacts with atoms and molecules in its path by scattering and absorption, with absorption occurring at specific wavelengths corresponding to transitions between different energy levels.

The optical system used in these experiments could measure UV-VIS absorption spectra from about 200 nm to 700 nm. For the NO_3^--N concentration range between 0 and 100 mg L^{-1}, we used absorbance spectra in the wavelength range 235 nm to 240 nm, which provided accurate results while still allowing strong (but not saturated) signals with minimum detectable values of about 1 mg $L^{-1.}$ Figure 2 shows absorbance spectra over this range. By using these spectral data, calibration data were obtained to relate the absorbance at a given wavelength to the amount of NO_3^--N present in the sample. The absorbance measurements of our study were done with a fiber optic T300-RT-UV-VIS transmission (where VIS denotes visible) dip probe that was obtained from Ocean Optics. A Heraeus FiberLight UV source was used to provide light for the measurements and a two-channel Ocean Optics SD-2000 UV-VIS spectrometer was used for spectrum analysis (Figure 1A). The dip probe included a reference fiber to correct for light intensity fluctuations of the light source.

Ion Selective Electrode (ISE) Method

The Ion Selective Electrode (ISE) method is a relatively simple and inexpensive analytical tool for measuring specific ion concentrations in the presence of other ions. An ISE converts the activity of a specific ion dissolved in a solution into an electrical potential to be measured by a handheld millivolt (mV) meter (Figure 1B). The electrical voltage is theoretically dependent on the logarithm of the ionic activity based on the Nernst equation (Durst 1969). For practical use, an ISE should be calibrated using KNO_3 solutions with concentrations between 1 and 100 mg L^{-1} NO_3^--N as standard solutions. The ISE must be calibrated using standard solutions before each measurement.

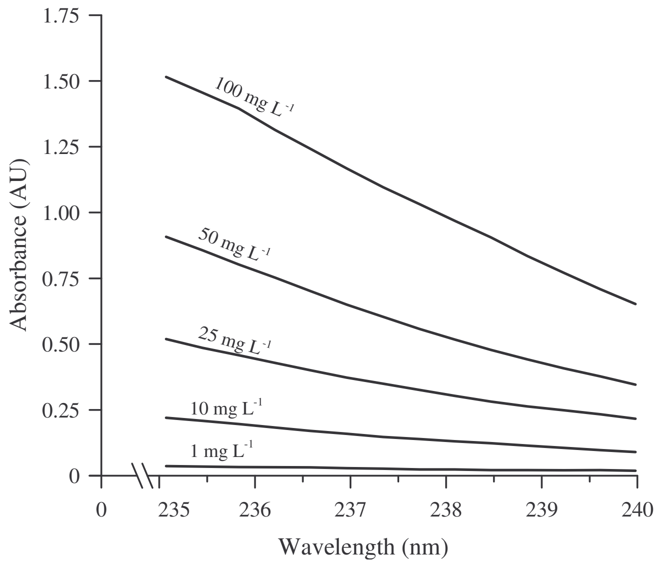

Figure 2. Plot of NO_3^--N absorbance spectra between 235 and 240 nm.

Ion Diffusion in Liquid Phase (experiments 1 through 6)

To investigate the size effect of the reservoir cup to the diffusion of NO^-_3-N solution, experiments 1 through 4 (Table 1) were conducted for a range of ratio values, as defined by outside radius (r_{iw}) of a SS cup divided by radius of outside reservoir (r_o), or $r_{iwo} = r_{iw}/r_o$. This set of experiments was chosen to establish a range of diffusion equilibration times for the same SS Cup I (OD. 0.0191 m, ID. 0.0157m, inside height 0.0376 m) with a porosity of 0.15 m^3 m^{-3}. Values for r_{iwo} were 0.82, 0.50, 0.31, and 0.16. This range in r_{iwo} values was obtained by changing the outside reservoir cup (Fig. 1A) with the desired diameter cup. For each of the 4 experiments, we filled the outside reservoir with a predetermined volume (V_o) of 50 mg L^{-1} NO^-_3-N solution (using KNO_3). Subsequently, the SS cup was filled with distilled water and placed in the center of the outside reservoir at t = 0. For t>0, the concentration changes inside the SS cup as caused by diffusion were monitored continuously using the UV dip probe (Figure 1A). The reservoir was covered with parafilm to prevent evaporation during the diffusion experiments. In experiments 5 and 6, we tested the ISE probe for SS Cup I with r_{iwo} values of 0.58 and 0.77 and using a 25 mg L^{-1} NO^{-}_3-N solution as the outside reservoir concentration.

Ion Diffusion in Saturated and Unsaturated Sand (Experiments 7, 8, and 9)

To compare nitrate (NO^{-}_3-N) concentration measurements in soil between UV and ISE probes, a diffusion experiment was conducted for a saturated sand (experiments 7 and 8 with volumetric water content of 0.434 m^3 m^{-3}) with 100 mg L^{-1} NO^{-}_3-N solution. Oso Flaco fine sand was wet-packed with nitrate (NO^{-}_3-N)

solution in a Buchner funnel to a final bulk density of 1,500 kg m^{-3}, resulting in an outside solution reservoir volume of 756 ml (Table 1). The Buchner funnel was covered to prevent evaporation. For the unsaturated case (experiment 9), 0.37 m suction was applied to the sample though a ceramic barrier at the bottom of the Buchner funnel, resulting in a volumetric water content of 0.347 m^3 m^{-3}. At t=0, Cup II (OD. 0.0193 m, ID. 0.0154 m, inside height 0.0476 m) with a porosity of 0.19 m^3 m^{-3} was filled with 12 ml distilled water and the change in concentration with time was monitored at different time intervals by lowering the ISE into the porous cup at predetermined time intervals (Figure 1B).

Table 1. Parameters for all presented diffusion experiments.

Experiment	Probe	Medium	SS Cup Type	r_{iwo}	r_o	V_i	V_o	V_t	C_o	C_{ave}	R_c	$t_{1/2}$‡	t_{95}‡
					cm	ml			mg L^{-1}		s ml^{-1}	h	h
1	UV	Liquid	Cup I	0.16	6.03	5.5	363.5	369.0	50	49.3	28984.2	30.2	131.1
2	UV	Liquid	Cup I	0.31	3.03	5.9	100.5	106.4	50	47.2	21513.7	23.1	100.4
3	UV	Liquid	Cup I	0.49	1.93	5.1	29.7	34.8	50	42.7	21095.3	17.7	76.2
4	UV	Liquid	Cup I	0.82	1.17	5.2	5.2	10.4	50	24.9	23324.5	11.7	50.1
5	ISE	Liquid	Cup I	0.58	1.64	4.5	21.6	26.1	25	20.7	11399.8	8.2	35.6
6	ISE	Liquid	Cup I	0.77	1.24	7.3	7.7	15.0	25	12.8	10452.3	7.5	32.6
7	ISE†	Sand	Cup II	0.12	7.80	11.9	755.6	767.5	100	98.4	11535.8	26.0	112.6
8	UV†	Sand	Cup II	0.12	7.80	11.9	755.6	767.5	100	98.4	11923.8	26.9	116.4
9	ISE	Sand	Cup II	0.12	7.80	11.9	604.1	616.0	100	98.1	36666.0	82.4	356.1

† Both probes were used in the same experiment; ‡ Time for concentration at 50 and 95 % level of the final concentration

RESULTS and DISCUSSION

Diffusion in Liquid Phase by ISE and UV Spectroscopy

In a set of experiments 1 through 4, we tested the diffusion equilibration method using both the RC (Riga and Charpentier, 1998) and ECA (Electrical Circuit Analog) model, and estimated the effective diffusion coefficient for nitrate (NO^{-}_3-N) in water solution using 4 sizes of outside reservoirs with radii, r_o, varying from 6.03 to 1.17 cm, with the same SS cup with inside (r_i) radius of 0.79 cm and wall thickness of 0.17 cm. Thus, as r_o is smaller, the r_{iwo} ratio increases from 0.16 to 0.82 (fifth column of Table 1). The diffusion coefficients were estimated for each r_{iwo} value for both analytical solutions, using the parameters listed in Table 1. The results for the time-change in concentration in the SS cup are presented in Fig. 3 for each of the 4 ratios. As r_{iwo} decreases, both the average equilibration concentration, C_{ave}, and the equilibration time will increase, because of the corresponding increase in the outside reservoir size.

To confirm such conclusions, we calculated the half-life ($t_{1/2}$), and time to 95 % of the final equilibration concentration (t_{95}) for all diffusion experiments in Table 1. The half-life is independent of the concentration gradient and provides for an objective time constant of the diffusion process. As is intuitively clear, the presented $t_{1/2}$-values increase with decreasing r_{iwo} values, or as the outside reservoir is larger in diameter. The RC model provides for a point solution (r = 0) in the center of the SS cup, whereas the ECA solution focuses on average liquid concentration. However, we should realize that the sensor tip of both the ISE and UV probe are of finite sizes (O.D. 1.23 cm for ISE and O.D. 0.635 cm for UV probe), so that the measurements are likely a better approximation to the ECA model, as the measurement volumes of both probes are relatively large, thereby violating the point solution of the RC model.

Table 2. Estimated D_E values and their goodness of model fit.

Experiment	Probe	Medium	r_{iwo}	ECA Model			RC Model		
				D_E, cm²/s	R^2	SE, mg L^{-1}	D_E, cm²/s	R^2	SE, mg L^{-1}
1	UV	Liquid	0.16	0.026 x 10^{-5}	0.99	1.49	0.286 x 10^{-5}	0.99	2.15
2	UV	Liquid	0.31	0.034 x 10^{-5}	0.99	0.97	0.370 x 10^{-5}	0.98	2.19
3	UV	Liquid	0.49	0.039 x 10^{-5}	1.00	0.49	0.462 x 10^{-5}	0.95	2.61
4	UV	Liquid	0.82	0.031 x 10^{-5}	0.99	0.89	0.281 x 10^{-5}	0.90	2.58
5	ISE	Liquid	0.58	0.070 x 10^{-5}	0.98	0.79	0.860 x 10^{-5}	0.97	0.97
6	ISE	Liquid	0.77	0.076 x 10^{-5}	0.96	0.77	0.469 x 10^{-5}	0.67	2.50
7	ISE†	Sand	0.12	0.063 x 10^{-5}	1.00	1.80	0.421 x 10^{-5}	0.97	5.87
8	UV†	Sand	0.12	0.061 x 10^{-5}	1.00	3.22	0.371 x 10^{-5}	0.96	5.64
9	ISE	Sand	0.12	0.020 x 10^{-5}	0.99	1.12	0.150 x 10^{-5}	0.87	4.01

† Both probes were used in the same experiment

Overall, by visual inspection, the ECA model fits the measured concentrations better than the RC model, especially at later times. As expected, the ECA solutions and the experimental data should approach C_{ave} at long times, simply from the principle of mass balance, whereas the RC solution will approach to C_o. Therefore, one would expect that the D_E values for the ECA model are more representative than those estimated using the RC model. However, both models incorporate the increasing cup resistance to diffusion, thereby reducing D_E, relative to that of the diffusion coefficient of nitrate (NO^-_3-N) in water, D_o, only. We note that D_o for nitrate is 1.902 x 10^{-5} cm^2 s^{-1} (Vanysek, 2008), whereas D_E values vary from 0.026- 0.039 x 10^{-5} cm^2 s^{-1} (ECA model) and 0.28- 0.46 x 10^{-5} cm^2 s^{-1} (RC model), respectively. The effective diffusion coefficients values, estimated from the ECA and RC model are presented in the fifth and eighth columns of Table 2. The values of diffusion coefficients from both models are about one order-of-magnitude different. Also, the standard error of the predictions (SE) were consistently lower for the ECA model predictions than for the RC model, indicating that the ECA model produces better fitting results. Both diffusion models are affected by the size of the outside reservoir, as quantified by r_{iwo} (Table 2). Regarding the ECA-model, we expect that the resistance to diffusion (R_c) will increase with lower r_{iwo} values (higher r_o), leading to lower values of D_E. In a subsequent set of experiments 5 and 6, we evaluated diffusion using the ISE electrode (Tables 1 and 2). Estimated D_E values were about 2 to 3 times larger as compared to the UV measurements. We concluded that various factors can explain this difference. First, diffusion by the fiber optics method is expected to be smaller, because of the partial shielding of the sensor tip, which can account for about 30 % of the difference. This partial shielding will inhibit diffusion of nitrate ions to the sensor element, thereby decreasing the estimated diffusion coefficient. Moreover, as the sensor diameter of the ISE is about twice as large as that of the UV, one would expect higher and more accurate diffusion coefficient values, as measured with the ISE sensor, because it provides better measurement of the average concentration of the SS cup.

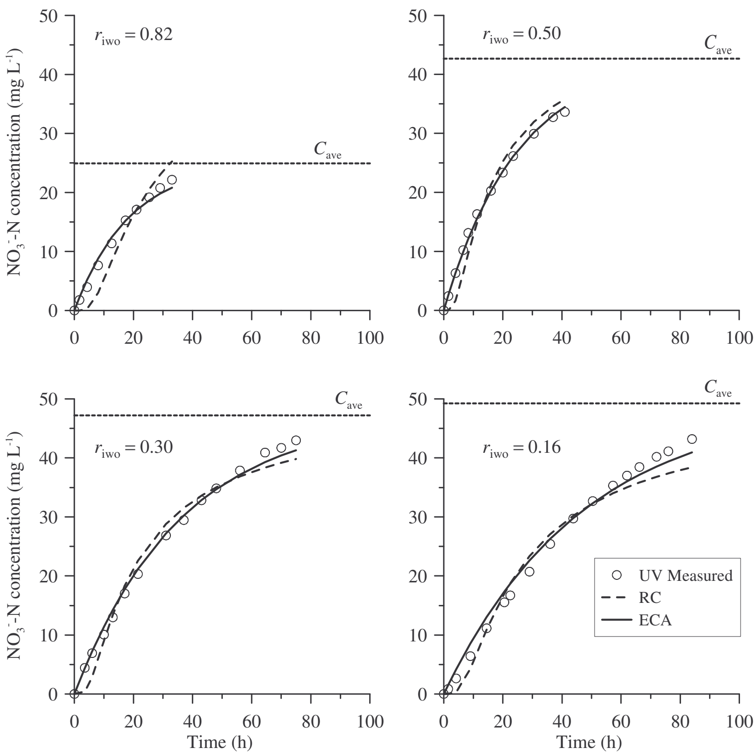

Figure 3. Model fitting of RC and ECA models to nitrate concentration data for different r_{iwo} values (Experiments 1 through 4).

Diffusion in Saturated and Unsaturated Soil by ISE and UV Spectroscopy

Using SS Cup type II and a soil solution concentration of 100 mg L^{-1} NO_3^-N solution, both the UV and ISE probe were compared in experiments 7 and 8, to determine nitrate (NO^-_3-N) diffusion for the saturated Oso Flaco sand (Fig. 6). At approximately equal times, both probes were inserted sequentially into the SS cup one after the other for solution nitrate (NO^-_3-N) measurements. Both the RC and ECA model were fitted to the experimental data for ISE (Fig. 4A) and UV method (Fig. 4B). Both probes produced similar results of concentration changes as a function of time. This can be expected since both probes were mixing the cup contents when they were inserted and removed. At unsaturated conditions (experiment 9), the ECA model was produced better fitting results than the RC model (Fig 4C).

Fitting results (Table 2) of the ECA model were excellent for saturated sand (R^2 = 1.0 and SE = 1.80 and 3.22) for both probes and unsaturated sand ((R^2 = 0.99 and SE = 1.12), whereas the RC model underestimated the measured data at early times and overestimated at later times (Fig 4). The half-life time, $t_{1/2}$, and calculated time required for t_{95} were quite similar for both probes (Table 2). The half-life time at unsaturated condition is much longer than saturated sand indicating proportional increase in equilibration time for unsaturated soils, as ion diffusions in partially-saturated soils are controlled by the degree of saturation and the pore water tortuosity (Tuli et al., 2004). The estimated diffusion coefficient values as determined by ISE and UV measurements were nearly identical, with slightly lower values using the RC model. Intuitively, one would expect the diffusion coefficient of nitrate in the saturated sand to be lower than for the liquid solution. However, the fitting results produced equal or larger D_E values for the sand diffusion experiments. We provide two reasons. First, it is very likely that the porous steel only is controlling nitrate diffusion into the SS cup, as its porosity is much smaller than for the sandy soil (Table 1). Second, the porosity of SS cup II is higher than of cup I (0.15 versus 0.19 cm^3 cm^{-3}). As the diffusion expressions (Jury et al., 1991) predict, diffusion is proportional to porosity, thus partly explaining the higher diffusion coefficient and lower diffusion resistance (Table 1) values for SS Cup II. As before, the slightly lower D_E values as determined with the UV method are likely caused by the partial blocking of the sensor tip. The estimated diffusion coefficient of unsaturated sand was much lower than saturated sand due to the increasing diffusion resistance (Table 1) and tortuosity of for the diffusion (Tuli et al., 2004).

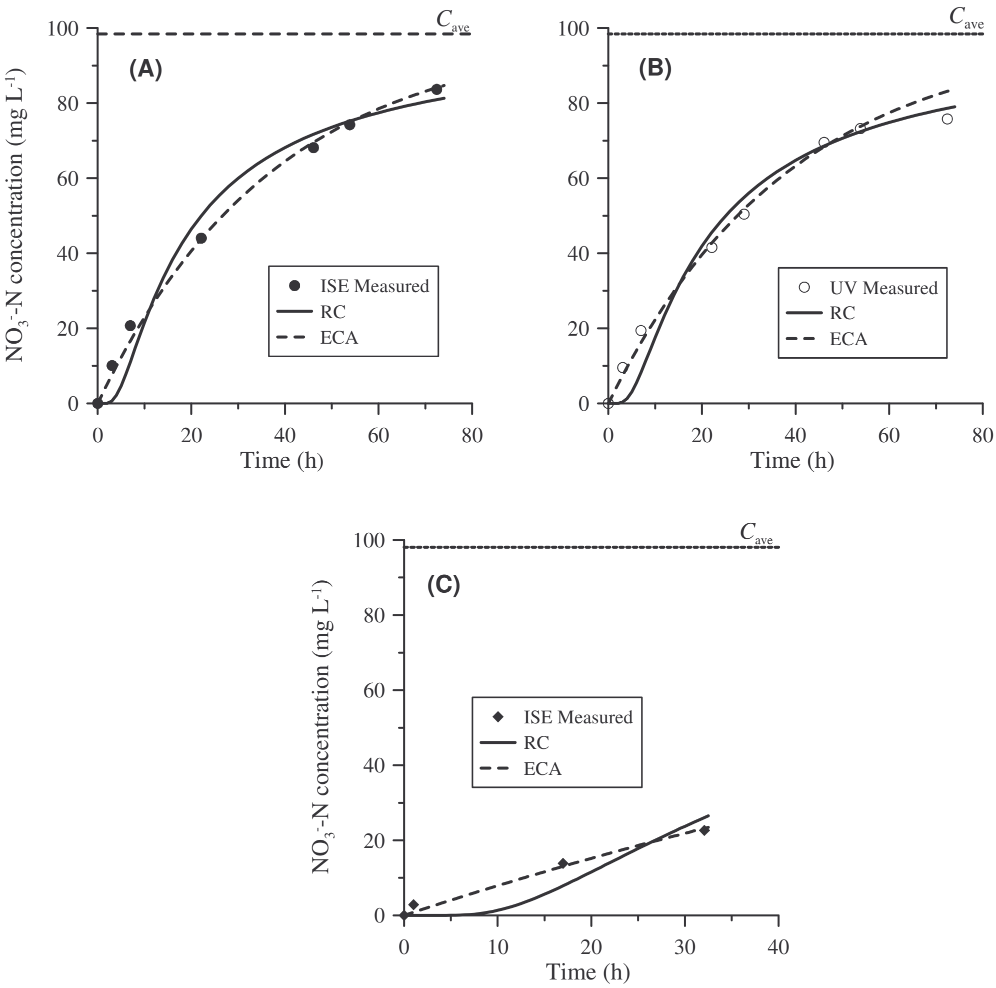

Figure 4. Fitting of RC and ECA models to nitrate diffusion as measured (A) ISE, (B) UV probes (Experiments 7 and 8 at saturation) and (C) ISE (Experiment 9 at unsaturated conditions).

CONCLUSIONS

We propose that continuous long-term deployment and real-time monitoring of the soil solution can be accomplished with both UV fiber optic technology and ion specific electrode measurements. The results for solution nitrate showed that the UV and ISE probes produced similar successful results for Oso Flaco sand. To evaluate the concept of the diffusion equilibration method, the effective diffusion coefficient of nitrate was determined by fitting experimental diffusion data to two analytical model solutions. Both the Electrical Circuit Analog (ECA) and the Riga and Charpentier (1998) (RC) model generally fitted the experimental data, but resulted in nitrate diffusion coefficients that were about one order of magnitude different between the two theoretical diffusion models. We concluded, however, that the performance of the ECA model was significantly better than the RC model. The calculations showed that increasing the outside cup radius significantly increased the half-life time and overall resistance to molecular diffusion, thereby lowering the values of the fitted nitrate diffusion coefficient. In concept, we showed that the application of UV technology can be used for real-time monitoring of nitrate (NO^{-}_3-N) concentration in soil solution.

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Analyzing the Soil Texture Effect on Promoting Water Holding Capacity by Polyacrylamide

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ABSTRACT

Polyacrylamide (PAM) has been widely used to improve soil water holding capacity and control infiltration rate of the soils. However, limited studies have been conducted on the interactions between soil water holding capacity and PAM rates in different soil textures. This study targeted to analyze the relations between soil texture and water holding capacity as a response of increasing PAM applications rate. PAM rates of 0.03, 0.1, 0.13, 0.16, 0.23, 0.33 and 0.67% by weight were applied to clay loam, clay and sandy loam soils. Water holding capacity (θ) at field capacity ($\theta_{0.01\ MPa}$ for sandy loam and $\theta_{0.033MPa}$ for clay loam and clay) and wilting point ($\theta_{1.50\ MPa}$) were measured with a pressure plate apparatus. The values of water holding capacity were regressed as a function of PAM rate, and the slope and intercepts of regression lines for clay loam, clay and sandy loam soils were compared to decide the homogeneity of these functions. Increasing PAM rate significantly increased the water holding capacity in all three soils ($P<0.05$). The regression lines obtained for sandy loam, clay loam, and clay were all significantly different from one to another, revealing that soil texture has a significant effect on the function of PAM in promoting water holding capacity in these soils. Therefore, we concluded that soil texture should be considered in optimizing the results from PAM applications.

Key Words: PAM, water holding capacity, soil texture, field capacity, wilting point.

INTRODUCTION

Many researcher have used Polyacrylamide (PAM) as a soil conditioner since 1950s (Ajwa and Trout, 2006). It has been long known that Polyacrylamide (PAM) could develop aggregates and soil structure, reduce crust hardness, disrupt massive structures, increase infiltration rate and as a result prevent the erosion (Ben-Hur and Letey, 1989; Ben-Hur et al, 1990; Bjorneberg et al., 2003; Ajwa and Trout, 2006).

In general, studies involving PAM have been carried out to control irrigation-induced soil erosion on clay loam and silt loam soils with low aggregate stability (Ajwa and Trout, 2006). In soil surface layers with low infiltration rate due to high density, high strength, fine pores, and low saturated hydraulic conductivity, addition of Pam could be effective in increasing infiltration rate, hydraulic conductivity, and porosity by improving or maintaining aggregates stability (Ben-Hur et al., 1990). McElhiney and Osterli (1996) reported that when PAM applied to fine-textured soil in San Joaquin Valley, infiltration rate increased due to improved development of more stable aggregates.

Conversely, addition of PAM to furrow irrigation water applied to sandy loam soils with low infiltration due to surface seal formation in the San Joaquin Valley did not show any increase in infiltration rate (Trout and Ajwa, 2001). Polyacrylamide (PAM) was also used to improve plant growth for enhancing seedling emergence, reducing crust hardness, and increasing soil physical properties (Cook and Nelson 1986, Helalia and Letey, 1989, Aly and Letey, 1990). Busscher et al., (2007) used PAM and organic matter as amendments to improve physical properties of loamy sand soils of E and Ap horizons which contain cemented subsurface hard layers that restrict root development and yield even if soil water content is at field capacity in coastal plains of South Eastern USA.

Polyacrylamide (PAM) was also used to improve plant growth by increasing water holding content of soil and by preventing nutrients loss through leaching. Polyacrylamide is an acrylate polymer (-[$CH_2CHCONH_2$]-[CH2CHCOOK]-) formed from acrylamide subunits that is readily cross-linked. When water touches this cross-linked chain, it passes into the molecule by osmosis and rapidly inside the polymer net. With this property, it is highly water-absorbent, and forms a soft gel (Anonymous, 2008a).

PAM, used for agricultural purposes, has been marketed by some private companies in Turkey (Anonymous, 2008b; Anonymous, 2008c). PAM can hold water 400 times of its own volume. When applied in correct doses and conditions, it can conserve water up to 70% by holding water that would normally be lost by drainage and evaporation. This is especially important, considering the fact that our water reserves are limited. In addition, PAM may save 15-30% on fertilizer by absorbing plant nutrients and by preventing nutrients loss with leaching (Anonymous, 2008b; Anonymous, 2008c).
Pam rates applied to soil may need to be adjusted based on soil properties, slope, and type of erosion targeted (USDA-NRCS, 2001). Older Pam formulation required hundreds of kilograms of PAM per hectare. However, PAM with newer longer-chain polymers is more effective even in lower rates (Wallace and Wallace, 1986). There are studies available on PAM rates to be applied in irrigation water toward prevention of erosion by improving infiltration. Many researchers found that application of 20 kg ha^{-1} PAM prior to sprinkler irrigation increased infiltration rates and reduced runoff and erosion (Shainberg et al., 1990; Smith et al., 1990 and Stern et al., 1992). According to Aase et al. (1998), PAM, as low as 2 kg ha^{-1}, might be adequate to effectively reduce runoff. El-Morsy et al. (1991) found that 10 mg l^{-1} concentration of a cationic soluble polymer significantly increased the infiltration rate in sprinkler irrigation under laboratory conditions.
Soil texture must be taken into consideration in calculation of PAM rates to be applied to soil in order to improve water use efficiency. However, limited studies have been conducted on the interactions between soil water holding capacity and PAM rates in different soil textures. This study targeted to analyze the relations between soil texture and water holding capacity as a response to increasing PAM applications rate.

MATERIALS and METHODS

Soil Analysis

Soils used in this study were identified, based on their texture; as 1) clay loam, 2) clay, and 3) sandy loam. Soils were collected from topsoil (0-30 cm) in Kazova region of Tokat in Turkey. Soils were air dried and sieved through a 2-mm sieve. Particle-size distribution of the soils was measured with a Bouyocous hydrometer in laboratory (Gee and Bouder, 1986) (Table 1).

Table 1. Particle-size distribution of the soils used with PAM

Soil ID	Particle size			Texture class
	%clay	% silt	%sand	
1	38.40	32.50	29.10	clay loam
2	53.40	18.75	27.85	clay
3	16.80	22.50	60.70	sandy loam

Dry granular PAM in rates of 0.03, 0.1, 0.13, 0.16, 0.23, 0.33 and 0.67% by weight were mixed with soils. It was not possible to apply PAM in higher doses because it roughens the soil samples and disrupts the soil structure in a degree that hinders soil analysis. The experiment was conducted with three replicates. Soil with no PAM was used as a control for each texture type. Water content of all treatments at field capacity ($\theta_{0.01MPa}$ for sandy loam and $\theta_{0.033\ MPa}$ for clay loam and clay) and at wilting point ($\theta_{1.50\ MPa}$) were measured with a pressure plate apparatus (Klute, 1986). Then, plant available water content (θ_{PAW}) was calculated, subtracting $\theta_{1.50\ MPa}$ from $\theta_{0.01Mpa}$ and/or $\theta_{0.033\ MPa}$ .The bulk density (ρ_b) was measured by core methods (Blake and Hartge, 1986). The total porosity (f) was calculated by following equation;

$$f = 1 - \frac{\rho_b}{\rho_s}$$

Where, ρ_b is bulk density (g cm$^{-3)}$ and ρ_s is the particle density, which was simply assumed as 2.65 g cm^{-3}.

RESULT and DISCUSSIONS

According to the results of laboratory analysis, bulk density of loamy and sandy soils reduced with PAM addition compared to the control while there was a small increase in bulk density of clayey soil. Conversely, porosity increased with increasing PAM rates for clay loam and sandy soils. However, macro pore size increased in clay soil while it decreased in clay loam and sandy loam soils (Table 2).

Table 2. Analysis results of clay loam (1), clay (2), and sandy loam (3) soils

Soil property	Soil ID	PAM Rates % (by weight)							
		0.00	0.03	0.10	0.13	0.17	0.23	0.33	0.67
ρ_b (g/cm^3)	1	1.48	1.48	1.46	1.47	1.45	1.44	1.40	1.41
	2	1.39	1.38	1.39	1.39	1.38	1.39	1.41	1.42
	3	1.50	1.49	1.49	1.48	1.47	1.48	1.46	1.39
f	1	0.44	0.44	0.45	0.44	0.45	0.45	0.47	0.47
	2	0.48	0.48	0.48	0.47	0.48	0.47	0.47	0.46
	3	0.44	0.44	0.44	0.44	0.44	0.44	0.45	0.48
Macro	1	9.17	7.54	5.65	5.67	5.18	5.67	6.90	1.11
pore size	2	-6.99	-6.88	-7.72	-7.74	-7.20	-9.34	-10.93	-16.17
(%)	3	16.77	16.03	14.77	13.58	12.61	8.84	9.37	6.01

ρ_b: bulk density f: porosity

The effect of increasing PAM rates on water retention of soils were shown in Fig. 1 through 3. Volumetric water content at field capacity increased linearly with increasing PAM rates in all soil texture types. The greatest increase in water content was in soil 3 (55%) at 0.67% (by weight) PAM rate compared with its control. Application of 0.67% of PAM resulted in only 15% increase in water content at the field capacity in the Soil 2. This smaller increase may be attributed to increase in macro pore size by aggregation of clay particles by granular PAM. Sivapalan (2001) reported that, in sandy soil, amount of water retained at 0.01 MPa pressure increased 23% and 95% with addition of 0.03 an 0.07 %PAM, respectively, resulting in reduction in deep percolation. At 1.5 MPa pressure more water was retained by soil due to the presence of PAM. However, no significant increase in the amount of water released from the soil was observed. According to the results of pot experiments, soybean plants in soils treated with PAM at rate of 0.07% showed better growth compared to those in control soils that suffered from moisture stress due to insufficient available water content (Sivapalan, 2001). Therefore, the researcher concluded that the difference between the soil moisture content at 0.01and 1.5 MPa is not representative of the available water content for soybean plants.

Greatest increase in volumetric water content at wilting point occurred in sandy soils (55%) treated with 0.67% by weight PAM. On the other hand, with the same PAM treatment, volumetric water content of loamy and clay soils decreased (-11% and -16%, respectively).

Available water contents of loamy and clay soils showed highly significant increase (108% and 105%, respectively) with the highest PAM rate applied due to increase in water content at FC and decrease in water content at WP. Meanwhile, plant available water content (θ_{PAW}) of sandy soil increased by 55% since water content at WP increased. Hemyari and Nofziger (1981) observed that addition of PAM in the rate of 0.4% (by weight) to loamy sand and sandy loam soils resulted in higher water retention compared to their untreated counterparts. However, PAM had only little effect on water retention in clay and loamy soils.

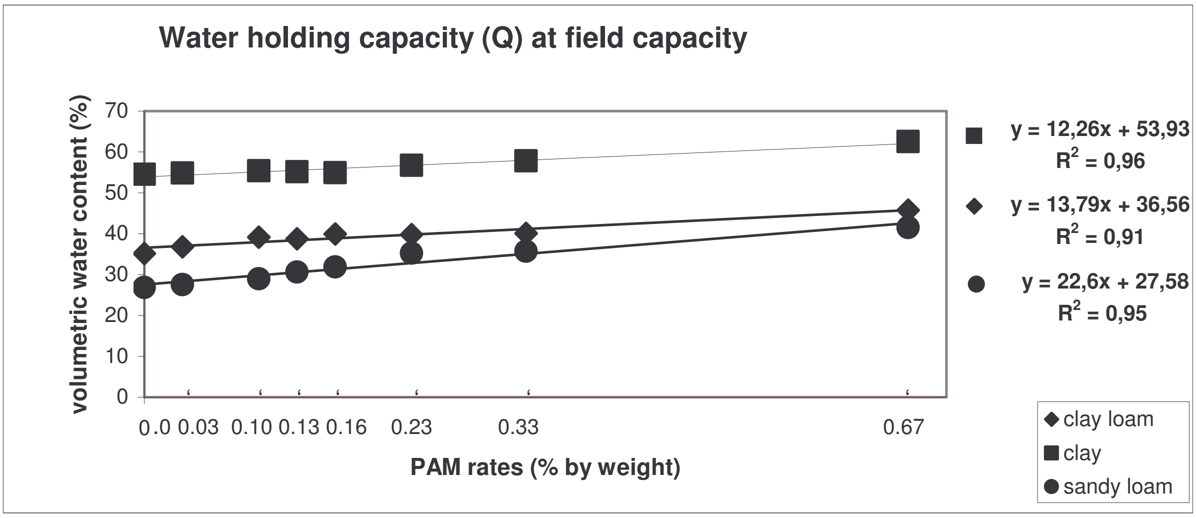

Fig. 1. Response of volumetric water content at field capacity to increasing PAM rates in clay loam, clay, and sandy loam.

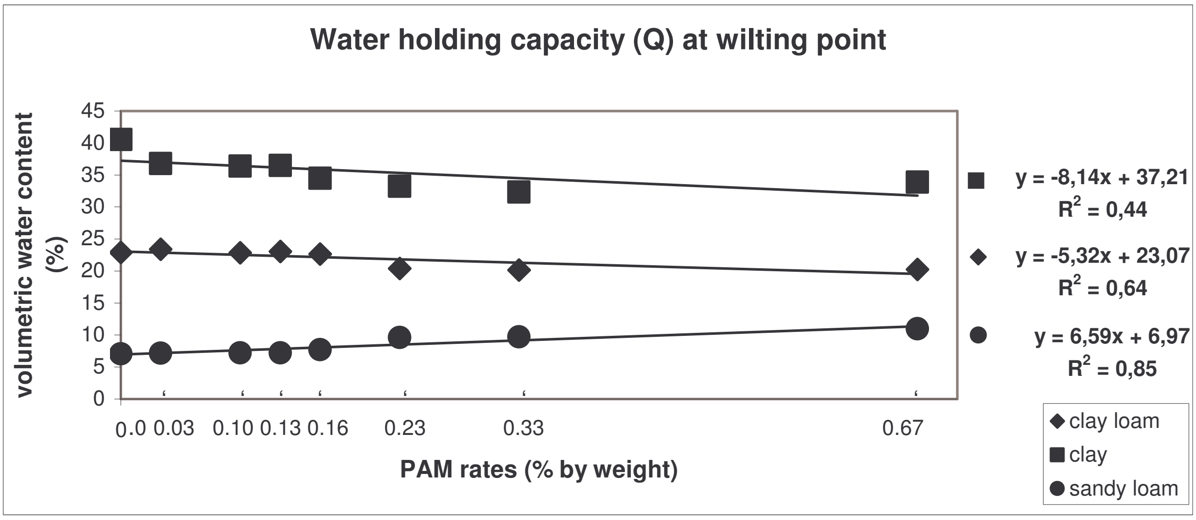

Fig. 2. Response of volumetric water content at wilting point to increasing PAM rates in clay loam, clay, and sandy loam.

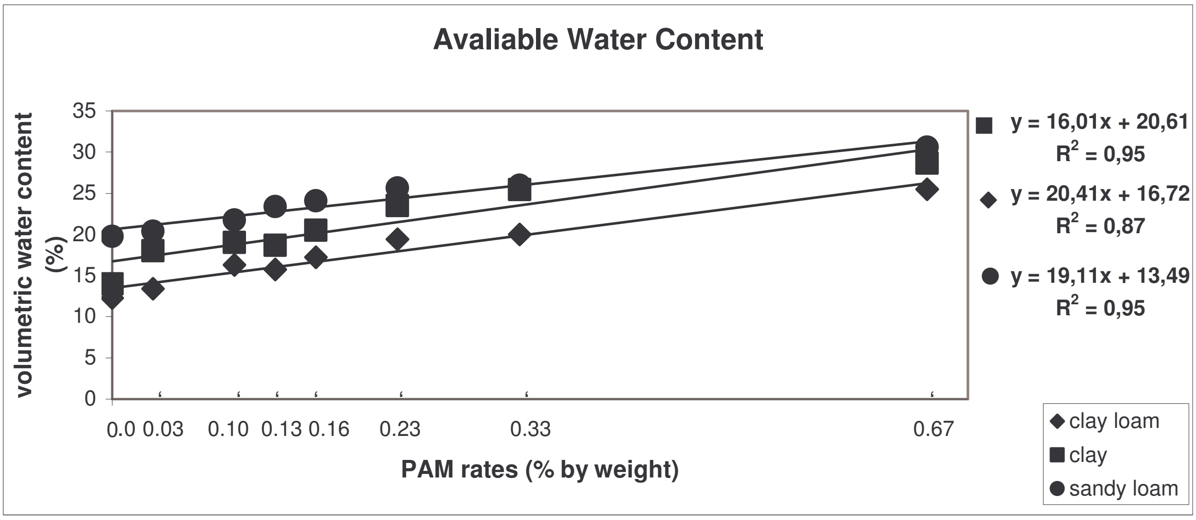

Fig. 2. Response of plant available water content to increasing PAM rates in clay loam, clay, and sandy loam.

To evaluate the soil texture effect on efficiency of PAM, linear regression analyses were conducted between values of water content and PAM rates at θ_{FC}, θ_{WP}, and θ_{PAW}; and then the regression lines representing clay loam, clay, and sandy loam were compared by their slopes (Kleinbaum et al., 1998). At both field capacity and wilting point, the slopes for clay and sandy loam were significantly different, while those for the clay loam and clay were the same. This revealed that sandy loam responded differently to increasing PAM rates than clay and clay loam. At plant available water content, the slopes for all the three soils were the same, indicating that addition of PAM affected water holding capacity of these soils in a similar way. We suggest that soil texture should be considered in application of PAM with the purpose of increasing water holding capacity of the soils. In a small quantity (0.07% by weight) of PAM addition to sandy soil can increase water use efficiency about 19 times due to the fact that more water is retained by PAM and used by plants (Sivapalan, 2001). This suggests that PAM could conserve more time, more money and energy required for frequent irrigation for plants in sandy soils

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Effects of Rice Husk Application on Mechanical Properties and Cultivation of A Clay Soil with and without Planting

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ABSTRACT

In this study, effects of rice husk (RH) application on mechanical properties and cultivation of a clay textured soil were investigated with and without barley planting. A rate of 5% (w/w) rice husk as a dry weight basis was added to a clay textured soil by alone (RH) and with 5 kg N/da of ammonium sulphate (RHN) in order to increase the biological activity and the decomposition rate of rice husk in soil. Rice husk applied soils including control treatment were incubated at field capacity under greenhouse conditions for 2 months. After this period, barley was sown in a half number of the pots. All pots having barley planted and without planted were incubated together for 6 more months. Study was carried out in a factorial experimental design on barley planting and without planting pots in 3 treatments (control, RH and RHN) with 3 replications. At the end of the study, liquid limit (LL), plastic limit (PL), plasticity index (PI), consistency index (Ic), field capacity (FC), permanently wilting point (PWP) and organic matter (OM) contents of soils were determined. The highest values were determined for LL in RH+nitrogen+barley planting (RHNP), for PL in RH application without planting and for PI in control application with barley planting (CP). Barley planting increased LL and PI values of soil significantly. LL values of soils significantly correlated with PL (0.664**), PI (0.880**) and PWP (0.948**). PL values of soils significantly correlated with OM (0.699**) and PWP (0.821**). PI values of soils significantly correlated with FC (0.654**) and PWP (0.713**). Ic values gave the significant correlations with PL (0.908**), OM (0.787**), FC (-0.611**) and PWP (0.615**). Ic values in all RH treatments were higher than that in control treatments. It was concluded that clay textured soil in control treatment can have deformation when it is cultivated at the field capacity without RH application; however clay soils can be cultivated without deformation after application of RH.

Keywords: Clay, rice husk, atterberg limits, planting, soil cultivation.

INTRODUCTION

Management of soil mechanical properties is useful to people interested in soil workability. Basic soil mechanical properties which are liquid limit, plastic limit and plasticity indexes known as Atterberg limits define soil consistency as related with soil moisture content. In agriculture, these limits are generally used for evaluation of soil suitable workability. Soil moisture content is one of the most important factors for soil tillage operation. The optimum water content for tillage defined as the water content at which tillage produces the greatest proportion of small aggregates (Dexter and Bird 2001). It is known that intensive agricultural practices cause soil structural degradation. One of the most important factors for bad soil characteristic is organic matter deficiency in soils. Adding organic matter to soils is one of the most important ways to solve this problem. Organic matter affected positively soils physical, chemical and biological properties (Flaig et al., 1977). These positive effects depend on the organic matter content and the quality of organic matter (Clapp, 1986; Ünsal and Ok, 2001). Organic matter increases the porosity and water holding capacity, decreases ground flux losses and manage the aeration of clay textured soils (Boyle et al., 1989; Chenu et al., 2000; Marinari et al., 2000). It has determined that increasing soil organic matter content cause to increase soil field capacity, wilting point and available water content (Gupta et al., 1977; Bargezar et al., 2002). Gülser and Candemir (2004) reported that incorporating the different organic wastes in to the clay soil caused increases in liquid limit and plastic limit compared to the control application. The objective of this study was to determine the effects of rice husk application on mechanical properties and cultivation of a clay textured soil with and without barley planting.

MATERIALS and METHODS

Soil used in this study was taken from Kavak-Samsun. Some basic properties of clay textural soil are given in Table 1. Rice husk as an organic matter source was supplied from a private rice factory in Terme and grounded by 1mm open size before using in the experiment. Rice husk had 46.97% organic C, 0.38% N by dry weight basis and 126.6 C:N ratio. Soil sample was air dried and sieved through a sieve with 2 mm size opening. After adding the soil sample in to pots, a rate of 5% (w/w) rice husk as a dry weight basis was incorporated in each pot and mixed homogeneously. Study was conducted in 3 treatments which are control (C), rice husk (RH) and rice husk + N (RHN) applications. 5 kg N da^{-1} of ammonium sulphate was added in order to increase the biological activity and the decomposition rate of rice husk in soil. All pots were incubated in 2 months for organic residue decomposition. End of the incubation period half number of the pots planted with barley. All treatments were incubated at field capacity under greenhouse conditions for 6 more months. Organic matter (OM) contents of soils were determined by modified Walkley-Black method (Kacar, 1994). Moisture contents in field capacity (FC) and permanent wilting point (PWP) were determined after the soil samples saturated and waited in the pressured table set at 1/3 atm and 15 atm respectively. Liquid limit (LL), plastic limit (PL) and plasticity index (PI) values of the soil samples were determined according to Demiralay (1993). Index of consistency (Ic) was estimated using the following equation (Baumgarti, 2002); Ic= (LL-FC)/PI.

Table 1. Some physical and chemical properties of the soil

Sand, %	22.08	pH (1:1)	8.13
Loam, %	26.29	Organic Matter, %	1.46
Clay, %	51.63	EC_{25}°C, dS m^{-1}	0.52

Variance analysis of the experimental data was carried out in a factorial experimental design on 3 treatments (control, RH and RHN) with and without planting pots with 3 replications. Pairs of mean values were compared by least significant difference (LSD) and relations between the properties expressed by correlation factors (Yurtsever, 1984).

RESULTS and DISCUSSION

All rice husk treatments significantly increased the organic matter content values of soils when compared the control treatment. While the lowest OM (1.14%) was determined in control treatment with barley planting (CP), the highest OM (3.01%) content was determined in RH + nitrogen + planting treatment (RHNP) (Figure 1). Doran and Smith (1987) reported that soils organic matter contents were changed with the application of different type and amount of organic residues.

Rice husk applications significantly increased LL and PL values of the soil samples according to the control (Figure 2). The highest LL value (49.53%) was in rice husk+nitrogen+planting (RHNP) treatment. Demiralay and Güresinli (1979) reported that a soil can be classified as low, medium and high plastic according to the LL values ranged less than 30%, between 30 and 50% and higher than 50%, respectively. In this study LL values ranged between 39.27 and 49.53%. Therefore, soil samples in all treatments showed medium plasticity. While the highest value of PL (29.58%) was determined in RH treatment, the lowest PL (23.45%) was determined in C treatment (Figure 2). Control treatment with barley planting (CP) showed the highest PI value (23.49%). The lowest PI value (14.06%) was determined in RHN treatment (Figure 2). It has been known that if PI value is low, workability of soils is possible without muddy condition or structural damage, but if PI value is high, soil workability is impossible and muddy condition or structural damage can occur (Demiralay and Güresinli, 1979; Mueller et al. 2003). It indicates that increasing PL and decreasing PI by the application of rice husk in this study can help the soil workability without any structural damage.

Generally, rice husk treatments did not increase FC of soils according to the control (Figure 3). Moreover, FC values in RH+planting (RHP) and RH+nitrogen (RHN) treatments were significantly lower than that in control treatment. The highest FC value (29.40%) was determined in CP treatment and the lowest FC (25.81%) was determined in RHN. All rice husk treatments significantly increased PWP values according to control treatment (Figure 3). While the highest PWP (20.83%) was determined in RHNP, the lowest PWP (15.28%) was in the control treatment. Candemir (2005) reported that application of organic wastes increased the FC and PWP of the clay and loamy sand textural soils according to the control treatment.

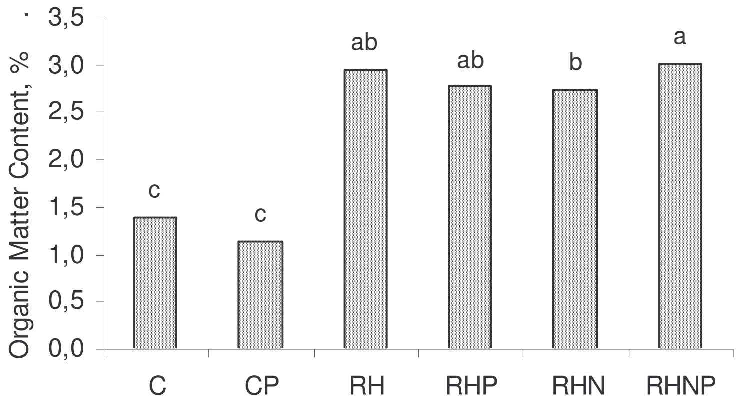

Figure 1. Effects of rice husk application on soil organic matter content (C:control, P:planting, RH:rice husk, N:nitrogen application).

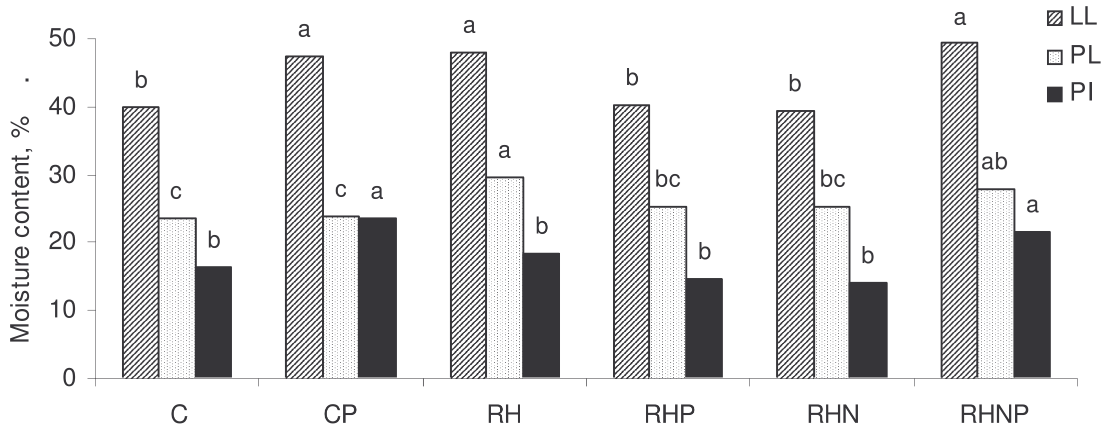

Figure 2. Effects of rice husk application on Atterberg limits with and without planting (C:control, P:planting, RH:rice husk, N:nitrogen application).

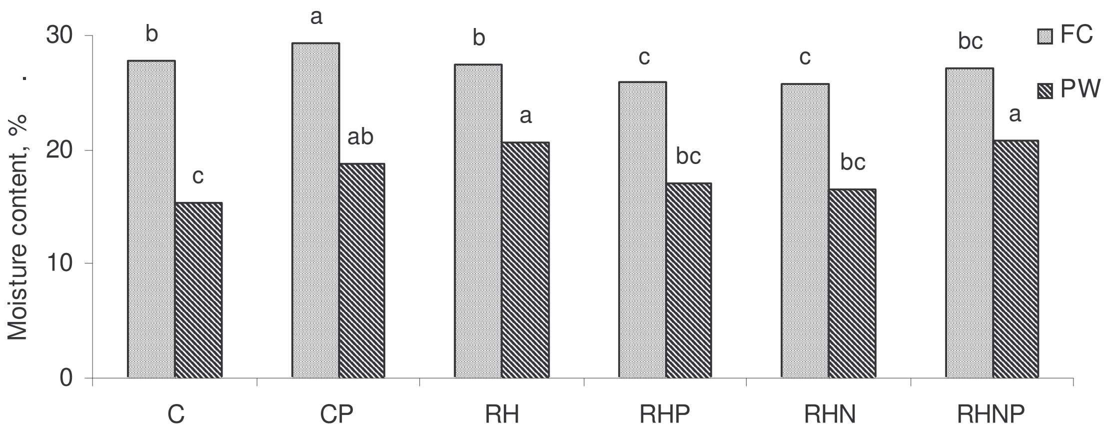

Figure 3. Effects of rice husk application on field capacity (FC) and permanent wilting point (PWP) values with and without planting (C:control, P:planting, RH:rice husk, N:nitrogen application).

All rice husk treatments increased consistency index (Ic) values when compared to the control treatments (Figure 4). While the highest Ic (1.11) was determined in RH treatment, the lowest Ic (0.73) was in the control treatment. Index of consistency value defines consistency condition of a soil at any given soil moisture content. If Ic value is becoming 1.0, soil is in plastic formation (PL at Ic=1.0), if this value is becoming 0, soil is in liquid formation (LL at Ic=0) (Baumgarti, 2002). In this study, Ic values were determined using the soil moisture contents at FC. Baumgarti (2002) reported that if a soil is cultivated when Ic is less than 0.75, soil structural deformation will occur. Ic values in this study ranged between 0.97 and 1.11 for all rice husk treatments, and between 0.73 and 0.75 for all control treatments. Therefore, it seems that soil cultivation in the control treatments at FC moisture contents would have structural deformation in clay soil. Increasing consistency index of the soil by the rice husk application will prevent the clay soil structural deformation when it is cultivated in FC moisture content.

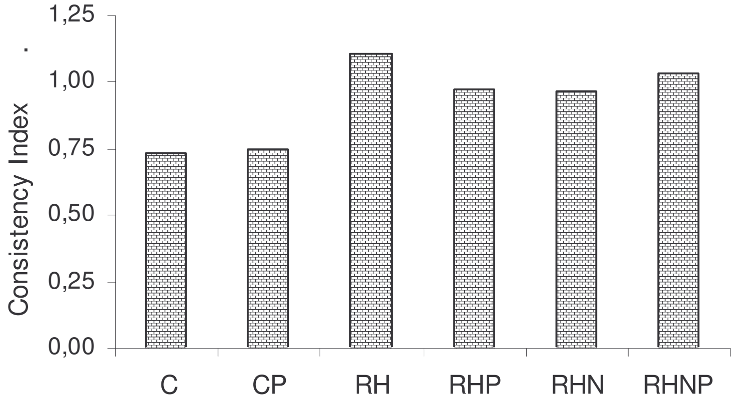

Figure 4. Effects of rice husk application on consistency index (Ic) with and without planting (C:control, P:planting, RH:rice husk, N:nitrogen application).

The relationships among the soil properties and Atterberg limits are given in Table 2. LL value of soils significantly correlated with PL (0.664**), PI (0.880**) and PWP (0.948**). Soil OM content showed a significant positive correlation with PL (0.699**). It has been known that LL and PL values generally increases when the organic matter and clay content increases (Demiralay and Güresinli, 1979; Baumgarti, 2002). Gülser and Candemir (2004) found that there were significant positive correlations between OC and Atterberg limits. They concluded that increasing application rates of organic wastes increased both LL and PL. Özdemir (1998) found that soil organic matter effects LL and PL positively but didn’t affect PI significantly. PI values of soils significantly correlated with FC (0.654**) and PWP (0.713**). Consistency index values of soils gave the significant correlations with PL (0.908**), OM (0.787**), FC (-0.611**) and PWP (0.615**). It indicates that rice husk application increased the consistency index and the soil plasticity when the soil had moisture content at field capacity. Therefore, clay soil cultivation without soil structural deformation at the FC moisture content can be possible, if rice husk is applied in to a clay soil.

Table 2. Correlations among the soil properties and Atterberg limits.

	PL	PI	OM	FC	PWP	Ic
LL	0.664**	0.880**	0.091	0.376	0.948**	0.409
PL		0.230	0.699**	-0.259	0.821**	0.908**
PI			-0.325	0.654**	0.713**	-0.043
OM				-0.635**	0.382	0.787**
FC					0.165	-0.611**
PWP						0.615**

** Correlation is significant at the 0.01 level.

As a conclusion, it is possible that increasing organic matter content in a clay soil by addition of some organic wastes will increase PL and consistency index in soil. Increasing consistency index in soil gives us an ability to cultivate soil at higher moisture contents. In this study, addition of rice husk into a clay soil increased soil plasticity and consistency index when compared with the control treatments. It indicated that rice husk application in to clay soils is useful for the cultivation of soil in FC or in early spring season when soil has higher moisture content.

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Quality Control and Homogeneity of Annual Precipitation Data in Büyük Menderes Basin, Turkey

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ABSTRACT

Precipitation is one of the most impotant climatic factors affecting agricultural production. Knowledge about spatial variability of precipitation amount over an agricultural area, its temporal change not only throughout a year but also over long-term span, start, end and length of rainy period, risk of wet and dry periods would be needed for appropriate agricultural planning and water management issues. However, analysis of long-term precipitation data for various purposes to be accurate, precipitation data must be homogeneous. It is defined that, as for other climatic time series, a homogeneous precipitation time series is to be affected by only natural weather and climatic conditions. Non-climatological factors such as changes in instrument, relocation of station, changes in observation practices make any climatic time series inhomogeneous. In this study, a quality control process involving outlier trimming and homogeneity checking were applied to 20 annual precipitation time series of various lenghts in Buyuk Menderes Basin, Turkey. Homogeneity analysis were performed using the Pettitt test and the Buishand range test. The results of the tests showed that 8 out of 20 stations can be considered to be inhomogeneous whose change points were found to be significant at 5% level by either one or both tests.

Keywords: Precipitation, Turkey, Büyük Menderes Basin, quality control, homogeneity, outlier

INTRODUCTION

Precipitation is one of the most impotant climatic factors affecting agricultural production. Knowledge about spatial variability of precipitation amount over an agricultural area, its temporal change not only throughout a year but also over long-term span, start, end and length of rainy period, risk of wet and dry periods would be needed for appropriate agricultural planning and water management issues. However, analysis of long-term precipitation data for various purposes to be accurate, high quality precipitation data must be used. Thus outliers and homogenization arise as important issues (Gonzalez-Rouca et al., 2001).

Detection of outliers has been considered an important part of quality control work. Outliers are data points that depart significantly from the trend of the remaining data (Naoum and Tsanis, 2003). They can be due to measurement errors or extreme meteorological events (Göktürk et al., 2008). When outliers are undoubtedly erroneous measurements those extreme data can be rejected and the problem is converted into one of missing data treatment (Gonzalez-Rouca et al., 2001). When outliers have a physical background the question arises whether they should be corrected or not (Barnett and Lewis, 1994), because, extreme data carry very valuable climatological information that should not be dismissed (Gonzalez-Rouca et al., 2001). On the other hand, outliers can affect the estimation of sample statistics during the use of nonresistant techniques (Göktürk et al., 2008). In order to retain the information of extreme events while not influencing nonresistant statistics too much, outliers can be replaced by a threshold value specific for each time series (Barnett and Lewis, 1994). Following Gonzalez-Rouca et al. (2001) and Göktürk et al. (2008) this approach was adopted as the quality control procedure in this work.

A homogeneous climate series is defined as one where variations are caused only by changes in weather and climate (Conrad and Pollak 1950). Most of the long-term climatic time series have been affected by a number of non-climatic factors that make these data unrepresentative of actual climate variations occurring over the time (Peterson et al., 1998). These non-climatic factors which makes data inhomogeneous are changes in location of the stations, instruments, formulae used to calculate means, observing practices and station environment (Göktürk et al., 2008). If a precipitation time series is homogeneous, all variability and changes of the series then can be considered due to the atmospheric processes (Karabörk et al., 2007).

There exists many methodologoies for detection of homogeneity of climatological time series. Firstly these methods can be grouped into two categories, direct or indirect methods, depending on availability or use of station history files known as metadata. Direct methods use metadata and indirect methods use a variety of statistical and graphical techniques to determine inhomogeneities (Peterson et al., 1998). The indirect homogeneity tests of a climatic time series could be classified into two groups: absolute tests and relative tests. The absolute tests depend on the use of a single station's records, whereas relative tests depend on the use of neighbouring stations' data that are supposedly homogeneous (Karabörk et al., 2007). Some relative homogeneity tests which do not require homogeneous reference series have become available (Szentimrey, 1999).

Numerous quality control, homogeneity testing and adjustment studies for many climatological time series were conducted at various temporal scales worldwide: for rainfall data in Kenya (Kipkorir, 2002), for daily air temperature and pressure series in Uppsala, Sweden (Bergström and Moberg, 2002), for precipitation and temperature series in Central America and northern South America (Aguilar et al., 2005), for precipitation in Taiwan (Yu et al., 2006), precipitation in Denmark (Frich et al., 1997), temperature and precipitation in Switzerland (Begert et al., 2005), precipitation in the Southwest of Europe (Gonzalez-Rouca et al., 2001), rainfall in Spain (Llasat and Quintas, 2004).

A number of studies checking data quality, testing and adjusting homogeneity for precipitation data in Turkey were conducted. Karabörk et al. (2007) checked the homogeneity of 212 precipitation records in Turkey for the period 1973-2002 by the Standard Normal Homogeneity Test (SNHT) and Pettitt Test. Authors found that 43 out of 212 stations were inhomogeneous based on the criteria that stations being considered inhomogeneous if at least one of the tests rejects the homogeneity. Göktürk et al. (2008) performed outlier trimming and homogeneity checking/correction on the monthly precipitation time series of various lengths from 267 stations in Turkey, by using the Standard Normal Homogeneity Test for homogeneity analysis. Sönmez and Kömüşçü (2007) tested the homonegeity status of monthly rainfall totals from 156 stations for 1977-2006 period by using Kruskal-Wallis Homogeneity test and found 16 stations being inhomogeneous. Em et al. (2007) assessed the homogeneity of annual precpitation totals recorded between 1970 – 2003 at 15 stations in GAP region of Turkey by using Swed-Eisenhart run test and graphical analysis method, and found only data of one station being inhomogeneous.

The purpose of this study is to check the quality and homogeneity of precipitation time series recorded at various stations within Büyük Menderes basin which could be used in later for water management, hydrology, climate change and variability studies. This study differs from other studies conducted for Turkish precipitation data in that it includes precipitation data recorded not only by State Meteorological Service of Turkey (DMI) but also by State Water Works of Turkey (DSI) which were not investigated before in terms of homogeneity.

MATERIALS and METHODS

Data

In this study, time series of annual precipitation totals from 20 stations within Büyük Menderes Basin were used. Locations of station are shown in Figure 1 and the list of stations is given in Table 1. Data were provided by the State Meteorological Service of Turkey (DMI) and by State Water Works of Turkey (DSI).

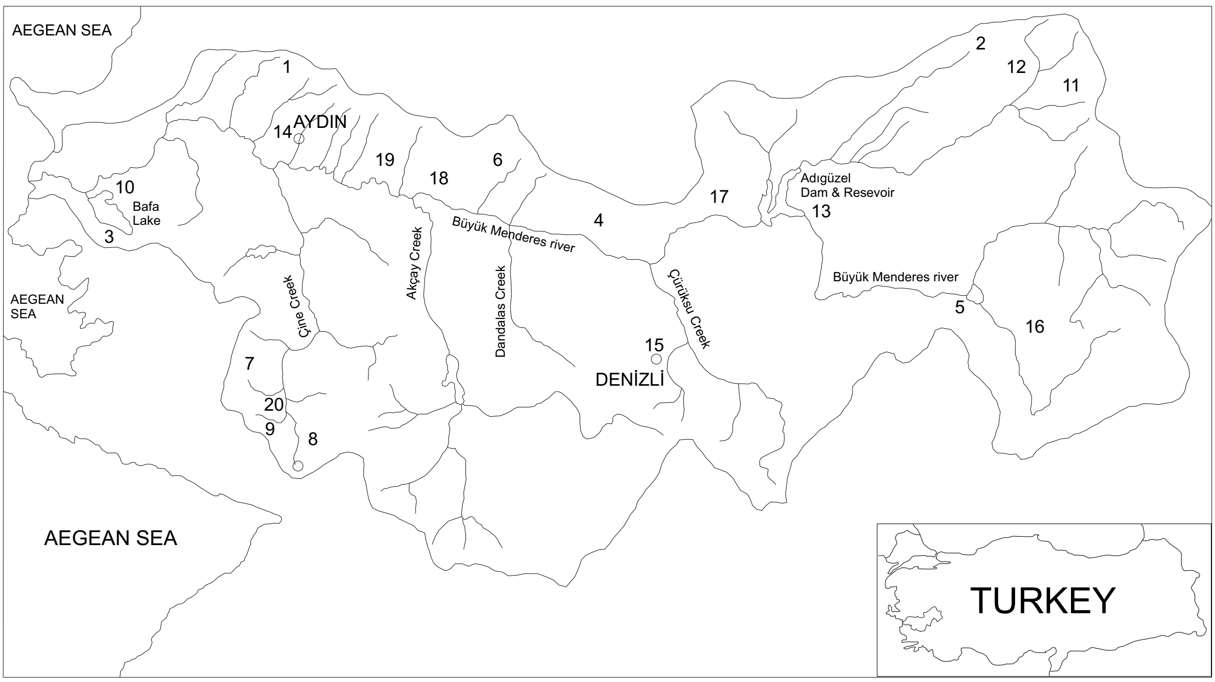

Figure 1. Distribution of 20 precipitation stations over Büyük Menderes Basin used in the study.

METHODS

Quality Control

The identification of outliers has been the primary emphasis of quality control work (Gonzalez-Rouca et al., 2001; Göktürk et al., 2008). Outliers are values greater than a threshold value specific for each time series, defined by

$$P_{out} = q_{0.75} + 3IQR$$

where $q_{0.75}$ is the third quartile and IQR is the interquartile range. In order to reduce the size of distribution tails and make a safer use of the nonresistant homogeneity testing methods used later, also to keep the information from extreme events, outlier values of each annual precipitation series were replaced by the unique P_{out} value (Gonzalez-Rouca et al., 2001; Göktürk et al., 2008).

Homogeneity Analysis

In this study, two methods to test the homogeneity in annual precpitation time series were used. These are the Buishand Range test (Buishand, 1982) and the Pettitt test (Pettitt, 1979). The mathematical formulation of the tests which were adopted from Wingaard et al. (2003) are given below. In the formulation given below, Y_i (i is the year from 1 to n) is the annual series to be tested, $\bar{Y}$ is the mean and s the standart deviation.

Buishand Range Test: In this test, the adjusted partial sums are defined as

$$S_0^* = 0 \quad \text{and} \quad S_k^* = \sum_{i=1}^{k}(Y_i - \bar{Y}) \quad k = 1,....,n$$

When a series is homogeneous the values of S_k^* will fluctuate around zero, because no systematic deviations of the Y_i values with respect to their mean will appear. If a break is present in year K, then S_k^* reaches a maximum (negative shift) or minimum (positive shift) near the year k=K. The $(S_k^* / s)/\sqrt{n}$ is depicted in the graphs representing the results of this test. The significance of the shift can be tested with the 'rescaled adjusted range' R, which is the difference between the maximum and the minimum of the S_k^* values scaled by the sample standard deviation:

$$R = (\max_{0 \le k \le n} S_k^* - \min_{0 \le k \le n} S_k^*)/s$$

Buishand (1982) gives critical values for $R/\sqrt{n}$.

Pettitt Test: This test is a non-parametric rank test. The ranks $r_1,......,r_n$ of the $Y_1,......,Y_n$ are used to calculate the statistics:

$$X_k = 2\sum_{i=1}^{k} r_i - k(n+1) \qquad k = 1,....,n$$

The X_u is depicted in the graphs representing the results of this test. If a break occurs in year E, then the statistic is maximal or minimal near the year k=E:

$$X_E = \max_{1 \le k \le n} |X_k|$$

The significance level is given by Pettitt (1979).

RESULTS and DISCUSSION

The results of quality control process are given in Table 1 in which P_{out} values and extreme year(s) corrected for each station are tabulated. This table shows the variation of data that reaches maximum values along mountainous southern and northern border of the basin, whereas, lowest values occuring on central lowland part of the basin.

Table 1. The list of precipitation stations and the results of outlier trimming process.

S/N	Station Name	Data Period	Missing Data	P_{out} (mm)	Extreme year(s) replaced by P_{out}	State agency from which data were provided
1	Somak	1970 – 2005	1974	1757.5	–	DSI
2	A. Karacahisar	1964 – 2005	–	1215.9	–	DSI
3	Bafa-Çamiçi	1967 – 2005	1991, 1992	1571.8	–	DSI
4	Burhaniye	1963 – 1999	1993	1065.5	–	DSI
5	Işıklı Gölü	1963 – 2005	–	737.7	–	DSI
6	Kayran	1971 – 2005	–	1329.7	–	DSI
7	Kırıkköy	1968 – 2005	1974	1795.6	–	DSI
8	Kozağaç-Muğla	1962 – 2003	–	2542.5	–	DSI
9	Kozağaç-Yatağan	1962 – 2005	1963	1995.4	1981	DSI
10	Sarıkemer	1968 – 2001	1971, 1976	1467.0	–	DSI
11	Serban	1967 – 2000	–	957.7	–	DSI
12	Yavaşlar	1964 - 2001	1965, 1982	896.6	–	DSI
13	Yeşiloba	1968 - 2005	1974, 1975, 1976, 1977	1570.4	–	DSI
14	Aydın	1960 – 2007	–	1262.6	–	DMI
15	Denizli	1960 - 2007	–	1098.3	–	DMI
16	Dinar	1960 - 2006	–	1011.0	–	DMI
17	Güney	1960 - 2007	–	1018.8	1968	DMI
18	Nazilli	1960 - 2007	1969, 1970, 1971	1069.8	–	DMI
19	Sultanhisar	1961 - 2007	1967	1340.2	–	DMI
20	Yatağan	1961 - 2006	–	1378.8	–	DMI

The total number of corrected values is only two: one in Kozağaç-Yatağan and the other in Güney. In Kozağaç-Yatağan, total annual precipitation in year 1981 of 2033.3 mm is higher than and repleced by corresponding P_{out} value of 1995.4 mm. In Güney station, total annual precipitation in year 1968 of 1215.1 mm is higher than P_{out} value of 1018.8 mm, and it was replaced. The neighboring stations of Kozağaç-Yatağan and Güney have total annual precipitations which were not higher than their corresponding P_{out} values in the same years, thus one can conclude that these two outliers could be considered as erroneous measurements rather than as natural variation.

After quality control (outlier trimming) process, annual total prcipitation time series were tested for homogeneity. In this study two homogeneity testing methods were used. The selected methods are Buishand Range Test and Pettitt Test. The results of the tests applied are given in Table 2 for each station.

Table 2. The results of homogeneity tests. Significant change points at 5% level shown in bold.

S/N	Station Name	Data Period	Missing Data	Pettitt	Buishand
1	Somak	1970 – 2005	1974	1981	1981
2	A. Karacahisar	1964 – 2005	–	1977	1977
3	Bafa-Çamiçi	1967 – 2005	1991, 1992	1993	1993
4	Burhaniye	1963 – 1999	1993	1969 1981	1969 1981
5	Işıklı Gölü	1963 – 2005	–	1970 1984	1970
6	Kayran	1971 – 2005	–	1981	**1981**
7	Kırıkköy	1968 – 2005	1974	**1984**	**1986**
8	Kozağaç-Muğla	1962 – 2003	–	1983	1983
9	Kozağaç-Yatağan	1962 – 2005	1963	**1984**	**1983**
10	Sarıkemer	1968 – 2001	1971, 1976	1984	1984
11	Serban	1967 – 2000	–	1972 1976	1971 **1976**
12	Yavaşlar	1964 - 2001	1965, 1982	**1971**	**1971**
13	Yeşiloba	1968 - 2005	1974, 1975, 1976, 1977	**1986**	**1985**
14	Aydın	1960 – 2007	–	1986	1986
15	Denizli	1960 - 2007	–	1969 1981	1969 1981
16	Dinar	1960 - 2006	–	1969	**1969**
17	Güney	1960 - 2007	–	1969 1983	**1969** **1983**
18	Nazilli	1960 - 2007	1969, 1970, 1971	1983 1993	1983
19	Sultanhisar	1961 - 2007	1967	1971 1981	1971 1981
20	Yatağan	1961 - 2006	–	1971 1984	1971 1984

The results of Buishand Range test showed that 8 out of 20 stations have an inhomogeneity. On the other hand, according to Pettitt test 4 out of 20 stations were found to be inhomogeneous. Pettitt test detected nonsignificant change points at three stations, namely in Kayran, Serban and Güney stations, which Buishand Range test found significant change points at 5% significance level. Totally, 8 out of 20 stations are considered to be inhomogeneous whose change points were found to be significant at 5% level by either one or both tests.

Another outcome of the tests is that both tests detected change points at around the same years at almost all stations. In other words, the test results confirmed outcomes of one another in terms of timing of change point. For example, both tests detected a change point around 1985 in Yeşiloba station, as shown in Figure 2.

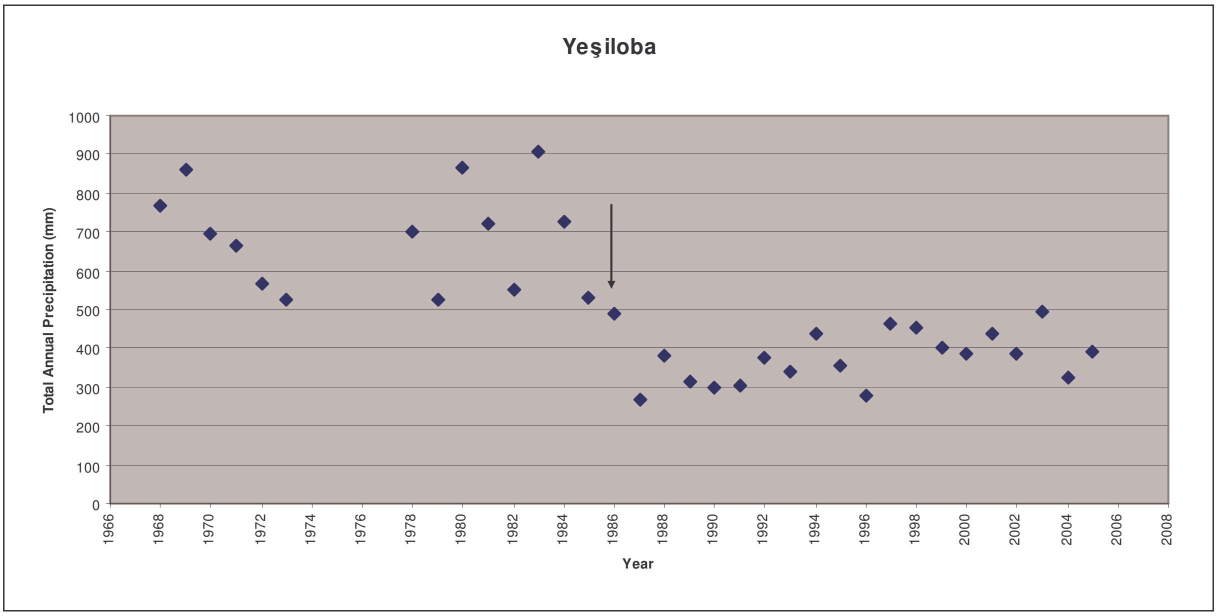

Figure 2. Annual precipitation time series of station Yeşiloba and detected inhomogeneity during 1985.

The test results depicts also that some neighboring stations exhibit simultaneous ocuurances of inhomogeneity. For instance, both tests detected a shift at the stations Kırıkköy and Kozağaç-Yatağan situated on southern border of the basin around the year 1984. On the other hand, two stations, namely Kozağaç-Muğla and Yatağan, neighboring to Kırıkköy and Kozağaç-Yatağan have change points around the same year which are not significant at 5% level. These simultaneous inhomogeneties may arise from simultaneous changes in observational routines (Karabörk et al., 2007).

Since thistorical metadata of the stations was not available in this study, no analysis could be made for the possible causes of the detected homogeneities. Some neighboring stations have simultaneous inhomogeneties or change points which are not significant at 5% level, therefore, it would be inappropriate to use the 'relative' homogeneity tests for Turkish precipitation data, as stated by Karabörk et al. (2007).

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Soil Salinity in a Drip and Furrow Irrigated Cotton Field under Influence of Different Deficit Irrigation Techniques

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ABSTRACT

We investigated the influence of conventional deficit irrigation (CDI) and partial root zone irrigation (PRI) on soil salinity in a drip- and furrow-irrigated cotton field. Under PRI, one half of the rooting zone is wetted while the other half is maintained partially dry, and thus reduced amount of water is applied. The wetted half of the root zone is alternately changed either every or every other subsequent irrigations. Effects of time length during which one side of the root zone stays wet or partially dry on soil salinity were investigated for only furrow irrigated cotton. We had compared proportional soil salinity developed under CDI and PRI under drip irrigation. Thus we had two field experiments consisting separately drip- and furrow-irrigated cotton. The treatments under furrow irrigated cotton were (1) FULL, control treatment where rooting zone soil water content was increased to field capacity at each irrigation; (2) 1PRI and (3) 2PRI, 50% deficit irrigation compared to FULL treatment was applied while interchanging wetted and partially dry sides every and every other irrigations, respectively. The drip-irrigated cotton had similarly three treatments: (1) FULL, the control treatment where full amount of irrigation water (100% Class-A pan evaporation) was applied to both sides of the plant rows; (2) 1PRI and (3) CDI, where the both treatments had 50% deficit irrigation compared to FULL treatment. Under CDI treatment, the deficit amount of water was uniformly applied to both sides of the cotton rows. Soil salinity was assessed utilizing root zone soil salinity profiles developed at planting and following harvest. Additionally we had iso-salinity maps constructed with grid soil sampling of plant root zone at harvest. The results showed that soil salinity increase was significant ($P<0.05$) only within soil surface layer of 0-20 cm. The highest increase in soil salinity was noted under the treatment of 2PRI with furrow irrigation. The drip irrigated cotton data showed that the salinity increase under PRI was in the same range as the FULL treatment whereas the increase under CDI was the highest. However, any likely soil salinity increase, resulting from deficit irrigation either with CDI or PRI practices, was at levels which could easily be leached with winter rains.

Keywords: Water use efficiency, PRI, salinity profile, water quality, salinity map, cotton.

INTRODUCTION

Fertile agricultural areas decrease as a result of uncontrolled soil salinity. Over 23% of world's agricultural lands are under the effects of salinity problem experienced by more than 100 countries (Szabolcs, 1989). Annually, 4×10^4 ha of agricultural lands is left out of cultivation due to salinity (Lamsal et al., 1999). Salinity problem existing in our country is nearly 20% of all irrigated areas (Konak et al., 1999). High soil salinity hinders plant growth and development and thus may reduce crop yields. Katerji et al. (1998) showed that the salinity reduces stomatal conductance and leaf area. Thus the crop water consumption was decreased. The decreasing water consumption led to significant yield loss. In another study, leaf area, plant height, plant dry matter and some other plant development parameters were all hindered with increased soil salinity in addition to decrease of crop water consumption (Romero-Aranda et al., 2001). It is known that increase of salinity both in soil and irrigation water adversely influence plant development and yield.Excess irrigation may cause rising of ground water table which may carry salts from subsurface to surface layers through capillary rise and evaporation (Turhan and Baser, 2001). Irrigation practice should be in such a way that soil salts could adequately be leached while no standing water left at surface following irrigation. To this effect, studies on new irrigation technologies aiming at both increasing water use efficiency and crop yields are receiving high priority. Conventional deficit irrigation (CDI) may adversely reduce leaf area and plant development although significant savings of irrigation water may be achieved (Kirda et al., 1999). However, there may be significant decrease of yield as well as quality of crops. It was documented that if partial root zone irrigation (PRI), an alternative to CDI, is used, the saving of irrigation water can be achieved without significant reduction of yields (Kang et al., 2000; Chaffey, 2001; Stikic et al., 2003; Nakajima et al., 2004). Half of the root zone is wetted with reduced amount of irrigation water under if the PRI technique is in use. Similar to CDI, available water resources are used effectively and most efficiently with PRI practice (Kang et al., 1998; Zegbe et al., 2004). Although vegetative growth was reduced, the yield and crop quality were not affected and maintained at nearly the same levels under PRI, compared to full irrigation with no deficit (Dry and Loveys, 1998; Kang et al., 2000, 2001; Mingo et al., 2003; Zegbe-Dominguez et al., 2003).

Water resources allotted to irrigated agriculture is to be reduced because of increase demand by municipal and industrial use of water. Therefore new innovations in irrigation techniques aiming at improving effective use of limited irrigation water resources are needed. The PRI is promoted as a new technique which was known to reduce significantly irrigation water requirement. The work under taken here evaluates soil salinity developed under furrow and drip irrigation with PRI practice.

MATERIALS and METHODS

The experimental work was carried out at Research Fields of Cukurova University, Faculty of Agriculture (36º 59' N, 35º 18' E, 20 m above see level), Adana, Turkey. The area has typical Mediterranean climate, with cool and rainy winters, hot and dry summers. Long term annual average rainfall in the area is 646.5 mm. During summer, humidity increases with starting of irrigation season. The humidity decreases during winter.

Soils at the site belong to Mutlu series with medium lime content of dark reddish brown color. Soil profile has high clay content of 2:1 type with swelling and cracking characteristics upon wetting and drying. Some physical and chemical properties of soils at the experimental site are given in Table 1. The site had no salinity problem. Salinity and other chemical analysis of irrigation water diverted from the irrigation channel were carried out using the methods described by USSL (1954). Irrigation water quality was rated as C_2S_1.

The field experiments testing 4 irrigation treatments (FULL, 1PRI, 2PRI and CDI) with 3 replicates were conducted for two seasons using randomized complete block design. The FULL treatment received full amount of irrigation water with no deficit. The 1PRI had 50% deficit irrigation compared to FULL irrigation and the irrigated half of the rooting zone was alternated every irrigation. The treatment 2PRI had also similar level of deficit as 1PRI with however alternation of the wetting side was done every second irrigation. The treatment CDI also had 50% deficit irrigation, compared to FULL irrigation, but water was applied uniformly to wet complete rooting zone as done under FULL treatment. During the first year of work, the treatments FULL, 1PRI and 2PRI were implemented with furrow irrigation. During the second year the treatments FULL, 1PRI and CDI were tested using drip irrigation.

Table 1. Some physical and chemical properties of the experimental soil

Depth, cm	FC, cm^3 cm^{-3}	PWP, cm^3 cm^{-3}	BD, g cm^{-3}	OC, %	pH
0-30	0.40	0.26	1.19	0.80	7.8
30-60	0.40	0.26	1.19	0.55	7.7
60-90	0.41	0.28	1.16	0.30	7.7
90-120	0.41	0.28	1.25	0.06	8.0

The experimental plots with 8 rows of plants were 40 m long and 6.4 m width. A cotton (*Gossypim hirsutum* L., cv. Çukurova-1518) cultivar, widely used in the area, was planted. The fertilizers rates used were similar to farmers' practice in the area as 160, 50 and 50 kg ha^{-1} of N, P and K applied, respectively. The seeds were planted to 3-4 cm depth along 80 cm row spacing at 5-6 kg da^{-1} rate. Irrigation was initiated when 40% of plant available soil water storage was depleted under furrow irrigation. Irrigation water applied was that amount which increased soil water content to field capacity under the FULL treatment. Under drip irrigation, irrigations were done weekly with irrigation water requirement estimated using Class-A pan data. Laterals of drip lines with drippers at 20 cm separation were laid along both sides at 40 cm distance from the plant rows. The drippers used were of 4 L h^{-1} discharge rate.

Experimental data collected included soil water status, irrigation water use efficiency (IWUE), soil salinity and the like. The salinity data, which were collected at early season at planting and immediately after harvest, were used to assess change of soil salinity profiles during irrigation season. The data was also used to construct iso-salinity maps of the plant root-zone. Soil samples for salinity measurements were collected in 3 replicates from soil depths of 5, 15, 45, 75 and 105 cm. The second sampling, following the harvest, was done following a grid system so that iso-salinity maps for salinity characterization of plant rooting zone can be made. For this purpose, 3 sites consisting a line perpendicular to the plant row: (1) immediately below an individual plant, (2) and (3) at 20 cm equal distance to the plant root, on the left and right of the plant row were sampled at the same depths as initial sampling. Soil saturation extracts were used for measurement of salinity as electrical conductivity (ECe, dS m^{-1}). The salinity data, used either as salinity profiles or iso-salinity maps, facilitated to assess salt accumulation under the tested irrigation treatments FULL, 1PRI, 2PRI and CDI.

RESULTS and DISCUSSION

Yield

Total of 5 irrigations were used for the furrow irrigated cotton. Although the treatments 1PRI and 2PRI received 50% reduced amount of irrigation water compared to the FULL treatment, the yield reduction was only marginal and not significant; however, IWUE was nearly doubled (Table 2). Similar results were earlier reported for maize by Kang et al. (2000). The FULL treatment produced the highest yield in the second year under drip irrigation; however the yield reduction under 1PRI was only marginal and non significant (P>0.05) compared to FULL treatment (Table 2). The CDI produced the lowest yield. The deficit irrigation treatments (i.e., PRI and CDI) had the highest IWUE (Table 2). Irrespective of the irrigation method used, furrow or the drip, the yield reduction with 1PRI, compared to FULL treatment, was only marginal in spite of as high as 50% reduced irrigation water application. Our results confirmed the earlier findings by Chaffey (2001) who reported that high amount of irrigation water can be saved without significant yield reduction with deficit irrigation. Wahbi et al. (2005) showed that 50% savings of irrigation water achieved with PRI for 15-20% yield reduction should have significant implications toward in easing of irrigation water shortage. There are numerous other work (e.g., Zegbe-Domiguez et al., 2003; Dorji et al., 2005; Gençoğlan et al., 2006) published recently which all confirmed similar findings that the PRI technique can achieve significant savings in irrigation water requirement with only marginal yield reduction.

Table 2. Cotton seed yield and irrigation water use efficiency (IWUE)[a]

Irrigation treatments		Y, t ha^{-1}	IWUE, kg $(ha\ mm)^{-1}$
Furrow	FULL	3.38	5.7 b
	1PRI	3.28	11.1 a
	2PRI	3.17	10.7 a
	Tukey's CV	NS	2.6
	P		0.01
Drip	FULL	1.82 a	8.2 b
	1PRI	1.51 ab	13.6 a
	CDI	1.37 b	12.3 a
	Tukey's CV	0.42	3.98
	P	0.05	0.05

[a] Data in columns followed with different letters are significantly different based on Tukey's mean range test for indicated critical value for comparison (CV).

Salinity

Increase of soil salinity within soil depths of 40 cm or below was about 0.2 dS m^{-1} under furrow irrigation. The largest increase was within the surface layer of 40 cm (Figure 1). As expected, the lowest increase was noted under the FULL treatment because of proportionally high leaching occurred. It was interesting to note that surface soil salinity was somewhat higher under 2PRI compared with that of 1PRI (Figure 1). The highest salinity was observed within the surface layer of 20 cm under 2PRI.

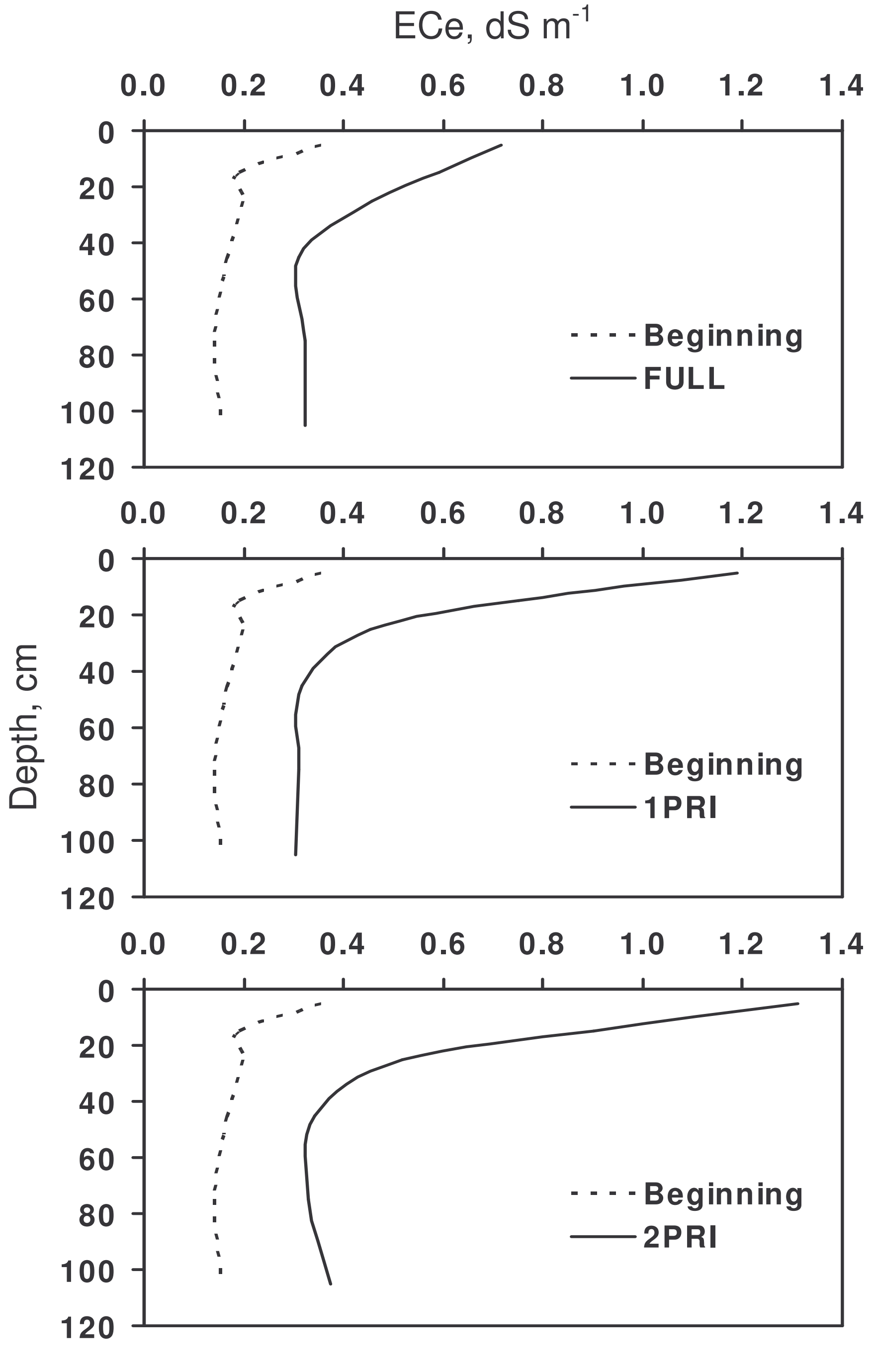

Figure 1. Salinity changing of the root zone under FULL, 1PRI and 2PRI treatments for furrow irrigated cotton at the beginning and at harvest (solid line)

The lowest salinity was observed under 1PRI treatment with drip irrigation (Figure 2). The salt accumulation was the highest under CDI. Similar to furrow irrigation, salinity was proportionally higher near soil surface. Iso-salinity maps at harvest (Figure 3) showed that the surface layer of ≈30 cm depth had the highest salinity which gradually decreased at deeper zones irrespective of the treatment. Salt accumulation essentially occurred at wetting front between the drippers and the plant root (Figure 3). This behavior was the most apparent under the CDI. Similar to furrow irrigation, salinity below 40 cm depth proportionally was lower compared to surface layers. Although salt accumulation was highest right over the plant rows under furrow irrigation (Kaman et al., 2006), the area of accumulation was shifted toward the center between the rows and the drip line under drip irrigation. The results obtained therefore suggested that the drip irrigation should be preferred if low quality irrigation water is to be used.

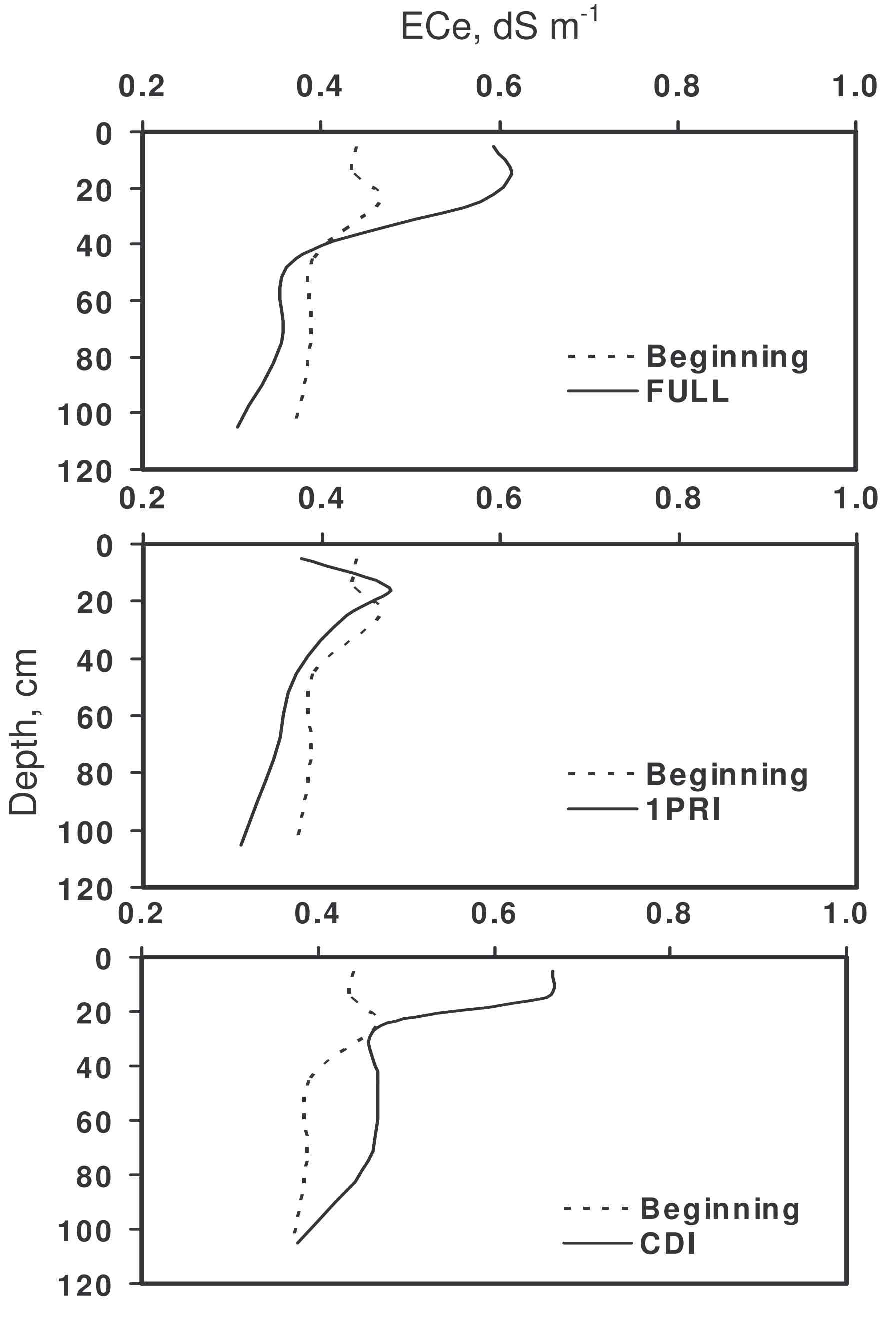

Figure 2. Salinity changing of the root zone under FULL, 1PRI and CDI treatments for drip irrigated cotton at the beginning and at harvest (solid line)

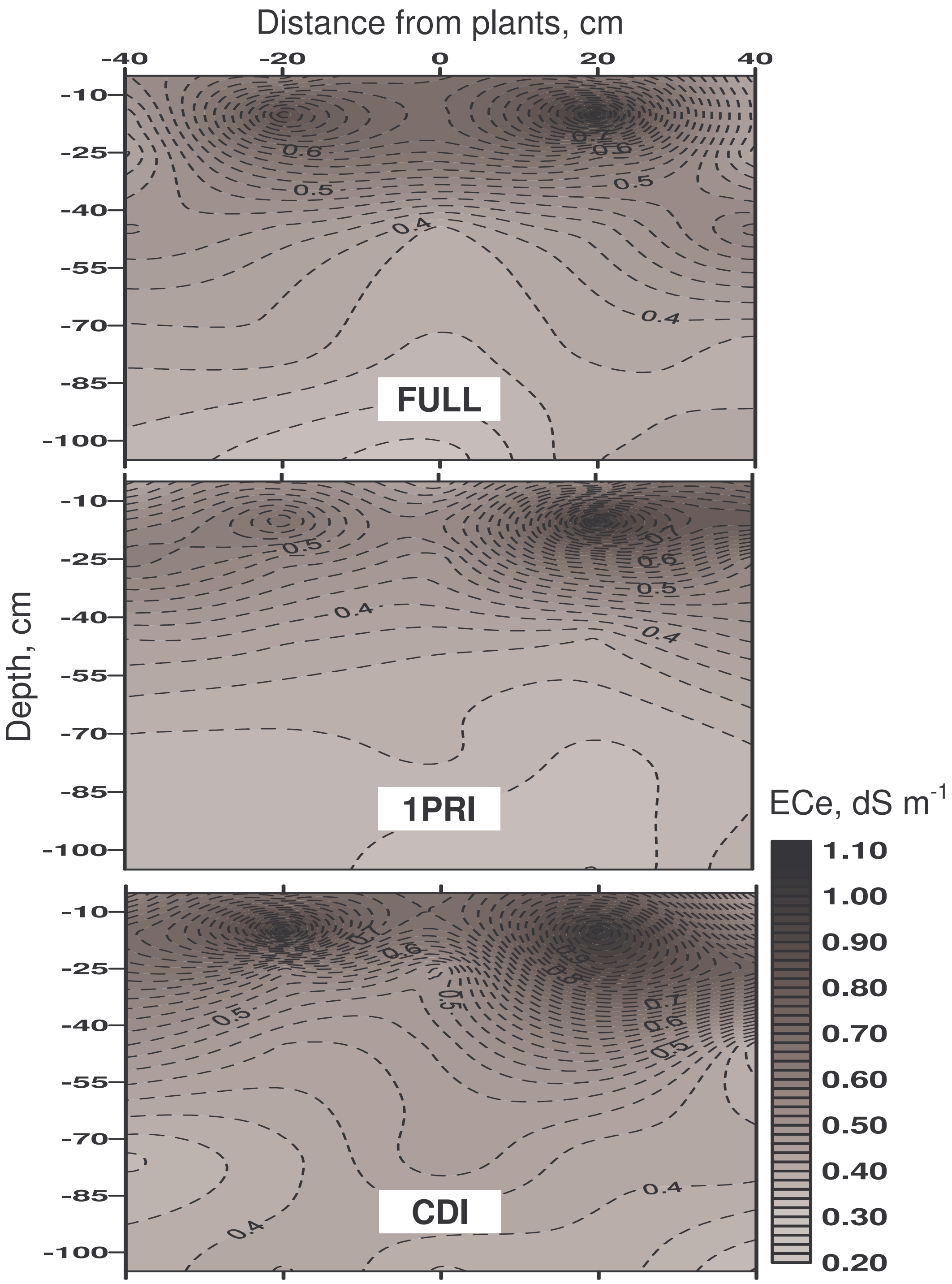

Figure 3. Map of the salt accumulation under FULL, 1PRI and CDI treatments in the root zone of drip irrigated cotton at harvest

The salt accumulation observed in the root zone was at maximum 1.3 dS m^{-1} over one year of irrigation because of the fact that irrigation water quality was good with EC of below 0.4 dS m^{-1}. However, it should be noted that in salt affected soils of EC_e>4 dS m^{-1}, the yield reduction may be likely depending on irrigation water quality. Nevertheless, our results showed that risks of salt accumulation under the deficit treatment PRI would not be much different than under FULL irrigation. Therefore in areas of limited irrigation water, the deficit irrigation practice of PRI should be preferred over FULL irrigation.

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Possibility of Using EM38 Device to Determine the Extent and Severity of Soil Salinity: A Case Study in the Lower Seyhan Plain, Turkey

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ABSTRACT

Salinity is an increasing problem in irrigated areas which causes important reductions in agricultural production. Distribution of soil salinity and its variability are required to set up measure-observation control in an irrigated area. The conventional methods to determine soil salinity in an irrigated area entail intensive land survey and laboratory analysis. However these take plenty of time and cost much. Instead of these conventional methods, lately, practical and simple techniques have become a current issue in salinity assessment. One of them is to use electromagnetic induction meter (Geonics-EM38) that measures apparent soil salinity, ECa. EM38 is a device which is designed to measure ECa horizontally and vertically, i.e., to a depth of 0-1 m and 0-2 m, respectively. In this research, we tried to investigate the effectiveness of EM38 device in identifying and mapping of soil salinity. The study was conducted in Yemişli Irrigation District (YID), covering an area of 7110 ha. YID is located in the Lower Seyhan Plain in the eastern part of the Mediterranean region, Adana, Turkey. The majority of farmers in YID use irrigation return flows of poor quality, diverted from main drainage canals. For this reason, the fields in YID are always under the risk of soil salinization. Therefore, soil salinity has to be monitored frequently in a quick and efficient way. Because of these characteristics, YID was chosen and 112 EM38 readings were done for salinity assessment. Concurrently, soil samples from 20 points, distributed randomly in the field, were taken from 1 m soil profile with 0.3 m intervals, summing up three totally. Extracts of soil saturation paste were obtained. Composite samples for 0-1 m depths were prepared by using extracts of each layer and salinities of composite samples were measured, ECe, to determine average ECe of 0-1 m depth. The relationship between ECe and ECa is determined. Then, ECe map was produced and salinity profile distribution was developed for the study area. The results showed that the electromagnetic induction meter (EM38) can be used very efficiently to determine soil salinity in areas prone to salinization like in YID. Additionally, spatial and temporal changes in soil salinity can be derived from EM38 readings, provided that the deterministic association between ECa and ECe is determined.

Keywords: Soil salinity, salinity map, electromagnetic induction meter (EM38), drainage water.

INTRODUCTION

Irrigation is essential in arid and semi-arid regions for agricultural production. However it should be noted that soil salinity may be an important risk for sustainable agricultural production owing to mismanagement of irrigation schemes and other inherent problems of irrigation methods. Salt accumulation which may occur in plant root-zone may closely be associated with the irrigation methods used (Tuzcu et al., 1988). Irrigation with inferior quality waters may also increase soil salinity (Cetin and Kirda, 2003). Salinity, which is among the most important factors limiting agricultural production, would adversely influence plant development and thus cause decreasing crop yields. Soil salinity is among the main cause for desertification in arid climates. Inferior water quality causing soil salinity limits biodiversity and harms environment. Increased soil salinity causes decrease of fertile agricultural lands. Of World's agricultural areas, 37% sodium and 23% are salt affected soils, and the remaining 40% is only fertile agricultural areas. There are more than 100 countries whose agriculture is severely affected by salinity (Szabolcs, 1989). Areas left annually out of agricultural production is 4×10^4 ha (Lamsal et al., 1999). Salt affected soils in Turkey are nearly equal to 20% of whole irrigated areas (Konak et al., 1999).

Soil salinity may some time be caused by saline main material. In such areas, soil salinity may occur with shallow groundwater and soil evaporation exceeding annual rains. Topographic features, natural drainage, climate, geological characteristics, soil forming main material and the distance to sea are among the factors influencing salt accumulation in agricultural areas (Amezketa, 2006). Salinity development in irrigated areas, however, may be attributed to using inferior quality of irrigation water. Mismanaged irrigation methods, low quality irrigation water, inadequate drainage and depressions in land topography are among the likely causes of salt accumulation in agricultural areas (Cetin and Kirda, 2003). Soil salinity in irrigated agriculture must be prevented to sustain soil fertility. To this effect, an easy assessment and quantification of soil salinity is essential.

High number of sampling is needed to assess salinity in large areas. Additionally, handling of high number of soil samples for standard soil analyzes for salinity is difficult, although it can be done. However, classical and conventional soil analyses methods for salinity assessment are difficult and time consuming. Therefore, new methodologies have been developed in recent years for easy and quick assessment of soil salinity in agricultural areas (Amezketa 2007). Electromagnetic salinity assessment is among recently developed techniques used for measuring soil salinity. The equipment called electromagnetic induction salinity meter (EM) is portable and designed for convenient salinity assessment in agricultural areas (Amezketa, 2006). Data collected with the EM technique are essentially so called apparent salinity (EC_a) which can be converted to standard soil extract salinity (EC_e) with proper calibration. Depending on how it is used, one can measure average soil salinity either over a depth of 0-1 m or 0-2 m. Field data collection is very easy and fast.

We had investigated assessment and distribution of soil salinity over a large area (7110 ha) within 0-1 m soil depth with EM38. The objectives of the work were (1) to study functional dependence between ECa and ECe and (2) to construct salinity map of the irrigated fields with EM38 data.

MATERIALS and METHODS

The work was undertaken on Yemisli irrigation district area in Karatas, Adana (Figure 1), Turkey, within the Fourth Development phase of the Lower Seyhan Irrigation Project. The study area of 7110 ha was within the service boundaries of the drainage scheme P2D1. Irrigation water source used in the area is diverted largely from drainage channels carrying low quality irrigation return waters from the upstream areas.

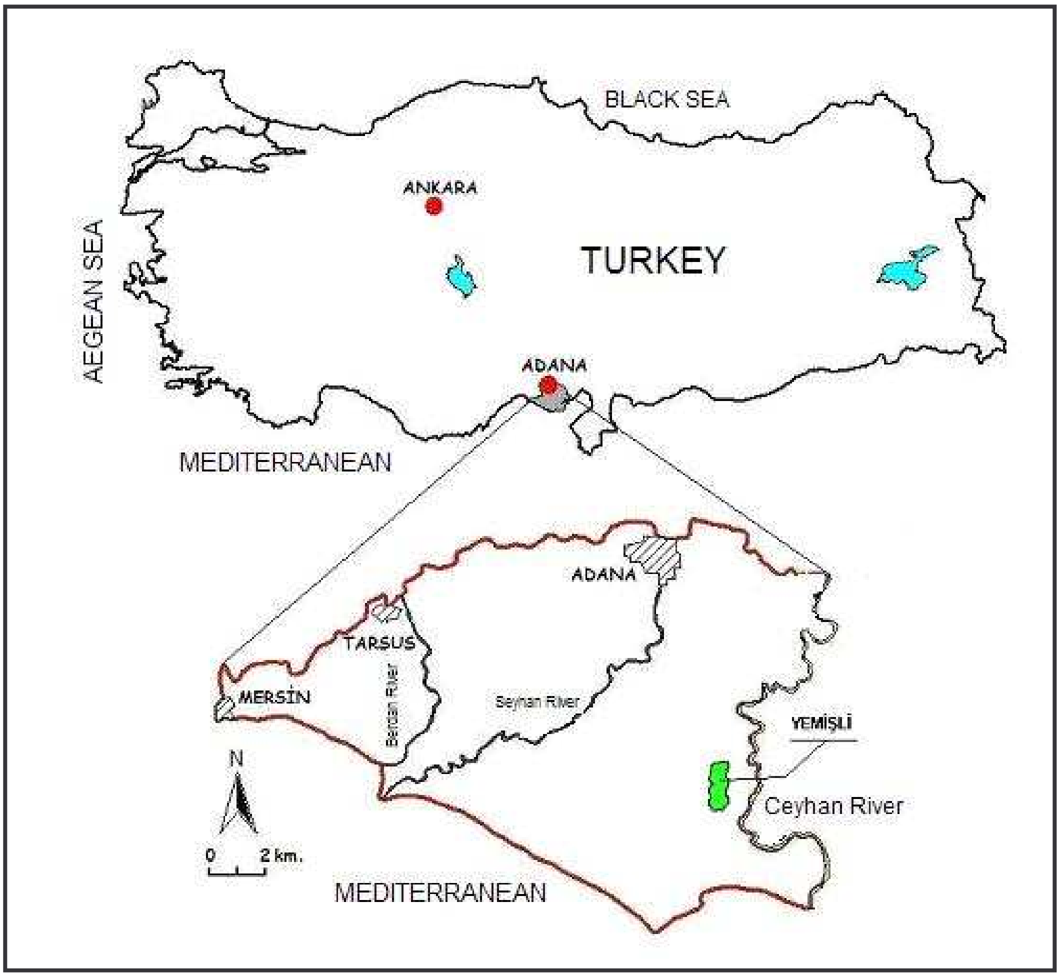

Figure 1. Location of the study area

Soils of the area belong to Helvaci series consisting of mainly alluvial deposits of delta plain. Soil pH changes within the range of 7.1 -7.4 and exchangeable Na is rather high. Although soil lime content of 20% should be considered rather high, the low soil permeability is the main limitation to problem-free irrigation practice.

Soil samples were collected from 3 layers of 0–30, 30–60 and 60–100 cm from 20 sampling sites with wide range of salinity. The samples were analyzed for standard ECe measurements. Additionally, EM38 measurements (ECa) were done at 112 different sites characterizing the study area. Soil temperature measurements which were needed for temperature corrections of the ECa data were also made at 2 depths, 50 and 100 cm. The measuring sites were selected in irrigated cropped fields.

The EM38 sensor can measure apparent soil salinity as an average either over a depth 0-1 m or 0-2 m depending on how it is positioned over the soil surface. If it is laid horizontally over the soil surface, the data collected represents average salinity over 0-1 m soil depth. Alternatively if it is placed over the soil surface vertically, the measurement represents the average salinity over proportionally deeper zone of 0-2 m depth. In the study undertaken here, only the measurement over shallow depth of 0-1 m was considered and therefore the equipment was placed over the surface horizontally (Figure 2).

Figure 2. The EM38 placed horizontally to assess soil salinity over 0-1 m soil depth

Soil samples collected from the study area were first air dried, then sieved to 2 mm size. Saturation pastes were prepared from 100 g sub samples, and the extracts obtained after 12 hours of equilibrium time were analyzed for standard electrical conductivity measurements (ECe).

The apparent salinity measurements (EC_a) made with EM38, close to soil sampling sites, were calibrated against classical EC_e measurements. The ECa data collected in the complete study area were later converted to ECe by using calibration equation and used conveniently for constructing the salinity map of the study area.

RESULTS and DISCUSSION

Soil salinity distribution profile constructed using samples from 20 sites is given in Figure 3 which showed that salinity increased from 2.9 dS m^{-1} in surface layer of 0-30 cm depth to 7.7 dS m^{-1} in 60–100 cm depth. Amezketa (2006) used EM38 data with ESAP program for mapping field soil salinity distribution in Spain. His data also showed that the soil salinity increased with soil depth owing to usage of low quality irrigation water and inadequate drainage. It appeared that the similar situation existed in our study area where irrigation water salinity may be as high as 5 dS m^{-1} and the drainage systems are generally blocked by farmers to facilitate easy diversion of drainage water for irrigation purposes.

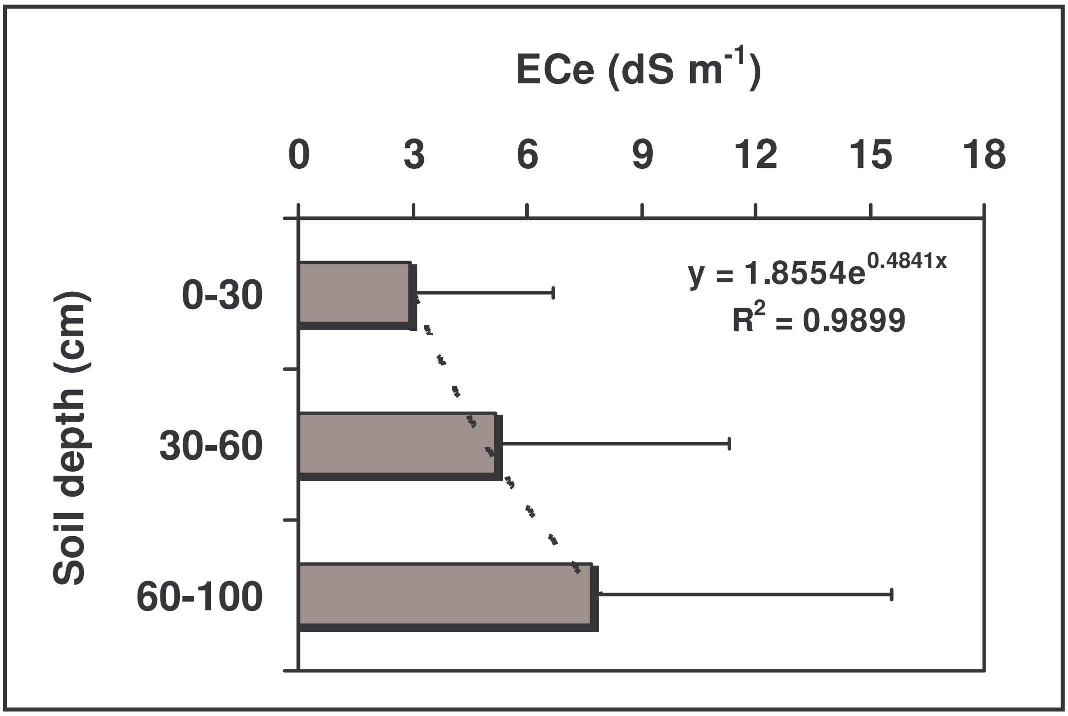

Figure 3. Soil salinity profile. Histograms show average soil salinities (n =20) with bars of standard deviations

The calibration relation EC_a on EC_e was linear with $r^2 = 0.85$ (Figure 4). The slope of the linear relation was nearly unity as earlier reported by Herrero et al. (2003) who used 22 data points. The calibration equation reported by Amezketa (2007) -who used 20 data points- also showed that the linear relation of EC_a on EC_e was nearly 1:1 as confirmed in our study.

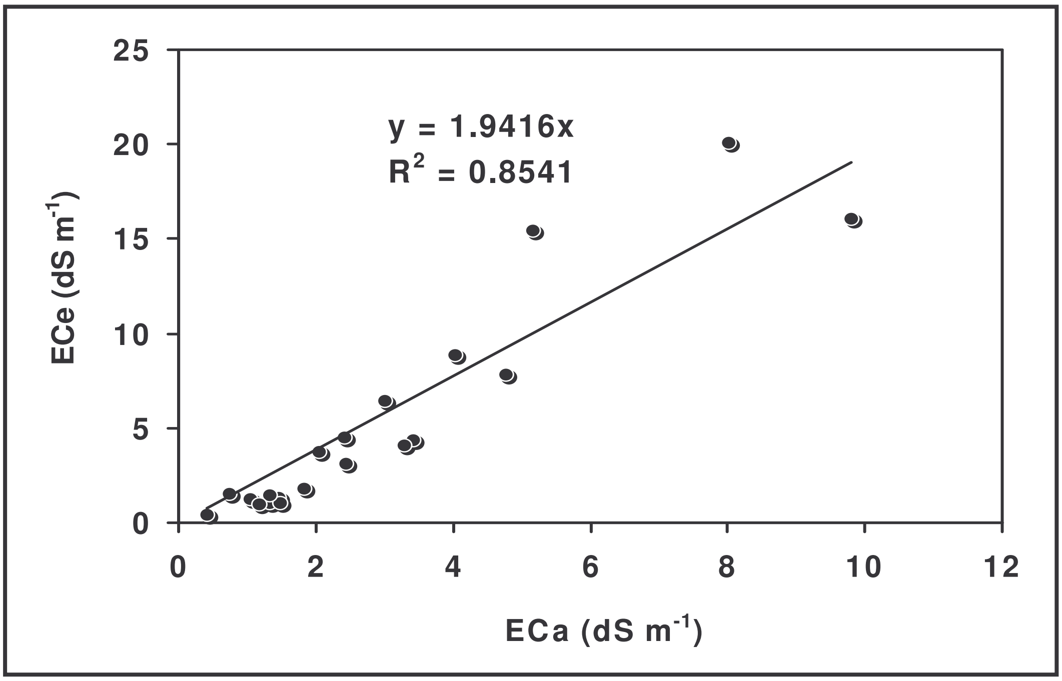

Figure 4. Calibration of EC_a described by a linear regression equation with EC_a on EC_e using 20 measurements.

The EC_a data collected with EM38 allowed conveniently mapping of spatial distribution of field soil salinity (Amezketa, 2007). Figure 5 shows spatial distribution of EC_e measurements assessed with using EC_a data collected with EM38. The average soil salinity calculated based on using actual EC_e data of the 20 composite soil samples was ~ 5.27 dS m^{-1} (Figure 3). Because the areal average soil salinity estimated from the salinity map (Figure 5) produced by using EM38 data were nearly the same (5.30 dS m^{-1}) with the mean of composite samples, the results lead us to conclude that calibrations with limited number of samples were adequate for describing salinity in large areas with EM38 device.

The results of this work showed that a good association existed between EM38 and ECe data. The calibration equation developed facilitated convenient assessment of soil salinity within the whole area of over 7000 ha. The equipment EM38 may therefore be a good device for monitoring the extent and severity of soil salinity in irrigation schemes.

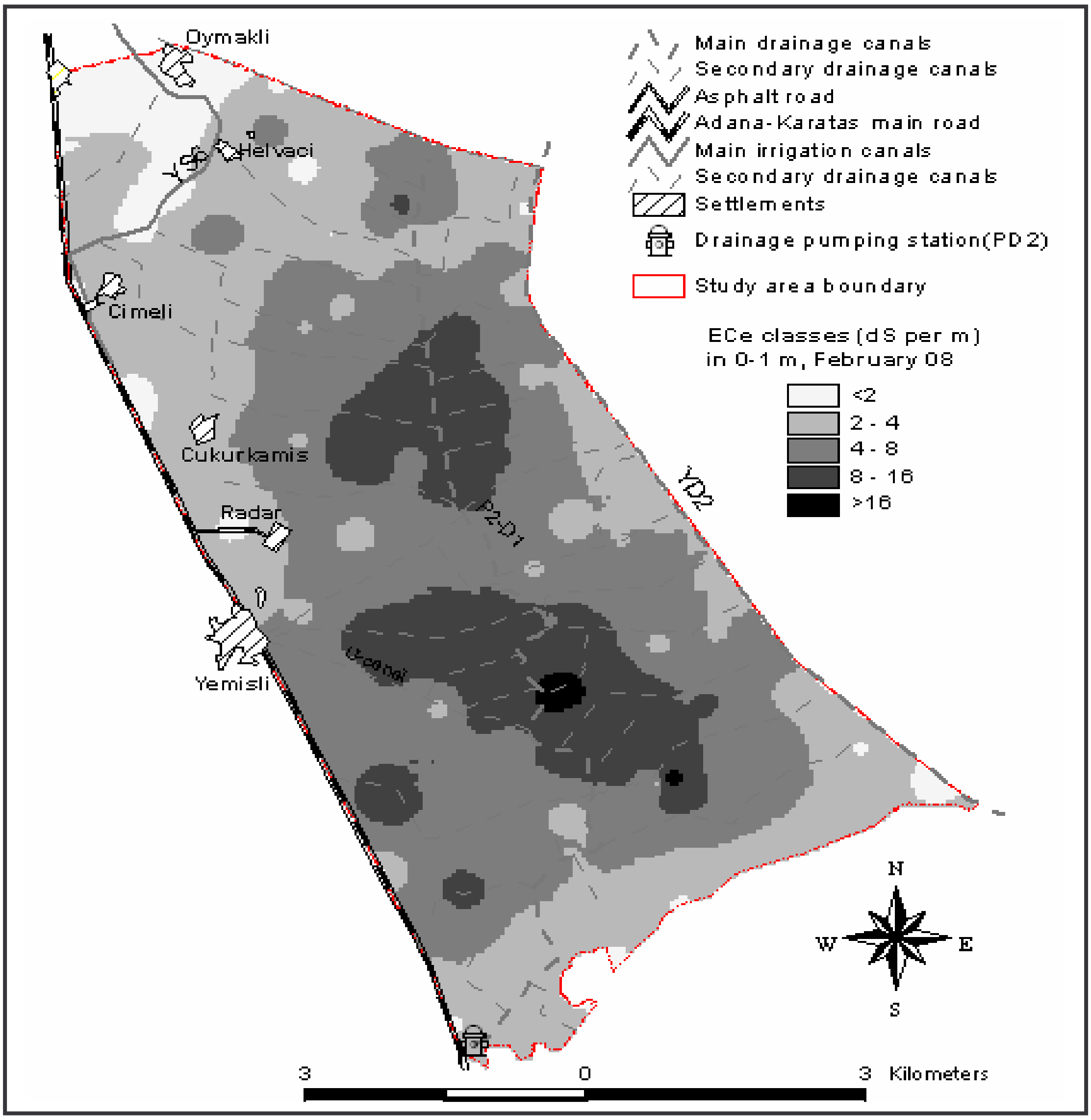

Figure 5. Salinity map constructed with EM38 data

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Application of Hydrus-2D for Simulation of Water Distribution in Different Types of Soils

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ABSTRACT

Study of water distribution in the soil as a result of water application involves simulation of water movement in porous media. Water distribution in the soil depends on the hydraulic properties of the soil. In the present study, water distribution in the root zone depth of the green pepper was simulated at various emitter discharges under different fertigation strategies for various types of soils. A two-dimensional water and solute transport model Hydrus-2D was selected for the simulation. Experiments were conducted with the research farm of Bastam Agricultural Center, Shahrood, Iran to investigate the water distribution pattern under different types of soils. Investigation of water distribution in soil was done in seven types of soils. For simulation of water movement in soil Hydrus-2D was calibrated and validated. Results of simulation indicated that for all the soils, water content was more in first layer of soil. Irrigation cycle was 48 hrs and adequate water content was available in the active root zone of the green pepper. Another result of this study showed that if the drip fertigation system designs properly, it will reduce drainage water below the crop root zone. Final result of simulation showed that in all types of soils amount of percolation from drainage boundary was less than one percent of applied water.

Keywords: fertigation, boundary condition, drip irrigation, simulation

INTRODUCTION

Fertigation under drip irrigation is being used commonly for the application of nitrogenous fertilizers in all fruits and vegetable crops. Many research studies have been carried out for the crop response under drip fertigation. Fertigation management is aimed at maximizing growers' income and minimizing environmental pollution.

A simulation model FUSSIM2 was developed by Heinen (2001) for drip fertigation to study various fertigation scenarios. In this study water movement was described using Richards' equation with the constitutive relationships given by the Van Genuchten and Mualem functions. The Richards' equation was implicitly solved using the control volume finite element method. The solute dynamics described using convective-dispersive process equation and was explicitly solved. The analysis was carried out with alternative fertigation strategies which reduce the number of field experiments. The study although did not develop any best fertigation strategy however, demonstrated the simulation model could help in finding the alternative fertigation strategies.

A properly calibrated and validated flow and solute transport model can reduce time and cost required for studying the water and nutrient dynamics under drip irrigation system. Simunek *et al.* (1999) developed the HYDRUS-2D software package for simulating two-dimensional movement of water, heat and multiple solute in variably saturated media. Ajdary (2005) used hydrus-2D model to simulation of water and nitrogen distribution in drip fertgation system.

Gardenas *et al.* (2005) investigated nitrate leaching for various fertigation scenarios under micro-irrigation. The effect of fertigation strategy and soil type on nitrate leaching potential for four different micro-irrigation systems was assessed. It was observed that seasonal leaching was the highest for coarse-textured soils. Antonopoules (2001) reported that nutrient leaching models provide an understanding of the relationship amongst the amount and timing of water and nutrient application. Many studies have reported that frequent or continuous fertigation of drip-irrigated vegetables is an efficient method of fertigation (Tompson *et al*.,2003; Hopman and Bristow, 2002; Ajdary *et al.*, 2007; Halvorson, 2002).

Water and solute transport models enrich the understanding of their movement in the soils and nutrient uptake by plants and can be valuable tools in designing drip fertigation system. Several models have been used for simulating the water and nutrient movement in drip fertigation system. However, most of these models describe the early stage of infiltration and provide an estimate of water content behind the wetting front (Clothier and Scotter, 1982). Although they are easy to implement, they deal mainly with design considerations of the drip source (Cote *et al.* 2003). Analytical solutions of transient axi-symmetrical infiltration (Warrick, 1974; Revol *et al.,* 1997) can simulate the dynamic condition associated with the drip irrigation but their application was limited in simulation of water and nutrient movement under drip fertigation system under simple boundary conditions. Numerical solution of water and solute transport equations can be an effective tool for simulating the time dependent flux and other boundary conditions. These solutions can implement wide range of boundary conditions, irregular boundary and soil variability. Comparison of HYDRUS-2D simulation of drip irrigation with experimental observations was investigated by Skaggs *et al.* (2004).
In this study, data were collected from drip fertigated green pepper crop field for simulating of water distribution in different types of soils using selected model Hydrus-2D.

MATERIALS and METHODS

In this study field experiments were conducted with green pepper crop. This crop was transplanted on 11 April 2007 in 12 plots. Area of each plot was 9 m^2. Plant to plant and row to row spacing were 25 cm and 40 cm, respectively. The applied fertilizers were 96 kg/ha of N, 50 kg/ha of P and 70 kg/ha of K. Experimental site was located at the Bastam Agricultural Center Farm, Shahrood, Iran which lies the latitudes of 36^0 27' 33.29" N and longitudes of 54^0 58' 31.85" E. Climate of Shahrood is categorized as semi-arid, subtropical with hot dry summer and cold winter. The mean annual temperature is 14.4^0 C. July and August are the hottest months with 40 years normal maximum temperature of 42^0C. January and February are the coldest months with a mean temperature of -14^0 however, the minimum temperature dips to as low as 1^0 C. The mean annual rainfall is 156.5 mm of which as much as 75 % is received during spring season (March to June).Soil samples were collected from different layers from surface till the depth of 0.9 m and analyzed to determine physical and chemical properties.

Drip System

In this research work a drip irrigation system was designed for green pepper crop transplanted in sandy loam soil using the standard design procedures. The control head of the system consisted of sand filter, screen filter flow control valve, pressure gauges etc. The system was connected with fertigation tank which was used for the application of fertilizers. A PVC sub main line (50 mm outer diameter, 4 kg/cm^2 working pressure) was laid for the experimental area. Lateral lines (10 mm diameter) were taken out from the sub main line for the irrigation of the onion crop. The lateral lines were spaced at 60 cm interval. The lateral lines were laid in such a manner that the same lateral line supplied water and fertilizer to all the randomized replicated plots. This caused zigzag path of laterals in the experimental area.

Drip emitters with 4 l/h rated discharge were placed on the lateral line at a spacing of 50 cm. Each lateral line was provided with flow control valve at the start of the line. Average emitter discharge observed in the field condition was 4 l/h. Drip laterals were spaced at 0.60 m. The emitter to emitter spacing was 0.50 m. Each lateral served two plant rows. Total number of emitter in each plot was 35. Irrigation scheduling is determination of amount, time, interval and duration of irrigation. Water requirement of onion crop was estimated using the pan evaporation method. Five years average daily pan evaporation values were multiplied with the pan and crop coefficients to estimate the daily crop water requirements. Irrigation requirement was estimated by subtracting corresponding effective rainfalls. Irrigation was applied on every alternate day. On an average irrigation was applied 3 days in a week. Amount of water applied was 5000 m^3/ ha.

Observations

To determine the amount of water in the various layers of the soil and their spatial and temporal distribution, soil samples were collected from different depths (0-15, 15-30, 30-45, 45-60 cm) at different times using tube auger as per sampling schedule. Determination of soil moisture was done by gravimetric method.

Hydrus-2D Model

In this research work a water and solute transport model Hydrus-2D was used to simulate the water distribution. Hydrus-2D is a finite element model, which solves the Richard's equation for variably- saturated water flow and convection-dispersion type equations for heat transport. The flow equation includes a sink term to account for water uptake by plant roots. The model uses convective-dispersive equation in the liquid phase and diffusion equation in the gaseous phase to solve the solute transport problems. It can also handle nonlinear nonequilibrium reactions between the solid and liquid phases, linear equilibrium reactions between the liquid and gaseous phases, zero-order production, and two first–order degradation reactions: one which is independent of other solutes, and one which provides the coupling between solutes involved in sequential first-order decay reactions. The program may be used to simulate water and solute movement in unsaturated, partially saturated, or fully saturated porous media. The model can deal with prescribed head and flux boundaries, controlled by atmospheric conditions, as well as free drainage boundary conditions. The governing flow and transport equations are solved numerically using Galerkin-type linear finite element schemes. The current version 2.0 of Hydrus-2D also includes a Marquardt-Levenberg parameter optimization algorithm for inverse estimation of soil hydraulic and/or solute transport and reaction parameters from measured transient or steady state flow and/or transport data. A detail description of model and related theory is presented in the report documents version 2.0 of Hydrus-2D (Simunek *et al.*, 1999)

The simulations were done for a soil profile of depth Z = 60 cm and radius r = 30 cm, with a trickle emitter placed at the surface (Figure 1). The flux radius was taken equal to the wetted radius considering emitter in centre. Surface area for irrigation without causing ponding was determined from the flux radius and subsequently flux per unit area, resulting from single emitter was estimated. Fig. 1 shows the conceptual diagram of simulated area and the imposed boundary conditions. No flux was allowed through the lateral boundaries. Bottom boundary was considered as free drainage boundary. Surface boundary was considered as variable flux boundary (up to the radius of 25 cm) and atmospheric boundary for the remaining 5 cm radius. The system was conceptually divided into four layers depending the variability of the soil physical properties.

Initial distribution of the water content in different soil layers within the flow domain was kept as observed in the experimental field. For the purpose of investigating the influence of drip emitter discharge, soil hydraulic properties and frequency of water input on wetting patterns, a time dependent flux boundary condition at the surface in a radius of 25 cm from emitter position emitter was used. This was done to take into account the irrigation and no irrigation periods and temporal changes in duration of irrigation in the growing period. In the present case, water table was situated far below the domain of interest and therefore free drainage boundary condition at the base of the soil profile was considered. On the sides of the soil profile, it was assumed that no flux of water took place and hence no-flux boundary condition was chosen, which in Hydrus-2D is specified for impermeable boundaries where the flux is zero perpendicular to the boundary.

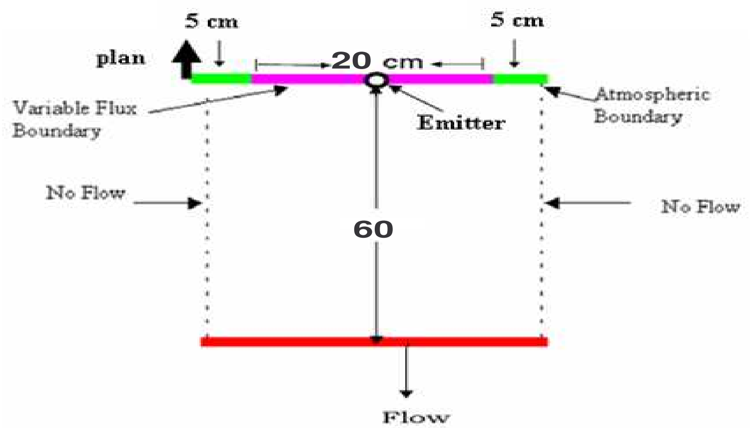

Figure 1. Simulated area with 30 cm radial direction and 60 cm soil depth

RESULTS and DISCUSSION

Calibration of Model

The model was calibrated mainly for hydraulic conductivity values of the sandy loam soil. Model worked well with the measured hydraulic conductivity values. Results of the calibration for water distribution at the end of first month after transplanting is presented through Figures 2 and 3. X-axis of this figure shows volumetric water content and Y-axis shows depth from the soil surface. Field observations for water content in the soil were taken at the end of first month and second month at 2, 4, 12h after irrigation. Simulated and observed values of water at 2, 4 and 12 h after irrigation were used to evaluate the performance of the model.

Figure 2 shows that simulated and observed water contents follow a similar trend and there is not much difference between simulated and observed values. Values of simulated and observed water content at the end of 2, 4 and 12 h after irrigation varied from 20 to 38% , 21 to 35% and 22 to 35% respectively.

Figure 3 also shows that simulated and observed water contents follow a similar trend and there is not much difference between simulated and observed values. Values of simulated and observed water content at the end of 2, 4 and 12 h after irrigation varied from 23 to 37% , 20 to 35% and 19 to 36% respectively.

Correlation coefficient between observed and simulated water contents were determined to find out the closeness between them. The higher R^2 values (varying from 0.94-0.97) showed that simulated and observed values are closely related.

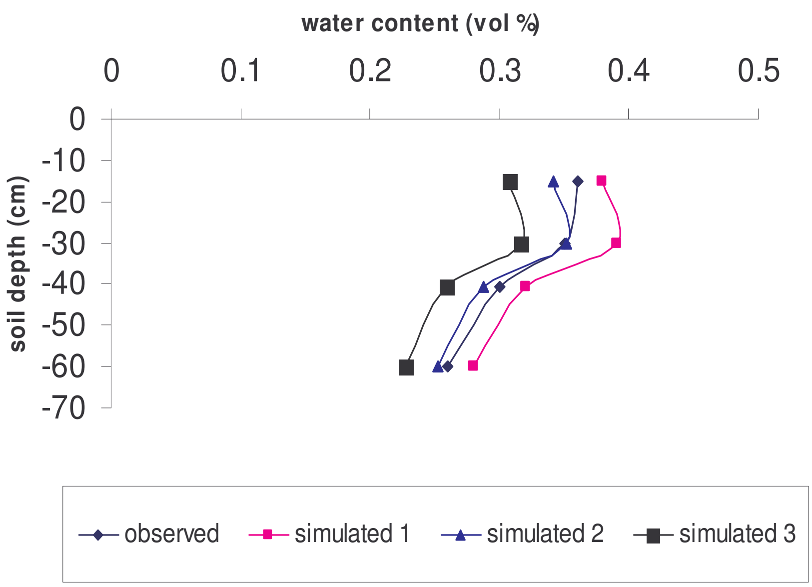

Figure2. Comparison of simulated and observed water content in first month after transplanting: simulated1=2 h, simulated 2= 4 h and simulated 3= 12 h after irrigation.

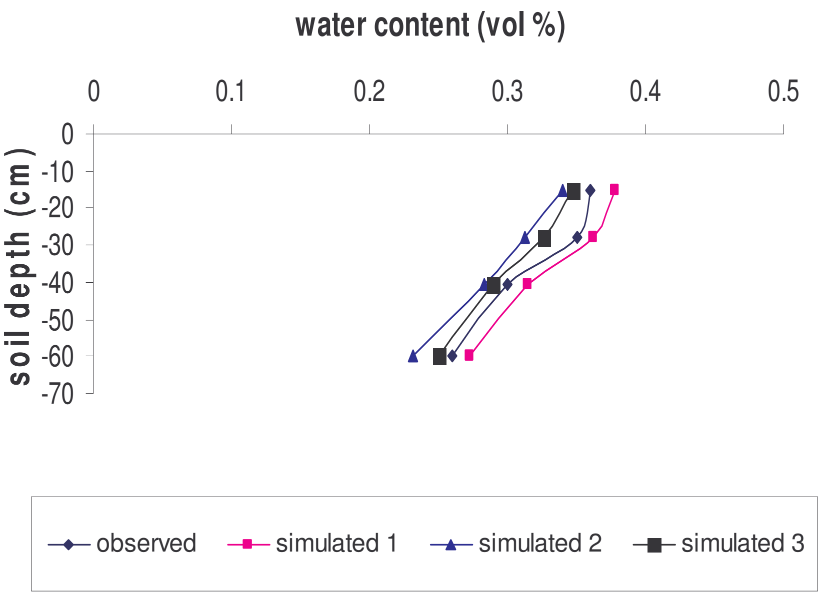

Figure 3. Comparison of simulated and observed water content in second month after transplanting: simulated 1=2 h, simulated 2= 4 h and simulated 3= 12 h after irrigation.

Simulation of Water Distribution

Simulation of water distribution at the end of first month after transplanting 2h after irrigation with emitter discharge of 4 l/h in sandy loam soil is presented in Fig. 4 through color spectrum. It may be mentioned that initial moisture content was kept same in various soil layers. The duration of irrigation was 1 h. The color spectrums in this figure shows simulated values of water content 2 h after irrigation. X-axis of this figure shows 30 cm radial distance from emitter and Y-axis shows depth from the soil surface. This figure shows that 2 h after irrigation amount of water content was highest in first layer of soil which means in this duration only first layer of soil has got maximum water content. Fig.4 (a) shows that 2 h after irrigation amount of soil moisture not coming down and it is not effecting second layer of soil (middle layer). Fig.4 (a) shows that 2 h after irrigation effect of water distribution increasing only in upper layer. Scale of colure spectrum reveals that adequate soil moisture is available even12 h after irrigation in soil layers.

Simulated water content distribution 12 h after irrigation is presented in fig.4(b). This figure reveals that water content at 12 h after irrigation is nearly same in radial direction. This may be due to the fact that the emitter discharge was distributed uniformly over the radius of 30 cm as the time dependent variable boundary condition at the soil surface. This figure shows water distribution in sandy loam soil under 4 l/h emitter discharge and at 12h after irrigation. Analysis of this figure shows that water content in the first layer decreases at a little faster rate with the elapsed time after irrigation compare to other layers. Applied flux was calculated from the emitter discharge rate of 4 l/h distributed uniformly over the radius of 20 cm. In this case, duration of irrigation was 60 minutes.

It may be mentioned that 24 h after irrigation the initial moisture content in first, second, third and forth layers were 0.29, 0.27, 0.25, 0.23. Analyzes of color spectrums revealed that free drainage water below the crop root zone is less than one percent of applied water.

Simulated water content distribution 4 h after first irrigation at surface and 15 cm depth under 4 lh-1 emitter discharge rate are presented through Fig. 5. This figure reveals that water content at 4 h after first irrigation is nearly same in radial direction for each soil layer. This may be due to the fact that the emitter discharge was distributed uniformly over the radius of 30 cm as the time dependent variable boundary condition at the soil surface. However, simulated moisture content varied with the soil layer near the surface as well as 15 cm depth. In both the cases, water content was lowest in case of last layer. In this study irrigation interval was 48 h and adequate amount of moisture was available in active crop root zone in this duration.

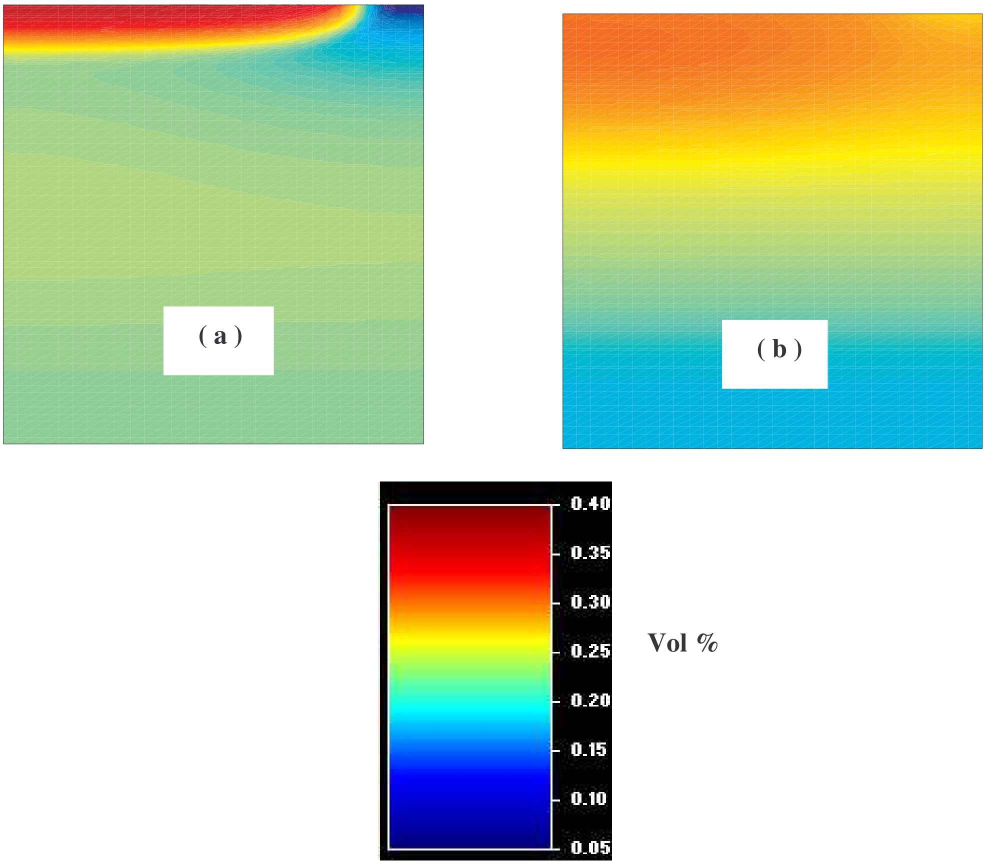

Figure 4. Simulated water content distribution with 4 lh-1 emitter discharge (**a**) 2 h after irrigation (**b**) 12 h after irrigation

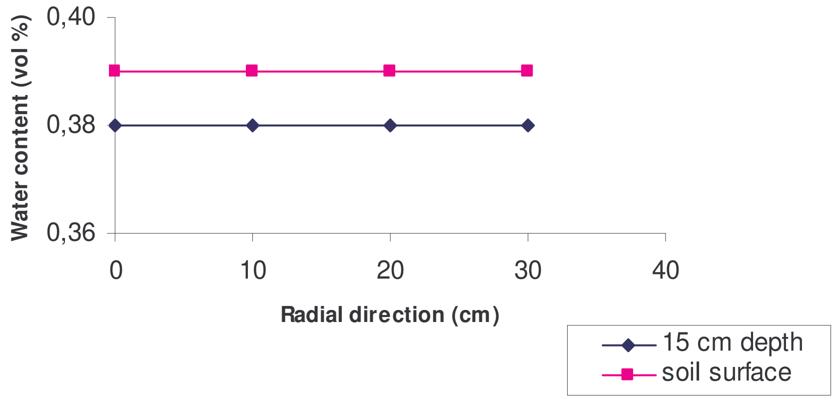

Figure 5. Simulated water content distribution in radial direction 4 h after irrigation

It may be mentioned that in this research work simulation of water distribution was done in different types of soil but in this paper only results of simulation of water distribution in sandy loam soil are presented.

CONCLUSION

Observed moisture contents at various points in the root zone of green pepper were used to calibrate the water and solute transport model, Hydrus-2D. Field experimental was also conducted to study the water distribution in a sandy loam soil irrigated by drip irrigation system. Simulation of water distribution in various soils were done with average emitter discharge rate of 4 l/h. Simulation studies and experimental work have led to conclude that adequate water content was maintained in the active root zone up until 48 hr after irrigation. Further, this research suggests that irrigation scheduling on alternate day bases is an appropriate cycle. It has also been shown that if the drip system design properly, it will distributes water uniformly in radial direction. This study also revealed that in a proper fertigation system free drainage water below crop root zone in sandy loam soil was less than one percent.

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Correlation Coefficient Analysis Between Grain Yield and Its Components in Corn (Zea Mays L.) Hybrids

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ABSTRACT

In order to study of the correlation coefficient analysis between grain yield and its components in maize hybrids an experiment was carried out in randomized complete block design with four replications in Shahrood Agricultural Research Station during 2006-07. The result of correlation analysis between grain yield and other traits showed that number of grains per ear and 100 grain weights had high and positive direct effects and ear length had positive and moderate direct effect on yield. Furthermore, ear height had low and negative direct effect on grain yield.

Key Words: Correlation coefficient, Grain yield, Maize hybrid, Path analysis

INTRODUCTION

Estimation of simple correlation between various agronomic characters may provide good information necessary for maize breeders, when, selection is based on two or more traits simultaneously. Information obtained from correlation coefficients for these characters could also be useful as indicators of the more important ones under consideration. The association among traits may be measured by gerotypic and/ or phenotypic coefficients of correlation depending on the types of studied materials and the kind of experimental design used (Sadek et al(2006)). it is worthy to mention that the characters most responsible for variation plant yield(directly and indirectly) were in order of importance, LAI, blades area, ears dry weight/plant, number of kernels/ row, number of days to 50% of plant silking , ear length, ear diameter, plant height, 4th leaf area, 100 kernels weight, ear height and migration coefficient. Mohan et al (2002) studied path analysis on corn cultivars (169 cultivars) for grain yield and oil content and resulted that number of seed per row, 100 seed weight, Number of seed row and ear, Length had direct effect on grain yield and ear height, plant height and number of days until 50% Tasseling had most minus direct effect on grain yield. Our intention from this investigation is to study correlation and path coefficient analysis. Thus, the path coefficient analysis which in turn associated with yield. Thus, the path coefficient analysis which measure the direct influence of one variable upon another and permits the separation of the simple correlation coefficient into components of direct and indirect effects was done according to Wright and Snedector and Cochran.

MATERIALS and METHODS

In order to selection of best hybrids of corn between 17 hybrids (including KSC700, ZP434 ,BC678 COVENTRY , MAVERIK,PONCHO , BC504 , BC666, BC404,NS540 ,OSSK444 ,OSSK499 ,OSSK590 ,KOSS444 ,CISKO) an experiment was carried out as Randomized complete block design with 4 replications in Agricultural Research Station of Shahrood. Plots included 2 rows of corn with 6 mt in each row. Distance between rows was 70 cm and between plants 20 cm . Traints included plant height without tassel, plant height with tassel, cub dry weight, seed dry weight, Number of seed row per ear, Number of seed per row, Number of seed per ear, seed deep, ear length, ear diameter, cub diameter, 100- seed weight, seed yield, Biological yield and harvest index. Analysis of variance did with SAS program.Correlation analysis did with SPSS program ver. 9 .

RESULTS and DISCUSSION

Components of variance revealed a wide range of variability for all the characters. Variance arising due to differences among genotypes were highly significant for all the characters.

Analysis of variance showed different between that all of traits between hybrids was significant. Except for Number of seed per ear, seed deep, ear diameter and cub dry weight traits phenotypic correlation coefficient showed that grain yield had highly significant and positive correlation with all of traits except cub diameter, ear height(P<1%).

For separating of simple correlation coefficient between traits to direct and indirect effects with using of path analysis, grain yield used as depend variable and step wise regression analysis did. Seed dry weight was eliminated because it hidded effects of other traits. Results showed that Number of seed per ear, 100 seed weight, ear length, ear height had high significant effect on grain yield(82% of grain yield variation) for calculating of direct effect on yield, path analysis estimated (Table 1). Results showed that Number of seed per ear (0.51) and 100 seed weight (0.41) had maximum and minimum effect on grain yield. Ear length had moderate and positive effect on grain yield (0.21) but ear height had negative direct effect (0.12) on grain yield inspite of (Non significan correlation coefficien with grain yield. This results showed that simple regression cefficient is not enough for selection of traits which effect grain yield. Indirect effect of traits showed that only ear length trait had highly significant effect (0.35) on grain yield through out Number of seed per ear and indirect effect of other traits was not important. Then, Number of seed per ear and 100 seed weight traits significantly effected graim yield and could be used as selection index for selection of corn hybrids with high grain yield. Ear length trait was important after number of seed per ear trait and 100 seed weight trait and effected yield directly and inehiretly by number of seed per ear trait (r= 0.76), this trait could be another trait for inerease of yield.

In directly effect of this trait was throught 100 seed weight (r=0.146), ear length (r=0.144) traits and correlation coefficient was significant. Indirect effect of namber of seed per ear trait through out of ear height (r=0.0321) was minus. Directly and index effect of 100 seed weight trait (r=0.41) was through out other traits. This trait through out number of seed per ear (r=0.18), ear length (r=0.08), and ear height traits had direct effect on grain yield. Direct and indirect effects of 100 seed weight on grain yield produced significant correlation coefficient (r=0.68**). Direct and indirect effect of ear length on grain yield was throught out all of studied traits. Maximum and minum indirect effect on yield was thrugh out number of seed per ear (r= 0.35), 100 seed weight (r=-0.16) and ear height (r=0.02) traits.

Correlation between ear length and grain yield was through out indirect effect of number of seed per ear (r=0.35). ear height was last trait that explaired by path analysis and had positive indirect effect on grain yield by ear length (0.04) and number of seed per ear (0.13) and negative indirect effect 100 seed weight (r=-0.06) correlation between. This trait with grain yield was non significan(r= -0.014). (Table1).

Table 1. Path analysis of 17 hybrids of corn for grain yield

Correlation with seed yield	Ear height	Ear length	100 seed weight	Number of seed per ear	Independet traits
**0.761	-0.0321	0.1446	0.1469	0.5128	Number of seed per ear
**0.678	0.0198	0.0829	0.4175	0.1805	100 seed weight
**0.699	-0.0275	0.2111	0.1640	0.3512	Ear length
-0.014	-0.1256	0.0462	-0.0659	0.1312	Ear height

0.87 = R^2
E = 0.42
** , significant at 5% level

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The Study of Phenotypic Variation and Cluster Analysis for Quantitative Traits of Corn (Zea mays L.)

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ABSTRACT

In order to study the relationships between grain yield an experiment was carried out in randomized complete block design with four replications in Shahrood Agricultural Research Station during 2006-07. Cluster analysis with minimum ward variance method grouped the hybrids in 4 groups. In order to proving the truth of the classification obtained from cluster analysis discriminate function analysis and multivariate analysis verified the accuracy of classification from cluster analysis and grouped the hybrids in 4 groups. Result of four methods of multivariate analysis of variance Wilk's lambda showed that there were significant differences between 4 groups resulted from the cluster analysis

Keywords, Cluster analysis, Discriminate function analysis and Multivariate analysis,

INTRODUCTION

Cluster analysis is commonly used for studying the genetic diversity and for forming core subjects for grouping accessions with similar characteristics into homogeneous categories. Rahimian. S. et al (2004) classified rice cultivars to 5 groups with cluster analysis. Abozari (2006). Classified IRANIAN and foreign rice cultivars to 4 groups with cluster analysis for hybrids production and breeding for high yield.

MATERIALS and METHODS

In order to evaluation of selection of best hybrids 17 hybrids KSC700, NS540, OSSK444, OSSK499 ,OSSK590 , ZP434 ,BC678, COVENTRY , MAVERIK, BC504 , BC666, BC404, KOSS444 ,CISKO, PONCHO was studied in Randomized complete block design with 4 replications. Agricultural Research Station of Shahrood.

Plots included 2 rows of corn with 6 mt in each row. Distance between rows was 70 cm and between plants 20 cm. Traints included plant height without tassel, plant height with tassel, cub dry weight, seed dry weight, Number of seed row per ear, Number of seed per row, Number of seed per ear, seed deep, ear length, ear diameter, cub diameter, 100- seed weight, seed yield, Biological yield and harvest index. Analysis of variance did with SAS program. Correlation analysis did with SPSS program ver. 9

RESULTS and DISCUSSION

Analysis of variance showed that all of traits between hybrids was significant. Classification of hybrids resulted into 4 clusters grouping of 17 genotypes.Cluster 1 accommodated maximum number of genotypes

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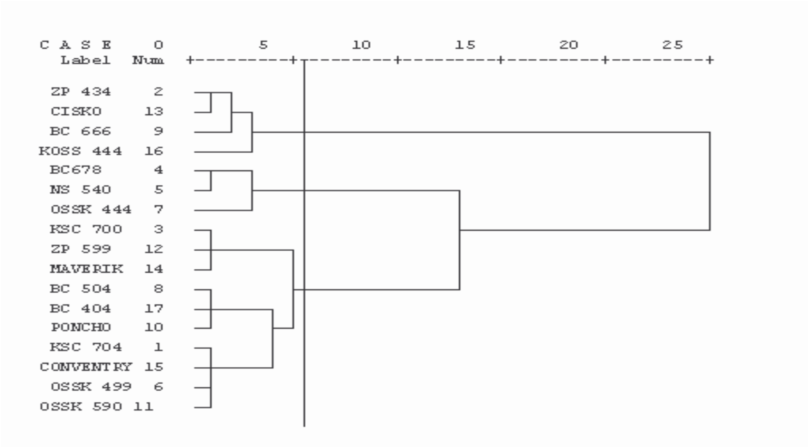

Figure1. Dendrogram of corn hybrids on different traits using ward method

First group including hybrids ZP 434, CISKO, BC 666 and KOSS 444. first group hybrids for Ear diameter (4.2), Number of seed per row (35.44), Number of seed row (14.81), 100 seed weight (28.84), Seed dry weight per ear (106.10), Number of seed per ear (519.95), Seed yield (7798.75), Seed deep (0.6807), Biological yield (17912.5) were lower than general mean. This cluster and its hybrids are valuable because Cub diameter (2.818), Ear length (20.64), Plant height without tassel (172.4), Plant height with tassel (207.25), Ear height (72.03), Cub dry weight per ear (16.09) and Harvest index (0.4303) were high. Between these traits together and with grain yield correlation is high and positive and could be used for hybrid and transform of desirable traits. Second group included hybrids BC 678, NS 540 and OSSK 444. Second group hybrids for Cub diameter (2.895), Ear length (20.28), Number of seed per row (34.92), Plant height without tassel (179.36), Plant height with tassel (218.06), Ear height (81.33), Cub dry weight (17.71), Seed yield (6685.33) and Harvest index (0.5072).

Third group including KSC 700, ZP 599 and MAVERIK. Third group hybrids for Cub diameter (2.996), Number seed row (14.58) and Ear height (77.33), Ear diameter (4.15), 100 seed weight (22.77), seed dry weight (69.37), Number of seed per ear (462.86), Seed deep (0.5979), Ear length (18.23), Cub dry weight (15.83), Seed yield (4955.66), Harvest index (0.3858), Biological yield (13620), Number of seed per row (31.75), Plant height without tassel (167.76) and Plant height with tassel (205.96).

Group including BC 504, BC 404, PONCHO, KSC 704, CONVENTRY, OSSK 499 and OSSK 596. group hybrids for Ear diameter (4.198), 100 seed weight (25.98), Plant height without tassel (176.8), Plant height with tassel (214.01), Seed deep (0.6866) and Biological yield (15084.28).Seed dry weight per ear (85.96), Number of seed per ear (484.78), Ear length (19.46), Cub dry weight (16.34), Seed yield (6488.28), Harvest index (0.4351), Number of seed per row (34.05) and Ear height (76.37) and seed deep at this cluster were high which could be used for confluence. First group of cluster had high yield and yield components and could be used for production of new hybrids. Second cluster hybrids could be used for plant height trait. Forth cluster hybrids could be used for harvest index and seed deep hybrids. Mean bias percent for each of groups measured for 16th traits. This bias revealed that there was variation in hybrids. In each groups, genetic relationships are high and between each groups are low, then for confluence and heterosis different groups hybrids according to traits man value for each of groups could be used. There were not differences between 4th groups of hybrids according to distinction function correction groups selection according to cluster analysis was about 94.1%. For test of correction groups selection according to cluster analysis multiple variance analysis and wilks lambda statistical carried out and showed significantly differences between groups carried out by cluster analysis.

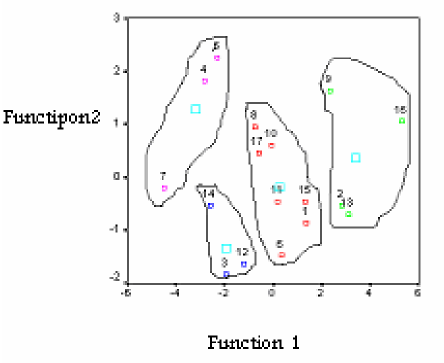

Figure 2. Canonical discriminate functions by fisher method

	dft	dfe	valid	F	Pr<F
Wilk's lambda	3	13	0.541	3.67	0.04

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Measuring Water Flow Velocity and Discharge with Acoustic Doppler Velocimeter (ADV)

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ABSTRACT

The discharge measurement in river is the basis for using of water, planning, designing and operating water management and development projects. The traditional method of measuring the discharge is based on measurement of the water velocity and cross section area. Current meters are commonly used to determine of water velocity but they require calibration at frequent intervals in laboratory flumes to get accurate results. Because cup and propeller equipments of current meters may be physically damaged, especially river conditions. Recently, acoustics velocimeters are increasingly used with the advances in remote sensing and data processing techniques. There are currently several manufacturers of commercial acoustic devices but the general principles of operation are based on the Doppler shift effect which is the difference in frequency (shift) between transmitted pulses and received echoes in water. Acoustics velocimeters provide accurate and economical discharge measurements with simple and fast operation under different flow conditions. The purpose of this paper is to present principles of operation of acoustic Doppler velocimeters with results of field and open channel discharge measurements.

Keywords: Flow rating curve,flow velocity, acoustic, dopplers shift,

INTRODUCTION

Accurate flow and discharge measurement is crucial for an efficient river basin management and especially for flood forecasting and planning and management of water storage structures. The traditional method of measuring the discharge in hydrological practice is to measure the water level and to convert into discharge by using the rating curve, which indicates the relationship between the level and discharge. The rating curve is obtained from direct measurements of discharge, which are done at convenient times with measurements of flow velocities at different points over the gauging cross section. (Sen 2003).

There are different methods to measure of the velocity of water, such as, floating material, chemical gaging, and current meters. Measurement of floating material is a simple method but it can not represent profile velocity of water. Current meters are commonly used which two different types: cup and propeller. Current meters should be recalibrated at frequent intervals in laboratory flumes to get accurate results (Usul 2001).

Recently, with the technological advances, acoustic velocimeters are used to measure water velocity in rivers. (Takeda 2002, Chanson at al., 2008, Yau Lu at al., 2006). Acoustic water velocity measurement has been used since 1980s. The early instruments required deep water (more than 3-4m), which limited their use to deep water river or estuaries. In advanced acoustic Doppler instrument was developed that could be used in sallow waters (Yorge and Oberg 2002). In this study an acoustic instrument and principles of operation are presented with a field measurement results at river and channel conditions.

Principles of Acoustic Velocity Measurement

The difference in frequency (shift) between transmitted pulses and received echoes, known as the Doppler Effect, can be used to measure the relative velocity between the instrument and suspended material in the water that reflects the pulses back to the instrument. The acoustic Doppler profiler uses the Doppler Effect to compute a water velocity component along each beam (Kostaschuk et al. 2005)

$$F_D = 2F_S(V / c)$$

Where;

F_D : change in received frequency

F_S: frequency of transmitted sound

V: velocity of source relative to receiver, represents the relative speed between source and receiver (motion that changes the distance between the two).

c: speed of sound

There are different types of acoustic velocimeter and sensors. Although they have different geometric configuration, transducer characteristics, emitting and measuring frequency, etc., they share the same principle and similar properties. The FlowTracker Handheld ADV (Acoustic Doppler Velocimeter) is designed for a variety of current monitoring applications. (Fig.1). The FlowTracker can be used for: river discharges measurement, open-channel flow measurement, current measurements in large pipes, multi-point current surveys, and, current monitoring in water treatment facilities. The principles of velocity measurement with this device as fallows (SonTek/YSI Inc, 2007):

- The transmitter generates a short pulse of sound at a known frequency (Fig 3).
- The sound travels through the water along the transmitter beam axis.
- As the pulse passes through the sampling volume, sound is reflected in all directions by particulate matter (sediment, small organisms, bubbles).
- Some portion of the reflected energy travels back along the receiver beam axes.

• The reflected signal is sampled by the acoustic receivers. The receiver sees an increase in signal strength (fig 3).

• The FlowTracker measures the change in frequency (Doppler shift) for each receiver

Figure 1. FlowTracker with 2D probe.

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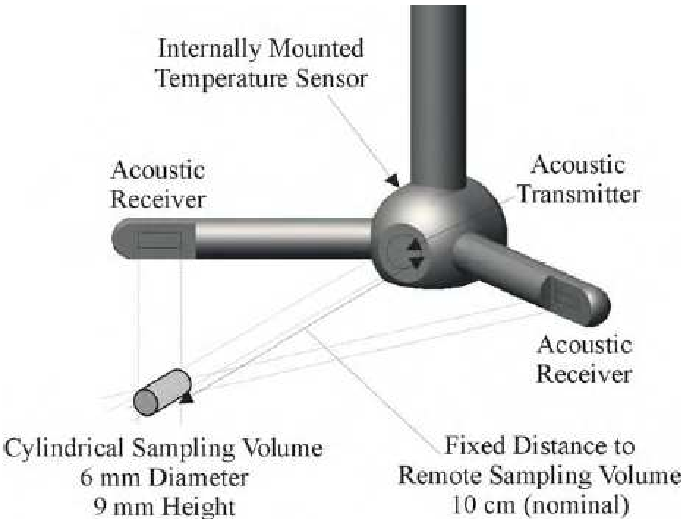


Figure 2. The detail of FlowTraker probe and sampling volume (SonTek/YSI Inc, 2007).

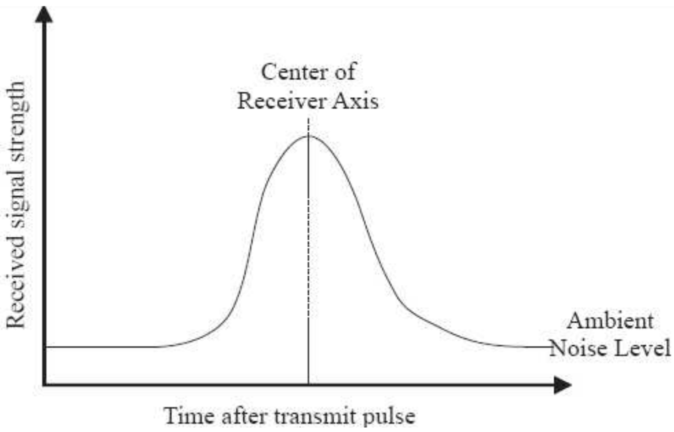
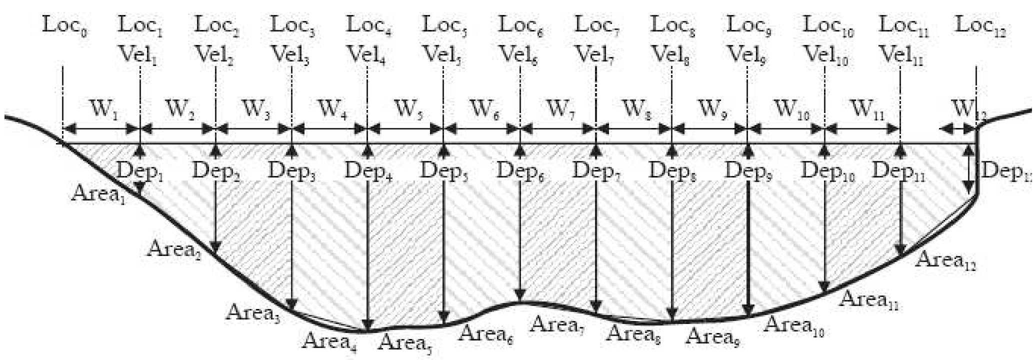


Figure 3. FlowTracker Signal Strength Profile (SonTek/YSI Inc, 2007).

Field Measurements

Field measurements were conducted at river and open channel condition. The average of the velocities at 20% and 80% depth below the water surface is used to estimate the mean velocity in profile. For shallow flow (<50 cm) at 60% depth below the water surface may be used to approximate the mean velocity (Chow, 1959; Usul 2001).In this study flow depth was measured lower than 50 cm and, velocity measurements were taken on 60% depth level. The mean section method was fallowed to calculation discharge calculation with flow depth and velocity values. This method is described in ISO Standard 748 (1992). Figure 4 shows the mean section equation.



i: edge station, j; adjacent station

Station width; $W_i = Loc_i - Loc_{i-1}$;

Station area; $Area_i = W_i * (Dept_i + Dep_{i-1})/2$

Station velocity; $Vel_i = (Vel_i - Vel_{i-1})/2$;

Station discharge ; $Qi = Vel_i * Area_i$;

Total discharge ; $Q = Sum*Q_i$

Figure 4. Mean section discharge equation (SonTek/YSI Inc, 2007)

RESULTS and DISCUSSION

The results of river and open channel discharge measurement with FlowTracker devices were given at Table 1 and 2. In addition, depth, velocity and percentage of discharge values are shown on cross section of river and open channel. Fig (5).

Table 1. FlowTracker discharge measurement summary for river

Units	metric units	Disch. equation		Summary			
Distance Velocity Area Discharge	: m : m/s : m^2 : m^3/s	Mean Section		Total Width Total Area Mean Depth Mean Velocity Total Discharge		:20.000 :5.555 :0.242 :0.613 :4.206	
Station	Location	Depth	Velocity	Width	Area	Discharge	%Q
0	0	0.000	0.000	0.000	0.000	0.000	0.000
1	1	0.270	0.486	1.000	0.135	0.033	0.780
2	3	0.430	1.043	2.000	0.700	0.535	12.722
3	5	0.460	0.945	2.000	0.890	0.885	21.031
4	7	0.220	0.821	2.000	0.680	0.600	14.274
5	9	0.250	1.058	2.000	0.470	0.442	10.497
6	11	0.180	0.655	2.000	0.430	0.368	8.755
7	13	0.250	0.632	2.000	0.430	0.277	6.578
8	15	0.240	0.586	2.000	0.490	0.298	7.094
9	17	0.380	0.721	2.000	0.620	0.405	9.632
10	19	0.220	0.414	2.000	0.600	0.341	8.095
11	20	0.000	0.000	1.000	0.110	0.023	0.541

Table 2. FlowTracker discharge measurement summary for open channel

Units	metric units	Disch. equation		Summary			
Distance Velocity Area Discharge	: m : m/s : m^2 : m^3/s	Mean Section		Total Width Total Area Mean Depth Mean Velocity Total Discharge		:4.400 :1.783 :0.322 :1.571 :1.320	
Station	Location	Depth	Velocity	Width	Area	Discharge	%Q
0	0	0	0	0	0	0	0
1	0.350	0.250	0.675	0.350	0.044	0.015	1.119
2	0.700	0.480	0.820	0.350	0.128	0.095	7.238
3	1.450	0.480	0.764	0.750	0.360	0.285	21.610
4	2.200	0.480	0.763	0.750	0.360	0.275	20.833
5	2.950	0.480	0.788	0.750	0.360	0.279	21.160
6	3.700	0.480	0.723	0.750	0.360	0.272	20.614
7	4.050	0.250	0.604	0.350	0.128	0.085	6.424
8	4.400	0.000	0.000	0.350	0.044	0.013	1.001

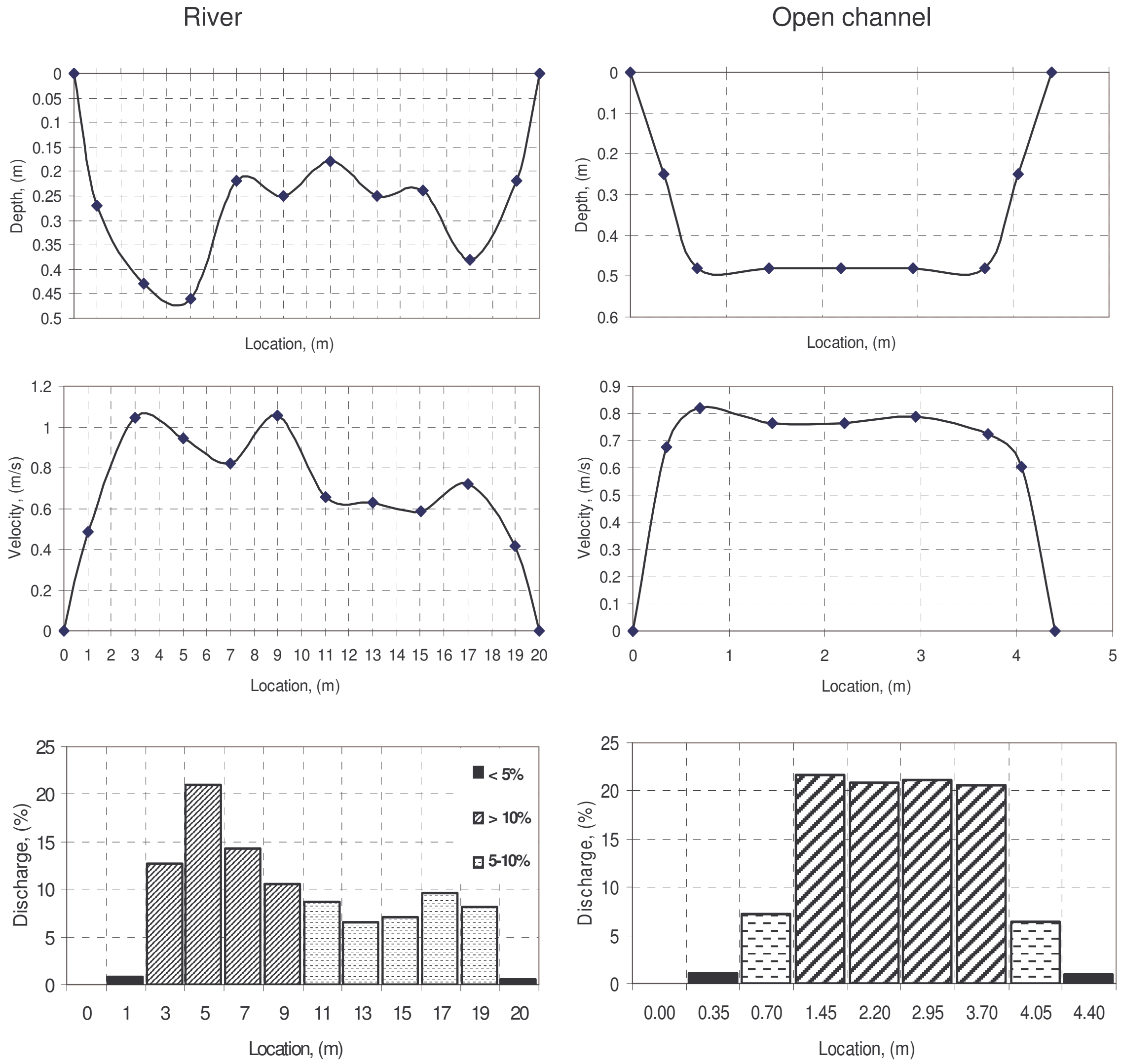


Figure 5. Discharge measurement results on cross section of river and open channel

Acoustic velocimeters provide accurate and economical discharge measurements with simple and fast operation under different flow conditions on rivers and open channel conditions. The other advantage is calibration of devices doesn't change unless the probe is physically damaged and thus periodic calibration is not required. However, water quality and some environmental condition may effect on precisely determine of velocity (Voulgaris at al., 1998; Mueller 2002). It is known that a temperature change of 5^0C or a salinity change of 12 ppt results in sound speed change of ≈1%. Acoustic velocimeters include a temperature sensor and user input value of salinity is used for automatic sound speed correction (SonTek/YSI Inc, 2007). In addition, as with any equipment, the accuracy of velocity and discharge measurements with an acoustic velocimeter depends on the training, skill, and experience of instrument operators. Finally acoustic velocity measurements seem favorable method for continuous monitoring river and open channel discharge studies in future.

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Watershed Modeling with ArcSWAT: Calibration and Validation for the Prediction of Flow, Nitrate and Phosphorus load

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ABSTRACT

The European Water Framework Directive requires that all surface waters and groundwater within defined river basin districts must reach at least 'good' status by 2015. Thus, the directive requires the development of management strategies to restore rivers and lakes to "good" status within a specified timeframe.

Simulation models are essential tools to evaluate potential consequences of proposed strategies and to facilitate management decisions. One of the most commonly used river basin model is ArcSWAT, a combination of the simulation model SWAT with a GIS user interface.

To test the application of ArcSWAT under German conditions, a relatively small watershed (52 km²) with sufficient data on soils, land use, climate, water flow and river water quality was selected. The watershed shows a wide variety of land use (intensive farm land, extensive pasture, and forest), soils (light sandy soils and heavy loams), surface slopes (flat to 30 % slope) and a few potential point sources of nutrients, like fish ponds, wastewater treatment plants and a public compost plant. The measured Phosphate concentration over a period of 20 years was relatively uniform and low (0.2 mg/l), whereas the Nitrate concentration varied considerably between 10 and 50 mg/l.

The model was calibrated and validated for the prediction of flow, Nitrate and Phosphate concentration and load at the main basin outlet. Sensitive model parameters were determined and adjusted within feasible ranges to minimize model errors monthly flow and quality data. The calibration resulted in good model predictions of the monthly discharge, whereas the error in Nitrate and Phosphorus concentration and load was much larger.

Possible reasons for the poor simulation results for the nutrients are incorrect amounts of fertilizers in the automatic fertilization option of ArcSWAT. This resulted in incorrect yield and biomass production in the model. For a further improvement of the simulation quality, different arable crops and adequate model fertilization values have to be considered.

The model can be used for German conditions with data usually available in Germany without too much calibration work for simulating and predicting the monthly and annual discharge. To simulate nutrient concentration and load, much more calibration work is necessary.

INTRODUCTION

The European Union passed the European Water Framework Directive in the year 2000. Subsequently, it was transposed into national law by 2003. An assessment of the contamination risk for all water bodies in the European Union had to be finished by 2006. The development of measures to improve the state of the water bodies has to be finished by 2009 and the measures must be implemented by 2012.

The final goal is that all surface waters and groundwater within defined river basin districts must reach at least ‘good’ status by 2015.

Simulation models are essential tools to evaluate potential consequences of proposed strategies and to facilitate management decisions. One of the most commonly used river basin model is ArcSWAT, a combination of the simulation model SWAT with a Geographical Information System (GIS) user interface (Winchell et al., 2007).

ArcSWAT and its predecessors have been intensively used to simulate surface and groundwater quality by several authors in the last two decades (review by Gassman et al., 2007). However, the program has been developed for American conditions and most studies have been carried out in the United States. Relatively few studies have been carried out in Central Europe or particularly in Germany. One working group in Germany concluded that the program had to be adjusted severely with respect to Nitrate related processes to reflect the conditions in Germany correctly (Eckhardt et al, 2002; Pohlert et al., 2005).

Background of the present study was that many official sites in Germany own a lot of data on water quantity and quality for sometimes periods as long as several decades. This data could be used to calibrate watershed models and, in case a calibration is successful, later significantly help to determine the effect of water protection measures. However, official sites do usually not have the resources to invest very much time into the calibration process of watershed models for the many catchments the have to take care of.

Therefore, the present study was carried out to evaluate the effort necessary to calibrate and use the watershed model ArcSWAT with usually in Germany readily available data.

MATERIALS and METHODS

The basic model SWAT is a watershed-scale model that operates on a daily time step and is designed to predict the impact of management on water quantity and quality and sediment load in groundwater and surface waters. Major model components include weather, hydrology, soil properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. In SWAT, a watershed is divided into multiple sub watersheds, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land use, management, and soil characteristics (Neitsch et al., 2005). A review of the development of the model system is given by Gassman et al. (2007). The interface between the model SWAT and ArcGIS is called ArcSWAT. ArcGIS is used to calculate basic hydrologic information for the model (i.e. surface slope, water flow paths), calculates the position and the size of the hydrologic response units and provides the necessary files which are used by the SWAT model (Winchell et al., 2007).

Climatic Data

The model SWAT requires daily precipitation, maximum/minimum air temperature, solar radiation, wind speed and relative humidity. The weather data was taken from the weather station of University of Applied Sciences at the Haste Campus which is situated a few kilometers south-west of the watershed area for the years 1996-2007. The available data were daily minimum and maximum temperatures measured 2 m above the ground (°C), temperatures at 14.00 hrs measured 2 m above the ground (°C), daily precipitation (mm), maximum rainfall intensity in one hour for any month, relative humidity at 14.00 hrs (%), and total daily sunshine duration (hrs). Additional data for daily average wind speed were taken from a weather station in Osnabrueck for the years 2003 to 2007. The solar radiation was calculated from the total daily sunshine duration with the Angstrom equation.

The model SWAT additionally needs long term monthly statistical data (mean, standard deviation) to generate representative daily climate data when measured data is missing. The statistical parameters were calculated from the available daily weather data.

Soil Data

The soil data for the watershed were taken from the official digital soil map at the scale 1:25.000 or were estimated based on this map. In the digital soil map a few soil units had 7 or more layers. In these few cases, some thin layers were discarded and the neighboring horizons were used instead so that a maximum of 6 layers was used in the soil profiles. The necessary parameters are the

• Soil hydrologic group (calculation based on the texture of the first horizon)

• Maximum rooting depth (Generally, a maximum rooting depth of 200 cm was used. Only in those cases where the rooting depth was obviously reduced due to bed rock in the description of the digital soil map, the depth to the bed rock was used)

• Bulk density (g/cm³; values were recalculated from the classes of the digital spoil map according to the German classification (AG Boden, 1994)

• Available water capacity (cm³/cm³; estimated from the textural class, the bulk density humus content classes according to the German classification system (AG Boden, 1994). For organic soils, the available water capacity (AWC) was estimated from the type of organic material and the decomposition status. The AWC used in ArcSWAT is the American AWC, i.e. the difference of the water contents between pF 4.2 and the American field capacity (pF2.5). The AWC estimated with the procedure outlined above is the German AWC, i.e. the difference of the water contents between pF 4.2 and the German field capacity (pF1.8). Therefore, the estimated AWC is slightly larger than the American AWC. Therefore, a procedure was developed to transform the German AWC to the American AWC which increased the quality of the calibration significantly.

• Saturated hydraulic conductivity (mm/hr; estimated from the textural class and the bulk density according to the German classification system (AG Boden, 1994). For organic soils, the saturated hydraulic conductivity was estimated from the type of organic material and the decomposition status).

• Organic carbon (%weight; the central values of the humus content classes divided by 1.72 were used as organic carbon values. For organic soils, a value of 30 % organic carbon was used).

• Clay content, silt content and sand content (%weight; textural classes are available in the digital soil map. The central values of the clay, silt and sand content of the textural classes were used according to the tables of the German classification system (AG Boden, 1994).

• Coarse particles (%weight): the amount of coarse particles (> 2mm) in classes is available in the digital soil map. The central values of the classes were used as an approximation of the coarse particles.
For bedrock, a value of 90% coarse particles was assumed.

• Soil albedo (fraction): The soil albedo (moist) was calculated from the sand content (%).

• Erodibility factor (.013tm²h/m³tcm; the erodibility factor was calculated according to Williams (1995) from texture and organic carbon data.

Land Use

The land use was taken from the digital soil map. The eight different land uses from the digital soil map were transformed into the respective land uses classes of the SWAT model: arable land (AGRL), permanent pasture (PAST), coniferous forest (FRSE), deciduous forest (FRSD), forest in general (FRST), soil pits and lakes (WATR), and villages and urban areas (URBN).

Slope

The slope was calculated in ArcGIS from digital elevation data at a distance of 50 m. Two slope classes of 0 - 2.5% and >2.5% were defined.

Hydrologic Response Units

The Hydrologic Response Units (HRU) will be defined in ArcSWAT by overlaying soils, land use and slope classes. This overlay resulted in a total of 557 HRU for the Nette catchment. Some of the HRU, however, were very small. Therefore, the final HRU were defined based on a threshold percentage, i.e. only those land use classes, soil units and slope classes in a sub-catchment were taken into account, which were larger than the respective threshold value. Threshold values of 20% for land use, 20% for soils and 10% for slope classes resulted in a reduction to 111 HRU for the whole Nette catchment.

Sensitivity Analysis, Calibration and Validation

The SWAT model has many parameters which can be optimized in the calibration process. To make the time consuming calibration process most effective, a sensitivity analysis of the main parameters influencing the water discharge and the water quality were carried out. The most sensitive parameters were later used to calibrate the model. For the calibration with respect to water discharge, a period of three years from 2001 to 2003 was used (plus one initial year as a "warming up" period for the model). A model run for the ten year period 1997 to 2006 was used with the optimum parameters as validation period. The same procedure was used for the water quality.

RESULTS and DISCUSSION

The basic information, i.e. soil data, land use classes, slope and river reaches and sub basins for the model is given in Fig. 1.

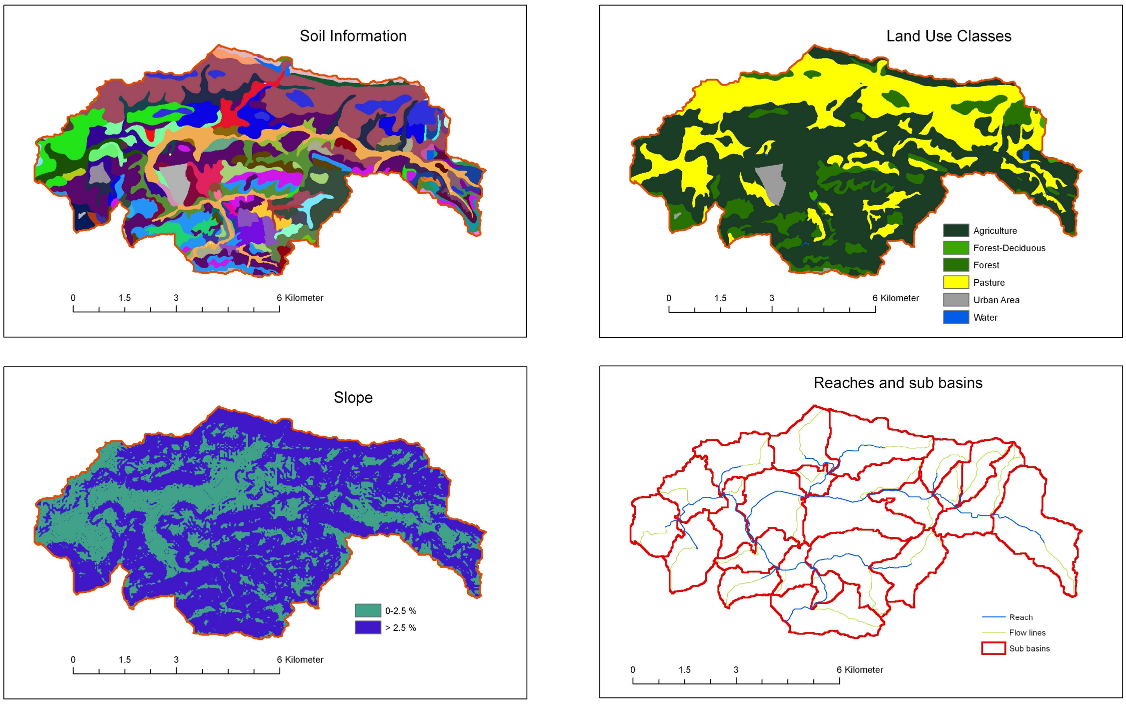


Fig: 1: Soil data, land use classes, slope and river reaches/sub basins

The sensitivity analysis for the river discharge showed that four parameters were the most sensitive ones: the baseflow recession constant determining the relation between baseflow and surface flow, the runoff curve number determining the surface flow, the soil depth determining the amount of seepage water and surface flow, and the soil evaporation compensation factor determining the amount of evaporation from the soil. The sensitivity analysis for the nutrients NO_3 and P showed that the runoff curve number was the most important parameter for both.

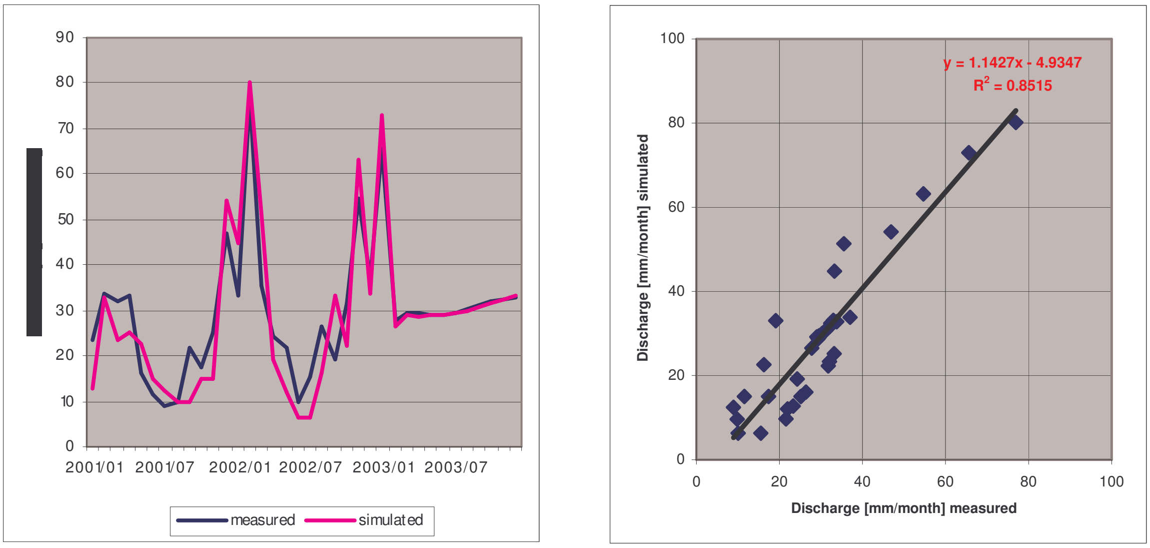


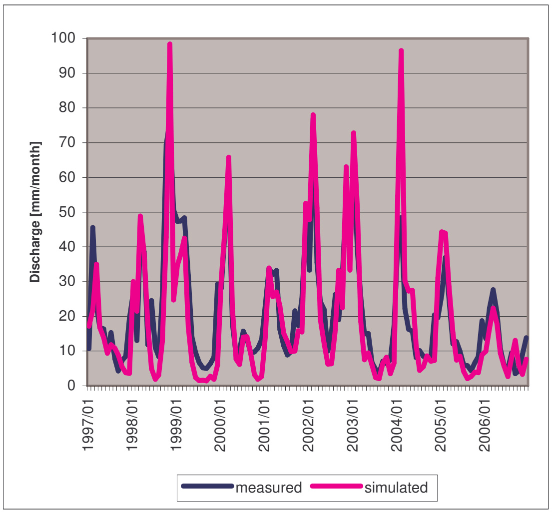
Fig. 2: Measured and simulated discharge (calibration period): discharge versus time (left) and simulated versus measured (right)

After calibration, the simulation showed good results for the monthly average discharge values with a slope of the simulated versus measured values close to unity, a high R^2 of 0.852 and a Nash-Sutcliffe efficiency ENS of 0.75 (fig. 2). The daily discharge, however, showed less accurate simulation with some major discrepancies and a R^2 of only 0.433 and a Nash-Sutcliffe efficiency ENS of only 0.46. The peak values were at times too high or too low, but the peak position was generally correct (not shown). Table 1 show the final parameters used in the calibration.

Table 1: Calibrated Values for Parameters determining the river discharge

parameter	**default value**	**calibrated value**	**parameter**	**default value**	**calibrated value**
CANMX		7.5	**RCHRG_DP**		0.20
CHN2		0.02	**TIMP**		0.45
CHK2		115	**ESCO**		0.5
CH_COV		0.8	**EPCO**		1.0
GW_Delay		0	**EVLAI**		3.0
ALPHA_BF		0.1885	**SURLAG**		2.5
GWQmn		0	**MSK_CO2**	3.5	7
GWRevap		0.05	**MSK_CO1**	0	2
RevapMN		90			

After calibration, the simulation was extended to a 10 year period 1996 to 2006. The simulated monthly averaged discharge was sufficiently well with a R^2 = 0.756 and a Nash-Sutcliffe efficiency ENS of 0.63 which shows that the calibration parameters were chosen correctly to describe the behavior of the hydrologic system (fig. 3).



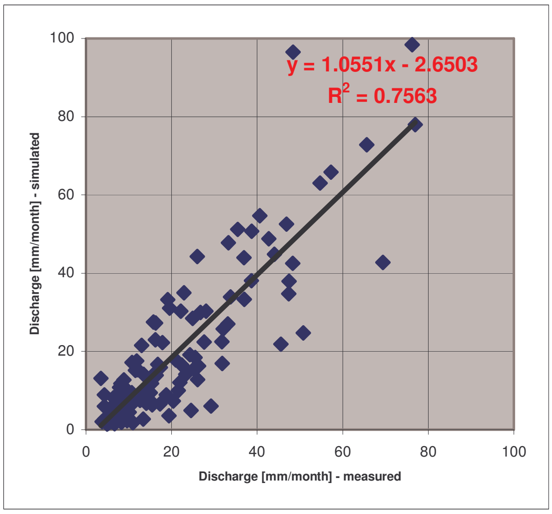


Fig. 3: Measured and simulated discharge (validation period): discharge versus time (left) and simulated versus measured (right)

The Nitrate concentration and load was simulated in a next step. The results for the monthly averaged values were poor. The correlation between measured and simulated monthly averages showed a R^2 of 0.37 and a Nash-Sutcliffe efficiency ENS of 0.29 only. The positions of the high and low peaks were correct; the fluctuation, however, was much too high. The monthly averaged Nitrate load showed better results. The correlation between measured and simulated monthly averages showed an R^2 of 0.45 and a Nash-Sutcliffe efficiency ENS of 0.43. The position of the high and low peaks was correct but the agreement of the peak height is poor.

The average annual values (fig. 4) showed that the overall level of the Nitrate concentration is simulated relatively well (5.3 mg/l Nitrate-N simulated versus 5.8 mg Nitrate-N measured. The same is true for the Nitrate-N load (258 kg/day for the whole catchment simulated versus 203 kg/day measured).

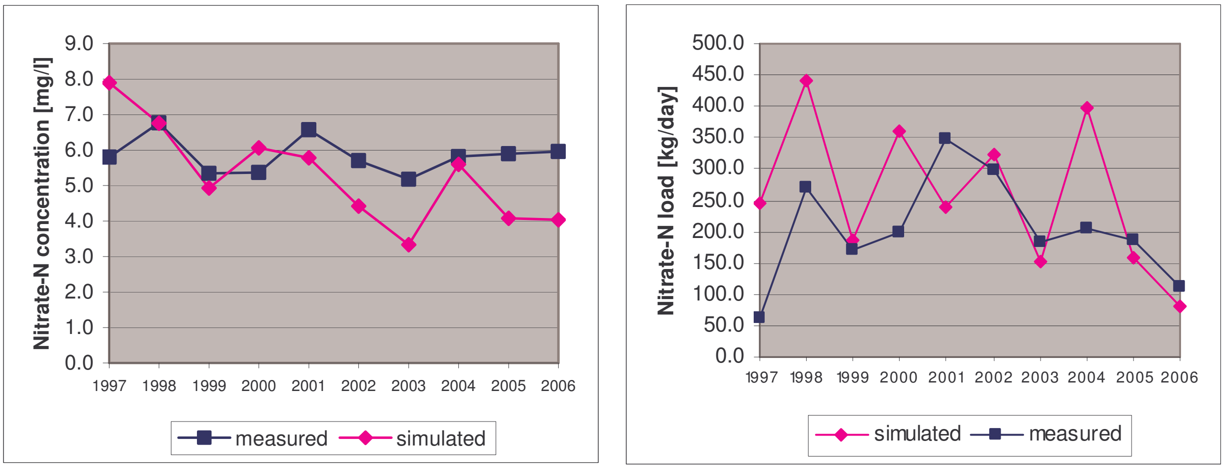


Fig. 4: Measured and simulated Nitrate concentration (left) and load (right)

The monthly averaged phosphorus concentration and load showed an inferior quality of the results compared to Nitrate. The correlation between measured and simulated monthly averages showed an R^2 of 0.02 and a Nash-Sutcliffe efficiency ENS of -0.29. The position of the high and low peaks was partly wrong and the fluctuation was much too high. The phosphorus load also showed an insufficient simulation quality with a correlation between measured and simulated monthly averages of $R^2 = 0.04$ and a Nash-Sutcliffe efficiency ENS of -0.46. The position of the high and low peaks was partly correct but the agreement of the peak height was poor.

The average annual values (fig 5) showed that the overall level of the phosphorus concentration is simulated relatively well (0.16 mg/l Phosphate-P simulated and 0.17 mg/l measured). The average annual Phosphate-P load (5.2 kg/day simulated and 5.6 kg/day measured) was simulated correctly with a correlation coefficient $R^2 = 0.56$ and a Nash-Sutcliffe efficiency ENS = 0.42.

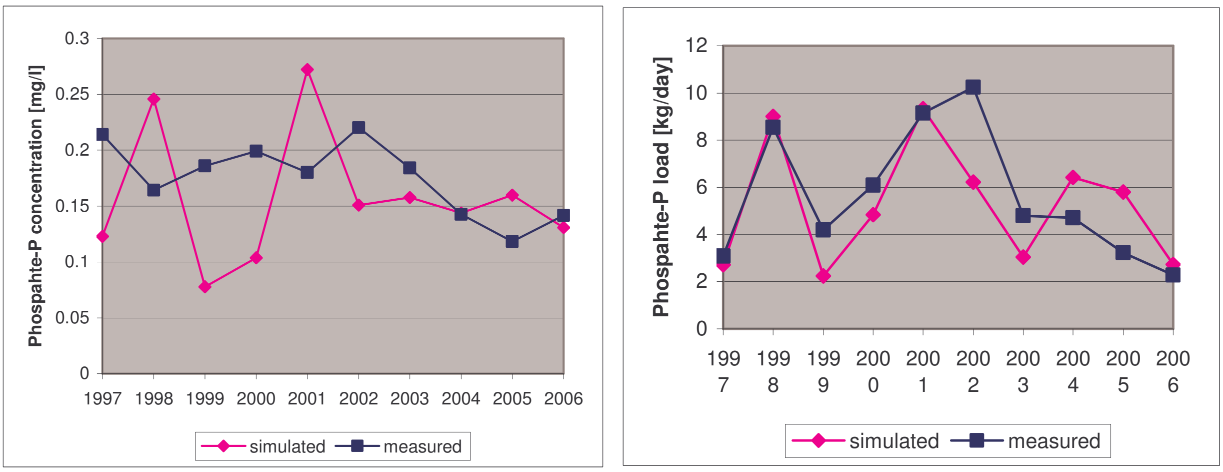


Fig. 5: Measured and simulated Phosphate-P concentration (left) and load (right)

Possible reasons for the poor simulation results are wrong amounts of fertilizers applied in the model and an incorrect amount of nutrients taken up by the plants. The fertilizer used in the SWAT model runs were applied automatically dependent on the simulated plant growth in that way, that there are always sufficient nutrients for plant growth in the model, i.e. never nutrient stress. The simulated yield on arable land is based on parameters for winter wheat, although other crops are planted as well, such as oil rape, barley, corn. The simulated yield for winter wheat is too low compared to the yield of farms in that region. The amount of automatically applied N-fertilizer in the model for winter wheat is much too low, i.e. only 139 kg N/ha instead of up to 200 kg/ha normally used on farms. The simulated biomass (forest and grass) is too low compared to values expected in that region.

CONCLUSIONS

The results show that the ArcSWAT model simulates the monthly and yearly averaged discharge correctly. The quality of the monthly averaged simulated Nitrate concentration is poor; the peak position is correct but the high peaks are too high and the low peaks are too low; the general level is correct. The simulation quality of the monthly averaged Nitrate and Phosphate load is better, but the peaks too high. The simulation of the yearly averaged Nitrate and Phosphate concentration and load was correct in that sense that the overall level was simulated correctly. The simulated grain yield for winter wheat and biomass (Pasture and Forest) is too low. The N fertilizer applied with the "automatic" option is too low.

In a next step plant parameters must be adjusted so that yield and biomass production will be simulated correctly. Only after that, a further calibration of N and P related parameters can be carried out to adjust N and P concentration and load.

The introduction of further land use, i.e. splitting the arable land use to winter wheat, barley, corn and oil rape must be evaluated in order to increase the accuracy of the simulation.

Potential point sources, such as fishponds, a waste water treatment plant and a compost plant will be incorporated in the model in order to increase the accuracy of the simulation.

The model can be used for German conditions with data usually available in Germany without too much calibration work for simulating and predicting the monthly and annual discharge. To simulate nutrient concentration and load, much more calibration work is necessary.

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Neural Networks for Predicting Flow Discharge in the Balarood River (Iran)

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ABSTRACT

In this study an artificial neural networks (ANNs) model, multi-layer perception using back-propagation algorithm (MLP/BP) was used for predicting flow discharge in the Balarood River which located in Khozestan province, Iran. The rain and temperature data as monthly collected at the five meteorology stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood river were used to train and validate the ANN model. The ANN model was performed by varying the network parameters to minimize the prediction error and determine the optimum network configuration. The results show that the best architecture for the MLP/BP model comprised of 10 neurons in the hidden layer and a learning rate of 0.01. Overall, the performance of the MLP/BP neural network was good in predicting the discharge of Balarood River. This information can be used for proper water management studies in that area.

Keywords: Water Management, Discharge Predicting, Artificial Neural Networks, Balarood River , Rain, Temperature.

INTRODUCTION

The accurate estimation of the river discharge is the most important parameter in the water management studies and it would causes the studies will be more accurate and confidence. In some rivers, there is not hydrometric station and as a result, there is not measured discharge data, or sometimes there is not enough time series data in this station. Therefore in such conditions, the studies would be encountered to problems. In such cases it can be used different methods such as using the relationship between the runoff and discharge. But in the recent years, the new approach which has attracted attention of the hydrologist engineers for such conditions is the using of neural network. Balarod River flow forecast is a fundamental step for water resource system planning and management problems, since storage-yield sequences are frequently related to monthly periods. Recently, artificial neural networks have been widely accepted as a potential useful way of modeling hydrologic processes, and have been applied to a range of different areas including rainfall-runoff, water quality, sedimentation and rainfall forecasting (Nagy et al., 2002, Agarwal et al., 2005, Azmathullah and Deolalikar, 2006; Bateni et al., 2007; Muzzammil, 2008; Tavakoly and Kashefipour, 2008). In this study neural networks have been applied to predict the hydrologic behavior of the runoff for the Balarood basin, located in Khzestan (Iran), at the Dokohe section, by using the monthly time unit. For this purpose the rain and temperature data as monthly collected at the five meteorology stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood river were used to train and validate the model.

Artificial Neural Networks

A neural network consists of a large number of simple processing elements that are variously called neurons, units, cells, or nodes. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. The weights represent information being used by the network to solve a problem. Neural networks operate on the principle of learning from a training set. They must be trained with a set of typical input/output pairs of data called the training set. The final weight vector of a successfully trained neural network represents its knowledge about the problem. In general, it is assumed that the network does not have any a priori knowledge about the problem before it is trained. At the beginning of training the network weights are usually initialized with a set of random values (Dastorani and Wright, 2002). A neural system should be capable of storing information through training. Thus the objective of training the ANN is to develop an internal structure enabling the ANN to correctly identify or classify new similar patterns. Thus, neural network is a dynamic system, its state changes over time in response to external inputs or an initial unstable state (Negm et al., 2003). Various types of ANN are in use and could be reviewed from Schalkoff (1997). Most of the applications of ANNs in fields of water Engineering were reviewed in Negm (2002). In this paper, we present a neural network (ANN) technique for fifteen year ahead forecasting of the runoff at the hydrometric station of Dokohe section in the Balarood basin.Therefore one ANN model, multi-layer perception using back-propagation algorithm (MLP/BP) was used.

Study Area

Balarod river basin is situated in the Southern Western part of Iran. The main river originates from the slopes of mounts Golaho. This river is a water source for the city of Andimeshk in Khozestan

Providence. The major tributaries of this river are Balarod 1 and Balarod2. After 58km this river joined with the Dez River. The river basin measures 1200 km^2. There is a hygrometry station (Dokohe) on this river which constructed in the 1984. The mean flow of this river at the fifteen year period is 7.642 m^3/s. There are five meteorology stations in the Balarood basin and its neighbor (Dez Ab, 1999). Figure 1 shows a map of the watershed, hydrometric station of Dokohe and five meteorology stations.

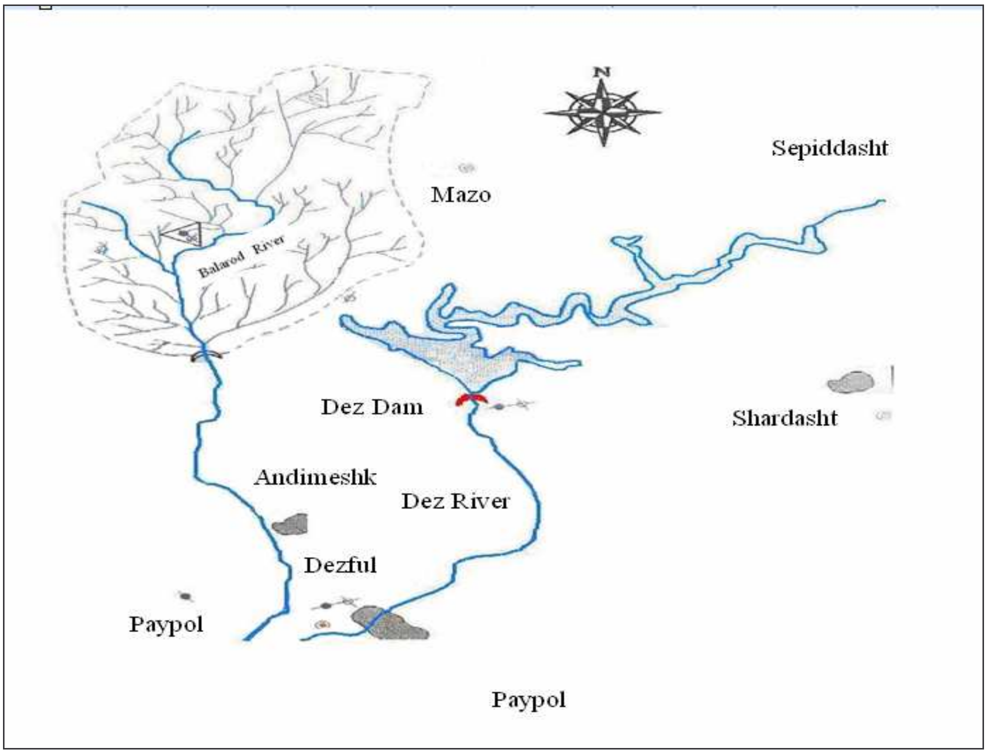

Figure 1- The schematic of the Balarod Basin and the meteorology stations

The data which are used in this study include the rain and temperature data as monthly collected at the five stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood River. These data were used to train and validate the ANN model. The five stations are Mazo, Dezful, Paypol, Sardasht and Sepiddasht. The 10 input layers include five rainfall node and five temperature node, 10 hidden layer and one output node include discharge of the hydrometric station of Dokohe introduced to the ANN model. The available field data were divided into training and testing scenarios, with the training file consisting of ten inputs and one output. In general 182 data series at the 15 common years (1984-1999) are used for neural network model. For this purpose, 70% of all data selected randomly for learning the model. Validation of the model was made with the using of reaming 30% of the data, which were not involved in their derivation. In the ANN model, the number of hidden layer has direct effect to the results of the model. Therefore in order to investigate the effect of it, the model runs with different hidden layers. As in ANN model which used in the present study, maximum eight hidden layers can be used, therefore the model was run with different hidden layer from 1 to 8. For comparison the results of the model, the criteria of RMSE and R^2 are used. The comparisons of the achieved results with different hidden layer show that the model with one hidden layer has better than other. Another parameter which influences the results of the model is the transfer function between the nodes. In order to investigation the effects of it, the model run with different transfer functions including Sigmoid ($f(x) = 1/(1+\exp(-x))$, Gaussian ($f(x) = e^{-x.x}$), Hyperbolic Tangent ($f(x) = \tanh(x)$) and Hyperbolic Secant ($f(x) = Sech(x)$). The results of the ANN model with different transfer functions are presented in table 1. For comparison the results, the criteria of RMSE, and R^2 are used

Table 1- The results of the MLP model with different transfer functions

Functions	**Stage**	**RMS Error**	**Std Dev**	**R^2**
Sigmoid	Training	0.083192	5.54532	0.829392
	validation	-	6.05363	0.77666
Gaussian	Training	0.0306869	20.455	0
	validation	-	18.62	0
Hyper. Tan.	Training	0.068824	4.57431	0.88751
	validation	-	7.51037	0.70750
Hyper. Sec.	Training	0.306863	20.45439	0.501656
	validation	-	18.61855	0

In overall, the training and validation results of the MLP model with different transfer functions (Sigmoid, Gaussian, Hyperbolic Tangent and Hyperbolic Secant), show that the model perform much better results when analyzed with Sigmoid function. To assess the performance of the ANN model, observed discharge values are plotted against the predicted ones. Figures 2 and 3 illustrate the results with the performance indices between predicted and observed figures 2 and 3, MLP has performed well in predicting discharge of Balarod River. The results of the model showed relatively good correlation (>0.7) throughout the training and testing.

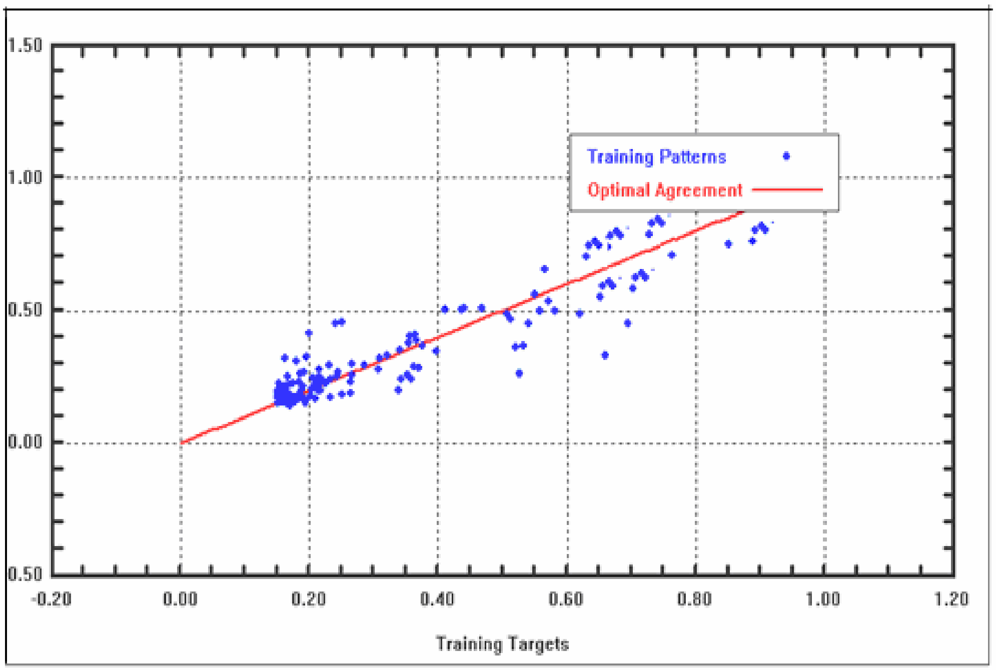

Figure 2- Plot of observed and predicted discharge with using MLP model with Sigmoid transfer function for training patterns

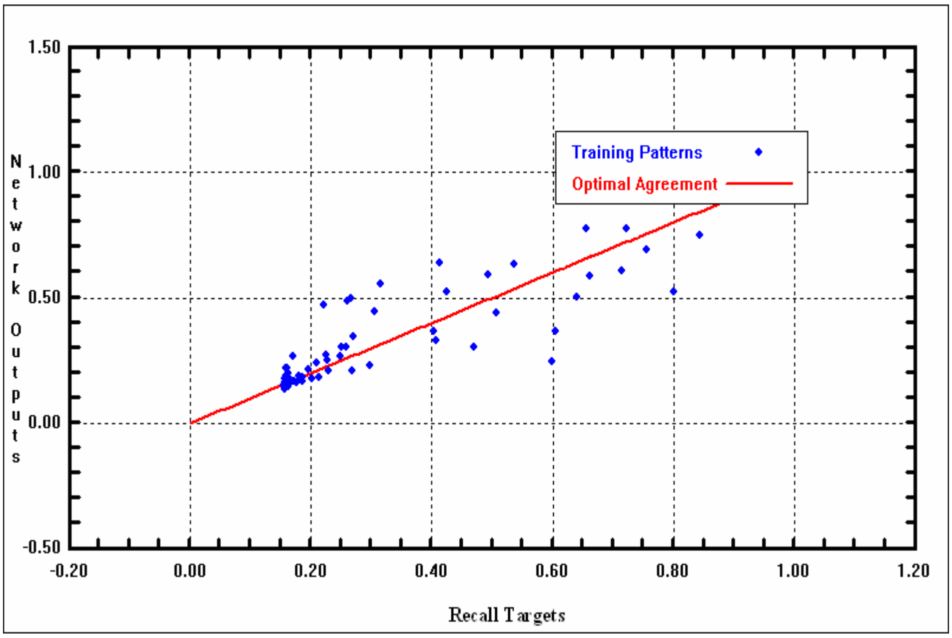

Figure 3- Plot of observed and predicted discharge with using MLP model with Sigmoid transfer function for validation patterns.

RESULTS and DISCUSSION

In this paper, the application of the ANN model namely, multi-layer perceptron (MLP/BP) in the estimation of discharge of the Balarod River has been outlined. The study includes the manipulation of the collected data of the five metrological stations in order to train and to validate the network. The results of this study shows that the neural network approach predict discharge carefully.

The MLP network with configurations of ten input nodes (rainfall and temperature), one hidden layer and 10 hidden nodes within that layer was selected as the optimum network to predict discharge. Comparison the results of MLP with different transfer functions (Sigmoid, Gaussian, Hyperbolic Tangent and Hyperbolic Secant) illustrates that the Sigmoid transfer function was better than the mentioned transfer functions. The regression coefficient (R^2) was achieved 0.83 and 0.78 for trading and validation stage, respectively.

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Assessing the Capability of Satellite Data for Soil Mapping

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ABSTRACT

The purpose of this research is to evaluate the potential of using landsat ETM+ data for soil mapping. The study area is located in center of Iran and covers about 1300 ha. The database of studied area was created by introducing topographic map (1:25,000), soil map (1:20,000) and reports and satellite data. After pre-possessing stage, selection of the best informative bands was carried out using optimum index factor (OIF) calculation and principle component analysis (PCA). Results showed that bands TM1, TM4 and TM6-2 contain the highest information and the lowest redundancy. Besides the mentioned bands, TM5 and TM7 were considered for digital image classification. The images were classified using maximum likelihood classifier into seven mapping units. Separability of mapping units examined at 95% confidence level. Comparison of the prepared soil map from satellite data and ground truth showed a relatively high accuracy of 80%. Also, comparison of prepared soil map from satellite data and detailed soil maps prepared using conventional methods showed imagery data could increase the classification and interpretative purity percentage up to 50% and 85%, respectively. The results indicated high potential of imagery data for inventory and increasing the precision of existing soil maps. Therefore, incorporation of high-resolution satellite data for soil survey especially in arid and semi-arid regions is highly recommended.

Keywords: Landsat ETM+ data, Soil mapping, Purity

INTRODUCTION

The objective of soil survey is to study about actual and potential land use management strategies (Rossiter, D.G., 2000). For employment a better strategy for land use management, the soil maps that are prepared through the soil survey should following characteristics (Patrick A. Agbu et al. 1990): (i) Variation in terms of significant soil properties within mapping units should be minimum whereas the variation among mapping units should be maximum. (ii) Effectively characterize the mapping units in terms of significant soil properties. (iii) Grouping the soils that are similar, and then to express accurately the properties of each grouping. According to Western (1978) and Bregt et al. (1992), the quality of a map is a function of reliability, relevance and presentation of the information

Perhaps, the most serious limitation of traditional soil survey process is the assignment of properties derived form typical soil profiles to the entire map unit regardless of the inherited spatial and temporal variability of field soils (Beckett and Webster, 1971; Baker 1978; Bouma et al. 1980; Breeuwsma et al. 1986). Salehi et al. (2003) expressed that although criteria for purity of mapping units have been improved; however, traditional soil mapping approaches are not able to reasonably show the variability of pedons and top soil properties even in a detailed soil map named at series level.

It seems that the capability of imagery data can compensate drawbacks of traditional soil maps. Many researchers applied Landsat TM data for predicting soil properties (Rayan et al., 2000, Campling et al., 2002) or soil classes based on a soil classification system (Lee et al., 1988; Thomas et al., 1999). Dobos et al. (2000) defined digital soil mapping as computer assisted production of a digital map of soil type and soil properties. We believe that the progresses in computer software and satellite data can help to soil surveyors to denote soil surface changes and increase the precision of soil maps. The objective of our research is to study the possibility of soil mapping with integration of ETM+ satellite data, field works, and thematic maps like digital topographic maps and its derivates in Central Iran.

MATERIALS and METHODS

Study Area and Data Collection

The study site locates between 32° 17´ to 32° 20´ N and 51° 3´ to 51° 5´ 3˝ E in the Chaharmahal and Bakhtiari province, Iran and encompasses an area of 1300 ha. Mean annual rainfall is 220 mm and mean altitude of study area is 2100m above the sea level. Main landforms are alluvial plain, outwash and hills. According to U.S. Soil Taxonomy (soil survey staff, 2006) the soil moisture and temperature regimes of the area are Xeric and Mesic, respectively.

Database of the study area was constructed by collecting digital topographic maps (1:25,000), existing detailed soil map (1:20,000) and reports (the information of 85 soil profiles; Salehi et al. 2003), aerial photographs (1:20,000) and Landsat (ETM+) digital imagery data. The satellite data obtained on 2 July 2001, including reflectance TM bands (TM1-TM5 and TM7), thermal bands (TM6-1 and TM6-2) and panchromatic band (TM8). Image processing was performed using ILWIS 3.3 (Integrated Land and Water Information System, developed by ITC, 2007).

Preparing of Digital Soil Map

Preparing of digital soil map was carried out in three stages. At first, the satellite data were georeferenced using topographic map (1:20,000) and GPS (Garmin 12XL) during preliminary field work with minimum possible error. In the second stage, the best informative bands were selected by considering statistical characteristics of them and calculating of optimum index factor (OIF) and principle component analysis (PCA).

Considering of different soil forming factors showed the topography have a major impact on soil variability. Thus, the study area was divided based on major landforms into three units, including hill (H), alluvial plain (P) and outwash (O), by using topographic map and digital elevation model (DEM).

In third stage, A supervised image classification approach and maximum likelihood algorithm was performed by introducing the pixels related to 46 sites covering the major physiographic units as training area. The training sites were determined by considering physiographic units, DEM, depth of A horizon and its properties like percent of sand, silt and clay, organic matter content, CaCO3 equivalent and soil surface gravel percentage (data not shown) and were addressed to the false color composite (obtained from best informative bands) of the area. Feature spaces were considered during introduction of training sites. Because of different spectral behavior of training sites in three main units (H, O and P), each units were divided into several subunits (spectral classes). By considering mean and standard deviation of each subunits, separability of different spectral classes were examined at 95% confidence intervals and the importance of informative TM bands for separation and distinguishing of different spectral classes were determined. The supervised classified image divides the study area into several spectral units, which were considered as soilscape/soil map units. The resulted map was smoothed by post classification filtering. Thus individual pixels and the resulted units which cover areas less than 1.6 ha (minimum legible area (MLA) according Soil Survey Manual, 1993) were merged into main units.

At post classification stage, A confusion matrix was elaborated by crossing known samples as ground truth (major taxons at soil series level in each spectral unit) and the classified image, to evaluate accuracy of classification performance. In this study, besides saved information of soil profiles and observation points in database, 12 profiles were excavated and described in unsampled areas and were used as ground truth.

Comparison of Digital and Traditional Soil Map

The new soil map (NSM) was assessed by calculating taxonomic and interpretation purities and compared with the traditional soil map (TSM). The taxonomic purity of the dominant soil in each map unit at family and series levels was determined and compared with the traditional soil map. To find interpretive purity, percentages of the dominant taxon and soils similar to dominant taxon in each map unit were combined. In this study, similar soils were marginally outside the limits of the particle size and/or mineralogy classes defined in soil control section at family level for dominant taxon.

RESULTS and DISCUSSION

Band Selection

Table 1, shows the results of OIF calculation. The table indicates that the thermal bands have important role in soil inventories. According to Alavi Panah et al. (2001), thermal bands have a key role for studying different soils in arid and semiarid zones; therefore application of these bands improves the accuracy of classification in such regions. According to Table 1, optimum index factor (OIF) calculations indicate the most informative bands are TM1, TM4 and TM6-2. Besides bands TM1, TM4 and TM6-2, we applied bands TM5 and TM7, which are emerged in the second and third ranks. Therefore, TM1, TM4, TM5 and TM6-2, and TM7 were selected for image classification.

Table1. OIF values of TM bands combinations.

Bands composition	OIF value
TM6-2, TM1, TM4	42.5
TM6-2, TM4, TM7	36.43
TM6-2, TM1, TM5	35.99
TM6-2, TM1, TM7	33.89
TM6-1, TM1, TM	32.37
TM6-2, TM3, TM4	32.37

Based on suggestions of Masul et al. (1990), results from principle component analysis (PCA) can be used for image classification. They suggested four bands that have maximum eigenvectors in the first principle component, are useful. Therefore, beside of OIF calculation principle component analysis (PCA) was applied for band selection. The results of principle component analysis indicate that TM1, TM3, TM6-2 and TM7 have maximum eigenvectors in the first principle component, respectively (Table 2). Therefore the results of PCA highly confirm OIF results. The results correspond to the findings of other workers in arid and semi-arid zones. Al-Bakri (2000) and Ziadat et al. (2003) recommended TM1, TM5 and TM7 combination for mapping soils in arid and semi-arid zones.

Table 2.The eigen values for nine principle components

Principal components		TM Bands								
		TM1	TM2	TM3	TM4	TM5	TM6-1	TM6-2	TM7	TM8
	PC1	0.510	0.300	0.506	0.152	0.203	0.329	0.740	0.512	0.213
	PC2	-0.112	0.088	-0.025	0.021	-0.096	0.156	0.481	-0.071	-0.009
	PC3	0.405	0.430	0.477	0.175	-0.533	0.021	0.015	-0.294	0.012
	PC4	0.039	0.100	-0.077	0.748	0.055	-0.028	-0.008	-0.475	0.458
	PC5	-0.641	-0.291	0.574	0.176	-0.327	-0.089	-0.067	0.128	0.088
	PC6	-0.084	0.010	0.328	0.123	0.430	-0.002	-0.002	-0.481	-0.674
	PC7	-0.139	0.140	0.168	0.575	0.359	-0.001	-0.006	-0.436	0.532
	PC8	-0.585	0.776	-0.211	0.095	0.028	0.018	-0.024	-0.010	-0.011
	PC9	0.032	0.019	-0.001	0.008	0.002	0.491	-0.870	0.870	0.00

Separability of Training Sites

Considering of feature spaces (data not shown) indicated that the studied area can be divided into several subunits or spectral classes including H1, H2, P1, P2, P3, Agri., O1 and O2. Agir. was a cultivated area and merged into the appropriated unit by considering its attributed profile description. Figure 1 shows separability of different spectral classes at 95% confidence intervals. According to Figure 1, bands TM5 and TM6-2 could be able to separate classes H1 and H2. Band TM5 could differentiate class H2 from other spectral classes. Spectral class O1 could be separated from classes O2, P1, P2 and P3 using TM1. Classes O1 and O2, which are varied in gravel content (Table 3) could be differentiated using visible and infrared bands (Figure 1). Class P1 with the lowest surface gravel (Table 3) expresses higher radiation in the thermal band. Overlaying of single standard deviations of units P2 and P3 indicates hardly discrimination of these features by single bands.

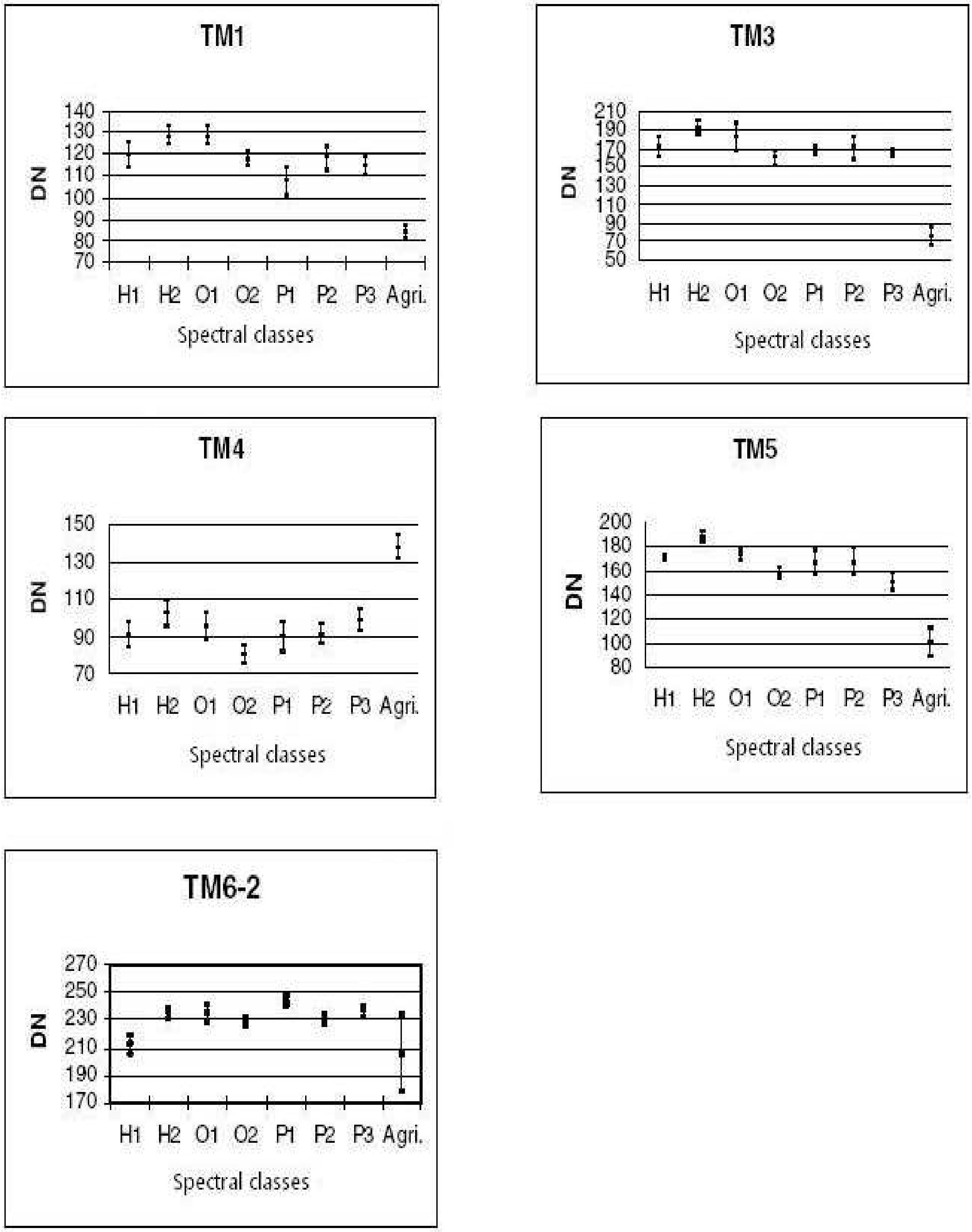

Figure 1. separability of different spectral classes at 95% confidence intervals

We hope using multispectral bands and maximum likelihood approach, which considers the probability of membership of pixels for each class aid to optimize differentiation of these features. Training areas of alluvial plains P1, P2 and P3 are varied in gravel and $CaCO_3$ equivalent content (Table 3) and in the feature space plot of TM5-TM7 these units are separated efficiently.

Table 3. Some physical and chemical characteristics of A horizons of training areas

Spectral class	Soil surface characteristics in spectral classes (soil mapping units)					
	Land form	Texture	$CaCO_3$ (%)	Gravel (%)	Organic matter (%)	Depth of A horizon (cm)
P3	Alluvial plain	Clay loam	10-20	14-28	0.4-0.7	20
P2	Alluvial plain	Loam- silty clay loam	19-43	21-57	0.7-0.9	20
P1	Alluvial plain	Clay loam- silty clay	10-25	2-11	0.7-0.9	20
H1	Hill	Clay loam	23-36	30-35	0.95-1.1	20
H2	Hill	Loam	37-51	25-35	0.7-0.8	20
O1	Outwash	Loam	19-30	45-65	0.6-0.9	15
O2	Outwash	Clay loam	15-30	25-45	0.95-1.12	15

Evaluation of Image Classification Accuracy

For classification assessment, a confusion matrix was formed and the classified image and the field verified samples of different classes not used for training were compared (data not shown). The results show maximum class accuracy is 91.2% and belongs to class O2 and minimum accuracy is for H1 (71.6%). The overall classification accuracy is 80%.

Comparison of Some Mapping Precision Parameters in New and Traditional Soil Maps

Comparison of taxonomic purities of new soil map and traditional soil map at soil family level shows that the purities of mapping units for the digital soil map varies between 40% and 59% while these values range from 27% to 60% for the traditional soil map. Taxonomic purities of dominant soils in the digital soil map at soil series level range from 40% to 50% whereas for the traditional soil map such purities range from 19% to 33.5%, respectively (Figure 2). This shows that results obtained by the digital soil map are closer to the expected criteria of American Soil Survey Manual (1993).

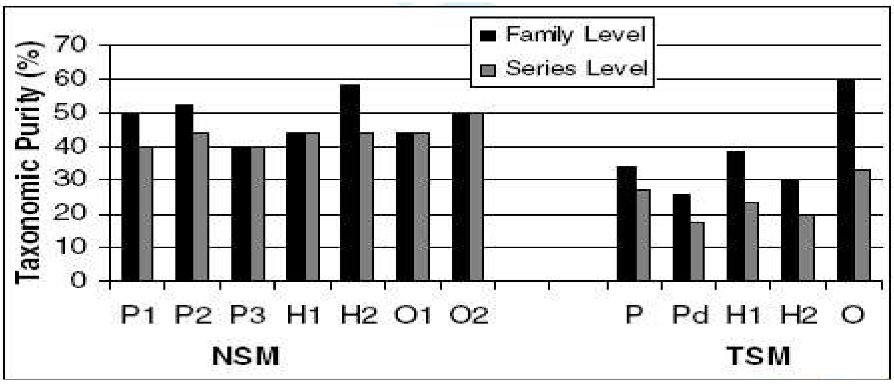

Figure 2. Taxonomic purity in map units of NSM and the TSM at family and series levels.

Interpretative purity is considered as a reliability index of soil maps (Beckett and Webster, 1971; Bie and Beckett, 1973; Marsman and De Gruijter, 1986). The results indicate that interpretive purities of mapping units for the new soil map vary between 60 and 85 percent while these values for the traditional soil map were range between 40% and 75% (Figure 3). Consequently, the definition of the mapping units according to interpretive purity instead of taxonomic purity can be used for increasing the reliability of soil maps.

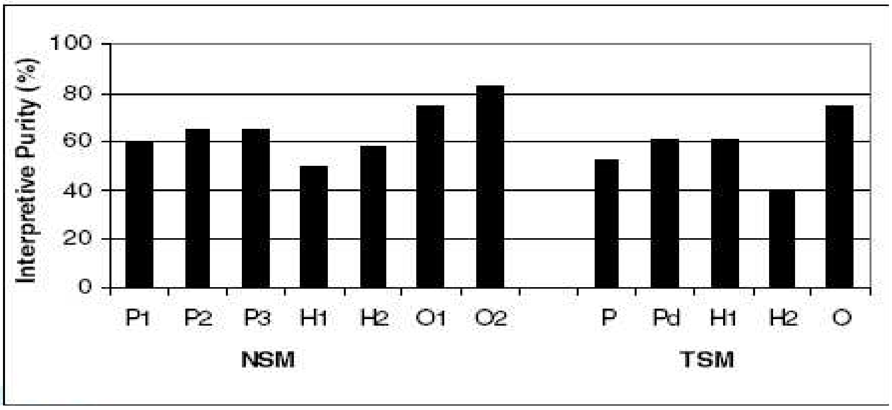

Figure 3. Interpretive purity in map units of the NSM and the TSM

CONCLUSION

The results indicate high potentials of Landsat ETM+ data for differentiation soil mapping units in arid or semi-arid soils with no or sparse vegetation. Possible inventory of new mapping units using satellite data promise improving the quality of traditional soil maps. By Integration of satellite imagery data, field works, digital elevation models and with employment of geographic information systems may facilitate soil mapping in arid and semi-arid zones.

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Updating of the Soil Map of the Çukurova University Campus Area by Using Geographic Information System (GIS)

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ABSTRACT

The aim of this study is to update the previous soil map of the Çukurova University campus which was completed in 1974. The widely distributed soil series were selected on previous soil map. Soil series are re-identified and re-sampled in the present study. Physical and chemical analyses were repeated on newly collected soil samples. Satellite image of Quickbird dated 17th of August 2004 were employed for the unsupervised classification. All classes were checked by field truth studies. Previous soil series borders were taken into account during field surveys. The ILSEN software is used to generate Suitability Class of Agricultural Applications (SCAA) and Potential Land Use (PLU). Land Use Capability map (LUC) was made by considering some characteristics which are limiting agricultural managements. Current Land Use map (CLU) is produced via field observations for each land use.

Finally, we determined that there is no significant change between 1974 and updated maps for soil series. But there are some differentiations for soil phases since 1974. All maps of the study are produced at 1:5000 scales.

INTRODUCTION

Soils on the surface of the earth have very complex structure. To determine of the soils is very difficult because of their complication. Soils material which is including productions of the rocks and minerals, inorganic and organic matter with water and air are found in this complex structure (Özbek, 1974). There are many factors for soil formation on the earth; these are different climates, rocks, topography, many living organisms and soils which are different age (Simonson, 1957). When these factors are same in any field, soils have similar properties with each other (Smith, 1963). To know of the soils similar physical, chemical and morphological properties is very important because of suitable using of soils and to raise living standard of the next generation (Özbek, 1974). And effective using of the soil maps is also very significant. Because, use of the soils for agricultural or not agricultural without considering their capability can be confront the human being with uncovering results. We should protect soils against incorrect usage of the people all over the world. Because, soils are valuable for life and it is essential source for life on the earth.

It is possible that soil maps keep their validity for a long time with using new technologies. Hence, satellite images, Geography Information System (GIS) and Geographic Position System (GPS) should be used for updating soil maps. And soil maps which are prepared with field controls should be drew using computer and software.

Aim of this study is updating of the soil map of the University of the Çukurova, which is finished in 1974 by using GIS and QuickBird satellite images. For this aim, satellite image was classified and identified to find for different soil boundaries. Consequently, a new dated soil map of the study area was made and data of the soil series was processed with Ilsen software for land evaluation.

MATERIAL and METHODS

MATERIAL

The study was applied in area of the University of the Çukurova that have 13.305da agricultural field of the total 18.024da areas (Figure 1). QuickBird satellite image, dated from 17 August 2004, and digital topographic maps, at scale 1:25000, was used as base map for field work and laboratory studying. An excavating machine (backhoe) was used in the field work for digging soil profiles. To make soil map bounders certain in the field work was used shovel, auger and standard color chart. Coordinates of the profile sites on satellite image was identified by using GPS. 11 soil profiles was dug, 32 undisturbed and 24 disturbed soil sampling was gathered for chemical and physical analyses. Image process and classification were applied by using Erdas 8.4 and ArcView 3.3 software.

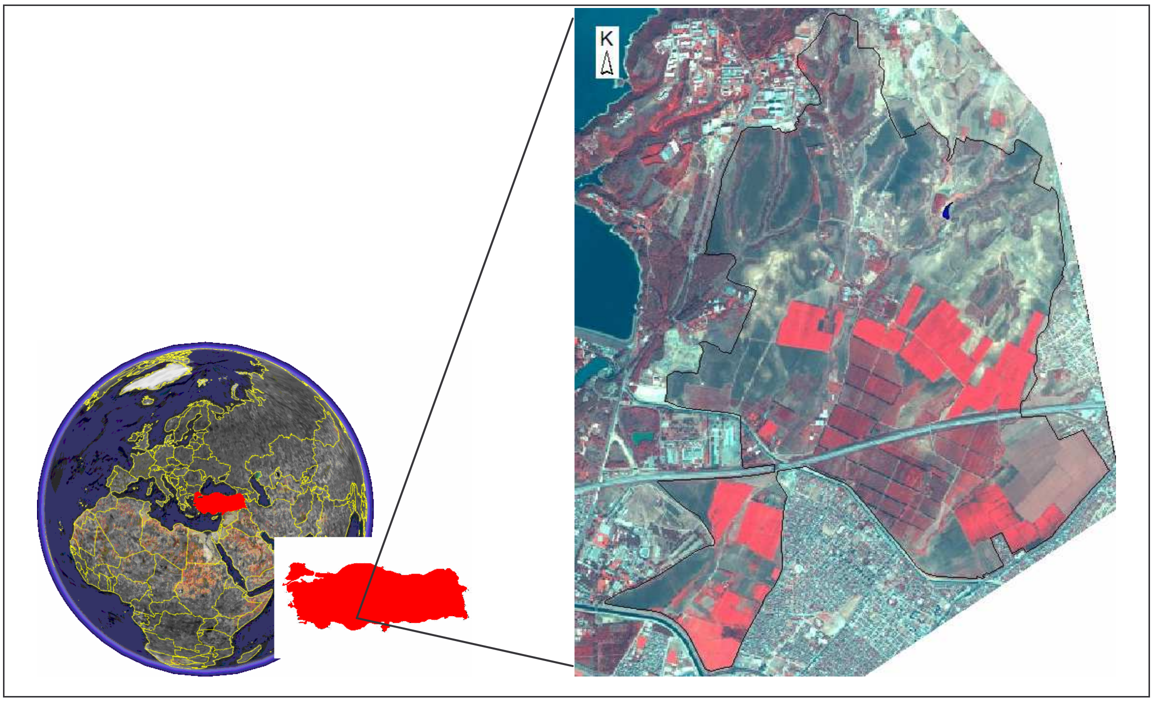

Figure 1. Geographic location of the study area.

METHODS

This study was completed 4 main stages. First stage was including geographic correction of the satellite image and its classification, overlaying border of the study area on the image, digitizing features which are on the topographic map, and identifying soil profiles sites. Second stage was including digging of the soil profiles in the field, its identification and sampling, and physical and chemical analyses of soil samples. Third stage was including digitizing of the detailed soil map (DSM), soil classification and creating of the Land Use Capability (LUC), Potential Land Use (PLU), and Current Land Use (CLU) maps. Fourth stage was including gathering the data and its interpretation, printing of the created maps and final report.

Classification of the satellite image; Image was classified at first 10, 24, 30 classes. All classes were controlled in the field and 24 classes were most suitable for soil diversity of the study area than other classes. Aim of this classification was clustering similar reflectance in the same class. Profile sites were identified on different geographic unite on this satellite image before go to field for first stage.

To excavate of the soil profiles and their sampling; profiles, which were identified on the satellite images, were dug at about 2 meters and 3 or 5 meters length by an excavating machine (backhoe).

Analyses of the laboratory; updated soil analyses were made according to the soil survey report in 1974. Soil samples were sieved <2 mm. Soil texture, acidity (pH), lime (%), Cation exchange capacity (CEC me/100g), changeable cation (K2O kg/da), organic matter (%), bulk density (gr/cm3), electrical conductivity (EC) (mmhos/cm) and phosphor (P2O5 kg/da) were made in this study. Analyze of the soil texture; soil samples were determined content of the sand %, silt % and clay % and texture classes were identified by using texture triangle (Bouyoucos, 1951). Acidity (pH) was determined in the saturation mud by using pH meter (U.S. Salinity Laboratory Staff, 1954). Lime was identified according to Schlichting and Blume (1966). Cation exchange capacity and changeable cations were determined with sodium acetate and acetate extraction methods (U.S. Salinity Laboratory Staff, 1954), respectively. Organic matter was determined by using modified Lichterfelder method (Sclicting and Blume, 1966). Bulk density was identified using undisturbed soil samples according to Yeşilsoy and Güzeliş (1966). Total salinity was defined in saturation mud depending on electrical conductivity (U.S. Salinity Laboratory Staff, 1954). Phosphor analyze was established according to Olsen et al (1957), removing of the color was process according to Kaya (1982), and phosphor was determined as colorimetric according to method of Murpy and Riley (1962).

Soil classification was established according to Soil Taxonomy 2003 (Soil Survey 2003). Shovel, auger, standard color chart and HCl (10%) were used in the field to make definite possible soil borders on the classified satellite image. Possible soil borders were identified according to soil characters which was probe for every 100 or 150 meter distance depending on homogeneity of the study area. Preparing of the soil maps; updated map was established by using QuickBird satellite image and its classified image and topographic map at 1:25.000 scale.

Differentiations of the soil map (1974) were considered when updating of the DSM. The soil map (1974) was overlaid on QuickBird satellite images for effective updating by digitizing. In addition, updating soil map has more comprehensible soil units and soil characteristics than soil map (1974). All maps were established and printed in the Remote Sensing Laboratory of the Soil Science Department of the Çukurova University. LUC, PLU, and CLU maps were generated by using interpretation of the DSM with ILSEN software.

RESULT and DISCUSSION

We determined 10 different soil series on 4 main physiographic units in study area (18.024da). Physiographic units were high marine terrace, shoulder lands, river terrace and alluvial lands (Table 1). There is no significant changing between soil map 1974 and DSM 2008, but there are many changing on phases of soil series. There were two soil series on soil map 1974 which are called Menekşe and İşaret. We did not identify them because there were existed in very little range of the study area according to our soil survey study and satellite images. In addition, we established a new soil series which is called Kabaktepe. It has eroded surface characteristic of the Karaburun series. This characteristic was not identified in soil map 1974. But it was clearly distinguished on satellite image.

Table 1. Soil series and physiographic units of the study area

Soil series	Parent Materials	Physiographic unites
Kızıltapır	Conglomerate	high marine terrace
Baraj	Conglomerate	
Kabaktepe	Travertine	
Balcalı	Travertine	
Karaburun	Travertine	
Konaktaş	Conglomerate	shoulder lands
Hurma	Aged river terrace	river terrace
Mutlu	Aged alluvial deposit	alluvial lands
Arık	Aged alluvial bed deposit	
Menzilat	New alluvial deposit	

We selected some results of the physical, chemical analyses and morphological characteristics of the soil profiles. These are; horizon name, depth of the horizons, pH, salinity, P_2O_5, Cation Exchange Capacity (CEC), lime content, organic matter, texture and classes of the textures. Main descriptive characteristics of the horizons in the soil profiles are cambic, calcic, illuviation of clay and slickenside. These identified properties for each soil series in study area are given following (Table 2).

Identified soils in the study were classified according to Key the Soil Taxonomy, 2003. Inceptisols has more soil series than others, four soil series were classified as Inceptisols. One soil series was classified as Entisols. Orders, suborders, great groups and subgroups are given in Table 3.

Table 2. Soil properties for each soil series in study area.

Soil Series	horizon	Depth (cm)	pH	P_2O_5	CEC	$CaCO_3$ (%)	Org. mat	Tex. Dis. (%) S	Si	C	Tex. Clas
Karaburun	Ap	0-20	7,32	6,02	33,06	18,1	2,2	26	24	50	C
	A2	20-35	7,34	2,75	27,30	17,7	2,0	28	20	52	C
	Bw	35-66	7,28	1,27	17,17	14,8	1,1	17	20	63	C
	BCk	66-109	7,34	2,16	11,22	47,7	0,7	24	31	45	C
	Ck	109-120	7,24	0,50	8,34	66,2	0,4	19	40	41	SiC
Kabaktepe	Ap	0-19	7,19	22,28	33,06	52,8	1,1	29	44	27	L
	A2	19-36	7,30	2,31	27,30	55,7	0,9	30	44	26	L
	2Ck	36-90	7,34	0,40	17,17	63,1	0,3	22	52	26	SiL
Balcalı	Ap	0-10	7,27	21,71	16,68	8,8	2,3	37	23	40	CL
	A2	10-24	7,31	2,93	14,59	10,8	1,9	34	21	45	C
	Bt1	24-44	7,24	2,82	15,78	11,5	1,5	29	23	48	C
	Bt2	44-64	7,31	1,18	33,36	26,8	1,0	29	20	51	C
	BC	64-79	7,13	1,05	15,78	19,7	0,8	31	18	51	C
	Ck	79-118	7,44	0,19	9,23	58,5	0,3	35	41	24	L
	Ap	0-13	6,80	9,92	17,67	0,8	2,5	18	22	60	C
	Bt1(BA)	13-28	6,68	1,87	20,65	0	1,6	25	17	58	C

Kızıltapır	Bt2	28-43	6,60	1,65	18,37	0	1,7	18	25	57	C
	B/Ck	43-64	7,35	0,89	29,19	45,4	1,0	42	26	32	CL
	Ck	64-80	-	-	-	-	-	-	-	-	-
Baraj	A1	0-11	6,93	16,65	18,07	25,9	5,8	39	30	31	CL
	A2	11-33	7,30	2,74	14,89	27,4	2,8	37	29	34	CL
	Ck	33-70	7,19	0,66	20,15	73,9	1,0	21	41	38	CL
	Cr	70+	-	-	-	-	-	-	-	-	-
Konaktaş	A	0-17	6,97	3,42	16,18	6,0	4,4	60	13	27	SCL
	Bw	17-35	7,40	1,40	11,52	11,5	1,8	51	16	33	SCL
	Ck	35-	-	-	-	-	-	-	-	-	-
Hurma	Ap	0-14	7,04	2,27	23,23	6,2	2,1	23	21	56	C
	A2	14-33	7,16	0,91	19,06	9,2	1,2	23	20	57	C
	A3ss	33-87	7,47	0,57	38,91	9,5	1,1	19	22	59	C
	A4ss	87-111	7,46	1,40	16,08	10,6	0,9	18	19	63	C
	AC	111-150	1,40	0,44	17,87	11,4	0,9	15	20	65	C
Menzilat	Ap	0-31	7,57	4,99	20,50	31,5	1,51	36	27	37	CL
	CA	31-59	7,95	1,99	17,87	47,4	0,49	36	30	34	CL
	C1	59-94	7,80	1,49	24,90	48,8	0,51	14	41	45	SiC
	C2	94-125	7,81	1,25	18,40	55,0	0,52	11	44	45	SiC
	C3	125-150	7,90	2,16	19,99	47,5	0,47	18	40	42	C
Mutlu	Ap	0-20	7,29	3,73	14,69	12,2	1,5	29	27	44	C
	A2	20-48	7,29	0,84	17,37	13,4	1,0	24	19	57	C
	ACss	48-82	7,19	0,69	17,57	8,0	0,9	18	19	63	C
	Css	82-133	7,37	0,65	17,67	12,2	0,9	18	19	63	C

	Cr	133-150	-	-	-	-	-	-	-	-	-
Arık	A	0-25	7,63	7,11	46,83	27,2	1,17	17	28	55	C
	A2ss	25-45	7,80	1,92	37,51	27,0	0,62	15	27	58	C
	A3ss	45-84	7,81	1,28	38,14	26,3	0,57	14	27	59	C
	ACss	84-110	7,89	1,17	39,84	25,6	0,55	15	26	59	C
	Css	110-150	7,96	1,23	40,77	25,0	0,44	14	25	61	C

Table 3. Soil Classification of the soil series of the study area.

	Key the Soil Taxonomy, 2003			
	Sub Group	Great Group	Sub Orders	Orders
Kabaktepe	Lithic Calcixerepts	Calcixerepts	Xerepts	Inceptisols
Konaktaş				
Baraj	Typic Calcixerepts			
Karaburun				
Mutlu	Chromic Haploxererts	Haploxererts	Xererts	Vertisols
Hurma	Typic Haploxererts			
Arık				
Kızıltapır	Calcic Rhodoxeralfs	Rhodoxeralfs	Xeralfs	Alfisols
Balcalı				
Menzilat	Typic Xerofluvents	Xerofluvents	Fluvents	Entisols

There are four utilization groups for PLU; these are horticulture, field crops, vegetables and nonagricultural areas. Contents of each utilization group were given in Table 4. V4, H2, F9 and N8 are including most suitable plants for their utilization groups. V4, H2, F9 and N8 are suitable of 53%, 35%, 28% and 25%, respectively (Figure 2, 3, 4, 5). Utilization groups of PLU for horticulture, filed crops, vegetables and nonagricultural are given in Table 4.

Table 4. Utilization Groups of PLU

1	**Utilization Group of Horticulture** (Citrus tree, Vineyard, Peach tree, Olive tree, Almond tree, Fig tree)
H0	:no suitable
H1	:Olive tree, Fig tree
H2	:Vineyard, Olive tree, Almond tree, Fig tree
H3	:Citrus tree, Vineyard, Peach tree, Olive tree, Almond tree, Fig tree
2	**Utilization Group of Field Crops** (Wheat-barley plant, Maize plant, Clover, Chickpea plant, Potato plant)
F0	:no suitable
F1	:Chickpea plant
F2	:Chickpea plant, Potato plant
F3	:Wheat-barley plant
F4	:Wheat-barley plant, Chickpea plant
F5	:Wheat-barley plant, Maize plant
F6	:Wheat-barley plant, Maize plant, Chickpea plant
F7	:Wheat-barley plant, Maize plant, Chickpea plant, Potato plant
F8	:Wheat-barley plant, Maize plant, Clover
F9	:Wheat-barley plant, Maize plant, Clover, Chickpea plant, Potato plant
3	**Utilization Group of Vegetables** (Tomato plant, Watermelon - melon plants, Strawberry plant)
V0	:no suitable
V1	: Watermelon - melon plants
V2	:Tomato plant
V3	:Tomato plant, Watermelon - melon plants
V4	:Tomato plant, Watermelon - melon plants, Strawberry plant
4	**Utilization Group of Nonagricultural** (Greenhouse, Grassland, afforest ration (for erosion control), afforest ration (for timber), Natural land, Cow house, Buildings, Recreation land)
N0	:Natural land, Recreation land
N1	:Natural land, Cow house, Buildings, Recreation land
N2	:Grassland, Natural land, Recreation land
N3	:Grassland, Natural land, Cow house, Buildings, Recreation land
N4	:Grassland, afforest ration (for timber)
N5	:Grassland, afforest ration (for timber), Natural land
N6	:Grassland, afforest ration (for erosion control), afforest ration (for timber)
N7	:Grassland, afforest ration (for erosion control), afforest ration (for timber), : Natural land
N8	:Greenhouse, Grassland, afforest ration (for timber)
N9	:Greenhouse Grassland, afforest ration (for timber), : Natural land

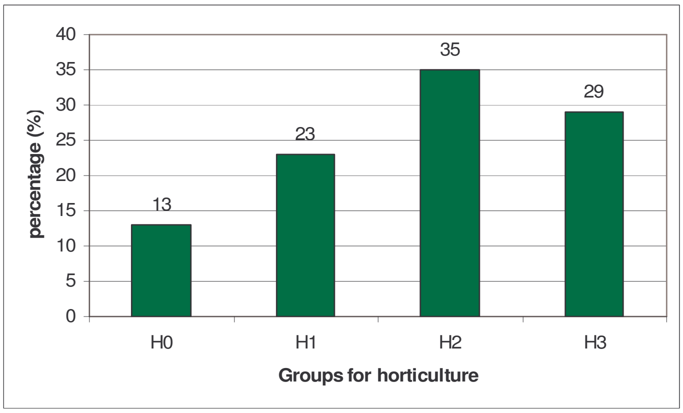

Figure 2. Percentage of the PLU of groups for horticulture in whole study area.

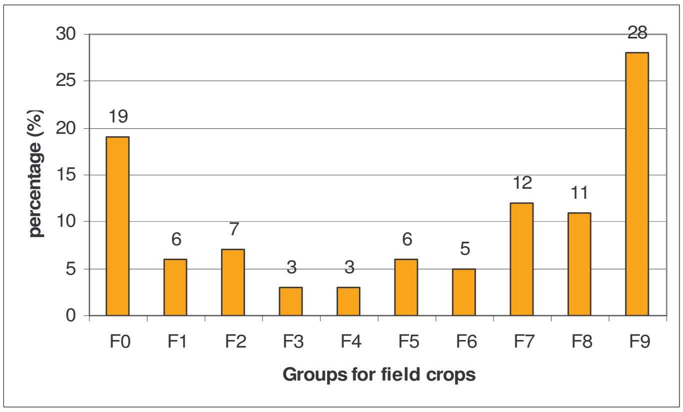

Figure 3. Percentage of the PLU groups for field crops in whole study area.

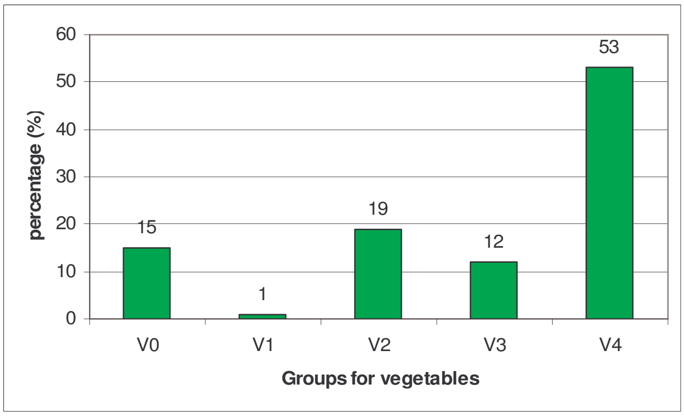

Figure 4. Percentage of the PLU groups for vegetables in whole study area.

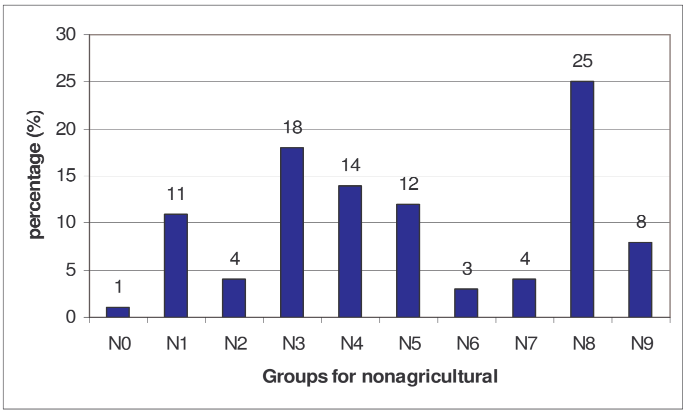

Figure 5. Percentage of the PLU groups for nonagricultural in whole study area.

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Studying Features of NDVI Dynamics for Vegetation Monitoring of the South of Central Siberia

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The work presents the results of studying NDVI (Normalized Difference Vegetation Index) for identification and mapping of ground vegetation using Terra/Modis satellite data. NDVI dynamics for various types of agricultural crops and lands at the south of Krasnoyarsk krai and Khakasia Republic was detected during the 2006 growth period and analyzed.

INTRODUCTION

Numerous experiments showed that NDVI (Normalized Difference Vegetation Index) is among the most reliable indicators [1]. Using the intensity of reflected light in the red and near infrared spectrum ranges, NDVI allows one to isolate green vegetation against other natural formations, especially soil and dry vegetation [2].

Using one-day NDVI values, it is possible to precisely isolate vegetative objects from other natural objects and analyze them, while identification and classification of various types of vegetation becomes complicated and inefficient. In this connection, it was decided to use these differences in NDVI dynamics during growth period as a basis for identification and classification of vegetative objects.

Used Data

In this work we used Terra/Modis and Landsat 7 ETM+ satellite data. Terra/Modis satellite data were used for calculation of NDVI. Landsat 7 ETM+ data, due to higher spatial resolution, are more suitable for geographical reference of the contours being studied. The task of monitoring of agricultural fields can successfully be solved by using daily average spatial resolution data (150-250 m) [1]. In this connection, we used satellite data obtained in the red (620-670 nm) and near infrared (841-876 nm) channels with a 250 m spatial resolution (MOD09GQK product) of Terra/Modis satellite. Satellite data of Terra/Modis satellite channels 1, 2, 3, 5, 6 with a 500 m spatial resolution were used for detection of territories covered with clouds and cloud shadows. To cover the whole growth period of agricultural fields at the Krasnoyarsk krai and the Khakasia Republic, Terra/Modis images for a period from May 10 to September 10 of 2006 were used. Information about the position of the satellite and the Sun was obtained from MODMGGAD products. Geographical reference of the studied contours was made with the help of the spatial data of the image taken on September 4, 2001 by Landsat7 ETM+ satellite with a 30 m spatial resolution.

Preprocessing Algorithm

Terra/Modis satellite images were processed by stages.

1. Using MODIS Reprojection Tool software, the projection of MOD09GQK images was transformed from Sinusoidal projection (ISIN) into Transverse Mercator projection. At the same time HDF format was converted into GeoTIFF format.

2. Using the possibilities of ENVI procedure of Band Math and decision-tree-type classification, the mask of unsuitable values was generated.

2.1. Observations made at a zenith angle more than 40º were excluded from the initial satellite data.

2.2. To make possible the analysis of vegetation development by satellite data, it is necessary to generate the time series of observation data free from the effect of negative factors such as cloud cover and shadows of clouds. Identification of clouds was based on spectral data of Terra/Modis channels 1, 2, 3, 5, 6. A decision-tree-type classification was developed in ENVI software environment for generation of cloud masks. The multi-level classification based on binary conditions related each pixel of an image to one or another class. The conditions (tree nodes) included: normalized differential snow index (NDSI) [3] and the values of the spectral data of Terra/Modis channels 1, 2, 5 [4].

Thematic Treatment of Satellite Data

An important indicator characterizing the physiological state, phytopigment dynamics and biological productivity of plants is Normalized Difference Vegetation Index. For Terra/Modis satellite data NDVI is calculated by the following formula:

$$NDVI = (\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + \rho_{red}) \quad (1)$$

where ρ_{NIR}, ρ_{red} are spectral reflectance in the near infrared (841 - 876 nm) and red (620 – 670 nm) zones.

Within the visible range (λ = 400÷700 нм) the reflection of plant radiation is connected with pigment concentration (mainly chlorophyll and carotenoids). Up to 95% of ρ value variations within the visible range are due to alteration of chlorophyll content. In the near infrared band (λ = 700÷1300 nm) radiation reflection is determined mainly by the inner structure of phytoelements [5, 6].

Studying of NDVI Dynamics of Plants during Vegetation Period

The process of growth and ripening of various types of plants has its own peculiarities connected with different distribution of green mass in time. That is why it is possible to distinguish between different types of vegetation studying vegetation indices at different growth periods on the basis of satellite images.

If the vegetation index dynamics of plants during growth period is displayed in a schematic form, as on Fig. 1, and if the following characteristics are chosen as parameters describing the form of the curve:

- slope of line during growth and development of vegetative organs (G),
- maximum value of NDVI during the whole growth period (M),
- slope of line during ripening and fruiting (R),

it will be possible to characterize the state of vegetative cover and, in particular, distinguish several types of vegetative cover.

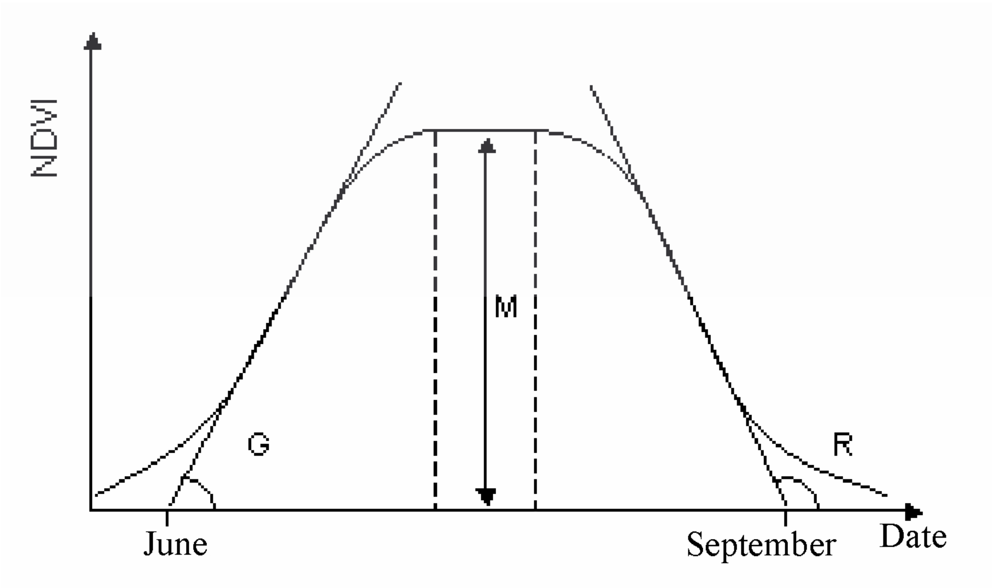

Fig. 1. Diagram of dependence of vegetative cover NDVI upon time

Calculation of parameters G and R at the indicated periods is based on finding slope of line that passes through the set of points of NDVI curve on a plane in the best way possible (using the least square method).

The first stage of thematic treatment was generation of daily NDVI maps by the data of the red and near infrared channels with a 250 m spatial resolution of Terra/Modis satellite. Next, the mask of values was superimposed on the daily NDVI maps, and the obtained data were exported to the special ENVI module developed in IDL that calculated the above mentioned parameters G, M, R.

RESULTS

To demonstrate the work of the above described algorithm, we processed the data of Terra/Modis satellite at the south of Krasnoyarsk krai and the Khakasia Republic during the 2006 growth period. A fragment of the composite image obtained by RGB synthesis of G, M, R parameter values is shown on Fig. 2.

Comparison of the obtained composite image with the field research data [7] and topographic maps of the same regions revealed the following classes of the earth surface:

- agricultural crops:
  - buckwheat (1),
  - oat (2),
  - wheat (3),
- bottomland meadows in complex with brushwood, willow coppice and poplar stands (4);
- pine forests (5);
- alfalfa and cereal communities (6);
- settlements (7);
- water surface (8).

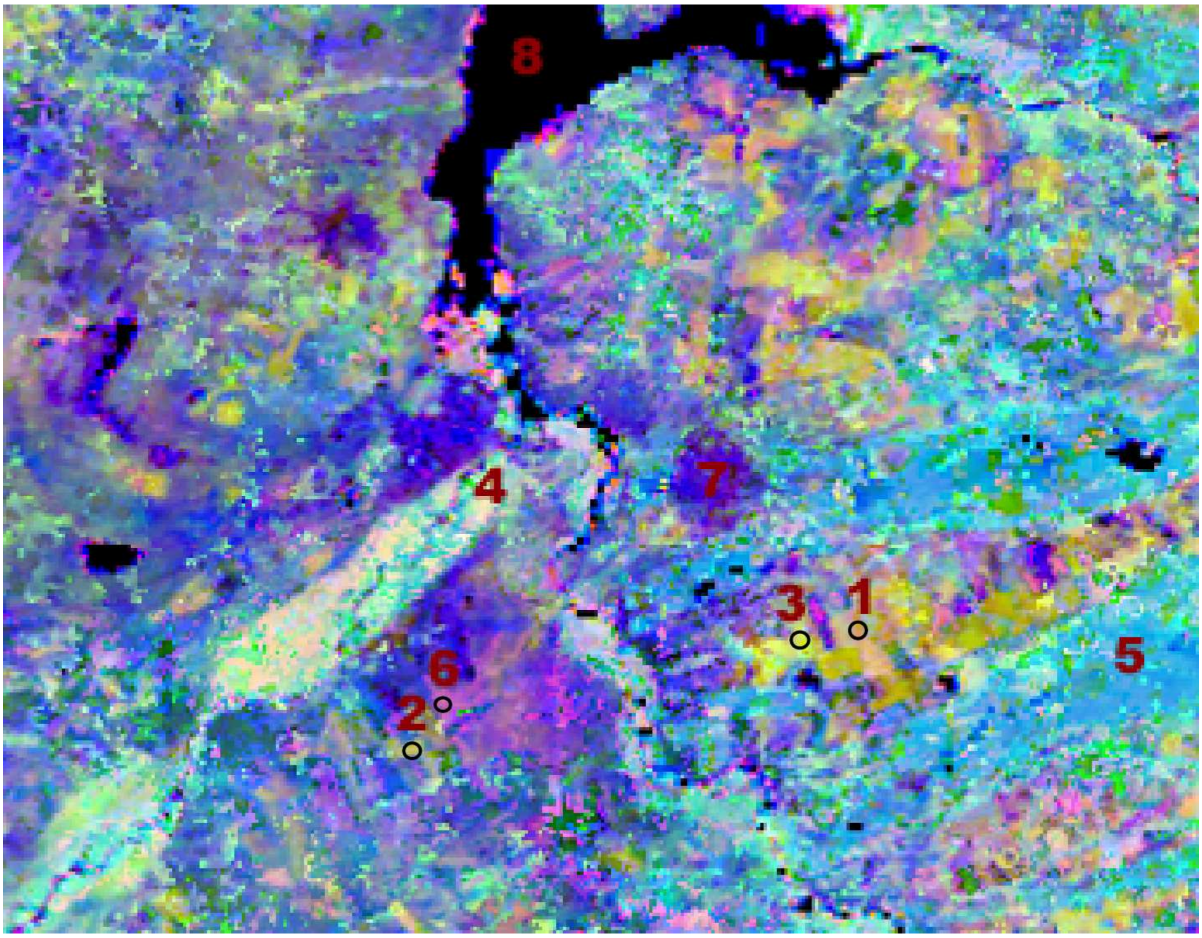

Fig. 2. A fragment of the composite image of the south of Krasnoyarsk krai and north-east part of the Khakasia Republic obtained by RGB synthesis (G: M: R)
(interpretation of numerical values is given in the text)

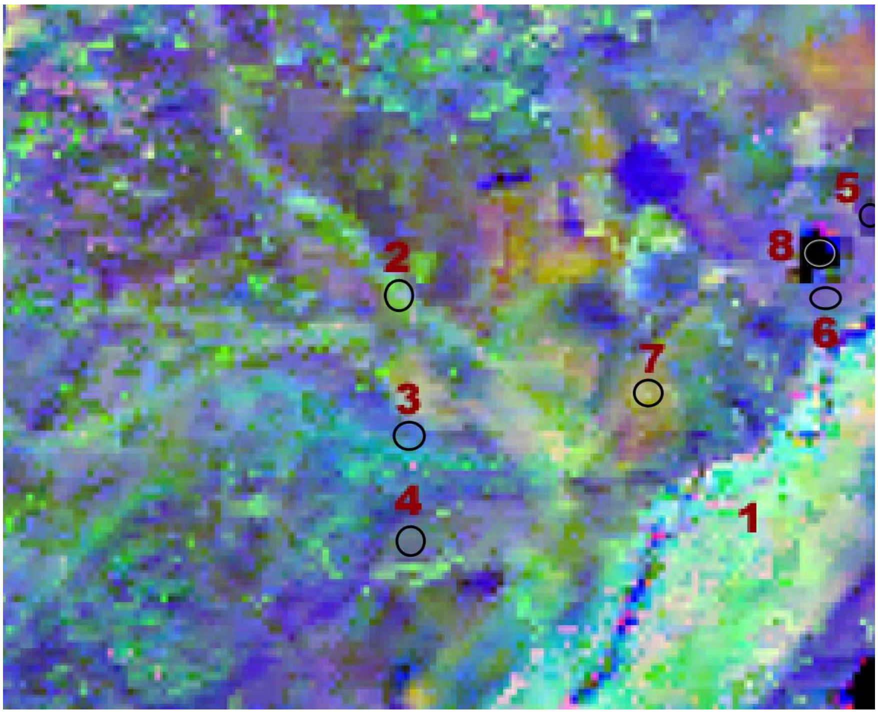

Fig. 3. A fragment of the composite image of lake Solenoye of Askiz Region of the Khakasia Republic obtained by RGB synthesis (G: M: R) (interpretation of numerical values is given in the text)

For a detailed analysis of the composite image a test area was chosen near Lake Solenoye located at the territory of Askiz Region of the Khakasia Republic. According to the field research data [7] and the data of the land use schematic map of Askiz Region of the Khakasia Republic, the following classes of the earth surface can be discerned on the composite image (Fig. 3):

- bottomland meadows in complex with brushwood, willow coppice and poplar stands (1);
- steppificated boggy areas (2);
- Stony steppes (3);
- Bunch grasses (4);
- Weed encroachment (5),
- Awnless brome (6),
- oat crops (7);
- water surface (8).

The results of the investigations show that the developed method makes possible the identification and classification of various types of vegetation on the basis of satellite images. This will reduce ground-based experimental work, opening possibilities for large-scale mapping of agricultural lands and other land plots.

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Mapping of Inner Water Bodies in the Krasnoyarsk Territory Based on the Digital Analysis of Ground True and Satellite Data

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ABSTRACT

In this work historical investigations and modern results of classification of the Krasnoyarsk Reservoir are presented. The paper presents results of studying the dynamics of phytopigments and other optically active components, using multispectral satellite data. Several approaches to interpreting satellite data for optically complex inland water bodies are offered. Based on results of historical investigations it is shown that the spatial distribution of phytoplankton in the reservoir stems back to the time of its formation. Color index in the red spectral region (CIR) is introduced. A relationship between the color index and chlorophyll concentration is investigated. The CIR, derived from the AVHRR data, has been found to be related to chlorophyll concentration. Based on MODIS data, the waters of the Krasnoyarsk Reservoir have been classified in accordance with their optical spectral variability, using the technique of unsupervised ISO data classification. An empirical relationship between multispectral MODIS data and the ground-truth measurements of chlorophyll concentration has been found.

INTRODUCTION

Satellite monitoring is the most effective method for assessing the state of inland water bodies. The assessment is based on three main optically active components of water – phytoplankton, dissolved organic matter and suspended mineral matter. The most important factor is the chlorophyll concentration of phytoplankton because it depends on levels of blooming in the reservoir and levels of human impact. It is well-known that waters of continental lakes are optically complex. That is why they cannot be studied using the ocean type of analysis. Remote sensing of inland water bodies can be used to assess 3 main optically active components: chlorophyll “a” concentration, suspended mineral matter and dissolved organic matter. These parameters are related to the quality of the water. Chlorophyll “a” is of particular interest, because it is the main pigment for various types of phytoplankton in the water; moreover, it serves as the basis for calculation of primary production, biomass etc. In the open ocean waters, where the color of the water is basically determined by phytoplankton, this parameter can be easily and effectively calculated using remote sensing data and simple empirical algorithms based on the sensor channel ratio (Gordon et al., 1983; Gitelson et al., 1988). At the same time, optically complex waters of inland water bodies make this task much more difficult, as they contain large amounts of suspended mineral matter and dissolved organic matter (Bukata et al., 1995; Tiit Kutsera et al., 2005; Curran and Novo, 1988). The optical parameters of these components change independently of phytoplankton and, when monitored by remote sensing, can significantly alter the integrated spectrum registered by the photodetector. What makes it even more difficult is considerable radiation scattering (even in the near-infrared (IR) spectral region) in the shallow water. Thus, the relationship between remote sensing data and optically active components becomes nonlinear, and the determination of water quality parameters, especially Chl “a”, using regression analysis becomes more complicated (Lathrop, 1992; Shevyrnogov et al., 2002; Arst, 2003; Pozdnyakov and Grass, 2003). An alternative approach is classification, in which components are not quantified but rather their relative amounts are estimated (Chernetsky et al., 2006). Using this method, one can make a map of the studied water body. This method is effective when used along with ground-truth measurements. This study was performed at the Krasnoyarsk Reservoir using remote sensing methods (Aponasenko et al., 1985; Gitelson et al., 1985).

The purpose of the study was to investigate spatial and temporal distribution of spectral optical parameters of the surface water layer in the Krasnoyarsk Reservoir. The spectrum received by the satellite sensor is determined by the composition of the major optically active components and can be used to reveal the seasonal and long-term dynamics of biological processes in inland water bodies, which, in turn,serve as an indicator of the state of the water body.

Study Sites

The main sites for long-term integrated hydrobiological and hydrooptical studies were the Krasnoyarsk Reservoir and the Dnieper cascade reservoirs. The Krasnoyarsk Reservoir is a very large (71.3 km3), deep-water (the mean depth 36.9 m, the maximum depth 105-110 m), weakly circulating (the water cycle rate 1.2 yr-1) water body of an intricate shape. The Dnieper cascade reservoirs are shallow (the mean water depth 6-7 m) and contain much smaller amounts of water. Blue-green algae and diatoms are the predominant phytoplankton. The Secchi disk depth (SD) in the Krasnoyarsk Reservoir decreases steadily, from about 3 m at the dam to 0.5-0.7 m at the reservoir backwater (300-330 km). In the Dnieper cascade reservoirs, SD does not exceed 2-1.5 m, decreasing to 0.2 and less when the water surface is covered with a film of blue-green algae (during their blooming period).

RESULTS

Historical Spectrometric Investigations

As is well known, to investigate ecosystem biotic parameters using satellite remote sensing, it isnecessary to make ground-truth spectrophotometric measurements. Expeditions to the Krasnoyarsk Reservoir were conducted in the 1970-80s, but the spectral data obtained in the course of those expeditions can still be useful (Shevyrnogov and Sidko, 1998). During the expeditions, direct biological measurements of Chl “a” in the surface layer of the reservoir were taken as reference data. In addition to that, the researchers made spectrophotometric measurements of spectral brightness coefficients using a PDSF differential spectrophotometer in different parts of the reservoir, varying in hydrobiological and hydrochemical conditions. Optical measurements in inland water bodies and reservoirs have their specific features uncharacteristic of measurements in relatively pure and transparent open ocean waters. Due to these features, a non-standard approach can be used to interpret remote sensing data (Han and Rundquist, 1997). Our investigations showed that during phytoplankton bloom the near-infrared subspectrum is suitable for the estimation of Chl “a” concentration due to strong reflection of light in this part of the spectrum by the Chl “a” phytopigment. Based on this, we were able to use the Normalized Difference Vegetation Index (NDVI) formula to calculate the color index in the near infrared region (CIR), as opposed to the generally accepted color index in the blue spectrum region, which can be used to estimate Chl ”a” concentration. CIR=NDVI=(R2-R1)/(R1+R2) (1), where R1 is reflectance in the red channel and R2 is reflectance in the near-infrared channel. In our previous studies we showed that measurements in different types of the waters can be performed using different spectral regions. For the open ocean water, the use of the maximum light absorption by chlorophyll at the 434-nm wavelength is the only choice, while for the water bodies with large amounts of dissolved organic matter and high concentrations of phytoplankton and suspended matter the use of the red spectrum region is quite acceptable. That was taken as a basis for determining the CIR, as this region was available at NOAA satellites. Thus, large amounts of satellite data were made available. As the amount and frequency of the data are of particular importance for revealing temporal dynamics, the use of the CIR seems to us quite justified. Using such ground-truth data as chlorophyll concentration and color index in the red spectral region, we made regression analysis. The results revealed an exponential relationship between the variables when the concentration of chlorophyll was lower than 150 mg/m3 (Fig. 1a). To investigate the relationships at concentrations higher than 150 mg/m3, we used the data from similar measurements conducted at the Dnieper cascade reservoirs, which are characterized by extremely high chlorophyll concentrations. Thus, combining the data for the Krasnoyarsk Reservoir and the Dnieper cascade reservoirs, we obtain a pooled array of data on chlorophyll concentration. Regression analysis was used to find the relationship between red radiation reflected from the surface layer and phytopigments present in extremely high concentrations. High concentrations complicate this relationship, and, as a result of linear regression analysis, the correlation coefficient is 0.97 (Fig. 1b).

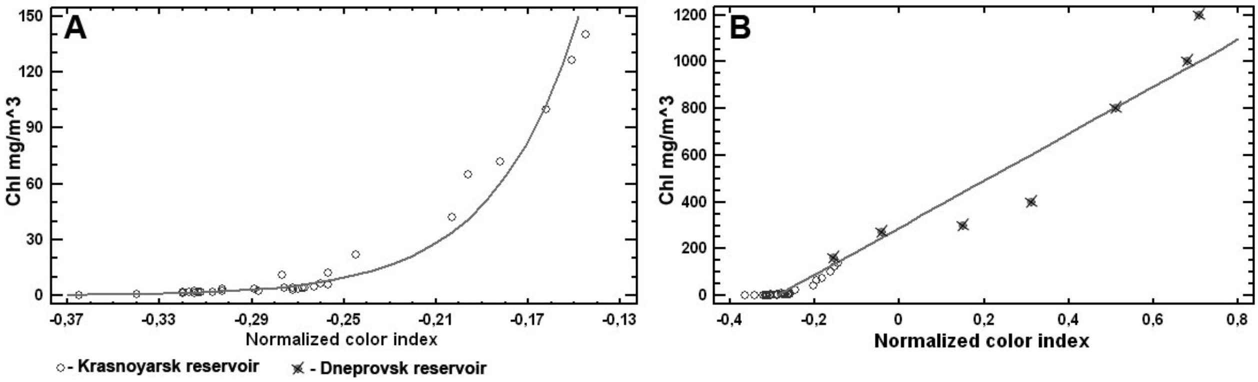

Fig. 1A, B Comparison of ground-truth data on Chl “a” concentration and normalized color index

In the first case, it is more reasonable to use nonlinear regression analysis, and in the second, the best result was obtained using linear regression. Systematic spectrophotometric measurements revealed spatial inhomogeneity of the chlorophyll concentration distribution in the surface layers of the Krasnoyarsk Reservoir. Our measurements revealed small-scale inhomogeneities of phytopigment distribution and a tendency of Chl ”a” increase in the south part of the reservoir. This can be generally accounted for by the shallowness and higher temperatures of the south part as opposed to the north part of the reservoir, where the water is up to 120 meters deep (Fig. 2 a, b).

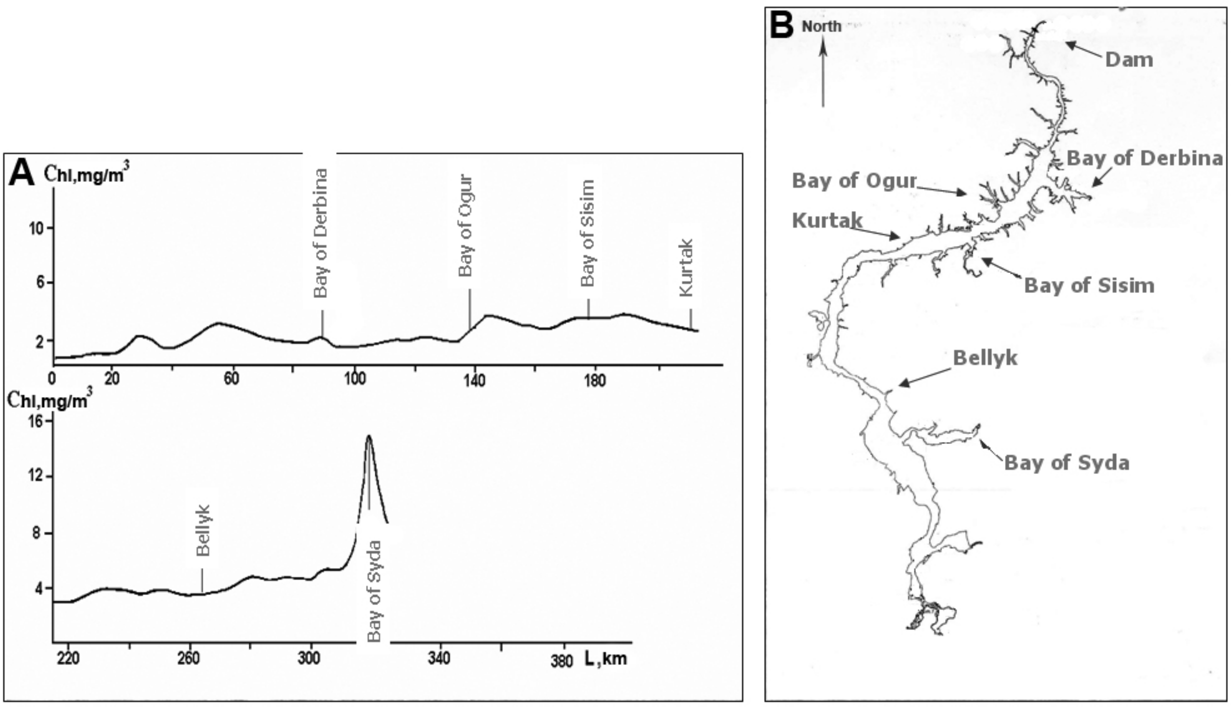

Fig. 2A, B Longitudinal subsurface distribution of chlorophyll “a” concentration in the Krasnoyarsk Reservoir obtained using remote sensing equipment (August 1983).

However, extremely high chlorophyll concentrations can be found in shallow bays of the Krasnoyarsk Reservoir, which have specific hydrologic features and slow water circulation. One of such bays is the Syda Bay. The maximum concentration is observed in the place where the wide and shallow Syda River flows in. The surface layers there are heated better, so the average temperature is 4-5 higher than in the reservoir itself and the chlorophyll concentration is 2-4 times higher. The concentrations of phytoplankton chlorophyll vary from 1.4 to 16 mg/m3.

Results Obtained Using NOAA/AVHRR Data

The Institute of Biophysics SB RAS has a large archive of NOAA satellite data. These data have low spatial resolution and wide spectral channels. Despite this fact, AVHRR information can be used to determine bloom areas, as blue-green algae form more or less continuous film. Chl "a" concentration reaches 1000-1400 mg/m3 and more. Under these conditions, the CIR can be calculated on the basis of AVHRR data. Direct hydrobiological measurements of phytoplankton biomass were performed at the same time (Gold, Z.G., 2003). Based on the results of regression analysis, the correlation coefficient between the CIR and chlorophyll concentration was 0.74. So, we were able to use this statistical model to calculate bloom levels (Sirenko et al, 1986). Figure 3 shows changes in bloom levels of the surface waters of the Krasnoyarsk Reservoir from July to September.

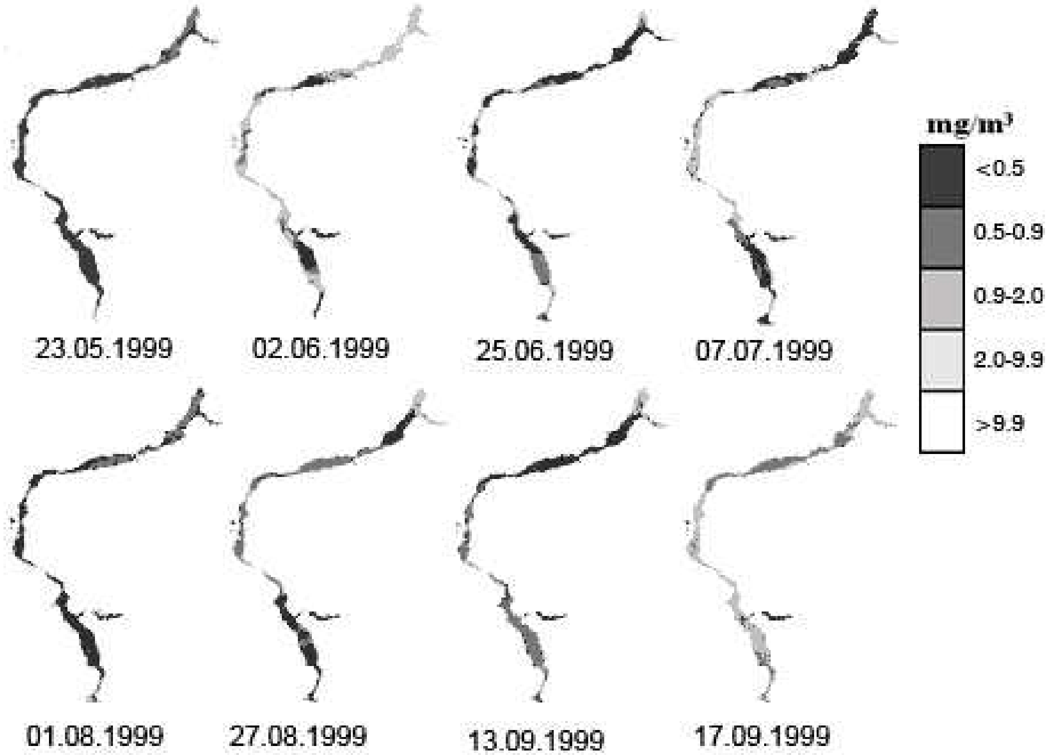

Fig. 3 Bloom classes on the surface of the Krasnoyarsk Reservoir distinguished based on integrated satellite (AVHRR) and ground-truth data.

Results Based on TERRA/ MODIS Data, Using Unsupervised Classification

The TERRA-MODIS space spectroradiometer, which was used to obtain data for this study, has 36 narrow spectral bands with spatial resolutions of 250, 500 and 1000 m. All bands for the ocean Chl investigation have a spatial resolution of 1 km and relatively high radiometric sensitivity. However, these bands have no atmospheric correction for land and lakes. We used 8-day composite images with a spatial resolution of 500 m (productMOD09A1 downloaded from http://edcimswww.cr.usgs.gov/ pub/imswelcome/) for classification of the reservoir based on spectral variability. In this product atmospheric effects are removed using a standard MODIS algorithm of atmospheric correction (E. F. Vermote and A. Vermeulen, 1999). The MOD09 product data have 7 spectral channels. In our study we used channels 1-4: 645, 858, 469, and 555, respectively. Unfortunately, at the present time it is difficult to obtain synchronous ground-truth data for the Krasnoyarsk Reservoir. Therefore, most of supervised classifications are unusable, as algorithms of this type require quite a large number of training samples (ground-truth data). Thus, we used unsupervised “ISO data” classification. Other researchers, e.g., (Nellis et al., 1998), reported using this classification method to analyze multispectral satellite data for inland water bodies. Our analysis yielded 5 spectral classes (Fig. 4 A, B).

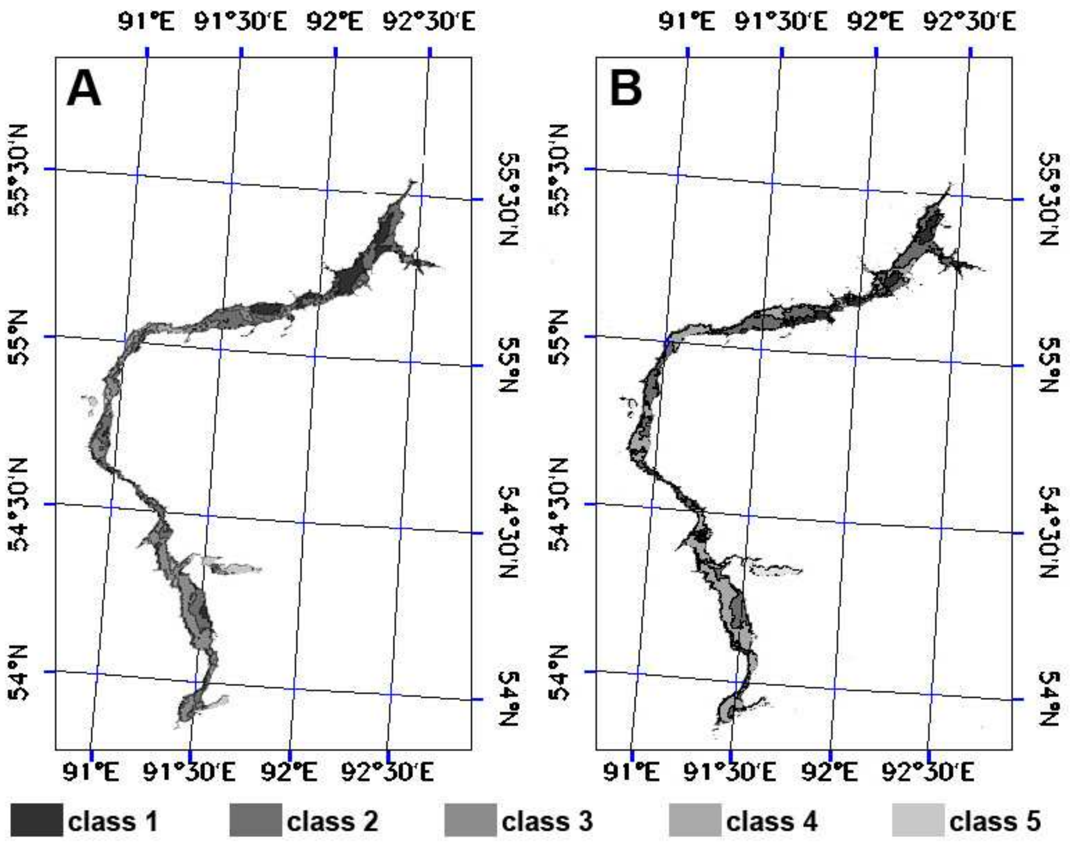

Fig. 4 8-day composite MODIS images mapped using unsupervised classification. A – 2005.08.20, B – 2005.08.28.

Results of the analysis visualized as a map of spectral classes show rather gradual changes in the spectral types and an increase in the level of reflection from north to south. The Syda Bay clearly has the highest reflection level. The increase in the reflection level in the green and red spectral regions is probably related to the increase in Chl "a" concentration. The increase in reflection values, which can be seen in the graphs of different classes, generally indicates an increase in water turbidity. Nevertheless, the discovered nature of spatial changes is similar to changes in chlorophyll concentration and spectral optical characteristics obtained in field investigations of 1983. MODIS spectral bands designed for measuring Chl concentration in the ocean and featuring high radiometric sensitivity can be used along with land channels. MODIS "water" bands were interpolated to increase the spatial resolution to 500 m and united with land bands. In this case, standard atmospheric correction was unavailable as this image was constructed using 1B level MODIS data. Thus, only Rayleigh scattering correction was used. As can be seen in the satellite image of August 2005 (Fig. 4 A, B), the spectra changes along the reservoir are similar to the changes of June 2004 (Fig. 5 A).

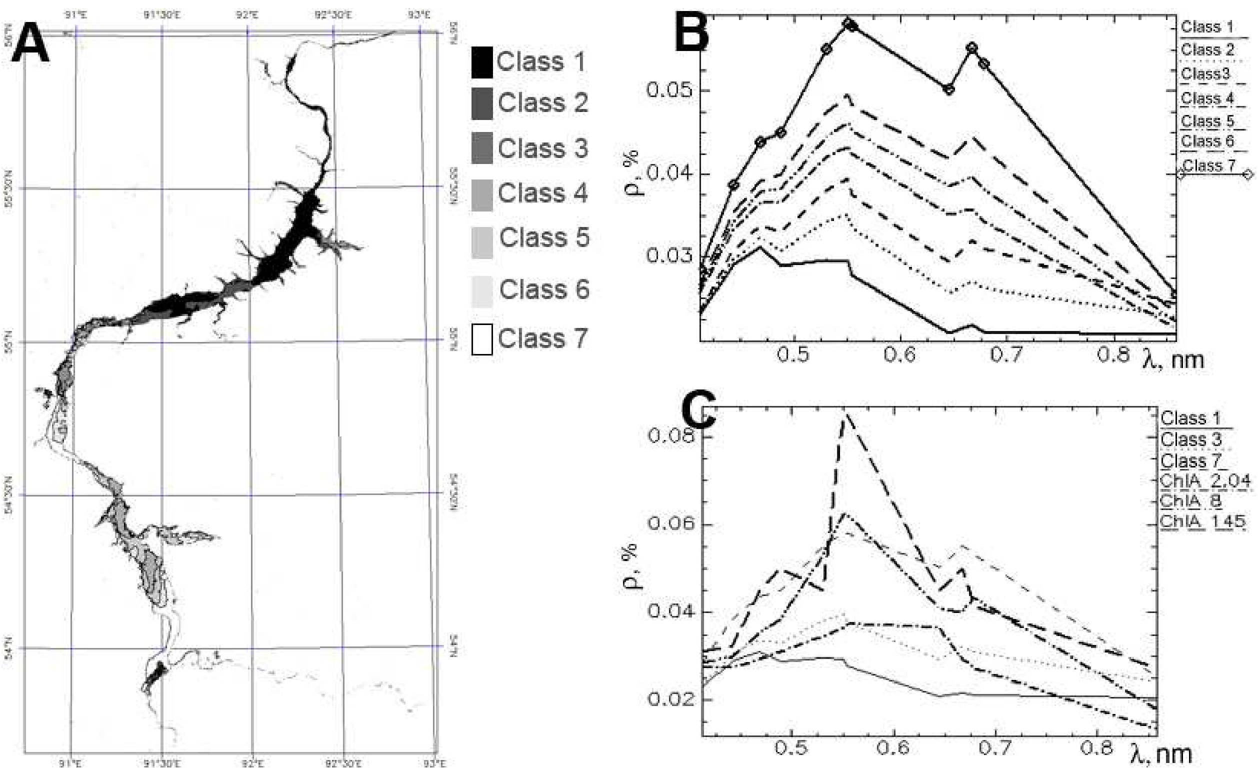

Fig. 5 Unsupervised classification by IsoData method. 2004.06.04. A - Unsupervised classification by IsoData method, B - Spectra obtained from classification, C - Satellite and ground-truth spectra.

The use of additional channels improves statistical significance of the obtained results as the spectra contain more points. This processing results in more effective comparison between the satellite spectra and the high resolution spectra obtained in the on-ground investigations. We have shown that the satellite reflectance spectra (Fig. 5B) are similar to the spectra of field measurements. In Figure 5C the spectra based on the field data are superimposed on the spectra based on the MODIS data. As chlorophyll concentration increases, the peaks grow 0.6 and 0.7 nm higher in the spectra based on ground-truth and satellite data. Analysis of the spatial distribution of areas with different spectral classes shows that reflectance increases southwards. The previously obtained ground-truth data show that chlorophyll concentration in the Krasnoyarsk Reservoir increases southwards. The more southerly classes correspond more closely to the spectra with higher chlorophyll concentration (Fig. 5 A,C).

Results Based on TERRA/ MODIS Data, Using Regression Analysis

We performed regression analysis of field data using the following values: surface chlorophyll concentration according to the ground-truth hydrobiological measurements taken at the beginning of August (Gold, Z.G., 2003) and satellite data of 01 August 2005, 17 August 2005, and 25 August 2005. The satellite data obtained at different dates were used to verify statistically the correlation between the satellite and ground-truth data time-synchronized to different extents. Table 1 illustrates the results of the analysis. Processing of the data obtained at different dates distinctly showed better results of regression analysis for the data of 01 August 2005, i.e. for the data that was maximally time-synchronized. Thus, two conclusions can be drawn. One is methodological – for small water bodies with highly inhomogeneous spatial distribution of dissolved and suspended matter it is particularly important to interpret satellite information using the data that are maximally time-synchronized with it. The other conclusion is related to the properties of the studied environment – the Krasnoyarsk Reservoir. Its hydrobiological properties are so variable that the most appropriate way to monitor them is to perform instantaneous space measurements. Thus, we deduced the following quantitative relationship between chlorophyll concentration and reflectance values for the Krasnoyarsk Reservoir: $C_{Chl} = 674.4 - 10369.7*b1 - 681.7*b2 - 10207.6*b3 - 3851.1*b4$, (1) where CChl is surface chlorophyll concentration, mg/m3; b1, b2, b3, b4 are reflectance values in the corresponding bands.

Table 1 Regression analysis of the data on surface chlorophyll concentration using ground-truth and satellite measurements.

Statistical characteristics	01 August 2005	17 August 2005	25 August 2005
Multiple correlation coefficient, R	0.98	0.65	0.68
`F – value	46.04	0.57	0.64
Multiple determination coefficient, R2	0.97	0.42	0.47
Adjusted multiple determination coefficient, R*2	0.93	-0.33	-0.22
t – value	12.707	-2.5668	2.48
Standard error of estimate	23.78	124	118

DISCUSSION

The best results can be attained by combining the presented methods. That is, continuous groundtruth measurements of the spectra of radiation emerging from the water and simultaneous measurements of phytoplankton chlorophyll must provide the basis for constructing empirical relationships. Data provided by different satellites have different features. The AVHRR data archive is the most complete and can be used to study long-term changes in the state of water bodies. MODIS satellite data are of better quality and can provide nearly continuous monitoring of the state of water bodies. The CIR method is workable only if there is a 720-nm band because at high chlorophyll concentrations, in the 720-nm band there is a narrow peak that determines whether CIR values will be negative or positive. Moreover, this method is more effective at high chlorophyll concentrations. The AVHRR sensor works in the broad range from 725 to 1000 nm. That is, although this sensor has a low sensitivity, it will “see” the bloom. The MODIS sensor has no spectral bands that would correspond to the 720 nm wavelength, so measurements of chlorophyll concentration are not related to absorption in the red spectral region. The reason is that in all MODIS bands in the near-IR spectral region reflection is much lower than in the visible red bands. Dall'Olmo and co-authors (2005) reported using red and near-infrared bands to study inland water bodies. When MODIS data are used, reflection values in different channels contain useful information on chlorophyll concentration. Due to optical complexity of the reservoir water it is difficult to find the combination of spectral channels and respective coefficients that would yield reliable estimates of chlorophyll concentration. Thus, it would be rational to use multivariate linear regression. Linear regression analysis was used to relate field and satellite data for inland water bodies by other authors (Buttner et al, 1987). Although the sensitivity of these methods is rather low, they can be used to determine extreme hydrobiological and hydrologic states of inland water bodies, such as dramatic increases in the amounts of suspended matter or phytoplankton "blooms". In addition to this, the described methods can be used to monitor in time spatial changes in "blooming" regions.

CONCLUSIONS

This work presents results of different types of investigations using remote sensing. Field spectrometric measurements during the period of formation (The period of formation is the time when the reservoir was being filled with the water and the hydrologic conditions were being formed) of the hydrobiological properties of the Krasnoyarsk Reservoir compared with the satellite data showed that the general pattern of the chlorophyll concentration distribution had been formed in the 1970-80s. Our investigations showed that in certain cases, when chlorophyll concentration is high (during blooming), the near-infrared region can be used to estimate the concentration. For this purpose a criterion was developed - color index in the red region (CIR). This index can be used in some situations for other inland water bodies. At chlorophyll concentrations lower than 150 mg/m3 the correlation between chlorophyll concentration and CIR has exponential form. The possibility of using unsupervised classification to map spectral optical characteristics of the Krasnoyarsk Reservoir was demonstrated. - Using clustering, it was shown that both the spatial distribution of phytoplankton and the form of the spectra are similar to the ground-truth data. A significant relationship between multispectral satellite data and the ground-truth hydrobiological measurements of chlorophyll concentration was found. The results show a good potential of both continuous monitoring and investigation of time series of inland water bodies using TERRA/MODIS satellite data, although this is not a standard procedure of processing MODIS data.

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Can Location of Sample Area and Expert Knowledge Affect the Results of Geopedological Approach in Soil Mapping?

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ABSTRACT

Soil maps are used for different purposes like agriculture, natural resources, mining and engineering. Thus, their quality is a prerequisite for rational land use and soil management. New versions of soil surveys are used to increase the reliability of soil maps. Geopedology is a systematic approach of geomorphic analysis for soil mapping that construct field operation upon work mainly in a sample area and generalization of the results obtained from sample area to similar landforms in the region. The objective of this study is to determine the effect of location of sample area and expert knowledge on credibility of generalization the results of geopedological approach for similar landforms in south-east of Borujen area, Central Iran. After preparation of primitive interpretation map of the study area on air photos (1:20 000), considering different locations of Pi111 unit that encompasses the maximum space of the study area, the sample area was planed in three different locations. Then, a second-order soil survey was conducted and final soil map was prepared. Also, the idea of two different experts was considered to determine the amount of credibility of generalization the results of geopedological approach for the mentioned unit. Results showed that changing the location of sample area has taxonomic levels (order, subgroup and/or family) and map unit type (complex and consociation) differences in Pi111 unit. In spite of similarity the profiles selected by two experts, soil taxonomy of these profiles were different in comparison with representative pedons (at family level). Therefore, the use of landform phases is recommended to increase the accuracy of geopedological results.

Keywords: Geopedology; Soil mapping; Sample area; Generalization; Borujen area

INTRODUCTION

Soil maps are used for different purposes like agriculture, natural resources, mining and engineering. Thus, their quality is a prerequisite for rational land use and soil management. Zhu et al. (2001) highlighted complete limitations of conventional soil surveying. As a result of these limitations, the current way of conducting soil survey needs to expenditure a lot of time and charge. Therefore, over the past decades, soil survey institutions have tried to minimize field mapping and to substitute conventional mapping methods by modern procedures to facilitate direct interpretation of the soil. In terms of the above-mentioned concepts, models of this kind attempt to comprehend the systematic part of soil variation with information on the geology, geomorphology and pedology.

Geopedological approach for soil survey was developed by Zinck (1989) and is essentially a systematic application of geomorphic analysis for soil mapping (Rossiter, 2000). The main objective in geopedology is to organize and classify the soils in their geomorphological expression in the earth's surface by using a hierarchical legend system (Zinck, 1989). Hengl and Rossiter (2003) concluded that geopedology can be applied by soil survey teams to edit and update current maps and to enhance or replace API for new surveys. Aiman et al. (2004) declared geopedological map and an appropriate interpolation technique can be used to map soil salinity in both discrete and continuous models. Farshad, et al. (2005) also stated that geopedology plays an important role in making decision on how to use salt-affected soils in the Northeast of Thailand. Udomsri (2006) illustrated the geopedological approach is quite valuable to obtain soil data from inaccessible areas particularly sloping lands. Moemeni (1994) illustrated this approach is better than traditional soil mapping method for land suitability classification due to separation of more homogeneous units. Other studies based on geopedological approach have done at different areas of Iran (for example: Moemeni and Farshad; 1998; Toomanian et al., 2006). The fundamental question in this issue is: to what extent the geopedological approach is authentic in generalization of its results? Therefore, the main goal of this research is to determine the effect of location of sample area and expert knowledge on credibility of generalization the results of geopedological approach for similar landforms in south-east of Borujen area, Central Iran.

MATERIALS and METHODS

Study Area

The area under investigation has a size of approximately 1100 ha. It is located between 31° 54' and 31° 56' N, and 51° 12' and 51° 15' E in south-east of Borujen region, Chaharmahal-Va-Bakhtiari province, Central Iran. The study area consists of two dominant landscape units namely hilland and piedmont. Piedmont is the major landscape which divides into two different lithologies by the main road in this area (Fig. 1 and Table 1). The mean annual precipitation and temperature in the Borujen region are 255 mm and 10.7 °C, respectively. The mean altitude in the area is 2277 m above the sea level. The soil moisture and temperature regimes of the area are xeric and mesic, respectively. Irrigated wheat cultivation and pasture are the major land uses in this area.

Soil Surveying

To prepare the photo-interpretation map (geoform map), aerial photographs (1:20 000) were interpreted under stereoscope by considering geopedological approach (Zinck, 1989). Then, interpreted air photos with the milars were imported into ILWIS software 3.4 (ITC, 2007). After ortho-photo geo-referencing (Rossiter and Hengl, 2001), landforms were mapped and glued via onscreen digitization.

The summarized data for each landform of the geoform map and legend are shown in Fig. 1 and Table 1, respectively.

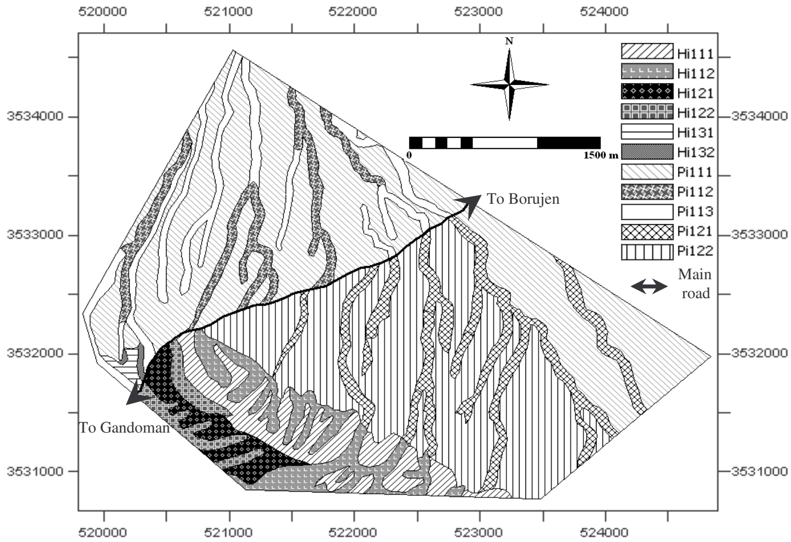

Fig. 1. The geoform map of the study area prepared by geopedological approach.

Table 1. Legend of the geoform map in the study area.

Landscape	Relief	Lithology	Landform	Symbol	Area
Hilland	Low hill	Marl/limestone slaty in part	Shoulder-backslope	Hi111	66.83
			Footslope	Hi112	62.92
		Conglomerate bedded with marl and silt	Shoulder-backslope	Hi121	29.44
			Footslope	Hi122	22.99
		Young terraces and alluvial fans	Shoulder-backslope	Hi131	4.29
			Footslope	Hi132	1.92
Piedmont	Undulated glacis	Young terraces and alluvial fans	Thread-riser complex	**Pi111**	**388.96**
			Swale with grass cover	Pi112	52.21
			Riser	Pi113	73.56
		Old terraces and alluvial fans	Riser	Pi121	103.25
			Thread-riser complex	Pi122	296.20

Considering different locations of Pi111 unit that encompasses the highest surface of the study area (Table 1), the sample area was planned in three different locations. In order to determine the amount of credibility of generalization the results of geopedological approach for the mentioned unit two different expert's knowledge (A and B) were also considered for validation. Then, a stratified grid sampling method with 250 m interval was performed in each sample area to select the profile locations. Three random profiles were dug by each expert for validation (Figs. 2, 3 and 4) and geographic position of all soil profiles was determined by a GPS. Types of map units were determined using criteria of Soil Survey Manual (Soil Survey Division Staff, 1993). Soil samples from different horizons of representative pedons in the sample area were taken for soil physical and chemical analyses and final soil classification according to American Soil Taxonomy (Soil Survey Staff, 2006).

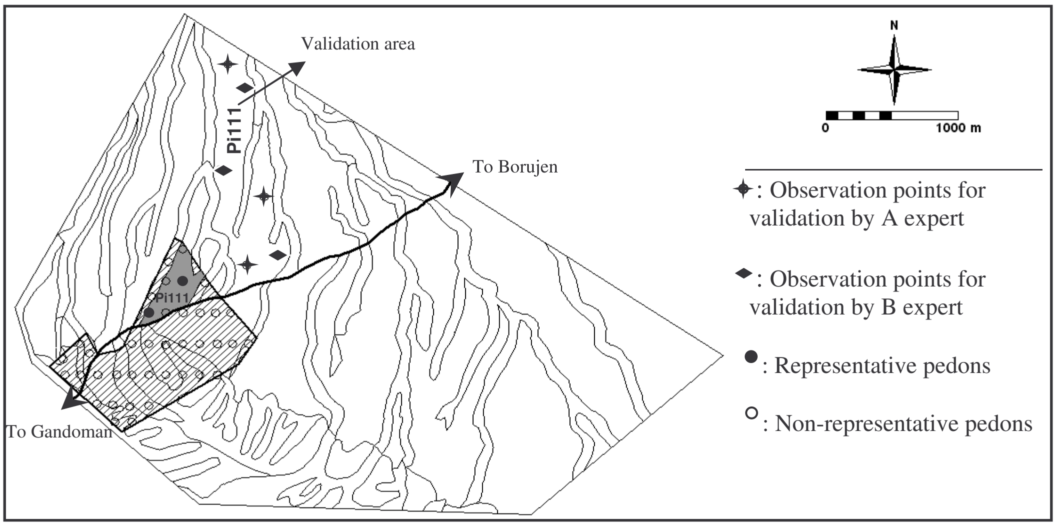

Fig. 2. Location of sample area (Hatched zone), first location of Pi111 unit in the sample area (Dark zone) and validation area with observation points on the geoform map.

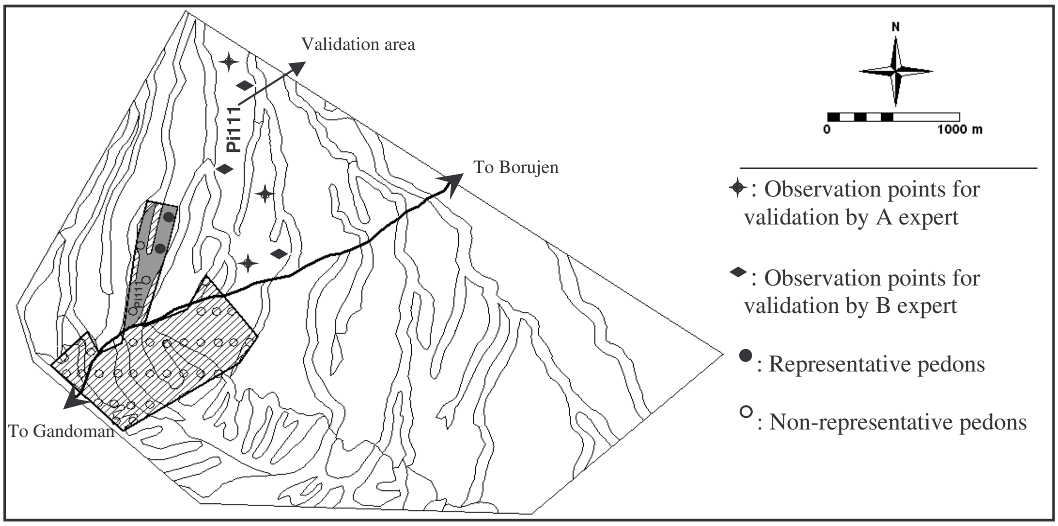

Fig. 3. Location of sample area (Hatched zone), second location of Pi111 unit in the sample area (Dark zone) and validation area with observation points on the geoform map.

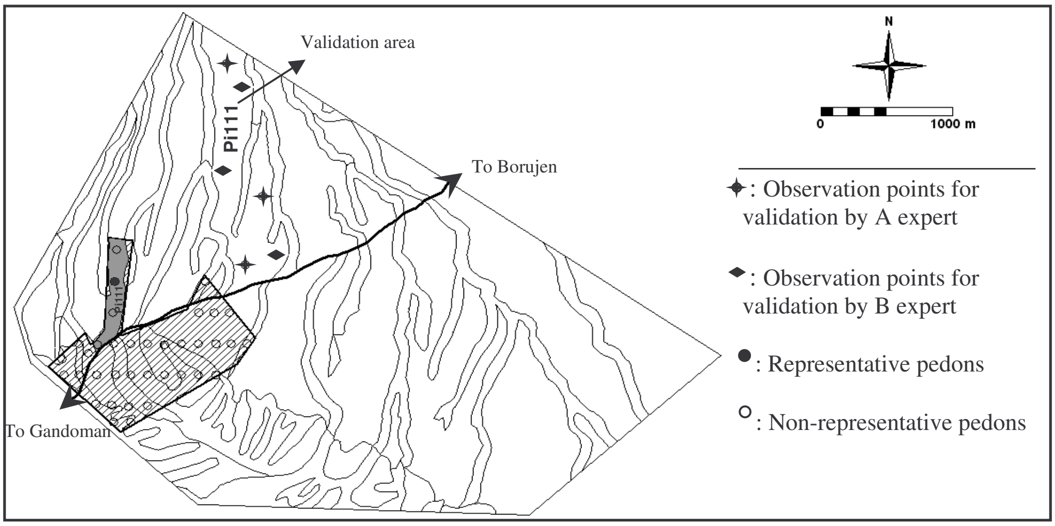

Fig. 4. Location of sample area (Hatched zone), third location of Pi111 unit in the sample area (Dark zone) and validation area with observation points on the geoform map.

RESULTS and DISCUSSION

Classification of representative pedons of Pi111 unit and type of mapping units at three locations are shown in Table 2. Results indicated that changing the location of sample area has taxonomic levels (order, subgroup and/or family) and map unit type (complex and consociation) differences in Pi111 unit. Table 3 shows classification of pedons for validation by two experts. In spite of similarity the profiles selected by two experts, soil taxonomy of these profiles were different in comparison with representative pedons at family level.

Therefore, the results of our study showed that the same soils should not be expected in similar landforms at family level. Now, the fundamental question is “why this much variability is occurred in the soils of the similar landforms”. Following points may help to answer:

1. Disability of the mentioned scale (250 m interval) to separate environmental processes due to their scale dependency.
2. Chaotic nature of the soil and landform variability in the study area, as a result of different historical developments (landscape evolution).
3. Lack of efficient and precise landform stratification and the act of extrapolation done by geopedological approach to similar landforms.
4. Area-class models or polygon-based methods for determination of soil variability can not completely represent soil continuous spatial variabilities.

Therefore, although geopedological approach tries to separate more homogeneous soil mapping units (Zinck, 1989), it still is not able to fully define and represent the variability and chaotic nature of the soils. In addition, the convention of describing map units based on representative soil pedons, which differ only in soil type or details of a genetically-based classification system, seems to be not sufficient in describing the real soils distribution. We recommend further investigations in traditional soil surveying methods as well as using new pedometric techniques in order to better analyze and understand the soil variability and to improve sampling and mapping approaches. As the optimum scale for geopedological approach is semi-detailed (1:50 000 to 1:100 000) to reconnaissance (1:100 000 to 1:250 000) surveys (Rossiter, 2000; Udomsri, 2006), the use of landform phases is recommended to increase the accuracy of geopedological results.

Table 2. Classification of representative pedons of Pi111 unit with type of mapping units at three locations.

Type of mapping unit	Soil family	Location of Pi111
complex	Fine-loamy, carbonatic, mesic Typic Calcixerepts Fine, carbonatic, mesic Calcic Haploxeralfs	first
complex	Clayey-skeletal, carbonatic, mesic Typic Calcixerepts Fine, carbonatic, mesic Petrocalcic Calcixerepts	second
consociation	Clayey-skeletal, carbonatic, mesic Petrocalcic Calcixerepts	third

Table 3. Classification of pedons for validation by two experts.

Soil family	Expert
Fine, mixed, active, mesic Calcic Haploxeralfs Clayey-skeletal, carbonatic, mesic Petrocalcic Calcixerepts Fine, carbonatic, mesic Petrocalcic Calcixerepts	A
Fine, mixed, active, mesic Calcic Haploxeralfs Clayey-skeletal, carbonatic, mesic Petrocalcic Calcixerepts Fine, carbonatic, mesic Petrocalcic Calcixerepts	B

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Developing Soil Cation Exchange Capacity Pedotransfer Functions using Regression and Neural Networks and the Effect of Soil Partitioning on the Accuracy and Precision of Estimation

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ABSTRACT

Soil fertility measures such as cation exchange capacity (CEC) may be used in upgrading soil maps and improving their quality. Direct measurement of CEC is costly and laborious. Therefore, indirect estimation of CEC via pedotransfer functions may be appropriate and effective. Several delineations of two consociation map units consisting of two soil families (Shahrak series and Chaharmahal series), located in Shahrekord plain, Iran were identified. Soil samples were taken from two depths of 0-20 and 30-50 cm and were analyzed in lab for several physico-chemical properties. Clay and organic matter percentages as well as moisture content at -1500 kpa best correlated with CEC. Pedotransfer functions were successfully developed using regression and neural networks. Soil partitioning increased the accuracy and precision of functions. Compared to regression, neural network technique resulted in pedotransfer functions with higher R^2 and lower RMSE.

Keywords: Cation Exchange Capacity (CEC), Pedotransfer, Regression, Neural network, Soil partitioning

INTRODUCTION

There is an increasing demand for reliable large-scale soil data to meet the requirement of models for planning of land-use systems, characterization of soil pollution, and prediction of land degradation (Mc Bratney et al., 2002). Cation Exchange Capacity (CEC) is among the most important soil properties that is required in soil databases (Manrique et al., 1991), and is used as an input in soil and environmental models (Keller et al., 2001). Cation Exchange Capacity is the total of the exchangeable cations that a soil can hold at a specified pH. Soil components known to CEC are clay and organic matter, and to a lesser extent, silt (Martel et al., 1978; Manrique et al., 1991).

Soil fertility measures such as CEC may be used for upgrading soil maps and improving their quality. Simulation models such as the Erosion-Productivity impact calculator (Williams et al., 1989) require large amounts of soil physical and chemical data and CEC is one key property used in this issue.

Although CEC can be measured directly, its measurement is difficult, time consuming and expensive especially in the semiarid region of Iran because of the large amounts of calcium carbonate. Pedotransfer Functions (PTF_s) provide an alternative by estimating CEC from more readily available soil data. The term pedotransfer function was coined by Bouma (1989) as translating data we have in to what we need. In recent years, several researchers tried to estimate CEC from basic physical and chemical soil properties (Breeusma et al., 1986; Manrique et al., 1991; Bell and Keulen, 1995; McBratney et al., 2002). In most of these models, CEC is assumed to be a linear function of soil organic matter and clay content (Breeusma et al., 1986; McBratney et al., 2002). Results show that greater than 50% of the variation in CEC could be explained by the variation in clay and organic C content for several New Jersey soils (Drake and Motto, 1982), for some Philippine soils (Sahrawat, 1983), and for four soils in Mexico (Bell and Keulen, 1995). Only a small improvement was obtained by adding pH to the model for four Mexican soils (Bell and Keulen, 1995). In B horizons of a toposequence, the amount of fine clay was shown to explain a larger percent of the variation in CEC than the total clay content (Wilding and Rutledge, 1996).

Multiple Linear Regression (MLR) analysis is generally used to find the relevant coefficients in the model equations. Often, however, models developed for one region may not give adequate estimates for a different region (Wagner et al., 2001). Because the most essential input variables can be found automatically using stepwise regression, initially, linear and polynomial regressions were applied (Pachepsky and Rawls, 1999).

A recent approach to model PTF_s is the use of artificial neural networks (ANN_s) (Schaap et al., 1998). Artificial neuaral networks have been successfully employed to predict soil hydrological properties (Pachepsky and Rawls, 1999; Minasny and McBratney, 2002). A type of ANN known as multilayer perceptron (MLP), which uses a back-propagation training algorithm, is usually used for generating PTF_s (Schaap et al., 1998; Minasny and McBratney, 2002; Amini et al., 2005). An advantage of using ANN_s is that no specific type of function needs to be assumed a priori to model the relationship between inputs and outputs. The optimum relation that links input data to output data is obtained through a training procedure (Schaap et al., 1998). Because of their greater feasibility, ANN models are generally expected to be superior to MLR models (Schaap et al., 1998; Minasny et al., 1999). The drawback of ANN_s is that they do not provide an explicit procedure to select the most essential PTF input variables (Pachepsky et al., 1996).

The PTF accuracy is assessed from the correspondence between measured an estimated data for the data set from which a PTF has been characterized by various quantitative measures, such as the mean error, the standard deviation of the mean error, the mean squared error, determination coefficient R^2, etc.(Kern,1995; Leenhardt, 1995). Results show that when soils are grouped by similarities in origin or properties, accuracy of predictive models has been shown to improve (Pachepsky and Rawls, 1999). Examples of soil grouping include lithomorphic classes (Franzmeier, 1991), hydraulic-functional horizons (Wosten et al., 1985), genetic classification (Leenhardt, 1995), texture classes (Clapp and Hornbergere, 1978) and numerical soil classification (Williams et al., 1983). Drake and Motto (1982) grouped soils by taxonomic order or province. Similarly, Asadu and Akamigbo (1990) predicted CEC from organic matter and clay content by grouping the soil based on taxonomic order

(Inceptisols, Alfisols, Ultisols, and Oxisols). The U.S. Soil Taxonomy systems (Soil Survey Staff, 1999) also classifies soils by mineralogical composition at the family level which may be useful in soil partitioning to improve both accuracy and reliability of predictive models (Pachepsky and Rawls, 1999). The objectives of this study were (1) developing of PTFs for CEC using methods of regression and neural networks, (2) studying the possibility of upgrading the soil maps by determining the CEC for two dominant soil families in soil mapping units in Chaharmahal-va-Bakhtiari province and (3) assessing the effect of soil partitioning into families and different layers on the quality of the models.

MATERIALS and METHODS

The study area consists of several irrigated lands in Chaharmahal-Va-Bakhtiari province, Central Iran (Fig. 1). The soil moisture and temperature regimes of the area are xeric and mesic, respectively. One hundred and twenty samples were collected from several delineations of two consociation map units consisting of two soil families (Shahrak series and Chaharmahal series) located in Shahrekord plain, Central Iran. Dominant soils at two consociation map units are classified as follow at family levels:

1) *Fine, Mixed, active, Mesic Typic Calcixerepts*

2) *Fine, Carbonatic, Mesic Typic Calcixerepts*

The classification of these soils are similar up to subgroup level but their family was different because of difference in mineralogy class.

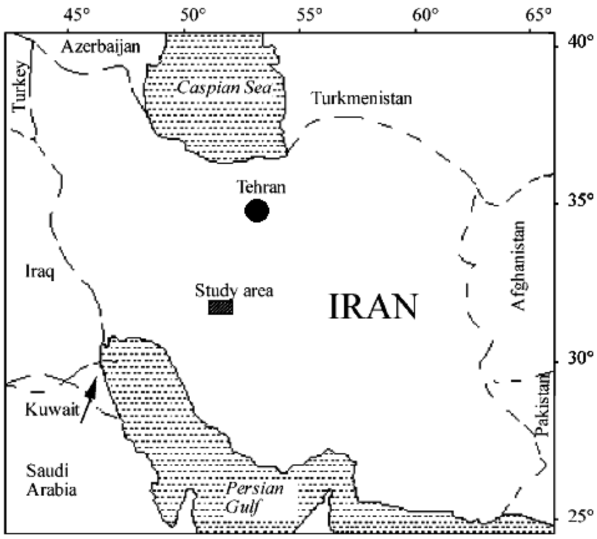

Fig. 1. Location of the study area in Central Iran

Soil samples were taken from two depths of 0-20 and 30-50 cm and were analyzed in lab for several physico-chemical properties including soil particle size distribution, organic matter, moisture content at wilting point at -1500 KPa, pH, calcium carbonate equivalent and cation exchange capacity. Statistical analysis and multiple regressions were performed by STATISTICA 6.0 software and neural network models were developed by JMP 5.0 software. Prediction models were developed at first for all data without partitioning and then for each family and also surface and subsurface layers. The best linear regression models suggested by researchers for each level (each family, each layer and all samples) were considered for model developing.

The MLP algorithm developed in this study is a feed forward back propagation network (FFBP) model. This network consists of layers of interconnected non linear processing elements called neurons. The architecture of the MLP model is such that the numbers of input and output neurons are usually matched to the numbers of input and output elements. The transfer function was selected a sigmoidal function that is selected such that it accommodates the nonlinearity of the specific input–output relationship. Profiler diagram possibility was used to select suitable number of node in the hidden layer and avoid under fitting and over fitting.

The performance of the models was evaluated using the root mean square error (RMSE) and the correlation coefficient (R^2) between predicted and measured values. Relative improvement (RI) index was used to compare the performance of two models developed from regression and neural networks.

RESULTS and DISCUSSION

Descriptive Analysis

The summary statistics of the soil properties for two families are given in Tables 1 and 2.

Table 1. Summary statistics of soil properties for family one

property	Mean			Max	Min	CV%	Mean of two layers	
	Surface Layer	Depth Layer	Family		Family		Difference *	Significant Level
%Sand	17.8	16.4	17.1	35.3	5.7	39.7	1.4	*ns*
%Silt	42.7	39.7	41.2	65.4	27.3	22.8	3	*ns*
%Clay	33.7	45.3	39.5	63.7	24.6	21.7	-11.6	99%
%OM	1.8	1.1	1.4	2.9	0.32	34.7	0.73	99%
%PWP	19.2	19.3	19.2	27.6	12.4	16.6	-0.1	*ns*
%$CaCO_3$	22.1	25	23.4	39.0	12.5	28.2	-2.9	*ns*
pH	7.8	8	7.9	8.4	7.2	2.5	-0.1	*ns*
CEC ($cmol_c\ kg^{-1}$ soil)	36.5	37	36.7	69.2	14.7	39.8	-0.5	*ns*

* The negative difference means that quantity of properties in depth layer is greater than surface layer

Table 2. Summary statistics of soil properties for family two

property	Mean			Max	Min	CV%	Mean of two layers	
	Surface Layer	Depth Layer	Family		Family		Difference *	Significant Level
%Sand	25.4	24.4	24.9	42.6	11.5	22.6	0.1	*ns*
%Silt	41.4	36.9	39.1	53.6	22.0	15.7	4.5	*ns*
%Clay	32.8	40.5	36.7	49.7	24.6	11.3	-7.7	99%
%OM	1.6	0.94	1.27	2.4	0.63	18	0.7	99%
%PWP	20.0	19.4	19.7	26.5	12.4	13.6	0.6	*ns*
%$CaCO_3$	23.0	31.2	27.1	45.0	14.0	27.3	-8.3	*ns*
pH	7.6	7.7	7.7	8.0	7.1	3.6	-0.1	*ns*
CEC ($cmol_c\ kg^{-1}$ soil)	31.5	30.56	31.0	71.4	9.7	54.4	0.9	*ns*

* The negative difference means that quantity of properties in depth layer is greater than surface layer

The organic matter content of the soils in the region is usually low, ranging from 0.32 to 2.9% and 0.63 to 2.4% for families one and two, respectively with an average of 1%. The coefficient of variation (CV) of CEC showed more variability than those of the soil particle size distribution, OM, pH and PWP in two families. A mean difference (L=0.99%) was observed for OM and clay contents between layers in two families (Tables 1 and 2). Significant difference between clay content in two layers is probably due to more clay in depth layers of each family because of transmission clays from epipedon toward endopedon (Arnaud and Septon, 1972). These results were in general agreement with those of Nourbakhsh et al. (2002) who obtained significant difference for OM and clay contents between two horizons.

Correlation of Soil Properties

The linear correlation coefficients between CEC and independent variables are given in Table 3.

Table 3. Simple linear correlation coefficients (r) between CEC and independent variables

Partitioning Level	*OM* (%)	*PWP* (%)	*Clay* (%)	*Sand* (%)	*Silt* (%)	*$CaCO_3$* (%)	*pH*
All Samples (No Partitioning)	0.53*	0.73*	0.51*	**-0.30***	0.16	-0.15	0.10
Family one	0.58*	0.78*	0.51*	-0.20	0.11	-0.17	0.07
Surface layer of family one	0.89*	0.77*	0.66*	-0.23	0.32	-0.29	0.03
Depth layer of family one	0.70*	0.80*	0.73*	-0.16	0.17	-0.01	0.11
Family two	0.50*	0.75*	0.53*	-0.29	0.19	-0.07	0.02
Surface layer of family two	0.86*	0.76*	0.58*	-0.21	0.04	-0.03	0.05
Depth layer of family two	0.82*	0.76*	0.81*	-0.35	0.31	-0.15	0.00

*The relation is significant at the 0.05 level.

This table shows OM, clay and PWP has higher correlations with CEC (L=95%) among the measured properties. As expected, the correlations between the CEC and sand content were negative. Positive correlation between CEC, soil OM and clay content is related to existence of negative charges on these properties (Manrique et al., 1991; Bell and Keulen., 1995 and Noorbakhsh et al., 2005).

Positive significant correlation between CEC and PWP may be explained by the same influence of OM and clay on them. Najafi (2005) also observed high correlation coefficient between CEC and PWP (r=0.90) in his results.

The correlation coefficient between CEC and OM in each family decreased from surface layer to depth layer, whereas the correlation coefficient between CEC and clay in each family increased from surface to depth layer (Table 3). It seems that existence of more OM in surface layer and more clay in depth layer is the main reason for significant correlation coefficients in this layer. These results are similar to the results of several researchers (Wilding and Rutledge, 1966; Noorbakhsh et al., 2005). In general, partitioning each family in to layers caused to increasing significant correlation coefficients for CEC, clay and OM. The partitioning of soils in to family and layer could not effect on correlation coefficient between CEC and PWP (Table 3).

Developing Soil CEC PTFs using Regression

The following models suggested by researchers in literature review were used for calibration of the soils in our study area:

Model 1: $CEC=B_o+B_1$ %OM (Bell and Keulen, 1995; Noorbakhsh et al., 2005)

Model 2: $CEC=B_o+B_1$ %Clay (Bell and Keulen, 1995)

Model 3: CEC=B_o+B_1 %Clay + B_2% OM (Martel et al., 1977; Bell and Keulen, 1995; Noorbakhsh et al., 2005)

Model 4: CEC=B_o+B_1 %OM+B_2%PWP (Seybold et al., 2005)

The results of calibration and its accuracy are given in Tables 4 to 7.

Table 4. Test results of the regression for model 1.

Number	Partitioning Level	Calibration coefficients		R^2	*RMSE*
		B_o	B_1		
1	No Partitioning	8.7	18.5	0.28	14.0
2	Surface layers of two families	-28	36.4	0.75	8.8
3	Depth layers of two families	49.7	-16.2	0.52	11.8
4	Family one	14.1	15.75	0.31	12.3
5	Surface layer of family one	-20	31/6	0.79	7.4
6	Depth layer of family one	0.32[a]	34.12	0.47	10.1
7	Family two	3.6 [a]	21.5	0.25	15.9
8	Surface layer of family two	-48.4	49.8	0.73	9.0
9	Depth layer of family two	-45	80.86	0.67	11.3

[a] The coefficients are not significant at the 0.05 level

Without partitioning, models (1) and (2) predicted CEC weakly. Results showed that although soil partitioning in to families didn’t improve accuracy of models (1) and (2), partitioning each families in to layers caused to increase R^2 and decrease the RMSE. However, model (1) for upper layer and model (2) for depth layer were more suitable. These results accord well with correlation of CEC with OM and clay in Table 3. It seems that using simultaneous variables of OM and clay percentage caused to make better estimation for CEC (Model 3, Table 6). Accuracy of model 3 without partitioning is also higher than models 1 and 2. Comparison the R^2 and RMSE of model 3 with models 1 and 2 showed an increase of R^2 from 0.28 to 0.67 and a decrease of RMSE from 14 to 9.5.

Table 5. Test results of the regression for model 2.

Number	Partitioning Level	Calibration coefficients		R^2	*RMSE*
		B_o	B_1		
10	No Partitioning	-10.8 [a]	1.17	0.28	14.3
11	Surface layers of two families	-46	2.2	0.38	13.0
12	Depth layers of two families	-46	1.85	0.54	11.5
13	Family one	2.3a	0.87	0.26	12.7
14	Surface layer of family one	-29.4 [a]	2	0.43	12.2
15	Depth layer of family one	-25.4	1.37	0.54	9.4
16	Family two	-28	1.6	0.28	15.5
17	Surface layer of family two	-56.6	2.7	0.34	14.1
18	Depth layer of family two	-91.25	3	0.65	11.6

[a] The coefficients are not significant at the 0.05 level

Table 6. Test results of the regression for model 3.

Number	Partitioning Level	Calibration coefficients			R^2	*RMSE*
		B_o	B_1	B_2		
19	No Partitioning	-51.2	22/8	1.4	0/67	9/5
20	Surface layers of two families	-43	31/7	0.68	0/75	8/4
21	Depth layers of two families	-46.5	29/6	1.17	0/65	10/0
22	Family one	-35.1	19/5	1.11	0.72	7.9
23	Surface layer of family one	-30.97	27/8	0.51[a]	0.81	7.2
24	Depth layer of family one	-30	20/4	0.97	0.66	8.3
25	Family two	-90	30.65	2.24	0.74	9.4
26	Surface layer of family two	-74.9	43.5	1/1	0.78	8.3
27	Depth layer of family two	-85.2	49	1.7	0.78	9.3

[a] The coefficients are not significant at the 0.05 level

Soil partitioning in to family and family in to surface and subsurface layers could improve the quality of model (3) especially in surface layers (Functions no. 23 and 26). An unexpected value for function no. 24 is probably related to existence of different clay minerals. As texture and organic material data are more available and their measurement is more convenient than CEC, the use of the model (3) seems more practical and useful.

When the PWP measurement is possible or the data related to the PWP and the percentage of the OM is accessible, the model (4) may be used (Table 7). The RMSE values in our research are in agreement with Noorbakhsh et al. (2005). Bell and Keulen (1995) reported less RMSE (1.5) and more R^2 (0.85) rather than the results of the present research. Seybold et al. (2005) found the RMSE average of 0.3 and the average of 0.7 for R^2 using two attributes of O.M and clay and exponential models.

Table 7. Test results of the regression for model 4.

Number	Partitioning Level	Calibration coefficients			R^2	*RMSE*
		B_o	B_1	B_2		
28	No Partitioning	-42.4	15.4	3.3	0.58	10.8
29	Surface layers of two families	-42.6	49	1.6	0.77	8.0
30	Depth layers of two families	-42.2	29.14	2.4	0.66	10.0
31	Family one	-31.5	2.3	3	0.65	8.8
32	Surface layer of family one	-33.5	43	1.28	0.81	7.0
33	Depth layer of family one	-26	2	2.5	0.70	7.8
34	Family two	-57.7	13.2	4	0.60	11.8
35	Surface layer of family two	-66.5	64.5	1.88	0.78	8.3
36	Depth layer of family two	-61.4	97	2	0.73	10.4

Developing Soil CEC PTFs with Neural network

We used same independent variables discussed in regression models as input data and CEC was supposed as only output variable for developing neural networks models. So, the models 1 to 4 were also used for neural network.

Table 8 indicates that the model 3 usually is the best for estimation of CEC in comparison with models 1 or 2 (data not shown). Therefore, O.M and clay contents were suitable inputs for developing soil CEC pedotransfer functions in both neural network and regression methods, Manrique et al. (1991) also concluded that contributions of clay and OM to the prediction of CEC increased significantly when soils were grouped by order. Partitioning soils in to layers especially in each family caused to improve quality of model 4 like regression method (Table 9).

Table 8. Test results of the neural network for model 3.

Number	Partitioning Level	R^2	*RMSE*
55	No Partitioning	0.73	0.38
56	Surface layers of two families	0.85	0.38
57	Depth layers of two families	0.75	0.50
58	Family one	0.74	0.51
59	Surface layer of family one	0.90	0.31
60	Depth layer of family one	0.67	0.58
61	Family two	0.77	0.46
62	Surface layer of family two	0.83	0.41
63	Depth layer of family two	0.88	0.34

Table 9. Test results of the neural network for model 4.

Number	Partitioning Level	R^2	*RMSE*
64	No Partitioning	0.63	0.60
65	Surface layers of two families	0.85	0.38
66	Depth layers of two families	0.72	0.53
67	Family one	0.68	0.56
68	Surface layer of family one	0.90	0.30
69	Depth layer of family one	0.73	0.52
70	Family two	0.65	0.57
71	Surface layer of family two	0.82	0.42
72	Depth layer of family two	0.83	0.41

Comparison of regression PTFs with neural networks

Relative Improvement shows R^2 and RMSE values of the models in all levels of separation heavily decrease. This means that the neural network for CEC estimates has more accuracy.

Amini et al. (2005) also indicate that using the neural network model with FFBP algorithm toward regression method estimates CEC with high accuracy. Our results with one node showed greater R^2 and less RMSE in comparison with their results. It seems that the main reason for higher accuracy is soil partitioning and more homogeneity of soils.

CONCLUSION

Soil partitioning increased the accuracy and precision of functions. The main reason for increasing the accuracy of models is increasing the homogeneity and uniformity of soil properties.

In both regression and neural network methods, concurrent input of clay and OM caused higher accuracy for estimation of CEC. Compared to regression, neural network technique resulted in pedotransfer functions with higher R^2 and lower RMSE. Upgrading soil maps may be done by developing models of estimation for time consuming and costly variables.

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Basic Soil Properties and Soil Classification of Hazelnut Cultivation Area in the Eastern Black Sea Region, Case Study; Ünye-Tekkiraz District*

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ABSTRACT

The objective of this research was to investigate physical, chemical and morphological properties, classification and mapping of soils of hazelnut cultivation in Ünye-Tekkiraz district of The Eastern Black Sea Region. The study area is located between west of the Ordu and south of the Samsun provinces, at coordinates 4542495-4537485 N and 342549-347523 E and total area is approximately 31.5 km^2. Average annual precipitation and temperature are 1162.4 mm and 14.2 ^{o}C, respectively. Elevation varies from 200 m to 550 m above sea level. According to soil taxonomy, the soil temperature regime and moisture regime were classified as mesic and ustic, respectively. Most of the study areas have been commonly used for hazelnut cultivation, whereas southern part of the study area generally cover small forest and pasture lands. In the study area, distribution of geological pattern is palaeocene and eocene rocks consisting of sandstone, siltstone and marl including widely distributed and altered eocene aged volcano-clastics which are composed of basalt and andesite. After examination of topographic, land use, geologic and geomorphologic maps and land observation, 15 profile places were excavated in the study area. The soil samples were taken from each profile based on genetic horizons and their analyses were done in the laboratory. According to the results of laboratory analyses by taking into consideration of soil taxonomy, 11 different soil series were classified and described. Two them were classified as Entisol due to their young age and five are Inceptisol, three are Alfisol, and one is Vertisol. Whereas Hatipler seri has the largest area (14.7 %), Yenicuma Dere soil seri has the smallest area in the study area (3.2 %).

Key Words: Soil survey and mapping, soil characteristics soil taxonomy

INTRODUCTION

In order to produced food for increasing population soil and water resources have to be used more sustainable manner. In last decade, catastrophic events like land use change and land degradation have occurred due to mismanagement practices such as soil tillage, irrigation, overgrazing, illegal timbering etc. Therefore, detailed knowledge about land recources is imporant for any project planning to prevent the environmental conditions. In this case, soil resource inventory provides an insight into the potentialities and limitation of soil for its effective exploitation. Soil survey provides an accurate and scientific inventory of different soils, their kind and nature, and extent of distribution

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so that one can make prediction about their characters and potentialities (Manchanda et al., 2002). It also provides adequate information in terms of land form, terraces, vegetation as well as characteristics of soils (texture, depth, structure, stoniness, drainage, acidity, salinity and so on) which can be utilized for the planning and development. Consequently, soil survey and mapping are an integral part of an effective agricultural recearch and advisory for planers and decision makers to provide information about soil and they are inventory of the soil resource of the land. Particularly they give information needed for land use planning and soil management programs (Ramakrishnan, 2000).

Today advanced computer programs including decision support systems (Geographic Information System and Remote Sensing) contribute to the speed and efficiency of the overall planning process and allow access to large amounts of information quickly. Especially during the last decade, GIS and RS have received much attention in application related to resources at significantly large spatial scales (Green 1995; Hinton 1996).

Turkey is one of the few countries in the world with a favorable climate for hazelnut production. Hazelnut is an important nut species for Turkish economy. Turkey is responsible for about 70% of world hazelnut production and 75% of the world hazelnut trade. The production area is spread densely all along the Black Sea coast, where the hazelnut has been native for the last 2500 years. In addition, hazelnut farming has been the chief for livelihood in the region for centuries, and still is today. Ordu is one of the most important hazelnut production centers. It constitutes 28% of Turkish hazelnut production. Although hazelnut has the long history in this region, there has been still low level of production in hazelnut farming (Dengiz, 2008). Howevre, there is insufficiently soil survey and mapping studies for hazelnut farming areas. Therefore the objective of this research was to investigate physical, chemical and morphological properties, classification and mapping of soils of hazelnut cultivation in Ünye-Tekkiraz district of The Eastern Black Sea Region.

MATERIALS and METHODS

Field Description

The study area is located between west of the Ordu and south of the Samsun provinces, at coordinates 4542495-4537485 N and 342549-347523 E and total area is approximately 31.5 km^2 (Figure 1). Average annual precipitation and temperature are 1162.4 mm and 14.2 ^oC, respectively. Elevation varies from 200 m to 550 m above sea level.

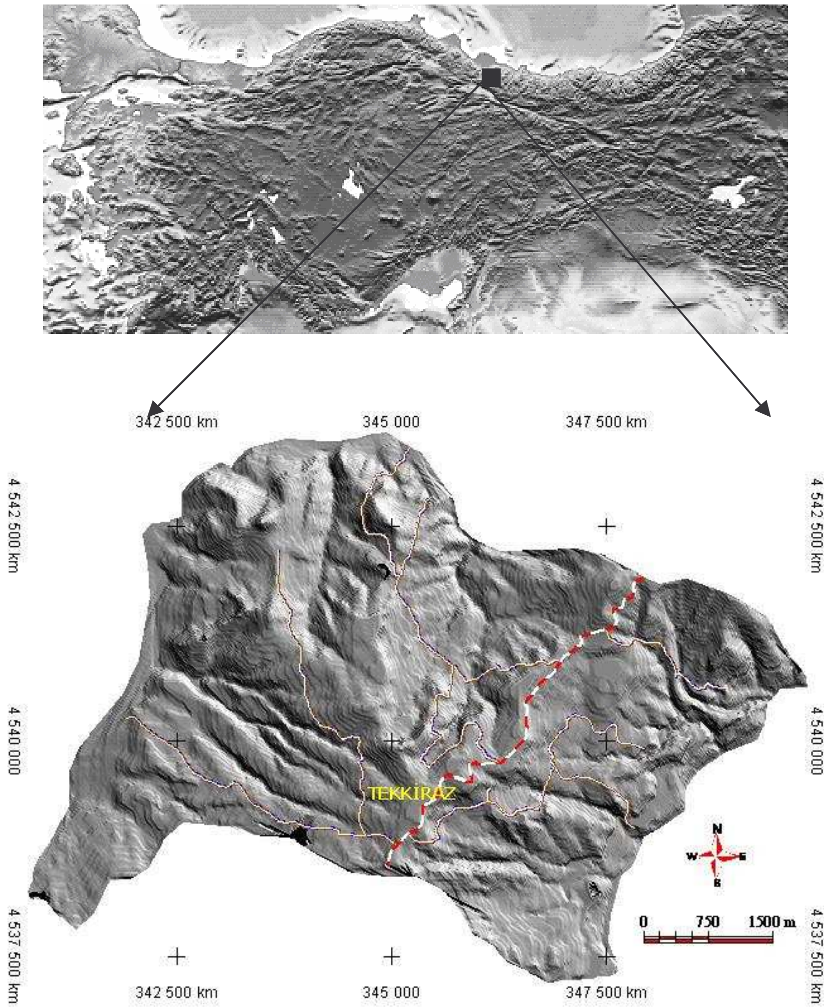

Figure 1. Location of the study area

Most of the study areas have been commonly used for hazelnut cultivation, whereas southern part of the study area generally cover small forest and pasture lands. In the study area, distribution of geological pattern is palaeocene and eocene rocks consisting of sandstone, siltstone and marl including widely distributed and altered eocene aged volcano-clastics which are composed of basalt and andesite.

METHODS

Soil surveyors consider the topographic, parent material, vegetation and climate variations as a base for depicting the soil variability. In addition, soil mapping needs identification of a number of elments. These elements which are of major importance for soil survey are land type, vegetation, landuse, aspect, drenage patern, geological material, slope, relief and so on. Soils are surveyed and mapped, following three tier approachs, comprising interpretation of all data, field survey (including laboratory analysis of soil samples) and cartography (Sehgal *et al.*1989, Soil Survey Staff, 1993). However, computer aided digital image processing and GIS techniques have also been used for mapping soil (Epema 1986; Korolyuk & Sheherbenko 1994; Kudrat et al. 1990, Dengiz et al., 2003) and advocated to be a potential tool (Kudrat et al. 1992; Lee et al. 1988, Manchanda et al., 2002).

Descriptions of soils in the stusy area were accomplished according to soil survey manual (1993). Soil samples collected from all horizons were analyzed for total soluble salts, CEC (Cation Exchange Capacity) and pH (Soil Survey Staff,1992), texture (Bouyoucos, 1951), organic matter (Nelson and Sommers, 1982), $CaCO_3$ (Soil Survey Staff,1993) and bulk density (Blacke and Hartge, 1986). Soil classification was accomplished using Soil Taxonomy (1999).

RESULTS and DISCUSSION

Topographic, land use-land cover, geological maps and meteorological data were used to detect different soil profile places, to prepare soil map and to form soil data-base of study region. First of all, Digital Elevation Model (DEM) was generated by digitizing from topographic sheets to determine elevation, slope percentage, aspect and physiographic variations (Figure 2). All these data were analysed using of TNT Mips 6.4v MicroImage GIS and RS programme.

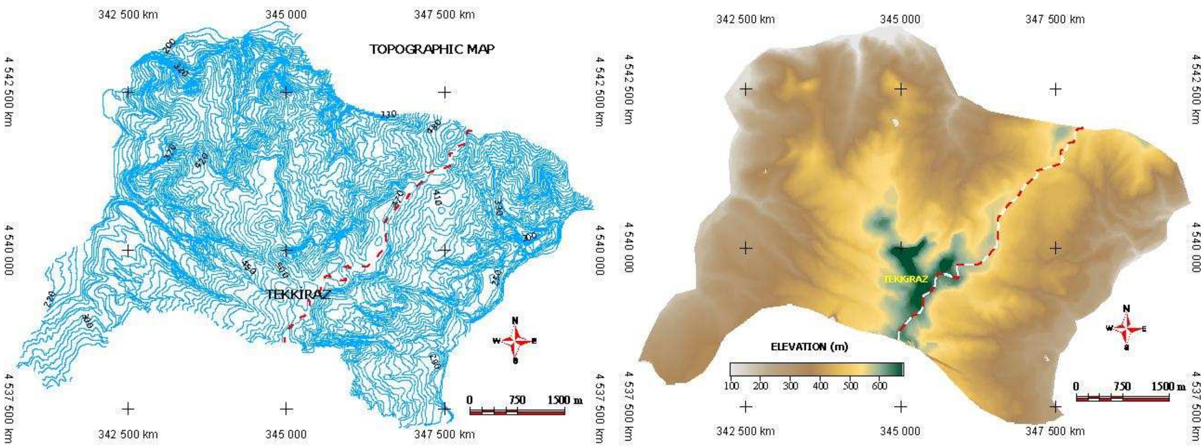

Figure 2. Topographic and dem maps of the study area

Soils on slope ofen vary in response to the way in which water and soil materials move through and over the land surface, this movement is in turn controlled by the geometry of the land surface (Huggett, 1975). This approach has rapidly gained popularity with the recent development of techniques for the direct calculation of terrain parameters from DEM. According to slope distributions derived from DEM are 30.4% of the study area has less than 20% slope and 69.6% has more than 15% slope varying from steep to very steep land

Physico-chemical Properties of Soil

Soil is the combined product of different parent material or rock type, topographic position, or land form, biosfer and climate. Thus, these soil forming factors determine soil properties by governing the type and intensity of the pedological processes (Dengiz et al., 2007). Soil is a three dimensional natural body and is characterised by surface and subsurface diagnostic horizon characteristics. 11 soil series were identified and their horizon orders of the profiles in the study area were defined to be A-B-C form except for especially Kırantepe, Yenicuma and Tekkiraz soil series'profiles which have A-C or

A-R horizons. This means these soils have no diagnostic subsurface horizons and low pedogenetic development. Therefore, these soils can be defined as young soils. There are significant differences in the values of pH 5.95-7.70 among soil series' solum. According to Benton (1984) soil reaction classification, these soils varied from acid to alkaline (Table1). In addition, generally they have very high base saturation except for Mehellü soil series. Salic horizon did not exist in soils of the study area, therefore there is problem about salt concentration. Soil CEC varied between 15.00 to 64.54 $cmol.kg^{-1}$. The soil with the highest CEC was Kireçlik soil series (Vertic Calciustept) with high clay content and organic mattre, while the lowest value was determined in Mollic Ustifluvent soil (Yenicuma soil series).

All soils have low to high $CaCO_3$ content, ranging from 1.36 to 54.56%. Particularly, in some soil series these ratios have been increasing with soil depth leading to $CaCO_3$ accumulation colled calcification thus, Tekkiraz, Hapan and Kireçlik have a calcic horizon. Soil organic matter content depends on the complex interaction of several factors including the quantity and quality of litter fall, climatic factor, soil properties (especially the amount and type of clay), and erosion (Dahlgren, 1997). The soils of the study area were determined commonly to be poor in soil organic matter for the first two horizons ranging from 15-77 cm in depth. For all soils, the organic mater is highest in the surface horizon and decreases sharply to its lowest level in the subsoil. In the study area, the reasons of the low level organic matter are attributable to rapid decomposition and mineralization of organic matter (especially, due to intensive agricultural activities), to overgrazing and to soil erosion. Soil organic matter ranged from 2.75 to 5.14% in upper horizons.

Among all the horizons, the maximum clay content (80.1%) throughout the soils of the study area was determined in Ayazlı soil seris (Chromic Haplustert), while the lowest content (12.2%) was determined in Yenicuma soil series classified as Mollic Ustifluvent. Furthermore, argilluviation was determined in Hacıoğlu, Hatipler and Eksikli soil series. That refers to the movement of clay in solum and also known as lessivage (Bockheim and Gennadiyev, 2000; Duchaufour, 1998). Therefore, these soil seris have argillic horizon and slickensides with high clay accumulation that leads to low hydraulic conductivity.

Soil Classification

Four soil orders, fife suborders, seven great groups and eleven subgroupswere identified in the study area. The soils were classified according to the criteria proposed by the Soil Taxonomy (1999) based on morphological, physical and chemical characteristics. According to the meteorological data, the study area has ustic soil moisture regime and mesic temperature regime. Soils of the study area were classified as Entisols (13.3%), Inceptisol (47.3%), Alfisol (31.3%) and Vertisols (8.0%), according to Soil Taxonomy (1999) (Table 2).

Table 2. Classifications of Soils of Salt Lake (Tuz Gölü) Specially Protected Area according to Soil Taxonomy (1999)

Soil Series	Orders	Suborders	Great Groups	Sub Groups	Area (ha)	Ratio (%)
Yenicuma Deresi	Entisol	Fluvent	Ustifluvent	Mollic Ustifluvent	100.6	3.2
Kıran Tepe		Orthent	Ustorthent	Lithic Ustorthent	319.5	10.1
Mehellü	Inceptisol	Ustept	Dystrustept	Humic Dystrustept	210.6	6.7
Tekkiraz		Ustept	Calciustept	Lithic Calciustept	404.6	1.9
Hapan		Ustept	Calciustept	Typic Calciustept	166.1	5.3
Kireçli		Ustept	Calciustept	Vertic Calciustept	302.2	9.6
Sırmaköy		Ustept	Haplusept	Typic Haplusept	403.3	12.8
Hacıoğlu	Alfisol	Ustalf	Halustalf	Vertic Halustalf	215.4	6.8
Hatipler		Ustalf	Halustalf	Typic Halustalf	462.9	14.7
Eksikli		Ustalf	Halustalf	Typic Halustalf	309.9	9.8
Ayazlı	Vertisol	Ustert	Haplustert	Chromic Haplustert	253.4	8.0
Total					3111.8	100.0

CONCLUSION

This research demostrated a clear diffrerence in the spatial distribution of individual soil properties, which is mainly determined by in suit pedogenesis processes. The major problem faced in conventional soil survey and soil cartography is the accurate delineation of boundary. Field observations based on conventional soil survey are tedious and time consuming. DEM, aspect, slope data in conjunction with other digital ancillary data using GIS provide the best alternative, with a better delineation of soil mapping units. However, there is a need to check with field obsevation for accurate soil boundary delineation. In addition, the manual soil map production process limits soil scientists' ability to update soil surveys rapidly and accurately. Therefore, soil map production process must be repeated for each future soil survey update. For this reason, a radical change is needed to move soil survey to a more acceptable update rate and to a product that can be continually updated efficiently and accurately. In this case, GIS techniques have very important role by consolidating the entire process and update soil data

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Table 1. Results of physical and chemical analyses of soils of the study area

Soil Seris	Horizon	Depth (cm)	pH	Total salt (%)	CEC (cmol kg^{-1})	$CaCO_3$ (%)	OM (%)	Hid.Codn. (cm h^{-1})	Texture (%)			
									Clay	Silt	Sand	Class
	Mollic Ustifluvent											
Yenicuma	A1	0–21	6.96	0.013	28.73	5.19	5.14	11.02	39.1	23.9	36.9	CL
	A2	21–43	7.42	0.012	24.76	4.92	3.91	13.91	39.7	14.2	45.9	SC
	C1	43–78	7.17	0.008	23.69	5.75	1.71	22.25	28.3	11.3	60.3	SCL
	C2	78–95	7.24	0.002	15.00	4.56	1.56	31.36	12.2	7.5	80.2	SL
	C3	95+	6.67	0.013	22.77	6.53	1.26	8.91	30.2	15.3	54.4	SCL
	Lithic Ustorthent											
Kırantepe	A	0–15	7.20	0.024	20.12	7.68	4.59	47.71	23.9	29.5	46.4	SCL
	R	15+	-	-	-	-	-	-	-	-	-	-
	Humic Dystrustept											
Mehellü	A	0–20	5.95	0.039	35.58	1.36	4.61	0.15	52.7	28.5	18.7	C
	Bw	20–45	6.45	0.028	33.82	2.22	3.34	0.92	34.7	22.7	42.4	CL
	C1	45–80	7.30	0.016	26.80	2.30	0.37	5.57	17.6	28.3	53.9	SL
	2C2k	80+	7.85	0.024	14.63	28.38	0.29	0.67	49.1	34.1	16.7	C
	Lithic Calciustept											
Tekkiraz	A1	0–10	7.15	0.085	38.13	12.09	5.2	3.15	57.6	18.3	23.9	C
	A2	10–32	7.55	0.048	39.81	17.65	4.0	0.52	67.2	18.6	14.1	C
	Ck	32+	7.65	0.017	19.32	54.56	2.2	5.96	39.9	25.0	34.9	SiC
	Typic Calciustept											
Hapan	A	0–17	7.40	0.046	39.26	10.20	4.1	0.70	50.8	24.2	24.8	C
	Bk1	17–43	7.70	0.041	29.39	16.46	3.1	0.43	53.3	24.3	22.3	C
	Bk2	43–89	7.65	0.040	30.73	12.27	3.1	0.77	55.8	23.8	20.3	C
	C	89+	7.85	0.023	25.86	4.61	3.4	0.14	60.9	21.1	17.9	C
	Vertic Calciustept											
Kireçlik	Ap	0–15	7.53	0.051	53.71	5.33	4.6	0.052	72.8	17.1	9.9	C
	Bw	15–77	7.49	0.055	64.54	3.80	3.9	0.153	70.8	16.2	12.8	C
	Bk	77–108	7.58	0.041	45.94	15.68	2.9	0.874	52.9	22.3	24.6	C
	2C	108+	7.81	0.053	46.06	6.89	2.8	0.148	57.6	22.3	19.9	C
Typic Haplusept												
Sırmaköy	Ap	0–15	7.29	0.054	30.86	6.91	2.9	0.57	73.9	20.1	5.9	SiCL
	2Bwb1	15–40	7.35	0.037	22.51	19.42	1.7	0.88	74.5	21.7	3.7	SiCL
	2Bkb2	40–68	7.90	0.029	24.63	29.16	1.6	1.69	66.4	26.2	7.2	SiCL
	2Crb	68+	-	-	-	-	-	-	-	-	-	-

Table 1 continue

Soil Seris	Horizon	Depth (cm)	pH	Total salt (%)	CEC (cmol kg^{-1})	$CaCO_3$ (%)	OM (%)	Hid.Codn. (cm h^{-1})	Texture (%)			
									Clay	Silt	Sand	Class
	Vertic Halustalf											
Hacıoğlu	Ap	0–15	7.50	0.062	38.13	7.76	4.3	0.65	68.1	18.0	13.8	C
	A2	15–40	7.30	0.057	35.73	13.82	3.1	0.06	47.7	22.4	29.8	C
	Bt1	40–79	7.10	0.039	33.09	7.65	3.0	0.13	53.3	22.6	24.0	C
	Bt2	79–131	7.55	0.083	37.84	5.30	2.6	0.44	55.9	22.1	22.0	C
	2Cr	131–150	8.05	0.033	26.89	26.73	1.2	0.27	38.4	23.9	37.7	CL
	R	150+	-	-	-	-	-					
Typic Halustalf												
Hatipler	Ap	0–21	7.20	0.037	38.73	4.96	4.5	0.14	39.1	34.4	26.5	C
	Bt1	21–50	6.86	0.024	31.27	3.84	3.1	1.15	48.3	31.4	20.2	C
	Bt2	50–85	6.69	0.024	28.19	3.79	2.4	0.03	57.9	23.87	18.3	C
	Cg	85+	7.01	0.051	27.23	13.03	1.7	-	70.9	17.7	11.4	C
	Typic Halustalf											
Eksikli	A	0–15	7.15	0.062	51.91	3.07	5.2	0.67	54.8	16.5	28.5	C
	Bt1	15–50	7.70	0.018	38.25	3.20	1.4	0.11	68.4	14.5	17.0	C
	Bt2	50–78	7.83	0.031	38.95	3.46	1.3	0.24	65.2	15.1	19.6	C
	C	78+	7.32	0.048	38.05	11.06	1.5	0.25	57.9	18.1	23.8	C
	Chromic Haplustert											
Ayazlı	Ap	0–16	7.56	0.063	46.95	4.58	2.75	0.657	76.6	17.5	5.8	SiCL
	Bss1	16–46	7.27	0.051	45.96	6.50	1.85	0.313	71.0	20.8	8.0	SiCL
	Bss2	46–72	7.28	0.032	52.14	8.40	1.64	0.078	80.1	15.7	4.1	SiCL
	C	72+	7.42	0.027	34.86	13.39	1.33	0.097	59.8	24.2	15.9	C

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Carbon Stock in Hydromorphic Soils of the North-Eastern Part of Germany

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ABSTRACT

Changing climatic conditions in Germany mainly affect hydromorphic soils formed by groundwater. They offer comparatively high carbon contents and, as the only soil group, also accumulate C in the subsoil. The assessment of the storage capacity of these soils is essential to assign 'risk areas' according to national (German Federal Soil Protection Act, 1998) and international (EU Soil Protection Strategy, 2006) soil protection requirements. An appropriate water management enables preservation and protection of the soil organic matter in hydromorphic soils. Both aims, as a part of resource protection, require knowledge of the carbon stock of the soils and the transformation of area restricted results to a regional scale. Assessments comprise of two steps: in the first step, the carbon content of so-called horizon-substrate-combinations (HSC) for profiles of the dominant soil of a soil mapping unit is determined. This method is based on the hypothesis, that comparable soil properties are formed by equal soil substrates and pedogenetic processes. In the second step, the results are assigned to the profiles of the dominant soil of the soil mapping unit and extended to spatial polygons of functional maps. Carbon stock of hydromorphic soils is determined for the federal state Brandenburg, located in the northeast of Germany. Brandenburg is characterised by a percentage of 40 % hydromorphic soils of the country's territory and features a high vulnerability according to studies concerning climate change. The authors offer a proposal for the assignment of 'risk areas' and management principles for hydromorphic soils.

Key words: Gleysols, Histsols, estimation method, risk areas

INTRODUCTION

Organic and inorganic carbon compounds are stored as C pools in different reservoirs in various quantities. Flux between the C pool and the reservoir exists as continuous exchange in both directions (IPCC, 2001; Mannion, 2006). Among the natural carbon reservoirs of the earth the pedosphere has a significant status since it stores a C pool of 2500 Gt. of carbon, which amounts to about three times the magnitude stored by the atmosphere (Lal, 2004).

Hydromorphic soils, whose characteristics are based on the ground water and its dynamics, store the greatest amounts of carbon. Due to the specific site conditions, organic matter decomposition is limited and carbon is accumulated. As opposed to the terrestrial soils, hydromorphic soils also store carbon in the subsoil. Among the hydromorphic soils Histosols are of special significance. Although Histosols comprise only 3 % surface area of the pedosphere, and therefore are of secondary importance, they store 16 till 24 % of the total soil bound carbon (Bridgham et al. 2006; Joosten, 2008). Histosols in total store more carbon than is stored by all forests world wide and contain as much carbon as is stored in the total terrestrial biomass of the earth (Joosten and Clarke, 2002). Globally this amounts to a storage of as much as 350 till 535 Gt. of carbon (Gorham, 1995; Strack, 2008).

Soil moisture in the different soil horizons can vary, due to natural or anthropogenic fluctuations in ground water level, resulting in different redox potentials. Under aerobic conditions, readily decomposable carbon compounds can be oxidised. Through this an increase in release of climate-relevant gases, i.e. CO_2 and N_2O, as result of mineralisation can be recorded. Therewith the characteristic of the soils as carbon sink is altered to a carbon source (Drösler, 2005, Schulze and Freibauer, 2005). Especially peatland shows an increase in carbon loss, as was assessed in studies conducted between 1978 and 2003 by Bellamy et al. (2005) for various soils in England and Wales. In addition to requirements of lowering the ground water level, mainly due to the requirements in land cultivation, mineralisation processes in hydromorphic soils were further intensified in the previous years through climatic change.

Climatic change will lead to further limitations in water supply with a main problem resulting from summer drought (IPCC, 2007). Through summer drought soil warming is increased, resulting in an intensified mineralisation of the organic substance (Kuka, 2005). On the other hand extreme weather situations, i.e. torrential rainfall will increase, so that requirements for a greater retention capacity of the soils exist.

Due to alterations of moist soil conditions to dry and especially warmer soil conditions, soil carbon release is increased resulting in a decrease in soil organic matter (SOM) content. The cause effect relationship finally acts as driver, since dry and warm soil conditions lead to a release of climate-relevant gases (Byrne et al., 2004; Höper, 2007). In the final outcome soil carbon contents are reduced. In this respect hydromorphic soils show the greatest vulnerability of all soils (Eckelmann et al., 2006; Höper, 2007).

Decreases in SOM lead to an impairment in soil functions (Zeitz and Velty, 2002); this contradicts requirements of the German Federal Soil Protection Act (§1 and 2 general requirements and §17 with requirements regarding the good agricultural practice) as well as requirements of international law as postulated in the shortly to be implemented EU Soil Protection Strategy, which defines soil organic matter decline as one of the five main threats. According to the EU Soil Protection Strategy, every country will be asked to identify these vulnerable areas as „risk area“.

Maintenance and protection of SOM in hydromorphic soils can be achieved by adapted water management. To achieve the named goals of resource protection it is necessary to evaluate the soils in regard to their carbon stock.

Therefore the objective of this research was to provide a method to detect areas with very high carbon stock on the basis of available point and area databases using the federal state Brandenburg, situated in northeast Germany, as model region to assess and present first results. Emphasis was to be given to the relevance of C storage in the subsoil as is found in hydromorphic soils. The federal state Brandenburg was chosen, because it has a comparatively high vulnerability as compared to other federal states in Germany (Integriertes Klimaschutzmanagement, 2007) and because hydromorphic soils cover more than 40 % of the land area (soil map, scale 1:300 000).

MATERIALS and METHODS:

Test Area

The federal state Brandenburg is situated in northeast Germany and holds an area of approximately 30 000 km-2. As part of the North German Lowland it is the southern part of the North European Pleistocene glaciations so that the morphological form was shaped mainly by the Pleistocene ice age. Resulting from the quaternary development, two main morphological forms evolved: the glaciogene plateau and the (glazio-) fluviatile lowlands, to which the glacial valleys belong. The lowlands are structured by postglacial mire formations and dune drift. The mean altitude of vast areas in Brandenburg lies between 30 and 50 m above sea level. In the Pleistocene and Holocene valleys Gleyic Arenosols and Haplic Gleysols dominate and, with rising ground water levels, mainly Mollic or Histic Gleysols as well as Histosols are present.

Brandenburg is one of the federal states with the highest proportion of Histosols in Germany. A specific significance can be attributed to the Fluvisols in the floodplains. These soils, comprising of silty-clay deposits, are usually highly humous down into deep soil layers and mostly have high fluctuations in ground water level. Fluvisols are regarded the most fertile soils in Brandenburg.

Area Data

Soil geological maps with area polygons and linked subject contents exist for various requirements and target scales. These are generated by combining and describing approximately homogenous soil sections of a landscape to area polygons. Descriptions of the dominant soil type as well as important accompanying soil types, occurring with less area coverage, are the basis for the subject content of the area polygons i.e. area related data. Subject contents are based on established geological records (relatively stable parameters such as parent rock and soil textural class) as well as data from remote sensing and present survey data, which are appropriately blended.

Point Data and Horizon-Substrate-Combinations (HSC)

Area related data are based on the characteristics of dominant soil profiles representative for the area and are used to describe a section of a landscape by means of a this soil profile. This can be obtained in various ways: i) each area is assigned a typical soil profile on the basis of expert judgement; ii) a mean profile is assessed on the basis of statistical analysis, which does not truly exist but describes the given homogenous landscape section. The last-mentioned method was used in the present case. The method is based on the following hypotheses: soil material from the same parent rock and with the same soil texture as well as the same pedogenesis has comparable soil characteristics. By combining a large number of comparable data sets from the soil profiles "mean and typical" combinations of horizons and substrates are derived by statistical averaging, resulting in the so-called horizon-substrate-combinations (HSC) for which soil parameters are then calculated (Bauriegel, 2004; Zeitz et al., 2008).

Classification

The German soil classification scheme differs from the WRB. Therefore, appropriate translations and assignments were made, so that results of the soil types given in the German classification could be assigned to the corresponding nomenclature of Reference Soil Groups in the WRB classification. The Nomenclature of the horizons in the HSC is only available in the German classification mode, so that the depth distribution of the bulk density and C_{org} are given in the German HSC nomenclature and are explained in the corresponding legends.

Calculation of Carbon Stock

The calculations of the carbon stock of various hydromorphic soils include four steps:

1.) Assessment of content homogenous area polygons for the hydromorphic soils
2.) Calculation of C amounts for the dominant soil profiles representative for the area using:
    C amount per HSC = depth of HSC * bulk density * C_{org} content
3.) Calculation of C amount for the soil sections 0 – 0.3 m; 0 – 1 m, and 0 – 2 m soil depth
4.) Assignment of profile values to the area data and quantification on the basis of carbon content classes. For carbon content classes the German humus classification scheme, which comprises 7 classes for the mineral soils and an eighth class for all organic soils was expanded to ten classes with classes 8 till 10 differentiating organic soils.

C_{org} was analysed with a CNS Analyser (Variomax 2 Elemental, double analyses) and the bulk density using 100 cm-3 soil sampling cylinder (3 - 5 replicates).

RESULTS and DISCUSSION:

Bulk Density and C_{org} Content of Different HSCs in Hydromorphic Soils

Soils examined comprised three different mineral hydromorphic soils, belonging to the Gleysols, as well as Histosols. The selected soils differ in their ground water regime and therefore show great variations in the development of their horizons and soil characteristics.

Gleysols are wetland soils that, unless drained, are saturated with groundwater for long enough periods to develop a characteristic *"gleyic colour pattern"*. (WRB, 2006). According to the depth of organic matter and base saturation the three soils can be differentiated as presented in Fig. 1a – c.

If the ground water level is high during long periods of time and has only minor fluctuations a Mollic horizon develops (Fig. 1b). Even higher soil moisture content, resulting from a very high water level throughout the year and very small fluctuations of the ground water level, leads to the development of a Histic horizon in the Gleysol (Fig. 1c). This horizon comprises larger amount of organic material and the substrate can be classified as peat.

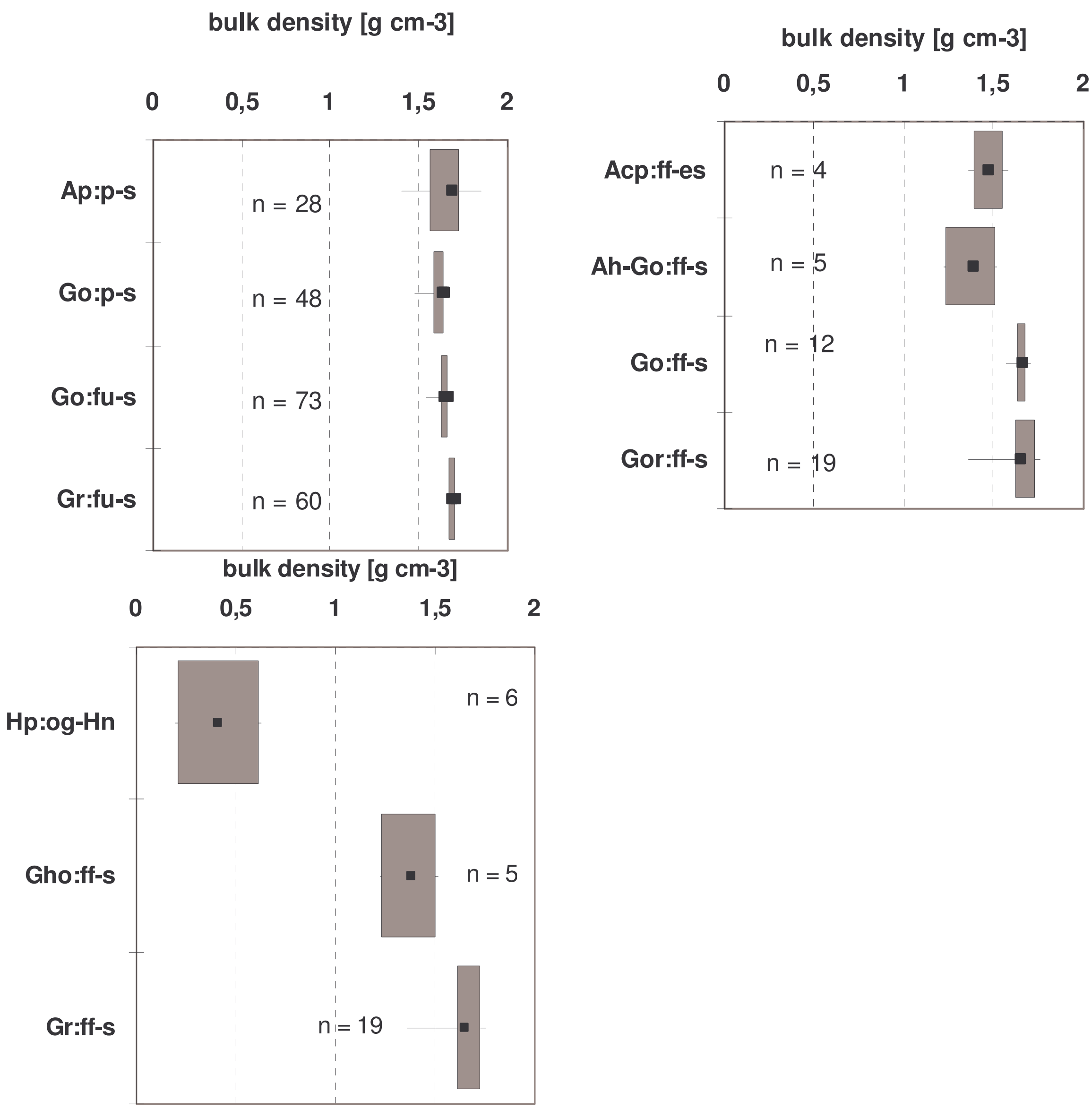

Figure 1(a-c): Bulk density values of the horizon-substrate-combinations (HSC) of representative soil profiles of hydromorphic soils in Brandenburg; a) Haplic Gleysol; b) Mollic Gleysol; c) Histic Gleysol (legends of HSC of all figures published on the end of the paper)

The lowest bulk density in the top soil (0 – 0.25 m depth) is found in the Histic Gleysol (Fig 1c). Bulk density in the subsoil (Gho horizon) of this soil is also comparably low, which can be attributed to a high soil organic matter content. The highest values in bulk density are found in the Haplic Gleysol in the top soil as well as in the in all other horizons throughout the profile (Fig. 1a). Mineral horizons show an increase in consolidation with increasing soil depth, which is especially developed in the Haplic Gleysol. The Mollic Gleysol has lower values in bulk density in the topsoil than the Haplic Gleysol, but higher values than the Histic Gleysol (Fig. 1b).

Mineral horizons in the subsoil affected by ground water fluctuations have comparable values in bulk density, if identical substrates are given; i.e. Gr:ff-s horizons of the Mollic Gleysol and Histic Gleysol (median value 1.64 g/cm-3).

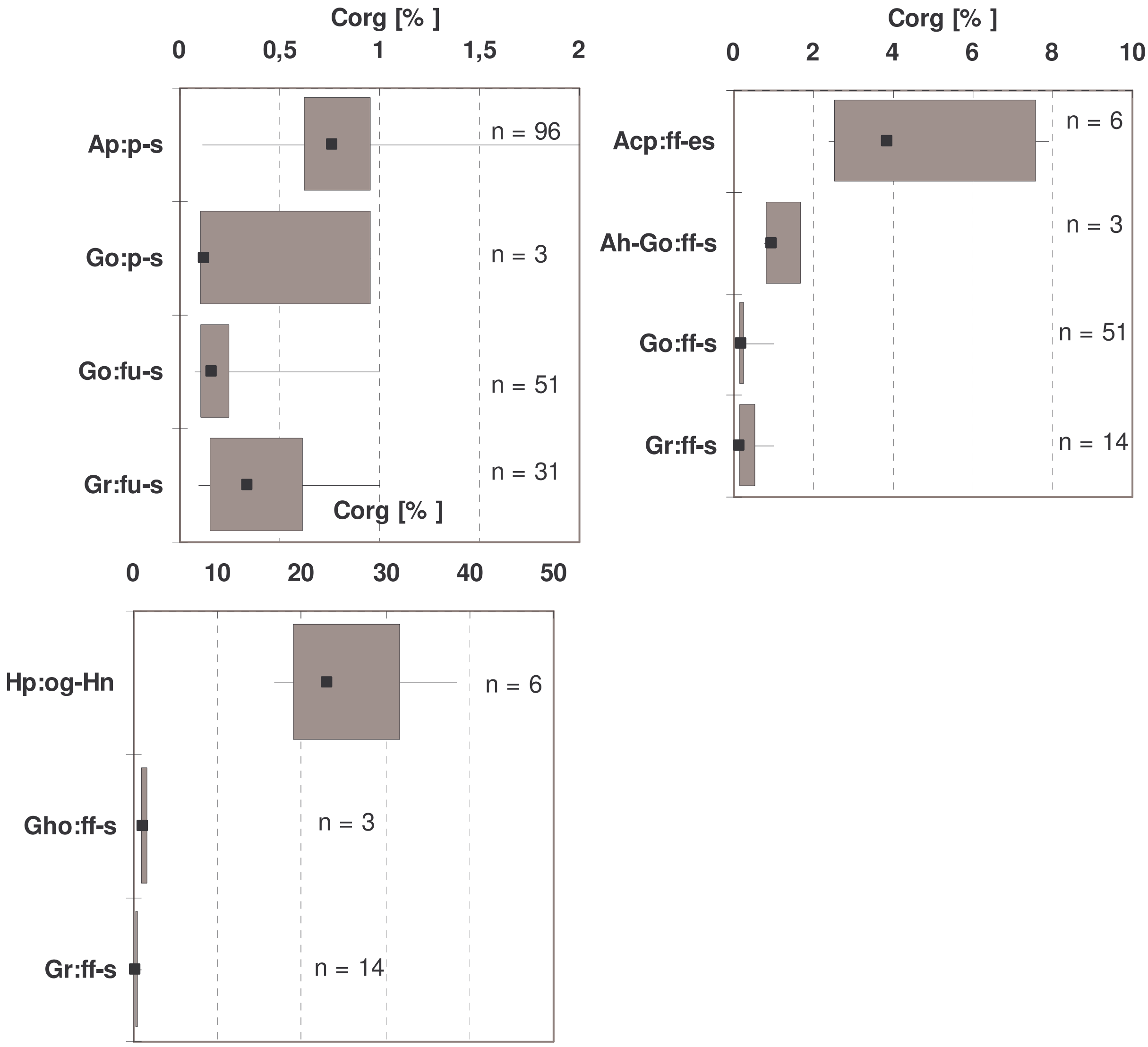

Figure 2 (a – c): C_{org} content of the horizon-substrate-combinations (HSC) of representative soil profiles of hydromorphic soils in Brandenburg; a) Haplic Gleysol; b) Mollic Gleysol; c) Histic Gleysol

The small range of the values for all results in bulk density is conspicuous. This was also found by Bauriegel (2004), who provided evidence that the bulk density is a soil parameter with very low statistical variation and is therefore highly suitable for modelling and quantification of e.g. soil functions.

Results for the Histosols (see Fig. 3) are based on data obtained from the federal state north of Brandenburg, Mecklenburg-Western Pomerania, which has a comparable geological development and considerably better data basis of Histosols than the federal state Brandenburg.

In the top soil of the Histosols bulk density values are similar to values assessed for the Histic Gleysol, but all HSCs of the Histosols have considerably lower bulk densities in the subsoil, due to the peat substrate in these layers. For Histosols, soil development as influenced by drainage and land use is of special importance: the anthropogenic affected top soils (nHv and nHa horizons) have clearly higher bulk densities than the only slightly degraded peat in the subsoil (nHt and nHr horizons).

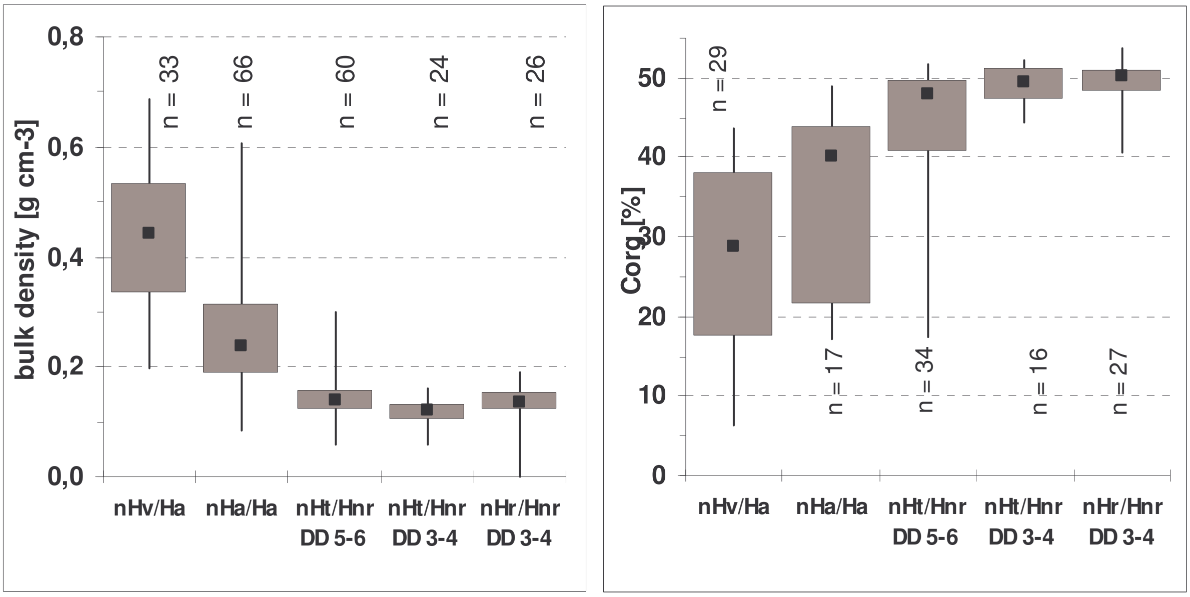

Figure 3 (a and b): Bulk density and C_{org} content of horizon-substrate-combinations (HSC) of Histsols

The contents in C_{org} are directly connected with the ground water conditions of the soils and affect bulk density. The higher the C_{org} content, the lower the bulk density. The highest C_{org} contents in the top soil, with mean values amounting to nearly 30 %, are found for the Histosols and with 25 % for the Histic Gleysols, respectively (Fig. 2c and 3b). All three soils with mineral substrate in the subsoil have lower contents in C_{org} in the subsoil than in the top soil, but it must be taken into account that in both cases, in the Mollic Gleysol as well as in the Histic Gleysol, an enrichment in organic substance of 0.9 % C_{org} (median value) in the subsoil till 0.5 m depth is given, due to water logging over long periods of time (Fig. 3b and 3c; Ah-Go:ff-s and Gho:ff-s). Despite the ground water influence present in the Haplic Gleysol, this soil has a very low value, with the C_{org} content amounting to 0.8 %. One reason could be the agricultural utilization (Ap horizon), since this involves intensive drainage and permanent aeration in effect of ploughing. The Histosol has very high C_{org} contents in the subsoil (Fig. 3b), which reaches a maximum value of 50 % C_{org} in the permanently ground water effected horizon nHr.

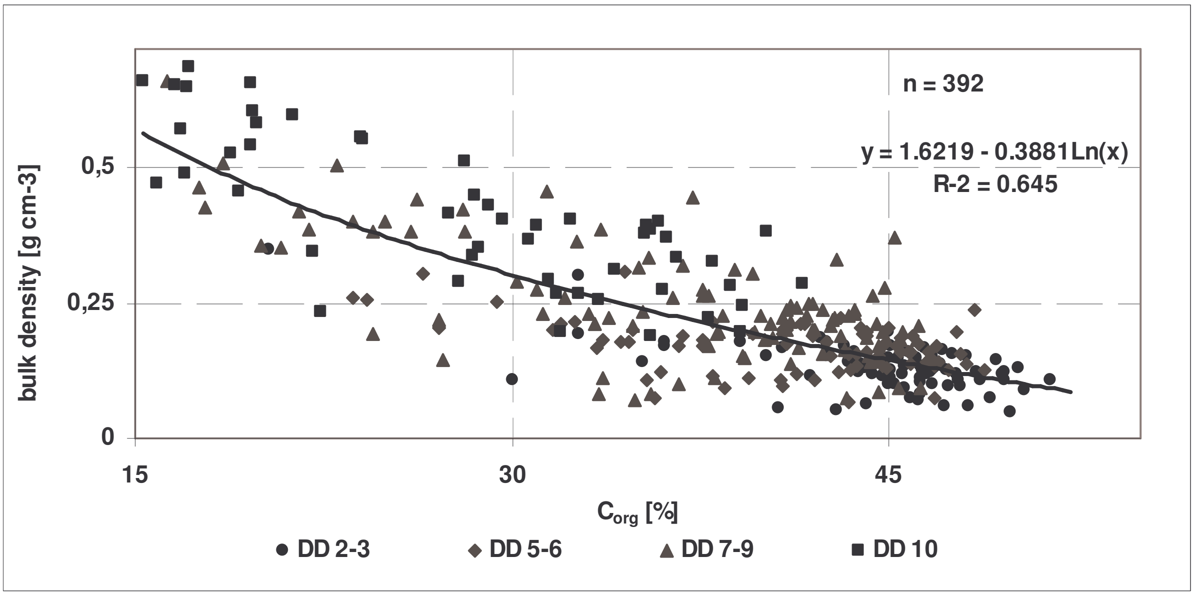

Figure 4: Correlation between C_{org} content and bulk density of various organic substrates (Data from Mecklenburg-Western Pomerania) (DD = degree of decomposition according to Von Post (1924)

Due to the laborious sampling method (undisturbed soil cores), results of bulk density in hydromorphic soils are often only available for the top soil. Within the scope of the EU-Project „CARBO-EUROPE" Bryne et al. (2004) identify detailed information on bulk density and depth of the organic layers in soils as crucial information gap for reporting of results to carbon occurrences in Histosols. For Scottland Chapmann (2008) also refers to gaps in the data basis of bulk density data due to the high labour intensity. On the basis of the comparably excellent data basis available for the federal state Mecklenburg-Western Pomerania, correlations between bulk density and soil organic matter of BD = 1.6219 – 0,3881 * Ln (% C_{org}) could be assessed for Histosols (Fig. 4).

Whilst marginally degraded peat has similar values in bulk density and C_{org} content, especially top soils with increased mineralization processes show variations with increasing bulk densities at decreasing C_{org} contents.

The results agree well with Chapmann (2008), who stated the pedotransfer function for Scottish Histosols as: BD = 1.772 – 0.4127 *Ln (%C_{org}). For two selected hydrological types of mires (percolation mire and water rise mire (with n = 242)) Zeitz et al. (2008) identified the correlation as BD = 1.68 – 0.40 * Ln (C_{org}) (R-2 = 0.70).

All profile related results indicate the significance of C storage in lower soil layers. Data published up to date all refer to the top soil only, as in the very interesting work of Bellamy et al. (2005) to carbon loss in soils of England and Wales between 1978 and 2003.

Area Related Data and Carbon Stock

Analysis of the area data for the federal state Brandenburg for all soils shows, that the land area comprises 51.4 % non-hydromorphic soils, 16 % Endogleyic soils, 5.3 % Haplic Gleysols, 5.0 % Mollic Gleysols, 5.2 % Fluvisols, 4.5 % Histic Gleysols, 8.1 % Histosols, and 4.5 % Anthrosols. For these soil units soil organic carbon content was calculated for the three given soil depths, 0 till 0.3 m, 0 till 1 m, and 0 till 2 m, and was ranked in a metric classification system. Distribution in area percentage shows the great importance of the hydromorphic soils and Histosols for C storage (Fig. 5). In all classes up till 90 t C_{org} ha-1, carbon stock in the top soil (till 0.3 m) is dominant. The high area percentage of terrestrial soils is documented in the classes with ≤ 90 t C_{org} ha-1. The area percentage in the classes with a very high carbon stock is generally high for hydromorphic soils and is highest for these soils for the class with > 240 t C_{org} ha-1 in the subsoil.

For the class with > 240 t C_{org} ha-1 the area percentage continually increases from 0.3 m to 1 m to 2 m soil depth. For all three soil depths maps were generated, which contain areal distribution. As an example Fig. 6 shows the distribution in area of carbon content classes for the soil depth of 0 till 2 m. Histosols and Fluvisols are clearly visible with their connection to the glacial lowlands in the landscape.

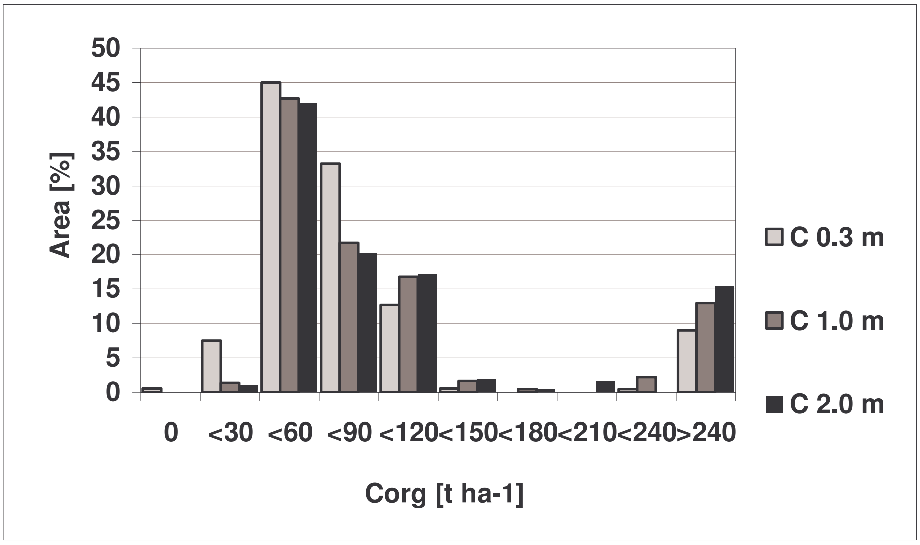

Figure 5: Classes of organic carbon stock and their area percentage in the landscape for 0 till 0.3 m, 0 till 1 m, and 0 till 2 m soil depth

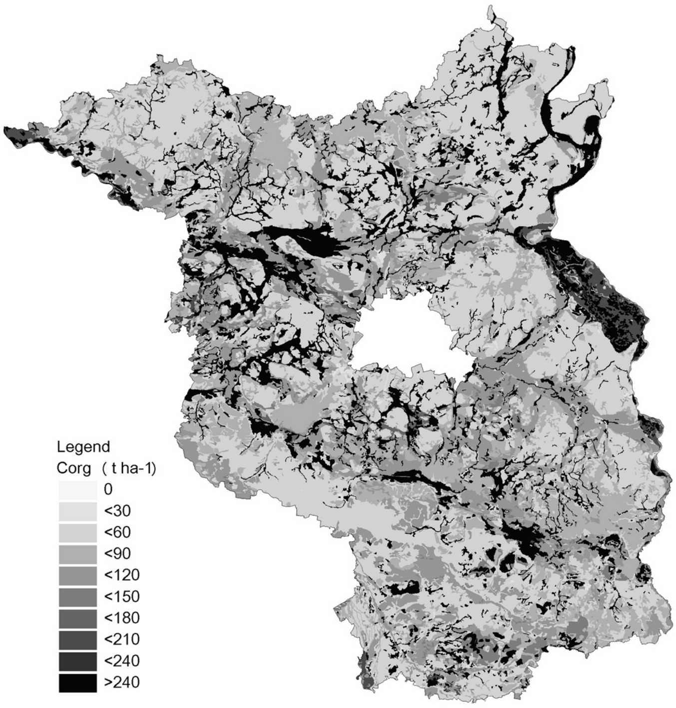

Figure 6: Organic carbon stock (C_{org} t ha-1) in soils of the federal state Brandenburg in 0 till 2 m soil depth

Presently available data and map materials for the federal states of Germany do not allow for a comprehensive calculation of soil characteristics and carbon stock, as presented in this article.

Also in the future in Germany the availability of funds for these very extensive field mappings and laboratory assessments can not be expected. Knowledge on the amount of carbon in soils is however of great importance for many international and national reporting requirements for climate protection.

The two-tier method described and using dominant soil profiles representative for the area, based either on pedotransfer functions or on carbon content values derived from HSCs, as presented for the federal state Brandenburg have proven to be successful. Uncertainty exists in area units (circumference : content) of hydromorphic soils, due to the utilized soil maps with a scale of 1:300 000. Furthermore, the data power could be enhanced by supplementary soil samples. The method allows for a depth dependable estimation of carbon content and for an areal allocation of areas with especially high contents. These areas, identified as „hotspots“ by the IPCC (2007), are to be regarded with special attention in land use. Water management schemes orientated on goals defined for resource management and incentives for farmers according to the conservation of soil carbon are conceivable. With the presented method land users can be recognised and a ranking depending on vulnerability can be established.

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Legend of HSC:

Example: Go:ff-s: subsurface horizon with gleyic properties and an accumulation of sesquioxides from holocene fluvic sands

Horizons: Ap - ploughing topsoil; Acp - ploughing topsoil horizon with accumulation of pedogenetic carbonates; Go - subsurface horizon with gleyic properties and an accumulation of sesquioxides; Gr - subsurface horizon with gleyic properties and reduction conditions; Gor - subsurface horizon with gleyic properties and mostly reduction conditions; Gho - subsurface horizon with gleyic properties and an accumulation sesquioxides and in parts of organic matter; Ah-Go - subsurface horizon with gleyic properties and an accumulation of organic matter and sesquioxides; nHv – earthified peat horizon, nHa – peat-crumb horizon, nHt – peat shrinkage horizon, nHr – peat horizon below groundwater table, reduced state,

Substrates: p-s: periglacial sands; ff-s: holocene fluvic sands; fu-s: periglacial fluvic sands; ff-es: river sands; Ha – amorph peat, Hnr – sedge peat

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The Changes in Biological and Physical C Fractions after Conversion of Native Forest to Grassland and Cultivated land in the Northern Turkey

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ABSTRACT

Soil management systems have greater effect on soil chemical, physical and biological properties. Conversion of forest to grassland and cultivated land can alter carbon and nitrogen dynamics. The objective of this study was to evaluate the changes in biological and physical carbon and nitrogen fractions after conversion of native forest to grassland and cultivated land in the northern Turkey. Some soil physical, chemical, and biological properties were measured. Soil texture ranged from sandy clay loam through clay loam. The highest bulk density was observed in the grassland (1.41 g cm^{-3}) and the lowest one was in the cultivated land (1.14 g cm^{-3}). Soil pH was the similar (pH = 7) in the three land uses. Microbial biomass C and total organic carbon were almost two times greater in the forest than forest cleared grassland and four times greater than cultivated land. The greater portion of organic carbon was stored in macro aggregates (>250 micron) in the three land uses. Physically unprotected organic carbon (light fraction) comprises smaller portion of soil organic carbon in the three land uses. Therefore, this study indicated that microbial biomass C, mineralizable C, and protected organic C decrease in forest cleared grassland and cultivated lands.

Key words: Carbon Fractions, native forest, cultivation, microbial biomass, grassland.

INTRODUCTION

Soil physical, chemical, and biological properties have greater variability even in a smaller distance. The variability of soil properties generally attributed to changes in environmental factors. Soil organic carbon is the largest and dynamic C pool in terrestrial ecosystem. The changes in organic carbon pool have a greater effect on atmospheric CO_2 content. The factors controlling soil organic C contents are soil temperature, precipitation, and soil management systems (Plante et al., 2006). Soil organic C cycle can reach a steady state condition when the changes in these environmental factors are minimized. The time of reaching steady state condition can also controlled by the character of soil organic carbon pools. Soil organic C pools are determined as physically, chemically, and biologically.

Soil physical C pools are fractioned as light fraction (unprotected organic C) and aggregate (micro and macro aggregates) associated (protected) organic carbon. The fractions of soil physical C pools are more sensitive to the changes of soil management systems. Cultivation breaks down soil aggregate and release organic matter as unprotected. The unprotected organic matter can be easily decomposed by soil organisms. Therefore, cultivated soils generally have lower protected organic carbon compared to uncultivated and native ecosystems. Some studies indicated that aggregate associated organic C accounts for %42-74 of total organic C and this ratio is generally greater in uncultivated and pasture ecosystems, and decrease with cultivation (Chan, 2001). The intensive cultivation and drying and wetting decrease aggregation and result reduction of soil organic C content (Chenu et al., 1999). Short-term cultivation (1-4 years) changes aggregate protected organic C and microbial biomass C with no effects on total organic C (Chenu et al., 1999). Conversion of a cultivated land to pasture increased aggregate stability and physically protected organic C after second year of pasture with no effects on total soil organic C (Robertson et al., 1991). Some researchers reported that aggregate stability under long-term cultivation (5-8 years) mostly depends on microbial biomass C other than total soil organic C (Sparling and Shepherd, 1986; Hart et al., 1988; Sparling et al., 1992). Long-term crop production reduced total organic C %70 and 60% compared to pasture and wood land, respectively (Saviozzi et al., 2001). Therefore, the management of forest ecosystem is important for the terrestrial C management. However, the ecology of forest also plays important role for carbon storage. Forest in cold climates stores more C than warm climate (Post et al., 1982). However, forest clearing with cultivation decreases %30-35 soil organic C in A and B profiles (Ellert and Gregorich, 1996). The changes in the cover vegetation and soil management systems either improve or retardate soil biological properties.

Microbial biomass C, total organic C tided up to soil organisms, compromise smaller and most active portion of soil organic C. This fraction plays critical role the distribution of C fraction and is a good soil quality indicator. Soil organisms produce exracellular enzyme and hyphea which hold soil particles and create aggregates. Soil microbial biomass is more sensitive to agricultural management than other fractions. Therefore, the short-term effect of soil management on soil properties can be determined by looking at the soil microbial biomass (Churchman and Tate, 1987; Haynes, 1993). Generally, soil microbial biomass is more dynamic fraction of soil organic C. Microbial biomass can be a store and source for plant nutrients. Therefore, microbial biomass controls C and N cycle in biosphere (McGill et al., 1986). Soil fauna (for example earthworms) not only controls nutrient cycling but also increases macro aggregation.

Soil macro aggregates are more sensitive to agricultural practices compared to micro aggregates (Janzen et al., 1992; Cambardella and Elliott, 1992). Cultivation practices decreases protected organic C and increases light fraction (unprotected C) compared to native ecosystems (Jastrow ve Miller, 1997). However, the effect of different management systems on soil organic carbon fractions varies based on the climate and location on the world. In this study, three different land management (native forest, pasture, and cultivated land) have been evaluated based on soil organic C and physical and biological C fractions in the northern Turkey, Tokat.

MATERIAL and METHODS

This experiment was conducted on the three different land management (forest, pasture, and cultivated lands) of the northern Turkey, Tokat. The history of the study site was previously native forest for more than 10 years. Some parts of the forest were cleared and converted to cultivated land and pasture. The cultivated land has been under dry land continuous wheat production with plowing and disking before planting. Since, the forest cleared pasture has been used as grazing land with sheep without any chemical fertilizer application. Four sampling locations were randomly chosen from each site. Total 12 composite samples were taken from 0-5, 5-15, and 15-30 cm depth of each land management. Soil samples were passed through 4-mm sieve and stored at 4 ^{o}C until analysis. Before analysis, soil water content was determined gravimetrically and The all results were expressed based on oven dry weight. Soil bulk density was measured by taking undisturbed soil samples at spring.

Some physical and chemical properties of soils were determined. Soil texture was performed based on Bouyocous hydrometer method (Bouyocous, 1951). Soil pH was also determined based on 1:2.5 (w:v) dilution method. Organic matter content and N contents were determined using wet oxidation method. Soil inorganic N was extracted using 2 M 100 mL KCL solution and analyzed total inorganic N using distillation procedure. Total organic N content was determined by subtracting inorganic N from total N.

Biological C and N fractions (mineralizable C and N, microbial biomass C and N pools) were determined under laboratory conditions. Mineralizable C and N contents were analyzed after short-term incubation at 23 ^{o}C for 28 days (Russell et al., 2004). Soil samples (20 g) were placed in 100 mL flacks and soil water contents were adjusted to %50 of water holding capacity. These flacks were placed inside of mason jars with 10 mL of NaOH solution. These alkaline traps were replaced weakly and CO_2 contents were determined diluted HCl solution. Mineralizable N was extracted at the end of incubation and analyzed for N content.

Microbial biomass C was determined using fumigation incubation method (Horwath and Paul, 1994). The CO_2 produced during incubation was trapped inside alkaline solution and titrated with diluted HCl solution. Microbial biomass N was determined using extraction and distillation method at the end of incubation.

Soil organic C was fractioned as light fraction (unprotected) and protected (micro and macro aggregates) organic C. Light fraction of soil organic carbon was removed from soil using 1.8 g cm^{-3} NaI solution (Eliot and Cambardella, 1991). Macro (>250 µm) and micro (between 250 and 52 µm) aggregates were separated using wet sieving and analyzed for soil organic C (Le Bissonnais, 1996). After separation of soil aggregates, macro and micro aggregates were dried at 50 ^{o}C and organic C were determined.

The experimental design was completely randomized design with four replications. Analysis of variance and separation of means by least significant differences test ($p<0.05$) were performed for soil data using SAS procedures (SAS Institute Inc., 1996).

RESULTS and DISCUSSIONS

The clay content was significantly greater in the forest and cultivated lands compared to the pasture at the all depths ($p<0.001$) (Table 1). Soil texture from surface through profile was the similar in the each land use. Thus, soil depth was not significant on soil texture at the three managements (p>0.05). The interaction between soil management and soil depth was not significant, as well.

The effect of soil management on soil pH was not significant in this study (p>0.05) (Table 2). Soil pH changed from 6.97 to 7.18. The similar pH in the managements could be result of lack of chemical fertilizer application to the cultivated land. Grerup et al. (2006) reported that cultivation of forest soil increases soil pH. In this study, soil pH tends to be increase in pasture and cultivated land, but the increases were not significant. The changes in the soil pH could be the result of leaching of nutrients and fertilizer application. Soil bulk density significantly increased at the surface of pasture compared to the other managements (p<0.05). The increase of soil bulk density in the pasture is the result of compaction of soil surface due to animal grazing. Soil organic matter content significantly decreased in the cultivated and pasture fields (p<0.001). The highest soil organic matter content was absorbed at the surface of forest, pasture, and cultivated fields, respectively. Organic matter content significantly changed from surface through deeper depths. The changes in organic matter content through the soil depth were greater in the forest and pasture. This can be attributed to the larger amount of soil organic matter addition and undisturbance of pasture and forest. Soil organic mater content generally controlled by climate, soil texture, topography, drainage, and cover vegetation. Cultivated soils generally have low organic matter content compared to native ecosystems, since cultivation increases aeration of soil, which enhances decomposition of soil organic matter. In addition, most of the soil organic matter produced in the cultivated lands was removed with harvest. Conversion of forest to cultivated land significantly decreased soil organic matter content (Riezebos and Loerts, 1998; Jaiyeoba, 2003)

Table 1. Soil texture of forest, cultivated land, and pasture at 0-5, 5-15, and 15-30 cm depths.

Soil management	Depth cm	% Sand	% Silt	% Clay
Pasture	0-5	50,09 (1,44)	27,19 (0,80)	22,73 (1,95)
	5-15	48,34 (3,20)	27,38 (1,73)	24,29 (2,16)
	15-30	50,84 (2,19)	25,31 (1,07)	23,85 (1,98)
Forest	0-5	43,96 (1,18)	24,38 (0,36)	31,66 (1,39)
	5-15	41,46 (1,56)	24,25 (0,44)	34,29 (1,85)
	15-30	43,96 (2,07)	27,19 (2,12)	28,85 (3,85)
Cultivated	0-5	40,71 (0,99)	23,13 (0,49)	35,98 (0,51)
	5-15	40,53 (1,20)	23,31 (0,67)	36,16 (0,99)
	15-30	39,59 (0,60)	23,19 (0,51)	37,23 (0,38)

( ) Standard error (n = 4).

Microbial biomass C significantly changed with soil managements (Table3). The greatest microbial biomass C was observed in forest (0.505 mg C g^{-1}). Cultivation resulted the lowest microbial biomass C compared the other managements (0.120 mg C g^{-1}). Some studies indicated that microbial biomass C significantly decreases with cultivation, but conversion from cultivated land to pasture significantly increases soil microbial biomass (Haynes and Swift, 1990; Haynes et al., 1991).

Table 2. Some soil chemical and physical properties of pasture, cultivated, and pasture lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	pH	Bulk density (g cm^{-3})	Soil organic matter (%)	Lime (%)
Pasture	0-5	7,13 (0,05) a*	1,41 (0,03) a	2,96 (0,50) a	1,31 (0,24) a
	5-15	7,17 (0,06) a	1,41 (0,09) a	2,22 (0,21) a	2,24 (0,85) a
	15-30	7,13 (0,11) a	--------------	1,31 (0,18) a	1,72 (0,73) a
Forest	0-5	7,01 (0,07) b	1,21 (0,06) b	4,73 (0,22) b	0,88 (0,34) a
	5-15	6,99 (0,08) a	1,32 (0,04) a	2,49 (0,19) a	1,01 (0,06) a
	15-30	6,96 (0,11) a	--------------	1,89 (0,11) b	1,10 (0,30) a
Cultivated	0-5	7,18 (0,05) a	1,14 (0,07) b	1,65 (0,04) bc	0,82 (0,07) a
	5-15	6,97 (0,09) a	1,26 (0,11) a	1,62 (0,06) b	0,93 (0,08) a
	15-30	7,02 (0,11) a	--------------	1,72 (0,07) a	0,80 (0,21) a
Soil management		ns	0,03	0,0001	0,03
Depth		ns	ns	0,0001	ns
Soil Management* Depth		ns	ns	0,0001	ns

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Mineralizable C was significant affected by soil management and depth (Table 3). Mineralizable C content was greater in the forest and pasture due to greater amount of organic matter addition annually. However, proportional distribution of mineralizable C was greater in the cultivated land. Cultivation increased labile fraction of soil organic C while decreasing resistant fraction of soil organic C. Thus, cultivation disturbs soil aggregates and releases soil organic C to the soil, which increases proportionally mineralizable organic C. Similarly, total organic C content was lower in the cultivated field and increased in the pasture and forest.

Total N, mineralizable N, and microbial biomass N were significantly decreased after conversion from forest to pasture and cultivated fields (Table 4). Soil managements, depth was significant on mineralizable N and microbial biomass N. Cultivation of forest decreased almost two times total organic N, mineralizable N, and microbial biomass N, and the decreases in the pasture was smaller compared to cultivated land. Mineralizable N is an important source of nitrogen in native ecosystems. The higher mineralizable N in the forest and pasture could be the result of higher organic matter at the surface of soil.

Table 3. Total organic C, mineralizable C, and microbial biomass C of pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Microbial biomass C mg C g^{-1}	Minerelizable C mg C g^{-1}	Total soil organic C %
Pasture	0-5	0,295 (0,019) a*	0,280 (0,12) a	1,506 (0,24) a
	5-15	0,286 (0,011) a	0,384 (0,16) a	0,997 (0,10) a
	15-30	0,276 (0,025) a	0,705 (0,31) a	0,588 (0,08) a
Forest	0-5	0,505 (0,074) b	0,328 (0,12) a	2,351 (0,23) b
	5-15	0,409 (0,059) a	0,475 (0,16) b	1,122 (0,09) a
	15-30	0,264 (0,030) a	0,871 (0,34) a	0,851 (0,05) b
Cultivated	0-5	0,120 (0,021) a	0,253 (0,10) ab	0,741 (0,02) bc
	5-15	0,171 (0,033) b	0,343 (0,13) a	0,730 (0,03) b
	15-30	0,187 (0,047) ba	0,433 (0,16) a	0,775 (0,03) ab
Soil management		0,0001	0,0001	0,0001
Depth		ns	0,0001	0,0001
Soil management*Depth		ns	0,0001	0,0001

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Table 4. Soil organic N, inorganic N, mineralizable N, and microbial biomass N of pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Organic N mg N g^{-1}	Inorganic N mg N g^{-1}	Mineralizable N mg N g^{-1}	Microbial biomass N mg N g^{-1}
Pasture	0-5	0,079 (0,014) a*	0,0112 (0,0007) a	0,0178 (0,0018) a	0,135 (0,015) a
	5-15	0,050 (0,012) a	0,0047 (0,0003) a	0,0107 (0,0002) a	0,081 (0,011) a
	15-30	0,049 (0,009) a	0,0027 (0,0008) a	0,0064 (0,0006) a	0,038 (0,003) a
Forest	0-5	0,105 (0,009) a	0,0138 (0,0012) a	0,0229 (0,0013) b	0,271 (0,009) b
	5-15	0,065 (0,013) a	0,0062 (0,0010) a	0,0128 (0,0014) a	0,115 (0,020) a
	15-30	0,040 (0,011) a	0,0058 (0,0011) b	0,0094 (0,0012) b	0,067 (0,007) b
Cultivated	0-5	0,045 (0,017) ab	0,0043 (0,0017) b	0,0122 (0,0005) c	0,057 (0,012) c
	5-15	0,028 (0,002) ab	0,0035 (0,0005)ab	0,0089 (0,0005) ab	0,039 (0,007)ab
	15-30	0,025 (0,002) ba	0,0027 (0,0006) a	0,0065 (0,0002) a	0,026 (0,006) a
Soil management		0,002	0,0001	0,0001	0,0001
Depth		0,002	0,0001	0,0001	0,0001
Soil management*Depth		ns	0,003	0,006	0,0001

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Physical fractions of soil organic C were significantly affected by soil management (Table 5). Macro aggregates was greater in the forest, cultivated, and pasture fields, respectively. The lower macro aggregate in the pasture is the result of low clay content and high compaction by grazing animals. Macro aggregate associated organic C was significantly decreased in the cultivated and pastures fields. This indicates that conversion of a forest to agricultural use leads to the loss of soil organic C in the macro aggregates. Some studies reported significantly reduction of macro aggregates in agricultural lands (Janzen et al., 1992; Cambardella and Ellioott, 1992). Micro aggregates tend to be greater in the pasture compared to the other managements. Micro aggregate especially at the surface of forest was lower compared to the other depths. Therefore, macro aggregate plays significant role for C sequestration in forest ecosystem. Light fraction (free soil organic matter) was greater in the pasture than forest soil. This higher amount of light fraction in the pasture can be related to low clay content and macro aggregates.

Table 5. Physical fraction of soil organic C in pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Macro Ag. g/100 g soil	Organic C g C kg^{-1} Macro Ag.	Light Organic C >250µm g C/ 100 g Macro Ag.	Light organic C 53-250 µm g C/ 100 g Micro Ag.	Micro Ag. g/100 g soil	Organic C g C kg^{-1} Micro Ag.
Pasture	0-5	35,65 (1,88) a*	71,44 (3,79) a	11,65 (0,95) a	12,71 (1,84) a	14,34 (1,37) a	90,22 (2,27) a
	5-15	40,48 (6,93) a	64,68 (3,29) a	10,71 (1,27) a	10,47 (1,09) a	12,98 (2,75) a	85,84 (1,43) a
	15-30	43,75 (7,18) b	66,69 (1,62) a	9,36 (1,74) a	12,14 (1,33) a	11,70 (2,47) a	94,06 (1,57) a
Forest	0-5	53,25 (3,09) b	73,94 (4,83) a	9,16 (1,78) a	15,12 (0,94) a	6,82 (0,58) b	110,75 (9,94) b
	5-15	53,27 (0,92) a	66,12 (3,21) a	7,08 (0,35) b	10,96 (0,98) a	8,45 (0,76) a	103,90 (5,58) b
	15-30	50,68 (2,36) a	65,31 (2,51) a	6,98 (0,82)a	9,35 (0,89) a	8,86 (0,27) a	88,34 (2,87) a
Cultivated	0-5	55,17 (1,51) b	57,39 (1,80) b	7,96 (1,09) a	9,01 (0,70) ab	8,29 (0,48) b	79,70 (4,10) a
	5-15	49,96 (3,62) a	59,76 (0,89) a	9,49 (0,78) ab	11,94 (0,37) a	7,82 (0,28) a	85,52 (1,06) a
	15-30	42,65 (2,87) a	65,16 (6,38) a	9,99 (1,13) a	10,67 (0,82) a	8,34 (0,57) a	83,83 (1,67) ba
Soil Management		0,002	0,02	0,02	ns	0,0001	0,0001
Depth		ns	ns	ns	ns	ns	ns
Soil management*Depth		ns	ns	ns	0,006	ns	0,02

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Conversion of a native ecosystem to agricultural use decreases soil organic C. However, the changes in soil organic C fractions was greater compared to total organic C. Greater portion of soil organic C is stored in macro aggregates at forest. Therefore, macro aggregates play critical role for C sequestration in native ecosystems and are more sensitive to changes of soil management systems. Conversion of forest to cultivated land and pasture significantly decrease total organic C and N, microbial biomass C and N, mineralizable C and N and the changes was greater in the cultivated lands.

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Nitrate and Nitrite accumulation in Tomato and Potato in Ardabil Province

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ABSTRACT

The research was conducted to determine the residual nitrite and nitrate on potatoes and tomatoes, two commercially important vegetables in Ardabil province. Samples of these plants were collected randomly from farms and wholesale markets in 10 day intervals at harvesting time in three sites (Ardabil, Parsabad and Meshkin Shahr) during 2004 and 2005. The samples were analyzed for residual nitrate and nitrite using spectroscopic method. The results revealed that in 10% of potato samples nitrate concentration was more than acceptable level (465 – 519.3 mg/kg fresh weight). Nitrite residue in potatoes ranged from 0.1 to 1.12 mg/kg. The nitrite and nitrate concentrations of 83.4% and 33% of tomato samples were lower than detecting limit of the methods. The amount of nitrate in tomato samples of Meshghin shahr was 20 fold lowers than Parsabads region that probably resulted from higher nitrogen fertilizers application in this region.

INTRODUCTION

Accumulated nitrate in plants related to plant species, season variation resulted from geographical situation, light intensity, temperature, amount of applied fertilizer and plant growth habit such as green house or field condition; and so availability of nitrate and other nutrients such as P, S, K, Fe, Mo, Ca, Mn and B in root zone. In fact this factors affect nitrate reductase enzyme activity (Carter and Bosma 1974). Also many plants predominance reduce nitrate in roots but some of them do it in shoot organse. For this reason we can detect more nitrate in several shoot organs of this plant relative to nitrate availability, plant species and growth stage. Nitrate accumulation in root increased with increasing temprature and so nitrate accumulation will inease by growth devalopment (marschner 1995). Nitrate accumulation in vegetables and fruits are hazarduce for human health. In this study oure efforts was to determine how is nitrate amount of potato and tomatoes that produce in Ardabil province.

MATERIAL and METHOD

We produced nitrate free potato and tomato for calibration of analytical instruments. Real potato samples were taken periodically (10 days interval) from wholesale markets of Ardabil and tomato from wholesale markets and farms at harvest time. Nitrate and nitrite were analyzed using standard spectroscopic method at 520 nm.

RESULTS and DISCUSSION

Only in 10% of potato samples (table 1) nitrate were higher than MRL (maximum residue limits). Based on Dedeh (2003) and Mare (2001) potato nitrate MRL is 250-300 mg /kg). Increasing fertilizers cost and attention to scientific plant production methods are the reasons for lowering nitrate rsidue in potat. Nitrite residue of potato samples was also lower.

Nitrate and nitrite residu of tomato were very lowe. There were no nitrite in 83.4 percent of samples and 33% of samples had no nitrate. Nitrate residue of regions was different each other. Meshkinshahr region had litle nitrate and its amount was 20 fold lower than Parsabads samples(Tab 2). This results show that in Parsabad region higher amounts of nitrogenous fertilizers are used.Christou et al (2003) found that in 10 Meditrranian regions tomato nitrate was between 0.003-0.17 percent of dry mass. Although this results showed that there is nitrit and nitrate residue lower than MRL, but we suggest that there is nesesity to determine chemical substances in food periodicaly all over the year.

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Table 1: Nitrite and nitrate amounts of potato samples and their daily intake if one 60kg body weight person feed one kg potato.

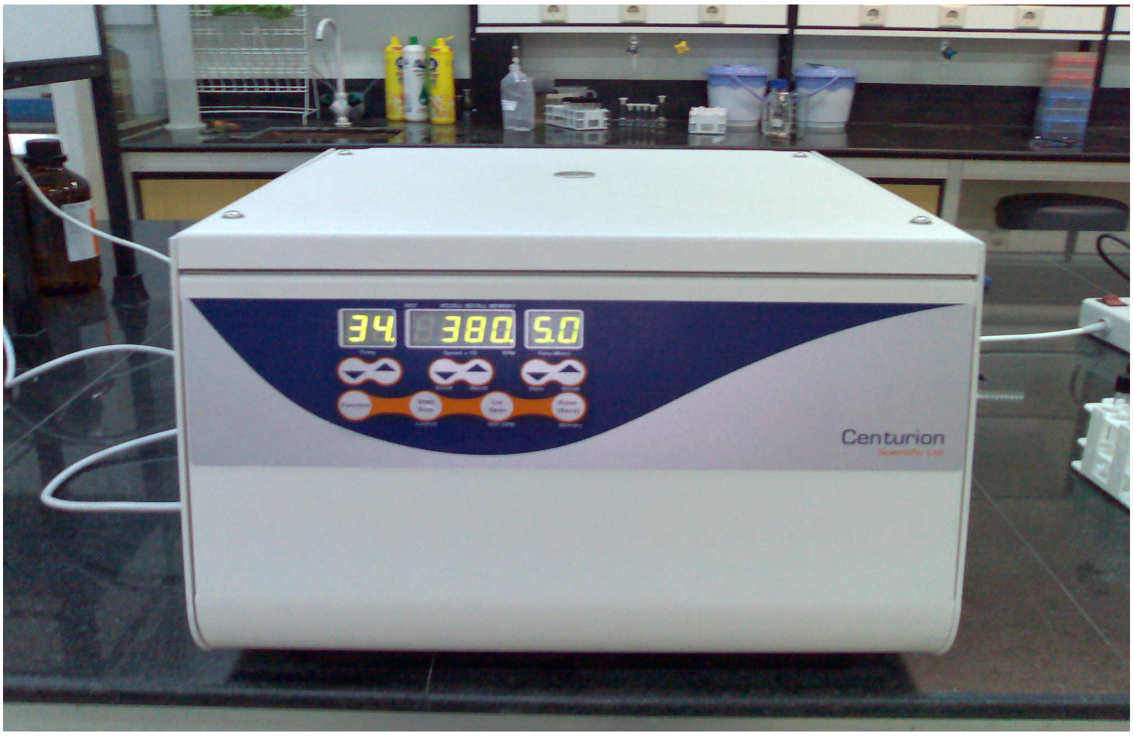
Potato sample	NO_2^- (mg/Kg)	nitrite(mg / kg body weight)	NO_3^- (mg/Kg)	nitrate(mg / kg body weight
T_1r_1	0.36	0.0060	11.6	0.1933
T_1r_2	0.71	0.0118	2.2	0.0367
T_1r_3	0.10	0.0017	188.6	3.1433
T_1r_4	0.87	0.0145	2.3	0.0383
T_2r_1	1.12	0.0187	465.0	7.7500
T_2r_2	0.34	0.0057	4.9	0.0817
T_2r_3	0.42	0.0070	1.2	0.0200
T_2r_4	0.36	0.0060	94.7	1.5783
T_3r_1	0.40	0.0067	148.7	2.4783
T_3r_2	0.34	0.0057	3.2	0.0533
T_3r_3	0.62	0.0103	93.3	1.5550
T_3r_4	0.44	0.0073	8.3	0.1383
T_4r_1	0.38	0.0063	2.5	0.0417
T_4r_2	0.60	0.0100	519.3	8.6550
T_4r_3	0.36	0.0060	69.4	1.1567
T_4r_4	1.01	0.0168	73.1	1.2183
T_5r_1	0.36	0.0060	125.7	2.0950
T_5r_2	0.28	0.0047	61.9	1.0317
T_5r_3	0.95	0.0158	1.0	0.0167
T_5r_4	0.38	0.0063	0.5	0.0083
Free	0.36	0.0060	0.5	0.0083

Table 2: Nitrite and nitrate amounts of tomato samples and their daily intake if one 60kg body weight person feed one kg tomato.

Tomato samples	**NO_2^- (mg/Kg)**	**nitrite(mg / kg body weight)**	**NO_3^- (mg/Kg)**	**nitrate(mg / kg body weight)**
A11	n.d.	n.d	0.15	0.0025
A12	0.26	0.0043	0.046	0.0008
A13	n.d.	n.d	n.d.	n.d
A21	0.46	0.0077	n.d.	n.d
A22	n.d.	n.d	0.15	0.0025
A23	n.d.	n.d	0.303	0.0051
A31	n.d.	n.d	1.26	0.0210
A32	n.d.	n.d	0.51	0.0085
A33	0.24	0.0040	0.17	0.0028
A41	n.d.	n.d	0.165	0.0028
A42	n.d.	n.d	0.21	0.0035
A43	n.d.	n.d	n.d.	n.d
P11	n.d.	n.d	0.037	0.0006
P12	n.d.	n.d	1.14	0.0190
P13	0.24	0.0040	n.d.	n.d
P21	0.52	0.0087	0.82	0.0137
P22	n.d.	n.d	0.87	0.0145
P23	n.d.	n.d	0.046	0.0008
P31	0.76	0.0127	0.97	0.0162
P32	n.d.	n.d	0.17	0.0028
P33	n.d.	n.d	2.67	0.0445
P41	n.d.	n.d	1.06	0.0177
P42	n.d.	n.d	0.147	0.0025
P43	n.d.	n.d	0.202	0.0034
M11	n.d.	n.d	n.d.	n.d
M12	n.d.	n.d	n.d.	n.d
M13	n.d.	n.d	n.d.	n.d
M21	n.d.	n.d	0.073	0.0012
M22	n.d.	n.d	0.36	0.0060
M23	n.d.	n.d	n.d.	n.d
M31	n.d.	n.d	0.027	0.0005
M32	n.d.	n.d	0.49	0.0082
M33	n.d.	n.d	n.d.	n.d
M41	n.d.	n.d	n.d.	n.d
M42	n.d.	n.d	n.d.	n.d
M43	n.d.	n.d	n.d.	n.d
Free	n.d.	n.d	0.055	0.0009

n.d. = not detected

Some of instruments that used in this research:



Centrifuge Centurion England

The Effect of Using Olive Oil Vegetation Water on Some Physical and Chemical Characteristics of Soil and Nutrient Element Contents of Fig (*Ficus carica* L. cv. Sarilop) Leaves

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ABSTRACT

In that project, it has been aimed to determine method of using that olive oil vegetation water as on organic manure in dried fig production and to obtain positive solution for environmental pollution. Fig and olive are important agricultural products in Aydin province. It has been accepted that reducing of crop nutritient quantities in agricultural lands is caused negative effect on dried fig product quality and yield. The oil vegetation water which is occurred in olive oil factory is caused very serious environment pollution. That project will be carried out in 2006-2012 years. The study is conducted in a farmer orchard which has 80 'Sarilop' dried fig trees, located in Isafakilar village, Incirliova, Turkey. This experiment was designed in respect of randomized blocks with four replications and each replication was consisted of two trees. Totally five applications are on the carpet, those olive oil vegetation water applications include control, 25, 50, 75, 100 kg/per tree, respectively. In addition, there are two groups that determined implementing olive oil vegetation waters in every year and every two years (implementing one year and no implementing one year). According to 2006-2007 periods results; it has been defined that olive oil vegetation water applications are composed some dissimilarities on some physical and chemical properties in the soil. However, similar variations weren't seen on leaf analysis.

Keywords: dried fig, olive oil vegetation water, plant nutrients, soil characteristics.

INTRODUCTION

Turkey is the world's largest fig producing country. In respect of FAO statistics world fig production is 1056820 tones. Turkey's production of 285000 t is 27% of the world's total production and, Turkey's 177900 t of fig exports represents 52% of total world fig exports (Anonymous, 2005). About 70% of Turkey's total fig production is for dry consumption (Aksoy et al., 2003). Because of environmental effects on fruit quality, it is commonly believed that the highest quality dried figs are grown in limited areas of the Big and Small Meander valleys where temperature, relative humidity and wind conditions are optimum for production of high quality dried figs (Özbek, 1978).

'Sarilop' [(*Ficus carica* L.) (syn. 'Calimyrna')] (Storey, 1975) is the most important dried fig cultivar in Turkey and the USA. Aydin and Izmir provinces are the main production centers in Turkey.

Take into account olive production in Turkey which has about 88 million olive trees and annual olive oil production varies from 35000 tons to 200000 tons. Hence, Turkey ranks fourth after Spain, Italy and Greece in the Mediterranean. There are two major by products of the olive oil industry, which are olive pomace and the vegetation water. Because of periodicity of the trees, seasonal operation, small and scattered nature of the olive oil mills, installation and proper management of the treatment facilities are difficult, costly and non-profitable.

Fig (*Ficus carica* L.) is one of the most important cultivar in Turkey. Aydin and Izmir cities are the main production regions for that 'Sarilop' dried fig cultivar.

Fig and olive are important agricultural products in Aydın province. It has been accepted that reducing of crop nutrient quantities in agricultural lands is caused negative effect on dried fig product quality and yield. The oil vegetation water (VW) which is occurred in olive oil factory is caused very serious environment pollution.

In addition, VW is used for different purposes in olive oil producer countries like Spain, Italy and Greece. But, the important one for us is the VW as fertilizer. Nevertheless, when the related literature reviewed, it could be seen that there are not many researches done about the effects of VW when used as fertilizers on chemical and physical properties of soil. Therefore, this project will contribute to obtain some basic knowledge on the related subject (Llamas, 1978; Alvarez, 1979; Potenz, 1980; Morisot, 1981, Levi- Minzi et all. 1992).

That project will be carried out in 2006-2012 years. Main aim of that project is to investigate olive oil vegetation water on tree growth, yield and quality on organic dried fig growing in Turkey. Besides, problem of olive oil vegetation water in Turkey would be able to solve in practical way.

MATERIALS and METHODS

That project will be carried out in 2006-2012 years. The study is conducted in a farmer orchard which has 80 'Sarilop' dried fig trees, located in Isafakilar village, Incirliova, Turkey. This experiment was designed in respect of randomized blocks with four replications and each replication was consisted of two trees. Totally five applications are on the carpet, those olive oil vegetation water applications include 0 (control), 25, 50, 75, 100 kg/per tree, respectively. In addition, there are two groups that determined implementing olive oil vegetation waters in every year and every two years (implementing one year and no implementing one year). Thus, it would be able to determine impacts of different dosages and treatments which are made together with diverse interval on tree habits, yields and quality.

Olive oil vegetation water slush which have been waited in summer months, is dried and then is perfused in tree canopy with explained dosages and is covered by soil.

Leaf samples are selected from four different directions of the tree, primarily the whole third leaf from the base with the first fruit of the current shoots from July to August, the accepted stable period (Kabasakal, 1983). And the leaves are taken in August as 60 leafs and are analyzed and also soil samplings are received from 0-30 cm soil depth and analyzed in October as 60 numbers. Leaf and soil analyses are performed in every year.

Macro and micro nutrient element levels for leaf analyses and texture, salinity, sand-spindle-clay, pH, total salt (%), organic material and macro and micro nutrient element levels for soil analyses are determined considering research calendar.

In soil samples, texture was determined by hydrometer methods (Bouyoucus, 1955), pH was measured using 1/2 soil/water suspension (Anonymous, 1980), electrical conductivity was assigned according to Soil Survey Stuff (1951), %organic matter was also specified by Walkey-Black method (Anonymous, 1980), %$CaCO_3$ was obtained by Scheibler calsimeter (Caglar, 1958), total nitrogen was extracted by Kjeldahl's method (Bremmer, 1965); phosphorus by Bingham's (1949); potassium, calcium and magnesium by IN HN_4 OAc method (Kacar, 1962). By using DTPA extraction, microelements have been determined as Lindsay and Norvell (1978) suggested. Soil excavated from two different depths (0-20 cm., 20-40 cm.), form the materials of the study. After the plant samples had been dried at 70^0C, total nitrogen was analysed by Kjeldahl's method (Kacar, 1972). In extracts obtained by applying Wet Burning, phosphorus was determined by colour-metric via Vauadomolibdo phosphoric yellow colour methods with colormatic; potassium, calcium was determined by fleymphotometric; magnesium and micro elements (Fe, Zn, Mn, B) by using Atomic Absorbtion Spectrophotometer. The results of the analysis have been evaluated by the SPSS statistical software.

RESULTS and DISCUSSION

Dried fig production and marketing is noteworthy for Turkish agricultural sector. Nevertheless, Turkey has also strong position in world olive and olive oil production. Scarcely, seasonal operation, small and scattered nature of the olive oil mills, installation and proper management of the treatment facilities are difficult, costly and non-profitable. In that study, it would be aimed investigation of utilization circumstances of olive oil vegetation water on dried fig trees. In this way, this is the first report from two years results which have been obtained by running project in Erbeyli Fig Research Institute, Aydin, Turkey.

Olive Oil Vegetation Water Composition

Olive oil vegetation water composition was analyzed in 2007 and was shown below (Table 1). Some parameters in the table are different than indicated by Seferoglu et al. (2000). They explained some indicators such as pH:6.24, $CaCO_3$(%): 0.69, organic matter (%): 11.65, total N (%): 1.78, total P (ppm): 154, total K (ppm): 3500, total Ca (ppm): 1000, total Mg (ppm): 1657, total Na (ppm): 240, total Zn (ppm): 79, total Mn (ppm): 190. On the other hand, Anonymous (1996) stated some parameters from olive oil vegetation water analysis pH: 4.83, total N (%): 1.69, total P (%): 0.19, total K (%): 2.6, total Ca (%): 1.0, total Mg (%): 0.33, total Fe (ppm): 197, total Mn (ppm): 54, total Zn (ppm): 43, total Cu (ppm): 12.

Comparison of some physical and chemical characteristics of soil and macro and micro element contents of fig leaves

In that chapter, it is explained alteration of soil nutrient elements respectively. In 2005 year, there wasn't implemented olive oil vegetation water on soil in the fig tree. Soil nutrient elements were shown in Table 1. So far olive oil vegetation water applications were made in 2006 and 2007. Belonging the two years soil nutrient elements results were performed in Table 3 regarding different olive oil vegetation water dosages. There are two groups that determined implementing olive oil vegetation waters in every year and every two years (implementing one year and no implementing one year). Implementations are specified in that way. Treatments which have been conducted, have been shown in the Table 4 are explained in Table 3a and Table 3b.

When the results of the analyses are considered, it was observed that after the application of VW there was a rise in the salt contents of the soils. After the application, soil pH first lowered and then rose and reacted its former level. Likewise, in their study Levi and et all. (1992) and Seferoglu et al. (2000) had the same results for salt and pH. On the other hand, there was not a considerable increase in nitrogen and calcium content of the soils increased in accordance with the doses used.

Table 1. Olive oil vegetation water composition

Elements	Values
pH	5.7
EC (dS/m)	20.5
Organic matter (%)	51.4
Organic carbon (C) (%)	28.8
Total nitrogen (N) (%)	1.3
C/N	22.1
Total phosphorus (P) (%)	0.19
Total potassium (K) (%)	1.57
Total calcium (Ca) (%)	0.82
Total magnesium (Mg) (%)	1.31
Total sodium (Na) (%)	0.06
Total iron (Fe) (ppm)	5130
Total zinc (Zn) (ppm)	57
Total copper (Cu) (ppm)	29
Total manganese (Mn) (ppm)	66

Table 2. Some physical and chemical properties of soil samples in the experimental orchard in 2005

Elements	Values	Statements
pH	6	middle acid
EC (mS/cm)	0.074	non salt
$CaCO_3$ (%)	0.40	poor in lime
Texture (%)	44	with sand
Organic matter (%)	1.271	poor
Total nitrogen (N) (%)	0.064	middle
Total phosphorus (P) (ppm)	1.400	poor
Total potassium (K) (ppm)	63.89	very poor
Total calcium (Ca) (ppm)	579.7	very poor
Total magnesium (Mg) (ppm)	92.19	middle
Total sodium (Na) (ppm)	13.92	very low
Total iron (Fe) (ppm)	10.9	enough
Total manganese (Mn) (ppm)	19.64	enough
Total zinc (Zn) (ppm)	0.27	insufficient
Total copper (Cu) (ppm)	0.49	enough
Total boron (B) (ppm)	0.15	very low

Table 3a. Declaration of different olive oil vegetation water applications in diverse tables

	Control	25 kg application (implementing one year and no implementing one year)	25 kg application (implementing every year)	50 kg application (implementing one year and no implementing one year)	50 kg application (implementing every year)
Term	1	2	3	4	5

Table 3b. Declaration of different olive oil vegetation water applications in diverse tables

	75 kg application (implementing one year and no implementing one year	75 kg application (implementing every year)	100 kg application (implementing one year and no implementing one year	100 kg application (implementing every year)
Term	6	7	8	9

In considering of some physical and chemical characteristics of soil before vegetation water application in the experimental orchard, such as dried fig trees especially located in slope and mountainous areas, soils have poor macro and micro nutrient elements. That result is harmonious with reports of Anaç et al. (1987) and Askin et al. (1998). One of the most important points from that article, acid and salt values haven’t been increased thorough vegetation water application. And also %$CaCO_3$, organic matter, phosphorus, potassium values are augmented after applications. Those parameters are important to continue sustainable dried fig production systems in Turkey. For leaf analysis, it was understood that there is no difference taking cognizance of control, different vegetation water dosages and years.

There was not a considerable increase in Mg, Na contents of the soils after the application. There was a parallelism between the rise and the amounts of doses used. Likewise, Püskülcü et all. (1995) arrived at similar results. It was observed that there was a small increase in aggregation stability which is closely related to structure, organic material, lime and sodium contents. This is especially important for those regions where there is low aggregation stability. Yet, if the Na contents decrease as a result of the applications which will be done later, it could decrease aggregation stability. However, because VW has some positive effects on the soil the improvement of the negative factors might increase aggregation stability. It should be remarked that Fe contents of the soil in 2006 and 2007, comparing 2005 year which there was no application, had been increased. We think it would be able to observe what kind of impacts of high Fe contents of the soil on the fig tree and fruit characters in oncoming years.

Table 4. Some physical and chemical properties of soil samples in the experimental orchard in 2006-2007 years*.

	1		2		3		4		5		6		7		8		9	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
pH	6.66	6.91	6.61	6.40	6.30	6.71	6.76	6.43	6.29	6.33	6.82	6.59	7.01	6.65	6.31	6.40	6.95	6.60
EC**	0.095	0.20	0.086	0.10	0.099	0.10	0.155	0.10	0.072	0.13	0.124	0.10	0.194	0.10	0.094	0.10	0.204	0.10
$CaCO_3$ (%)	0.82	0.76	0.94	1.14	0.87	1.05	1.22	1.14	1.02	1.24	0.92	1.05	1.07	1.24	1.14	1.14	1.08	12.4
Organic matter (%)	1.28	2.30	1.04	3.53	1.56	3.53	0.98	3.43	1.07	3.28	1.04	2.87	1.28	2.64	1.45	3.36	1.69	3.38
N (%)	0.07	0.05	0.07	0.06	0.10	0.07	0.06	0.08	0.07	0.07	0.08	0.07	0.09	0.07	0.09	0.07	0.12	0.06
P (ppm)	2.80	2.75	1.33	3.91	3.15	3.69	3.73	4.13	1.77	3.67	3.48	4.00	3.10	3.67	2.86	3.91	4.74	4.04
K ppm)	90.4	90	67.06	155	112.7	170	256.5	120	55.1	130	235.7	157	163.0	145	181.2	155	390.1	140
Ca (ppm)	1030.0	500	875.6	250	1059.0	475	1263.5	275	767.1	200	800.5	275	995.3	300	875.2	250	1065.6	275
Mg(ppm)	188.6	64.5	281.6	281.6	170.2	170.2	233.1	233.1	223.7	223.7	159.3	159.3	159.1	159.1	233.1	198.7	174.3	174.3
Na (ppm)	48.84	65.00	62.53	62.53	51.01	51.01	57.35	57.35	51.97	51.97	39.22	39.22	46.44	46.44	57.35	53.56	45.01	45.01
Fe (ppm)	29.32	3.62	15.61	15.61	15.16	15.16	48.90	48.90	19.11	19.11	23.44	23.44	34.71	34.71	48.90	39.84	18.31	18.31
Mn(ppm)	13.58	2.90	11.04	11.04	12.55	12.55	12.76	12.76	13.74	13.74	11.14	11.14	13.28	13.28	12.76	12.74	13.45	13.45
Zn (ppm)	0.24	0.26	0.44	0.44	0.16	0.16	0.58	0.58	0.57	0.57	0.28	0.28	0.33	0.33	0.58	0.51	0.22	0.22
Cu(ppm)	0.67	0.61	0.36	0.35	0.34	0.34	0.53	0.53	0.39	0.39	0.31	0.31	0.48	0.48	0.53	0.37	0.44	0.44
B (ppm)	0.22	0.69	0.57	0.57	0.17	0.17	0.80	0.80	0.50	0.50	0.45	0.45	0.39	0.39	0.80	0.40	0.18	0.18

* Meaning of the number in the first row in the Table 4 was explained in Table 3a, b.

**EC values are clarified as mS/cm in 2006 and as % in 2007.

Table 5. Macro and micro element contents of fig leaves in the experimental orchard in 2006-2007 years*.

	1		2		3		4		5		6		7		8		9	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
N (%)	1.42	1.42	1.44	1.62	1.41	1.65	1.26	1.59	1.37	1.56	1.25	1.58	1.40	1.49	1.33	1.57	1.28	1.47
P (%)	0.10	0.10	0.10	0.10	0.09	0.11	0.10	0.10	0.09	0.10	0.09	0.10	0.09	0.10	0.09	0.11	0.05	0.09
K (%)	0.65	0.54	0.55	0.80	0.52	0.92	0.37	0.76	2.38	0.79	2.04	0.89	0.57	1.03	1.73	0.98	0.37	0.74
Ca (%)	3.83	4.53	3.05	4.59	2.91	5.00	3.31	4.76	2.98	5.09	2.92	4.88	2.73	4.72	2.78	4.64	2.74	4.38
Mg (%)	1.00	0.89	0.90	0.89	0.90	0.93	0.95	0.91	0.84	0.88	0.71	0.97	0.74	0.90	0.64	0.81	0.79	0.83
Cu (%)	2.58	1.80	1.96	3.33	1.57	3.30	2.10	2.60	1.34	2.04	1.80	2.00	1.56	2.31	1.44	2.31	1.29	2.03
Mn (ppm)	74.95	86.40	94.57	131.2	76.71	117.0	82.47	112.0	90.45	123.1	105.76	162.9	93.35	172.8	102.47	162.6	87.88	122.7
Zn (ppm)	6.19	10.80	8.04	11.39	5.93	12.05	5.35	11.00	5.76	10.64	9.27	17.34	9.01	16.44	6.69	11.38	4.23	10.99
B (ppm)	37.30	52.43	30.94	56.02	33.06	62.14	34.15	69.37	27.59	63.93	35.19	60.51	36.63	69.63	37.56	47.32	36.10	

* Meaning of the number in the first row in the Table 5 was explained in Table 3a, b.

Finally, that report was prepared from two years result of running project in Fig Research Institute to determinate of impacts using olive oil vegetation water on physical and chemical characteristics of soil, macro and micro element contents of leaves and tree growth, yield and quality on dried fig. In progressive years, it will be given more specific and comprehensive results and indicators from that project.

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Effect of Nitrogen Rates on Yield and Fruit Quality of Fig (*Ficus carica* L. cv. Sarılop)

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ABSTRACT

In this study, it is aimed to determine the effects of different nitrogen rates on yield and quality parameters, including aflatoxins in fig fruits (*Ficus carica* L. cv. Sarılop). For this study, one control and five different nitrogen levels were applied in a slope fig orchard in Egrek village in Incirliova, Aydin for two years. Yield, shoot length and some fruit quality parameters (cull ratio, ostiole width, color, brix and acidity) and aflatoxins were determined. An overall evaluation of fruit yield and quality notifies that up to 500g N/ tree can be recommended in the fertilization of fig according to findings of two years. However, it would be able to give absolute results from final report of that project in one year later.

Key words: Fig, quality, nitrogen, fertilization, and aflatoxin.

INTRODUCTION

It is estimated that Turkey produces 300.000 tons of fig fruit per year and The Aegean Region comprises 75% of the production. On the other hand, Turkey comprises about 55% of the total production of the world (Bülbül et al., 1998).

Fertilization is very noteworthy practices for high yield and quality in fig (İrget et al., 2008).Very few research works have been carried out in world-wide on fig tree fertilization. Kabasakal (1983) studied seasonal changes of nutrient elements in fig fruits. Aksoy et al. (1987a) surveyed mineral nutrition of fig plantation of Germencik. Aksoy et al. (1987b), Anaç et al. (1987) and Aksoy et al. (1992) investigated the relations between mineral nutrition and fresh-dried fig fruits in Aegean region. Özer and Derici (1998) reported that there was a positive interaction between Ca and aflatoxin B_1 and a negative interaction between Cu and total aflatoxin, aflatoxin B_1. In addition, the samples showing fluorescence under UV light contained significantly higher levels of K, Na, and Ca. However, the samples which did not show fluorescence contained much more Cu than the other samples.

İrget et al. (2008) stated that basic NPK fertilization with additional 280g Ca /tree increased overall quality by reducing the number of sunscalded fruits and fruits with ostiole-end cracks. The results showed that the fertilizers applied significantly reduced the cull ratio and could alleviate the negative impact of drought, as well.

The aim of this research work to determine the effects of nitrogen application on the quality of dried fig fruits and aflatoxins. The study proved different nitrogen levels in soil may have effect on some parameters such as shoot and fruit quality, especially on aflatoxin formation inside the fruit.

MATERIALS and METHODS

The study was conducted in a slope fig orchard in Egrek village in Aydin between 2006 and 2008. In this study common fig variety, a 'Sarılop' tree nearly 15-20 years old (*Ficus carica* L. cv. Sarılop), which has the same plant canopy in a full yielding period was used. The tree vigour was almost similar, and the average canopy diameter was 6.90m.

In the first year of the study (2006), the orchard which no fertilization was applied was selected and some phenological and pomological characteristics of the trees were determined. In 2007 and 2008, different N rates were applied.

On the other hand, 450g P_2O_5/tree and 500g K_2SO_4/tree, were applied all the tree including control. As a P source triple superphosphate (TSP) (42-44%P_2O_5), as a K source K_2SO_4 (50%K_2O) and as N source $(NH4)_2SO_4$ (21%) were used. Fertilizers were applied to parallel line on all four sides of the tree at a depth of 10-15cm during the period in early February to late March.

The tested treatments are as follows:

(1) 100 g N/tree
(2) 200g N/tree
(3) 300g N/tree
(4) 400g N,/tree
(5) 500g N/tree
(6) Control

The experiment was designed as randomized blocks with three replicates, each replicate possessing two trees. In the first year of the study the leaf samples were taken during fruit maturation according to Kabasakal (1983).Partially shrivelled fig fruits fell onto the ground from the trees were collected separately and dried on drying trays. Cull fig fruits defined as defects in Turkish Dried Fig Standards TS 541 (Anonymous, 2006) and UN/ECE Dried Fig Standards (Anonymous, 2004) were removed and weighted. Total yield and yield components were determined and calculated at the end of the season in relation to the quality classification.

In the study, some important quality parameters about fig fruit were evaluated. Ostiole-end crack of the fruit was investigated in two ways. According to standards, if the ostiole-end crack is more than 1/3 of fruits length, those fruits are called sound. Sunlight damages less than 1/3 of fruit outer space was evaluated as good. Dried fig fruits of lower quality were defined as fruits that have cracks on and subject to solar damage and damage posed by the insects and birds. Dried fig fruits of lower quality are called cull figs that cannot be marketed for human consumption (Özbek, 1958). Ostiole width was measured with the a digital compass (BTS, 0-150mm) and the colour of the inner and outer parts of the dried fig fruits (Minolta, CR 400) and some shoot parameters (length, diameter, number of nods and length of inter nods) were determined with a digital compass (BTS, 0-150mm). The total soluble solids were measured with a hand-held refractometer (N.O.W., 0-32 %Brix) and titratable acidity (expressed as %citric acid) was determined by titration with 0.1 N NaOH. Aflatoxin analysis were made by high performance liquid chromatography (HPLC) (Shimadzu CLASS-VP V 613 SP1). ACE 5C 18 150 *4,6mm was used as colon.

Statistical analysis of data was made by using SPSS. Significant differences between the means were determined by Duncan's multiple range test.

RESULTS and DISCUSSION

Results of different nitrogen applications on some shoots parameters in 'Sarılop' fig trees is displayed on Table 1.

The highest shoot length, diameter, nod number and length of shoot inter nods were obtained from 500g N/tree application (Table 1). It was determined that there was statistically difference among nitrogen rates ($p<0.01$) and nitrogen rates*years interactions ($p<0.10$) on shoot length, while there was no difference between years. While the highest shoot length (85.19 mm) was obtained from 500 g nitrogen dosage, shoot lengths obtained from 100 g N (77.52 mm) and control applications (72.42 mm) followed it. The years ($p<0.01$) and nitrogen rates ($p<0.01$) had significant effect on shoot diameter. While the largest shoot diameter (11.63 mm) was obtained from 500 g nitrogen application, shoot diameter achieved from 100 g N application (11.15 mm) followed it.

Table 1. Shoot parameters (mm) obtained from tested treatments

Treatment	Shoot length (mm)	Shoot diameter (mm)	Number of nod (number)	Average internode Length
1. 100 g N	77.52 b	11.15 bc	6.36 c	15.47 ab
2. 200 g N	60.70 d	10.77 bc	6.03 d	13.08 c
3. 300 g N	71.52 bc	10.69 c	6.30 cd	14.55 b
4. 400 g N	70.58 c	10.89 bc	6.59 bc	15.19 ab
5. 500 g N	85.19 a	11.63 a	7.08 a	16.25 a
6. Control	72.42 bc	11.20 ab	6.75 b	14.67 b
Treatments (*p*)	0.000*	0.000*	0.000*	0.000*
Year 1	73.83 (2006)	11.26 a (2006)	6.82 a (2006)	14.90 (2006)
Year 2	71.99 (2007)	10.81 b (2007)	6.15 b (2007)	14.84 (2007)
Years (*p*)	ns	0.001*	0.000*	ns
Years x treatments (*p*)	0.058**	ns	0.003*	ns

*The mean difference is significant at the 0.01 level ($p<0.01$).

**The mean difference is significant at the 0.10 level ($p<0.10$).

The years, nitrogen rates ($p<0.01$) and years*nitrogen rates interactions had statistically significant effect ($p<0.01$) on the number of shoot nods. The highest number of shoot nods (7.08) were taken from 500g N applications, control group (6.75) followed this. Only nitrogen rates ($p<0.01$) had significant impact on the length of shoot inter nods. While the highest length of shoot inter nods (16.25 mm) was obtained from 500 g N application, 15.47 mm length was obtained from 100 g nitrogen application. The highest shoot length (85.19 mm.), shoot diameter (11.63 mm.), number of shoot nods (7.08) and length of shoot inter nods (16.25 mm) were achieved from the fig trees which were received 500 g N. Aksoy et al. (1987a) reported similar results. Considering all the shoot parameters, very little development was obtained in 2007 compare with 2006. This issue would be explained with drought climate conditions occurred in 2007.

Results of different N applications on some important quality parameters in 'Sarılop' fig trees are given at Table 2.

Taking cognizance of the total dried fig yields of each fig tree, it was obtained highest dried fig fruit yield (31770 g) from 100 g nitrogen and 500 g nitrogen application followed it (27525 g). Aydın and Izmir regions which are the most important dried fig production areas had heavy drought in 2007. It may be explained that dried figs showed lower quality and fruits subject to excessive sunlight. Hernandez et al. (1994) reported that nitrogen rates positively affect total soluble solids of fruits in only The ratio of severely sunscalded (sunburn damage) fruits in the 'Sarilop' cultivar grown under the Aegean Region conditions were reported range from 0.0% to 47.2% in 1992 and from 2.7% to 59.4% in 1993 (Aksoy, 1994).

Ostiole-end cracks and sunscald are leading defects in fig fruit quality. Ostiole-end crack has not been fully investigated in fig fruits yet, however, the previous studies based on observations and surveys display that ostiole-end cracking in a fig fruit was linked with variety, climatic conditions, soil properties (lime and available Ca content) and nutritional status, especially Ca (Aksoy et al., 1987b). The actual mechanism of sunscald needs further investigations as it is about fruit cracking. The results of surveys and on-going research display significant effect on soil properties and aspect (light intensity) on sunscald. In this respect, soil available potassium content seems to be effective on sunscald incidence, and K applications prevented or reduced the defect. Irget et al. (2008) explained that application of NPK enhanced fruit K content significantly, whereas, an addition to Ca to NPK decreased fruit K levels.

Table 2. Dried fig fruit (g/tree) obtained from different quality parameter tested treatments

Treatment	Sound	Sunscalded	Ostiole-end cracks	Cull figs	Total yield
1. 100 g N	16735	4504 b	7525	3006	31770
2. 200 g N	12596	3517 b	6403	1395	23911
3. 300 g N	12714	4942 ab	5340	1752	24748
4. 400 g N	11450	4484 b	3171	1314	20419
5. 500 g N	13649	7230 a	4679	1967	27525
6. Control	8354	4904 ab	2299	1110	16667
Treatments (*p*)	ns	0.084**	ns	ns	ns
Year 1	14084.72 (2006)	1472.33 b (2006)	7713.06 a (2006)	1566.11 (2006) 1949.17 (2007)	24836.22 (2006)
Year 2	11082.28 (2007)	8389.28 a (2007)	2093.28 b (2007)	ns ns	23514.00 (2007)
Years (*p*)	ns	0.000*	0.000*		ns
Years x treatments (*p*)	ns	0.095**	ns		ns

*The mean difference is significant at the 0.10 level (p<0.01).

**The mean difference is significant at the 0.10 level (p<0.10).

It wasn't defined statistically significant effect of years, nitrogen rates and years*nitrogen rates interactions on sound, ostiole-end cracks, cull and total yield of dried figs while it was only determined years (p<0.01), nitrogen rates (p<0.10), years*nitrogen rates interactions (p<0.10) had significant effect on sunscalded dried figs. The highest sunscalded dried figs (7230 g) were taken from 500 g nitrogen application. 300g N and control applications followed it. The most remarkable point is that while the degree of sunscalded and cull figs in 2007 (when drought conditions prevailed) was much more than 2006 (Table 2).

The effect of different nitrogen applications on the ostiole width and the colour of inner and outer parts of dried fig fruit colours are given in Table 3 and 4.

It has been indicated that ostiole width which causes access of insects and diseases is blocked by the effects of calcium (Aksoy et al., 1987a). Moreover, Irget et al. (1998) reported that $Ca(NO_3)_2$ and KNO_3 applications resulted in narrowing the ostiole width. Brightness, flexibility, softness, cracking and sugar content are accepted as essential parameters in terms of quality and taste in fig. Aksoy et al. (1991) stated iron, zinc and copper had an effect on fruit colour; iron and copper increase darkness. And zinc affects colour of the fig fruit .There wasn't identified no relations between nitrogen nutrition those quality parameters. Ferguson et al. (1990) suggested that breeding efforts should focus on the common type 'Calimyrna' for developing narrower ostiol end.

Table 3. The effects of different nitrogen applications on ostiole width and the colour of inner and outer (skin) parts of dried fig fruits

Treatment	Ostiole width (mm)	Colour L (inner)	Colour L (outer)	Colour a (inner)	Colour a (outer)	Colour b (inner)	Colour b (outer)
1. 100 g N	5.16	38.45	58.85	8.52	5.78	17.41	23.13
2. 200 g N	5.54	37.33	59.00	7.88	6.59	16.78	23.87
3. 300 g N	5.35	38.00	58.48	8.06	7.10	16.91	24.54
4. 400 g N	5.01	37.22	56.88	8.78	6.57	17.02	23.64
5. 500 g N	4.34	38.39	57.85	7.81	6.37	17.53	23.96
6. Control	5.49	37.96	57.64	8.69	7.10	16.56	24.30
Years							
2006	4.35	43.07	56.84	7.44	5.92	18.21	22.42
2007	5.50	32.71	59.39	9.13	7.25	15.85	25.40

Table 4. The correlation coefficients between ostiole width, the colour of inner and outer parts of dried fruits and factors

Factors	Ostiole width (mm)	Colour L (inner)	Colur L (outer)	Colour a (inner)	Colour a (outer)	Colour b (inner)	Colour b (outer)
Years	0.385**	-0.449**	0.251*	0.447*	0.443*	-0.375*	0.665**
Nitrogen dosages	-0.082	0.000	-0.107	0.035	0.176	-0.030	0.113

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

There was a positive correlation between ostiole width and years (r=0.385**). In 2007, when drought conditions prevailed, ostiole width was found larger than 2006. But there wasn't any correlation between nitrogen rates and ostiole width. By the way, despite the fact that there was correlation between years and all colour parameters, there wasn't any correlation between nitrogen rates and all colour parameters (Table 4).

The effects of different nitrogen applications on total soluble solids and acidity of dried figs were displayed and evaluated in Table 5.

The highest rate of total soluble solids was obtained from control group, 100 g, 400 g nitrogen applications and control group (56.33%). The lowest one was obtained from 200g application (53.00%). In addition, the highest acidity was determined from 500 g nitrogen application (0.88%) (Table 5).

The influence of various nitrogen sources on aflatoxin production in different species has been studied by several researchers. The possibility to use inorganic nitrogen for the production of higher yields of aflatoxin apparently depends on the strain of the fungus used and/or the composition of the nutrient solution.

Table 5. Effects of different nitrogen applications on dried fig fruit total soluble solids and acidity

Treatment	Total soluble solids (%)	Acidity (%)
1. 100 g N	56.33	0.65
2. 200 g N	53.00	0.61
3. 300 g N	54.33	0.75
4. 400 g N	56.33	0.63
5. 500 g N	55.33	0.88
6. Control	56.33	0.66
Years (Time)		
2006	55.28	0.70
2007	55.28	0.70

N nutrition, in combination with other agricultural practices, is reported to have a positive effect in reducing *A. flavus* group infections and aflatoxin contamination in corn when other environmental or biological stresses are not extreme. In contrary data from low N or late N treatments indicate that N may influence aflatoxin contamination at harvest. Significant differences are found in aflatoxin concentration due to nutrition. The result suggests that aflatoxin contamination can be related to inadequate irrigation, high population and/or extreme N deficiency. The late applications or large amounts of N or excessive fertilization with N, P and K also resulted in elevated concentrations (Wilson and Walker, 1981).

Jones and Duncan (1981) investigated the effects of N fertilization, planting date and harvest date on aflatoxin contamination of inoculated field corn. Regardless of the isolate used, less aflatoxin B_1 was detected in treatments receiving higher rate of nitrogen (145. 7 kg/ha) than in treatments receiving lower rate (11.2 kg/ha). Low nitrogen plants had 2.4 times more aflatoxin of B_1 than high nitrogen plants when results were averaged across cultivar, planting date and isolate. Jones and Duncan (1981) suggested that inadequate nitrogen fertilization alters the nutritional status of pre-harvest corn and makes it a better substrate for aflatoxin production.

Özer and Derici (1998), however, determined significant relation between the level of N in dried fig fruit and aflatoxin B_2 and total aflatoxin. According to the researches results can be attributed to the effect of N increasing the water content in the plant cell, causing turgidity in fruit and thus enhancing the growth rate of the pathogen. By increasing the water content N also extends the drying period and increases the risk of contamination. High levels of N cause colour deterioration in dried fig fruits and according to Gül (1990) there is a relationship between darker fruit colour and aflatoxin contamination of dried figs, which supports the correlation between N and aflatoxin levels.

It was found that as average in all applications, aflatoxin B_1, B_2, G_1, G_2 were 0.16, 0.14, 0.17 and 0.14 ppb, respectively. Those measures are very inconsiderable for export limits and market standards. And there wasn't any correlation between aflatoxin parameters and all nitrogen rates and years.

As a conclusion, it has been aimed to determine the effects of different nitrogen applications on some morphological, dried fruit quality parameters and aflatoxin levels on ‘Sarılop’ dried fig cultivar.

While the highest shoot length (85.19mm) was obtained from 500 g nitrogen dosage, 100 g N (77.52mm), control applications (72.42mm) followed it. The largest shoot diameter (11.63 mm), the highest number of shoot nods (7.08) and the highest length of shoot inter nods (16.25 mm) were obtained from 500 g nitrogen application. Taking cognizance of these results, up to 500g N/tree can be recommended to as optimum for dried fig according to findings of two years.

There wasn’t any significant effect of years, nitrogen rates and interactions on sound, cull, ostiole-end cracks and total yield of dried figs while it was only determined years ($p<0.01$), nitrogen rates ($p<0.10$), years*nitrogen rates interactions ($p<0.10$) had significant effect on sunscalded dried figs. The highest sunscalded dried figs (7230 g) were taken from 500 g nitrogen application. 300g N and control applications followed it. The most remarkable point is that while the proportion of sunscalded and cull figs in 2007 (when drought conditions prevailed) was much more than 2006.

In 2007 when drought conditions prevailed, ostiole width was found larger than 2006. Nevertheless, there wasn't any correlation between nitrogen rates and ostiole width. By the way, contrary to the fact that there was correlation between years and all colour parameters, it wasn't obtained any correlation between nitrogen rates and all colour parameters. And also there wasn't any correlation between acidity, total soluble solids and factors (years and nitrogen rates). Even though some significant correlations were found among some prominent parameters on dried fig, future studies should aim to exhibit mechanism of relationships among nitrogen rates, aflatoxin levels and other physiological indicators (ultraviolet radiation stress, free radicals, photosynthesis, nutrient assimilation etc.).

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Ammonium and Nitrate Status of the First Crop Corn Fields at Cukurova Region

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ABSTRACT

The ammonium (NH_4) and nitrate (NO_3) are the available nitrogen (N) forms that plants need in large quantities. Their existence in the soil is limited, and concentrations are kept low due to the losses by leaching in the soil profile and microbial consumptions. Sustainability of the plant available nitrogen forms in soil profile is important for plant growth and crop production. In this research, our main objective was to evaluate mineral nitrogen (Nmin) status of the first crop corn soils and plants in Akarsu Irrigation District of Cukurova Region in 2007. Soil samples prior to sowing and after harvest were taken from 0-30, 30-60 and 60-90 cm soil depths, and analyzed for ammonium and nitrate concentrations. Plant samples were also taken during harvest, and analyzed for N content for determination of total N uptake. There was considerable amount of ammonium and nitrate in the soil profile during preplanting and postharvest. Since the soils were mostly heavy texture, there is tendency to have ammonium also in the soil solution. However, ammonium concentration was far below the nitrate concentration throughout the profile. Plant nitrogen uptake in the irrigation district was very close to the amount that was applied by the local farmers. The results indicated that soil mineral nitrogen level is an important criteria for fertilization practices, especially the preplant Nmin values need to be considered to decrease the amount of N fertilizer that will be applied.

Key Words: Soil Mineral Nitrogen, Nitrate, Ammonium, Corn N Uptake, Irrigation District

BACKGROUND

One of the factors directing crop production in terms of quality and quantity is well-balanced by plant nutrition and therefore suitable fertilization. Nitrogen fertilizers are one of the most used fertilizers in Turkey and the world, and its application level increases day by day. Particularly since hybrid varieties were densely used in Turkish agriculture, the use of N fertilizer has increased greatly with effective irrigation. On the other hand, it is one of the elements that carries potential risk to environmental (e.g. soil and water sources) pollution (Marilla et al., 2004, Gallardo et al., 2005). Human health and environmental quality have been and will be under danger because of the polluted soil and water resources with residual fertilizer nitrogen (Halvarson et al., 2005).

Part of the nitrogen fertilizer which could be absorbed by plants enters into a cycle in which chemical and biological processes occur. This cycle shows great variety depending on the soil, climate and land usage. Depending firstly on water parameters and soil texture, accumulation of nitrogen in the soil, its leaching and deformation determine the amount of fertilizer to be used (Hofman and Cleemput, 2004).

On the other hand, although there is available mineral nitrogen (Nmin) (NO_3-N + NH_4-N) in the soil (Wehrmann and Sharph, 1986, Bock and Hergert, 1991) which could be used by plants, both farmers and experts ignore its consideration in the fertilization program. For instance, Cukurova University and other regional agricultural institutes have determined the nitrogen amount which should be applied to maize as 25 kg N da^{-1} on average, this amount reaches up to 50 kg N da^{-1} in farmers' practices. Including the amount of Nmin and other N forms, some N is ready present in the soil, this figure needs to be accounted in fertilization practices further (Ibrikci et al., 2001). To increase the crop yield and its quality in the Cukurova region (Lower Seyhan Plain) of Turkey, various field and greenhouse studies have been conducted. However, the N studies in a large irrigation district are very limited or hardly studies. Thus the aim of this study is to determine mineral nitrogen status of first crop corn soils and corn-plant N uptake in this specific area. The results will be evaluated and extended to at farmers' level.

MATERIALS and METHODS

Location

The Project area in Turkey is located in Lower Seyhan Plain (LSP), named after the River Seyhan, in the eastern part of the Mediterranean region, Adana, Turkey. The LSP covers a gross area of 213 200 hectares of land, of which 174 088 ha are suitable for irrigation. Akarsu irrigation district (AID) within LSP were selected for this project (Fig. 1, Fig. 2). The AID is located between 36^o 57′ 32″ and 36^o 50′ 43″ N latitudes and 35^o 40′ 22″ and 35^o 28′ 42″ E longitudes. It is in south-east of Adana and west part of the Ceyhan River. With a 630 mm precipitation a year and 18.7 ^{0}C average degrees, the region has the characteristics of the Mediterranean climate.

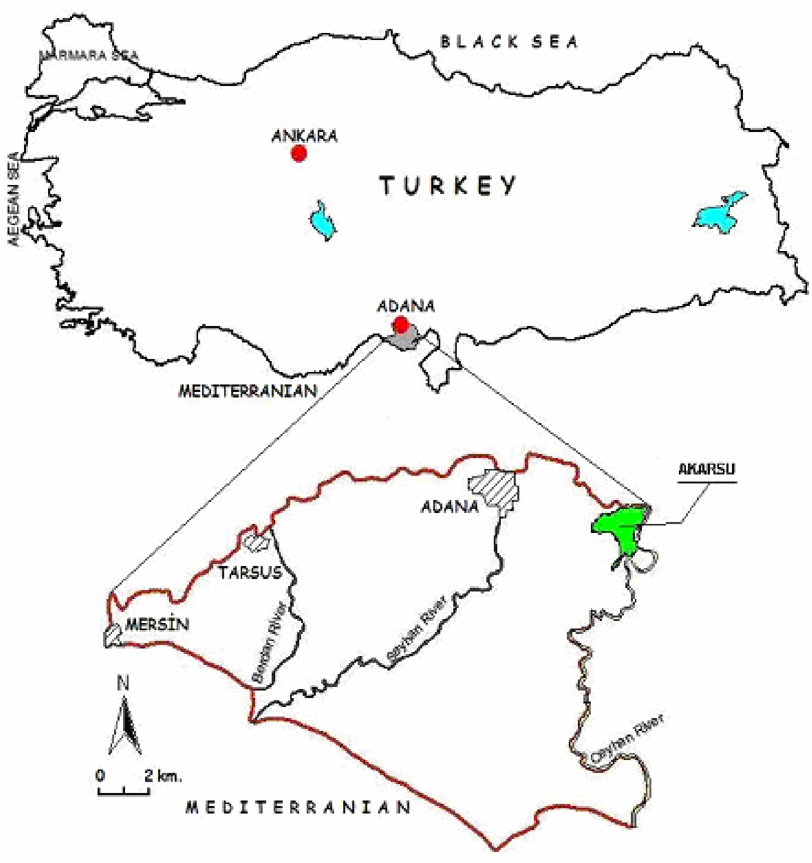

Figure 1. Geographical location of the study area

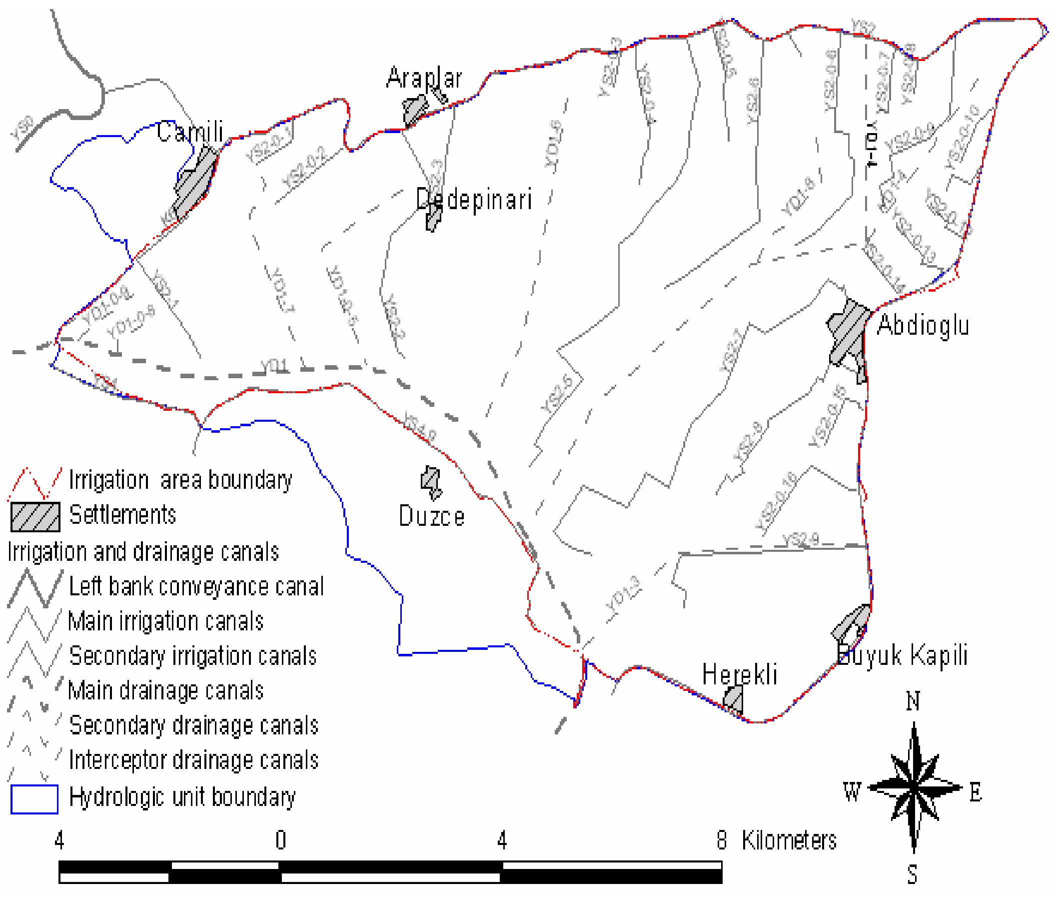

Figure 2. General layout of study area selected in Akarsu Irrigation District

Cropping pattern of the region according to the data in 2007 was 35% the first and second crop corn (80% of total corn was the first crop corn), 28% cereals, 25% citrus and 9% cotton (Figure 3).

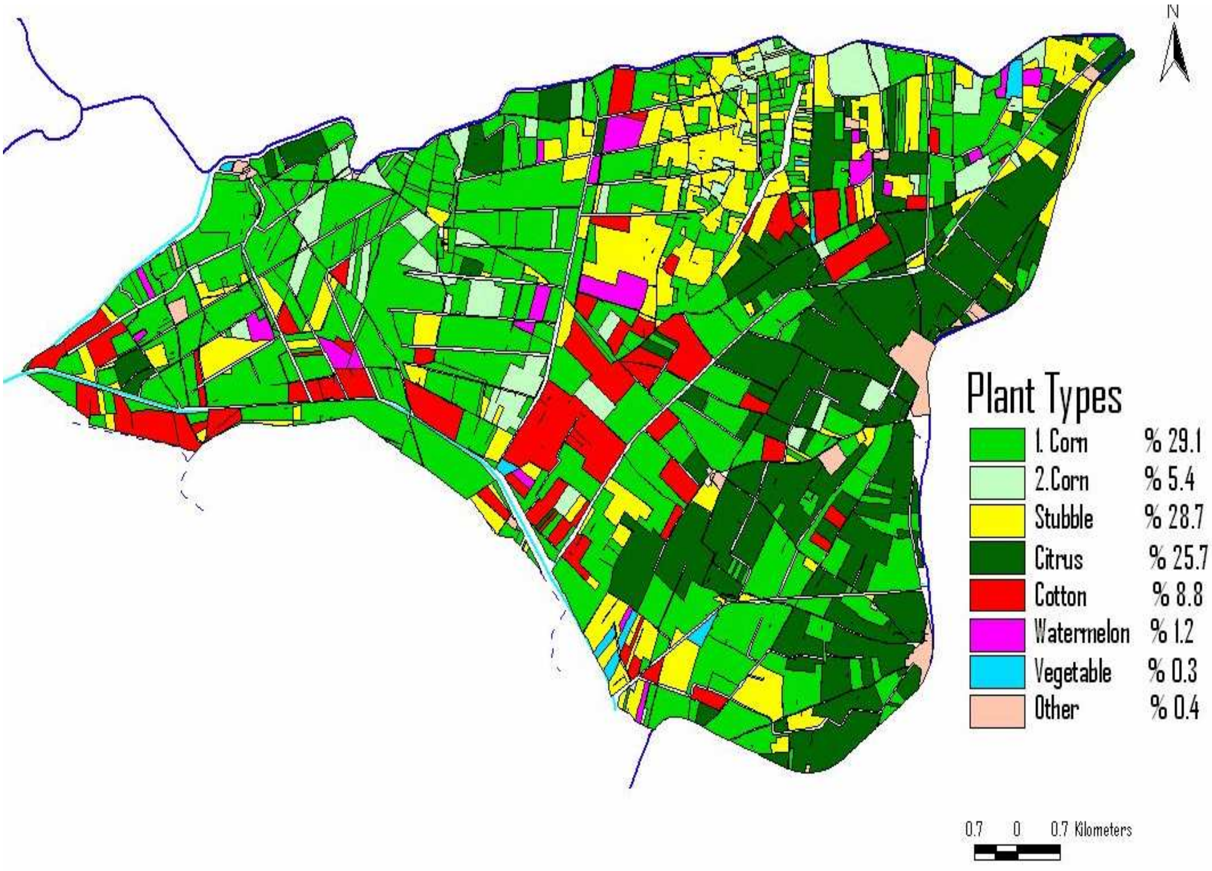

Figure 3. Cropping pattern of year 2007

METHOD

Soil Sampling and Analysis

With the assistance of the Water User Association personnel, representative fields of the first crop corn were selected for sampling purposes. During the sampling, GPS was used to determine the coordinates of the sampling points which will be used during course of the project.

In March just before the sowing and in August after harvest, soil samples were taken from the effective rooting depth (0-30, 30-60 and 60-90 cm). The samples without any treatment were immediately stored in a cold room (+4 ^{0}C) until the chemical analyses. Mineral nitrogen analysis (Nmin) (Nmin= NO_3-N + NH_4-N) were performed based on the procedure described by (Fabig, 1978). The main principle of the analysis is to measure the amounts of nitrate and ammonium in the soil solution using a spectrophotometer. Amounts of mineral nitrogen at each depth were determined as kg N ha^{-1} and calculated for the rooting depth.

Plant Sampling and Analysis

In August, representative plant samples from 54 first crop-corn fields were collected from the ground level prior to the harvest. A 1 m wooden stick was used as a sampling unit for plant sampling, and the procedure was repeated a few times for each field. These units were repeated a few times based on the size of field. The samples from each field were separately dried until the constant weight under outdoor conditions. Then shoots and grains of each sample were separated. Dry weights of whole plant, shoot and grain were taken separately for dry matter determination of a selected unit area. Dry weights of each unit area were then converted to kg N ha^{-1}.

Dry matter measurements of plant samples (shoot and grain) were taken, shoot and grain sub samples were taken from the bulk-dried samples, dried again at 65 ^{0}C (for 48 to 72 h) (Walsh and Beaton, 1973) in dryers and ground separately to pass 0.5 mm sieve for total N (Bremner,1965) analysis. Percentage N values from each field, in particular from shoots and grains, were determined, and used to calculate total N uptake by first crop corn.

In addition, we were recorded 340 kg ha^{-1} N fertilizer application to the first crop corn in survey studies.

RESULTS and DISCUSSION

✓ Average, maximum and minimum nitrate concentrations are reported in Table1.

Table 1. Soil nitrate concentrations (mg kg^{-1}) in the selected fields for first crop corn in Akarsu irrigation district in 2007.

Date	Crop	Number of Fields	Soil depth (cm)	Range of NO_3 conc.	Average NO_3 conc.
March, 2007	1. corn pre-plant	54	0-30	5.07-160.55	19.67
			30-60	6.52-130.47	30.46
			60-90	0.97-22.40	4.18
Aug., 2007	1. corn post-harvest	54	0-30	3.05-164.93	32.55
			30-60	3.71-175	24.84
			60-90	0.68-25.29	4.78

✓ There is a variation between pre and post harvest soil nitrate values. Average nitrate concentrations across the plant typology, soil depth and sampling time (pre plant and post harvest) throughout the irrigation season ranged between 19.7 and 32.6 mg NO_3 kg^{-1}. It could easily be attributed to the potential plant N uptake and loss from the soil through the various physical, chemical and biological processes.

✓ Nitrate values changed according to the soil depth and sampling time. In general, pre plant soil nitrate concentrations in 0-0.3 m soil depth were higher than the subsurface horizon (0.3-0.6 m).

✓ Since the N is very mobile in the soil, accumulation throughout the profile was obviously seen in the Table 1.

✓ Especially preplant high nitrate concentration in the first 60 cm needs to be considered in fertilization programs.

- Average, maximum and minimum soil ammonium concentrations are reported in Table 2.

Table 2. Soil ammonium concentrations (mg kg^{-1}) in the selected fields for first crop corn in Akarsu irrigation district in 2007

Date	Crop	Number of Fields	Soil depth (cm)	Range of NH_4 conc.	Average NH_4 conc.
March, 2007	1. corn pre-plant	54	0-30	0.34-9.63	3.86
			30-60	0.31-12.18	4.46
			60-90	0.07-1.72	0.69
Aug., 2007	1. corn post-harvest	54	0-30	0.3-8.06	2.43
			30-60	0.01-8.48	2.38
			60-90	0.08-0.90	0.40

- Ammonium values ranged throughout the profile during the both sampling times. During the both sampling periods the concentration was low in the bottom horizon.
- Even though extractable NH_4 values are low, it has valuable contribution to soil mineral nitrogen level which is the main fraction of plant available nitrogen in the soil profile.
- Although the definition of the mineral nitrogen in soil is defined as the sum of NO_3-N and NH_4-N, it is generally accepted as only NO_3 content. That's because NH_4 content is measured very low in many different climate and soil conditions, and therefore, it is not taken account.

However, the existence of NH_4 in the soil was determined in many controlled field and greenhouse experiments in Cukurova region.

♦ Grain yield, N concentration and N uptake by shoot and grain in 54 first crop corn fields were given in Table 3.

Table 3. Corn yield and N data

Plant part	Average N Conc.	Average yield	N uptake
	%	.........kg ha^{-1}………	
1st corn			
Shoot	1.11	12 014	129
Grain	1.44	13 738	177

n=54 first crop corn fields

♦ The grain yield is typical for the Cukurova Region.

♦ Total plant N uptake as 306 kg N ha^{-1} is very close to that the amount (340 kg N ha^{-1}) applied by the farmers.

♦ The remaining amount is a potential N source for the following crop.

Table 4. Average soil (in 0-90 cm) and plant parameters (kg N ha^{-1}) in 2007.

Crop Pattern	Pre-plant soil N	Post harvest soil N	Plant N uptake	Fertilizer Applied	Estimated Loss
1st crop corn	72.4	61.5	306.6	340	44.3

Estimated loss is calculated as 44.3 kg N ha^{-1} (N applied + pre soil N) – (plant N uptake + post soil N).

► 44.3 kg N may be lost by leaching, volatilization, microbial consumption and immobilization.

CONCLUSION

- Soil and plant N data represent the Akarsu Irrigation District.
- There is considerable amount of soil mineral N in the effective rooting depth for corn plants.
- In our conditions, NH_4 is also a potential mineral N source to be taken account.
- Consideration of preplant soil mineral N is a practical tool to be used in a fertilization program.
- In 2007, plant N budget, in terms of application level and the amount taken of by plants, is well balanced in farmers' conditions.

ACKNOWLEDGEMENTS

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The Disposal of Biosolids and Water Treatment Residuals on Soils of Arid Regions: A Glasshouse Investigation

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Abbreviation List: DW: Dry Weight; WTR: Water Treatment Residuals

ABSTRACT

Land co-application of biosolids and WTR is a new concept. Therefore, information on the effect of co-application of biosolids and WTR on plant growth and elements uptake are very limited especially in alkaline soils. A glasshouse experiments was established to evaluate the effects of co-application of WTR and biosolids on agronomic performance of wheat crop grown in alkaline soils as well as P plant concentration and uptake, and to improve management of industrial and toxic wastes and provides environmentally sound guidelines for their disposal. The results indicated that increases of 47, 359 and 55 % in total dry matter yield were achieved as a result of applying 40 gkg^{-1} WTR and 10 gkg^{-1} biosolids to clay, sandy and calcareous soils respectively. In all studied soils treated with a constant biosolid rate 10 gkg^{-1}, application of 20 gkg^{-1} WTR significantly increased plant P concentration in the plant materials. Combined analyses of all soils ,all treatments of biosolid and WTR rates studied indicated clearly significant relationships between ABDTPA P concentration and P uptake ($r = 0.81$, $p < 0.001$).

Keywords: - biosolids, water treatment residuals, phosphorus, aluminum, availability

INTRODUCTION

Alum [$Al_2 (SO_4)_3 . 14 H_2O$] is commonly used in the municipal water treatment process to destabilize colloids for subsequent flocculation and water clarification. Water treatment residuals (WTR) are by-products of water purification systems in which undesirable attributes of the raw water such as turbidity, color and dissolved solids are removed by a variety of physical and chemical processes. WTR have commonly either been returned to the source waterway downstream of the treatment plant intake or has been released to a municipal sanitary sewer. Both methods of disposal of water treatment residuals (WTR) have become unattractive for a variety of reasons. As the alternatives to disposal of WTR have decreased in recent years, more attention has focused on beneficial reuse of the material. One such beneficial reuse is land application. However, the potential benefits of applying WTR to the soil have been limited due to its postulated reduction of plant available P and potential plant Al toxicity with increasing WTR rates. Co-application of WTR with biosolids inherently high in P could offer a good opportunity to reconcile these problems. Land co-application of biosolids and WTR is a new concept. Therefore, information on the effect of co-application of biosolids and WTR on plant growth and elements uptake are very limited especially in alkaline soils. Co-application of WTR with biosolids may be advantageous in terms of a cost saving and potential reduction of bioavailable P in high P containing sludge (Ippolito,1999).The objectives of this study were: to evaluate the effects of co-application of WTR and biosolids on agronomic performance of wheat crop grown in alkaline soils as well as P plant concentration and uptake and to improve management of industrial and toxic wastes and provides environmentally sound guidelines for their disposal.

MATERIALS and METHODS

Soil, WTR and Biosolids Characterization

Three soils with different properties (clay, sandy and calcareous) were selected for the study and sampled (0-15 cm) from three different locations. Sub-samples of the air-dried soils were ground to pass a 2-mm sieve prior to the following chemical analysis: Soil pH and EC were measured in the soil-paste extracts (Richards, 1954). The organic matter content was determined by dichromate oxidation (Nelson and Sommers,1982), cation exchange capacity was determined by IM NaOAc (Rhoades , 1982). Particle size analysis was determined by the hydrometer (Day, 1965). Calcium carbonate content was determined using a calcimeter (Nelson, 1982). Total nitrogen was determined by the Kjeldahl/digestion method (Bremner and Mulvaney ,1982). Available P was extracted by AB-DTPA test (Soltanpour and Schwab, 1977). The selected properties of the three soils are summarized in Table 1.

The chemical properties of WTR and biosolids and metal content were determined (Table 1). The pH was determined in 1: 2 sludge /deionized water. Salinity was measured in 1: 2 sludge/deionized water extract. Cation exchange capacity of WTR and biosolids was determined by sodium saturation (Rhoades, 1982). Organic carbon content of WTR and biosolids was determined by dichromate oxidation (Nelson and Sommers, 1982). Total Al was determined using the acid ammonium oxalate method (Ross and Wang, 1993). Extractable Aluminum was extracted by 1M KCl (Barnhisel and Bertsch, 1982) and determined colorimetrically by 8-hdroxyquinoline butyle acetate method (Bloom et al., 1978).

Incubation and Greenhouse Experiments

To ensure amendment–soils equilibria, incubation experiment was conducted. Four biosolids rates (0, 10, 20 and 30 g kg^{-1} on an oven dry basis) and/or five WTR rates (0, 10, 20, 30 and 40g kg^{-1}) and/or co-application rates of WTR and rates of biosolids were applied to each soil (calcareous, sandy and clay soils) thoroughly mixed and placed in Jars (2 kg). Following amendments applications, the soil water content was brought to field capacity. Jars were covered with perforated plastic cover and incubated at 25^{o}C for 60 days. After the incubation period, corresponding soil samples were air-dried, crushed to pass a 2 mm sieve and stored for analysis.

Seeds of wheat (*Triticum aestivum*) were sown in pots containing 2 kg of soil (s) with co-application rates of WTR and biosolids .The seedlings were thinned to 4 seedlings per pot and distilled water was added to bring the soil moisture to 70% of field capacity. The experiment was arranged in split-split plot design with four replicates. Plants were harvested after 13 weeks. Plant shoots, panicles and roots were harvested separately, oven dried at 65°C for 48 h to determine dry matter yield. Plant tissues were ground in a stainless steel mill. Subsamples of ground plant material were ashed in muffle furnace at 450°C for 6h, and analyzed colorimetricaly for P (Jones, 2001).

AB-DTPA Extraction

The ammonium bicarbonate-DTPA extractant solution was used to extract available phosphorus from soils treated with and without WTR and biosolids after cultivation (Soltanpour and Schwab, 1977).

Data Analysis

Statistical and mathematical analyses were performed using Statistical Analysis System (SAS, 1994). Analysis of Variance (ANOVA) techniques was used to determine treatment effects and check for interaction. The least significant difference method was used to separate treatment means. Regression analysis was employed to determine the relationships between available P concentration in soils and P concentration in plants.

RESULTS and DISCUSSION

Soils, (WTR) and Biosolids Characteristics

Selected properties of the soils,WTR and biosolids used in the study are given in Table (1).

Table 1. Some physical and chemical characteristics of studied soils.

Characteristics	Units	Clay	Sandy	Calcareous	WTR	Biosolids
EC*	dSm^{-1}	2.66	3.84	2.92	1.67	11.25
PH*		8.13	7.69	8.08	7.45	6.69
$CaCO_3$	%	5.79	0.24	35.68	-	-
Sand	%	59.64	86.82	74.00	-	-
Silt	%	14.13	2.51	10.15	-	-
Clay	%	26.23	10.67	15.85	-	-
Texture		S.C.L	L.S	S.L	-	-
O.M	%	0.85	0.10	0.46	5.70	45.00
T-N	%	0.22	0.03	0.09	0.42	3.20
T-P	%	0.09	0.03	0.05	0.19	0.46
T-Al	$g\ kg^{-1}$				38.01	3.14
CEC	Cmol(+) kg^{-1}	39.13	8.70	26.00	34.78	73.57
AB-DTPA-P	$mg\ kg^{-1}$	8.13	3.12	5.15	8.32	24.00
Extractable Al	$mg\ kg^{-1}$	1.03	0.13	0.08	28.18	4.22
Soil solution-P	$mg\ kg^{-1}$	1.98	0.89	1.22	0.73	2.13
Soil solution-Al	$mg\ kg^{-1}$	0.03	0.01	0.02	1.80	0.18
W.H.C	$g\ kg^{-1}$	259.30	93.80	166.70	470.00	250.00

SCl:Sandy Clay Loam; LS:Loamy Sand; SL:Sandy Loam

The soils differ dramatically in their textures, $CaCO_3$ and organic matter contents. The sandy soil samples represent soil with coarse texture, low contents of $CaCO_3$ and organic matter (O.M). It is classified as (*Typic Torripsamments*). In contrast, the clay soil is (*Typic Torrifluvents*), containing approximately 3 to 10 times as much as clay and organic matter contents. The $CaCO_3$ content and the CEC are much higher than the sandy soil. The pH of the clay soil is 0.5 unit higher than the sandy soil. The calcareous soil is classified as (*Typic Calciorthids*). The calcium carbonate content in the calcareous soil samples is 6 times higher than that in the clay soil samples. The three studied soils had concentrations of ABDTPA-P ranging from low (sandy soil) to high (clay soil). The clay soil contains approximately 2.5 and 1.5 times ABDTPA-P concentration more that of the sandy and calcareous soils, respectively.

The WTR was slightly alkaline (7.45) within the adequate typical range for plant growth (5-8) (Bohn et al., 1985).The EC of WTR is well below the 4 dSm^{-1} associated with the high exchange capacity of the WTR indicates its ability to supply cationic nutrients for plant growth. The organic matter content of the WTR is considerably greater than typical levels in soils of arid ecosystems. The small amount water soluble P (< 0.04 % of the total P) extracted from WTR implied strong P binding by the WTR. Dayton et al.,(2003) reported that low P extractability of WTR was due to the abundance of Al. However, the ABDTPA-P concentration in WTR was very similar. The water holding capacity of WTR is high (470 gkg^{-1}). Therefore, the WTR could be considered a good ameliorating agent to soil properties (Skene et al., (1995).

Biosolid is slightly acidic with high content of organic matter . Biosolids could be regarded as a low analysis P source (0.46 %) but the AB-DTPA extractability suggests that total P may not completely assess P solubility. The total nitrogen and phosphorus was higher than WTR The water holding capacity of biosolid (250 gkg^{-1}) was lower than its value in WTR. Therefore, the coapplication of WTR and biosolids could be considered good ameliorating agents to soil properties.

Dry Matter Yield of Wheat

The effect of WTR rates, co-applied with different biosolids rates on total dry matter of wheat grown on the three studied soils is shown in Table (2).

Table 2. Total dry matter yield of wheat plants grown in the three soils as influenced by co-application of biosolids and WTR rates.

Biosolids rate, gkg^{-1}	WTR rate, gkg^{-1}	Total dry matter yield, g pot^{-1}		
		Clay	Sand	Calcareous
10	0	2.71	2.54	2.83
10	10	2.91	2.80	2.87
10	20	3.24	3.00	3.10
10	30	3.34	3.14	3.22
10	40	3.71	3.49	3.49
	$LSD_{0.05}$	**0.42**	**0.41**	**0.45**
20	0	3.11	2.83	3.03
20	10	3.31	2.74	2.92
20	20	3.56	3.15	3.29
20	30	3.85	3.37	3.55
20	40	3.37	3.23	3.28
	$LSD_{0.05}$	**0.30**	**0.28**	**0.64**
30	0	3.40	3.08	3.22
30	10	3.49	3.26	3.38
30	20	3.70	3.53	3.59
30	30	3.92	3.82	3.88
30	40	3.43	3.21	3.37
	$LSD_{0.05}$	**0.64**	**0.39**	**0.30**
Analysis of variance		F-test		
Soil (S)		*		
Treatment (T)		***		
Rate (R)		***		
T X S		NS		
R X S		NS		
R X T		***		
R X T X S		NS		

* ,*** significant at the 0.05 and 0.001 probability levels respectively.

NS: Not Significant.

In the all studied soils treated with WTR rates co-applied with 10 gkg^{-1} biosolids rate, the total dry matter yield was not significantly different between the control treatment and the 10 gkg^{-1} WTR treatment. However, a significant increase in total dry matter was found between the control treatment and 20 or 30 or 40 gkg^{-1} treatments. Increases of 47, 359 and 55 % in total dry matter yield were achieved as a result of applying 40 gkg^{-1} WTR and 10 gkg^{-1} biosolids to clay, sandy and calcareous soils respectively. However, increases of 52, 343, and 58 % in total dry matter yield were achieved as a result of applying 30 gkg^{-1} WTR and 20 gkg^{-1} biosolids to clay, sandy, and calcareous respectively. Increases of 55, 403 and 72 % in total dry matter yield were achieved as a result of applying 30 gkg^{-1} WTR and 30 gkg^{-1} biosolids to clay, sandy and calcareous soils respectively. In the soils treated with WTR rates co-applied with 20 gkg^{-1} biosolid rate, the total dry matter yield was significantly different between the control treatment and the 20,30 or 40 gkg^{-1} treatments.These results coincide with the results of Harris-Pierce et al.,(1993,1994). Heil and Barbarick (1989) also observed an increase in dry matter with WTR application at high rates. In sandy and calcareous soils treated with WTR coapplied with a constant biosolid rate of 30 gkg^{-1}, there was no significant different between the control treatment and that the 10 gkg^{-1} treatment. However, there was a significant different between the control treatment and 20 or 30 gkg^{-1} treatments. Soil, biosolid treatments and WTR rates main effects were significant for total dry yield ($p < 0.001$) (Table 2). According to the previous results,it can be concluded that the application of WTR to high P soils may be a very good opportunity for farmers and water municipalities to reconcile several problems. Many farmers are being pressured to reduce the pollution impact of their traditional fertilization practices are less threatened. Additionally, farmers would receive a very good conditioner material to improve the physical and chemical characteristics of soils and, consequently high production of yield. Water utilities could have a more economic and labor conservative disposal method than the more common methods of WTR disposal, such as land filling, sewage disposal and coagulant recovery. Finally, the co-application of WTR and biosolids, resulted in total dry matter yield more than WTR or biosolids when it is applied individually (Ippolito, 1999).

Phosphorus Concentration and Uptake

In general, phosphorus concentration in plants tends to be accumulated in the order panicles > shoots > roots (Table 3). Significant soil type, biosolid treatments, WTR rates and their interactions effects were found for phosphorus concentration in panicles, shoots and roots of wheat plants grown in all the soils studied (Table 3).

In all studied soils treated with a constant biosolid rate 10 gkg^{-1}, application of 20 gkg^{-1} WTR significantly increased plant P concentration in the plant materials (Table 3). The P concentration significantly increased in plant materials (e.g.panicles) from 3000 to 3504, from 2910 to 3180 and from 2902 to 3030 $mgkg^{-1}$ in clay, sandy and calcareous soils treated with 20 gkg^{-1} biosolid and WTR rates (Table 3). The increase in extractable P in the amended soil with increasing the application rate of WTRs might be due to the high content of available P in the WTRs used in this study. Therefore the addition of cations from the WTR-application (10-30 $g.kg^{-1}$) was not able to effectively reduce the extractable P in the soils, which might be attributed partially to the inaccessibility to P held on intraparticle sites (Makris et al., 2004) and also more reaction time might be required to reach the equilibrium between the cation of WTRs and extractable P of biosolids within the treated soils (Makris et al., 2004) .However, further increase in WTR application rate has resulted in negative significant impact on plant P concentration . The application of the highest sludge rate (30 gkg^{-1}) produced higher P concentration in plant materials than the other two lower treatments. These results coincide with the results of Heil and Barbarick (1989) who indicated that WTR have a high capacity to fix P and that plant P deficiencies develop when plants are grown in WTR-soil mixtures or coapplied with a constant rate of biosolids.

Table 3. Phosphorus concentrations and uptake of wheat plants grown in the three soils as affected by co-application of biosolids and WTR rates

Biosolids rate	*WTR rate*	*Clay*				*Sandy*				*Calcareous*			
gkg^{-1}		**PP**	**SP**	**RP**	***PU***	**PP**	**SP**	**RP**	**PU**	**PP**	**SP**	**RP**	**PU**
			mg.kg^{-1}		mg.pot^{-1}		mg.kg^{-1}		mg.pot^{-1}		mg.kg^{-1}		mg.pot^{-1}
10	**0**	2889.00	2003.00	1713.00	6.82	2801.00	1998.00	1415.00	6.27	2714.00	2101.00	1571.00	6.86
10	**10**	3020.00	1801.00	1780.00	7.26	2810.00	2000.00	1530.00	6.85	2736.00	2200.00	1600.00	7.10
10	**20**	3309.00	1906.00	1830.00	8.83	2990.00	2100.00	1770.00	7.77	2813.00	2391.00	1690.00	8.00
10	**30**	2811.00	1330.00	1260.00	7.02	2920.00	1550.00	1410.00	7.16	2501.00	2010.00	1201.00	7.12
10	**40**	2213.00	960.00	910.00	6.06	2660.00	630.00	510.00	5.99	2101.00	1830.00	410.00	6.67
	$LSD_{0.05}$	14.37	9.46	15.43	1.22	15.37	22.64	18.98	0.90	18.83	23.76	13.59	1.03
20	**0**	3000.00	2643.00	2180.00	8.81	2910.00	2315.00	2214.00	7.55	2902.00	2440.00	1857.00	8.09
20	**10**	3109.00	2020.00	1801.00	8.79	3020.00	2081.00	1606.00	7.03	2881.00	1880.00	1670.00	7.09
20	**20**	3504.00	2504.00	1880.00	11.03	3180.00	2220.00	1690.00	8.38	3030.00	1990.00	1717.00	8.27
20	**30**	2603.00	1440.00	1202.00	8.01	2690.00	1370.00	930.00	6.72	2201.00	1101.00	810.00	5.87
20	**40**	2091.00	710.00	580.00	5.14	2310.00	580.00	440.00	4.61	1681.00	630.00	507.00	3.89
	$LSD_{0.05}$	31.61	15.53	17.64	0.76	31.38	24.90	16.65	0.60	19.07	27.88	22.99	1.54
30	**0**	4786.00	2990.00	2500.00	13.53	3501.00	2612.00	2402.00	9.60	3334.00	2701.00	2423.00	9.83
30	**10**	4880.00	2201.00	1890.00	12.94	3440.00	2103.00	1630.00	9.16	2902.00	1803.00	1499.00	8.12
30	**20**	5010.00	2403.00	1901.00	14.25	3630.00	2221.00	1690.00	10.51	3011.00	1880.00	1560.00	8.95
30	**30**	2710.00	1101.00	710.00	7.63	2803.00	990.00	801.00	7.52	1801.00	621.00	570.00	4.89
30	**40**	1991.00	603.00	499.00	4.64	2002.23	510.00	460.00	4.33	1590.00	460.00	420.00	3.63
	$LSD_{0.05}$	33.19	24.36	81.36	3.05	52.78	26.66	24.09	0.80	35.79	21.65	21.81	0.53
Analysis of variance			**PP**			**SP**		**RP**				**PU**	
Soil (S)			***			***		***				***	
Treatment (T)			***			***		***				***	
Rate (R)			***			***		***				***	
T X S			***			***		***				***	
R X S			***			***		***				***	
R X T			***			***		***				***	
R X T X S			***			***		***				*	

*,*** significant at the 0.05 and 0.001probability levels respectively.

PP: panicles phosphorus SP: shoots phosphorus

RP: root phosphorus PU: phosphorus uptake

Similar to wheat phosphorus content data, P uptake increased at the low WTR rates coapplied with 10 or 20 or30 gkg^{-1} biosolid treatments (Table 3). Soil type, biosolid treatment, WTR rates and their interactions significantly affected P uptake. The P uptake was higher in clay soils than in sandy and calcareous soils at all biosolids treatments coapplied with WTR rates, but the 20 gkg^{-1} WTR coapplied with 30 gkg^{-1} biosolid treatment was the best co-application rate (2:3 ratio). Such data indicated that co-mixing of WTR and biosolids at ratios of 4:1 will adsorb all soluble biosolids P ,and beyond this ratio the WTR could adsorb all biosolids available P and possibly some soil-borne P (Ippolito,1999).

Phosphorus Extractability after Wheat Harvest

Soil type, biosolid treatments, WTR rates and their interactions significantly affected AB-DTPA extractable P (Table 4). Application of WTR at rates of 10, 20 and 30 g kg^{-1} to clay and sandy soils treated with 10 gkg^{-1} biosolid, significantly increased AB-DTPA extractable P. In calcareous soil the extractable P increased with increasing WTR up to 20 $gkg^{-1}$and decreased with increasing WTR application rate. In all the soils studied treated with WTR co-applied with 20 or 30 gkg^{-1} biosolid, the extractable P significantly increased at rates 10 and 20 gkg^{-1} WTR, then the extractable P dramatically decreased to about 35% compared with the control treatment (Table 4).

Table 4. AB-DTPA extractable phosphorus concentrations for three soils influenced by co-application of biosolid and WTR rates.

Biosolids rate	WTR rate	AB-DTPA extractable P , $mg.kg^{-1}$		
gkg^{-1}		**Clay**	**Sandy**	**Calcareous**
10	**0**	6.87	8.13	8.27
10	**10**	10.13	8.88	9.23
10	**20**	12.19	9.12	11.77
10	**30**	13.99	11.14	7.13
10	**40**	7.66	6.12	4.22
	LSD0.05	**0.82**	**0.82**	**1.18**
20	**0**	12.66	12.42	13.01
20	**10**	14.28	12.93	13.86
20	**20**	19.09	15.87	15.08
20	**30**	12.22	8.18	9.01
20	**40**	5.88	4.43	5.82
	LSD0.05	**1.03**	**0.88**	**0.43**
30	**0**	17.99	13.99	15.83
30	**10**	22.18	18.82	19.39
30	**20**	26.27	21.23	23.13
30	**30**	15.55	11.98	12.91
30	**40**	6.22	5.82	6.02
	LSD0.05	**0.53**	**0.70**	**0.53**

Analysis of variance	**F-test** AB-DTPA extractable P
Soil (S)	***
Treatment (T)	***
Rate (R)	***
T X S	***
R X S	***
R X T	***
R X T X S	***

*** Significant at the 0.001 probability level.

The use of WTR as a soil or poultry litter amendment have been reported to significantly lower extractable P concentrations (Moore et al., 1995). Codling et al.,(2000), Elliott et al.,(2002), and other researchers noted similar declines in soil P concentration after the addition of WTRs to manure-treated soils. Combined analyses of all soils, all treatments of biosolid and WTR rates studied revealed clearly significant relationships between AB-DTPA extractable P concentration and P uptake ($r = 0.81$, $p < 0.001$, fig.1) .These results agree with the studies of Harris-Pierce et al.,(1993) and Shreve et al.,(1995).

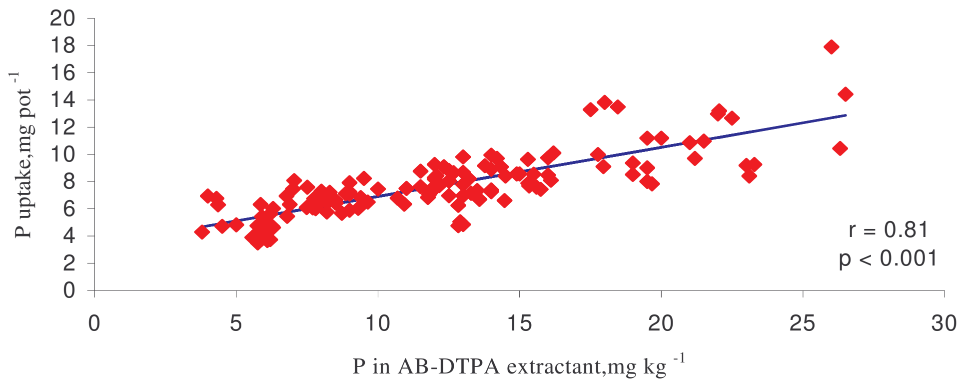

Fig.(1).Relationship between AB-DTPA P and P uptake of wheat plants grown in biosolids- WTR-treated soils .

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Effect of Nitrogen Foliar Application in Different Growth Stage on Canopy Light Receiving on 3 Polygerm Sugar Beet Yield

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ABSTRACT

An experiment was conducted on three sugar beet cultivars(IC, PP22 and 7233) and different application method of Nitrogen in a RCBD base factorial in three replication in 2005. Results showed that there was significant difference between light receiving in bottom and head of canopy among cultivars. N affected this attribute also. In IC the highest light receiving to bottom and head of canopy and yield in foliar N application at 6-8 leaf stage were 627 PPF, 1198PPF respectively. In soil application and 14-16 leaf stage foliar application of N led to 248 PPF in bottom and 988 PPF in head of canopy, recpectively.In IC the least root yield obtained in foliar application at 14-16 stage as 75/2 ton/ha. In PP22 light receiving to bottom and head of canopy was 472 PPF, 1134 PPF for soil and foliar application at 14-16 leaf stage and yield at that stage was 100 ton/ha. There was a %58 and %21 decreasing in light receiving to bottom and head in 6-8 leaf stage in compare with 14-16 leaf stage, foliar application at 14-16 leaf stage led to root yield increasing as %38 and %42 than soil and 6-8 leaf stage application, respectively.

In 7233 cultivar highest light received to bottom was 491 PPF in 14-16 leaf stage which was %17 higher than soil application. The highest light received to head of canopy was 1190 PPF in 6-8 leaf stage foliar application. There wasn't difference between root yield in different method N application in this cultivar. In spite of N fertilizer application led to increase leaf area and light absorption by plant canopy, there is limited information on the higher rates of N application between cultivars.

Keywords: *Beta vulgaris L.* light receiving canopy and root yield.

INTRODUCTION

Sugar beet is a plant ordered to Chenopodiaceous. This crop have very various and consist 4 main group that all of them have agricultural value. In all this groups' chromosome number is 18. Most European new verities are triploid hybrids of diploid (Thornhill., 1999).

Yield of sugar beet consist of biomes yield, root yield and sugar yield and their economical component are storage root especially sugar (Evans and Fischer., 1999).

Nutrition elements consisted of two group's macro and micro elements plant yield of nutrition elements have similar value for plant growth and loss each one of them can decrease plant yield. Rate of macro elements required Nutrition elements in tissues equal 1000 microgram in per gr dry matter or more(Oertli., 1979).

Nitrogen is important nutrition material for sugar beet. Nitrogen affected on sugar beet for primary growth and canopy establishment on sugar beet. Good nitrogen management in the season increased plant suitable growth and decreased number day's formation canopy and lasted the crop to use solar energy efficiency (Lamb *et al*., 2001).

Nitrogen is one of esstional nutrition for crop growth. Nitrogen deficient cause yellowing of low leaves downward leaf middle first and after that it becomes brown and at the end leaf tissue (Olson and sander., 1988).

Simpson *et al* (1981)reported that nitrogen deficient cause decreasing leaf area index, deformation of proteins and earlier leaves scenes especially with effect on RUBP carbocsilaz negatively effect on plant photosynthesis. Zhao et al (2005 reported that nitrogen deficiency significantly decrease leaf area extension.

In this experiment crop leaves that have nitrogen efficiency have low sucrose and a lot of sucrose and have lower concentration of nonstructural carbohydrate. Conducting this experiment to evaluation the effect of application methods on sugar beet cultivars.

MATERIAL and METHODS

For studying the effect of N fertilizers and application different methods on sugar beets cultivars an experiment was conducted in Islamic Azad University.Tabriz branch agricultural faculty station in 2005.with 3 replication, three cultivars(7233calibrate,IC and PP22) and Urea fertilizers application with methods arranged in a RCBD base factorials. Light receiving on different situation measured. Soil was loamy sand and pH was weak alkaline averaged (7/8-8/9).(Table 1).

Fertilizer application used in order to soil content and laboratories suggestion. Each experiment plot had 5 rows with 4m length planting distance between rows was 60 centimeter and the distance between two plants on rows was 18 centimeter and planting depth was 4 centimeter. Urea in a complex consisted of nitrogen that used in this experiment, this complex have 46 percentiles pure nitrogen. Soil application amount 300 kg in hectare (half of planting time and half after planting) and urea was used with 5 percent concentration in foliar application. Harvesting carried out for each plot separately in November. For elimination of border effect in each plot harvesting was done from middle rows in area equal to $5m^2$. After harvesting and weighing root took random samples from each plot of root yield to determine of sugar percent.

Analysis includes ANOVA and means comparison carried out with MSTATC program and correction of correlation indexes and multiple regressions with status program SPSS and figure drown with Excel.

Table 1: soil analysis in 0-30cm depth

Ntot (%)	P (ppm)	K (ppm)	B (ppm)	Silt%	Clay%	Sand%	OC%	TDN%	SpH	EC
0.097	14.84	281	0.91	20	15	65	0.88	4.1	7.8	1.72

RESULT

In IC cultivar maximum light receiving in surface equal 627PPF received with foliar application in 6-8 leafy stage that have significant difference with other application in this cultivar minimum light receiving equal 247/9 PPF with Nitrogen soil application received. Foliar application in 6-8 leafy stage caused 153/085 percent light receiving increased.

In PP22 cultivar hasn't significant difference between levels application. In this cultivar maximum light receiving equal 472/8 PPF with nitrogen soil application received but minimum rate equal 57/89 percent in 6-8 foliar application received. In 7233 cultivar maximum light receiving in surface canopy equal 491/1 PPF with foliar application in 14-16 leaf stage that showed increasing equal 16/79 percent than soil application. In 7233 cultivar minimum light receiving obtained (300/2 PPF) with foliar application at 6-8 leaf stage. Thus we can say that in this cultivar is effected foliar application at 14-16 leaf stage. Maximum light receiving in surface canopy between cultivars equal 403/9 PPF in 7233cultivar achievement.

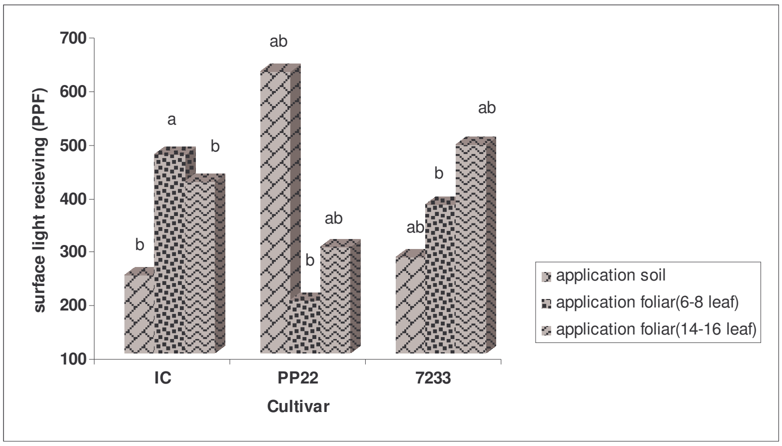

Figure 1. Effect of nitrogen application methods on light receiving in surface on soil sugar beet cultivars

In IC cultivar maximum light receiving in middle of canopy equal 1198 PPF received by foliar application at 14-16 leaf stage and in this cultivar minimum light receiving with nitrogen soil application equal 1172 PPF achievement.

In PP22 cultivar maximum light receiving in middle of canopy equal 1528 PPF received by soil application and this cultivar minimum light receiving by nitrogen foliar application at 14-16 leaf stage. That foliar application in 14-16 leaf stage caused decreasing 21/92 percent in receiving light compare to soil application.

In 7233 cultivar maximum light receiving in middle of canopy equal 1275 PPF received by soil application and in this cultivar minimum light receiving by nitrogen foliar application at 6-8 leaf stage.

Thus there are significant differences of receiving light between different cultivars in middle of canopy. Maximum and minimum receiving light respectively between cultivar in PP22 equal 1349 PPF and IC equal 1182 PPF achievement.

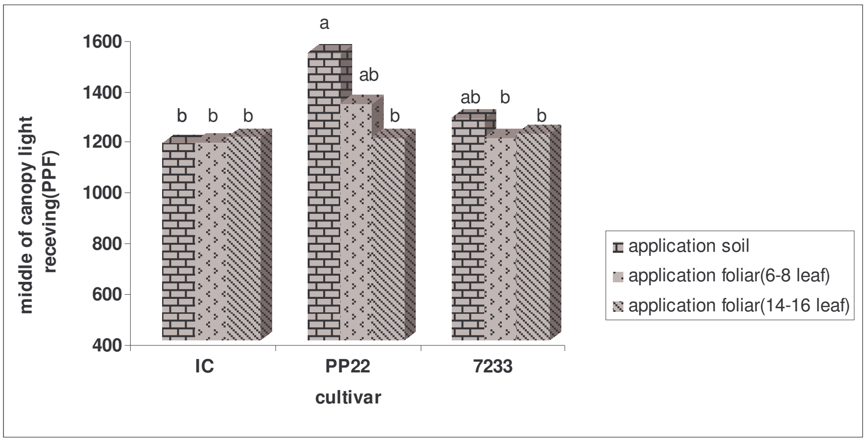

Figure 2. Effect of nitrogen application methods on light receiving in middle of canopy on sugar beet cultivars.

Comparing the mean light receiving on top of canopy in sugar beet cultivars by different treatment nitrogen showed significant difference between the effects of application methods.

Maximum and minimum receiving light respectively between cultivar in IC equal 1198 PPF and 988 PPF by nitrogen application at 6-8 and 14-16 leaf stage achievement.

Maximum light receiving in PP22 equal 1134PPF by nitrogen foliar application at 14-16 leaf stage. Minimum light receiving by nitrogen foliar application at 6-8 leaf stage achievement.

In 7233 cultivar maximum light receiving on top of canopy by foliar application at 6-8 leaf stage equal 1190 PPF showed and minimum by foliar application at 14-16 leaf stage receieved. There are no differences among root yield in different N application methods in this cultivar.

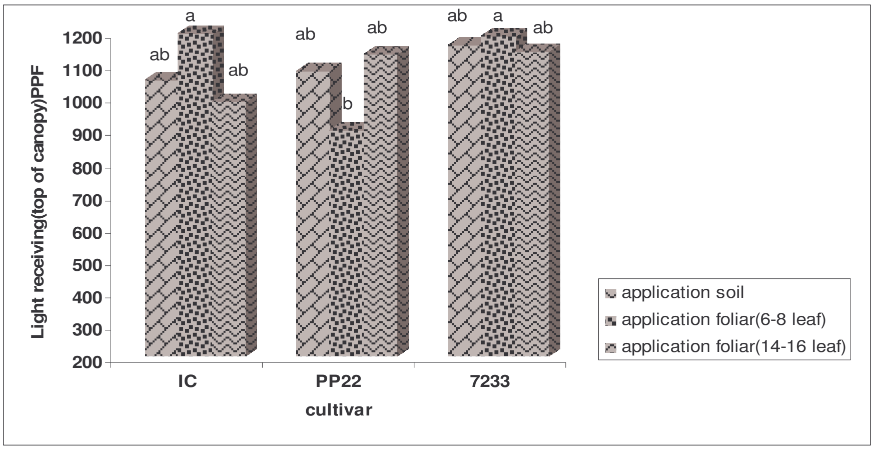

Figure 3. Effect of nitrogen application methods on light receiving on top of soil sugar beet cultivars

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Soil Alkaline Phosphatase and Phosphodiesterase Activities in Relation to Phosphorus Content in a Greenhouse Organic Tomato Crop in Almería (SE Spain)

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ABSTRACT
The aim of this work is to assess, in a greenhouse organic tomato crop, the effects of two soil organic amendments (T1:11.0 kg dry manure m^{-2}, and T2: 4.5 kg dry manure m^{-2} + 6.5 kg dry vermicompost m^{-2}) on levels of alkaline phosphatase and phosphodiesterase activities, in relation to available (P*a*), soluble (P*s*) and inorganic phosphorus content (P*i*). Four plots were compared: P1 and P2 had loamy sandy soil (79% illite clay) with saturated hydraulic conductivity (Kfs) of 17.07 mm h^{-1}; P3 and P4 had loamy soil (45 % smectite clay), and Kfs of 3.13 mm h^{-1}. Gravel mulch (5-10 mm) was added to plots P1 and P4, and sand mulch (0.05-2 mm) to P2 and P3. Three replicates per plot of each organic treatment were sampled on a weekly basis over seventeen weeks. There were no statistical differences among treatments for inorganic phosphorus content and phosphodiesterase activity. Available and soluble phosphorus were greater in T2 (901.6 ± 343.27 mg P*a* kg^{-1}; 6.93 ± 4.09 mg P*s* kg^{-1}) than in T1 (312.2 ± 137.69 mg P*a* kg^{-1}; 2.72 ± 1.66 mg P*s* kg^{-1}), while alkaline phosphatase activity was greater in T1 (856.0 ± 406.4 mg PNP kg^{-1} h^{-1}) than in T2 (684.9 ± 324.5 mg PNP kg^{-1} h^{-1}). Mean values for all analyzed variables were significantly higher ($p<0.01$) in plots with gravel mulch (P1 and P4). There were positive and significant correlations ($P< 0.01$) between enzyme activities and forms of phosphorus, except for alkaline phosphatase and available phosphorus content, where no correlation was detected. At plot scale, therefore, phosphorus availability did not inhibit enzyme activity. All values decrease with time in all plots, except in P4 which is the poorest drained.
Keywords: alkaline phosphatase, phosphodiesterase, phosphorus, soil, mulch, greenhouse.

INTRODUCTION

Food and environmental safety are often-cited reasons for the use of alternative soil amendments, but increasingly, economic considerations are becoming important due to a rise in popularity of organically produced foods (Bulluck III, et al, 2002). Greenhouse organic production can increase growers' profits by 12-40%, and this is attracting many new converts. On the other hand, the degradation of greenhouse soils as a result of excessive application of agrochemicals and the growing demand/market for pesticide-free produce have helped to persuade more and more greenhouse growers to adopt environment-friendly production systems based on organic fertilization and biological control. Although this is an area of growing research interest, there are few works on greenhouse ecological systems (Rippy et al. 2004), particularly referring to organic fertilizers applied traditionally or in fertigation systems and to the release of nutrients which is highly dependent on the soil's biological and enzymatic activity.

The application of organic amendments increases the soil's level of biological and enzymatic activity (Fraser et al., 1988; Workneh and van Bruggen, 1994; Satre et al., 1996; Gunapala and Scow, 1998; Colvan et al., 2001). As a result, the level of available nutrients for the edaphic biota and for the crop also increase. However, the overall activity of a single enzyme may depend on enzymes in different locations, including intracellular enzymes from viable proliferating cells, and accumulated or extracellular enzymes stabilized in clay minerals or complexes with humic colloids (Acosta-Martínez et al. 2003). Consequently, not all organic applications are equally effective for al soil types, and the level of humidity is a determining factor. Albiach et al. (2000) have demonstrated that commercial liquid organic amendments are of little use for increasing soil fertility. Edwars (1995), Aira et al. (2003) Chaoui (2003) and Aira et al. (2005) have shown that vermicompost is effective for increasing the levels of organic matter and enzymatic activity, although this enzymatic activity is brought about by the organic fertilizer itself to a great extent (Masciandaro et al. 1997). Díez (1987) demonstrated that manure is much more efficient than compost or peat for increasing phosphorus content, and Saha et al. (2008) showed that the nature and amount of organic fertilizers applied to the soil significantly affect phosphotase activity and available phosphorus. Moreover, mulching, a widespread greenhouse practice, has a great bearing on soil biota and on the evolution of the organic amendments and the mineral salts which they provide for the crop, as it modifies the soil's hydric and thermal balance and improves root growth (Benítez et al., 2000).

Soil phosphorus cycling and availability is controlled by a combination of biological processes (mineralization-immobilization) and chemical processes (adsorption-desorption and dissolution-precipitation) (Chen, et al., 2003). As a part of the P-cycle, alkaline and acid phosphatase activities catalyze the hydrolysis of both organic P esters and anhydrides of phosphoric acid into inorganic P. However, it has been suggested that the rates of synthesis, release and stability of acid and alkaline phosphatases by soil microorganisms are dependent on soil pH, so alkaline phosphatase activity is induced in high pH soils (Deng and Tabatabai, 1997; Acosta-Martínez and Tabatabai, 2000; Acosta-Martínez et al. 2003) but only from microorganisms, not from plants (Böhme, Böhme, 2006).

The aim of this work is to assess, in a greenhouse organic tomato crop, the effects of two soil organic amendments on levels of alkaline phosphatase and phosphodiesterase activities, in relation to available (P*a*), soluble (P*s*) and inorganic phosphorus content (P*i*).

MATERIALS and METHODS.

Experimental Site

The experiments were carried out in a greenhouse (20 m x 6 m x 3.8 m) at the University of Almería (southeastern Spain 36º50'N 2º27'W, 5 m above mean sea level). The climate is Mediterranean semiarid with less than 300 mm annual rainfall. The average temperatures inside the greenhouse were between 12.3 ºC and 24.8 ºC, and average soil temperature varied from 15 ºC to 18.7 ºC during the growing season.

Experimental Design

The greenhouse was divided into four plots (P1, P2, P3 and P4). Plots P1 and P2 had a *Hortic Anthrosol* (FAO, 2006) with a loamy sandy texture (79% illite clay), and saturated hydraulic conductivity (Kfs) of 17.07 mm h^{-1} (S1, Table 1); Plots P3 and P4 had a *Hortic Anthrosol* with loamy texture (45% smectite clay), and Kfs of 3.13 mm h^{-1} (S2, Table 1). Gravel mulch with dominant particle size > 5mm and water retention capacity at -33kPa of less than 3% p/p (M1, Table 2) was added to plots P1 and P4. Sand mulch with dominant particle size 0.1 mm – 1.0 mm and water retention capacity at -33kPa of 20.4% p/p (M2, Table 2) was added to plots P2 and P3. All soil types and mulches are of common use in greenhouses of southeastern Spain. Two organic amendments with three randomized replicates were applied per plot, mixed with soil to a depth of 10 cm. In T1 we applied 11.0 kg m^{-2} dry manure (30% w/w total organic matter, 4% w/w P_2O_5) in the crop row, while in T2 we applied 4.5 kg m^{-2} dry manure (30% w/w total organic matter, 4% w/w P_2O_5) mixed with 6.5 kg m^{-2} dry vermicompost (35% w/w total organic matter, 1.5% w/w P_2O_5) (Table 3). All combinations of soil, mulch and organic amendments are summarized in Table 4.

Table 1.- Particle size distribution (% w/w) of the soils used in the assays. Standard deviation in parentheses (n=4). Particle size in mm.

	S1	**S2**
Sand (2 mm - 0.05 mm)	75.1 (1.2)	52.1 (0.6)
Silt (0.05 mm - 0.002 mm)	11.1 (0.4)	35.3 (1.4)
Clay (< 0.002 mm)	13.8 (0.5)	12.6 (0.4)
pH	7.73 (0.18)	7.70 (0.15)

Table 2.- Particle size distribution (% w/w) of materials used as mulches. Particle size in mm

Particle size	**Gravel mulch (M1)**	**Sand mulch (M2)**
>= 5	83.38	4.95
5-4	6.37	0.84
4-3	2.92	0.94
3-2	1.78	1.42
2-1	1.51	2.78
1-0.5	1.02	15.70
0.5-0.25	1.20	41.08
0.25-0.1	1.11	22.16
0.1-0.075	0.30	3.71
0.075-0.05	0.19	2.36
<0.05	0.22	4.05

Table 3.- Properties of the organic amendments used in the assays. All values are expressed in percentages. Data from manufacturers.

	Manure	Vermicompost
Oxidizable organic matter	30	35
Total P_2O_5	4	1,5
Total humic extracts	15	10
Fulvic acids	9	3
Humic acids	6	7
Humins	15	25

Table 4.- Combinations of soil type, mulch type and organic amendment applied per treatment.

Plot	Soil type	Mulch type	Organic amendment	Treatment
P1	S1	M1	T1	1
			T2	2
P2	S1	M2	T1	3
			T2	4
P3	S2	M2	T1	5
			T2	6
P4	S2	M1	T1	7
			T2	8

The greenhouse tomato “Marmande Raf” was used in all treatments. Tomato seedlings were transplanted into the greenhouse on 15/10/02 and organic amendments had been mixed with the soil one week before. Crop management, i.e. staking, pruning suckers and leaves and pollination, was similar in both treatments. A drip irrigation method was used to supply crop water requirements. The drip flow was 3 L h-1 in a 1 m x 0.5 m arrangement.

Data Collection

Soil samples were collected on a weekly basis. Each sample, one per replicate, was a composite mixture from three points per crop row (2.9 m x 1.0 m) to represent better the treatment studied (Böhme et al. 2004). The mulch was removed before collecting the soil (0-10 cm). After sampling, soil samples were air-dried at room temperature and ground to pass a 2 mm sieve.

Soil Analyses

The pH values were measured in air-dried soil (<2mm) by using a glass combination electrode (soil:water ratio, 1:2.5). The particle size distribution of soils was determined by sieving and sedimentation, applying Robinson's pipette method (Soil Conservation Service, 1972). Field saturated hydraulic conductivity (Kfs) was measured in-situ with a Gelph permeater (Reynolds and Elrick, 1985). Mulch water content was measured in the laboratory with a ceramic pressure plate (Soilmoisture Equipment Corp., Santa Barbara, CA, USA) at air pressure of 33 kPa (Richards, 1954). Mulch particle size distribution was determined by sieving. The alkaline phosphatase (EC 3.1.3.1) and phosphodiesterase (EC 3.1.4.1) activities were assayed (<2 mm air-dried soil) at their optimal pH values including one control. The assays are described in Tabatabai (1994). Total soil organic carbon (*SOC*) was determined by wet oxidation with potassium dichromate (Tyurin, 1951). Available phosphorus (*Pa*) was determined by the Olsen method (Olsen *et al.* 1954). For inorganic phosphorus (*Pi*) determination we used the method described in Kuo (1996) after extraction with concentrated sulfuric acid and dilute sodium hydroxide. Soluble phosphorus (*Ps*) was determined in saturation extract by ion chromatography (Dionex ICS-1000)

Statistical analysis

Software package SPSS from SPSS Inc. v.15 was used for statistical analysis. Data were assessed by Duncan's multiple range test, with a probability $p < 0.05$. Differences between means were evaluated by univariant general linear model for each of the variables studied, analyzing the effect of the fixed factors, soil type, mulch type, organic treatment applied and their interactions. Pearson's bivariate linear correlation coefficient was calculated for all pairs of variables.

RESULTS and DISCUSSION.

Due to the granulometry of mulch type M1, the movement of water is primarily determined by gravitational potential. The flow of water through this type of mulch is mainly vertical and occurs extremely rapidly, and so the flow provided by the drip outlet reaches the soil surface practically unaltered. This flow exceeds the infiltration capacity of both soil types, causing temporary flooding, more notably in S2, which had a lower percentage of sand, a higher percentage of silt, smectite clays and a saturated hydraulic conductivity six times less than S1. As a result, for the same amount of water supplied the surface area moistened is greater and the depth of the moistened front is less in S2 than in S1, and this in turn affects both organic amendments in different ways. For mulch type M2, with much finer particles, the matric potential modifies the flow of water. Part of the water is retained permanently by the mulch and the rest is released more slowly into the soil. In this case the flow received by the soils is less than that emitted by the drip outlet and there is no temporary flooding. Also, the nature of the organic amendments and its P_2O_5 content differ, and this will affect each of the treatments in a different way. Manure provides more labile organic matter (with a higher percentage of less condensed fractions) than vermicompost, which apart from the composting process, has undergone the digestive process of the earthworms.

Therefore, the different treatments gave rise to significant differences in the variables studied (table 5). For the inorganic phosphorus (Pi) and phosphodiesterase variables the treatments gave rise to two significantly different groups, coinciding with the differences in the mulch type. For the remaining variables, however, the treatments cannot be grouped so clearly.

Table 5.- Average values for available phosphorus (Pa, mg kg^{-1}), soluble phosphorus (Ps, mg kg^{-1}), inorganic phosphorus (Pi mg kg^{-1}), alkaline phosphatase (mg pNP kg^{-1} h^{-1}), phosphodiesterase (mg bispNP kg^{-1} h^{-1}) and soil organic carbon (SOC, % w/w). In each column values sharing the same letter are not significantly different (p<0.05)

Treatment	Pa	Ps	Pi	Alkaline phosphatase	Phosphodiesterase	SOC
1	403.51^{b}	3.29^{b}	6645.23^{b}	983.02^{d}	929.63^{b}	13.04^{c}
2	1019.12^{d}	7.39^{e}	6962.59^{b}	805.84^{c}	892.94^{b}	11.96^{bc}
3	284.19^{a}	1.66^{a}	4177.37^{a}	579.61^{ab}	551.98^{a}	10.76^{b}
4	792.49^{c}	4.59^{cd}	4015.63^{a}	544.64^{a}	607.07^{a}	8.48^{a}
5	261.16^{a}	2.06^{a}	4088.67^{a}	691.36^{bc}	645.05^{a}	8.85^{a}
6	728.91^{c}	5.43^{d}	3946.88^{a}	565.66^{ab}	623.16^{a}	8.09^{a}
7	298.07^{a}	3.80^{bc}	6571.32^{b}	1156.57^{e}	974.25^{b}	14.78^{d}
8	1065.73^{d}	10.31^{f}	6387.85^{b}	823.40^{c}	871.31^{b}	12.85^{c}

In order to determne which factors (soil type, mulch type, organic amendment), or combination of factors, are responsible for said differences, we applied a univariant general linear model for each of the variables, also taking into account the time since the crop was planted. The soil type only had a significant effect on the average levels of Ps and alkaline phosphatase activity (table 6), and S2, with the worst drainage, had the highest values. The values of Pa and Ps are significantly greater on average when vermicompost is applied, and all the variables showed higher average levels with the mulch of larger particle size (M1).

Table 6.- Average values obtained for available phosphorus (Pa, mg kg^{-1}), soluble phosphorus (Ps, mg kg^{-1}), inorganic phosphorus (Pi mg kg^{-1}), alkaline phosphatase (mg pNP kg^{-1} h^{-1}), phosphodiesterase (mg bispNP kg^{-1} h^{-1}) and soil organic carbon (SOC, % w/w) as a function of the main factors analyzed. * significant at p<0.01

	Soil Type		Mulch type		Organic amendment	
	S1	S2	M1	M2	T1	T2
Pa	624.43	589.36	695.70*	518.09	312.22	901.56*
Ps	4.24	5.41*	6.20*	3.45	2.72	6.93*
Pi	5536.00	5328.89	6723.06*	4141.83	5465.62	5399.27
Alkaline phosphatase	728.82	812.07*	944.16*	596.74	856.01*	684.88
Phosphodiesterase	746.08	780.16	919.01*	607.22	777.61	748.62
SOC	11.08	11.15	13.18*	9.05	11.87*	10.36

The combination of the different factors analyzed does not give rise to significant differences for Pi or phosphodiesterase, whose average values only depend on the type of inorganic mulch used. However, the remaining variables analyzed are clearly determined by the combination of different factors. The highest values for Pa and Ps are found with the M1T2 combination, although in the case of Ps the values are systematically greater in soil type S2, which indicates an accumulation due in the main to worse drainage. Alkaline phosphotase activity is also greater in the worse drained soil and with gravel mulch. However, its highest values, and those of SOC, are found in treatment T1 without vermicompost, which is probably due to the more labile nature of the organic matter.

To investigate the relationship between variables, data were subjected to correlation analysis (table 7). There were positive and significant correlations between all variables under study except for available phosphorus and alkaline phosphatase, and for available phosphorus and SOC, where no correlations were observed. Nevertheless, when data were assessed for individual organic amendment, no correlation was observed between phosphatase activities and available phosphorus in T1 amended soils, but T2 amended soils produced positive and significant ($p<0.01$) correlations between Pa and alkaline phosphatase ($r = 0.57$) and phosphodiesterase ($r=0.64$). In any case, whether for lack of correlation or for positive correlation, no type of enzymatic inhibition was observed for the amounts of Pa at plot level.

Table 7.- Pearson's correlation coefficients (bilateral) for available phosphorus (Pa), soluble phosphorus (Ps), inorganic phosphorus (Pi), alkaline phosphatase, phosphodiesterase and soil organic carbon (SOC). * significant at p<0.01.

	Ps	Pi	Alkaline phosphatase	Phosphodiesterase	SOC
Pa	0.764*	0.265*	0.032	0.234*	0.071
Ps		0.431*	0.33*	0.472*	0.35*
Pi			0.68*	0.755*	0.566*
Alkaline phosphatase				0.876*	0.684*
Phosphodiesterase					0.63*

Masciandaro et al. (1997) state that, in the case of treatments with vermicompost, a considerable part of available phosphorus and phosphatase activity is supplied by the organic fertilizer itself. The results of the above-mentioned correlations agree with this statement.

Time since planting gives rise to a significant decrease in the average values of all the variables ($p<0.01$) (Fig. 1).

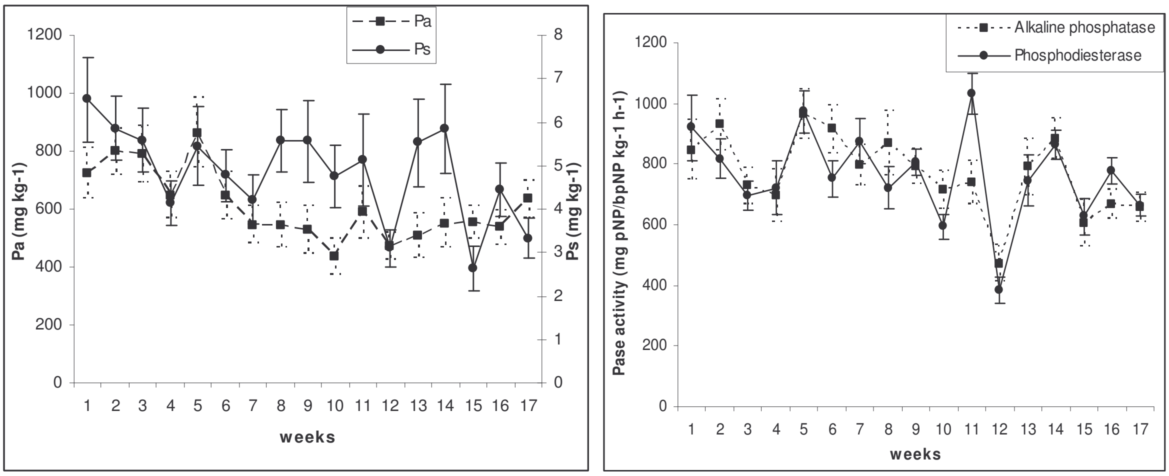

Fig. 1.- Evolution with time of average values for available phosphorus (Pa, mg kg^{-1}) and soluble phosphorus (Ps, mg kg^{-1}) (left) and Alkaline phosphatase (mg pNP kg^{-1} h^{-1}) and phosphodiesterase (mg bispNP kg^{-1} h^{-1}) activities (right) over the seventeen weeks of the assays. Error bars show one typical error for the mean.

Nevertheless, there are significant interactions between the factors studied and time. Figure 2 shows the gradual drop in Ps content over the sampling time, except for the M1S2 combination (P4), with worse drainage.

CONCLUSIONS

The effect of organic amendments depends on the nature of the fertilizer and the characteristics of the medium in which it is applied. On average the treatments with vermicompost gave rise to the highest values of available phosphorus and soluble phosphorus, although the type of mulch determined the final result of the organic amendments to a great extent, since it conditions the hydric dynamics of the underlying soil. The average values of the variables analyzed are greater in the plots with mulch of larger particle size. The lack of correlation, or the positive correlation between phosphatase activity and the concentrations of available or soluble phosphorus, do not permit the observation of enzymatic inhibition on the scale of this study.

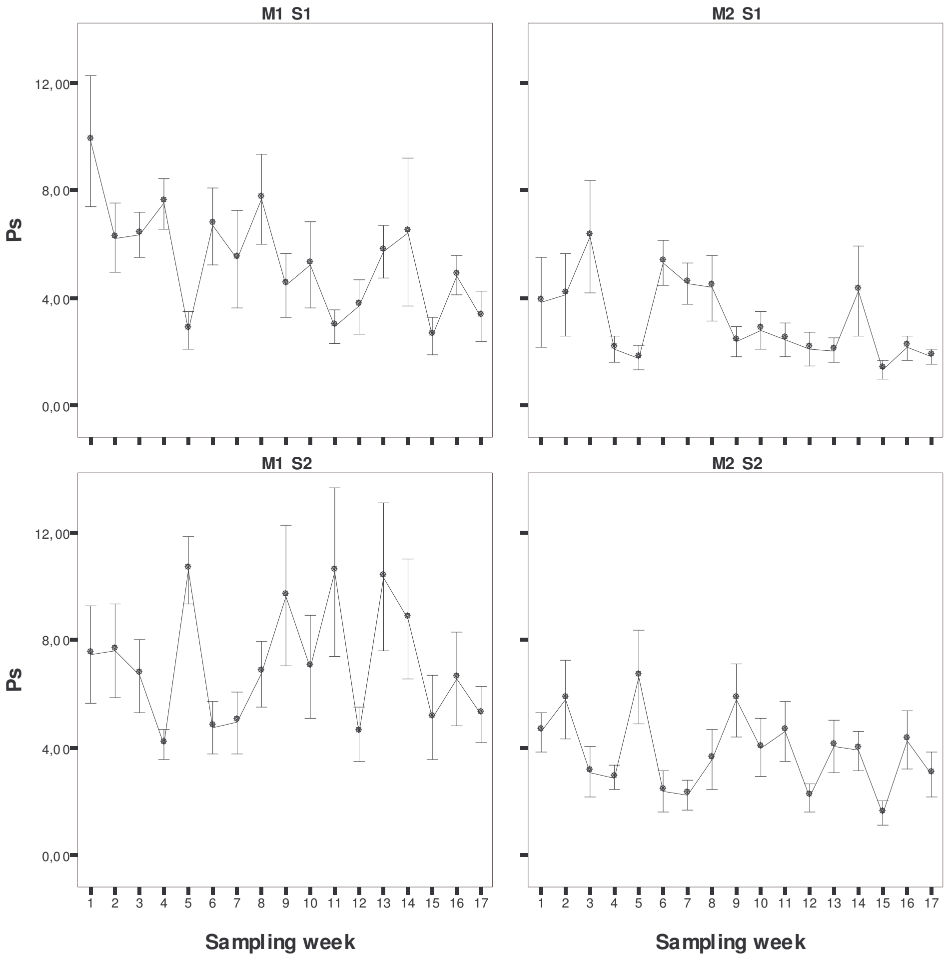

Fig. 2.- Evolution over time for soluble phosphorus (Ps, mg kg^{-1}) grouped by mulch type (M1 and M2) and soil type (S1 and S2). Error bars show one typical error for the mean.

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Effect of Lemon Waste on Soil pH and Availability of Micronutrient in Calcareous Soils of Fars Province, Southern Iran

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ABSTRACT

Most of soils of Iran are calcareous in nature. The orchard trees are widespread in south of Iran. Sour lemon is one product of the area and is processed for lemon juice. To evaluate the effect of lemon waste on soil pH and availability of micronutrients, composite soil samples were collected from 0-40 Cm of the area and analyzed for physico- chemical properties.

Lemon waste was gathered from processing factory, dried at 70$^{°c}$ and crushed to 1-2 mm size. A statistical complete randomized design with 4 replicate and 30 treatments were used for evaluation of lemon waste on soil properties. The treatments were 0, 100, 200, 400, 800, and 1600 PPM of lemon waste which were added to pots containing 160 go soils and leaved in incubator for 0, 2, 4, 8, and 16 weeks at 27-30$^{°c}$, pot moisture were kept at field capacity during the experiment. At dates of 0, 2, 4, 8, and 16 weeks after treatment the treated soils were sampled and physico-chemical properties were determined.

According the results, the pH of treated soils with lemon waste decrease and organic mater increase slightly with increase in amount of lemon waste and time of incaution.

The availability of Cu, Zn, Mn, Fe, and P in treated soils increased with increasing the amount of lemon waste and time of incubation.

INTRODUCTION

Most of soils of Iran are calcareous in nature and show high pH and micronutrients deficiencies. Micronutrients (Fe, Mn, Zn and Cu) and phosphorous deficiency is a problem in calcareous soils. It has been shown that plant availability of Micronutrients is profoundly affected by soil reaction (4, 6, 9, 13). Availability of micronutrients tends to increase with increase in soil organic matter and decrease with increase in soil reaction and calcium carbonate (2).Bloomfield and Pruden (3) showed the effect of time of aerobic incubation on availability of some trace elements. The orchard trees are widespread in south of Fars province and cover more than 20000 ha. Sour lemon is one product of the area and is processed for lemon juice. The waste is considerable and its land fill is one of environmental problem.

Study Area

Jahrom(study area), 5882 Km^2 is located 194 km south-east of Shiraz, Fars province, southern Iran at altitude of 25° ,30´ and latitude of 50° ,50´ with mean height of 1078 m from sea level (figure 1). Mean annual precipitation (33 years) is 266.2 mm and highest and lowest mean annual temperature is 48$^{°c}$ and -8$^{°c}$ respectively.

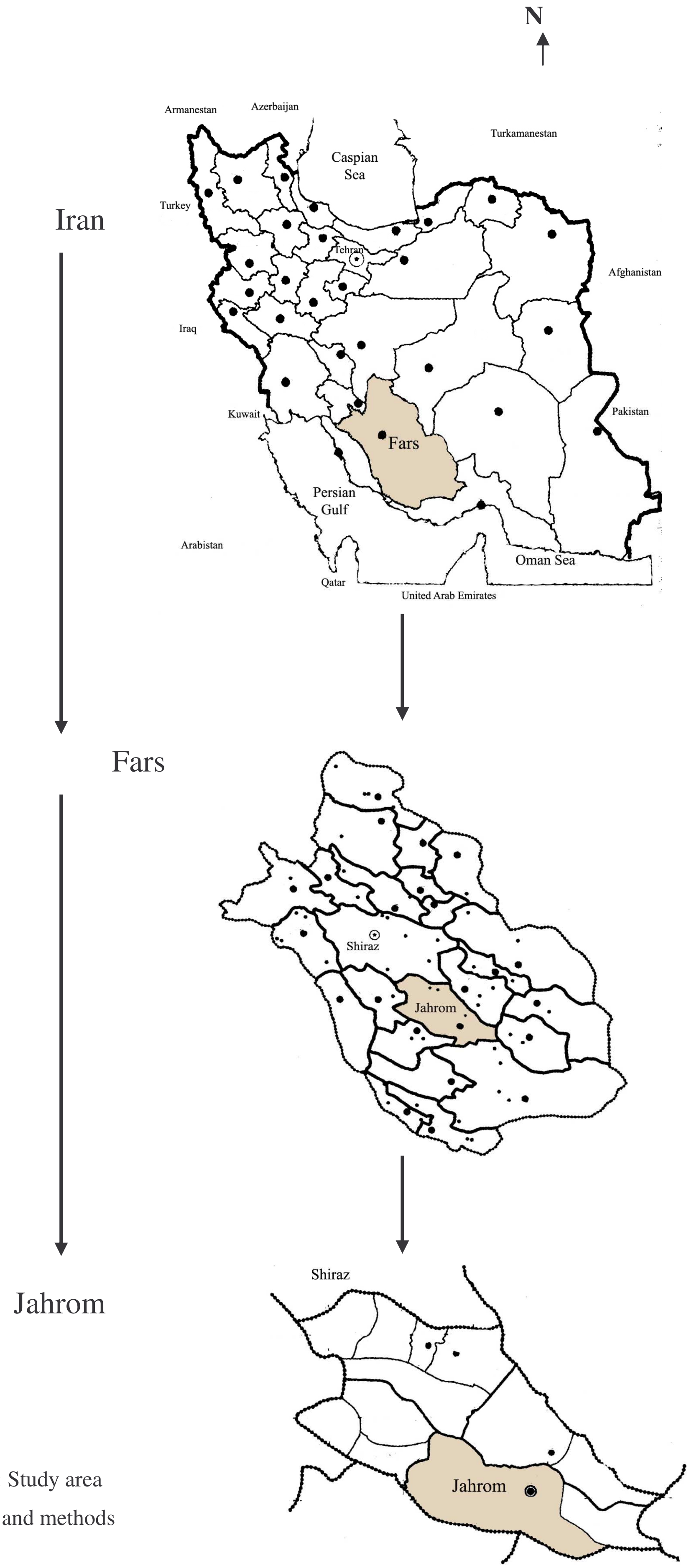

Figure 1: Study area

Material and methods

To evaluate the effect of lemon waste on soil pH and availability of micronutrients, composite soil samples were collected from 0-40 Cm of the area, air dried and passed from 2 mm sieve and analyzed for physico- chemical properties (table 1)

Table 1: physico-chemical properties of selected soils and Lemon waste

pH	CCE	OM	Texture	Zn	Cu	Fe	Mn	
	%			(PPM)				
7.87	66	0.6	silty clay loam	1.90	0.56	4.20	14.6	soil
4.80	-	86	-	0.22	0.18	0.80	0.60	Lemon waste

Lemon waste was gathered from processing factory, dried at 70℃ and crushed to 1-2 mm size. A statistical complete randomized design with 4 replicate and 30 treatments were used for evaluation of lemon waste on soil properties. The treatments were 0, 100, 200, 400, 800, and 1600 PPM of lemon waste which were added to pots containing 160 Gr. soils and leaved in incubator for 0, 2, 4, 8, and 16 weeks at 27-30℃, pot moisture were kept at field capacity during the experiment. At dates of 0, 2, 4, 8, and 16 weeks after treatment the treated soils were sampled and physico-chemical properties were determined (table 2).

RESULT and DISCUSSION

According the results, the pH of treated soils with lemon waste decrease and organic mater increase slightly with increase in amount of lemon waste and time of incaution.

The availability of Cu, Zn, Mn, Fe, and P in treated soils increased with increasing the amount of lemon waste and time of incubation.

It is recommendable that the agricultural waste can be used as green sources of fertilizer for land and environment restoration.

Table 2: the effects of amount of lemon waste and time of incubation chemical properties of treated soils with lemon waste

OM	CCE	Cu	Zn	Mn	Fe	P	pH	treatments
(%)		(PPM)						Time(weeks)
1.90b	65.9a	0.56b	1.98d	15.02c	4.27d	448a	7.87a	0
2.06b	67.6a	0.64b	3.16d	16.64c	11.94c	339b	7.82a	2
2.10a	69.2a	0.76a	4.00c	17.48c	15.56b	259c	7.75a	4
2.13a	67.0a	0.76a	6.77b	20.97b	16.83ab	333b	7.57b	8
2.24a	63.0a	0.84a	8.40a	22.28a	18.31a	347b	7.41b	16
								Conc.(ppm)
1.65b	66.9a	0.56b	4.29b	17.19c	5.39d	336b	7.81a	0
1.98b	65.7a	0.71a	4.61b	19.77bc	11.62c	336b	7.80a	100
2.14a	69.7a	0.71a	4.9ab	20.98b	12.48c	336b	7.72ab	200
2.18a	69.9a	0.72a	5.15ab	24.16a	13.26c	347b	7.66ab	400
2.21a	67.9a	0.76a	5.15ab	26.01a	16.42b	371a	7.60bc	800
2.36a	69.6a	0.81a	6.15a	26.76a	20.89a	376a	7.53c	1600

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Determination of Organic Matter Mineralization in Compost Amended Soils Using FT-NIR Spectroscopy

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ABSTRACT

This study is aimed at developing a non-destructive method for determining organic matter mineralization using FT-NIR (Fourier Transform-Near Infrared) spectroscopy. Soils with two different textures were mixed with olive solid waste (OSW), OSW composts and nitrogen, phosphorus and potassium (NPK) fertilizer. Samples have been incubated at 25 ^{o}C for 9 months. After this period, some chemical and physical analyses were performed on the samples using standard methods. Also reflectance spectra of the same samples were acquired right after the standard measurements using FT-NIR spectroscopy. Calibration models between the standard measurements and the spectral measurements performed on samples were established applying Partial Least Squares (PLS) method. Promising N prediction was obtained for the compost added soil group (R^2=0.62 and RMSECV=0.05) and good N prediction was performed for the control soil group (0.93 and RMSECV=0.01). C was predicted successfully for almost all of the data groups. Prediction of C for the data group that included all the soil groups was performed with a coefficient of determination of 0.88 (RMSECV=0.27) in validation. C was predicted with the coefficient of determination of 0.93 (RMSECV=0.23) for the compost added soil group. It was shown with this study that NIR spectroscopy has the potential of sensing soil contents non-destructively.

Keywords: FT-NIR spectroscopy, organic matter mineralization, olive solid waste.

INTRODUCTION

Olive oil solid waste (OSW) contains olive pulp, stones, residual oil and vegetative waters. OSW can be a good and available source for soil organic matter in Mediterrenian Countries. Approximately, 50-60% of olive by volume is solid waste. In general, seed part of olive has been used extensively as a fuel source in some parts of Turkey. Many studies have reported the toxic effects of oil by-products on plants and soil microbial activity, because of their phenolics, fatty acids and mineral salts contents (Martin et al., 2002). Alternative methods of treating the waste are necessary, and composting to produce a soil conditioner is identified as a viable alternative approach.

NIR spectroscopy has good potential to be used as a way of predicting soil quality components non destructively (Bogrekci and Lee, 2007; Maleki et., 2006; Terhoeven-Urselmans et al., 2005; Saeys, 2005).

NIR spectroscopy has advantages for analysis of soil samples in laboratory conditions without using any chemicals and with fast applications resulting multi reading with a single measurement; also, it has the potential to be developed for on line soil sampling needed for site-specific fertilizing applications in the field.

The aim of this research was to evaluate soil organic matter mineralization after the addition of OSW and OSW compost by using FT-NIR spectroscopy.

MATERIALS and METHODS

Soil Compositions: Soil compositions given in Table 1 below were used in this study. Soils had two different textures, Clay Loam and Loam. Treatments were Control soils (clay loam and loam with no organic addition), compost added soils (clay loam and loam) with three different percentages of compost (3, 5 and 7 % respectively), olive soil waste (OSW) added soils (clay loam and loam) with three different percentages of OSW (3, 5 and 7 % respectively), and soils mixed with the combination of OSW and the fertilizer containing nitrogen, phosphorus and potassium with the percentages of 3, 5 and 7 respectively.

Composting Olive Solid Wastes: Three different ratios of OSW were mixed with manure, alfalfa and straw to make compost under controlled conditions. Composts samples (Fig 1) dried at 70 C^{o}, ground and mixed with soil samples before incubation.
Detailed statistics of the N and C contents of soil groups used in the study are given in Table 2.

Table 1. Soil compositions used in the study

	Soil Types										
	Control soil										
	Clay Loam	Loam	Compost added*			OSW added*			OSW+NPK added*		
Percentages (%)	100	100	3	5	7	3	5	7	3	5	7
Number of samples	3	3	5	6	6	6	6	6	6	6	6
Total	6			17			18			18	
Total of all	59										

OSW: olive solid waste, NPK: Nitrogen, phosphorus and potassium fertilizer

*Each group having soils from both Clay Loam and Loam

Fig. 1. A prepared compost sample which was used FT-NIR spectral measurements

Table 2. Statistics of parameters of soil groups

Data	Number of samples	Statistics	N (%)	C (%)
Control soils	6	Average	0.196	2.991
		Standard Dev.	0.035	0.908
Compost added soils	17	Average	0.141	3.547
		Standard Dev.	0.083	0.565
OSW added soils	18	Average	0.127	3.540
		Standard Dev.	0.066	0.866
OSW+NPK added soils	18	Average	0.125	3.577
		Standard Dev.	0.055	0.829
All groups in one	59	Average	0.137	3.498
		Standard Dev.	0.067	0.781
Control soils+Compost added soils+OSW and NPK added soils	41	Average	0.142	3.479
		Standard Dev.	0.069	0.752

OSW: olive solid waste, NPK: Nitrogen, phosphorus and potassium fertilizer

Spectral measurements were performed in reflectance mode using a Bruker MPA (Multi-Purpose Analyzer) FT-NIR spectrometer (Fig. 2) (Bruker Optik, GmbH, Ettlingen Germany) equipped equipped with an InGaAs detector and a 20 watts high intensity tungsten-halogen NIR light source. Wavelength region scanned with the fiber optic probe (type IN 261) was from 780 nm to 2500 nm. Thirty two scans were performed per spectrum. Resolution was 8 cm^{-1}. Thirty two scans in about 15.32 s was performed per spectrum. Instrument control and spectra analysis were performed using OPUS software (Bruker Optik, GmbH, Ettlingen Germany). In all spectral measurements, the Blackman-Harris-3-term apodization function, a phase resolution of 64 cm^{-1}, a power spectrum phase correction method and a zero filling factor value of 2, were used.

Fig. 2. FT-NIR spectrometer used in the study

Reflectance spectra were obtained from both reference (Spectralon®) and sample consecutively for each sample. Fiber optic probe was placed directly on the equatorial surface of the fruit during spectral measurements. The fiber optic probe used had a bifurcated optical configuration which guided the light to the sample by the source fibers and received the reflected light with the detector (TE-InGaAs) fibers (Fig. 3). In the measuring head of the fiber optic probe, the source and detector fibers were mingled randomly forming a sensing area of about 11.7 mm^2.

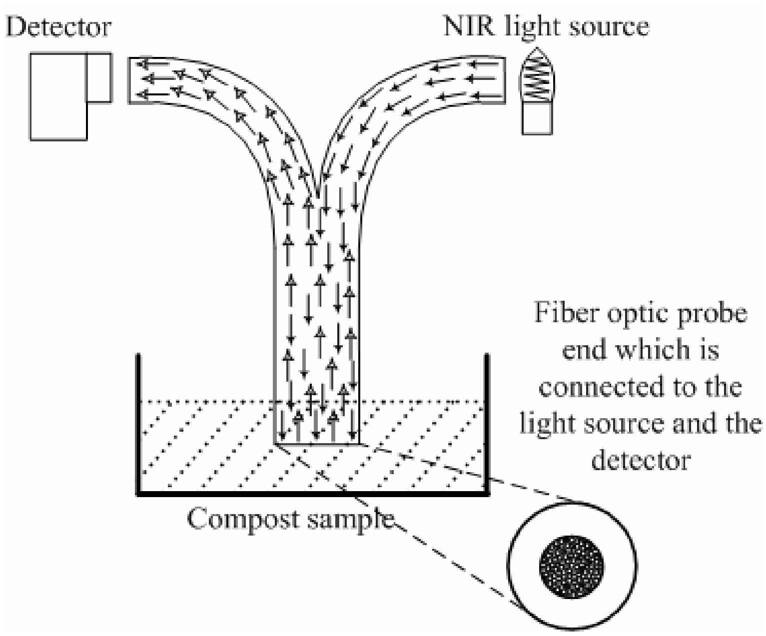


Fig. 3. Schematic view of FT-NIR spectroscopic measurements

Relative spectra of the samples were obtained dividing the sample spectra to the spectra of reference.

The optimal sub wavelength ranges that would yield the best correlations between the physical parameters and the spectroscopic measurements were sought in the wavelength range between 780 and 2500 nm. The partial least squares (PLS) analysis was performed in sub wavelength ranges in the full spectrum of samples. Calibration and validation models were developed using PLS method based on leave-one-out cross validation technique for predicting N and C percents in soil groups.

Different processing techniques were applied on olive spectra in addition to testing different wavelength ranges in PLS analysis, to determine if these techniques would improve the performances of the calibration models. First of all, the relative spectra were used without any pre-processing except smoothing. Second, the following spectrum pre-processing techniques were applied on the olive spectra, one at a time: constant offset elimination, min-max normalization, vector normalization, straight line subtraction, first derivative, second derivative, multiplicative scattering correction. Finally, two processing techniques, one after another, were applied on the olive spectra**:** first derivative and straight line subtraction, first derivative and vector normalization, and first derivative and multiplicative scattering correction. Mean centering was applied on all kind of spectra processed or not.

Establishing calibration models and performing validations were done using OPUS software. The coefficient of determination, the root mean square error of estimation (RMSEE), and the root mean square error of cross validation (RMSECV) were used to evaluate the performance of the calibration models.

Soil components given in Table 2 were included in the PLS analysis performed. Some statistics of soil data groups are given in Table 2.

RESULTS and DISCUSSION

Good models were obtained in calibration and validation procedures in the result of PLS analyses. Results obtained for each soil composition group and for each quality parameter are given in Table 3.

Although the prediction models developed for N were not as successful as those for C prediction, promising N prediction was obtained for the compost added soil group and good prediction was obtained for the control soil group: coefficients of determination and RMSECV values were as follows for these two soil groups respectively, 0.62 (RMSECV=0.05) and 0.93 (RMSECV=0.01) (Table 3 and Figure 4a-b).

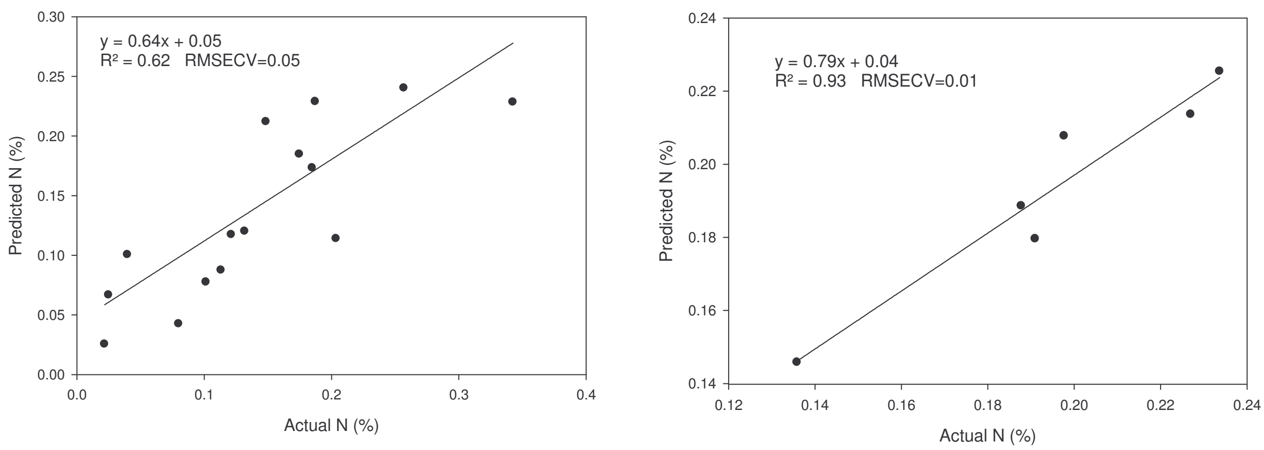
As can be seen from Table 3, C was predicted successfully for almost all of the data groups. Prediction of C for the data group that included all the soil groups was performed with a coefficient of determination of 0.88 (RMSECV=0.27) in validation (Fig. 5a). In calibration on the other hand, R^2 and RMSECV values were 0.93 and 0.21, respectively. C was predicted with the coefficient of determination of 0.93 (RMSECV=0.23) for the compost added soil group (Table 3 and Fig. 5b).

Table 3. Optimal prediction (calibration) results based on FT-NIR spectroscopy

	Parameters		Data Groups 1	2	3	4	5	6
N (%)	Validation	R^2	0.44	0.62	0.55	-	0.93	-
		RMSECV	0.06	0.05	0.04	-	0.01	-
	Calibration	R^2	0.52	0.91	0.71	-	0.99	-
		RMSEE	0.05	0.03	0.04	-	0.01	-
	# of latent variables		2	6	3	-	8	-
	Data processing		MSC	FDMSC	MMN	-	MSC	-
	Effective wavelength range(s) (nm)		1333-1640, 1835-2175	2173-2355	2260-2355	-	1640-2175	-
C (%)	Validation	R^2	0.88	0.88	0.93	0.92	0.92	0.89
		RMSECV	0.27	0.19	0.23	0.24	0.24	0.24
	Calibration	R^2	0.93	0.90	0.95	0.99	0.99	0.98
		RMSEE	0.21	0.18	0.20	0.11	0.04	0.12
	# of latent variables		6	1	2	8	3	9
	Data processing		MSC	COE	MMN	FDSLS	MSC	NSDP
	Effective wavelength range(s) (nm)		800-1640 1835-2063	2173-2355	1333-1640 2260-2355	1333-1470 1835-1991	1640-2175	800-2175

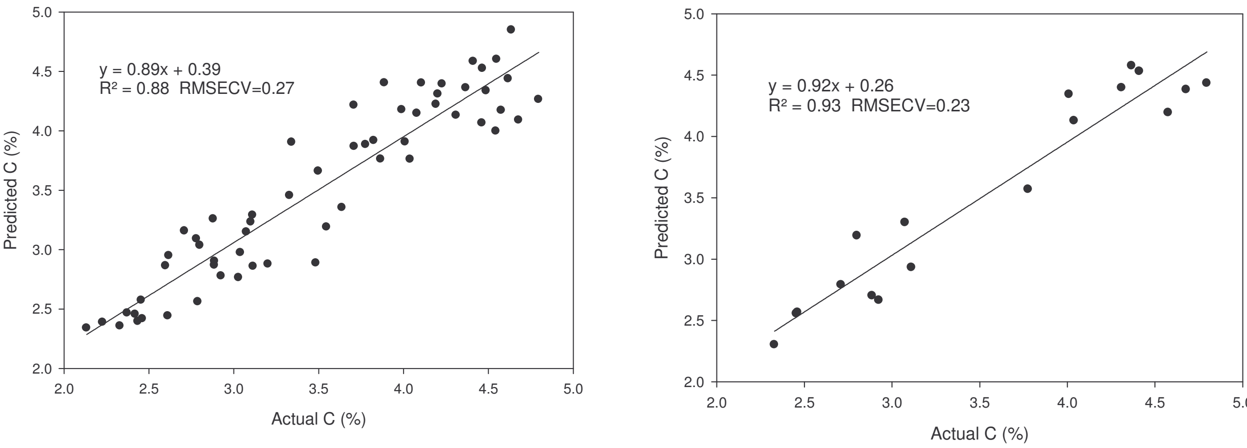
1: Includes all the soils compositions, 2: Compost added soil, 3: OSW added soil, 4: OSW and NPK added soil, 5: Control soil, 6: Include control soil, compost and OSW+NPK

OSW: olive solid waste, NPK: Nitrogen, phosphorus and potassium fertilizer. RMSEE: root mean square error of estimation, RMSECV: root mean square error of cross validation. MSC: multiplicative scattering correction, FDMSC: first derivative+multiplicative scattering correction, MMN: min-max normalization, FDSLS: first derivative+straight line subtraction, COE: constant offset elimination, NSDP: no spectral data processing.



(a) (b)

Fig. 4. FT-NIR prediction of N for (a) compost added soil and (b) control soil groups



(a) (b)

Fig. 5. FT-NIR prediction of C for (a) the soil group, which includes all the soil compositions in it, and (b) compost added soil group

Lower prediction results were obtained for N content of the soil composition groups compared to a previous study (Kavdir, 2008) performed for the prediction of N, C and other quality parameters of OSW composts. However, N prediction was performed successfully for soil groups with no addition.

In most of the cases, RMSECV and RMSEE values given in Table 3 were close to each other, indicating good performance of the model (Lammertyn et al., 1998).

It can be concluded that FT-NIR spectroscopy is a promising technique for non destructive prediction of compost quality. It has a good potential to be applied on line for soil sampling for site-specific fertilizing applications in the field. Therefore, further studies must be performed on this subject.

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Crop Residues Reuse to Improve Agricultural Soil Quality

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ABSTRACT

Since the 70´s in The Autonomous Community of the Region of Murcia, the irrigated agricultural area has increased, especially in the agrarian district "Comarca del Campo de Cartagena", (South East of Spain). As a consequence, the amount of crop residues generated has gone up too. At the present, harvest residues constitute a very serious environmental problem because, in most cases, these residues are dehydrated on the land and burned later on with subsequent negative consequences for the environment.

Therefore, it is important to find a suitable residue management system which would be able to recycle them, solving serious environmental problems related to their final disposal.

The main aim of this study is to reuse crop residues in order to recycle nutrients and improve soil properties. To do so, we will evaluate the influence of recycle vegetables residues on the quality of soil-plant system and therefore being able to reduce the use of chemical fertilizers. Plant waste use in this study comes from pepper crops because it represents more than 90% of the surface occupied by greenhouses in this Agrarian District.

In this experiment we compare two fertilization methods: chemical fertilization used by farmers and organic amendments with crop residues. In both cases plots are divided in subplots of 5 x 4 meters in which we evaluate different doses of nitrogen, to establish the most efficient dose to reduce nutrients leaching without affecting production.

Soil samples are taken at two different depths in order to know the evolution of several physical and chemical parameters such us organic matter, nitrogen, phosphorus, bioavailable cations, metals, etc. Plant samples, will be also collected at the end of the cycle to measure quality and productivity parameters.

INTRODUCTION

In the Autonomous Community of the Region of Murcia (Southeast Spain), agriculture plays a very important role in the economy of the area and especially in the agrarian district "Comarca del Campo de Cartagena" where vegetables crops ranks first regarding cultivated lands (fig. 1), pepper being among them .

In 2006 in The Autonomous Community of the Region of Murcia there were 1777 hectares (ha) of land occupied by greenhouses. Of those 1713 ha were of vegetables, being 90.83 % peppers (CARM, 2007). As a result of the intensive vegetable production system an enormous quantity of vegetables is generated and it remains after the crop, -more than twenty thousand tons from peppers in

1650 ha of land. This is due to the greenhouse management system, in which there must be a clear up to continue with the production. Nowadays there is no procedure to minimize this waste or to reuse it.

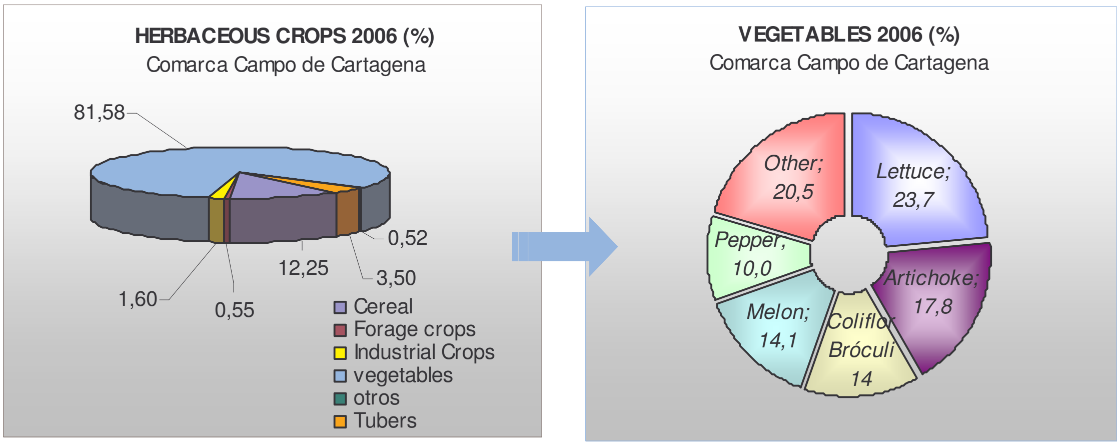

Figure 1: Area take up by herbaceous cropland and vegetables in the Agrarian District of the study

With this project we intend to establish the advantages of recycling post harvest remains from a very common crop in this area. Establishing an effective and advantageous recycling post-harvest remains procedure would be of great interest. From the agronomic point of view recycling allows an addition of organic material to the soil, improving its physico-chemical and biological characteristics Addition of organic materials is very important to maintain the fertility and productivity of soils (Lal, 1980; Lal *et al*., 1980; Maurya and Lal, 1981). Concerning the physical properties, organic matter (OM) contributes to the formation of aggregates which provide structural stability, an increase of percolation and water holding capacity (Dexter, 1988; Zhuang et al., 2008); the decreasing of surface crusting, compaction and soil erosion promote gaseous interchange. As regards chemical properties, it increases the cation exchange capacity, nutrients reserve for vegetables (Porta et al., 1999), and absorption capacity of dangerous substances such as plaguecide (Vangestel, 1996). Nowadays OM takes great interest due to the role that it plays to help to mitigate anthropogenic carbon emissions (Post et al., 2004). As regards biological properties, it enhances the mineralization process and development of plant cover. From the environmental point of view, OM also helps to the protection of the environment due to the diminution of the use of chemical fertilizers. This last contribution in relation with the use of recycling post-harvest remains is of great importance because the area covered by of this study is designated as Nitrate Vulnerable Zone by EU Directive related to the protection of waters against the pollution produced by nitrates coming from agricultural sources (91/676/CEE); this regulation has been implemented in our region through the Good Agricultural Practices Guidelines in where maximum nitrogen doses are recommended for application in agricultural fields based on crop type and irrigation.

MATERIALS AND METHODS

Site Description and Field Experimental Design: the study area is located in the Centro de Transferencia Tecnológica El Mirador, (San Javier), South east of the Autonomous Community of the Region of Murcia, (Fig 2).The study area is divided in two halves. Plot A treated with a chemical fertilization and plot B with organic amendment using crop residues –pepper- dry and crushed.

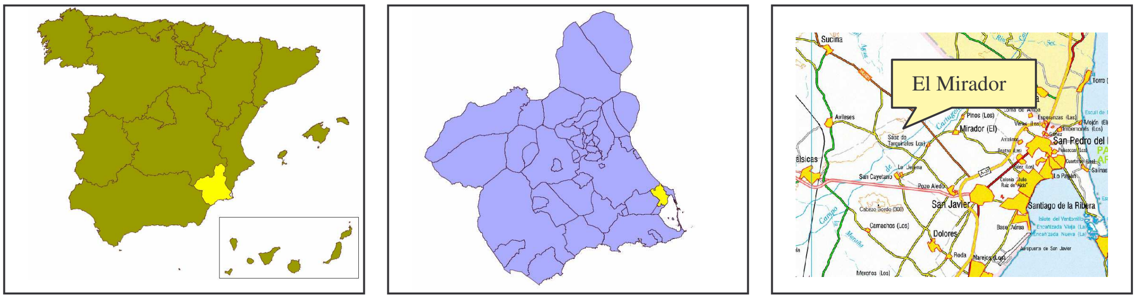

Figure 2: Geographical location

Each plot is divided in twelve sub-plots of 5 m x 4 m receiving four different input treatments per triplicate in order to establish the optimum dose. The plots are distributed in a random way and the doses are as follow: blank = 0 kg N ha^{-1}; dose 1 =170 kg N ha^{-1}; dose 2 = 255 kg N ha^{-1} and dose 3 = 383 kg N ha^{-1} (Fig. 3). After applying the different doses, broccoli will be planted and monitored.

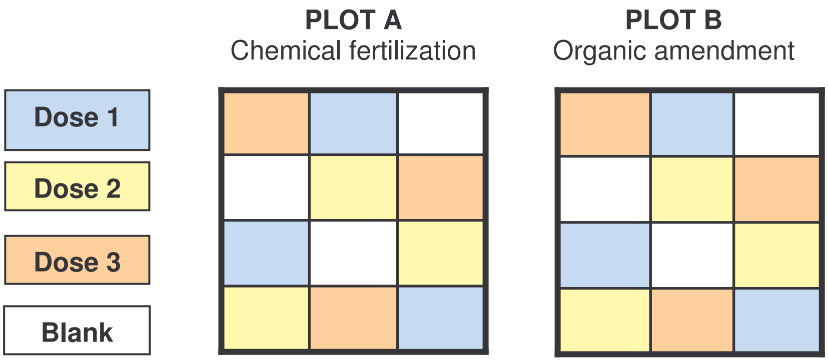

Figure 3: Experimental design of two plots for every study area

Sampling and Analysis: Total amount of Nitrogen (TON) is measured from the dry and crushed crop residues using Duchafour (1970), calculating in this way the amount of residues necessary to obtain the recommended doses All the plots are sampled at two depths: 0-30 cm, arable layer, and subsurface horizon between 30 y 60 cm, beneath the plough level. To obtain statistically significant measurements, 3 samples per plot are taken per each of the two depth mentioned, averaging them to obtain one single sample. On this single sample the following soil analysis are carried out: pH (Peech, 1965), electrical conductivity in 1:5 (w/v) aqueous solution (Bower and Wilcox, 1965), particle size (pipette Robinson) using FAO-ISRIC (1990) to determine the texture, and available phosphorus (Watanabe and Olsen, 1965). Total nitrogen is determined using Duchafour (1970) method, while equivalent calcium carbonate is determined by the volumetric method using a Bernard calcimeter. Organic carbon is determined using Anne (1945); Cation exchange capacity (CEC) by Chapman method (1965), Fe, Mn, Zn y Cu and exchangeable cations according to Pratt (1965). Water aggregate stability in > 0.25 mm size is measured (USDA, 1999), modified using a convection oven at 110 ºC (Soil Science Society of America, 1986.). Soil samples are taken again after the brocoli crop has been harvested. Broccoli plant sampling is collected at the end of harvest. Chemical and other parameters are determined to measure quality and production efficiency.

Expected Results: With this study, we hope to improve our knowledge on the influence of recycling vegetables residues on the quality of the soil-plant system. At the same time, we can compare two methods of fertilization and establish recommendations for the agricultural sector regarding the use of crop residues as an organic amendment in the Campo de Cartagena. The results will allow us to determine alternative disposal procedures to minimize the environmental risks from agriculture practices.

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Soybean Yield and Chemical Attributes in Soil after Five-Year Surface Application of Slag, Aqueous Lime and Sewage Sludge

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ABSTRACT

The agricultural use of industrial residues and sewage sludge in order to provide essential nutrients to a plant and soil liming, will be one of the most promising alternative options of soil fertilization and liming management in a very near future, as far as these applications follow the prevailing technical norms to prevent eventual environmental contamination. The aim of this study was to evaluate the effect of slag, aqueous lime, sewage sludge and limestone, under surface application, on soil chemical attributes and soybean yield during a 5-year cultivation period. The experiment was carried out in dystrophic Clayey Rhodic Hapludox in no-till system from 2002 to 2007. The experiment had a 4x4+1 factorial random block design and 4 replications. The treatments consisted of centrifuged sewage sludge (CS), biodigestor sewage sludge (BS), aqueous lime (AL) and slag (SL) doses of zero (control), 2, 4 and 8 Mg ha^{-1} and one additional treatment of dolomitic limestone of 2 Mg ha^{-1}. All treatments were applied on soil surface in 2002 and reapplied in 2005. CS, AL and SL wastes can be used as alternative materials of limestone in soil liming, presenting effects on pH and base saturation. Superficial application of wastes and limestone on soybean crop increased uptake of N and P in 2003, 2004 and 2005; K in 2003, 2004 and 2006; Ca in all studied years; Zn in 2003, 2004, 2005 and 2006, where applied the sewage BS. Superficial application of wastes increased soybean yield in 2003, 2004, 2005 and 2006; however, in 2007, this increase occurred only with the application of CS. Exchangeable heavy metals available in soil were insignificant and that contributed to the bioavailability absence of these toxic elements in soybean plants during all experimental years.

Keywords: urban wastes, industrial wastes, soil liming, *Glicyne max*.

INTRODUCTION

One of the main causes of low crop productivity in Brazil, independently of the yield system, is the high acidity of most of its soils, mainly in the cerrado region (Quaggio, 2000). Therefore, the appropriate use of correctives in soil liming is extremely important to sustainable assure agricultural productivity.

The most discussed topic in no-tillage soil management is the non-incorporating of limestone, even though it is a low water soluble product and its reaction products (carbonates and bicarbonates) present limited mobility on the soil surface, making it relatively slow (Ramos et al., 2006). Superficial application of limestone on no-tillage soil increases soybean crop yield because this system allows a differentiated dynamics of acidity characteristics due to superficial organic matter and nutrient accumulation, lower Al toxicity and higher water availability (Caires et al., 2003). However, there are other acidity correctives like slag, aqueous lime and centrifuged sewage sludge, which can have higher solubility and allow soil liming and superficial alkaline displacement in a shorter time interval when compared to limestone because of their dissociation reaction products that have higher mobility in the soil.

It is probable that the same favorable results occur to soybean crop development, but further studies on the application of liming materials like slag, aqueous lime and sewage sludge applied on no-tillage system soil surface are needed. Thus, the aim of this paper was to evaluate the effect of superficial application of sewage sludge, aqueous lime and slag on some chemical soil attributes and soybean productivity during 5 years.

MATERIAL and METHODS

The experiment was carried out under field conditions from 2002 to 2007 at Lageado Experimental Farm in the School of Agronomic Sciences (Faculdade de Ciencias Agronomicas – FCA), UNESP, Botucatu, State of Sao Paulo, Brazil, latitude 22^o 51'15''S, longitude 48^o 26'30''W and altitude 740m with relief lower than 10%. The predominant weather is Cwb according to Köeppen classification.

The experiment was planted in dystrophic Clayey Rhodic Hapludox (Embrapa, 1999), moderate A, medium texture, subtropical field phase, with wavy smooth relief, under no-tillage system. Sampling for chemical characterization of the soil was taken from layer at the depth of 0-20 cm, and presented the following attributes: pH ($CaCl_2$) 4.1; 43 $mmol_c\,dm^{-3}$ of H+Al; 16 $g\,kg^{-1}$ of O.M.; 5.6 $mg\,dm^{-3}$ of P (resin); 0.8, 15 and 6 $mmol_c\,dm^{-3}$ of K, Ca and Mg, respectively, (Raij et al., 2001) and 34% of base saturation.

The treatments consisted of four wastes, centrifuged sewage sludge with addition of CaO – CS (type A), biodigestor sewage sludge with addition of polyelectrolyte – BS (type B), slag – SL (waste from production process of pig iron and steel) and aqueous lime – AL (waste from cellulose whitening process), applied on soil surface in doses of zero (control), 2, 4 and 8 $Mg\,ha^{-1}$ (dry base) and one additional control treatment of dolomitic limestone of 2 $Mg\,ha^{-1}$.

Before the experiment installation, the total heavy metal content present in the wastes was determined (Table 1) using nitric and hydrochloric acids because this method is similar to the one of EPA SW-846, but without peroxide. Readings were made using an argon plasma-induced emission spectrophotometer (ICP/AES). It is noteworthy to point out that the wastes presented heavy metal levels lower than the minimum ones allowed by the Brazilian Legislation.

The treatments were distributed in a random block design and had a 4x4+1 factorial scheme and four replications. In each block, the plots were 6 m wide and 7 m long.

The experiment started in 2002 when guandu beans (*Cajanus cajan* L.) were dried in order to produce straw on which the treatments were applied without incorporation. The initial application took place three months before the soybean seeding in the 2002/2003 harvest, and the reapplication was done in May 2005, before the seeding of winter cultivation. In the experimental period, five soybean cultivations were carried out, using cultivar EMRAPA 48 (harvests of 2002/2003, 2003/2004, 2004/2005, 2005/2006 and 2006/2007), making result comparison within the same species possible. In the seeding, 300 kg ha^{-1} of formulated chemical fertilizer (00-20-10) was applied in the first three years and 300 kg ha^{-1} (08-28-16) in the last two years; the seeds were inoculated with *Bradyrhizobium japonicum* every year. In the winter, black oats were cultivated during four years (2003, 2004, 2005 and 2006) in order to produce straw; thus, 100 kg ha^{-1} of urea was used for nitrogen fertilization to improve the crop initial development. No-tillage system was used during all cultivation years.

Soil sampling for chemical characterization was done after 5 years of cultivation, from the layers at the depths of 0-5, 5-10, 10-20 and 20-40 cm, using a probe auger to collect four samples per plot for the composed sample. Levels of pH, base saturation, phosphorus and zinc were determined according to Raij et al. (2001). For heavy metal availability in the soil, extraction with DTPA was used. Leaf content of N, P, K, Zn macronutrients was determined using Malavolta et al. (1997) methodology, by sampling the third leaflet+petiole from the apex of 30 soybean plants. Two central rows were harvested in each plot, using a plot harvesting machine and then the grain weight was determined and moisture was corrected at 13% to obtain productivity results.

The results were analyzed as to their variance (Sisvar 4.2 program) and posterior regression, by adjusting equations through the F Test, significant at 1 and 5%, and also through the magnitude of determination coefficients (Sigmaplot 10.1 program). All treatments were contrasted with limestone using t Test (MSD) at 1 to 5% (Sisvar 4.2 program).

RESULTS and DISCUSSION

After five years of cultivation in no-tillage system, when two superficial applications with increasing doses of CS, BS, AL and SL and limestone control treatment were done, chemical analysis of pH, base saturation, P and Zn in soil show that there is still a contribution to the improvement of soil fertility conditions (Figure 1) and that it allowed good culture development.

There was an increase of pH and base saturation values because of the increasing dose application of CS, AL and SL and the limestone treatment. For CS, AL and SL, soil reaction happens in the 10-20cm deep layer whereas acidity neutralization for limestone occurs in the 5-10 cm layer. These results corroborate the ones by Melo et al. (2001) and Oliveira et al. (2002) for incorporated sewage sludge, and the ones by Prado & Fernandes (2003) and Carvalho-Pupatto et al. (2004) for incorporated slag. BS did not cause pH variation and base saturation in the soil (Figure 1), because of its polyelectrolyte content like DTPA and EDTA, which cause a very strict effect to soil liming and do not present desirable characteristics as acidity correctives.

Application and reapplication of CS, AL and SL wastes (Figure 1) increased pH and base saturation values because of the higher concentration of resulting products from liming reaction (CaO, NaO, $CaSiO_3$ and $CaCO_3$), allowing a higher availability and possibility of displacement of these products due to a lower concentration of acid cations in the dissolution zone of the corrective when compared to other cations, specially K^+, Ca^{2+} and Mg^{2+}. The continuous action of deep soil liming using CS, AL and SL wastes, mainly in higher doses and limestone dose of 2 Mg ha^{-1}, is related to the increase of soil base saturation (Figure 1). The displacement of resulting products from CS, AL and SL waste reactions, keeps on occurring until they reach the next acid layer and react again to acid cations, specially Al^{3+}, that will replace Ca and Mg due to its higher electrostatic strength, and then start the liming process in deeper layers (Fidalski & Tormena, 2005).

After five years of no-tillage cultivation there are still contributions of increasing doses of waste applications on the P content in the soil, observed for CS and SL up to the depth of 10 cm and for BS up to the depth of 5 cm (Figure 1). This increase of P availability is caused by the soil pH increase, presence of P in the chemical composition of CS, BS and SL wastes (4.9, 2.0 and 1.4% of dry matter mass) and the addition of P in the seeding of soybean crop.

Application of increasing doses of BS increased Zn content in the soil up to the depth of 20 cm (Figure 1), where the dose of 8 Mg ha^{-1} resulted in higher values of this micronutrient in the soil. This increase is a consequence of this element presence in its composition (Table 1), and also because this waste does not have any effect on the soil liming, making Zn available in the soil solution and, therefore, more likely to be absorbed by crops while, according to Raij (1991), pH increase in the soil reduces the contents of most cationic micronutrients, including Zn.

Application of wastes and limestone increased soybean N leaf content in 2003, 2004 and 2005 (Table 2). This increment results from the improvement of chemical attributes in the soil, as pH and base saturation, which allows a better interaction between *Rhizobium* bacteria and the root and, consequently, improving nitrogen biological fixation. Another probable cause for the N increase in soybean leaves is that wastes as sewage sludge are a direct source of this nutrient in the soil, where CS has 25 g kg^{-1} of N, and BS has 40 g kg^{-1} of N (Table 1). However, after the reapplication of wastes, significant effects of N were not observed, probably because of no-tillage system stability, that allows greater soil nutrient recycling and also a higher onset of microorganisms, especially for Rhizobium. According to Malavolta et al. (1999), the appropriate N leaf level to obtain a reasonable productivity of 2700 kg of soybean ha^{-1} is 36 g kg^{-1}. In 2003 and 2004, the obtained results were higher than the ones considered ideal to obtain reasonable productivity, and, in 2005, the dose zero and the treatments with 2 and 4 Mg ha^{-1} of BS were lower than those values.

P content in soybean increased due to the application of wastes and limestone, except for the AL treatment in 2004 and 2005 and the SL in 2005 (Table 2), because CS, BS, SL and AL provided a total P_2O_5 amount of 160, 392, 112 and 16 kg ha^{-1}, respectively, in the highest doses, and also caused increased values of soil pH for the treatments with CS, SL, AL and limestone, leading to greater P availability for plant absorption. In 2006 and 2007, there was no significant effect for P content in soybean, except for SL in 2006. This happened because there is more organic P in soil in no-tillage systems and due to the application of this nutrient in the soybean seeding, increasing P content availability in the soil and consequently its absorption by the plant. The P content in the soybean leaf of 2.6 g kg^{-1} is considered appropriate to obtain a productivity of 3000 kg ha^{-1} (Malavolta et al., 1999), thus, all treatments presented higher P values, except for the dose zero in the first year of the cultivation.

K leaf content in soybean increased with SL and AL wastes in 2003, but in 2004 all wastes improved the absorption of this nutrient, and linear behaviors were obtained for CS and SL, and quadratic ones for BS and AL. However, in 2006, after the reapplication of wastes, there was a decreasing quadratic behavior for CS, BS and AL (Table 2). In 2005 and 2007, there were no significant differences for K content in soybean because the treatment dose zero contained 3.2 and 2.0 $mmol_c$ dm^{-3} of K, which are considered appropriate values for soil fertility (Raij et al., 1996), in the 0-20 cm layer, allowing the increase of mass flow transportation through diffusion (Rosolem et al., 2003) as K presents high mobility in soil (Oliveira et al., 2002). Besides these factors in soil, plants present a double mechanism for K absorption, in an active way, through transporting proteins; and, in a passive way, through channel proteins when there are low or high concentration K contents in the soil (Malavolta, 2004). Thus, in 2005 and 2007, there was abundant K for the soybean crop to absorb, because of its high concentration in the soil, even for the treatments where there was no superficial applications of wastes and limestone.

There was a higher Ca concentration in soybean leaves because of the increase of waste doses and soil liming in 2003 and 2004, except for BS in 2004. The increase of soybean Ca content occurred because the wastes of CS, SL and AL directly provided this nutrient to the soil. In 2005, only AL increased Ca content in soybean. A possible reason for just one waste be the responsible for Ca absorption by the plant is that the no-tillage system stability provides better soil fertility conditions, guaranteeing the balance among Ca, Mg and K, and allowing better availability of this nutrient to soybean; this can be confirmed by the high Ca content on the leaf (11 g kg^{-1}) in dose zero. After the reapplication of wastes there was an increase in Ca content in soybean for the treatment with CS in 2006, and CS and SL in 2007. According to Malavolta et al. (1999), the appropriate Ca content to obtain appropriate soybean productivity is 10.8 g kg^{-1}; approximate or higher values to this one were obtained with application of wastes and limestone.

In 2003 and 2004, Zn leaf content in cultivated soybean was influenced only by BS application, and increased when the dose was increased; in 2005, there was a significant effect to all wastes with linear and decreasing responses in function of the increased doses of CS, AL and SL, due to soil pH increase while BS showed opposite behavior, an increasing response. In 2006, when BS was applied, the highest Zn leaf content occurred with the dose of 4 Mg ha^{-1}.

Superficial application of SL, BS, CS and AL and limestone increased soybean productivity in 2003, 2004 and 2006. In 2005, there was an increment for CS, AL, SL and limestone, and in 2007, just for CS and limestone (Table 3). This productivity result may be caused by the improvement of the soil chemical properties, increase of pH level and base saturation, which provided a higher absorption of N, P, Ca and K nutrients in soybean for some treatments. Thus, the use of these wastes, as well as liming in no-tillage system soil surface, is an alternative option to obtain good soybean productivity.

Considering the presence of available heavy metal content in the soil after 5 years of cultivation, the superficial application of CS, BS, AL and SL wastes did not cause environmental pollution because the average content found for the 0-20 cm layer were: n.d. (not detected) to 0.360 mg dm^{-3} for As; n.d to 0.045 mg dm^{-3} for Cd; 0.081 to 0.355 mg dm^{-3} for Ni; 0.370 to 1.225 mg dm^{-3} for Pb; n.d. to 0.418 mg dm^{-3} for V and n.d. for Hg. Because of the low availability of heavy metals present in the soil, there was not phitoavailability of those toxic elements to the soybean crop; only low leaf content was detected. Considering the last two crops, after two applications, average soybean leaf contents were: 0.00 – 6.02 mg kg^{-1} for As, 0.35 - 1.15 mg kg^{-1} for Cd; 2.25 – 5.00 mg kg^{-1} for Cr; 4.54 - 30.52 mg kg^{-1} for Ni; 5.21 – 35.55 mg kg^{-1} for Pb; 1.00 – 33.95 mg kg^{-1} for V; these values were lower than the critical level of phitotoxicity according to Kabata-Pendias and Pendias (1992). According to these results, it can be inferred that doses up to 8 Mg ha^{-1} of centrifuged and biodigestor sewage sludge and industrial wastes of aqueous lime and slag may be applied and reapplied after three years, in a no-tillage system without environmental contamination on a dystrophic Clayey Rhodic Hapludox with Cwb type weather, under soil management, mainly organic matter one. However, in the long run, the increase of heavy metal concentration in the soil, due to successive application of sewage sludge may become a concern because it may threaten the trophic chain if it is not appropriately controlled (Hue, 1995).

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Table 1. Chemical composition (total contents, d.m.) of wastes used in the experiment and maximum permitted concentration (MPC) values of metals in sewage sludge and wastes.

Parameter	Unity	CS	BS	AL	SL	MPC (1 a)	MPC (1 b)
Moistness	%	5	29	19	2		
Organic Matter	%	26	50	3	1		
Organic Carbon	%	14.4	27.8	1.7	0.3		
C/N Relation	%	6/1	7/1	7/1	1/1		
pH	$CaCl_2$	12.0	7.0	12.0	12.0		
Nitrogen	g kg^{-1}	25	40	4	3		
Phosphorus	g kg^{-1}	20	49	2	14		
Potassium	g kg^{-1}	3.0	2.0	1.0	1.0		
Calcium	g kg^{-1}	280	20	370	230		
Magnesium	g kg^{-1}	4	4	6	21		
Sulpher	mg kg^{-1}	0.5	1.6	0.3			
Sodium	mg kg^{-1}	640	500	20400	600		
Copper	mg kg^{-1}	72	760	90	16	1500	
Iron	mg kg^{-1}	1600	36750	1096	22900		
Manganese	mg kg^{-1}	104	218	158	34300		
Zinc	mg kg^{-1}	660	2950	86	24	2800	
Arsenium	mg kg^{-1}	14	27	1.4	5	41	1000
Cadmium	mg kg^{-1}	n.d.	0.1	n.d.	n.d.	39	n.a.
Chromium	mg kg^{-1}	4	19	13	61	1000	n.a.
Lead	mg kg^{-1}	17	107	60	308	300	1000
Mercurium	mg kg^{-1}	n.d.	n.d.	n.d.	n.d.	17	100
Nickel	mg kg^{-1}	7	180	96	19	420	n.a.

CS= centrifuged sewage sludge; BS= biodigestor sewage sludge; AL= aqueous lime; SL= slag.

(1) Brazilian Legislation: (a) CONAMA (2006), (b) NBR 10004 (ABNT, 1987), n.d. (non-detected) and n.a. (non-applicable at the NBR 10004/1987).

Table 3. Soybean crop productivity during five years, due to superficial application of wastes and limestone on no-tillage soil.

Treatments		Productivity				
		2002/2003	2003/2004	2004/2005	2005/2006	2006/2007
		kg ha^{-1}				
CS	2	4179	3495	3072	2403	3684
CS	4	4377	3598	3578	2500	4620
CS	8	4611	3958	3502	2941	4950
Regression		L**	L**	L**	L*	L**
BS	2	4257	3636	2768	2752	3716
BS	4	4344	3624	2745	2879	4175
BS	8	4391	3748	3033	2408	3047
Regression		L**	L**	n.s.	Q*	n.s.
AL	2	4049	3585	3223	3337	3653
AL	4	4113	3831	3478	3372	4070
AL	8	4291	3996	3407	2828	3645
Regression		L**	L**	Q**	Q**	n.s.
SL	2	4290	3734	3245	2918	3903
SL	4	4457	3885	3272	3729	3796
SL	8	4735	3942	3559	2957	3451
Regression		L**	Q**	L**	Q**	n.s.
Control	0	3786	2997	2626	2312	3530
Limestone	2	4100	3600	3100	3116	4117
V.C. (%)		7	10	12	14	21

CS= centrifuged sewage sludge; BS= biodigestor sewage sludge; AL= aqueous lime; SL=slag. * significant at 5%, ** significant at 1% and n.s.= non-significant, L= linear and Q= quadratic.

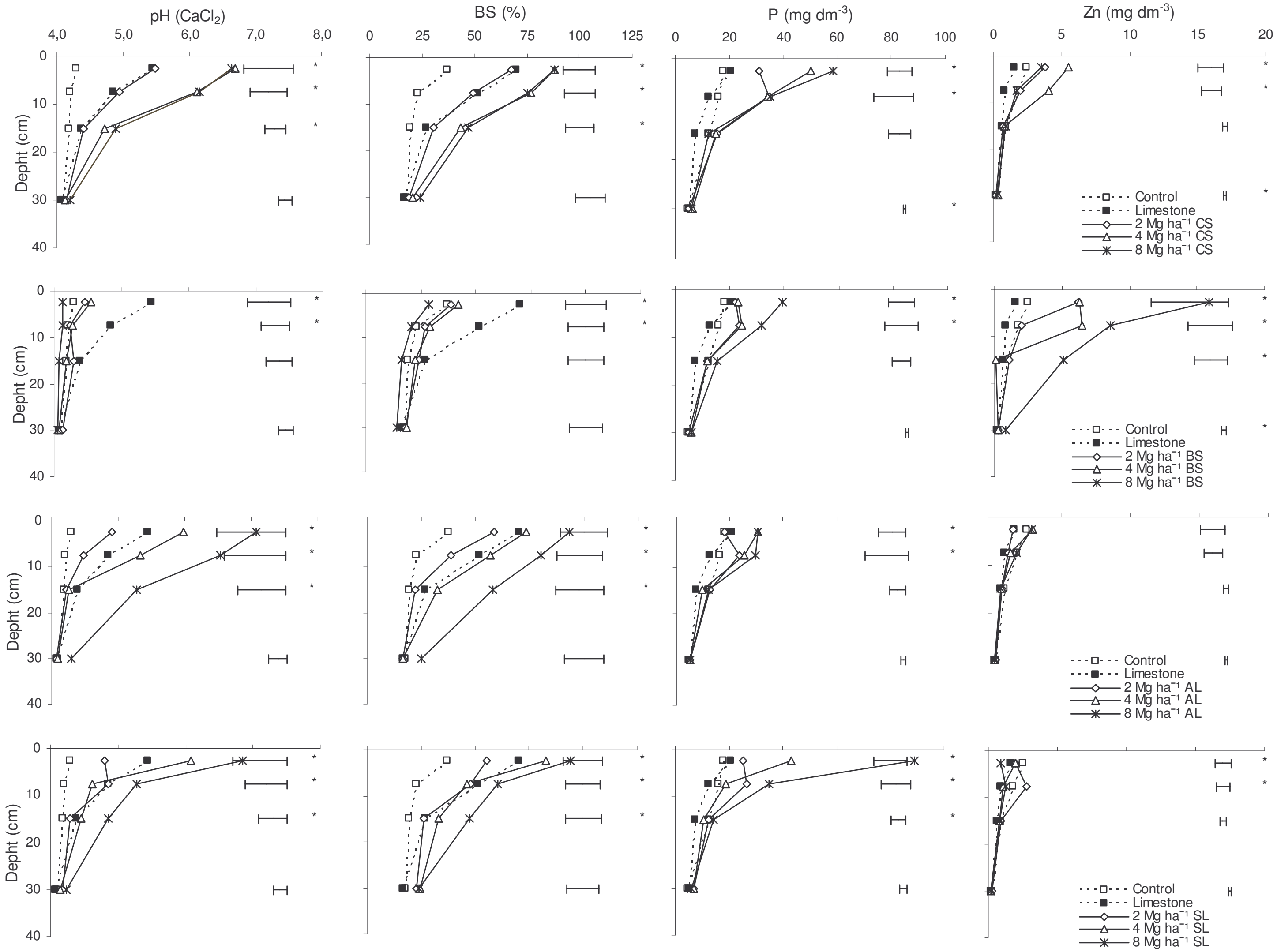

Figure 1. Dynamics of pH, base saturation (BS%), P and Zn after five years of soybean cultivation, in function of application of wastes and limestone under no-tillage system soil surface. * minimum significant difference (MSD) among averages by t Test at 5%.

Table 2. Leaf Content of N, P, K, Ca and Zn in soybean during 5 years of cultivation, due to superficial application of wastes and limestone under no-tillage system soil surface.

Treatments		2003					2004					2005					2006					2007				
		N	P	K	Ca	Zn	N	P	K	Ca	Zn	N	P	K	Ca	Zn	N	P	K	Ca	Zn	N	P	K	Ca	Zn
		------------------- g kg^{-1}--- ----------------				mg kg^{-1}	------------------- g kg^{-1}---- --------------				mg kg^{-1}	------------------- g kg^{-1}--- ----------------				mg kg^{-1}	------------------- g kg^{-1}- ------------------				mg kg^{-1}	------------------- g kg^{-1}-------------------				mg kg^{-1}
CS	2	47	2.8	15	12	81	43	3.0	24	11	44	36	3.0	25	13	46	38	3.2	15	16	62	52	3.3	18	12	62
CS	4	49	2.9	15	12	85	45	3.5	27	11	43	39	3.2	22	12	43	37	3.2	13	18	61	53	3.2	18	11	85
CS	8	51	3.1	16	13	77	46	3.5	28	13	42	42	3.2	24	13	40	41	3.5	16	19	60	52	3.4	18	13	49
Regression		L**	Q**	n.s.	L**	n.s.	L**	L*	L**	L**	n.s.	L**	L**	n.s.	n.s.	L**	n.s.	n.s.	Q*	L**	n.s	n.s.	n.s.	n.s.	L*	n.s.
BS	2	47	2.7	16	10	92	41	3.0	24	10	80	32	2.6	22	12	60	38	3.2	15	15	81	50	3.0	18	9	91
BS	4	49	2.8	14	13	130	46	3.5	23	11	128	35	3.0	20	12	118	41	3.4	14	16	136	50	3.2	17	11	94
BS	8	50	3	15	13	155	45	4.0	26	10	128	40	3.2	20	12	128	36	3.3	17	16	78	51	3.2	18	10	142
Regression		L**	L**	n.s.	L**	L**	Q**	L**	Q**	n.s.	Q**	L**	L**	n.s.	n.s.	Q**	n.s.	n.s.	Q*	n.s.	Q**	n.s.	n.s.	n.s.	n.s.	n.s.
AL	2	47	2.7	17	10	81	44	3.2	27	10	45	41	3.1	24	11	46	39	3.3	16	18	62	54	3.4	18	12	67
AL	4	49	2.7	15	11	71	44	3.1	27	12	40	42	3.1	22	13	41	40	3.2	13	17	72	51	3.1	17	11	87
AL	8	48	2.9	17	13	77	44	3.2	26	14	38	42	3.1	20	15	34	39	3.3	16	17	76	50	3.1	22	11	106
Regression		L**	L**	L**	L**	n.s.	Q**	n.s.	Q**	L**	n.s.	Q**	n.s.	n.s.	L**	L**	n.s.	n.s.	Q*	n.s.	n.s	n.s.	n.s.	n.s	n.s.	n.s.
SL	2	48	2.9	16	11	81	44	3.2	24	12	44	41	3.3	27	11	42	38	3.1	15	16	58	52	3.2	18	10	67
SL	4	50	3.1	17	11	74	44	3.2	26	12	43	37	3.2	24	13	38	39	3.1	15	18	64	55	3.3	18	11	87
SL	8	50	3.1	19	12	81	46	3.7	28	14	40	42	3.3	22	12	35	40	3.4	15	17	59	51	3.5	18	12	106
Regression		L**	Q**	L**	L**	n.s.	L**	L**	L**	L**	n.s.	Q**	n.s.	n.s.	n.s.	L**	n.s.	n.s	n.s.	n.s.	n.s	n.s.	n.s	n.s.	L*	n.s.
Control	0	44	2.5	15	9	78	39	3.0	24	9	46	29	2.9	22	11	59	38	3.2	18	13	75	53	3.2	20	9	68
Limestone	2	48	2.8	15	10	85	42	3.2	25	11	48	37	3.1	24	12	50	41	3.4	17	15	73	55	3.3	21	9	67
V.C.%		5	6	9	15	9	6	12	7	14	14	6	8	15	16	17	9	5	17	16	13	5	9	20	22	60

CS= centrifuged sewage sludge; BS= biodigestor sewage sludge; AL= aqueous lime; SL=slag. * significant at 5%, ** significant at 1% and n.s. non-significant, L= linear and Q= quadratic.

Differential Response of Cotton Cultivars to Boron Toxicity

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ABSTRACT

A greenhouse experiment was performed to study the effects of boron (B) on growth, and B distribution in the plant parts. The reactions of cotton varieties, grown in a mixture of sand and perlite medium, were investigated in point of boron doses. The experiment was conducted with four B doses (0.5, 7.5, 15, 22.5 mg B L^{-1}) and eight cultivars (Barut 2005, Gossipolsüz Nazilli, Gürel Bey, Nazilli 143, Nazilli 342, Nazilli 39, Nazilli-503, STN 8A) in factorial experiment design. Number of damaged leaf from boron toxicity, root, stem and leaf boron concentrations increased by boron application doses while fresh weight, dry weight and leaf numbers per plant decreased. In point of yield relations on boron doses, Gürel Bey and Gossipolsüz Nazilli cultivars were the most tolerant and Nazilli 39 cultivar was the most sensitive against boron toxicity.

Key words: *G. hirsutum* L, cultivars, leaf, stem, root, boron concentration

INTRODUCTION

Boron (B) toxicity, an important agricultural problem that limits crop productivity in different regions of the world, can occur in B-rich soils or in soils exposed to B-rich irrigation waters, fertilizers, sewage sludge, or fly ash (Nable *et al.*, 1997). Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. For example, there are 20 geotermal areas in The Büyük Menderes River Basin which is one of the most important lands for cotton production in Turkey (Akar, 2007).

Furthermore, in recent years, B toxicity has attracted increasing interest owing to the greater demand for desalinated water, in which the B concentration may be too high for healthy irrigation (Parks and Edwards, 2005). A wide range of crops was tested for boron tolerance by using sand-culture techniques (Eaton 1944).

The typical symptoms shown by plants exposed to excess B are reduced vigour, delayed development, leaf burn (chlorotic and necrotic patches in older leaves), and decreased number, size and weight of fruits (Paull *et al.*, 1992; Nable *et al.*, 1997). However, despite the importance of this nutritional disorder, it is not understood why B is toxic to plants, or how tolerant plants avoid toxicity (Reid *et al.*, 2004). It has long been known that the optimum B level for one species could be either toxic or insufficient for other species (Blevins and Lukaszewski, 1998). Genetic variation in response to high B concentrations has prompted investigation into the mechanism operating in plants against B excess. In wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) cultivars, several possible tolerance mechanisms have been proposed, these operating mainly by exclusion (Paull *et al.*, 1992; Hayes and Reid, 2004). Tolerance to B toxicity operates not only at the whole-plant level but also at the organ and cellular level. For example, susceptibility to B toxicity is expressed among barley genotypes at either the whole plant or organ or cellular level (Kalayci et al., 1998; Torun et al., 2003).

These mechanisms are based on studies demonstrating an ability of plants to accumulate less B in shoots, although the transporters which participate in the exclusion process have not yet been identified. The objectives of this study were to investigate the differential response of eight cotton cultivars, developed for western part of Turkey, to boron toxicity and B distribution in the plant parts.

MATERIALS and METHODS

The eight cultivars of cotton plants (*Gossypium hirsutum* L.) used in the present study. Seeds were sown in 2:l of perlite-sand (1:2, v:v) mixture and grown for 43 days in a 3 l pot placed on benches in an experimental greenhouse in a nethouse. For 10 days after germination, pots were irrigated with ¼ strength Hoagland nutrient solution (Hoagland and Arnon, 1950). Then, following days, full strength Hoagland nutrient solution alone (control namly B1, 0.5 mg B L^{-1}) and Hoagland nutrient solution with three levels of boron doses (B2, B3, B4 as 7.5, 15, 22.5 mg B L-1) were applied. Cotton cultivars were Barut 2005, Gossipolsüz Nazilli, Gürel Bey, Nazilli 143, Nazilli 342, Nazilli 39, Nazilli-503, STN 8A) in factorial experiment design with 4 replication. There was one plant in each pot. The nutrient solution (pH 5.5-6.0) was supplied to the root zone as 250 ml day^{-1} per pot and drained solution was discarded to avoid nutrient accumulation.

Plants were harvested at the day of 43 from the sowing. Before the harvest, leaves per plant were counted as total and suffering from B toxicity which was defined as leaf having the spot necroses covered area was 30% of total leaf blade. The roots were cleaned from perlite and sand by washing. Roots and leaves were detached from stems. Roots, stems and leaves were rinsed in three times with distilled water after disinfecting with 10 g l^{-1} non-ionic detergent (decenoly-N-methyl-glucamide). Then they were blotted on filter paper and dried in a forced air over at 70°C for 24 h. Boron content was determined after digestion of dried and milled plant material with 6 M H_2SO_4 and H_2O_2 (Wolf, 1982).

To determine the B concentrations in the plant parts, the azomethine-H+ method was followed using spectro-photometry at 410 nm (Wolf, 1974). Standard analysis of variance techniques were used to assess the significance of treatment means. Differences between treatments were compared using LSD at the 0.05 probability level. Levels of significance are presented as follows:*P<0.05; **P<0.01; ***P<0.001; NS, not significant.

RESULTS and DISCUSSION

Symptoms of B excess caused by rising amounts of boron, developed as follows: A few brown necroses first developed at the leaf. B toxicity then resulted in brown marginal necroses and further spot necroses in the centre of the leaf. In treatment B4, some of the leaf tissue died from the leaf tip, which had a dirty-white discoloration, with marginal spot and larger necrotic areas developing towards the leaf base. B damage first occurred in older leaves and with increasing uptake in younger leaves as well.

Addition of B in the culture medium had a dramatic influence on number of leaf suffering from B toxicity (Table 1). The number of leaf suffering from B toxicity varied between 1.0-3.7, 2.7-5.0 and 3.7-5.3 plant^{-1} for B2, B3 and B4, respectively. It was the lowest for Gürel Bey in all excess B treatments. It was highest for Nazilli-39 in B2 and Nazilli 143 and Nazilli 503 in both B3 and B4 treatments.

Table 1. The effect of B applications on number of leaf suffering from B toxicity in the cotton cultivars

Cultivars	Suffering leaf number per plant			
	B0	B1	B2	B3
Barut 2005	0	2.3 b	4.0 b	4.3 b
Gossipolsüz Nazilli	0	2.0 bc	2.7 c	4.3 b
Gürel Bey	0	1.0 d	3.3 bc	3.7 c
Nazilli 143	0	3.3 a	5.0 a	5.3 a
Nazilli 342	0	2.3 b	4.0 b	5.0 a
Nazilli 39	0	3.7 a	4.0 b	4.3 b
Nazilli-503	0	1.7 d	5.0 a	5.3 a
STN 8A	0	2.0 bc	4.0 b	4.3 b
Mean	0	2.3	4.0	4.6

Addition of B in the culture medium had a dramatic influence on dry biomass (Table 2). Dry matter yield varied from 1.61 - 2.66, 1.18 - 1.92, 0.47 – 1.34 and 0.25-1.06 g plant^{-1} for B1, B2, B3 and B4, respectively. As B rate increased the dry matter yield decreased. Compearing the control the less decreases were in STN 8A, Gossipolsüz Nazilli and Barut 2005 for B2, B3 and B4, respectively. A reduction in growth and increase of B concentration in the plant tissues as a consequence of B toxicity has previously been observed in tomato (Güneş et al., 1999), sunflower (Ruiz *et al.*, 2003), barley (Karabal *et al.*, 2003) and Cervilla et al., 2007).

Applications of boron significantly increased B concentration in leaves, stems and roots of fig cultivars (Table 2). Boron concentrations ranged between 41-1409, 4.8-144, and 11.9-93.8 mg kg^{-1} for leaves, stems and roots, respectively (Table 3). Among the cultivars, Gürel Bey generally had the lowest B concentrations in the measured plant parts. Boron concentrations in the plant parts were in following order leaves>roots>stems for B1, B2 and B3 and leaves> >stems>roots for B4. This result corroborates the findings of Garate et al (1984); Subedi et al. (1999); Oyinlola (2005) who also reported that the B concentration in roots and stems were generally much lower than those in leaves. In a resant study, cotton plants were grown under greenhouse conditions in complete nutrient solution in order to determine for providing guideline values for estimating the boron status from deficiency to toxicity (El-Gharably and Bussler, 2007). The lower critical levels for boron in roots, young leaves and old leaves were 103, 61 and 78 ppm, while critical nutrient toxicity levels were 129, 80 and 91 ppm, respectively. For the Gossypium herbaceum-Etawa cultivar, the maximum growth was obtained when 1 ppm boron was applied as H_3BO_3 in the nutrient solution.

Table 2. The effect of B applications on dry matter yield of cotton cultivars

Cultivars	-----Dry matter yield (g pot^{-1})-------				----Decreases, %-----		
	B0	B1	B2	B3	B1/B0	B2/B0	B3/B0
Barut 2005	2.27 b	1.94 ab	1.21 a	1.06 a	15	47	53
Gossipolsüz Nazilli	1.93 bc	1.59 ab	1.11 ab	0.83 ab	17	42	57
Gürel Bey	1.99 b	1.18 b	1.01 ab	0.74 ab	41	49	63
Nazilli 143	2.16 b	1.83 ab	1.08 ab	0.60 b	15	50	72
Nazilli 342	1.61 c	1.39 b	0.47 b	0.42 b	14	71	74
Nazilli 39	2.66 a	1.92 a	0.81 b	0.33 b	28	69	88
Nazilli-503	2.71 a	1.80 ab	1.34 a	0.96 ab	33	50	65
STN 8A	1.61 c	1.47 b	0.55 b	0.25 b	9	66	85
Mean	2.12	1.64	0.95	0.65	21	56	69

Table 3. The effect of B applications on B concentrations (mg B kg-1) in leaves, stems and roots of cotton cultivars

Cultivars	B concentrations (mg B kg^{-1})			
	B0	B1	B2	B3
Leaves				
Barut 2005	70 a	181 c	668 c	1004 c
Gossipolsüz Nazilli	43 a	291 b	649 c	793 d
Gürel Bey	41 a	144 c	449 d	604 e
Nazilli 143	53 a	166 c	267 e	518 e
Nazilli 342	72 a	238 bc	787 b	1409 a
Nazilli 39	48 a	234 bc	822 bc	1181 b
Nazilli-503	97 a	161 c	733 bc	1225 b
STN 8A	73 a	307 a	106 a	1355 a
Mean	62	203	679	1011
Stems				
Barut 2005	13.1 a	16.5 b	35.0 e	56.8 e
Gossipolsüz Nazilli	10.8 b	23.4 b	24.9 f	61.1 e
Gürel Bey	20.1 a	23.7 b	36.3 e	44.3 f
Nazilli 143	4.8 b	32.1 ab	97.1 a	123.7 b
Nazilli 342	13.4 a	40.7 a	69.1 b	89.2 c
Nazilli 39	6.6 b	11.6 c	51.7 c	75.4 d
Nazilli-503	13.8 a	24.3 b	35.1 e	60.1 e
STN 8A	12.2 a	22.5 b	41.7 d	144.3 a
Mean	11.9	24.3	48.9	81.9
Roots				
Barut 2005	12.0 b	27.8 c	36.9 d	51.8 d
Gossipolsüz Nazilli	15.7 ab	70.3 a	72.9 ab	93.8 a
Gürel Bey	20.4 ab	42.3 bc	64.1 b	66.7 c
Nazilli 143	17.8 ab	33.4 c	56.8 b	78.1 b
Nazilli 342	25.1 a	51.7 b	54.2 bc	60.3 cd
Nazilli 39	12.0 b	35.1 c	46.9 c	52.0 d
Nazilli-503	15.8 ab	45.4 b	59.6 b	85.4 b
STN 8A	11.9 b	41.4 c	74.5 a	81.1 b
Mean	16.3	43.4	58.2	71.2

Relationship between B rates and dry matter yield and its parameters were given in Table 4. Dry matter yields were negatively correlated by applied B rates. The slope figures in this relations ranged from -0.108 to -0.050. Cultivars which were affecded by excess B treatments were in following order Nazilli 39> Nazilli-503> Nazilli 143> STN 8A> Nazilli 342> Barut 2005> Gürel Bey> Gossipolsüz Nazilli.

Table 4. Relationship between B rates and dry matter yield and its parameters

Cultivars	Slope	Intercept	R^2
Barut 2005	-0.058	2.276	0.94
Gossipolsüz Nazilli	-0.050	1.929	0.99
Gürel Bey	-0.052	1.820	0.88
Nazilli 143	-0.072	2.228	0.98
Nazilli 342	-0.060	1.645	0.88
Nazilli 39	-0.108	2.645	0.98
Nazilli-503	-0.076	2.560	0.95
STN 8A	-0.067	1.720	0.92

The results presented here indicate that shoot and leaf concentrations of B can be used in screening cotton cultivars under greenhouse conditions for B tolerance. Plant biomass was also very significantly correlated B doses, suggesting that plant biomass under B toxicity can also be a reliable criterion in distinguishing genotypes for their tolerance to B toxicity.

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A Study on the Differential Response of Malting Barley Genotypes to Boron Toxicity

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ABSTRACT

A field experiment was carried out to study the differential response of eight malting barley genotypes to boron toxicity in Aydın, Turkey. Genotypes were grown with and without the application of 40 kg B ha^{-1}. Total dry matter yield, grain yield and boron concentration of roots, stems, leaves and ears were determined. Boron application resulted in toxicity symptoms at the flag leaves and reduced total dry matter and grain yield as 12.2% and 30.5%. Line 7 gave both the lowest yield reduction and toxicity reading score. In soils both with and without added boron, boron concentrations from the lowest to the highest were determined as ear, stem root and leaf, respectively. When boron was added to the soils, boron concentration of root, stem and leaf were found to be different from each. Applying excess amount of B to the soil resulted in dramatic increases in B concentration of plant parts, demonstrating that cultivars have different abilities to accumulate B if the supply in the soil is too high. In general, line 7 was found as the most tolerant to B toxicity. Another conclusion drown leaf symptom scoring for B tolerance was more reliable than measuring plant boron concentrations.

Key words: Boron, malting barley, genotypes, tolerance

INTRODUCTION

Boron is an essential trace element required for normal growth of plants. But, plants vary in their B requirement. The range between deficient and toxic soil solution concentrations of B is smaller than for any of other nutrient element. In arid and semi-arid areas, B toxicity results from high levels of B in soils and from additions of B via the irrigation water (Marschner, 1995; Nable et al., 1997). Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. For example, there are 20 geotermal areas in The Büyük Menderes River Basin of Turkey (Akar, 2007).

A 17% difference in the grain yield of adjacent areas of barley (cv Clipper) was related to differences in the concentration of boron in shoots just prior to anthesis (Cartwright et al. 1984). Soil amelioration of boron toxicity appears to be impractical. Toxic effects are more marked in dry seasons, when roots penetrate deeper into the soil. Excess B can not be removed from soil or treated in any way under dry-land farming conditions. Therefore, use of tolerant crop varieties is the best option to overcome this problem. Tolerance to B toxicity operates not only at the whole-plant level but also at the organ and cellular level. For example, susceptibility to B toxicity is expressed among barley genotypes at either the whole plant or organ or cellular level (Kalayci et al., 1998; Torun et al., 2003).

Of the plant parameters studied for assessing B-tolerant genotypes controversial results have been reported especially in use of B concentration in plants (Nable et al., 1997) Critical toxic concentrations of B in barley plant tissues were found to vary from approximately 2 to 15 µg/g for grain and from approximately 50 to 420 µg/g for shoot (Riley and Robson, 1994). Shoot reflect well the extent of genotypic variation in barley for tolerance to B toxicity (Nable, 1998). Mahalakshmi et al., 1995 reported that shoot concentration of B is not useful parameter for distinguishing genotypes for their tolerance to B toxicity. There is few published research on malting barley relating with boron. The objectives of this study were to investigate the differential response of eight malting barley genotypes to boron toxicity and B distribution in the plant parts grown in field conditions.

MATERIALS and METHODS

Four malting barley cultivars and 4 advanced lines (Table 1) were grown under rainfed conditions at the Aydın, Turkey in 2004-2005 growing season. Water-extractable B in the 0-30 cm soil was 0.42 mg B kg^{-1}. Other properties of the soil at the 0–30 cm were as follows: soil texture loamy, $CaCO_3$ 25 g kg^{-1}, pH (H_2O) 7.7 and organic matter 12 g kg^{-1}. Plants were grown with 100 kg Borax ha^{-1} (+B) and without (-B) boron applications. Borax containing 11% B was applied onto soil surface and introduced into the soil by disc-plough just before planting.

Table 1. List of genotypes used in the experiment

No	Name	Code of lines
1	Akhisar	
2	Süleyman Bey	
3	Şerife Hanım	
4	Kaya	
5	Line 1	F-10-2001
6	Line 2	MÇTB-2001/177/1
7	Line 3	Arupo/K8755// Mora/3/Cerise/Shyria//Alepo/4…
8	Line 4	MB 2000/13-9

Experimental layout was a split plot design with four replications where main plots were B treatments, and subplots were genotypes. Plot sizes were 6 m^2 (1.2*5 m). Sowing was done in December with a seeding rate of 450 seeds m^{-2}. At planting 60 kg P_2O_5 ha^{-1} and 23 kg N ha^{-1} were applied in the form of diammonium phosphate, and 50 kg N ha^{-1} was top-dressed as ammonium nitrate at the tillering stage in late February. Shoot damage readings were taken using a 1-5 scale (1 = tolerant, 5 = highly sensitive). Boron content was determined after digestion of dried and milled plant material with 6 M H_2SO_4 and H_2O_2 (Wolf, 1982). To determine the B concentrations in the plant parts, the azomethine-H^+ method was followed using spectrophotometry at 410 nm (Wolf, 1974).

RESULTS and DISCUSSION

Boron Reading Score, Shoot Dry Matter and Grain Yield

Malting barley cultivars differed in severity of leaf symptoms of B toxicity when grown in the toxic level B applied. The toxicity symptons, reddish-brown necrotic spots along the margins of flag leaves, became more apparent in the heading stage , being most severe in Akhisar and Şerife Hanım and least severe in Line 3 and Kaya (Table 2).

Shoot dry matter production and grain yield were affected by cultivar and B treatment and there were an interaction between them. Boron application resulted in decreases in shoot dry matter production and grain yield as an average 30% and 8.3%, respectively. The decreases by +B treatment ranged from 1.7% to 38.4% for dry matter yield and from 1.7% to 25.3% for grain yield. Interestingly line 3 gave the highest dry matter production and grain yield when grown in +B. When the response of individual genotypes studied, genotypes behaving similarly in both shoot dry matter and grain yields were found. In case of grain yield, Line 3 was superior genotype in both –B and +B conditions. The results in Table 2 indicate that line 3 and Line 1 seem to be more tolerant to B toxicity while Akhisar is highly susceptible. These results were similar to Torun et al. (2003) and Rehman et al. (2006) who studied genotypic variation in tolerance to B toxicity.

Table 2. The effect of B application on the B reading score, shoot dry matter and grain yield of malting barley cultivars

Genotypes	Leaf symptom scores +B	Shoot dry matter (kg ha^{-1})			Grain yield (kg ha^{-1})		
		-B	+B	Decreases (%)	-B	+B	Decreases (%)
Akhisar	4.1a	5417a	3409c	37.1	3300b	2732bc	17.2
Süleyman Bey	3.7ab	5778a	3937b	31.9	3900a	3502a	10.2
Şerife Hanım	3.5b	5752a	3543bc	38.4	3420b	2940b	14.0
Kaya	2.9c	4333c	3632b	16.2	2975d	2223c	25.3
Line 1	3.3bc	4889b	4396c	10.1	3850a	3625a	5.8
Line 2	3.1bc	5000b	4048ab	19.0	2503c	2339c	6.6
Line 3	1.0d	4500c	4425a	1.7	4000a	3932a	1.7
Line 4	3.6ab	5000b	3923b	21.5	3060b	2782bc	9.1
Average		5376	3733	30.0	3493	3218	8.3
Genotypes (G)	**		**			*	
Boron (B)			*			**	
(GxB) int.			**			*	

Boron Concentrations of Roots, Stems, Flag Leaf and Grain

Boron concentration in the root at harvest was affected by cultivar and B treatment ($P<0.01$). In treatment –B, there were no significant differences among the cultivars and their B the concentrations ranged from 20 to 26 mg B kg^{-1}. In treatment +B, the differences were much greater (75-113 mg B kg^{-1}), demonstrating that cultivars have different abilities to accumulate to accumulate B if the supply in the soil is too high. Increases in B concentrations was maximum for Süleyman Bey and minimum for line 3 (Table 3). Root B concentrations in -B and +B were similar with the nutrient solution experiment reported by Kalayci et. al., 1998.

Boron concentration in the stem at harvest was affected by cultivar and B treatments ($P<0.01$). In treatment –B, the range of the concentrations were too small (5.46-6.56 mg B kg^{-1}). In treatment +B, the differences were much greater (16.5-36.4 mg B kg^{-1}). Increases in B concentrations was maximum for Süleyman Bey and minimum for Kaya (Table 3).

Table 3. The effect of B application on the boron concentrations of roots and stems

Genotypes	Root			Stem		
	-B	+B	Increases (%)	-B	+B	Increases (%)
Akhisar	20a	108a	433	6.24a	36.4a	483
Süleyman Bey	20a	113a	459	5.46a	16.5c	202
Şerife Hanım	21a	112a	449	6.51a	26.4b	306
Kaya	25a	87bc	243	6.22a	17.9c	187
Line 1	19a	75c	298	6.17a	30.5ab	394
Line 2	20a	95b	368	5.67a	22.6b	299
Line 3	26a	105a	297	5.63a	32.3ab	474
Line 4	22a	106a	372	6.56a	27.1b	313
Genotypes (G)	**			**		
Boron (B)	**			**		
(GxB) int.	**			**		

Boron concentration in the flag leaf at harvest was affected by cultivar and B treatment ($P<0.01$). In treatment –B, there were no significant differences amongst cultivars although the concentrations ranged from 24 to 30 mg B kg^{-1}. In treatment +B, the differences were much greater 69-144 mg B kg^{-1}. Increases in B concentrations was maximum for Akhisar and minimum for line Line 3 (Table 4). Nable et al. (1997) reported that shoot growth is reduced when shoot B concentrations are excess of 120 mg kg^{-1} dry weight. In pot experiment critical toxicity concentrations of B in barley shoot varied between 40 and 150 mg kg^{-1} dry weight (Riley et al., 1994).

Boron concentration in the grain was affected by cultivar and B treatment (P<0.01). In treatment –B, there were no significant differences amongst cultivars although the concentrations ranged from 2.45 to 3.12 mg B kg^{-1}. In treatment B^{+}, the differences were much greater 11.1-18.5 mg B kg^{-1}. Increases in B concentrations was maximum for Akhisar and minimum for Line 3 (Table 4). Critical toxic concentrations of B in barley grain were found to vary from approximately 2 to 15 µg g^{-1} (Riley and Robson, 1994) which was similar with +B treatment of present experiment.

Table 4. The effect of B application on the boron concentrations of flag leaf and grain

Genotypes	Flag leaf			Grain		
	-B	+B	Increases (%)	-B	+B	Increases (%)
Akhisar	25a	182a	617	2.50a	18.5a	640
Süleyman Bey	24a	116b	378	2.73a	14.7b	439
Şerife Hanım	24a	106c	336	2.45a	13.4b	447
Kaya	26a	94cb	267	2.64a	11.1c	319
Line 1	28a	83c	201	3.12a	16.5ab	428
Line 2	25a	124b	397	2.94a	15.7b	435
Line 3.	30a	69c	133	3.02a	11.3bc	275
Line 4	29a	144b	401	2.53a	12.3bc	388
Genotypes (G)		**			*	
Boron (B)		**			*	
(GxB) int.		**			*	

Boron concentrations of in the analyzed plant parts were not differed among the cultivars in control treatment. Applying excess amount of B to the soil resulted in dramatic increases in B concentration of plant parts, demonstrating that cultivars have different abilities to accumulate to accumulate B if the supply in the soil is too high. In general, these increases were maximum for Line 3 (in leaf and grain) and Kaya (in root and stem) and maximum for Akhisar.

Correlation coefficients between dry matter yield reductions (%) by +B and different parameters were presented in Table 5. Flag leaf symptom scores, flag leaf B concentration in -B and +B gave the highest correlation with dry matter yield reductions (%) by +B as correlation coefficient of 0.797*, -0.745* and 0.689*, respectively. Low the dry matter reduction (%) by +B could be attributed to the lower toxicity symptoms score of leaf blade and the lower flag leaf B concentration in +B and the higher flag leaf B concentration in -B. Similar results were reported by Kalayci et al., (1998) who also concluded that leaf symptom scoring to B tolerance was more reliable than measuring plant boron concentrations. Jenkin (1993) assessed differences in both grain yield and leaf symptoms in three populations derived from crosses between tolerant and intolerant parents grown on soil high in boron concentration and yet found no consistent relationship between leaf-symptom expression and grain-yield response.

The results presented here indicate that among the genotypes line 7 is the most tolerant to B toxicity. Further researches should be carried with Line 7. Leaf symptom scoring for B tolerance is more reliable than measuring plant boron concentrations.

Table 5. Correlation with dry matter yield reductions (%) by B^+ and different parameters

	Correlation coefficient	
Parameters	-B	+B
Root B concentration	-0,537ns	+0,604
Stem B concentration	0.304ns	-0,087ns
Flag leaf B concentration	-0,745*	0,689*
Grain B concentration	0.303ns	-0.087ns
Flag leaf symptom scores		0.797*

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Effects of Drinking Water Treatment Sludge on Crop Quality of *Zea mays L.*

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ABSTRACT

This research was conducted to evaluate effects of drinking water treatment sludge on crop quality. In this trial *Zea mays L.* (pioneer 32 w 86) was used, and the research was planned according to random blocks sampling design with three replicates. Increased amount of sludge, as of 0, 1, 2, 3, 4 t da^{-1}, was applied on blocks. *Zea mays L.* seeds were sewed between rows within a distance of 65 cm, and on rows within a distance of 25 cm. Blocks were irrigated to stimulate germination during dry conditions. When the numbers of leaves were reached 8, 10 kg da^{-1} of N fertilizer was applied. Plant length, first corncob height, corncob length, corncob diameter and number of corncob were observed and measured using randomly selected 10 plants from each block. As a result, the highest plant length, 206.97 cm, was found on blocks of control. The lowest plant length 189.76 cm was found on blocks with 1 t da^{-1}. The highest first corncob height, 85.62 cm, was found on blocks with 1 t da^{-1} sludge applied. The lowest first corncob height, 82.09 cm, was found on blocks with 4 t da^{-1} sludge applied. Average of the highest corncob number 1.23 was found on blocks with 4 t da^{-1} sludge applied. Average of the lowest corncob number 1.03 was found on blocks with 1 t da^{-1} sludge applied. The highest corncob length 22.08 cm was found on blocks with 2 t da^{-1} sludge applied. The lowest corncob length 19.94 cm was found on blocks with 3 t da^{-1} sludge applied. The highest corncob diameter 4.15 cm was found on blocks with 0 t da^{-1} sludge applied. The lowest corncob diameter 3.86 cm was found on blocks with 1 t da^{-1} sludge applied.

Key Words: Water Treatment Sludge, *Zea mays L*, Soil

INTRODUCTION

Plant Corn (*Zea mays L.* 2n=20) has a great importance in the World and in Turkey to produce sufficient amount of plant based proteins, economically. In addition, corn production also supports animal based protein production. Starch, Glucose and corn oil produced from corn kernels are sources for industrial raw materials. Turkey is ranked as the 7th place in corn production based on 585.000 ha growing area, 2.5 million ton yr^{-1} corn production and 425 kg ha^{-1} corn kernel production (Süzer, 2005). Areas used for corn production have been increased due to their usage for silage. The best variety of corn for silage should have some properties like long height, higher leaf number and leaf ratio, high corncob weight and less stem diameter (Anonymous, 2005). Suitable fertilizer and soil amendment use are important for high quality corn production and earliness. Recently, application of water treatment sludge on farm soils has been widely used. Use of water treatment sludge in agriculture is becoming beneficial for plant nutrition, and aids getting rid of recovery material like sludge of treatment facilities (Kocaer et al., 2003). The quality of sludge is important if being used for agricultural purposes. Farmers and related authorities should be encouraged to use sludge of domestic

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and food industries on agricultural purposes. Decision making should be used according to regulations (Kocaer and Başkaya, 2001). During the process of water treatment facilities, treated water was release to environment and bulk amount of sludge has been stocked. Discarding the treatment sludge has been problem economically and environmentally. Current methodology for discarding sludge is inefficient. Hence, development of new methods is inevitable. For more than 20 years, discarding sludge by application on agricultural lands has been accepted as an economic way. But, the quality of sludge measured by its pH, EC, heavy metal and toxic substances content was limits its application on agricultural areas (Topçuoğlu et al., 2003).

In this research, effects of drinking water treatment sludge on corn plant and some properties of corncob were investigated. To eliminate edge effects, plants on edges were discarded.

MATERIAL and METHODS

This trial was conducted in the field of Arslanbey Vocational School, Kocaeli University, in 2005. In the study Corn variety Pioneer 32 W 86 was used. This variety has been used as silage and cips industry due to its long length. Texture components of soil used in this trial were 37.53% sand, 25.07% clay and 37.40% silt. Total carbonate was 2.05%, pH was 7.3 and ECx10^3 was 0.13 mS cm^{-1}. Organic matter content of trial soil was 5.59% and nitrogen content was 0.28 %. Trial was conducted based on the random blocks sampling design with three replicates. Increased amount of sludge, as of 0, 1, 2, 3, 4 t da^{-1}, was applied on blocks. Sludge applied on blocks was supplied from Kocaeli city drinking water treatment facilities. This facility has 480.000 m^3 day^{-1} and minimum 300.000 m^3 day^{-1} water treatment capacity. The main technology used in water treatment systems contain filters, clarifiers and flock blankets. Heavy metal contents of sludge were measured by Laboratory of Chemistry and Environmental Institute, TUBITAK. Based on the heavy metal content of sludge, measured in Lab., concentration level of heavy metal contents were among the ranges allowed by Soil Contamination and Control Regulations, appendix I-B: Allowable limits of heavy metal concentrations in stabilized treatment sludge used in soils (Anonymous, 2005). *Zea mays L.* seeds were sewed between rows, each block having 4 rows, within a distance of 65 cm, and on rows within a distance of 25 cm. Blocks were irrigated to stimulate germination during dry conditions. For germination and for early growing periods, until plants were reaching the length of 40-50 cm, sprinkler irrigation, and when plants were taller for sprinkler irrigation, furrow irrigation were applied. When the numbers of leaves were reached 8, 10 kg da^{-1} of N fertilizer was applied. In addition, soils between rows and on rows were cultivated with hoe. Ten plants were randomly selected, and observations and measurements were conducted with selected plants. Plant length (distance between soil surface and node which corn tassel occurred), first corncob height (distance between soil surface and node which firs corncob occurred), corncob length, corncob diameter and number of corncob for each plant were measured and determined.

Data of the research were evaluated statistically using SPSS program.

RESULTS

Some chemical properties of Water Treatment Sludge, and effects of increased amount of sludge applied to soil on some quality properties of corn plant were given in Table1 and Table 2.

Table 1. Some chemical properties of water treatment sludge.

pH (1:2.5)	EC dS m^{-1} (1:2.5)	Organic Matter (%)	$CaCO_3$ (%)	N (%)	Available P mg kg^{-1}	Available K mg kg^{-1}
8.03	1.88	24	4.33	1.63	265	1089

Table 2. Effects of increased amount of sludge applied on some quality properties of corn plant.

Sludge doses applied (t da^{-1})	Plant length (cm)	First corncob height (cm)	Number of corncob for each plant	Corncob length (cm)	Corncob diameter (cm)
Control	206.97	83.10	1.06	20.5	4.15
1	189.76	85.62	1.03	20.4	3.86
2	208.80	84.22	1.10	22.08	4.04
3	190.76	85.28	1.10	19.94	3.92
4	195.23	82.09	1.23	21.21	4.03

Effects of sludge doses on plant length were given in Fig.1. As of the average value of replicates, plant lengths varied between 189.76 cm and 208.80 cm. Average plant length was 206.97 cm for control blocks. There is no important trend found between sludge applications, statistically. There are no steady changes observed on plant length due to the increased amount of sludge applications.

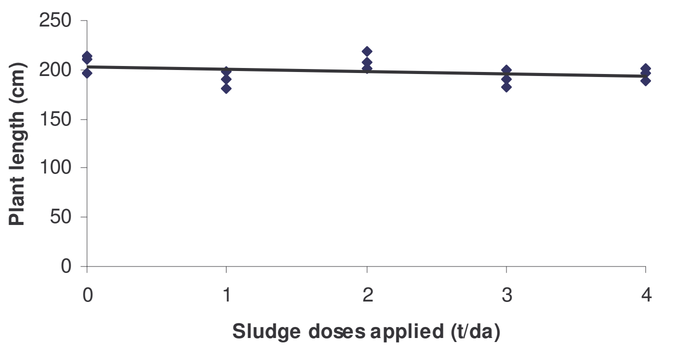

Figure 1. Effects of water treatment sludge doses on plant length.

Effects of increase amount of sludge doses on first corncob height of corn plant were given in Fig. 2. First corncob heights were increased with doses 1t da^{-1}, 2 t da^{-1} and 3 t da^{-1} sludge applied, and decreased with dose of 4 t da^{-1} sludge applied compared to control treatment. The highest value 85.62 cm and lowest value 82.09 were found for the treatments 1 t da^{-1} and 4 t da^{-1} sludge applications, orderly. However, there is no significance was found among treatment blocks, statistically.

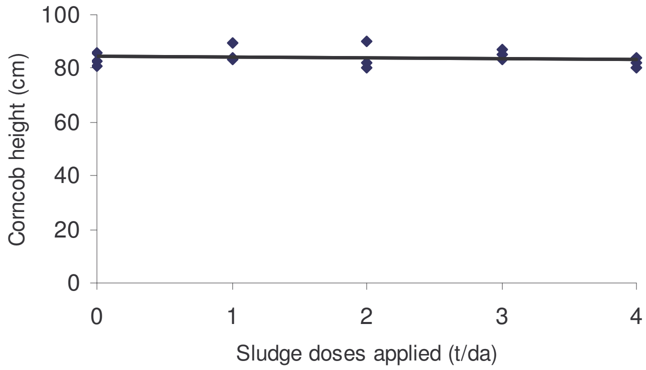

Figure 2. Effects of water treatment sludge doses on first corncob height of corn plant.

Effects of increase amount of sludge doses on corncob number of corn plant were given in Fig. 3. Although, there is significant relations found between sludge doses and corncob number, evaluation of Fig. 3 showed that highest number 1.23 and lowest number 1.03 were found on blocks where 4 t da^{-1} and 1 t da^{-1} of water treatment sludge applied, accordingly.

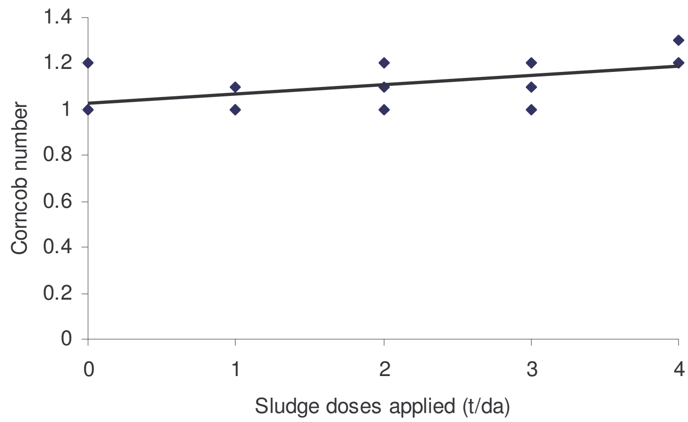

Figure 3. Effects of water treatment sludge doses on corncob number

Effects of sludge doses on corncob length were given in Fig. 4. Evaluation of Fig. 4 showed that the highest corncob length 22.08 cm was found on blocks 2 t da^{-1} of sludge applied, and the lowest corncob length 19.94 cm was found on block 3 t da^{-1} sludge applied on. The value found for control treatment was 20.05 cm. However differences among treatments were not found significant, statistically.

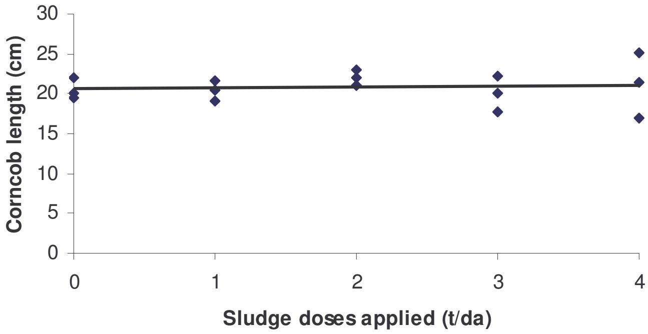

Figure 4. Effects of water treatment sludge doses on corncob length.

In fig. 5, effects of sludge doses on corncob diameter were given. The highest corncob diameter 4.15 cm and the lowest corncob diameter 3.86 were found for control treatment and 1 t da^{-1} sludge application. But there was no significances found among treatments considering corncob diameter.

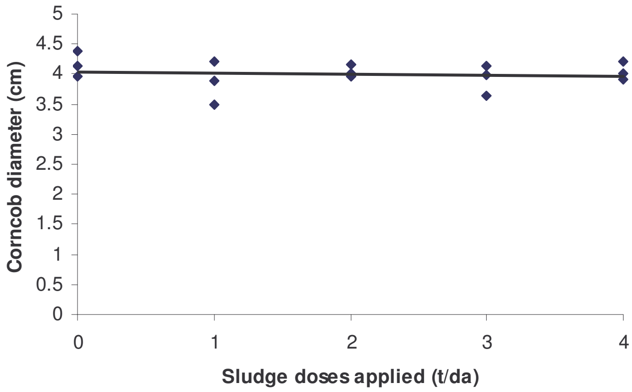

Figure 5. Effects of water treatment sludge doses on corncob diameter.

DISCUSSION and SUGGESTIONS

There are varieties of results of conducted researches related to application of water treatment sludge on soils. The research conducted by Cimrin et al. (2000) was focused on use of municipal treatment sludge in agricultural fields as a phosphorus sources. The results showed that sludge applications increased the phosphorus content of corn pant compared to control while increase in sludge portion in combination of TSP and Sludge decreased the phosphorus content of corn plant. This decrease was found statistically not significant. Topcuoglu et al. concluded that one of the main topics is increase in heavy metal content of tomato plant its mineral content when treatment sludge applied to soil repeatedly. The heavy metal contents were found higher in the second year of the work than the first year of the work (Topçuoğlu et al., 2003). Bozkurt et al. searched effects of sludge application on yield, growth, nutrition content and heavy metal content of apple trees. It is found that there were no significant differences statistically between the sludge and manure applications and leaf mineral content, and trunk development. They also reported that long time use of sludge repeatedly may cause increase in heavy metal accumulation in soils and in plants more than the limits allowed by regulations (Bozkurt and Yarılgaç, 2003). Sensoy, in his work, observed that there were positive effects of municipal treatment sludge, applied to soil, on emergence and seedling growth of cucumber (Şensoy, 2001). Villaroel et al., stated that phosphorus and heavy metal content of plant increased several times after application of sludge, 8 years repeatedly (Villaroel et al., 1993). In this research, effects of drinking water treatment sludge applied to soil with increased doses on corn plant and some quality properties of corncob were investigated. Based on the results there were no significant quality increases found among sludge treatments. In addition there were no significant differences found, statistically. According to results derived from the research, these suggestions can be made: Organic matter content is become important for application of sludge in agricultural field. Water treatment sludge can be used as soil amendment to increase soil organic matter content. Even heavy metal content of sludge is less than the limit allowed by the regulation; due to the application of sludge repeatedly heavy metal content of soil and plant may be increased for later times. Due to the fact that, sludge should not be used in agricultural fields where plant grown for human demand or food. However, piling sludge on fields as a way of discard has cause environmental problems.

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Nitrate Uptake and Assimilation Efficiency of Excised Leaves of Barely (C3) and Maize (C4) Plants. I) Effect of Temperature on Nitrate Uptake and Assimilation

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ABSTRACT
Nutrient assimilation by seedling is an early indicator of subsequent plant growth and development. This study was conducted to compare the effect of temperature on NO3 uptake and reduction by excised leaves of Barley (C3) and Maize (C4) plants with and without source of energy supply. The seedling Barley (Hordeum Vulgare L.CV UC 337) and Maize (Zea Mays L.CV pioneer 3162) were sown in vermiculate in pots kepts in growth chamber at 25°C. The tip 10 cm portion of leaves excised and placed in small glass vials containing 8 ml from,3.0,6.0 and10 mM of KNO3 solution with and without sucrose. The temperature treatments were 15,20,25,30 and 35°C. Net NO3 uptake were determined by following it`s depletion from uptake solution that initially contained the same concentration of NO3 as the induction solution. NO3 uptake by both C4 and C3 leaves was increased as NO3 level and temperature increased. While C3 leaves(Barley) was more efficient than C4 leaves (Maize) in NO3 uptake at all NO3 concentration for NO3 reduction percent (assimilation),C4 (Maize) leaves were efficience than C3 (Barley) plants, and NO3 reduction percent increase with increasing the temperature until 25°C then decreased. The addition of sucrose by 1% to the medium as energy source increased the NO3 reduction percent in both C3 and C4 leaves.

INTRODUCTION

NO3 uptake & accumulation are influenced by many environmental factors as respiration (Willis & Yemm ,1955) , and strongly affected by temperature (Ezeta & Jackson 1975).Nitrate accumulation in plant tissues is response to increasing ambient nitrate concentrations (Chamtarotwong et al ,1976). Nitrate uptake affected by low light (Cantliffe ,1972). Also NO3 uptake & reduction by plants differed from (C3) plants to (C4) plants,plants with C4 (Maize) photosynthesis produce more dry matter per mg nitrogen utilized than plants with C3 (Barley) metabolism (Brown, 1978).Oaks(1994) pointed out that uptake of nitrate as also it`s accumulation was greater in Barley than in Maize. While conversion of of NO3 –N to protein –N was greater in Maize. Lawlor et al (1980) found that leaves grown at the lower temperature, especially with more nitrate , contained much more soluble protein,nitrate reductase & free amino acids per leaf unit area than plants grown in warmer conditions. High temperature affect photosynthesis by altering the excitalion energy distribution by chaning the structure of thylakoids (Berry & Bjorkman 1980),and by chaning the activity of the calvin cycle and other processes such as photorespiration and product synthesis.Also the changes in temperature induce variations in the activity of enzymes & that because of their different Q10 values (Pollock & Rees,1975).

The aims of this work was to study the effects of ambient nitrate concentration, temperature & the addition of sucrose on the processes of nitrate uptake & reduction by Barley (C3) and Maize (C4) plants.

MATERIALS and METHODS

Barley (Hordeum Vulgare L.CV.337) and Maize (Zea maize L.CV. Pioneer 3162) seeds were sown in vermiculite as growth media in pots. The pots kept in growth chamber at 25°C in the darkness for 7 days & then in continous light (500 U.E m 25-1) for anther 3 days. During the light period, plants were irrigated with N-free, one fourth strength Hoaglan nutrients solution (Hoagland & Arnon ,1950). The seedlings were irrigated with 10 uM potassium nitrate ,24 h prior to the experiments. The tip 10.0cm portion of leaves were excised & placed in small glass vials containing 8.0ml of NO3 as K NO3 (without and with sucrose) ,kept in growth chamber in light and different temperature treatments 15,20,25,30 and 35°C . After 8.0 h uptake period, leaves were removed from the solution, rinsed in water & frozen until NO3 extracted. In vivo nitrate reduction was determined by subtracting the amount of nitrate present in the leaves from that disappeared from vial. Nitrate from excised leaves was extracted by grinding the tissues in mortar & pestle in liquid nitrogen, adding deionized water and centrifugation at 10.000 RPM for 10 minutes. The nitrate in solution was determined using HPLC. In vivo reduction was determined by subtracting the nitrate concentration of the tissue at time (t) from the initial nitrate concentration of the tissues at time (t0) plus the amount of nitrate taken up (Chantarotwong et al,1976). PH did not change significantly during the experiments. Each treatment contained three replicates, and each experiment was replicated three times. The results of the three experiments were then combined for statistical analysis.

RESULTS

NO3 **Uptake**

Response curves of NO3 uptake , reduction & reduction percent to increasing concentrations of ambient nitrate constructed for seedling equilibrated in a solution of 0.1 mM for 24 hr. before uptake studies began [Table (1),Figure(1&2)]. Nitrate uptake was linear with increasing NO3 ambient concentration with all temperature treatments in both Barley & Maize plants . NO3 uptake was higher in Barley than Maize at all NO3 ambient concentration. (OAKS et al,1994) found that NO3 uptake was higher in Barley than Maize. For sucrose addition to the nutrient solution [Table (2), figure (3&4)] , the data shows that this addition increased NO3 uptake only with high ambient concentration,especially in corn plants. [Table (1), figure (1&2)] show's that increasing the temperature increased the NO3 uptake in both plants. This relation is more clear in Barley than Maize but increasing the temperature over 30 C the NO3 uptake in Barley decreased . Since nitrate uptake are largely dependent upon respiration, their response to increasing temperature as expected.

NO3 **Reduction**

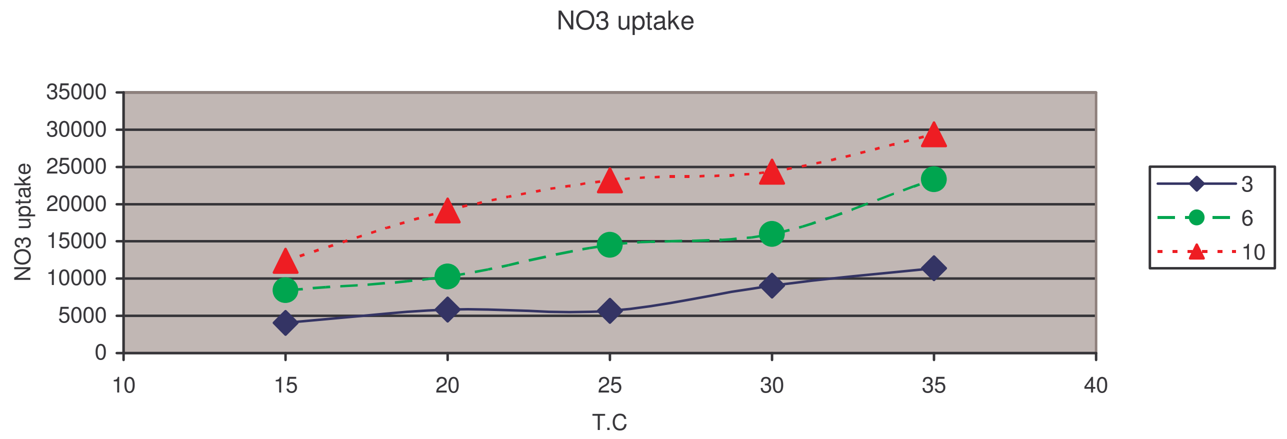
In Vivo,reduction was determined by subtracting the nitrate concentration of the tissues at time (t) from the initial nitrate concentration of tissues at time (t0) plus the amount of nitrate taken up(Chantarotwong et al,1976). The data presented in [Table (1), figure (1&2)] shows that NO3 reduction increased with increasing ambient NO3 concentration .Also the values of NO3 reduction were higher in Maize than Barley leaves. For the effect of temperature , in Maize leaves NO3 reduction increased with increasing the temperature at all NO3 levels , while in Barley NO3 reduction increased with increasing the temperature until 25 C,while increasing the temperature over 25 C the NO3 reduction increased . For sucrose treatment [Table (2),figure (3&4)] , the data shows that in Maize the effect of sucrose on increasing NO3 reduction was observed in low concecntration (3 mM). while in Barley it's increased NO3 reduction in high concentration (6,10 mM)

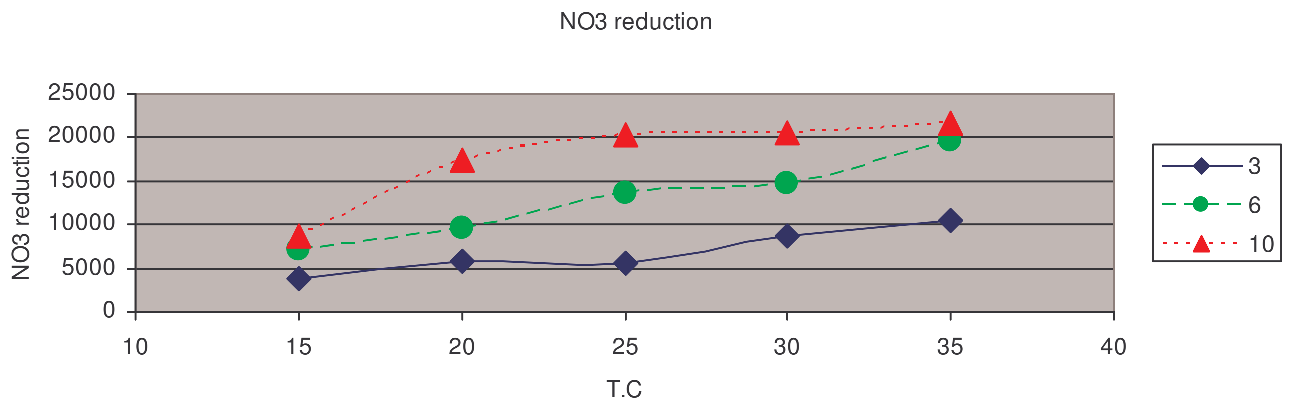
NO3 **Reduction Percent (%) :**

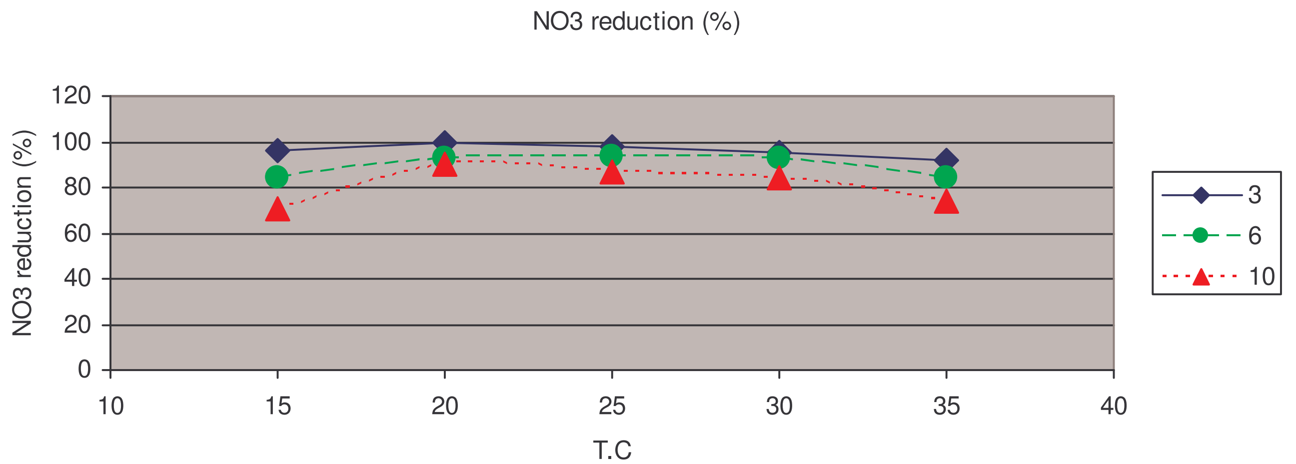
In both Maize and Barley leaves, increasing ambient NO3 concentration decreased the percentage of NO3 reduction (with or without sucrose). For effect of temperature on NO3 reduction percent,increasing temperature until 25°C increased reduction percent,while increasing temperature over 25°C caused a decrease in NO3 reduction percent in both Barley and Maize plants [Table (1),figure (1&2)].This effect of high temperature is more pounced in Barley than Maize leaves. This effect due to the effect of high temperature on nitrate reductase enzyme. Also Brown,1978 found that plants with C4 photosynthesis produce more dry matter per mg nitrogen utilized than plants with C3 metabolism. It has been recently reported in spite of a saturating N supply, the youngest mature leaves of Corn contained little of NO3 reserve (Foyer et al 1998)

Table (1) effect of NO3 concentration & temperature on NO3 uptake,reduction & reduction (%)

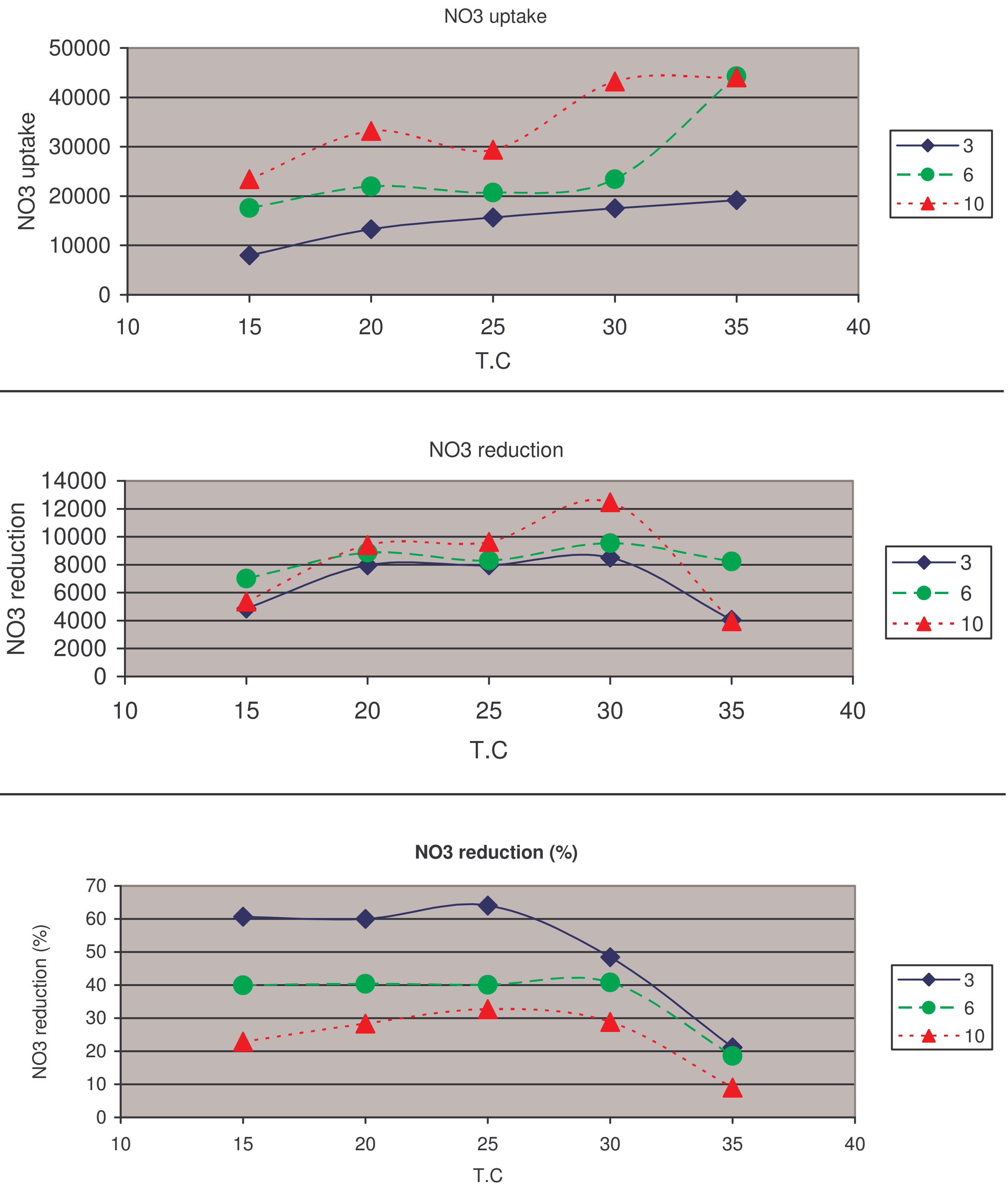
NO3 Conc.(m.mole)	T.C°	Corn			Barley		
		NO3 uptake uM	NO3 red.	NO3 red. (%)	NO3 uptake uM	NO3 red.	NO3 red. (%)
3.0	15.0	4028.5	3861	95.84	8010.9	4861	60.68
	20.0	5842	5821	99.64	13271	7961	60.03
	25.0	5685	5588	98.29	15669	7967	64.06
	30.0	9056	8619	95.17	17550	8500	48.43
	35.0	11395	10437	91.59	19154	4056	21.17
6.0	15.0	8439.3	7137	84.57	17571.9	7013	39.91
	20.0	10258	9521	92.82	21967	8871	40.38
	25.0	14535	13549	93.21	20699	8294	40.07
	30.0	15958	14823	92.89	23423	9547	40.76
	35.0	23332	19637	84.16	44253	8225	18.59
10.0	15.0	12389	8773	70.81	23402	5351	22.87
	20.0	19137	17333	90.57	33173	9413	28.37
	25.0	23182	20219	87.21	29407	9634	32.76
	30.0	24342	20512	84.27	43191	12471	28.87
	35.0	29386	21710	73.88	44016	3965	9.01







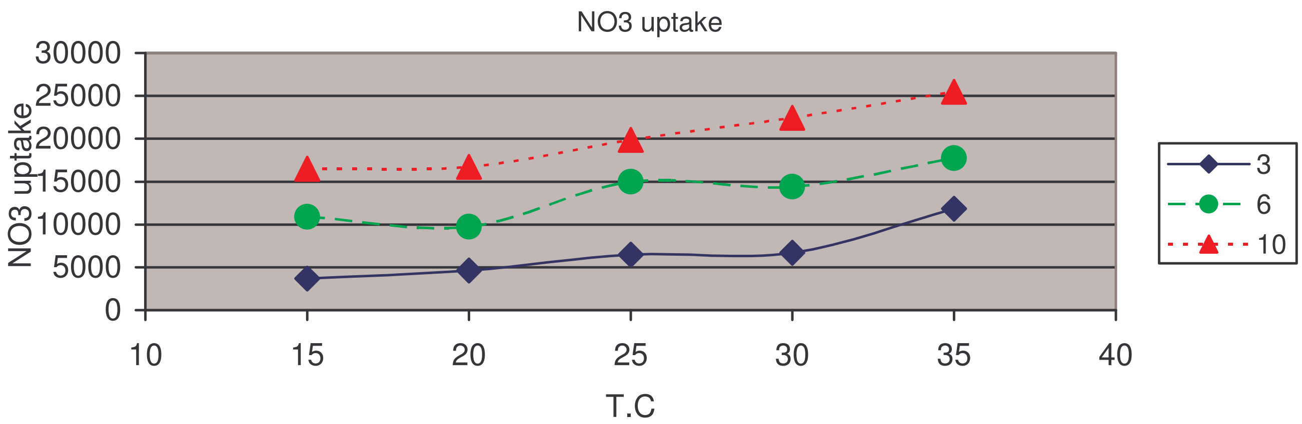
Fig(1) effect of NO3 concentration & temperature on NO3 uptake , reduction & reduction (%) of Corn plant

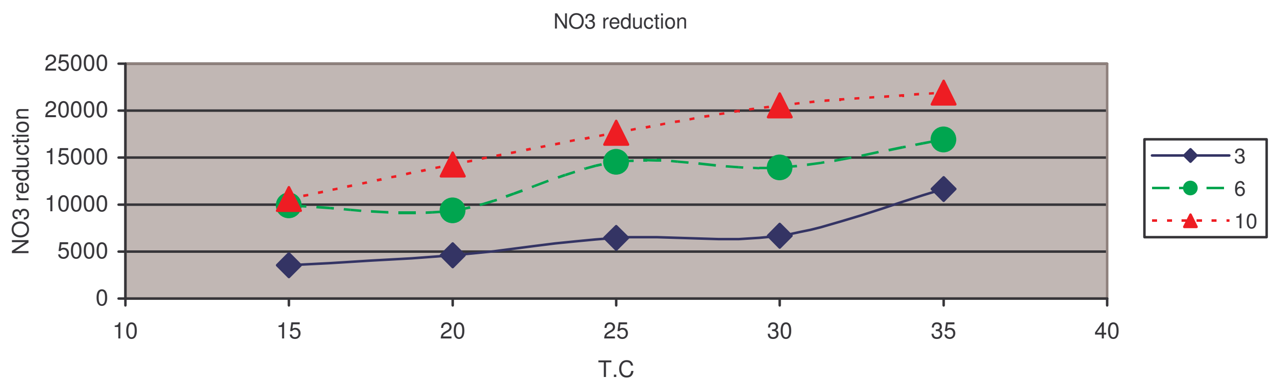


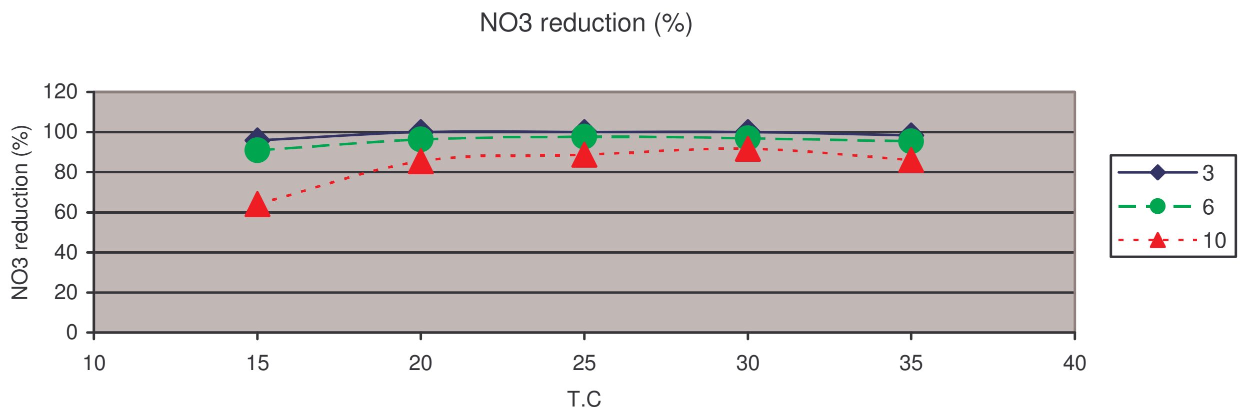
Fig(2) effect of NO3 concentration & temperature on NO3 uptake , reduction & reduction (%) of Barley plant

Table (2) effect of NO3 concentration & temperature & sugar(1%) on NO3 uptake , reduction & reduction (%)

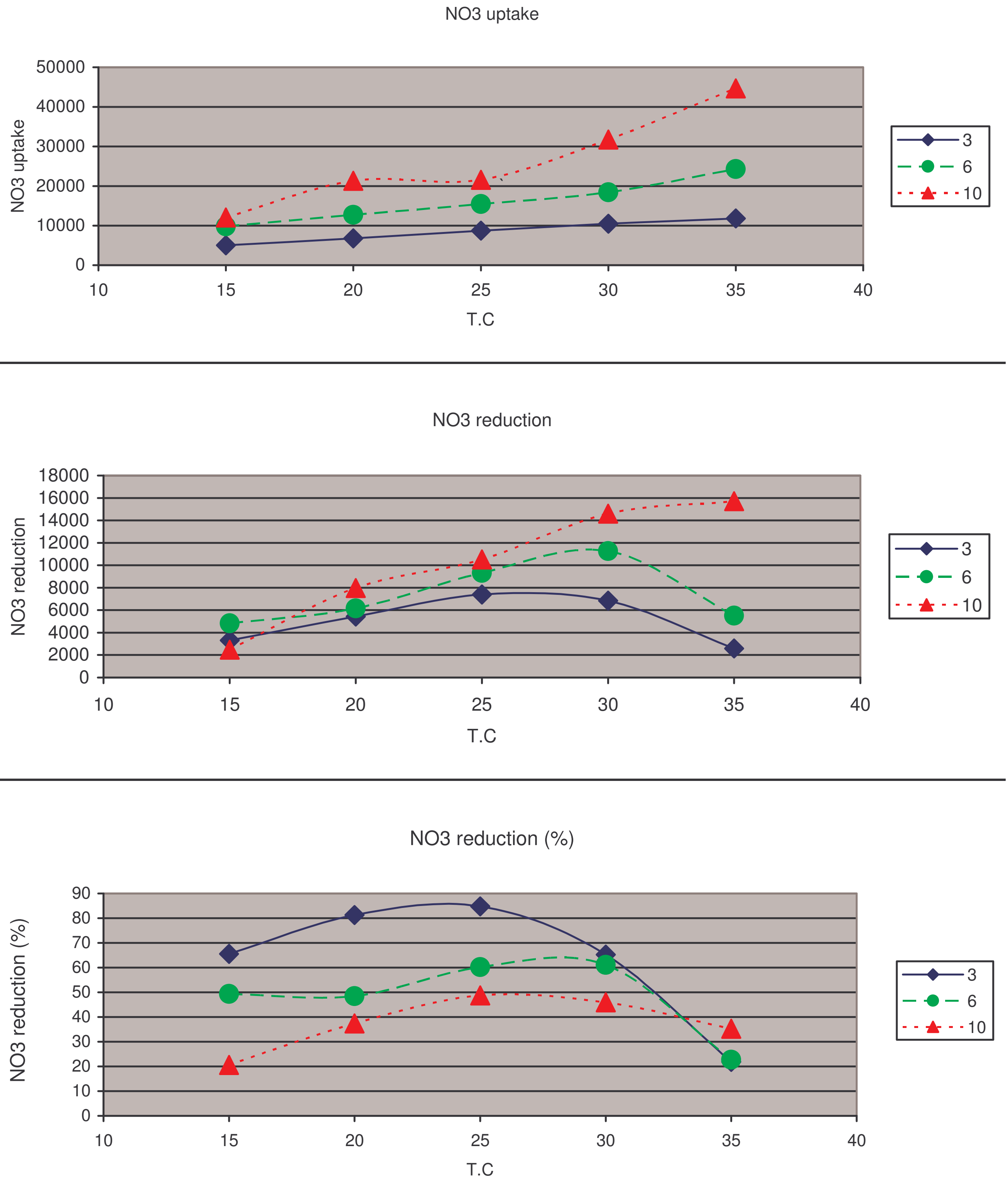
Suc(%)	NO3.Conc(m. mole)	TC0	Corn			Barley		
			NO3 uptake uM	NO3 red.	NO3 red. (%)	NO3 uptake uM	NO3 red.	NO3 red. (%)
1.0%	3.0	15.0	3680	3527	95.84	5049	3307	65.50
		20.0	4617	4617	100	6764	5437	81.27
		25.0	6463	6463	100	8734	7405	84.78
		30.0	6684	6687	100.04	10474	6831	65.22
		35.0	11845	11651	98.36	11796	2579	21.86
	6.0	15.0	10883	9894	90.91	9798	4829	49.29
		20.0	9722	9356	96.24	12713	6163	48.48
		25.0	14993	14637	97.63	15466	9316	60.23
		30.0	14402	13952	96.88	18446	11273	61.11
		35.0	17739	16917	95.37	24326	5520	22.69
	10.0	15.0	16518	10602	64.18	12054	2476	20.54
		20.0	16724	14285	85.42	21353	7982	37.38
		25.0	19880	17648	88.77	21601	10522	48.71
		30.0	22430	20563	91.68	31781	14591	45.91
		35.0	25478	21917	86.02	44657	15722	35.21







Fig(3) Effect of NO3 concentration , temperature & sugar (1%) on NO3 uptake , reduction & reduction (%) of Corn plant



Fig(4) Effect of NO3 concentration , temperature & sugar (1%) on NO3 uptake , reduction & reduction (%) of Barley plant

DISSCUSION

Nitrate reduction was essentially idendintical to uptake in response to ambient nitrate. This shows the strong regulatory effect that nitrate uptake has on its subsequent reduction by furnishing the nitrate flux into the plant (Chantartwong et al ,1976). Rate of nitrate assimilation based on the disappearance of nitrate from detached leaves preloaded with nitrate may be confounded by the different nitrate pools found in plants as it is recognized that cell of higher plants have both metabolic (easily accessible and cytoplasmic) and storage (probably vacualar) pools (Aslam et al.1976) they indicated that after leaves are excised and removed from the roots supplying nitrate, nitrate is depleted in cytoplasmice pools by both reduction and movement into a storage pool (vacular). Efflux of nitrate from the vacule back into the aytoplasm could then regulate the rate of nitrate reduction. Finally it mean that the seedling were capable of lowering their steady-state rates of uptake and reduction. It`s clear from data that corn leaves more efficiency than Barley in adaptation to high ambient NO3 concentration .For temperature effect on nitrate reduction percent increased when the temperature raised from 15°C to 25°C in both plants. But increased temperature from 25°C to 30 °C, the reduction percent decrease and big decrease with raising the temperature to 35°C,this maybe inrelation to nitrate reductase activity. (Hallmark & Huffaker ,1978) observed an increase in enzymatic activity occurred from 0°C to 40°C above which decrease occurred, but in our study the harmfull effect of temperature begin at 30°C.Also high temperature affected the photosynthesis by altering the excitation energy distribution by changing the structure of thylakoids (Berry and Bjorkman,1988) and by changing the activity of he calvin cycle and other metabolic processes. Also Maize (C4) plants more efficience than Barley (C3) plants in nitrate reduction percent. (Hallmark & Huffaker ,1978) found sudangrass seedling pretreated in nitrate reduced 80 to 100 of nitrate taken up. While for Barley (Chantarotwong et al 1976) and wheat (Ashley et al 1976) reduced about 35% of that taken up,from this data in Maize we concluded that nitrate reduction was approximetly equal to uptake (reduction percent 90-100%), while in Barley the nitrate uptake bigger than the reduction (reduction percent not more than 60%). Also it clear from the results that sucrose addition to the nutrient solution improve the efficiency of Barley to reduce NO3 uptake.

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Effect of Cobalt on Growth and Cobalt Uptake of Barely In Relation to Cobalt Availability in Alkaline Soils

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ABSTRACT

A short term Neubauer experiment was conducted to evaluate the effect of cobalt on the growth as well as cobalt uptake of barely (Giza 126 variety) grown in three alkaline soils from the north west coast of Egypt in relation to AAAA-EDTA (Acetic Acid Ammonium Acetate-EDTA) extractable cobalt in the tested soils of the uncropped treatments. Treatments of five levels of cobalt (0, 5, 10, 20, 40, 80, and 100 mg/kg soil) were superimposed on the tested soils. The data indicated that the available cobalt concentration increased with increasing cobalt application rate. The concentration of cobalt extracted with AAAA-EDTA increased polynomialy in response to cobalt application for the three studied soils. The data showed also, that the effect of cobalt application on the growth of barely plants was significant on the clay soil (Soil A) and insignificant on the clay loam and sandy loam soils (Soils B and C). The higher dry matter yields were obtained with the application of cobalt to the soils at the rate of 20 mg Co/Kg soil. The tolerance index (Ti) for the addition of 5 to 80 mg Co/Kg soil (>1) shows a favourable effect for the growth of barley. Also, the tolerance index was varied with the soil characteristics. Cobalt concentration or uptake by barley was increased significantly with cobalt application and this was also evidenced by the increase in AAAA- EDTA extractable cobalt from the tested soils. The average uptake values of cobalt followed the sequence order: soil C (sandy loam) >soil B (clay loam)> soil A (clay). Also percentage utilization of added cobalt was highest in soil C followed by soil B and soil A. In conclusion the application of cobalt in a low level improved growth of barely and may be applied to the soil at the recommended rate in term of cobalt sulphate.

Keywords: Cobalt, alkaline soils, barely, growth, availability, uptake and tolerance index.

INTRODUCTION

The essentiality of cobalt for higher plants has not been definitely established, even though cobalt is required by Rhizobia for nitrogen fixation and indirectly by leguminous and other plants (Ahmed and Evans, 1964; Riley and Dillwarth, 1985; Jana *et al.*, 1994). It is clear, however, that low concentrations of cobalt can have a favourable effect on plant growth of non leguminous ctrops (Lipskaya *et al.*, 1978; Lipskaya, 1980; Vyrodova, 1981; Yagodin and Sablina, 1981; Hussein, 1984; El-Kobbia and Osman, 1987; Toma and Lisnik, 1988; Yagodin and Stupakova, 1988; Yagodin *et al.*, 1990; Liu *et al.*, 1995 and Walser *et al.*, 1996).

According to some reports, cobalt is associated with auxin metabolism and promotes elongation of cell envelopes, activates dehydrogenises, nitrate reductase, increases the content of chlorophyll, total hematin and vitamin E genetically associated with chlorophyll (Yagodin, 1982). Application of cobalt is very important to enhance the nutritive value of farm products as a result of its increased content in crops. It has been demonstrated that , when the cobalt content in feeds is less than 0.07 mg/Kg of dry hay, animals suffer from cobalt deficiency (McDowell *et al.*, 1983) Therefore, cobalt containing fertilizers should be applied to pastures in areas of cobalt deficiency to obtain high quality animal feeds and foodstuffs.

The upper critical level of an element is the lowest tissue concentration at which it has toixic effects (Macnicol and Beckett, 1985). Anderson *et al.*, (1973) mentioned that with cobalt content above 6 ppm in plant, toxicity appeared. Cobalt deficiency occurs in highly leached sandy soils derived from acid igneous rocks or in highly calcareous soils. In Egypt, the studies of cobalt in soil and plant have received practically little attention till now. The aim of this work was to study the response of barley to applied cobalt in a short-term experiment in relation to cobalt availability in the alkaline soils.

MATERIALS and METHODS

Soil Samples:

Three samples of surface soil were collected from the Northern western coast of Egypt. Two selection criteria were followed in choosing the soils, i.e. the organic carbon and $CaCO_3$ contents in the 0-30 cm layer. Soil samples were air dried, ground, and passed through a 2 mm sieve. Some of the chemical and physical characteristics of these soils are presented in Table 1. Total cobalt was determined by atomic absorption spectrometry after digestion the soil samples using perchloric and nitric acids mixture according to Hesse(1971). Also, available cobalt in the tested soils was measured by extracting the soils with acetic acid-ammonium acetate-EDTA mixture (AAAA-EDTA) according to Sillanpaa and Jansson (1992) and the extractable cobalt were measured using the atomic absorption spectrophotometer. The other physical and chemical characterizations were determined in accordance with the procedure described in Black *et al.*, (1965).

Response of Barley:

A Neubauer experiment was carried out to study the effect of adding cobalt in the form of $CoSO_4$ at the rates 0, 5, 10, 20, 40, 80 and 100 mg Co/kg soil using the selected three soils on relative cobalt availability to barley plants (Giza 126 variety). 100 g air-dry soil samples were thoroughly mixed with 50 g acid-washed sand and placed in polyethylene containers 9.5 cm in diameter and 4 cm in height. The soil-sand mixtures were covered with 50 g acid-washed sand. Hundred barley seeds were uniformly planted on the sand surface, then covered by another 50 g sand layer. Barley seeds were soaked in distilled water for three hours before planting. Successful seed germination exceeded 90% and moisture losses were replenished daily. All treatments were conducted in duplicate, in addition to a blank treatment of 100 seeds in acid-washed sand. After 21 days, whole plants (shoots and roots) were harvested, washed and dried at 65°C for 48 hours. The plants were weighted, grounded and ashed according to Jackson (1973) for cobalt measurement. The same treatments were similarly prepared, but left uncropped for comparison. The soil sand mixture of the uncropped treatments at the end of the Neubauer experiment were air-dried, sieved through 1 mm screen for separating soil from sand and soil available cobalt were determined as previously described. The cobalt in the different soils was measured using the atomic absorbtion spectrophotometer.

Data Analysis :

Plant weight and cobalt concentration data were evaluated by analysis of variance and by the least significant difference (LSD) mean separation procedures at the 0.05 level of significance (SAS Insituate., 1994). Non linear regression was used to develop predictive equations relating available cobalt concentration responses to cobalt application rates. Regression analysis also was employed to determine the relationships between cobalt application rates to soil and cobalt concentrations and uptake in plant tissues.

RESULTS AND DISCUSSION

Available cobalt:

The effect of cobalt application on the available cobalt concentration in the tested soils of the uncropped treatments are shown in Table 2. The data indicated that the available cobalt concentration increased with increasing cobalt application rate. Relatively differences in the available cobalt between the tested soils at the different rates of cobalt application were observed. Soil C gave the largest amounts of available cobalt under the experimental conditions. The variation in the available cobalt content between the tested soils may be due to the reactions of the extractant with the soil components and the ability of the extractant to dissolve the cobalt in soil. The polynomial quadratic model was used to describe the relationship between cobalt application rates and extractable cobalt (Fig. 1). The concentration of cobalt extracted with AAAA-EDTA increased polynomialy in response to cobalt application for the three studied soils. The ability of extractant to remove cobalt from soils was in the following order : Soil C > Soil B> Soil A. The highest amounts of extractable cobalt from Soil C soil may be due to its lowest content from organic matter and clay fraction (Table 1). Bloomfield (1981) considered that the soil rich in organic matter are known to have allow cobalt availability.

Barley Response:

The data in Table 3 showed that barley dry matter yields increased significantly with cobalt application up to certain limit (20 mg Co/kg soil) for soil A and insignificantly for soils B and C. However higher cobalt applications reduced the yield to a values nearly equal to yield of the untreated plants with cobalt. The maximum dry weight was obtained at 20 mg Co/kg soil and accounts for 108.8 , 123.2 and 107.8% as compared with control for soils A, B and C respectively. The dry weight of barley plants were decreased at the higher rates of cobalt application without visual chlorotic symptoms on barley plants. The tolerance index (T_i) as defined by Bradshaw (1968) was calculated for the addition of 5, 10, 20, 40, 80 and 100 mg Co/kg soil (Table 3). The toxicity of cobalt under the present soil conditions depends not only on the absolute concentrations of cobalt in soil but also, on several other factors such as pH, fixation and /or complexing of cobalt by organic matter, and relative concentrations of other nutrients. The values of T_i that are more than one, shows a favorable effect for the growth of barley grown in the three soils. For soils A and C the cobalt application at 100 mg Co/kg (Table 3) showed a slight phytotoxic effect (T_i = < 1). The slight increases in growth of barley with cobalt application may be due to DNA synthesis and cell division (Yagodin, 1982). Similar results were obtained by Atta Aly *et al.* (1991) using nutrient culture.

Plant Uptake:

Table 4 shows that the concentration and uptake of cobalt were increased significantly with cobalt application up to 100 mg Co/kg soil. A highly positive significant correlations between cobalt application and cobalt concentration or uptake for the barley plants grown in the tested soils were observed (Table 5). The uptake values of cobalt varied widely among soils. The barely plants grown in the soil C (sandy loam) had a higher assimilative capacity or uptake of cobalt than the other two soils. The increases in cobalt concentration and uptake with increasing cobalt application were also evidenced by the increase in the AAAA-EDTA extractable cobalt from these soils (Table 2 and Fig. 1). In general the average uptake values of cobalt followed the sequence order: soil C (sandy loam) > soil B (clay loam) > soil A (clay). Corresponding to the data in Table 4, the percentage utilization of added cobalt was highest also in soil C, followed by soil B and soil A (Fig.2).

Both essential and non-essential elements exhibit an upper critical level above which yields are reduced because of toxic effects (Burton and Morgan, 1983). Considering cobalt element as non essential element to barley plants, the upper critical level range of cobalt will be 17.24 to 27.30 mg/Kg dry matter of barley for all the tested soils and the corresponding AAAA-EDTA cobalt in same soils were 10.56 to 14.56 mg Co/Kg soil. Davis *et al.*(1978) reported that 6 mg Co/Kg dry matter of barley seedlings produced toxicity symptoms. However, commonly reported critical cobalt levels in plants ranged from 30 to 40 mg Co/Kg dry matter (Macnicol and Beckett, 1985).

In conclusion the application of cobalt in a low level improved growth of barely and may be applied to the soil at the recommended rate in term of cobalt sulphate. Also, application of cobalt is very important to enhance the nutritive value of farm products as a result of its increased content in crops. The critical level derived in this study are no more precise, but we present it as the basis for preliminary assessments of cobalt in the tested plants to obtain high quality animal feeds and foodstuffs. Thus we need to develop more exact tests through more exploratory experiments on several fodder plants to drive more precise values for cobalt.

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Table (1). Some physical and chemical characteristics of the tested soils

Characteristics	Units	Soil A	Soil B	Soil C
Sand	g kg $^{-1}$	197.2	357.2	813.6
Clay	g kg $^{-1}$	467.2	308.5	130.1
Silt Texture	g kg $^{-1}$	335.6	334.3	56.3
		Clay	Clay loam	Sandy loam
$CaCO_3$	g kg $^{-1}$	95.0	206.0	333.0
Organic matter	g kg $^{-1}$	19.0	13.0	6.0
CEC,	cmol kg $^{-1}$	44.3	33.9	5.3
pH (1 : 1)		7.5	7.3	8.2
EC (1 : 2.5)	dS m $^{-1}$	1.6	1.5	0.3
Total cobalt	g kg $^{-1}$	29.0	18.2	21.1
Available cobalt,	g kg $^{-1}$	4.8	4.8	4.3

Table (2). The effect of cobalt application on the AAAA-EDTA extractable cobalt in soils without cropping.

Cobalt rate, mg/Kg soil	Soil A	Soil B	Soil C
0	4.10	4.70	4.18
5	6.30	6.85	6.84
10	8.18	7.20	8.74
20	10.56	13.87	14.56
40	18.00	20.34	25.94
80	39.20	45.50	47.40
100	48.00	63.00	73.02
L.S.D.$_{0.05}$	3.27	2.54	2.60

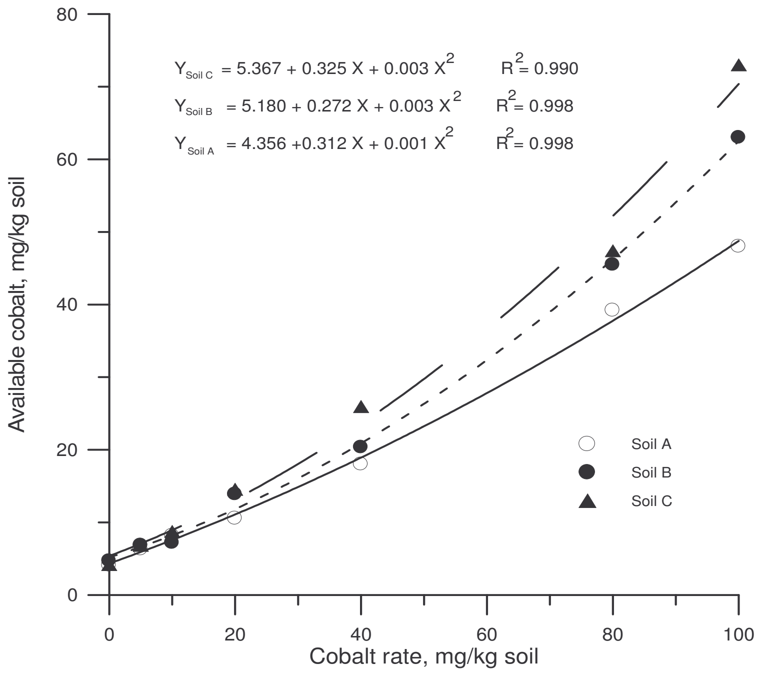

Fig. 1: Effects of cobalt application rates on the levels of AAAA-EDTA extractable cobalt in the three studied soils

Table (3). Growth and tolerance index (T_i) of barley plants as affected by cobalt application.

Applied Co mg kg $^{-1}$soil	Soil A		Soil B		Soil C	
	Dry matter yield g/pot	Tolerance index (T_i)	Dry matter yield g/pot	Tolerance index (T_i)	Dry matter yield g/pot	Tolerance index (T_i)
0	2.15	1.00	2.18	1.00	2.38	1.00
5	2.46	1.14	2.24	1.03	2.50	1.10
10	2.60	1.21	2.28	1.05	2.59	1.10
20	2.65	1.23	2.35	1.08	2.59	1.10
40	2.64	1.23	2.35	1.07	2.48	1.00
80	2.21	1.08	2.26	1.04	2.40	1.01
100	2.13	0.99	2.20	1.01	2.36	0.99
L.S.D$_{0.05}$	0.217	-	ns	-	ns	-

$$Ti = \frac{\text{Growth in enriched soil}}{\text{Growth in normal soil}}$$

Table (4). Cobalt concentrations and uptake of barley as affected by cobalt application to the three soils.

Applied Co mg kg $^{-1}$soil	Soil A		Soil B		Soil C	
	Conc. mg/kg D.M.	Plant uptake µg Co/pot	Conc. mg/kg D.M.	Plant uptake µg Co/pot	Conc. mg/kg D.M.	Plant uptake µg Co/pot
0	0.32	0.69	0.44	0.95	0.27	0.65
5	3.65	8.75	3.50	7.85	7.24	18.13
10	12.32	32.03	9.28	21.16	14.08	36.56
20	17.24	45.68	27.30	64.29	26.12	67.39
40	28.20	74.44	42.00	98.70	46.24	114.86
80	76.72	169.93	69.60	157.57	83.12	199.48
100	76.88	163.75	76.80	169.26	86.84	205.29
L.S.D$_{0.05}$	8.788	22.35	4.135	16.87	8.543	22.76

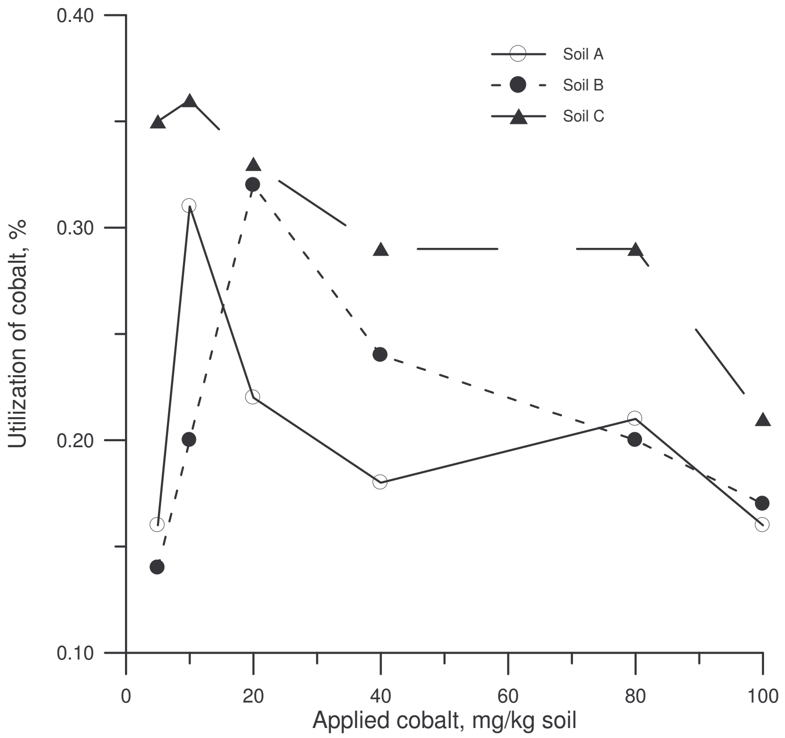

Fig.2 :Utilization percentages of added cobalt by plants in the three studied soils.

Table (5). Simple regression equation between applied cobalt (Y) and cobalt concentration in barley (X_1) or plant uptake (X_2).

Soil No.	Simple regression equation	r
A	$Y = 1.1807\ X_1 + 0.1214$	0.986**
A	$Y = 0.5508\ X_2 - 2.5432$	0.982**
B	$Y = 1.2355\ X_1 - 3.9769$	0.984**
B	$Y = 0.5495\ X_2 - 4.7448$	0.978**
C	$Y = 1.0921\ X_1 - 4.7448$	0.988**
C	$Y = 0.4597\ X_2 - 5.7541$	0.985**

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The Role of Microbial Activity on Iron Uptake of Wheat Genotypes Different in Fe-Efficiency

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ABSTRACT

Soils in many agricultural areas have high pH, resulting in low availability of Fe. Wheat grown on such soils suffers from most micronutrient deficiencies, in particular Fe deficiency. The objective of this investigation was to determine the potentials of indigenous fluorescent Pseudomondas for siderophore production and their effects on ^{59}Fe acquisition. For this purpose, some strains of *Pseudomonas putida*, *Pseudomonas fluorescens*, and *Pseudomonas aeruginosa* were isolated from different locations representing rhizosphere of wheat. The potentials of these strains for siderophore production were evaluated by chrome azorel-S assay (CAS blue agar) through color change. High siderophore producing Super-strains were selected for extraction of siderophores. These isolates were grown in SSM (standard succinate medium) for 72 hr at 28 °C. Bacterial cell were removed by centrifugation (10000 g for 20 min) and the supernatant was filtered through filter membrane (0.22 μ) and used as crowd siderophore. Evaluation of Fe uptake and translocation were carried out with complexes of bacterial siderophores and ^{59}Fe compared with standard sierophore Desferrioxamine (DFOB) in randomized complete block design with three replications. This experiment was conducted on two wheat genotypes different in Fe-efficiency at hydroponic condition. The results showed that among the three most effective siderophores producing strains considered, the *P. putida* produced a sidrophore complex that showed efficiencies of 76 %, compared with the standard siderophore (DFOB) in the uptake of Fe and was statistically in the same group as the control. The effect of bacterial siderophores in the uptake of labeled ^{59}Fe by wheat became significant, indicating that the chemical structure of the siderophores from different strains were different. The effects of wheat genotype in ^{59}Fe activity of shoots was also significant, where the efficient Tabasi genotype contained 46 % more Fe in shoots than the inefficient Yavarous genotype. It was concluded that the siderophore complex from *P. putida* was the most effective in translocating Fe to shoots, particularly in efficient Tabasi genotype. Siderophore effectiveness in Fe availability decreased in the order;

Sid-DFOB> Sid-*putida*>Sid-*fluorescens*> Sid-*areuginosa*.

Keywords: siderophore, ^{59}Fe, wheat, Fluorescent Pseudomonads, iron-efficiency

INTRODUCTION

Soil microbial activity in rhizosphere may influence the growth of higher plants by various processes. The plant growth-promoting activity of rhizobacteria such as fluorescent pseudomonads is well-established. Several mechanisms by which plant growth-promoting rhizobacteria (PGPR) promote plant growth include the production of extracellular growth-promoting chemical substances, phytohormones, iron chelating siderophores, antibiotics and HCN which improve plants growth, reduce the population of major root pathogens, compete for energy yielding nutrients, induce plant resistance and mineralize soil nutrients (Patten and Glick, 2002; Kloepper et al., 1980). Furthermore, PGPR have shown promise as potential biological control agents for many soil-borne root diseases (Gray and Smith, 2005).

Fluorescent pseudomanads are an important component of the rhizosphere of many plants, and are known to colonize the rhizosphere of wheat, potato, maize, grasses, pea and cucumber (Cakmakci et al., 2006; Khalid et al., 2004; Howie and Echandi, 1983; Brown and Rovira, 1976). These microorganisms improve plants efficiency in nutrients acquisition in particular iron. In calcareous soils the availability of Fe is very low due to the high pH of the soil solution and its buffering capacity that may impede Fe uptake mechanisms of many plants. Plants grown in such soils may suffer from sever Fe deficiency (Marschner et al., 1986). In order to avoid Fe deficiency, various graminaceous plants seem to rely on excretion of phytosiderophores by the roots and their uptake as a Fe complex by a highly specific uptake system that is enhanced by Fe deficiency (strategy I plants). In dicotyledonous as strategy II plants, release of protons and reducing substances combined with enzymatic splitting of chelates have been proposed as mechanisms of solubilizing soil Fe and/or uptake of chelated Fe (Marschner et al., 1986). Rhizosphere fluorescent pseudomonads are known to be antagonists to plant pathogens via siderophore production (Kloepper et al., 1980).

The efficiency of a chelate in supplying Fe to plants or microorganisms depends on its stability constants with Fe at various pH levels and competing ion concentration. Microbial siderophores form Fe complexes with high stability constants and therefore play a role in the Fe uptake by microorganisms (Neilands, 1995). Siderophores were found in soil solutions at concentrations that may influence the Fe nutrition of plants. Soil microbial activity is essential for Fe acquisition by soil-grown rape. Similarly, sorghum which is able to release phytosiderophores from the roots requires soil microbial activity to ensure satisfactory Fe supply (Rroco et al., 2003).

The aim of this study was to evaluate the effect and efficiency of pesudomonads siderophores on as Fe carrier to wheat genotypes different in Fe efficiency.

METHODS and MATERIAL

Bacterial Isolation

Soil samples were collected from 52 different locations representing rhizosphere of different wheat genotypes. Root samples were shaken vigorously to remove loosely adhering soil. The rhizosphere samples including adhering soil with root were plated on King's B-medium and the plates were incubated at 37 $^{\circ}$C for 24 h. Colonies that fluoresced under UV light (λ=356 nm) were selected and further purified on the same medium. Finally 201 strains confirmed as fluorescent pseudomonads based on biochemical tests such as arginine hydrolysis, catalase activity, production of fluorescing compounds, gelatin liquefaction and growth at 4 $^{\circ}$C and 42 $^{\circ}$C. Plant growth-promoting properties of the strains were confirmed with their ability to produce siderophore, indole acetic acid and phosphate solubilization. The potentials of these strains for siderophore production were evaluated by chrome azorel-S assay (CAS blue agar) through color change (Schwyn and Neilands, 1987). Among the isolates, 3 super-strains (high siderophore-producing strain) belong to different species of *Pseudomonas* sp (*P. putida* FP159, *P. fluorscens* FP73 and *P. aeruginosa* FP35) were selected for subsequent experiment.

Collection of Siderophores

The isolates were grown in standard succinate medium (SSM) consisting of (g l^{-1} distilled water): K_2HPO_4, 6.0; KH_2PO_4, 3.0; $(NH_4)_2SO_4$, 1.0; $MgSO_4$ $7H_2O$, 0.2; succinic acid, 4.0. The pH adjusted to 7 by addition of NaOH before sterilization (Meyer and Abdallah, 1978). Cultures were grown at 28 $^{\circ}$C for 72 h with shaking. After 72 h, the cultures medium had turned yellow-green indicating production of siderophores (Meyer and Abdallah, 1978). Bacterial cells were removed by centrifugation at 10000g for 20 min. The supernatants were filter sterilized through 0.22 µm membrane filter. The filtrates were kept in frizzier and used as crude siderophore source.

Preparation of ^{59}Fe-Siderophores (FeSid) Complexes

Standard sierophore (DFOB) was obtained from Sigma. The bacterial siderophores prepared as described above. ^{59}FeFOB and ^{59}FeSid were prepared by dissolving the ligands in distilled water and adding appropriate molar amounts of $^{59}FeCl_3$ in dilute HCl. Solution were stirred until dissolved and the pH was adjusted to ca. 5.8 with 10 mM 2-N- morpholino ethanesulfonic acid (MES). FeSids were used for experiments immediately after preparation (Johnson et al., 2002).

^{59}Fe Uptake and Transport

Evaluation of Fe uptake and translocation were carried out with complexes of bacterial siderophores and ^{59}Fe compared with DFOB in randomized complete block design with three replications. These processes was done by placing the intact root system of 8 wheat seedlings in 100 ml of nutrient solution, additionally containing 10 mM MES at pH of 5.8 and 10 µM ^{59}Fe labeled chelates (1.11 Bq mol^{-1}Fe). Nutrition solution containing: 2 mM $Ca(NO_3)_2$, 0.25 mM KH_2PO_4, 0.1 mM KCl, 0.88 mM K_2SO_4, 1 mM $MgSO_4$ 7H2O, 1 µM H_3BO_3, 0.2 µM $CuSO_4$ $5H_2O$ and 0.2 µM $(NH_4)_6MoO_{24}$. Wheat genotypes had different Fe efficiency, Tabasi was Fe-efficient and Yavarous was Fe-inefficient in terms of phytosiderophore producing (Rasouli Sadaghiani et al., 2007). Seedlings were maintained under growth chamber condition with aeration in glass pots for 6 h. At the end of experiments, roots were washed with distilled water, followed by three washes in nutrient solution without Fe and containing 40 µM Na_2EDTA, followed by a final distilled water rinse. Each plant was separated into roots and shoots. After air drying, ^{59}Fe was measured using a gamma counter (Johnson et al., 2002).

RESULTS

Bacteria in the Rhizosphere of Wheat

Evaluation of wheat rhizosphere from 10 provinces of Iran showed to included 201 fluorescent pseudomonads isolates; among them, 53%, 44% and 3% were *P. putida*, *P. fluorescens* and *P. aeruginosa*. These results have some similarities with those found elsewhere for rhizosphere of lemon (Gardner et al., 1984) and maize (Lalande et al., 1989).

Plant Growth-Promoting Properties

Up to 92% of isolated strains produced IAA and detected by the Salkowski reagent under colorimetry, in the range 2.13 mg l^{-1} to 26.98 mg l^{-1}. The highest concentration of IAA was obtained from *P. putida* FP159. Most of *putida* species had higher ability to produce IAA compared to other species.

All 201 strains formed colony on CAS blue agar and produced siderophore at different level. Siderophore production by the *Pseudomonas* species, isolated from King B liquid medium can be seen in Fig. 1.

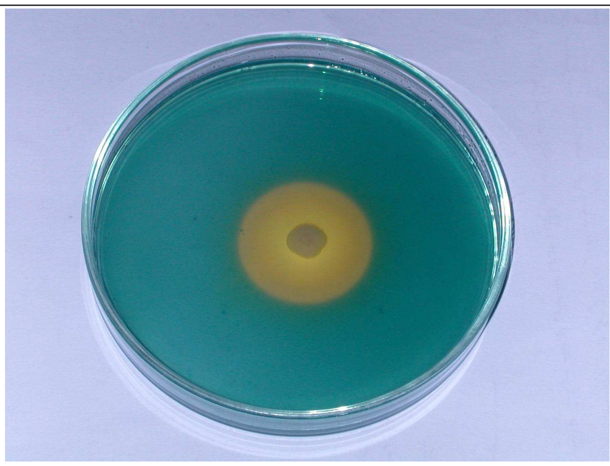

Fig. 1. Siderophore production by *Pseudomonas putida*

The results showed that among the three most effective siderophores producing strains considered, the *P. putida* produced a sidrophore complex that showed efficiencies of 76% in the uptake of Fe, compared with the standard siderophore (DFOB) and was statistically in the same group as the control (Table 1).

Table 1. Activity of ^{59}Fe in shoots and roots of wheat

Siderophore complex	^{59}Fe Activity (Bq/gDW)	
	Shoot	Root
^{59}FeFOB	0.446	0.441
^{59}Fe Sid- *putida*	0.341	0.739
^{59}FeSid- *fluorescens*	0.311	0.243
^{59}Fe Sid- *aeruginosa*	0.130	0.261
$LSD_{0.05}$	0.124	0.293

^{59}Fe activity of shoot in FOB complex was higher than pseudomonads siderophore complexes. However, this difference was not significant in case of siderophore complex of *putida*. Desferrioxamine B (DFOB), a siderophore produced by *Streptomyces pilosus* was shown to form stable Fe complex (FOB) in nutrient and soil solutions between pH 4 and 10 (Cline et al., 1982). The effect of bacterial siderophores in the uptake of labeled ^{59}Fe by wheat became significant, indicating that the chemical structure of the siderophores from different strains may be different. The effects of wheat genotype in ^{59}Fe activity of shoots was also significant, where the efficient Tabasi genotype contained 46% more Fe in shoots than the inefficient Yavarous genotype. Rasouli Sadaghiani et al. (2007) showed that Tabasi as bread wheat had high efficiency in terms of phytosiderophores release at Fe deficiency condition. In contrast, Yavarous as durum wheat was sensitive to Fe deficiency and produced very low amount of phytosiderophores at same condition.

Commercial Fe chelates as well as phytosiderophores have shown high efficiency in Fe uptake compared to siderophores. Reid et al. (1984) showed that the siderophore ferrichrome was a more efficient Fe carrier than FeEDDHA for oat. However there are controversy findings. Fe uptake from ^{59}Fe-siderophore was lower than uptake from $^{59}FeEDTA$ by cucumber and ^{59}Fe-phytosiderophore by maize. Siderophore complex of Fe could be effective in Fe uptake indirectly, by increasing the extracellular supply of Fe at the root surface (Walter et al., 1994). It was concluded that the siderophore complex from *P. putida* was the most effective in translocating Fe to shoots, particularly in efficient Tabasi genotype. Siderophore effectiveness in Fe availability decreased in the order;
Sid-DFOB> Sid-*putida*>Sid-*fluorescens*> Sid-*areuginosa*.

DISCUSSION

In higher plants two distinct strategies for Fe acquisition exist under condition of limited Fe supply (Marschner et al., 1986). The operation of strategy I depends on the supply of soluble Fe to the Fe reductase system at the plasma membrane of the rhizodermal cells (Romheld et al., 1987). Siderophores can increase the concentration of Fe at the uptake sites of the roots by increasing the solubility and mobility of Fe in the soil. Plant with strategy II, produce phytosiderophores. In this study, all strains formed colony on CAS blue agar and produced siderophore at different level (Fig. 1). In the Fe nutrition of strategy II plants, the role of microbial siderophores depends on their stability and thus on their ability to supply readily-accessible inorganic Fe^{3+} to the extracellular Fe pool (root surface and apoplasm) for the chelation by phytosiderophores released by the roots (Romheld and Marschner, 1986). In this study siderophore complex of *P. putida* showed high efficiency in Fe uptake compared to other species. Crowley et al. (1988) introduced a microbial siderophore-Fe transport system in oat. Our results suggest operation of heterologous ionophore uptake in Tabasi as efficient genotype. Similar results were observed in studies of Sharma et al. (2003). More recently, Fernandez et al. (2005) obtained evidence of plant Fe utilization after foliar treatment with microbial siderophores.

Sorghum and sunflower grown under Fe deficient condition in nutrient solutions were able to utilize Fe from the FOB complex (Cline et al., 1982). Reid et al. (1984) showed that the siderophore ferrichrome was a more efficient Fe carrier than FeEDDHA for oat grown in nutrient solution. In soil system a preliminary study showed that ferrated pseudomonad siderophores are active in the remedy of lime-induced chlorosis (Jurkevitch et al., 1988). Fe complex of *putida* let to increase Fe concentration of roots in contrast to the effects of other complexes as well as FeFOB (Table 1). Theses accumulated Fe serve as Fe apoplasmic pool and may involve in ligand exchange phenomena. In this hypothesis which is presented by Yehuda et al. (1996), Fe from Fe-siderophores is taken up by strategy II plants via an indirect mechanism that involves ligand exchange between the ferrated microbial siderophore and phytosiderophores, which are taken by the plants. Tabasi genotype has shown to produce large amount of phytosiderophores on Fe deficient condition (Rasouli Sadaghiani et al. 2007).

Several researches show that microbial inoculation enhances plant Fe uptake. Masalha et al. (2000) stated that plants (maize and sunflower) cultivated under non-sterile condition grew well, showed no Fe deficiency symptoms and had fairly high Fe concentration in the roots in contrast to plant grown in the sterile medium. It may be therefore assumed that microbial activity in particular their siderophores is of pivotal importance for plant Fe uptake.

The data presented in this study explores microbe-plant interaction in terms of iron uptake from particularly the insoluble oxide form of iron and supports the mechanisms of heterologous iron uptake in wheat system via microbial siderophores. For calcareous soils which prevalent in Iran, efficient strains of pseudomanads like studied strains here will be of great interest to combat iron chlorosis and additionally improve strategic crop yield.

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Diatomite: A New Substrate for Hydroponics

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ABSTRACT

Many different substrates are used for plant support in hydroponic culture, but one of the unique requirements for research is that the media be easily separated from the roots. Peat, perlite, and vermiculite are good substrates but roots and root hairs grow into these substrates, so they are unsuitable for studies of root size and morphology. Sand can easily be removed from roots, but roots grown in sand are shorter and thicker than hydroponic roots because the sand particles are so dense. Diatomite particules was the medium of choice for research hydroponics for many years because it can easily be removed from roots. Diatomite is a sedimentary rock primarily composed of the fossilized remains of unicellular fresh water plants known as Diatoms. This organic, natural product contains the fossilized skeletons of trillions of microscopic, single cell aquatic plants of fresh water origin. This lightweight, porous, non-toxic, non-hazardous mineral is a cost effective, highly efficient, horticultural growth promoting media. Diatomit is pH stable and the pH can be adjusted to suit various crops. Diatomite will absorb up to 150% of its own weight in fluids and slowly release the fluids as required by the plant. Diatomite is available in particle sizes from 1 to 10-mm diameter. Our tests indicate that Diatomite is chemically inert and has good water holding characteristics. The plant roots muffled with the media particles during the harvest were easily separated from each other by submerging roots in to filled cup and rinsing it in a few minutes time Its disadvantage is cost 3 TL/ 7 liter in Turkey. There are a lot of Natural Diatomite sources in Turkey.

Key words: Diatomite, soilless culture, hydroponic, plant, root, substrate

INTRODUCTION

Diatomite is a biochemical sedimentary rock composed mainly of the skeletons of a very common type of marine plankton - diatoms. Diatoms are tiny plants that float near the ocean surface. Their skeletons are composed of silica (silicon dioxide), a very durable substance. Since diatom skeletons are highly porous, diatomite is extremely light in weight, and pure samples make excellent water filters.

Biochemical sedimentary rocks form from sediment derived by biological processes. This typically occurs in the ocean where a variety of atoms float among the water molecules. Ions, such as calcium, magnesium, and potassium, along with trace elements like silicon, fluorine, iron and phosphorous, are used by marine organisms to form their hard and soft tissues. Once the marine plant or animal dies, it may settle to the ocean floor as biochemical sediment, then become compacted and cemented together into solid rock. Typically only the hard, skeletal parts of an organism are preserved as sediment (Anonymous, 2008a).

All Diatomite is not created equal. You may be familiar with diatomaceous earth that is used in filters and as an insect and slug repellant. These types of products are not suitable for horticulture because the diatoms are of salt-water origin, leaving them with a high salinity level that is not suitable for plants. Axis (AgroTech 2000, Plainsboro, N. J.) is a kiln – fired diatomaceous earth produced earth aggregate from diatomite deposits. It is inert and has a pH of 7. Its porous nature reportedly absorbs more than 100 % of its own weight in water, then releases the water to the surrounding soil as the soil's water content drops below field capacity.

A diatomaceous earth layer is a limnic layer that:1. Has a matrix color value of 3 through 5 if not previously irreversibily on shrinkage of organic matter coatings on diatoms, which can be identified by microscobic (440x) examination of dry samples: and 2. Yields a color highe rin value and lower in chroma than 10YR7/3 on white fitler paper that is inserted in to a paste made of the material in a saturated sodium pyrophosphate solution or the cation – excange capacity is < 240 meq per 100 gr of organic matter (by loss on ignition) or both . Diatomaceous earth layers normally are more nearly mineral than organic in composition

Diatomite is High in Silica, Absorbent, Porous, Long Lasting, Environmentally Friendly, pH Neutral, Sterilized, Natural and Reusable, all factors necessary for health plants, while still being cost effective for the grower (Anonymous, 2008a)

We have four sizes available for all of your growing needs

Fine 0.5mm to 2mm
Small 2mm to 7mm
Medium 7mm to 15 mm

Large 15mm to 25 mm (Anonymous,2008a)

The benefits to using " Diatomite" for all growing applications are:

1. High-Silica Content " Diatomite" will slowly release 'plant-available' silica to your plants, which is extremely important to the development of plant cell growth.
2. Absorption 150% of Solution " Diatomite" will absorb up to 150% of its own weight in fluids and slowly release the fluids as required by the plant.
3. Capillary Action The capillary action of " Diatomite" can be tested in a water vessel. Water can be drawn 200 mm from the bottom of the vessel to the top within a short time.
4. Lateral Movement " Diatomite" provides effective lateral movement of water and nutrients.
5. pH " Diatomite" is pH stable and the pH can be adjusted to suit various crops.
6. Assists Aeration, Air penetration of " Diatomite" is excellent owing to the fact that the granules are multi-faceted and do not compact.

7. Insulation Qualities
   The microscopic porous structure of each granule provides effective thermal insulation to plants and root zones.
8. Sterilized " Diatomite" is sterilized when Heat-treated to approximately 650 degrees Celsius.
9. Longevity " Diatomite" diatoms are fossilized exoskeletons and are approximately ten million years old prior to production of calcined diatomite. It will not break down.
10. Environmentally Safe " Diatomite" contains no Cristobalite, Tridymite or Quarts, making this product user friendly (Anonymous, 2007a).

High Silica Content Silica is essential for healthy plants and roots. Because diatomite is 90% silica, your plants will receive a slow release of silica resulting in healthier more robust plants. Absorbency and Porosity Diatomite is naturally very porous, and can hold 150% of its weight in water. The Silica Content, natural Absorbency, and Porous qualities result in a slow release of water and nutrients to your plants, contributing to higher yields and less watering. Capillary Action and Lateral Movement The porosity of the Diatomite contributes to its ability to draw water, while moving water and nutrients laterally throughout the medium, making Diatomite ideal for Hydroponics (Anonymous, 2007a).

Air Penetration Diatomite is multifaceted and varies in size. Because each rock is unique in shape it does not compact while in the pot. This leaves pockets, allowing air to penetrate and circulate to the root zone. Sterilized, Non-Toxic, pH Neutral When Diatomite is mined it is heat treated to over 600 degrees Celsius, making it completely sterile and safe for all of your planting needs. Whether you are using 100% diatomite or you are adding it to a mix of your soil it will not contribute to changes in pH. Diatomite is inert and will not break down or decompose like other growing mediums. It is Natural and completely reusable. When dry, diatomite is extremely lightweight, making it ideal for plant shipping purposes. Due to the variability of hydroponics systems and growing conditions, some trial and error will have to be used to determine your ideal nutrient levels and watering schedule. We suggest that you reduce your watering frequency and nutrient level because of the liquid retention of Diatomite (Anonymous, 2008b).

Frequently asked questions about Diatomite:

Q.1 What is Diatomite?

A.1 Diatomite is a mined product, a unique form of diatomite consisting of amorphous (not crystalline) silica.

Q.2 Is it a fertilizer?

A.2 No. Diatomite is not a fertilizer, it provides plant available silica which will enhance the uptake of water soluble fertilizers. The silica strengthens the plants' cuticular cell wall, and imparts a stronger physical resistance to disease and stimulates the plants' "immune system."

Q.3 Can I use it for seedlings?

A.3 Yes. Several leading commercial seedling producers use Maidenwell 0.5mm-2mm product for seedling raising. To name a few: Leppington Speedy Seedlings in N.S.W., Berwick Speedy Seedlings in Victoria and Highsun Express Plugs in Queensland.

Q.4 Do I use it by itself or mix it with other materials?

A.4 Diatomite can be used alone as a growing medium for hydroponics, or may be combined with normal seedling or potting mixes (generally between 20 to 50%)

Q.5 How do I use it in potted plants?

A.5 We recommend Maidenwell be used at around a 50% blend with normal potting medium and a standard fertilizing program. (usually 0.5mm-2mm or 2mm-7mm) produce the best results for normal potted plants.

Q.6 How does Diatomite work in potted plants?

A.6 Diatomite is an insulator, it's sterilized and pH is stable, has a water absorption capacity of around 150%, it provides capillary action and lateral movement of both water and nutrient to the plant as it's required and it aerates the soil or potting medium. When all these features are combined together with the plant available silica, it creates the perfect growing environment for the plants' root system.

Q.7 Why are there different sizes of Diatomite?

A.7 We produce Diatomite in different sizes to suit varying growing applications. A wide variety of plants with different root structures and individual growing characteristics will require different size medium for their growing environment .

Q.8 Which sizes are recommended for what type of plants?

A.8 The seedling and plug industry require a small size product (0.5mm-2mm) to prevent bridging of potting media within the root cell space. The medium sizes (2mm-7mm and 7mm-15mm) are more appropriate where increased drainage is required. eg. Orchids etc. (7mm-15mm and 15mm-25mm) are mostly for orchids,hydroponic medium, decorative ground cover and insulated garden mulch.

Q.9 How often do I need to water compared to ordinary soil?

A.9 Diatomite improves the physical structure of soils, allowing water to penetrate the soil profile around the root zone more thoroughly. Watering can usually be reduced to twice weekly.

Q.10 How many days do I need to wait before I need to water the plants again?

A.10 This depends on the climate, soil type / growing medium and the type of plants. In summer, pots may require watering daily, where as one watering every two weeks may be sufficient throughout winter.

Q.11 Is Diatomite safe to use?

A.11 Yes, Diatomite is safe to use. It is of freshwater origin (not saltwater), it consists of amorphous silica (not crystalline) as per the Amdel Report 6A05424 present and on our website www.maidenwell.com We recommend users to wet the product before use to settle any of the dust that may have been generated transit etc.

Q.12 How do I know for sure that Maidenwell will provide my plants with both a better and faster growth?

A.12 We suggest initially, that you pot at least one plant in your traditional potting mix alongside plants potted in Maidenwell, employ the exact watering and fertilizing treatment to all pots and you can judge for yourself the benefits of Maidenwell. After a short time you will no longer be sceptical about better and faster growth.

Q.13 Is this growing medium made from any chemical or harmful substances?

A.13 No. Maidenwell Diatomite is a naturally occuring, fossilized, mined mineral processed and heat treated to 650^{0}C, no other materials are added during any process.

Q.14 I am already using a fertilizer and growing medium, do I still need to add something like Diatomite to my plants?

A.14 Diatomite will enhance any growing medium and with its plant available silica, will provide improved quality together with, faster and more prolific growth to your plants and flowers.

Q.15 How do I apply Diatomite to my plants? Do I need to put 100% Maidenwell or only 10% and the remaining 90% made up of potting mix etc.?

A.15 The application rates for Diatomite should be around 50% blended with normal potting mix. Diatomite can be used at 100% if you so desire. One of the significant features of Maidenwell is that you can’t overdose with it. You can never use too much of it.

Q.16 How often must I replace?

A.16 Diatomite is fossilized and hence will never break down. You only need apply it once to growing media, however, other organic matter which makes up the remainder of the growing media, will probably need to be replaced at some stage.

Q.17 Do I need to wet it before using it?

A.17 It’s not really necessary, however, we recommend users to wet the product down before use, just to settle any of the dust that may have been generated in transit etc. Normally, water is added to Diatomite in the mixing process with other media.

Q.18 What is the recommended mix for growing in the ground.

A.18 This will vary from crop to crop. For roses, we recommend 3 litres of Diatomite per bush, dug into the soil and a further 3 litres around each bush. If it were incorporated at 5 litres per sq. metre, the results would be very noticeable in a short period of time.

Q.19 Can I use it to absorb oil?

A.19 Yes. In fact we currently supply Diatomite to several oil and chemicalcompanies for this very application. Diatomite, with its high absorbency rate is an excellent industrial absorbent for both oil and chemicals.

Q.20 Are there other uses for Diatomite apart from a growing medium?

A.20 Yes. There are a number of different applications for Diatomite. Snail and slug repellent, decorative ground cover (insulated garden mulch), pesticide for insects, oil & chemical absorbent, insulation for fire doors and panels etc. (or just as a thermal panel for insulation in domestic houses against heat or cold), pet litter, filler for paint, paper and plastic etc., it can also be used to produce heat resistant / heat retardant paint, cutting compound for polish and the manufacture of lighter weight, insulated bricks and concrete products (Anonymous, 2008b)

Decomposition and decay of diatoms leads to organic and inorganic (in the form of silicates) sediment, the inorganic component of which can lead to a method of analyzing past marine environments by corings of ocean floors or bay muds, since the inorganic matter is embedded in deposition of clays and silts and forms a permanent geological record of such marine strata (Anonymous. 2008c).

Diatomite is relatively inert and has a high absorptive capacity, large surface area, and low bulk density. It consists of approximately 90 percent silica, and the remainder consists of compounds such as aluminum and iron oxides. The fine pores in the diatom frustules make diatomite an excellent filtering material for beverages (e.g., fruit juices, soft drinks, beer, and wine), chemicals (e.g., sodium hydroxide, sulfuric acid, and gold salts), industrial oils (e.g., those used as lubricants in rolling mills or for cutting), cooking oils (e.g., vegetable and animal), sugars (e.g., cane, beet, and corn), water supplies (e.g., municipal, swimming pool, waste, and boiler), varnishes, lacquers, jet fuels, and antibiotics, as well as many other products. Its relatively low abrasive properties make it suitable for use in toothpaste, sink cleansers, polishes (for silver and automobiles), and buffing compounds.

Diatomite is also widely used as a filler and extender in paint, paper, rubber, and plastic products. The gloss and sheen of “flat” paints can be controlled by the use of various additions of diatomite. During the manufacture of plastic bags, diatomite can be added to the newly formed sheets to act as an antiblocking agent so that the plastic (polyethylene) can be rolled while it is still hot. Because it can absorb approximately 2.5 times its weight in water, it also makes an excellent anticaking carrier for powders used to dust roses or for cleansers used to clean rugs. Diatomite is also used in making welding rods, battery boxes, concrete, explosives, and animal foods (Anonymous, 2008d)

Diatomite has a growing use in agriculture. For a long time it has been used as an addition to ammonium nitrate fertilizers to prevent caking and ensure even spreading. It is important as a carrier for other agricultural products, particularly fertilizers. Our own manufactured product, Molodri is an example of the effectiveness of diatomite in this capacity. The use of diatomite in combination with other biogenic combinations is a key to its future uses as a beneficial for both plants and animals (Anonymous, 2007b). Diatomite is a sedimentary rock composed largely or wholly of the siliceous skeletal remains of microscopic, mainly aquatic plants called diatoms that are a type of algae. The skeletons (frustules) consist of amorphous (as opposed to crystalline), opaline or hydrous silica, but the rock may be contaminated by varying amounts of organic matter, alumina, iron, soluble salts, and sedimentary particles such as clay, carbonates, and sand (Anonymous, 2007b)

Hydroponics, simply defined, is the growing of plants in a water and fertilizer solution containing the necessary nutrients for plant growth. It is not a new science, with work being done by researchers as early as the 1600's. In the early 1930's, W.E Gericke, of the University of California, put laboratory experiments in plant nutrition on a commercial scale. In doing so, he termed these nutri-culture systems "hydroponics". The word was derived from two Greek words, hydro, meaning water, and ponos, meaning labor, or literally, water working. Gericke's application of hydroponics soon proved itself by providing food for troops stationed on non-arable islands in the Pacific in the early 1940's. In 1945 the U.S. Air Force solved its problem of providing its personnel with fresh vegetables by practicing hydroponics on a large scale on the rocky islands normally incapable of producing such crops. With the development of plastics, hydroponics took another large step forward and is now a widely accepted method of producing certain specialty crops such as tomatoes, lettuce, cucumbers, and peppers. Other crops that can be grown by this method include herbs, foliage plants, and flowers. Most of the roses exported from Holland are grown hydroponically (Anonymous, 2006)

There are various systems of soilless culture. One of them is Media culture This is a system in which crops are planted on solid substrate rather than on soil and nutrient solution is applied to the media. Both inorganic and organic media are used. Inorganic media are classified according to their shape into particles, foam, fiber and others. Particle media culture include sand culture, gravel culture, expanded clay culture and Kuntan culture. Passive hydroponics, also known as hydroculture, is one of the techniques of hydroponics. Hydroponics refers to the method of growing plants without soil. Instead of soil, hydroponics depends on a special substrate, known as a hydroponic growing medium.Passive hydroponics does away with the need for water or air pumps, by depending on the capillary action of the plant's own roots to transport water and nutrients to it. It essentially involves growing the plant in a porous container with a reservoir containing water and hydroponic nutrients. This system allows the plant to take in only the specific amount of nutrition it needs. The most basic passive hydroponics system consists of a pot placed in a nutrient solution or a capillary mat saturated with nutrient solution.Passive hydroponics, and other hydroponic techniques, offer many advantages over traditional methods of horticulture. Firstly, since a sterile medium is used instead of soil, the plant is protected against soil-borne diseases. Secondly, plants grown using hydroponics take up much less space than those grown in soil, which makes hydroponics the perfect choice for hobby horticulturistsThese are some common hydroponic growing mediums: Perlite: Perlite is an amorphous volcanic glass. It is a popular growing medium. Vermiculite: Vermiculite is a natural mineral that resembles mica rock in appearance. It retains moisture well. Vermiculite is often used along with perlite as the two materials complement each other. **Diatomite: Diatomite is a naturally occurring, soft sedimentary rock. It contains elemental minerals, required for the growth of plants, which makes it an excellent hydroponic growing medium.** Charcoal: Charcoal is a residue of impure carbon. It is often used in combination with other growing mediums. Rockwool: Rockwool is a manmade mineral fiber. Because it is chemically and biologically inert, it makes an ideal hydroponic growing medium. Information on passive hydroponics is readily available. Besides the technique requires little expense or care. Because of this, even enthusiasts who are beginners with passive hydroponics beginners often enjoy successful results with relatively little effort.Freshwater diatomite can be used as a growing medium in hydroponic gardens.It is also used as a growing medium in potted plants, particularly as bonsai soil. Bonsai enthusiasts use it as a soil additive, or pot a bonsai tree in 100% Diatomaceous earth. Like perlite, vermiculite, and expanded clay, it retains water and nutrients while draining fast and freely allowing high oxygen circulation within the growing medium (Anonymous,2008b)

MATERIALS and METHODS

Diatomite as a growth media for higher plants

As a Preliminary Study

A preliminary simple experimental work is conducted with a commercially available cheap material called diatomite which is sold in supermarkets (Bought in Migros) as a cat sand in order to look in to possibility of using as growth media for crop plants in place such materials as sand, gravel, saw – dust and others in sand culture experiments and gardening . The material is available as coarsely ground sand-like form (particle size varied between 0-10 mm) and packed in different sized bags.

The experimental material have been filled in to pots (2 liter) and sawn with tomato seeds. After emergence of seedlings pots and plants are watered with (Arnon ,1938) nutrient solution weekly in the beginning and once in a few days later on . Namely plants are irrigated with the nutrient solution less frequently towards the end as needed . The experiment has continued till the beginning of the flowering stage.

Growth of the test plant, tops and roots a like was very healty. In this simple observatory work separation ease of plant roots from the diatomite particles were also studied and evaluated. The plant roots muffled with the media particles during the harvest were easily separated from each other by submerging roots in to filled cup and rinsing it in a few minutes time.

RESULTS and DISCUSSION

With the above mentioned perfect phisico-chemical properties (high water holding capacity , freedom of pathogenes, to be chemically inert or inactive, ideal pH , etc..) of the test material (diatomite), it seems to be an exellent growth media for crop plants in sand culture experiments , greenhouse propogation and gardening (Table. 1-2) . It is partucularly suitable for studies concerned with plant root physiology and plants needing much air circulation (figure.1).

Our tests indicate that Diatomite is chemically inert and has good water holding characteristics. The plant roots muffled with the media particles during the harvest were easily separated from each other by submerging roots in to filled cup and rinsing it in a few minutes time Its disadvantage is cost 3 TL/ 14 liter in Turkey. But there are a lot of natural ditomite sources in Turkey (Figure. 2)

Table. 1.The Physical and Typıcal chemical properties of diatomite (Anonymous,2008b)

Physical properties	**Typical chemıcal properties**
Color- White, cream to yellow	Silicon Dioxide (SiO_2) 82.17%
Moisture- Approximately 6%	Aluminum Oxide (Al_2O_3) 6.74%
Bulk Density- Approximately 0.4	Iron Oxide (FeO_3) 3.15%
PH- 6.2 to 6.9	Calcium Oxide (CaO) 0.04%
Water absorption- 150% - 170% w/w	Magnesium Oxide (MgO) 0.37%
Oil absorption- 115% - 125% w/w	Titanium Oxide (TiO_2) 0.60%
	Sodium Oxide (Na_2O) 0.30%
	Potassium Oxide (K_2O) 0.04%
	Phosphate Oxide (P_2O_5) 0.09%
	Manganese Oxide (MnO) 0.01%
	Strontium Oxide (SrO) 0.01%
	Sulphur Trioxide (SO_3) 0.04%
	Loss on Ignition L.O.I 5.93%

Table 2. Some phisico-chemical properties of diatomite used in experiment (Jackson, 1962)

pH	**CEC cmol.kg^{1}**	**Na K cmol.kg^{-1}**	**P mgk g-^{1}**	**O.M %**	**$CaCO_3$ %**	**W.H.C %**
6.6	2.7	6.5 0.4	2.1	0.03	0.28	190
7.1	3.0	6.0 0.5	2.0	0.02	0.25	185

Figure.1. Tomato roots were separated from diatomite particules easily

Figure. 2 .Diatomite sources (44 224 029 tone good quality Diatomite) in Turkey (Bayırtepe, 2001)

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Determination of Phosphorus and Potassium Status of Erzurum Plain Soils with Neubauer Seedling Technique

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ABSTRACT
The purpose of this investigation was to determine phosphorus and potassium status of Erzurum plain soils .Representative 22 soils samples were collected from Erzurum plain. A greenhouse experiment was conducted using randomized block design each treatment replicated three times Rye (S.cerale tetraploid) was used as the test plant according to Neubauer seedling method

Rye plants have been grown for 17 day duration. In a short time P and K in soil has been exploited by multiple branched roots, obtained from plants grown on 100 g soil. The plants harvested after 17 days growing period. P and K concentration in plants were determined quantitatively by using chemical analysis methods.

As a result, soils, except 2 ,6 and 15 numbered samples were found adequate for P_2O_5 and except 6 and 10 numbered soils, all samples were found adequate in terms of K_2O for Erzurum plain soils

Key Words: Soil, available, phosphorus, potassium, Neubauer method, rye.

INTRODUCTION

The determination of plant available nutrient fraction can be carried out by various techniques . This differ basically in principle and three different approaches are provided by the methods of soil analysis , plant analysis , and plant experiments such as pot and field trials.

An important aspect which must be considered in relation to nutrient availability is the difference in nutrient requirement between crops . High yielding crops and intensive cropping systems place a greater demand on available nutrients in the soil and particularly on phosphate (P) and potassium (K) (Mengel and Kirkby ,2001).

The Primary meusurements to obtain availability ratios or availability indexes must be made using plants because the concept of availability is defined in terms of plants. Several different biological methods are used to provide primary indexes. Biological methods are three classes: internal standart, direct and slope ratio.

Internal standart methods , the nutrient availability index is derived from the comparative responses produced by the supply of the nutrient in the soil and by knovn additions of the nutrient in the form of fertilizer (Mitscherlich b value, Dean a value, Isotope dilution etc.).

In direct methods , no fertilizer is added, and the availability index is inferred directly from the magnitude of some plant response measurement (Neubauer method etc.).

Slope ratio methods are an adaptation of direct methods .

The purpose of this investigation was to determine phosphorus and potassium status of Erzurum plain soils used in The Neubauer Method. The Neubauer Method , proposed by Neubauer and Schneider (1923), and its numerous modifications probably have been used more than any other method. <u>In the original method</u>: 100 grams soil are mixed with 50 grams of sand the mixture is covered with 250 grams sand , and 100 rye seeds are planted in the surface layer of sand. The rye seedlings are harvested on the 17 th day after planting. The tops and roots are analyzed together to determinete the quantities of phosphorus and potassiumthey contain. The quantities contained in the plants grown in parallel cultures without soil are subtracted to obtain the quantities The resulting figures are taken as indexes of the availabilities of P and K in the soil. In this method , nutrients other than P and K are not added Because of the short period of growth , the seeds supply most of the nutrients needed. The affect of factors other than supply of P and K in the soil is limited by dilution of the soil with sand and by the short period of growth. The plants on different soils produce about the same yield of dry matter . Atechnical difficulty en countered with same soils is that the roots cannet readily be separeted from the soil for analysis (Black ,1992).

To determine P and K situation of soils found in different agro-climatic areas a lot of studies has been carried out and these studies has been continuing as well (Aksoy.1967 ; Kacar, 1964 ; Kacar, et al. 1973; Kacar, et al. 1974 ; Özdemir 1986 ; Zabunoğlu, 1967; Yildiz et al 2003).

MATERIAL and METHODS

Representative 22 surface soil samples were collected from Erzurum plain. A greenhouse experiment was conducted using randomized block design each treatment replicated three times Rye (S.cerale tetraploid) was used as the test plant according to Neubauer seedling method

Rye plants have been grown for 17 day duration. In a short time P and K in soil has been exploited by multiple branched roots, obtained from plants grown on 100 g soil. The plants harvested after 17 days growing period

P and K concentration in plants were determined quantitatively by using chemical analysis methods (Kacar, 1972).

RESULTS and DISCUSSION

For his study , freshly collected soil samples were air- dried , sieved to pass 2 mm mesh immediately after they were borught to the laboratory and the soil of the sampling site were **Loam, Clay Loam, and Sand texture** (Baykan et al. 1965) with the following properties: **pH 6.86-8.26** (1;2.5 soil-water , Peech, 1965) , **organic matter 0.46% - 4.49%** (Hocaoğlu, 1966) **, CEC 20.42-55.55 cmol.kg^{-1}** (Knudsen vd 1982)**, $CaCO_3$ content 0.46%-13.6%** (Hızalan ve Ünal. 1966) **, Available P 17.01-73.05**

ppm (Olsen ve Sommers, 1982)**, Exchangable K 0.84- 3.76 cmol.kg^{-1}** (Knudsen et al. 1982) respectively

(Table.1).

Table 1. Characteristics of selected experiment soils

Soil No	pH	$CaCO_3$ (%)	OM (%)	CEC cmol kg^{-1}	Exc.K cmol kg^{-1}	P mg kg^{-1}	Clay %	Silt %	Sand %	Texture clases
1	**6.86**	1.29	2.57	49.6	2.45	17.01	19.31	**27.54**	52.55	L
2	6.93	**1.01**	**4.49**	52.1	2.25	**13.95**	19.96	27.60	52.44	L
3	7.82	4.33	**0.46**	**55.55**	2.71	18.36	23.98	31.15	44.89	C
4	7.44	5.31	3.79	47.58	2.33	21.92	13.50	33.75	52.75	SL
5	**8.82**	7.16	3.55	49.19	3.69	22.47	19.92	38.14	37.71	C
6	8.26	8.23	2.04	45.8	1.36	19.87	15.60	35.83	48.57	L
7	8.10	6.74	1.98	48.27	1.99	17.62	13.50	46.41	40.09	L
8	7.92	4.36	2.79	51.34	1.71	17.50	13.50	39.97	46.53	L
9	7.92	3.16	0.79	38.84	1.53	16.86	13.52	42.28	42.40	L
10	7.89	2.96	1.56	36.01	**0.84**	23.25	9.65	**51.87**	38.48	SL
11	7.39	1.07	1.2	29.98	2.72	46.91	17.32	37.11	45.57	L
12	7.44	1.36	2.63	29.75	**3.76**	**73.05**	21.69	33.06	45.25	L
13	7.88	4.92	3.43	44.57	1.2	23.72	**30.29**	33.20	**36.51**	CL
14	8.02	5.51	2.53	32.64	1.11	18.11	17.41	35.25	47.36	L
15	7.96	7.94	2.39	44.19	2.15	27.59	23.74	33.31	42.95	L
16	7.85	10.16	3.6	49.93	3.72	26.74	19.67	36.66	43.67	L
17	8.10	**13.97**	2.24	40.74	1.68	24.19	17.61	29.34	33.05	SL
18	8.34	5.57	3.31	37.92	3.01	32.68	15.33	47.66	37.01	L
19	7.31	1.04	1.63	22.85	1.26	26.38	**4.91**	30.67	**64.42**	SL
20	7.33	2.59	1.74	**20.42**	1.65	16.19	4.92	34.84	60.24	SL
21	7.67	2.88	1.21	30.83	1.54	21.04	13.22	33.66	53.72	SL
22	7.66	3.1	1.55	35.77	1.89	20.09	9.11	43.48	47.41	L

22 surface soils representing in Erzurum soils were chosen for the glasshouse experiments. The calculation of P and K values of soils according to Neubauer assay showed in Table. 2 and 3 (Özbek, 1969 and Aydemir,1992):

Each mg nutrients in per 100 g at equal 6 kg per hectar when we consider 1 hektar soil is 3 billion kg , this value is equal 30 kg. But plants in nature takes 1/5 of P and K in soils , thus this value can be accepted as 6 kg.

Table.2. Dry weight and P_2O_5 values of rye plants grown according to Neubauer method (For Kontrol pot= pure sand, P_2O_5 =19.3 mg / 100 gr in 100 rye grain)

Soil Samp No	**Dry weight g pot^{-1}**	**P (%)**	**P uptake mg pot^{-1}**	**P_2O_5 (mg)**	**Control plant (pure sand) mg P_2O_5. 100 g^{-1}**	**P_2O_5 kg ha^{-1}**	**Deficient P_2O_5 Kg ha^{-1}**
1	3.22	0.38	12.24	28.03	8.68	52.08	2.08
2	2.64	0.41	10.82	24.78	5.43	32.58	**-17.42**
3	4.48	0.38	17.02	38.98	19.63	117.78	67.78
4	2.62	0.48	12.58	28.81	9.46	56.76	6.76
5	2.88	0.47	13.54	31.01	11.66	69.96	19.96
6	2.12	0.43	9.116	20.88	1.53	9.18	**-40.82**
7	4.10	0.42	17.22	39.43	20.08	120.48	70.48
8	3.86	0.41	15.83	36.25	16.9	101.4	51.4
9	3.04	0.44	13.38	30.64	11.29	67.74	17.74
10	2.60	0.47	12.22	27.98	8.63	51.78	1.78
11	3.44	0.46	15.82	36.23	16.88	101.28	51.28
12	2.56	0.51	13.06	29.91	10.56	63.36	13.36
13	4.16	0.37	15.39	35.24	15.89	95.34	45.34
14	3.28	0.42	13.78	31.56	12.21	73.26	23.26
15	2.52	0.45	11.34	25.97	6.62	39.72	**-10.28**
16	3.54	0.42	14.87	34.05	14.7	88.2	38.2
17	3.38	0.4	13.52	30.96	11.61	69.66	19.66
18	3.24	0.49	15.88	36.37	17.02	102.12	52.12
19	3.4	0.41	13.94	31.92	12.57	75.42	25.42
20	4.66	0.4	18.64	42.69	23.34	140.04	90.04
21	3.02	0.45	13.59	31.12	11.77	70.62	20.62
22	3.54	0.47	16.64	38.11	18.76	112.56	62.56

Rye plants with high yield takes up 50 kg and 100 kg available P_2O_5 and K_2O respectively (Özbek,1969) . For better rye yield at least 8.33 mg P_2O_5 and 16.6 mg K_2O should be found in 100 g soil for each element.

For Erzurum Plain soils:

When consider at least 8.33 mg P_2O_5 / 100 g soil and 16.6 mg K_2O / 100 g soil should be found in soil , the sample except Number 2, 6, and 15, all samples P_2O_5 is relevant and for K_2O all samples except Number.6 and 10 were found sufficient.

For Application P_2O_5 (kg ha^{-1}) :

For Nr. 2, 6 ve 15 soil samples :

17.4 P_2O_5 kg ha^{-1} x 100/20= 87kg ha^{-1}

40.8 P_2O_5 kg ha^{-1} x100/20= 200 kg ha^{-1}

10.2 P_2O_5 kg ha^{-1} x100/20= 51 P_2O_5 kg ha^{-1} needed.

According to Neubauer Method , the plant can take up only 1/5 of total soil Phosphorus in natural conditions.

Table.3. Dry weight and P_2O_5 values of rye plants grown according to Neubauer method (For Kontrol pot= pure sand, K_2O mg=14,37 / 100 gr in 100 rye grain)

Soil sample No	Dry weight g pot^{-1}	K (%)	K Uptake mg pot^{-1}	K_2O (mg)	Control plant (pure sand) mg K_2O 100 gr^{-1}	K_2O Kg ha^{-1}	Deficient K_2O Kg ha^{-1}
1	3.22	1.13	36.39	44.03	29.66	177.96	77.96
2	2.64	1.18	31.15	37.69	23.32	139.92	39.92
3	4.48	1.48	66.3	80.23	65.86	395.16	295.16
4	2.62	1.50	39.3	47.55	33.18	199.08	99.08
5	2.88	1.25	36	43.56	29.19	175.14	75.14
6	2.12	0.78	16.54	20.01	5.64	33.84	**-66.16**
7	4.1	0.90	36.9	44.65	30.28	181.68	81.68
8	3.86	0.88	33.97	41.1	26.73	160.38	60.38
9	3.04	1.00	30.4	36.78	22.41	134.46	34.46
10	2.6	0.93	24.18	29.26	14.89	89.34	**-10.66**
11	3.44	1.15	39.56	47.87	33.5	201	101
12	2.56	1.38	35.33	42.75	28.38	170.28	70.28
13	4.16	0.70	29.12	35.24	20.87	125.22	25.22
14	3.28	0.95	31.16	37.7	23.33	139.98	39.98
15	2.52	1.20	30.24	36.59	22.22	133.32	33.32
16	3.54	1.35	47.79	57.83	43.46	260.76	160.76
17	3.38	1.40	47.32	57.26	42.89	257.34	157.34
18	3.24	1.25	40.5	49.01	34.64	207.84	107.84
19	3.4	0.93	31.62	38.26	23.89	143.34	43.34
20	4.66	0.85	39.61	47.93	33.56	201.36	101.36
21	3.02	1.30	39.26	47.5	33.13	198.78	98.78
22	3.54	1.53	54.16	65.54	51.17	307.02	207.02

For Application K_2O (kg ha^{-1}):

For Nr. 6 ve 10 soil samples.:

66.1 K_2O kg ha^{-1}x 100/60= 110 K_2O kg ha^{-1}

10.6 K_2O kg ha^{-1}x 100/60= 17.6 K_2O kg ha^{-1} needed.

(According to Neubauer Method ,the plant can take up only 1/3 of total soil Potassium in natural conditions (Aydemir,1992).

With this study , adequate fertilizer dose was defined by considering soil and plant analyses and the importance of Economical and Ekological were emphasized

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Impacts of Different Natural Fertilization Techniques that was Implemented on Organic Agriculture System on Fruit Quality Criterions of (*Ficus Carica* L. Cv. Sarilop) Dried Fig Cultivar

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ABSTRACT

Dried fig is second range (14,39%) as quantity and third range as value (15,89%) in Turkey total organic agricultural crops exports. Main aim of the project was determined that impacts on fruit quality parameters of 'Sarilop' dried fig variety of applied different natural fertilization technics on organic agriculture system. That research was carried out in a farmer orchard which consisted of Sarilop dried fig variety, located in Isafakilar village, Incirliova, Aydin, during 2002-2005 years. This experiment was designed in respect of randomized blocks with four replications and each replication was comprised of one tree. Totally six applications are on the carpet; those are includes control, vetch, natural vegetation, 20, 40 and 60 kg farmyard manure applications, respectively. The data which were obtained from the study was evaluated to analysis of variance using SPSS packet program. The means were separated by LSD multiple comparison test at 0.01 and 0.05. In that research, rate of the cull figs (%) (the worst quality dried fig fruit), cracking fruit rate (%), sunscalded (sunburn damage) rate (%), average fruit weight (g), total soluble solids content (TSS) (%), ostiole width (mm), skin colour parameters were investigated, respectively. It has been determined that impacts of the applications on some important properties on fig involved cracking fruit and sunscalded rate, average fruit weight, ostiole width.

Keywords: Dried fig, fertilization, fruit quality, organic agriculture.

INTRODUCTION

It is accepted that ecologic agriculture (biological agriculture, organic agriculture) is an active alternative for solution of health and environmental problems which has occurred by using of intensive agriculture inputs.

When it is analyzed period of ecological agriculture comprises environment friendly production techniques and aims to have increased welfare from farmer to consumer as years, the first half of 1900 years that was begun of using agrochemicals in agriculture, results of some approaches on soil productivity which were supported by some European pioneers, it has been seen that base of ecologic agriculture was occurred (Aksoy, 2001).

While Australia that has 11300000 hectare organic agriculture land is first range in total world organic agriculture land, such as countries of Argentina (2800000 ha), Italy (1052000 ha) have followed it. Turkey has 103190 hectare organic agriculture land. It is determined organic agriculture lands in total agriculture areas of the countries are 0.22-6.86% around. Turkey has 103190 hectare organic agriculture land and that area is constituted of 0.39% of total agriculture land (26000000 ha) (Table 1). The rate of organic agriculture lands is 0.4% (103190 ha) in its total agriculture lands (26000000 ha) (MARA, 2004).

Table 1. Total quantities of organic agriculture lands (ha) and the rate of its in total agriculture lands (%) in the world

Countries	Organic agriculture lands (ha)	The rate of its in total agriculture lands (%)
Australia	11300000	2.48
Argentina	2800000	1.70
Italy	1052000	6.86
the USA	930810	0.22
Brazil	803180	0.23
Uruguay	760000	4.00
Germany	734027	4.30
Spain	725254	2.84
England	695619	4.42
Turkey	103190	0.39
Others	6554190	-
Total	26458270	-

Source: SOEL, 2005. SOEL (Fondation for Ecology and Agriculture) Survey, February 2005.

MATERIALS and METHODS

The research material is consisted of the farmer dried fig orchard which is planted 'Sarilop' dried fig variety located in Isafakilar village, Incirliova, Aydin. In the trial, treatments were conducted of three different dosages of dairy manure and vetch, mulches application which was shaped from leaving of cutting foreign herbs.

The trial was conducted of randomized blocks experiment design, the treatments were 4 replications and each replication was consisted of one tree. Implementations were 6 numbers which have been explained below:

Control: It was continued the normal farming management and agricultural processes that have been made by a farmer in normal production period.

Natural vegetation: The natural herbs on the orchard land was cut and left on upper side of the soil.

Vetch: It was planted 12 kg/da in October-November months and it was mixed with soils in beginning of flowering in spring period.

20 kg fertilizer/tree: 20 kg/tree farm manure was given in each tree crown projection in January and February months.

40 kg fertilizer/tree: 40 kg/tree farm manure was given in each tree crown projection in January and February months.
60 kg fertilizer/tree: 60 kg/tree farm manure was given in each tree crown projection in January and February months.

Statistic analysis of data obtained from the trials were made considering randomized parcels experimental design using with SPSS Statistical Software Programs.
The methods of fruit analysis: Dried fig samples were obtained from dried fruits which fallen and were dried on wooden divan of shrink figs. Ostiole width (eye) was measured by a digital compass (BTS, 0-150 mm). Fruit skin was determined by sensitive tests and samples were evaluated considering colors with dark (1), middle (2), light (3) and very light (4) and average class values were calculated with sample numbers of each class were multiplied class values and were divided average class values. Soluble solids were determined with a hand-held refractometer (N.O.W., 0-32% Brix) from diluted fruits. In the study, some important quality parameters on fig such as different quality categories. Cracking parameter of fruits were evaluated in two ways. More than cracking of fruits length of 1/3 and good ones. It was evaluated the dried fruits for sunscalded parameter; more than sunlight damages of 1/3 of fruit outer space and good ones. The rate of the worst quality dried fig fruit was determined fruits from which had cracking, sunlight damage, excessive dried fruits and bird and insect damages fruits separately.). The worst quality dried figs are called cull figs which cannot be marketed for human consumption (Özbek, 1958)

RESULTS AND DISCUSSION

The rate of cull figs: For the rate of cull figs (the worst quality dried fig fruits), it was determined the significance among years in statistical manner. The fewest rate of the worst quality dried fig fruits were obtained from first year of the research as %22.35 value (Table 2).

Table 2. The rate of cull figs (%)

Application	2003	2004	2005	Average
Control	22.48	42.91	32.45	32.61
Natural vegetation	22.62	49.86	32.20	34.89
Vetch	20.17	31.55	31.81	27.84
20 kg fertilizer/tree	26.65	38.44	39.93	35.00
40 kg fertilizer/tree	19.28	24.16	30.74	24.73
60 kg fertilizer/tree	22.87	26.86	44.74	31.49
Year averages	22.35 b	35.63 a	35.31 a	31.09
Year $_{LSD, 0.05}$ = 6.18				

Among implementations, the rate of worst quality dried fig fruit wasn't found statistically significant. In addition, the most excessive rate of the worst quality dried fig fruit was obtained from 20 kg fertilizer/tree application as 35% value, the fewest rate of the worst quality dried fig fruit was obtained from 40 kg fertilizer/tree application as 24.73 % value.

Sunscalded and cracking damages are the first ranges in the fig growing. Aksoy et al. (1987) explained that the rate of sunscalded fig fruits rate may be arrived 27% and this negative event is increased the worst quality dried fig class. The ratio of severely sunscalded (sunburn damage) fruits in the 'Sarilop' cultivar grown under Aegean conditions were reported to range from 0.0% to 47.2% in 1992 and from 2.7% to 59.4% in 1993 (Aksoy, 1994).

Anac et al. (1991) obtained the rate of the worst quality dried fig fruits between 13.30-89.12% and they declared that unsuitable fruit bearing is caused product and value lost in fig production in the research had been made to determine nutrition status of dried fig orchards in Small Meander Valley, Turkey.

The rate of cracking fruits

Table 3. The rate of cracking fruits (%)

Application	2003	2004	2005	Average
Control	11.85	12.78	10.05	11.56 ab
Natural vegetation	5.26	2.81	9.94	6.00 c
Vetch	9.30	11.76	12.91	11.32 ab
20 kg fertilizer/tree	5.75	6.95	12.65	8.45bc
40 kg fertilizer/tree	9.79	11.22	16.16	12.39 ab
60 kg fertilizer/tree	12.23	10.73	19.40	14.12 a
Year averages	9.03 b	9.38 b	13.52 a	10.64
Year $_{LSD, 0.05}$ = 3.55 Implementation $_{LSD\ 0.05}$ = 5.03				

In the rate of cracking fruits, it has been fixed that there has been statistically difference among implementations. And also it was observed the most cracking fruits rate were 14.12% in 60 kg fertilizer/tree and the fewest cracking fruits rate were 6% in natural vegetation applications (Table 3).

According to published TS 541/T1 dried fig standard in 2007 year, cracking fig fruits were described between dried fig stalk and more than its 1/3 length cracking dried figs are inside split, torn dried fig descriptions.

The cracking in fig fruits is important quality losing and is affected by some factors such as high humidity and nutrition balance. Aksoy and Anac (1994) were investigated impacts of $CaCl_2$ implementations were carried out on the fig leaves on fruit quality and contents of fruit and leaf nutrition elements in 'Sarilop', 'Göklop' and 'Bursa Siyahi' fig cultivars. It was observed that the evidence of fruit cracking was diminished by 1% $CaCl_2$ application, statistically important.

Aksoy et al. (1987) declared that increasing of the rates of K/Ca and K/Ca+Mg in leaf palm and stalk was caused negative effects on fruit cracking. And also Aksoy and Anac (1994) obtained nitrogen levels were increased by 1% $CaCl_2$ applications in 'Sarilop', 'Göklop' and 'Bursa Siyahi' fig cultivars. Shear (1975) determined deficiency of calcium was caused cracking on apple, cherry, dried plums and carrot. In addition it was obtained some spoils which occurs depends on calcium, are increased with nitrogen fertilization. These findings are concordant with our results.

There was determined statistically difference among years. It was seen that the rate of cracking fruit was increased in the third year of the experiment.

The rate of sunscalded figs

Table 4. The rate of sunscalded figs(%)

Application	2003	2004	2005	Average
Control	10.63	10.30	12.79	11.24 b
Natural vegetation	17.36	8.77	13.83	13.32 b
Vetch	10.88	10.07	14.40	11.78 b
20 kg fertilizer/tree	20.90	12.35	19.03	17.43 a
40 kg fertilizer/tree	9.49	4.37	6.27	6.71 c
60 kg fertilizer/tree	10.64	4.46	6.78	7.29 c
Year averages	13.32 a	8.39 b	12.18 a	11.30
Year $_{LSD, 0.05}$ = 2.43 Implementation $_{LSD\ 0.05}$ = 3.44				

For the rate of sunscalded figs (sunborn damage), there was indicated statistically difference among implementations. And also it was observed the worst sunlight damages rate were 17.43% in 20 kg fertilizer/tree and the fewest sunlight damages rate were 6.71% in 40 kg fertilizer/tree application (Table 4).

According to published TS 541/T1 dried fig standard in 2007 year, dried fig fruits with sunborn damages were described more than 1/3 of dried fig stalk had been lost its elasticity, being hardiness and being occurred sunburn damages dried fig fruits.

Anac et al. (2001) indicated that while ripening period has been continuing, it was determined increasing sunburn damages and decreasing cracking fruit rate because of impacts of current climate conditions results. With increasing potassium rate, they were reported good fruits rate which haven't been affected from sunburn damages, were increased.

In addition nitrogen content of soils affected fruit numbers with positive direction and reduced sunburn damages but these correlations haven't been found for nitrogen content of leafs also. It was indicated in a research study which was made by Aksoy et al. (1987) on 'Sarilop' dried fig cultivar, potassium content of leafs impacts sunburn damages of the fruits significantly and there are positive correlations with potassium content of leafs and good fruit rate.

There was determined statistically difference among years. It has been seen that the rate of fruits with sunburn damage was increased first and third year of the experiment.

The average fruit weight

Table 5. The average fruit weight (g)

Application	2003	2004	2005	Average
Control	12.23 ab	14.42 d	15.10 d	13.92
Natural vegetation	13.37 ab	15.71 cd	22.03 b	17.03 c
Vetch	14.46 ab	17.97 bc	21.63 b	18.02 bc
20 kg fertilizer/tree	11.61 b	14.91 cd	18.21 c	14.91 d
40 kg fertilizer/tree	14.46 ab	20.23 ab	21.51 b	18.73 b
60 kg fertilizer/tree	14.64 a	21.29 a	26.09 a	20.67 a
Year averages	13.46 c	17.42 b	20.76 a	17.21
Year $_{LSD, 0.05}$ = 1.07 Implementation $_{LSD\ 0.05}$ = 1.51 Int. Year*Implementation $_{LSD\ 0.05}$ = 2.62				

Among implementations, for the average fruit weight there was determined statistically difference. While the largest fruit was obtained from 60 kg/tree fertilizer application as 20.67 g, the smallest fruit was measured from control treatment as 13.92 g. There was obtained statistically difference among years. In third year of the experiment, the largest fig fruit (20.76 g) was obtained, the smallest fig fruit was determined in first year of the research (Table 5).

Aksoy et al. (1987) declared in the research paper which was conducted to determine nutrition status of fig orchard located in Germencik province, average dried fruit weight which was dried in natural conditions and methods, was 16.3 g and it was explained phosphorous nutrient matter increases dried and fresh fig weight and impacts positive approaches.

Anac et al. (1991) indicated calcium content of soil impacts fruit size, especially causing small size. However, low potassium degree in the soil and K/Ca imbalance in a plant have been affecting on that result.

Depending of the years there was determined statistically difference among implementations. While 60 kg fertilizer/tree application was given the largest fruit size in every 3 years in the experiment, it was obtained the smallest fruit size in the second and third years of the trial.

Total Soluble Solids

Table 6. Total Soluble Solids (%)

Application	2003	2004	2005	Average
Control	50.88	56.00	46.90	51.26
Natural vegetation	46.63	57.63	47.95	50.73
Vetch	55.75	57.00	46.20	52.98
20 kg fertilizer/tree	44.50	51.75	49.48	48.58
40 kg fertilizer/tree	48.63	55.88	50.40	51.63
60 kg fertilizer/tree	48.88	60.50	48.65	52.68
Year averages	49.21 b	56.46 a	48.26 b	51.31
Year $_{LSD,\ 0.05}$ = 2.50				

There wasn't found statistical difference among implementations on the rate of total soluble solids. In vetch application, there was determined the highest total soluble solids as %52.98 (Table 6).

The sugars take the most important share in total dried fig structure. It has been explained that the rate of total soluble solids on the figs are changing between 47-63.1%. Beside the it was reported iron content of leafs impacts on fruit composition and increases total soluble solids and dissolves part of fruit in water which consists of important share of total soluble solids (Aksoy et al., 1987).

In the research paper which was carried out to investigate difference of soil specials in fig orchards on shoot developing and fruit quality, it was declared that physicals characteristics of soils are relating with fruit composition planted on ground fig orchards and pH state of soil has positive impacts total soluble solids of fruit (Aksoy et al., 1991).

Hernandez et al. (1994) explained in a research article which was made to determine 6 different irrigation and 6 different nitrogen levels on quality and nutrient contents of fruits in fig trees, nitrogen affected positive direction on total soluble solids of fruits in only one season, but nitrogen declined calcium (Ca) content of leafs.

There was determined statistical difference among years. In second of the experiment rate of total soluble solids was higher than other years.

Ostiole width (eye)

There was obtained statistical difference for ostiole width among the treatments. Considering grouping value, there was measured the highest ostiole width in 60 kg fertilizer/tree as 3.94 mm and the lowest ostiole width in control application as 2.88 mm (Table 7).

Table 7. Ostiole width (mm)

Application	2003	2004	2005	Average
Control	2.88	3.07	2.68	2.88 d
Natural vegetation	3.51	3.62	3.39	3.50 bc
Vetch	3.93	3.71	4.13	3.92 a
20 kg fertilizer/tree	3.17	3.23	3.12	3.17 cd
40 kg fertilizer/tree	3.85	3.96	3.73	3.85 ab
60 kg fertilizer/tree	3.94	3.97	3.91	3.94 a
Year averages	3.54	3.59	3.49	3.54
Year $_{LSD, 0.05}$ = 0.39				

Ferguson et al. (1990) states that breeding efforts focus on the common type 'Calimyrna' quality fig with closed ostiole to restrict insect access.

It has been indicated ostiole width which causes entrance of insects and diseases is narrowed by impacts of calcium (Aksoy et al., 1987).

In a study that to investigate impacts of zinc applications through leafs and soil on yield and some quality components ‘Sarilop’ dried fig variety, for zinc applications there wasn’t determined statistical difference on ostiole width (Aydin et al., 2000).

Irget et al. (1998) declared $Ca(NO_3)_2$ and KNO_3 applications caused narrowing of ostiole width.

Skin color (scale of class value)

Table 8. Skin color (scale of class value)

Application	2003	2004	2005	Average
Control	1.89	1.95	2.36	2.07
Natural vegetation	1.80	2.02	2.42	2.08
Vetch	1.88	2.01	2.32	2.07
20 kg fertilizer/tree	2.12	1.99	2.38	2.16
40 kg fertilizer/tree	1.80	2.13	2.50	2.14
60 kg fertilizer/tree	1.78	1.89	2.31	1.99
Year averages	1.88 b	2.00 b	2.38 a	2.09
Year $_{LSD, 0.05}$ = 0.13				

In the study, it was used scale of class value for skin color, from 1: dark, to 4: very light, there wasn’t obtained statistical difference among implementations for skin color. However, there was determined statistical difference among years. In the third year of the experiment, it was observed skin color of the fruit between middle and light.

Aksoy et al. (1987) explained in a research study, 49.8, 39.3, middle and 10.9% of total dried fruit samples were light, middle and dark color, respectively. In the same study, it was declared that magnesium, iron and boron has negative impacts on dried fig fruit skin color.

The dried fig with light color, flexible, soft, closed eye and sugar is important parameters as quality and delicious. Aksoy et al. (1991) indicated in another study iron, zinc and copper elements have impacts on fruit skin color, iron and copper increase rate of fruits with dark color, but zinc affect skin color of the fig fruits especially planted on ground orchards.

As a result, it was determined that the application of 40 kg fertilizer/tree was declining fruit rate which has sunburn damage, was increasing average fruit weight. Despite the fact that it wasn't obtained statistical difference, that application was declining the worst quality dried fig fruit rate.

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Changes in pH, EC and Concentration of Phosphorus in Soil Solution during Submergence and Rice Growth Period in Some Paddy Soils of North of Iran

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ABSTRACT

Changes in pH, EC and concentration of phosphorus in soil solution during submergence and rice growth period were studied in three paddy soils of North of Iran (one acid and two alkaline-calcareous soils). Also, changes in pH, EC and concentration of phosphorus in soil solution of an alkaline-calcareous soil after addition of 40 mg P/ kg of soil during submergence and rice growth period were studied. The experiment was performed in a set of specially fabricated pots equipped with a perforated sampling tube installed in the root zone area. At different times, pH, EC and concentration of phosphorus in soil solution of cultivated and uncultivated treatments were measured. The results are as follows: 1- After submergence, water soluble P increased initially and then decreased in all three soils in both cultivated and uncultivated treatments. 2- Both pH and concentration of water soluble P in both treatments was not significantly different at early stage of rice growth, but they were significantly lower in cultivated treatment afterward. 3- After submergence, the pH of alkaline soils decreased, while the pH of acid soil increased significantly. 4- The EC of rhizosphere soil solution changed differently in different soils during the rice growth period. In acid soil, the EC of rhizosphere soil was significantly lower than the bulk soil solution, while in one of the alkaline-calcareous soils, it was significantly higher than the bulk soil solution. 5- After P addition, the pH of the rhizosphere soil solution did not change significantly, but the pH of the bulk soil solution increased significantly. 6- Generally, the chemistry of rice rhizosphere was essentially different from the bulk soil.

Keywords: Rice, pH, EC, phosphorus, soil solution, rhizosphere, submergence, paddy soils.

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important crops in the world and Iran that is cultivated under submerged conditions. When a soil is submerged, air is excluded and the soil quickly becomes anoxic and reduced. This phenomenon changes physical, biological, and chemical properties of soil (Ponnamperuma, 1972; Kirk, 2004). Soil pH is probably the most important chemical soil parameter (Bloom, 2000). It reflects the overall chemical status of the soil and influences a whole range of chemical and biological processes occurring in the soil. Because of its implications in most chemical reactions in the soil, knowing the actual value of soil pH and monitoring its changes is critical for understanding the physicochemical functioning of the soil (Jaillard et al. 2003). After soil waterlogging, the pH tends to converge to neutrality irrespective of initial pH, whether acidic or alkaline (Ponnamperuma, 1972; Kirk, 2004). Narteh and Sahrawat (1999), and Dekamedhi and De Datta (1995) found that the soil solution electrical conductivity (EC) increased initially after submergence and then decreased. Also, the chemical behavior of phosphorus can easily be changed by flooding of paddy soils. Some investigations showed that the concentration of phosphorus in soil solution increased initially after submergence and then decreased (Ponnamperuma, 1972; Narteh and Sahrawat, 1999).

Root-soil interactions in the rhizosphere include different processes that have an important influence on the soil solution chemistry (Smiley, 1974). Chemical conditions in the rhizosphere can be very different from those of the bulk soil due to root exudation, nutrient uptake, microbial activity, and differences in water relations (Darrah, 1993; Hinsinger, 2001; Marschner, 1995; Wang et al., 2005). Thus, knowledge of rhizosphere chemistry and rhizosphere processes is essential for characterizing nutrient availability in soils. In the last decade, much progress has been made toward a better understanding of the role of rhizosphere processes in plant nutrition, particularly the root-mediated changes in the chemical, physical, and biological properties of the rhizosphere soil (Darrah, 1993; Gregory and Hinsinger, 1999). However, little attention has been given to the dynamics of rhizosphere solution, and little is known about the influence of rice plant on rhizosphere solution chemistry. Improved understanding of rhizosphere solution chemistry will enhance our ability to model nutrient dynamics and to develop on a broader scale, effective buffers to minimize nutrient movement to surface waters (Wang et al., 2005). In This investigation, Changes in pH, EC and concentration of phosphorus in soil solution during submergence and rice growth period in some paddy soils of North of Iran were studied.

MATERIALS and METHODS

On the basis of soil properties including pH, CCE, available-P, and texture, three soil samples (one acid and two alkaline-calcareous) collected from the surface layer (0-20 cm depth) of paddy soils of north of Iran. The soil samples were air-dried at room temperature, thoroughly mixed, and sieved (2-mm). Then, two greenhouse experiments were conducted. In the first experiment, changes in pH, EC and concentration of phosphorus in soil solution during submergence and rice growth period were studied. The experiment was performed as a 13×2×2 factorial experiment in a randomized complete blocks design, with two replications and three factors of soil at two levels, time at 13 levels, and cultivation at two levels (cultivated and uncultivated). In this Experiment, two soils (one acid and one alkaline-calcareous) with similar available-P contents were selected. The Olsen-P of the both soils was 45.5 mg P/kg of Soil. In the second experiment, changes in pH, EC and concentration of phosphorus in soil solution during submergence and rice growth period were studied after application of 40 mg P per kg of one alkaline-calcareous soil with the initial Olsen-P of 3.8 mg P per kg of soil. The experiment was performed as a 12×2×2 factorial experiment in a randomized complete blocks design, with two replications and three factors of P fertilizer at two levels (0 and 40 mg P/kg of soil), time at 12 levels, and cultivation at two levels (cultivated and uncultivated).The both experiments were performed in a set of specially fabricated pots equipped with a perforated sampling tube installed in the root zone area. The pots were filled to 20 cm depth with soils. The fertilizers, including 40 mg P as MCP (only in P-fertilized treatment), 140 mg Urea, 100 mg K_2SO_4, and 22 mg $ZnSO_4.7H_2O$ per kg of soil, were added in liquid form and mixed thoroughly with the soil. The soil moisture was held at almost saturation percentage during the first three days, and then five germinated rice seeds (*Oryza sativa* L. cultivar Khazar) were transplanted in each pot (only in cultivated treatments). After 10 days, water was added in sufficient amounts to maintain a water level of five centimeters above the soil surface for a period of three months. At different times, soil solution samples of cultivated and uncultivated pots were gathered using a 50 mL syringe and pH, EC and concentration of phosphorus in soil solution was measured. Inorganic P in the extracts was quantified spectrophotometrically by the ascorbic acid method (Murphy and Riley, 1962; Kuo, 1996). Statistical analysis of data including normality test, analysis of variance, and comparisons of means was performed by using MSTATC and Excel programs. Comparison of means was carried out by Duncan's multiple range test at $P \leq 0.05$.

RESULTS AND DISCUSSION

The selected chemical and physical properties of the experimental soils are listed in Table 1. The important data in Table 1 indicate that the three soils studied had a wide range in initial pH (6.2-7.9), organic C (18.9-49.3 g/kg), Calcium carbonate equivalent (0-423.7 g/kg), available-P (3.8-45.5 mg/kg), and texture (loam-sandy clay loam). Soils 628 and 635 are alkaline-calcareous and soil 650 is acidic. Soils 628 and 650 have similar available-P.

Table 1. Some chemical and physical properties of the soils used in the study.

Soil No.	$pH_{1:1(H2O)}$ -	CCE (g/kg)	OC (g/kg)	Olsen-P (mg/kg)	Sand (g/kg)	Clay (g/kg)	Texture -
628	7.9	115.7	18.9	45.5	427	214	L
635	7.7	423.7	25.3	3.8	460	255	L
650	6.2	nil	49.3	45.5	492	275	SCL

CCE: Calcium carbonate equivalent, OC: Organic carbon, L: Loam, SCL: Sandy clay loam.

Changes in pH of Soil Solution after Submergence

The results of two experiments showed that after submergence in uncultivated treatments, pH of alkaline-calcareous soils decreased initially and remained almost constant, then increased again (Figures 1, 2, 3), while pH of acidic soil 650 increased initially and then remained almost constant (Fig. 4). Following submergence, CO_2 formed in respiration, escapes from the soil only very slowly, and it therefore accumulates. As CO_2 continues to accumulate during anaerobic respiration and fermentation, large partial pressures develop, typically in the range of 5 to 20 kPa. The accumulation of CO_2 lowers the pH of alkaline soils (Kirk, 2004).

The observed increase in acidic soil solution pH as a result of submergence into water is well known (Ponnamperuma, 1972) and attributed to the consumption of protons during reduction processes (Narteh and Sahrawat, 1999; Kirk, 2004). The subsequent increase in soils pH after 50 days can be attributed to the predominance of reduction processes and pH increase by urea hydrolysis. In this study nitrogen fertilizer added as 100 mg urea/ pot (four times) to both rice cultivated and uncultivated pots during rice growth period. The pH increases during urea hydrolysis (Kirk, 2004):

$CO(NH_2)_2 + 3H_2O \rightarrow 2NH_4^+ + HCO_3^- + OH^-$

Changes in pH of Soil Solution after Rice Cultivation

Comparisons of means indicated that the pH of the rhizosphere (rice cultivated treatment) in all three soils studied was significantly lower than bulk soil (uncultivated treatment) solution (Figures 1, 2, 3, 4). The following processes may be expected to modify soil conditions near rice roots growing in submerged soil which lead to a considerable acidification of the rhizosphere (Kirk et al. 1993; Kirk, 2004):

- The oxidation of ferrous iron by rice root-released O_2 which leads to both an accumulation of $Fe(OH)_3$, and an acidification:

$$4Fe^{2+} + O_2 + 10H_2O \longrightarrow 4Fe(OH)_3 + 8H^+$$

- The direct release of H^+ ions from the roots to balance cation-anion intake, Because the main form of plant-available N in anaerobic soil is NH_4^+, the root absorbs an excess of cations (NH_4^+, K^+, Na^+, Ca^{2+}, Mg^{2+}) over anions ($H_2PO_4^-$, Cl^-, SO_4^{2-}). Consequently H^+ is released by the root to maintain electrical neutrality, tending to further decrease the rhizosphere soil pH.
- The release of organic acids from the root into the soil.
- The release of CO_2 from roots during respiration which reacts with water to form carbonic acid.

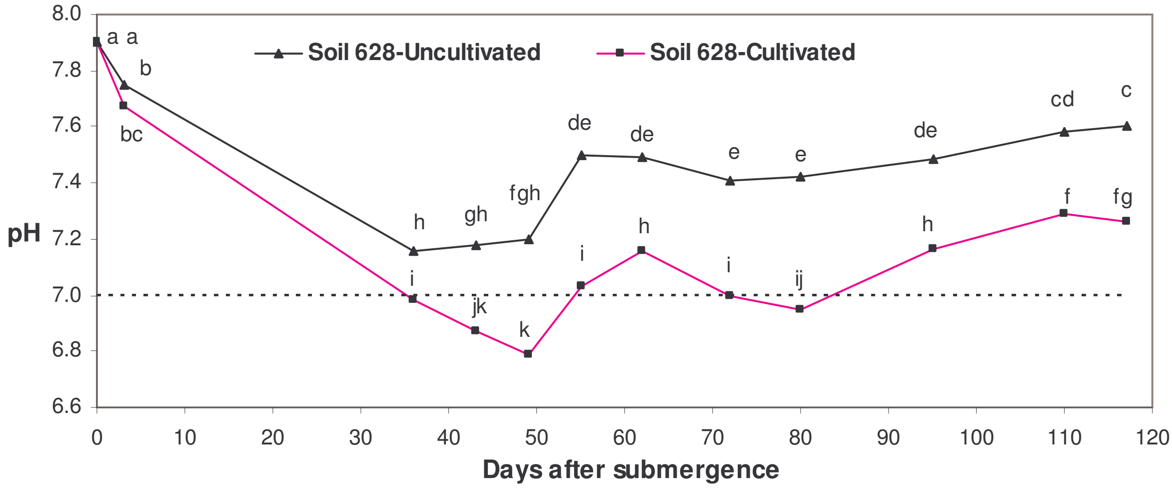

Fig.1. Changes in pH of soil 628 after submergence in both rice cultivated and uncultivated treatments.

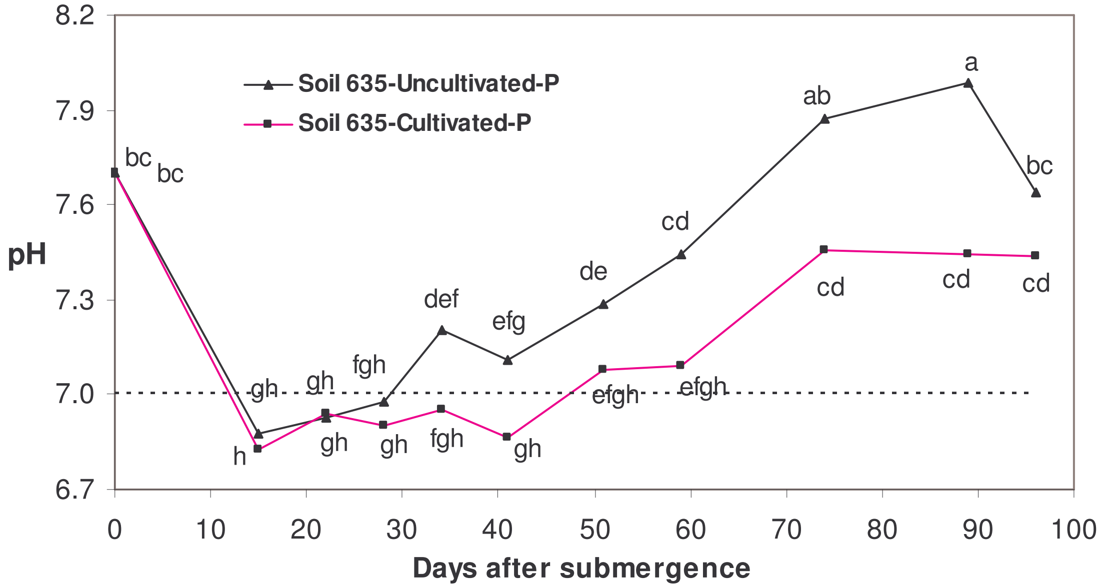

Fig.2. Changes in pH of soil 635 after submergence in both rice cultivated and uncultivated treatments (without P addition).

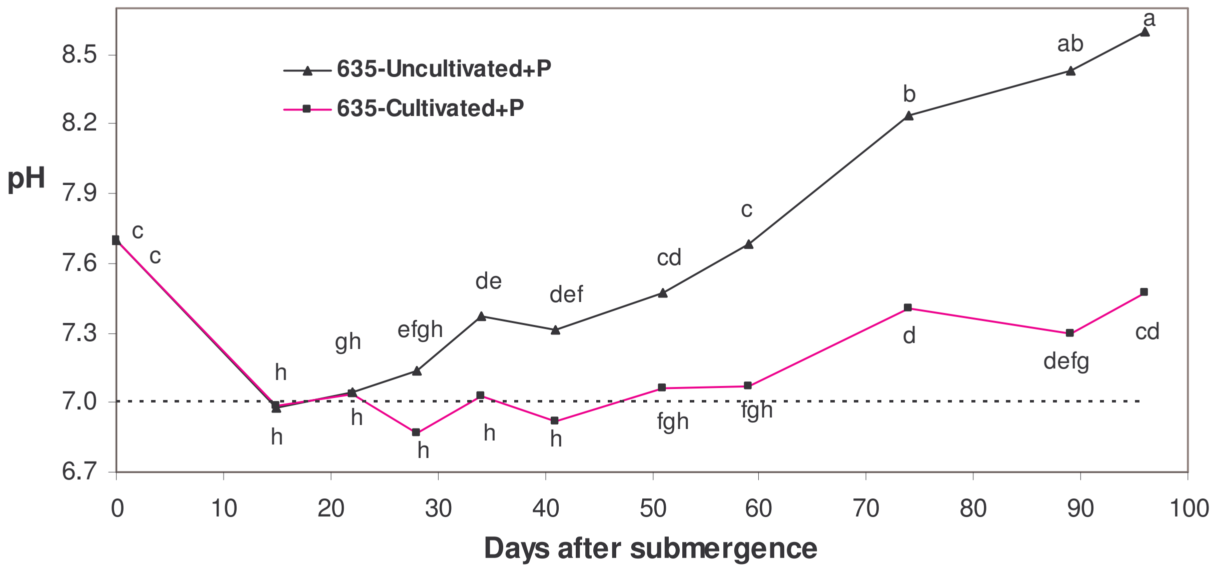

Fig.3. Changes in pH of soil 635 after submergence and P addition in both rice cultivated and uncultivated treatment.

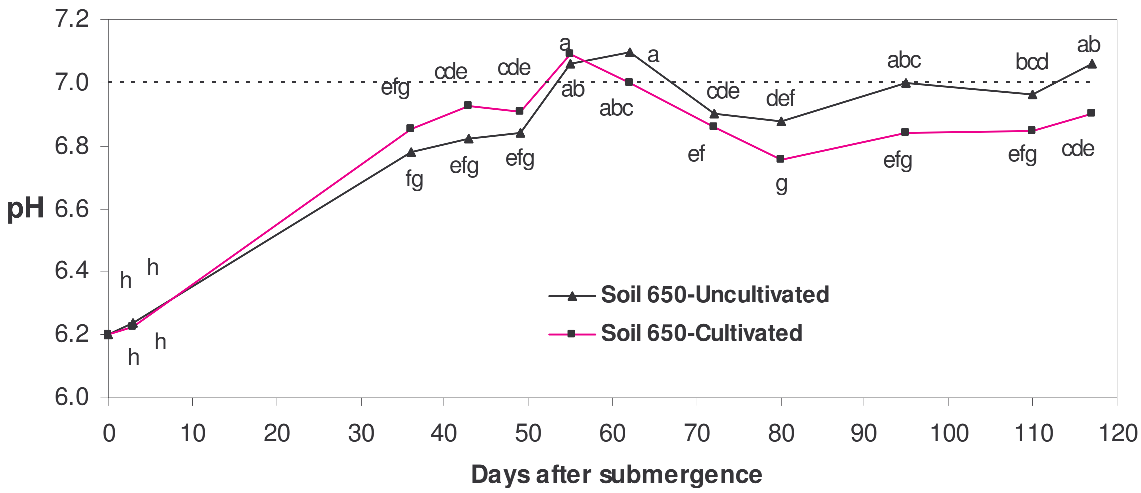

Fig.4. Changes in pH of soil 650 after submergence in both rice cultivated and uncultivated treatments.

Changes in Water Soluble Phosphorus after Submergence and P Addition

The results of two experiments showed that after submergence, water soluble-P of alkaline-calcareous soil 628 increased initially and then decreased, while water soluble-P of alkaline-calcareous soil 635 and acidic soil 650 increased initially and then remained constant and afterwards decreased in both rice cultivated and uncultivated treatments; the water soluble-P of three soils studied finally remained almost constant (Figures 5, 6, 7, 8). The highest concentration of P in soil solution (3 mg P/L) was recorded by alkaline-calcareous soil 628 and acidic soil 650 that had similar available-P (45.5 mg P/kg), while the highest concentration of water soluble-P of alkaline-calcareous soil 635 with available-P of 3.8 mg P/kg was 0.22 mg P/L. After P addition and submergence, water soluble-P of soil 635 decreased, and then remained almost constant and finally increased in uncultivated treatment (Fig. 7). Ponnamperuma, (1965), Ponnamperuma (1972), Islam and Islam (1973), Willet (1986) and Narteh and Sahrawat (1999) reported that soil water soluble-P increased initially after submergence and then decreased. The initial increase in soil solution P in submerged soils is particularly linked to the transformations of Fe and changes in pH. The main processes are (Ponnamperuma, 1965; Kirk, 2004):

- Reduction of Fe(III) compounds holding P on their surfaces and within their crystal lattices;
- Dissolution of Ca-P compounds in alkaline soils as the pH decreases and desorption of P held on variable-charge surfaces in acid soils as the pH increases;
- Displacement of sorbed P by organic anions and chelation of metal ions that would otherwise immobilize P; and
- Mineralization of organic P.

The subsequent decline in soluble P is caused by re-sorption or precipitation on clays and oxides as soil conditions continue to change, and decomposition of organic anions chelating P or chelating Al and Fe with which it would otherwise react. Following submergence soils often release more P to solutions low in P but adsorb more P from solutions high in P. This apparent paradox can be explained by the reduction of Fe(III) oxides to poorly ordered gel-like Fe(II) compounds with large surface areas. Phosphorus solubilized in soil reduction is sorbed on the amorphous surfaces and desorbed when P is removed from the soil solution; but fresh P added to the soil is removed from solution by sorption onto the Fe(II) surfaces. Consequently many soils do not show significant increases in P solubility during flooding (Willett, 1991), and with prolonged flooding the P may become re-immobilized in less soluble forms (Kirk, 2004).

Changes in Water Soluble Phosphorus after Rice Cultivation

Comparisons of means indicated that the water soluble-P of the rice rhizosphere (cultivated treatment) in all three soils studied was significantly lower than bulk soil (uncultivated treatment) (Figures 5, 6, 7, 8). In other wards, the uptake of phosphorus by roots resulted in a depletion of phosphate ions in the rice rhizosphere. So that the concentration of water soluble-P of the rice rhizosphere in all soils studied was lower than critical concentration (0.2 mg P/L) for optimum rice growth that has been reported by Khalid et al. (1977) and Roy and De Datta (1985). Jianguo and Shuman (1991) and Yuan and Huang (1995) concluded that the water soluble-P of the rice rhizosphere was lower than the bulk soil. Movement of phosphate ions to root by diffusion and mass flow is an important factor in supplying P to plants. Most of the P moves to the root by diffusion. When rice plant roots absorb phosphate ions from the surrounding soil solution, the P concentration at the root surface decreases compared with the bulk soil solution concentration. Therefore, a P concentration gradient is established that causes phosphate ions to diffuse toward the plant roots (Havlin et al. 1999). When P supplying rate by diffusion and mass flow to plant roots is lower than P uptake rate by plant roots, the concentration of P in the rhizosphere soil solution will be lower than the bulk soil solution.

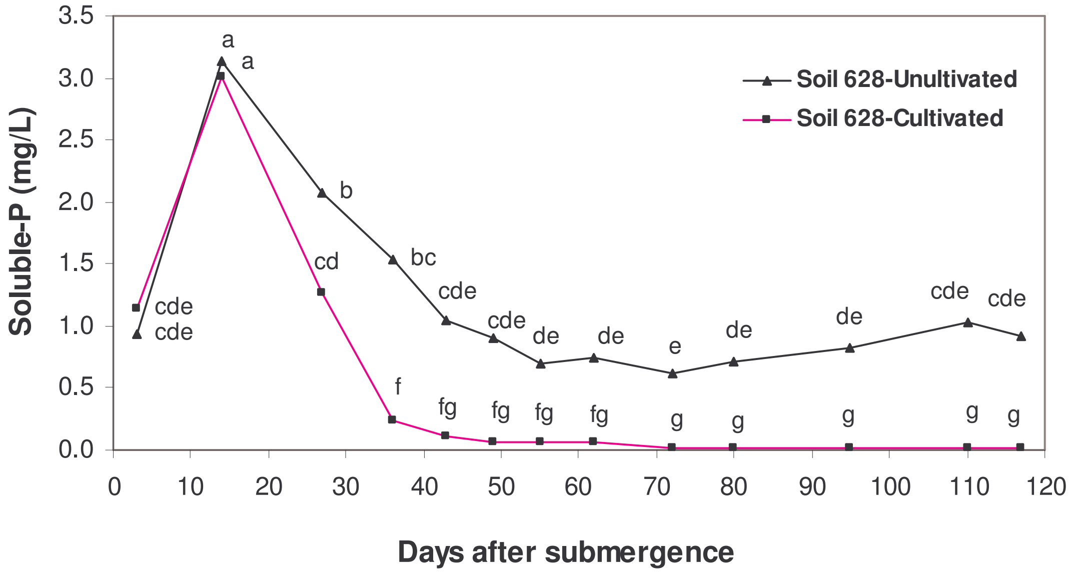

Fig. 5. Changes in water soluble-P of soil 628 after submergence in both rice cultivated and uncultivated treatments.

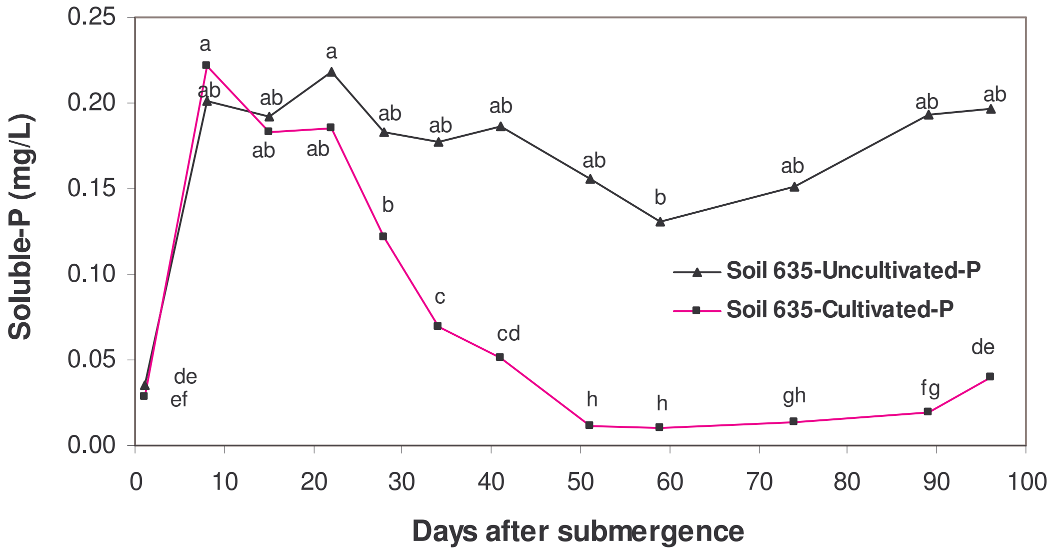

Fig. 6. Changes in water soluble-P of alkaline-calcareous soil 635 after submergence in both rice cultivated and uncultivated treatments (without P addition).

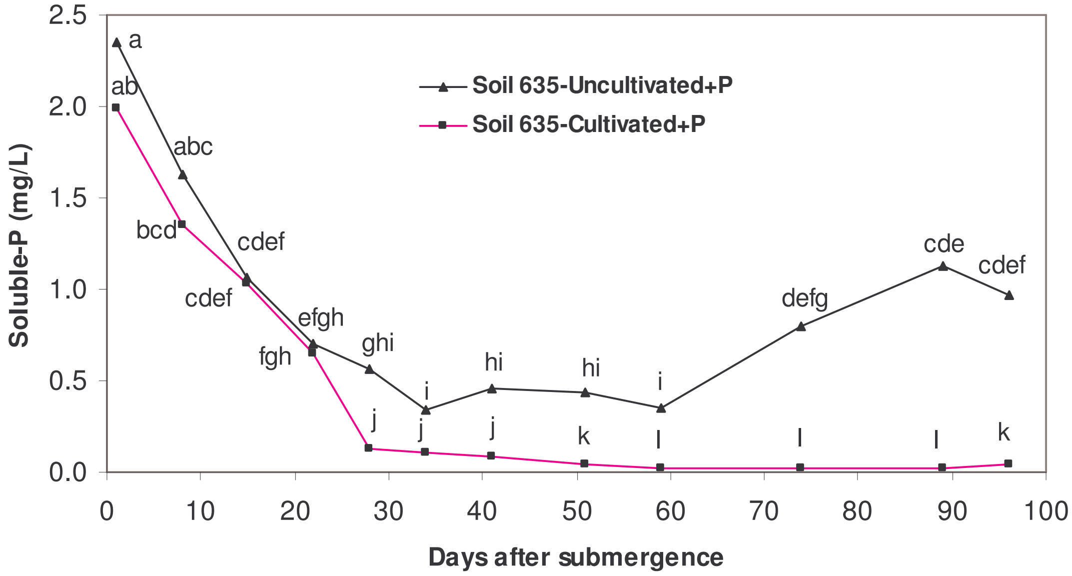

Fig. 7. Changes in water soluble-P of alkaline-calcareous soil 635 after submergence and P addition in both rice cultivated and uncultivated treatments.

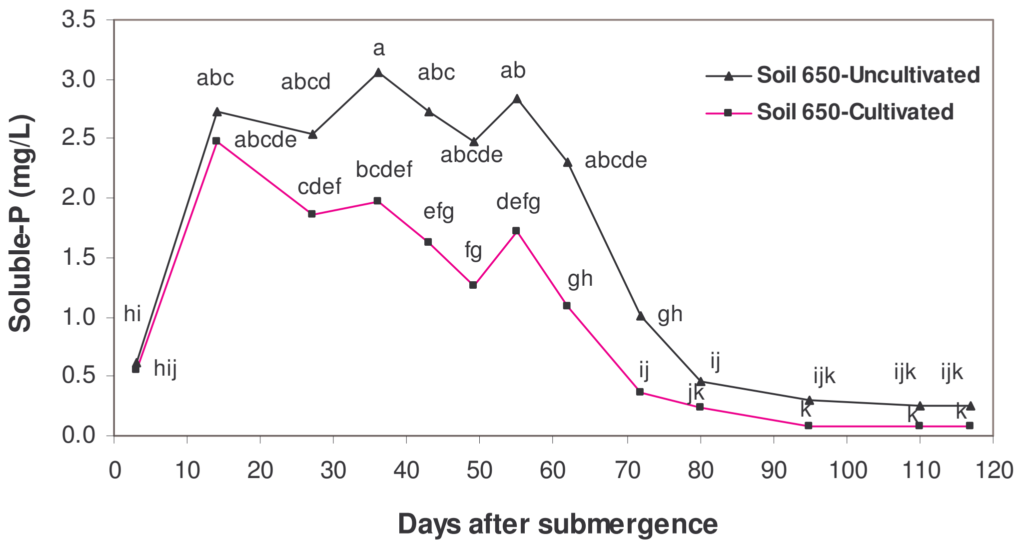

Fig. 8. Changes in water soluble-P of acidic soil 650 after submergence in both rice cultivated and uncultivated treatments.

Changes in EC of Soil Solution during Rice Growth Period

Comparisons of means indicated that the electrical conductivity (EC) of rhizosphere soil solution changed differently in different soils during the rice growth period (figures 9, 10, 11, 12). In alkaline soil 628, the EC of rhizosphere soil solution was significantly lower than the bulk soil solution until 108 days after rice cultivation; afterwards it was not significantly lower than the bulk soil solution (Fig. 9). In alkaline soil 635, the EC of rhizosphere soil solution was not significantly different from the bulk soil solution until 50 and 40 days after rice cultivation respectively in without and with P addition treatments; afterwards it was significantly higher than the bulk soil solution (Figures 10, 11). In acid soil 650, the EC of rhizosphere soil solution was significantly lower than the bulk soil solution during the rice growth period (Fig. 12). The following processes may be expected to modify the EC of rhizosphere soil solution:

- Simultaneously uptake of cations and anions by rice roots (e.g. H^+ and NO_3^-; Marschner, 1995); that decreases the EC of rhizosphere soil solution.
- Precipitation and adsorption reactions; that probably decrease the EC of rhizosphere soil solution.
- Water uptake rate as compared with nutrients uptake rate; when water uptake rate is higher than the nutrient uptake rate, the EC of rhizosphere soil solution is higher than the bulk soil solution (Barber, 1995).
- The pH changes; when the pH of rhizosphere soil solution decreases, the EC of rhizosphere soil solution increases, because proton has the highest equivalent conductance between ions (Pazandeh, 1992).

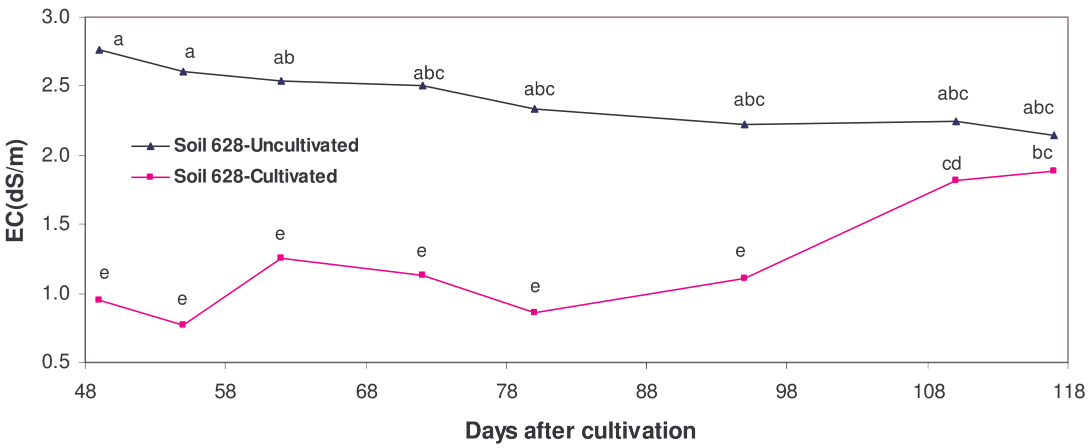

Fig. 9. Changes in EC of soil 628 in both rice cultivated and uncultivated treatments.

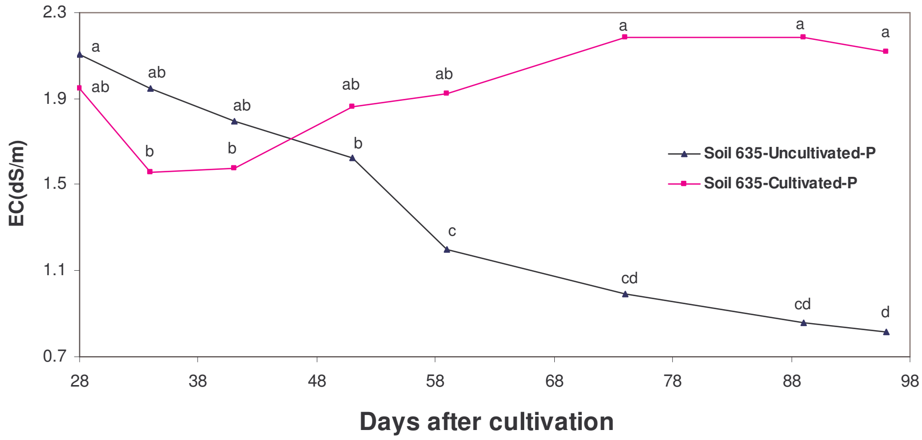

Fig. 10. Changes in EC of soil 635 in both rice cultivated and uncultivated treatments (without P addition).

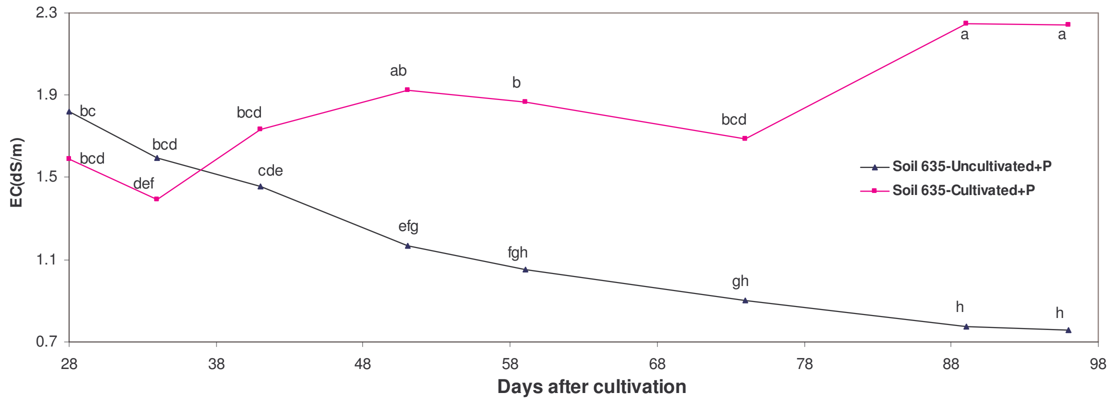

Fig. 11. Changes in EC of soil 635 in both rice cultivated and uncultivated treatments (with P addition).

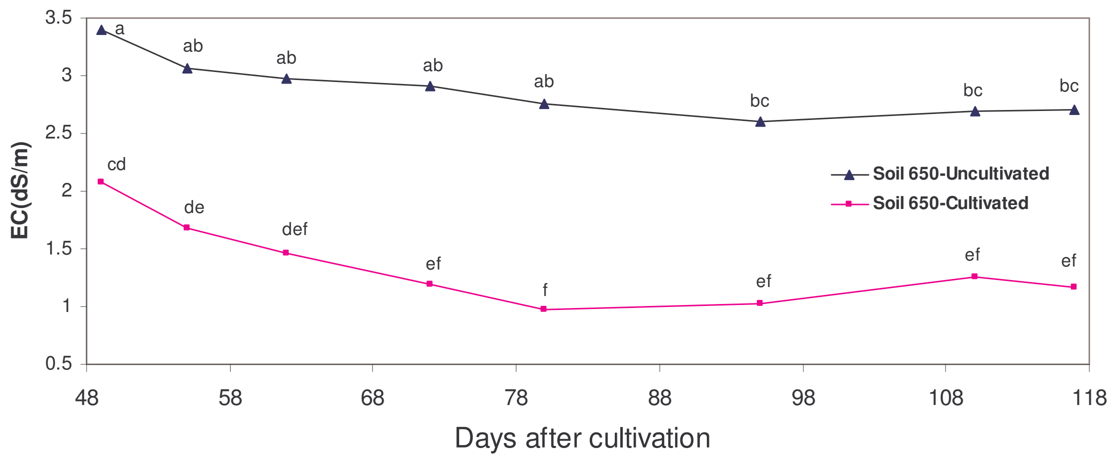

Fig. 12. Changes in EC of soil 650 in both rice cultivated and uncultivated treatments.

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Effect of Organic Amendments on Half-Highbush Blueberry Production and Soil Fertility

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ABSTRACT

Five treatments were compared using two half-highbush blueberry cultivars (cv Chippewa and Polaris) transplanted and grown for their first three growing seasons at a site in Boutiliers Point, N.S., a Gibraltar brown sandy loam (Ferro-Humic Podzol). The five treatments were as follows: Alfalfa meal + rock P + wood ash; NPK fertilizer; Municipal Solid Waste (MSWC) compost; Ruminant compost; food waste, manure and yardwaste compost (FMYC). All amendments were weighed and applied in an amount equivalent to the total N of the recommended NPK fertilizer for blueberries, assuming 25% N availability from each of the organic amendments. Soil extractable nutrients, leaf nutrients and fruit yields were measured and compared. The fertility treatments produced few effects on extractable levels of nutrients in the soil and leaf. 'Chippewa' responded more than 'Polaris' to the fertility treatments. The K fertilizing ability of the Ruminant compost was evident in all three growing seasons. 'Chippewa' showed consistent soil and leaf P response to Ruminant compost throughout the growing season; however, it failed to produce a comparative increase in the fruit yield. The NPK fertilizer treatment reduced the soil pH compared to other soil amendments while the MSW treatment increased the soil pH each year. The yield results showed that there were no statistical differences between the treatments for either cultivar (one year of data). Thus, the composts provided equivalent amounts of plant essential nutrients without increasing the trace element concentration in soil and tissue.

Key Words: Blueberry, Extractable soil nutrients, Leaf nutrients, Yield

INTRODUCTION

The Province of Nova Scotia has become a world leader at diverting valuable 'wastes' from disposal. Since the release of the Province's Solid Waste-Resource Management Strategy in 1996, Nova Scotia has achieved the target of recycling 50% of its solid waste, mostly by composting. Thus, it was inevitable that researchers would evaluate the application of organic amendments and composts made from solid wastes to grow various food crops. Furthermore, research and development of organic blueberry production is necessary due to growing agribusiness interests in the substantially higher market value of certified organic blueberries (Sciarappa et al., 2003).

Highbush blueberries have been considered a marginal crop for Nova Scotia due to their sensitivity to winter injury. Despite this, production has increased since 1930 when the first commercial acreage was planted, and currently blueberries are produced annually on over 54 hectares (John, 2000). Half-high blueberries are a cross between highbush *(Vaccinium corymbosum L.*) and lowbush blueberries (*V. angustifolium Ait.*) and were developed at the University of Minnesota (Finn et al. 1990). Half-high blueberry plants are short in stature and cold-hardier than highbush blueberries and could be favoured in the colder regions of Nova Scotia (John, 2000).

Only a few comparison studies between organic and conventional fertilizers have addressed the issue of soil and plant nutrients in small fruit production (Warman, 1987; Woese et al., 1997; Miller et.al., 2006; Hargreaves et al., 2008b). In addition, few studies have evaluated the use of municipal solid waste composts for agricultural production (He et al., 1992; Murphy et al., 2000; Warman et al. 2004; Hargreaves et al., 2008a). A comparative study is vital to evaluate the feasibility of using various organic amendments in place of chemical fertilizers. To this end, the first three years of a long-term study were initiated with the following objective: to evaluate plant nutrition, soil fertility, and yields from the application of four organic amendments and a chemical fertilizer treatment to half-high blueberries.

MATERIALS and METHODS

Two half-high blueberry cultivars (*Vaccinium corymbosum L. / V.angustifolium Ait.*) were chosen for the study. The cultivar descriptions are as follows (John, 2000): <u>'Polaris' ['Bluetta' x B15 (G65 X 'Ashworth')]</u> - early, very hardy, upright and spreading up to 1 meter, moderate size fruit, light blue, very firm, excellent fruit quality. <u>'Chippewa' [(B18A (G65 X 'Ashworth') X U53 ('Dixi' X Michigan lowbush No 1)]</u> - mid season, very hardy, large light blue berries, sweet, good flavor, upright and spreading bush (80 cm tall).

Field experiments were initiated in May 2002 at Boutiliers Point (near Halifax), Nova Scotia, Canada in a Gibraltar brown sandy loam (Ferro-Humic Podsol). The soil chemical properties (Mehlich-3 extractant) prior to the treatment applications were as follows: 4.61 pH; 315.5 mg Ca kg^{-1}; 44.5 mg Mg kg^{-1}; 9.5 mg P kg^{-1}; 58.5 mg K kg^{-1}; 21.5 mg Na kg^{-1}; 85.5 mg S kg^{-1}; 91.5 mg Fe kg^{-1}; 0.6 mg Cu kg^{-1}; 10.2 mg Mn kg^{-1}; 2.3 mg Zn kg^{-1}; 0.3 mg B kg^{-1}.

The study consisted of a randomized complete block design using five treatments (Alfalfa meal +rock P +wood ash; NPK fertilizer; Municipal Solid Waste (MSW) compost; ruminant compost; food waste, manure and yardwaste compost (FMYC). Each treatment was blocked five times giving 25 test plots for each variety, totaling 50 plots for the two varieties. Each block consisted of both the varieties 'Polaris' and 'Chippewa', each of them treated with all five treatments (10 plots per block). On May 24, 2002, single bushes were planted at the center of each of the plots (lm X lm). Rows were 2 m apart and plants were spaced at 1.5 m within rows.

All the amendments were weighed and applied in an amount equivalent to the total N of the recommended NPK fertilizers for blueberries, with an assumption of 25% N availability from each of the organic amendments. The P and K fertilizer calculations (NPK treatment, rock P and wood ash) were based on the pre-amendment initial Mehlich- 3 soil test values of extractable P and K using the N.S. Soil Test Recommendations (Soils and Crops Branch, 1985).

Amendments were hand broadcast onto each plot and raked into the soil in early June during the planting year and in mid May for the subsequent fruiting years. Inorganic fertilizer was a blend of urea N (45-0-0), super phosphate for P_2O_5 (0-20-0) and potash for K_2O (0-0-60). The rock phosphate used was 'North Carolina' rock phosphate; the total P analysis of the rock P was 100 g kg^{-1}, with ammonium citrate extractable P of 12 g kg^{-1}. The wood ash used in one treatment was obtained from a household wood furnace and was 50 g kg^{-1} total K. The alfalfa meal was purchased locally and had a mean N content of 28 g kg^{-1}. The analysis of the three composts is provided in Table 1.

Table 1: Analysis of the applied organic amendments averaged over the three study years

Parameter	**MSW Compost**	**Ruminant Compost**	**FMY Compost**
Moisture (%)	26.7	44.8	50.7
C:N Ratio	10:1	12.4:1	10.9:1
N (g kg^{-1})	21.2	18.7	11.4
P (g kg^{-1})	11.3	8.3	6.1
K (g kg^{-1})	6.0	15.4	7.1
Ca (g kg^{-1})	96.8	25.6	23.5
Mg (g kg^{-1})	6.0	5.8	4.3
S (g kg^{-1})	12.1	10.2	7.5
Fe (g kg^{-1})	10.4	7.4	9.8
Cu (mg kg^{-1})	176.9	26.0	23.3
Mn (mg kg^{-1})	1279	606	614
Zn (mg kg^{-1})	431	334	254
B (mg kg^{-1})	31.7	21.6	14.4
Cd (mg kg^{-1})	1.4	0.3	0.5
Cr (mg kg^{-1})	22.2	9.2	10.6
Ni (mg kg^{-1})	9.5	6.9	7.2
Pb (mg kg^{-1})	64.6	18.9	24.3

The treatment applications were based on the highbush blueberry N recommendation of 50 kg N ha^{-1} for 2002 and 2003 (planting year and first fruiting year) and 135 kg ha^{-1} for 2004 (second fruiting year). Table 2 shows the amounts of amendments applied for the three years of the study. The plots were hand weeded and rototilled throughout the growing seasons.

Initial soil samples were taken in early May 2002. After the harvest or at leaf sampling, four core samples from each plot, taken to a depth of 15 cm, were mixed and a composite taken. Leaf samples (50-60) were taken from the plots October 2002 and in mid-August of 2003 and 2004. Crows damaged immature fruit in 2003; thus, harvest data was not taken. Netting was used in the second fruiting season.

Mature fruit was harvested at weekly intervals from early August until mid-September in 2004 and the total fruit weight was recorded.

Table 2: Amount of amendments applied to the half-high blueberries from 2002 to 2004

Treatment		Rate (kg ha^{-1})		
		2002	**2003**	**2004**
1	Alf meal[a]	2400	6080	18000
	Rock P	5500	3400	2343
	Wood ash	400	30	0
2	N (45-0-0)	109	109	293
	P_2O_5 (0-20-0)	874	700	625
	K_2O (0-0-60)	120	50	183
3	MSW[b]	18500	17000	42400
4	Ruminant Compost[c]	20100	34000	61100
5	FMYC[d]	32050	30900	116000

[a] The meal averaged 3.8 %, 3.1 % and 2.8 % dry weight in 2002, 2003 and 2004, respectively.
[b] The compost averaged 79 %, 75 % and 66 % dry weight in 2002, 2003 and 2004, respectively.
[c] The compost averaged 66 %, 53 % and 46 % dry weight in 2002, 2003 and 2004, respectively.
[d] The compost averaged 54 %, 45 % and 49 % dry weight in 2002, 2003 and 2004, respectively.

Soil was mixed at a ratio of 2:1 (water:soil), left for 1 hour, and the pH was measured using an Accumet pH meter. Soil mineral elements (Ca, Mg, K, S, Fe, Cu, Mn, Zn, P, Cd, Cr, Ni, Pb, and B) were extracted using the Mehlich-3 extractant and determined using Inductively Coupled Argon Plasma Emission Spectroscopy (ICAP) (Thermo Jarrell Ash ICAP 1100, Thermo Jarrell Corp., Waltham, MA, U.S.A.).

All plant tissue was rinsed with distilled water and dried at 65˚C for 48 hours. The dried leaves were ground and digested with nitric acid according to Zheljazkov and Warman (2002). The digests were analyzed for Ca, Mg, K, S, Fe, Cu, Mn, Zn, P, Cd, Cr, Ni, Pb, and B using ICAP.

As indicated, the experiment began in 2002; the data/results presented in this paper only include 2004 in order to reduce the volume of the manuscript. Reference, however, will sometimes be made to the results of work evaluated in 2002 and 2003. Please note this paper represents the earliest stages of a long-term study that will continue until at least 2010.

Statistical analysis was completed using SAS software version 8.0 (SAS, 2000). After verifying the assumptions, the GLM with randomized complete block design was used for the analysis. If the model was significant at the 0.05 level, treatment means were compared using Tukey's means comparison test. SAS was also used to evaluate the significance of difference between the two-way interaction of cultivar and treatment, and the main effect of cultivar.

RESULTS and DISCUSSION

Extractable Soil Nutrients:

No significant treatment differences were noted in the extractable P content for either blueberry cultivar (Table 3) although soil P increased for each treatment since 2002. In the 'Chippewa' plots, the Ruminant compost-treated plots showed higher extractable soil K levels than the other fertility treatments. Also in the 'Chippewa' plots, MSW compost produced 80% higher soil extractable Ca levels when compared to the other treatments, and all compost treatments produced higher soil Mg levels (Table 3). Soil extractable S levels were significantly higher (double) in the NPK treatments plots for the 'Chippewa' cultivar. No significant treatment differences were noted for 'Polaris'; however, significant interactions between the cultivars and treatments were recorded in soil extractable Mg and S levels (Table 3).

Warman (1987) compared the response of soil nutrients to various manures and NPK fertilizers applied to lowbush blueberries and noted highest soil NH_4OAc extractable K levels in soils amended with Dairy Manure, which had comparable characteristics with the Ruminant compost used in this study. In a similar study, Warman et al. (2004) showed higher soil Mehlich 3 extractable K levels in lowbush blueberry soils amended with MSW compost when compared with K levels of NPK fertilized soils. Townsend (1973) showed an increase in exchangeable K levels compared to control plots in highbush blueberry soils amended with sawdust and peat mixtures. The higher soil P and K levels in compost treated plots could be due to rates of P and K applied from the composts that were higher than the inorganic fertilizers. This was the result of the relatively low total N content in the composts, that ranged from 11.4 to 21.2 g kg^{-1} (Table 1), which led to the addition of higher than recommended rates of P and K in the composts, in order to apply an equivalent amount of N from each fertility source. Warman et al. (2004) studied the response of similar MSW compost applications to lowbush blueberry soils and attributed the elevated soil extractable P and K levels to the compost nutrient contents. The high extractable Ca levels in MSW compost-treated plots could be attributed to the higher Ca levels in the MSW compost compared to other fertility treatments.

Ruminant and FMYC composts produced the highest levels of soil Zn for both cultivars in 2004 (Table 4). Ruminant compost also produced the highest soil Fe levels in 'Polaris' soils, with the alfalfa meal producing the lowest soil Fe. 'Chippewa' soils showed higher Mn levels in the NPK treatment compared to all other treatments, but there was no significant effect of treatments on soil Mn in the 'Polaris' soils (Table 4). Warman et al. (2004) also showed a similar weak effect on extractable Fe and Mn in lowbush blueberry fields amended with MSW composts. Soil B was lowest in the NPK plots for 'Chippewa', but was not influenced by treatments for 'Polaris'. Soil Cu was not affected by treatments for either cultivar.

No significant treatment differences were noted in the soil trace element concentrations of Cd, Cr, Ni and Pb in any of the three growing seasons for either cultivar. Generally, soil Cd, Cr, Ni were in the range of 0.1 to 0.4 mg kg^{-1} while Pb ranged from 2 to 3 mg kg^{-1}.

Table 3: Effect of treatments on the Mehlich 3 soil macronutrient content in 2004 (mg kg^{-1})

Cultivar (Cv)	**Treatment (Trt)**					
		P	**K**	**Ca**	**Mg**	**S**
Chippewa	Alf. Meal	58 a	161 ab	752 bc	60 b	113 b
	NPK	83 a	140 ab	414 c	18 c	248 a
	MSW	46 a	122 b	1255 a	95 a	115 b
	Ruminant	79 a	177 a	620 c	113 a	94 b
	FMYC	74 a	114 b	1012 ab	99 a	125 b
Polaris	Alf. Meal	56 a	123 a	821 a	82 a	121 a
	NPK	56 a	126 a	759 a	81 a	126 a
	MSW	50 a	119 a	653 a	60 a	125 a
	Ruminant	79 a	139 a	752 a	64 a	148 a
	FMYC	96 a	195 a	1071 a	102 a	158 a
Cv	P<	ns	ns	ns	ns	ns
Cv x Trt	P<	ns	ns	ns	0.03	0.03

*Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

The treatments produced a significant effect on the soil pH for both cultivars during the three growing seasons (Table 5). The NPK treatment reduced the soil pH and the MSW treatment increased the soil pH compared to the other soil amendments each year, responses that the senior author has noted in other experiments (Warman, 1988; Warman et al., unpublished data).

Leaf Nutrients

The fertility treatments failed to produce a significant effect on most of the macronutrients, especially leaf N, K, Ca and S (Table 6). Ruminant compost and NPK treatments resulted in the highest leaf P levels in 'Chippewa' (Table 6). The NPK treatment resulted in lower leaf Mg levels in both cultivars, and ruminant compost produced significantly lower Mg, but only in 'Polaris' (Table 6). Ring et al. (2004) wrote that the Mehlich 3 soil extraction method may not reflect the actual leaf P levels in Nova Scotia blueberry soils. Warman et al. (2004) also showed similar soil-plant relationship for P in lowbush blueberry soils amended with MSW compost and NPK fertilizers. Supporting this result, Townsend (1973) showed that leaf P levels did not increase with a corresponding increase in soil P levels due to organic treatments in highbush blueberry fields. In contrast, Black and Zimmerman (2002) showed higher P levels in highbush blueberry leaves in ash-compost treated plots than the control plots.

Table 4: Effect of treatments on the Mehlich 3 soil micronutrient content in 2004 (mg kg^{-1})*

Cultivar (Cv)	**Treatment (Trt)**					
		B	**Fe**	**Cu**	**Mn**	**Zn**
Chippewa	Alf. Meal	0.5 b	99 a	0.9 a	9 b	3.0 b
	NPK	0.3 c	115 a	0.9 a	15 a	3.2 b
	MSW	0.6 a	95 a	1.1 a	11 ab	3.8 b
	Ruminant	0.5 ab	104 a	0.8 a	11 ab	6.2 a
	FMYC	0.6 a	100 a	1.2 a	11 ab	6.2 a
Polaris	Alf. Meal	0.5 a	83 d	0.9 a	7.1 a	3.0 b
	NPK	0.5 a	97 cd	0.8 a	9.2 a	4.0 ab
	MSW	0.5 a	105 bc	0.8 a	9.2 a	3.2 ab
	Ruminant	0.5 a	123 a	1.0 a	17.5 a	7.0 a
	FMYC	0.6 a	114 ab	1.3 a	17.6 a	7.0 a
Cv	P<	ns	ns	ns	ns	ns
Cv x Trt	P<	0.02	ns	ns	ns	ns

* Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

The leaf micronutrients Cu, Zn and Fe were unaffected by any of the treatments (Table 7). In 2004, Alfalfa meal and MSW compost produced significantly higher levels of leaf B in 'Polaris'; however, the FMYC treatment showed higher leaf B in 'Chippewa' and the NPK and MSW compost treatments produced the lowest leaf B. The NPK treatment produced significantly higher leaf tissue Mn levels in both the cultivars (Table 7). The NPK treatment produced a strong effect on leaf Mn levels in both the cultivars during two fruiting years (Table 7). However soil analysis did not reveal many treatment differences in Mehlich 3 extractable Mn (Table 4). Manganese availability is directly related to pH and the lower the pH, the higher is the Mn availability (Warman et al., 2004). Haynes and Swift (1985) reported an increase in plant Mn levels as the soil pH was lowered in fertilizer-treated highbush blueberry plots. This explains the higher availability of Mn in NPK plots that were lower in pH compared to the other treatment plots (Table 5). Warman (1998) showed significant increase in Mn levels, both above and below ground, in plots treated with conventional fertilizers when compared to plots treated with organic amendments.

The leaf trace element levels of Cd, Cr, Ni and Pb were unaffected by the fertility treatments. The mean trace element values ranged from 0.1 to 1.8 mg kg^{-1}. Thus, to date, the composts did not increase these elements in the blueberries. Black and Zimmerman (2002) studied the effect of compost treatments on highbush blueberries and also did not find an increase in tissue trace elements due to treatments.

Table 5: Effect of fertility treatments on soil pH in 2002, 2003 and 2004

Cultivar (Cv)	**Treatment (Trt)**	**pH**		
		2002	**2003**	**2004**
Chippewa	Alf. Meal	4.70 a	4.85 ab	5.57 a
	NPK	4.23 b	4.36 b	4.41 b
	MSW	4.89 a	5.05 a	5.80 a
	Ruminant	4.78 a	4.93 a	5.67 a
	FMYC	4.86 a	5.01 a	5.76 a
Polaris	Alf. Meal	4.78 a	5.20 b	5.59 ab
	NPK	4.33 b	4.41 c	4.06 b
	MSW	5.09 a	5.54 a	5.95 a
	Ruminant	4.83 a	5.25 b	5.65 a
	FMYC	4.90 a	5.32 b	5.72 a
Cv	P<	0.05	0.00	ns
Cv x Trt	P<	ns	ns	ns

*Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

Fresh Fruit Yields

Harvest data was not taken in the 2003 fruiting season because birds removed immature fruit. There were no statistical differences between the treatments during 2004, which averaged 18 g $plant^{-1}$ for the 'Chippewa' and 12 g $plant^{-1}$ for the ''Polaris'' cultivars. Alfalfa meal produced numerically higher yields in 'Chippewa' than all of the other treatment means while the MSW treatment produced numerically higher yield in 'Polaris' than all of the other treatment means. Townsend (1973), using raw sawdust and peat as soil amendments, found no increase in yields, bush size or vigor during six years of a field study; however, Haynes and Swift (1986) recorded better growth and yield of blueberries when elemental S, peat and pine bark were used.

There is a definite need to determine critical macronutrient and micronutrient levels in half-high blueberries as Ballinger et al. (1958) has determined for highbush blueberries. Given that blueberries have relatively low nutrient requirements, with the exception of Fe, Mn, Cu and S (Korcak, 1988), it would be useful to determine which nutrients are most required to generate the highest yields. For example, Blevins et al. (1996) showed 10% higher yields of highbush blueberries in Missouri from B applications and McArthur (2001) stressed the importance of B in highbush blueberry nutrition.

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Table 6: Effect of treatments on the leaf tissue macronutrient content in 2004 (g kg^{-1})*

Cultivar (Cv)	**Treatment (Trt)**	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Chippewa	Alf. Meal	19 a	0.8 ab	3 a	5 a	1.3 a	2 a
	NPK	19 a	0.9 a	4 a	4 a	0.7 b	2 a
	MSW	18 a	0.7 b	3 a	4 a	1.1 ab	2 a
	Ruminant	18 a	0.9 a	4 a	4 a	1.2 ab	2 a
	FMYC	19 a	0.8 ab	3 a	5 a	1.3 a	3 a
Polaris	Alf. Meal	19 a	1 a	5 a	4 a	1.1 a	2 a
	NPK	17 a	1 a	4 a	4 a	0.6 b	2 a
	MSW	17 a	1 a	4 a	4 a	1.1 a	2 a
	Ruminant	14 a	1 a	3 a	2 a	0.7 ab	2 a
	FMYC	17 a	1 a	4 a	4 a	1.1 a	2 a
Cv	P<	ns	ns	ns	ns	0.01	ns
Cv x Trt	P<	ns	ns	ns	ns	ns	ns

* Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

Table 7: Effect of treatments on the leaf tissue micronutrient content in 2004 (mg kg^{-1})*

Cultivar (Cv)	Treatment (Trt)	B	Fe	Cu	Mn	Zn
Chippewa	Alf. Meal	24 ab	78 a	4 a	269 b	9 a
	NPK	18 b	78 a	3 a	777 a	9 a
	MSW	21 b	120 a	4 a	362 b	10 a
	Ruminant	23 ab	71 a	4 a	270 b	10 a
	FMYC	29 a	79 a	5 a	303 b	12 a
Polaris	Alf. Meal	30 a	85 a	3 a	250 b	9 ab
	NPK	17 b	75 a	2 a	645 a	9 ab
	MSW	31 a	76 a	4 a	381 b	11 a
	Ruminant	20 ab	62 a	2 a	208 b	7 b
	FMYC	27 ab	62 a	3 a	234 b	11 a
Cv	P<	ns	ns	0.00	ns	ns
Cv x Trt	P<	0.04	ns	0.04	ns	ns

*Means within columns (for each cultivar) followed by the same letter are not significantly different at P<0.05 when interaction or main effects are indicated to be significant.

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The Effect of Nitrogen on Seed and Oil Yield of Seven Sesame (*Sesamum indicum* L.) Genotypes in Isfahan

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ABSTRACT
Nitrogen is a major part of plant nutrition in agricultural ecosystems. It greatly affects the yield of crops, specially "oilseed crops" such as sesame. In order to study the effect of nitrogen and genotype on the seed and oil yield of sesame; an experiment was laid out in split plots based on randomized complete block design with three replications and 35 plants m^{-2} at the Lavark Research Farm, Isfahan University of Technology, in 2006. Three nitrogen levels (50, 100 and 150 Kg N ha^{-1}) and seven sesame genotypes (Local Ardestan, Nonbraccning Naz, Branching Naz, Yekta, Oltan, Darab 14 and Varamin 2822) were used in main and sub plots, respectively. With an increase in nitrogen application to at least 150 kg N ha^{-1}, despite a decrease in oil content, the seed and oil yield increased ($P \leq 0.01$) averaged over genotypes. Since Yekta and Oltan outyielded the rest of genotypes, the latter genotypes with application of at least 150 kg N ha^{-1} could be recommended for sesame production in Isfahan.

Key Words: *Sesamum indicum* L., fertility, nutrient, nitrogen, yield, oil

INTRODUCTION

Sesame (*Sesamum indicum* L.) possesses the highest oil content (nearly 50% of seed weight) among all oilseed crops (Wiess, 2000). However, according to FAO statistics in 2006, the seed yield of sesame in Iran was only 700 Kg ha^{-1} against maximum seed yield potential of around 3000 Kg ha^{-1} for irrigated farming (FAO, 2008). Besides low soil fertility, one of the most important reasons of low seed yield is unsufficient nutrient applications such as nitrogen (Wortmann et al., 2007; weiss, 2000). Nitrogenous fertilizers are among the most essential parts of plant nutrition in agricultural ecosystems and crop production. They extremely affect the physiological processes, plant functions and yield of crops (Addiscott, 2005).

Most of farmers believe that sesame does not respond well to the fertilizers (Tadele, 2005; Wiess, 2000). In addition, it is believed that nitrogen application declines economic yield of oilseeds via reducing the seed oil content. But, according to some reports sesame seed yield could be raised by 50% with proper fertilization (Prakasha & Gowda, 1992).

Abbreviations: EC: electrical conductivity, OM: organic matter, OC: organic carbon.

There is little information concerning sesame response to nitrogen application. Hence, this investigation was planned in order to determine the best nitrogen level and genotype for achieving a higher seed and oil yield of sesame in Isfahan.

MATERIALS and METHODS

The study was conducted at the Lavark Research Farm, Isfahan University of Technology (lat. 32°: 32' N, long. 51°: 23' E and 1630 m) during May to October, 2006. The soil was fine-loamy, mixed, thermic Typic Haplargids with pH: 7.6, EC: 0.07 S m^{-1}, OM: 0.23%, OC: 0.13% and 0.15: 7.2: 150 mg Kg^{-1} available N: P: K.

The experiment was laid out in split plots based on randomized complete block design with three replications. Three nitrogen levels including 50, 100 and 150 Kg N ha^{-1} as the urea form with 46% nitrogen and seven sesame genotypes including one local population from the region known as Local Ardestan; besides six hopeful breeded lines (cultivars) called Nonbranching Naz, Branching Naz, Yekta, Oltan, Darab 14 and Varamin 2822 (Seed and Plant Improvement Institute, Karaj, Iran) were used in main and sub plots, respectively. The plant density was 35 plants m^{-2}. One third of each nitrogen level was applied as the starter before sowing, while the second and third parts were dressed at seedling and early flowering phases, respectively.

The seed oil content was measured with soxhlet method following AOAC guide (AOAC, 2002) and the seed yield was corrected for 7% moisture content according to the standard water content for sesame seed in Iran, No. 3460 (ISIRI, 1994). The oil yield was calculated by multiplication of corrected seed yield and seed oil content. All statistical analyses were performed using the GLM procedure in SAS 9.1.3 package (SAS Institute Inc., Cary, NC). Treatment means were separated by LSD test at the P=0.05 level.

RESULTS and DISCUSSION

Seed Yield

Increasing nitrogen application significantly enhanced the seed yield of sesame (Table 1). This enhancement was, probably, achieved by a delay in photosynthetic organs senecence and an enhancement in chlorophyll and enzyme contents such as rubisco, which led to the more photosynthesis and assimilation. Schlemmer et al. (2005) suggested leaf available nitrogen content has a direct and proportional impact on leaf chlorophyll content and nutrients affect the chloropyll content of the leaf. In Sesame (Mujaya & Yerokan, 2003), safflower (Gawand et al., 2005) and soybean (Osborne & Riedell, 2006; Ray et al., 2006), a higher significant seed yield was obtained with the enhancement of nitrogen rate. Osborne and Riedell (2006) reported the increase could be due to an increase in early plant biomass and the possetive impact of nitrogen fertilizer on the early plant biomass. In this case, Yekta and Oltan indicated the highest seed yield among all genotypes, while Local Ardestan and Branching Naz demonstrated the lowest (Table 1).

Table 1. Mean seed yield, seed oil content and oil yield as influenced by various treatments.†

Treatment	Seed yield ($Kg\ ha^{-1}$)	Seed oil content (%)	Oil yield ($Kg\ ha^{-1}$)
Nitrogen fertilizer ($Kg\ N\ ha^{-1}$)			
50	1410.95 ^{c}	57.93 ^{a}	830.20 ^{c}
100	2078.90 ^{b}	49.54 ^{b}	1051.62 ^{b}
150	2590.67 ^{a}	45.39 ^{c}	1203.19 ^{a}
Genotype			
Local Ardestan	1189.24 ^{c}	35.29 ^{d}	408.95 ^{e}
Nonbranching Naz	2103.55 ^{b}	55.97 ^{a}	1153.19 ^{b}
Branching Naz	1241.54 ^{c}	55.72 ^{a}	682.76 ^{d}
Yekta	2734.83 ^{a}	56.15 ^{a}	1509.96 ^{a}
Oltan	2862.52 ^{a}	51.90 ^{b}	1454.39 ^{a}
Darab 14	2037.90 ^{b}	51.72 ^{b}	1015.01 ^{c}
Varamin 2822	2018.28 ^{b}	49.93 ^{c}	974.11 ^{c}

† In each column, means with the same letters are not significantly different by LSD test at $P \leq 0.05$.

Generally, Yekta with 150 Kg N ha^{-1} implied the highest seed yield, whereas Local Ardestan and Bbranching Naz with 50 Kg N ha^{-1} exhibited the lowest (Figure 1).

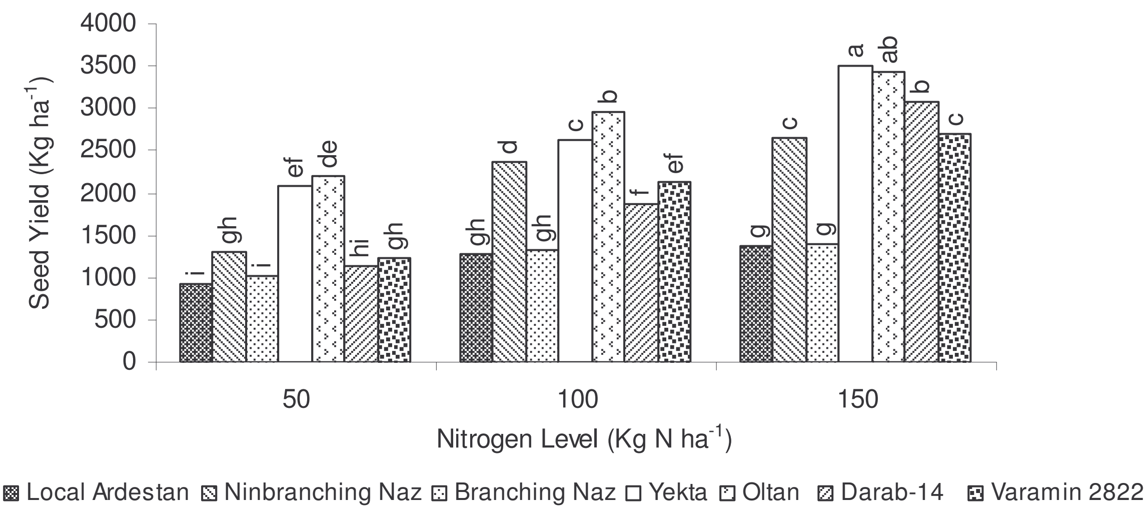

Figure 1. Seed yield of sesame genotypes influenced by nitrogen levels.

Seed Oil Content

Increasing nitrogen level significantly decreased the seed oil content. This decrease might have been resulted from an increase in allocation of assimilates into amino acid, protein and enzyme production in response to nitrogen application (Table 1). These sort of alterations have been reported in other oilseed crops such as soybean (Osborne & Riedell, 2006); safflower (Abbadi et al., 2008; Gawand et al., 2005) and sunflower (Abbadi et al., 2008). However, Mujaya and Yerokan (2003) did not observe any significant differences among sesame oil contents with increasing nitrogen level up to 90 Kg N ha^{-1}. Among the genotypes, the highest oil content extracted from Nonbranching Naz, Branching Naz and Yekta, whilst the lowest one was observed in Local Ardestan (Table 1).

In general, the gretast and smallest oil content of the seed were determined in Nonbranching Naz, Branching Naz and Yekta under 50 Kg N ha^{-1} and Local Ardestan under 150 Kg N ha^{-1}, respectively (Figure 2).

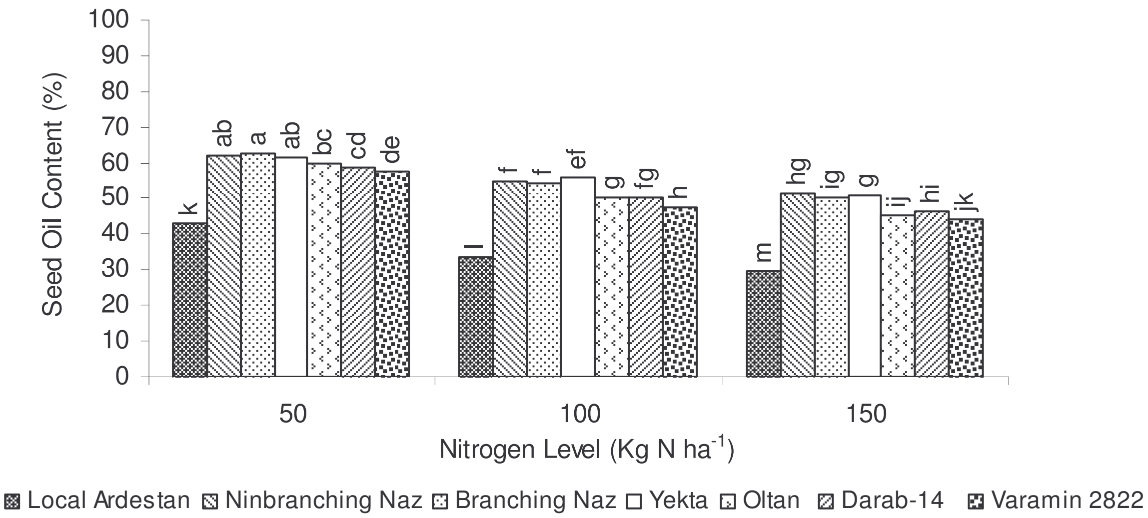

Figure 2. Oil content of sesame genotypes influenced by nitrogen levels.

Oil Yield

Although seed oil content was decreased, oil yield showed a significant enhancement (Table 1).

This is indicative of the fact that oil yield is more affected by seed yield than seed oil content. Mujuya and Yerokan (2003) stated that more oil could be obtained only by increasing seed yield. As a result, increasing nitrogen application will raise oil yield in addition to seed yield. Abbadi et al. (2008) in safflower and sunflower and Gawand et al. (2005) in safflower reported the same results with increasing nitrogen application. The highest oil yield was determined in Yekta and Oltan while the lowest one was detected in Local Ardestan and Branching Naz (Table 1).

Overall, the highest and lowest oil yield were obtained with Yekta at 150 Kg N ha^{-1} and Local Ardestan at all nitrogen levels, respectively (Figure 3).

Our results indicate that sesame responds well to nitrogen application and if appropriate cultivars with sufficient nitrogen levels are used, a high economic yield will be obtained. In cunclusion, because Yekta and Oltan outyielded the rest of genotypes, they could be recommended for sesame production with application of at least 150 kg N ha^{-1} in Isfahan.

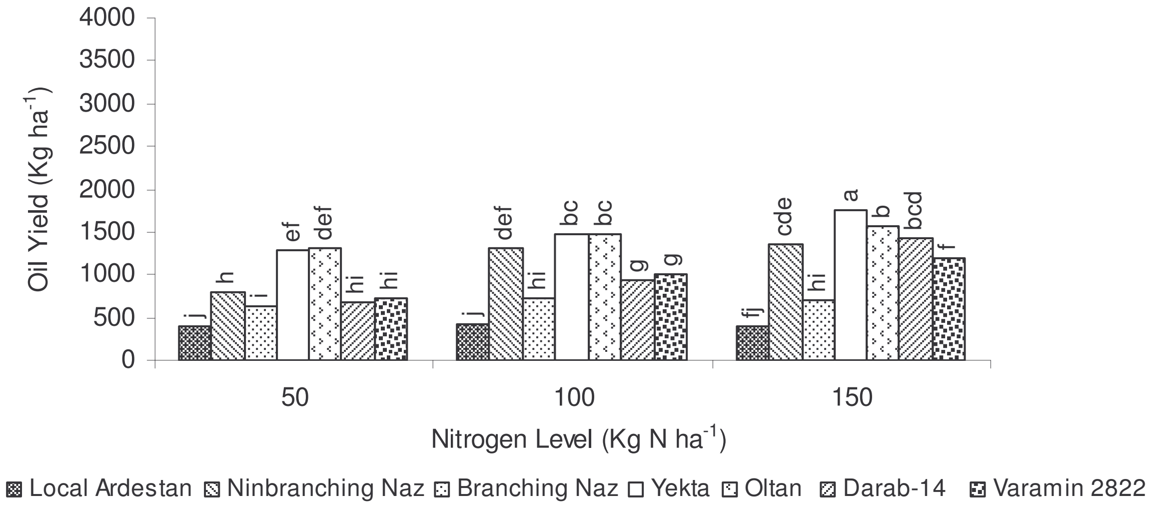

Figure 3. Oil yield of sesame genotypes influenced by nitrogen levels.

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Determination of Some Micro and Macro Elements of Bean *(Phaseolus vulgaris* L.*)* and Sunflower *(Helianthus annuus* L.*)* Plants after Addition of Olive Oil Solid Waste to Soil

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ABSTRACT
In this study, effects of olive oil solid waste (OSW) applications on bean and sunflower macro and micro element contents were investigated. Olive oil solid waste mixed with soil at the rates of 0, 3, 5 and 7 % by weight. Plants were grown in the pots under controlled conditions throughout 45 days for sunflower and 30 days for bean. Plant carbon/nitrogen (C/N), some macro elements; nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and micro elements; boron (B), iron (Fe), manganese (Mn) contents were determined and their relations with the application of olive oil solid waste have been investigated. As a result, while phosphorus, calcium, and boron have increased, nitrogen has decreased in sunflower plants. On the other hand, phosphorus, potassium, magnesium, and boron have increased but nitrogen, calcium, and manganese have decreased in bean plants.
Keywords: Olive oil solid waste, sunflower and bean, some macro and micro elements

INTRODUCTION

The average world production of olive oil is 2.5×10^6 tons, most of which comes from the Mediterranean countries (Alburquerque et al., 2004). The olive oil extraction industry has great economic and social importance in many Mediterranean countries such as Spain, Italy, Greece, Tunisia, Turkey and Morocco, but this is often associated with the generation of wastes and by-products that provoke adverse environmental problems. Improving the appropriate management of these materials urgently needs more intensive research (Cegarra et al., 2006).

Soil organic matter, and especially the humified fractions, constitute an important source of nutrients, and are also a key factor in maintaining or improving soil structure. Although changes in total soil organic matter (SOM) content induced by agricultural practice are important, changes in organic matter quality (the organic matter fractions) are also significant (Graham et al., 2002).Locally available organic wastes and by-products from agriculture and agro-food industries may be processed and converted to value-added products (Bernal et al., 1998; Madejon et al., 1998 and Paredes et al., 2000), which contribute to the sustainability and productivity of agro ecosystems in the Mediterranean region (Madejon et al., 1995; Martinolmedo et al., 1995; De Monpezat and Dennis, 1999; and Manios, 2004).

The end products such as compost can be used as soil conditioner and fertilizer, thereby recycling nutrients back to agriculture and horticulture. However may contain a wide range of organic pollutants (Brändli et al., 2005, 2007a, 2007b). The problem of olive solid waste (OSW) disposal, then, has not been fully resolved and research into new technological procedures that permit its profitable use is needed. One possibility to use compost is a method for the preparation of soil organic fertilizers and amendments, since the direct application of OSW to the soil has been shown to have a detrimental effect on the soil structural stability (Tejada et al., 1997). It may also negatively affect seed germination, plant growth and microbial activity. In fact, several studies have reported the phytotoxic and antimicrobial effects of both olive-mill wastes and by-products due to the phenol, organic and fatty acid contents (González et al., 1990; Riffaldi et al., 1993; Linares et al., 2001).

Piñeiro et al. (2008) reported that application of two - phase olive mill waste (TPOMW) caused significant increases ($P < 0.05$) in organic carbon, total N, available P and K, and aggregate stability were observed in the amended soils after two years and raw TPOMW has the potential to be valuable soil amendments and source of organic matter, with a positive effect on olive yield, and closing the cycle of residues-resources.

In this study we used OSW with high C/N ratio, and it was applied to soil directly for growing sunflower and bean.

MATERIALS and METHODS

Applications and Experimental Design

Two pot experiments were conducted for characterization of plant response to direct application of OSW to the soil. Soil samples were taken from field at 0-20 cm depths and sieved through 9 mm sieve. Some chemical and physical properties of soil are presented in Table 1. Olive oil solid wastes (two-phase centrifugation) have been provided from the Elta Agriculture enterprise in Gökçeada, Çanakkale. OSW was sieved through 6 mm and mixed with soil at the rates of 0, 3, 5, and 7% w/w.

Experimental design was randomized block design with four replications. There were four different levels (0%, 3%, 5%, and 7%) of OSW applications.

Five sunflower (Syngenta Sanay variety) and five bean (Asgrow variety) seeds were sown in each pot. Plants were thinned after the germination

Table 1. Some chemical and physical properties of soil sample

EC (μS/cm)	pH	N %	$CaCO_3$ %	OM %	Texture		
					Clay %	Silt %	Sand %
235	8.1	0.1	15.4	1.6	36.98	31.99	31.03
					CL		

Table 2. Some properties of OSW

EC (µS/cm)	pH	N (%)	C (%)	C/N	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
822	5.7	1.12	49.1	43.8	0.04	0.57	0.50	0.06	16.9	1243.91	32.75	17.34

METHODS

Dried plants were ground with plant grinder, and then total nitrogen was determined by using Leco TruSpec 2000 CN elemental analyzer. EC: Samples mixed with DI water at 1:2.5 ratio, set overnight and then EC was determined using WTC brand EC-meter model LF 320.(Richards, 1954). pH: Samples mixed with DI water at 1:2.5 ratio, set overnight and then pH was determined using Orion brand pH-meter, model 420A.(Richards, 1954). Lime: Scheibler calcimeter was used to measure $CaCO_3$ (Soil Survey Laboratory Methods Manual, 1996). Macro and micro element contents of OSW and plants were determined in dry ash (Peters, 2003) by using ICP-AES. Hydrometer method was used to determine soil texture (Gee and Bauder, 1986). Statistical analyses were computed using SAS software.

RESULTS and DISCUSSION

Table 3 shows that the nitrogen content of sunflower decreased gradually when the rate of applied OSW was increased. Phosphorus and calcium contents increased potassium and magnesium contents of sunflower did not change. Using of OSW that have high C/N ratio may cause low nitrogen content of sunflower. The application of organic materials showing C-to-N ratios around 25–35 into soils is generally expected to result in no direct net N mineralization or immobilization (Harris, 1988; Paul and Clark, 1996). Changes in micro element contents by applications of OSW on sunflower were presented in Table 4. It shows that the highest boron content was determined in %5 OSW application and it is statistically significant ($P < 0.05$). Iron and manganese contents did not change significantly by OSW applications.

Nitrogen and calcium contents decreased with the application of OSW in the bean while phosphorus, potassium, and magnesium contents increased (Table 4). On the other hand, the highest boron content was found in %7 OSW application in bean (Table 5) and boron content of bean was significant statistically ($P < 0.05$). The highest manganese value was found in the control treatment. Although it is statistically significant ($P < 0.001$) iron content was found not statistically significant ($P > 0.05$).

As a result directly application of OSW to soil has positive impact on phosphorus, calcium and boron contents of sunflower. While nitrogen content of sunflower reduced by OSW application, potassium, magnesium, iron and manganese contents did not change. Nitrogen content of bean reduced in OSW treatment. Other element contents statistically increased except calcium, iron and manganese. While calcium and manganese contents decreased by OSW application, iron content did not statistically change. Potassium content in bean increased consistently as it was also reported by Piñeiro et al. (2008). They reported that application of OSW increased available potassium content. The results showed that direct application of OSW as raw material to soil is unfavorable for annual plants. Some studies reported that composting OSW balances C/N ratio and transforms the plant nutrients to available forms. Also as an alternative way OSW may be mixed with soil several months before sowing. But ideal application time of OSW must be determined by incubation studies in laboratory or field experiments.

Table 3. Effect of OSW on some macro element contents of Sunflower

Applications	N%		P%		K%	Ca%		Mg%
0 % OSW	0.96	A	0.07	C	2.02	1.74	C	0.28
3 % OSW	0.64	B	0.19	A	2.35	2.44	A	0.29
5 % OSW	0.49	C	0.16	A	2.24	2.41	BA	0.31
7 % OSW	0.41	C	0.12	B	1.88	2.03	BC	0.26
Significant	***		***		ns	**		ns

*: P < 0.05, **: P < 0.01, ***: P < 0.001, ns: Not Significant

Table 4. Effect of OSW on some macro element contents of Bean

Applications	N%		P%		K%		Ca%		Mg%	
0 % OSW	4.21	A	0.23	B	3.49	CB	3.44	A	0.44	B
3 % OSW	1.76	B	0.29	A	3.29	C	2.78	B	0.43	B
5 % OSW	1.75	B	0.29	A	3.65	B	2.73	B	0.47	BA
7 % OSW	1.70	B	0.32	A	4.00	A	2.64	B	0.52	A
Significant	***		***		***		***		*	

*: P < 0.05, **: P < 0.01, ***: P < 0.001, ns: Not Significant

Table 5. Effect of OSW on some micro element contents of Sunflower and Bean

Applications	Bean					Sunflower			
	B(ppm)		Fe(ppm)	Mn(ppm)		B(ppm)		Fe(ppm)	Mn(ppm)
0 % OSW	33.44	B	179.68	118.77	A	33.83	B	53.55	30.65
3 % OSW	39.38	BA	169.86	70.41	C	41.84	A	54.30	30.25
5 % OSW	37.15	B	207.63	86.96	B	43.98	A	61.48	31.75
7 % OSW	44.56	A	173.76	87.07	B	40.75	BA	49.72	32.38
Significant	*		ns	***		*		ns	ns

*: P < 0.05, **: P < 0.01, ***: P < 0.001, ns: Not Significant

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The Effects of Olive Oil Solid Waste Applications on the Some Physiological and Morphological Parameters of Bean (*Phaseolus vulgaris* L.) and Sunflower (*Helianthus annuus* L.) Plants

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ABSTRACT
By considering the storage problems and the environmental harms caused by agricultural by-products and industrial wastes, researches on reusing these wastes are gaining great importance. In this study we investigated the olive oil solid waste applications on beans and sunflower growth. Olive oil solid waste (OSW) mixed with soil at the rates of 0, 3, 5 and 7 % by weight. Some physiological and morphological parameters such as chlorophyll contents, plant height, plant thickness etc. have been examined. As a result, it is determined that direct applications of olive solid waste negatively affect bean and sunflower growths.
Keywords: Olive Oil Solid Waste, morphological properties, bean, sunflower

INTRODUCTION

Olive oil extraction is one of the most traditional agricultural industries in the Mediterranean region, and is still of primary importance for the economy of most of the Mediterranean countries (Owen et al., 2000). The average world production of olive oil is 2.5×10^6 tons, most of which comes from the Mediterranean countries (Alburquerque et al., 2004).

Locally available organic wastes and by-products from agriculture can be processed and converted to other products (Bernal et al., 1998), which contribute to the sustainability of agro ecosystems in the Mediterranean region (Manios, 2004). Final products and compost can be used as soil conditioner and fertilizer, for recycling nutrients to agriculture and horticulture. However, compost contains a wide range of organic pollutants (Brändli et al., 2005; Brändli et al., 2007a and 2007b) and care must be taken before apply them to soil.

Soil organic matter is the most sensitive component to characterize soil quality, to reduce its erosion and improve crop production (Stevenson, 1994; Reeves, 1997). Moreover, Hachicha et al. (2006) studied that composting of olive mill wastes with poultry manure and noticed that olive mill wastes compost can be used as an organic fertilizer for agricultural soils, without any phytotoxic effect. Studies have indicated that various sources and forms of composted and raw wastes can be used effectively as organic support media, a fertilizer source with reduced cost (Ingelmo et al., 1998; Riberio et al., 2000,). One possibility is to use OSW compost is the preparation of soil organic fertilizers and amendments, since the direct application of OSW to the soil has detrimental effect on seed germination, plant growth and microbial activity. Composting of olive mill wastes can be used as organic fertilizers or soil amendments (Tomati et al., 1995; Madejón et al., 1998; Paredes et al., 2001, Paredes et al., 2002).

Application of OSW increased soil aggregate stability of sandy and loamy soils (Kavdir and Killi, 2008). On the other hand when plant growth considered, direct application of OSW reduced tomato plant growth while OSW compost increased it (Killi, 2008). Therefore influences of OSW on various plant growths must be determined in order to overcome these negative effects.

In this research, we studied the suitability of OSW as an organic amendment, for growing sunflower and bean.

MATERIALS and METHODS

Applications and Experimental Design

Two pot experiments were conducted for characterization of plant response to direct application of OSW to the soil. Soil samples were taken from field at 0-20 cm depths and sieved through 9 mm sieve. Some chemical and physical properties of soil are presented in Table 1. Olive oil solid wastes (two-phase centrifugation system) have been provided from the Elta Agriculture enterprise in Gökçeada, Çanakkale. OSW was sieved through 6 mm and mixed with soil at the rates of 0, 3, 5, and 7% w/w.

Experimental design was randomized block design with four replications. There were four different levels (0%, 3%, 5%, and 7%) of OSW applications.

Five sunflower (Syngenta Sanay variety) and five bean (Asgrow variety) seeds were sown in each pot. Plants were thinned after the germination.

Table 1. Some chemical and physical properties of soil sample

EC(µS)	pH	N %	$CaCO_3$ %	OM %	Texture		
					Clay %	Silt %	Sand %
235	8.1	0.1	15.4	1.6	36.98	31.99	31.03
					CL		

Table 2. Some properties of OSW

EC (µS/cm)	pH	N (%)	C (%)	C/N	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
822	5.7	1.12	49.1	43.8	0.04	0.57	0.5	0.06	16.9	1243.91	32.75	17.34

METHODS

Plant height was determined by using a ruler and stem thickness was determined by an absolute digital caliper (Mitutoyo). Chlorophyll readings were measured by using Chlorophyll Meter-Spectrum CM

1000 (BRT 1) under light source (Unit 1347 pro lamb). Dried plants were ground with plant grinder, and then total nitrogen was determined by using Leco TruSpec 2000 CN elemental analyzer.
EC: Samples mixed with DI water at 1:2.5 ratio, set overnight and then EC was determined using WTC brand EC-meter model LF 320. (Richards, 1954). pH: Samples mixed with DI water at 1:2.5 ratio, set overnight and then pH was determined using Orion brand pH-meter, model 420A. (Richards, 1954). Lime: Scheibler calcimeter was used to measure $CaCO_3$ (Soil Survey Laboratory Methods Manual, 1996). Macro and micro element contents of OSW were determined in dry ash (Peters, 2003) by using ICP-AES. Hydrometer method was used to determine soil texture (Gee and Bauder, 1986). Statistical analyses were computed using SAS software.

RESULTS and DISCUSSION

The results were statistically analyzed and they showed that direct application of OSW to soil inhibited bean and sunflower plants growth (Tables 3, 4). Plants height, leaf numbers, dry weight, wet weight, stem thickness and chlorophyll meter readings of bean and sunflower were greater in control treatments than other treatments. Plant height of bean in the 7% OSW treatment was the lowest as compared to all other treatments. Stem diameter was lower in the OSW application than control measurement.

Bean plant height reduced significantly ($P<0.001$) in the OSW treated soils. Respectively bean stem thickness, leaf numbers, wet weight, dry weight and chlorophyll meter readings reduced significantly by using OSW too. ($P<0.01$, $P<0.05$, $P<0.001$, $P<0.001$, $P<0.001$)

Sunflower plant height, stem thickness, leaf numbers, wet weight and dry weight significantly reduced by using OSW ($P<0.001$, $P<0.001$, $P<0.001$, $P<0.001$, $P<0.001$). But OSW application effect on chlorophyll meter readings was not significant ($P> 0. 05$).

Some morphological measurements showed that using OSW directly to the soil negatively effected sunflower and bean growth in short term. Although informed the phytotoxic and antimicrobial effects of both olive-mill wastes and by-products due to the phenol, organic and fatty acid contents (González et al., 1990; Linares et al., 2001), Piñeiro et al., (2008) reported that application of two - phase olive mill waste (TPOMW) caused significant increases ($P < 0.05$) in organic carbon, total N, available P and K, and aggregate stability were observed in the amended soils after two years and also, a general increase in olive production was observed in the treated plots and reported that raw TPOMW has the potential to be valuable soil amendments and source of organic matter, with a positive effect on olive yield, and closing the cycle of residues-resources.

As a result direct application of OSW to soil has negative impact on morphological growth of sunflower and bean. Using this waste is unfavorable for annual plants. Some studies reported that by composting OSW balances C/N ratio and transform the plant nutrients to available forms. Also another alternative can be mixing this material with soil several months before sowing. But its time must be determined by incubation studies in laboratory or field experiments.

Table 3. Effects of OSW on some morphological properties of bean

Applications	Plant Height (cm)		Stem Thickness (mm)		Leaf numbers		Wet weight (gr)		Dry weight (gr)		C.M. Readings	
0 % OSW	138.50	A	3.42	A	11.75	A	12.16	A	1.23	A	120.53	A
3 % OSW	113.25	B	2.89	B	11.00	BA	6.36	B	0.72	B	52.52	B
5 % OSW	95.50	C	3.09	BA	11.00	BA	6.00	B	0.59	C	52.62	B
7 % OSW	84.50	C	2.81	B	10.25	B	4.98	C	0.48	D	52.82	B
Significant	***		**		*		***		***		***	

*: P < 0.05, **: P < 0.01, ***: P < 0.001, ns: Not Significant, C.M: Chlorophyll Meter

Table 4. Effects of OSW on some morphological properties of sunflower

Applications	Plant Height (cm)		Stem Thickness (mm)		Leaf numbers		Wet weight (gr)		Dry weight (gr)		C.M. Readings
0 % OSW	51.65	A	5.97	A	18.25	A	22.74	A	4.92	A	95.92
3 % OSW	38.15	B	3.45	B	9.75	B	4.08	B	0.78	B	67.39
5 % OSW	31.58	B	3.38	B	7.50	C	3.14	B	0.70	B	70.45
7 % OSW	34.83	B	3.60	B	7.00	C	3.43	B	0.81	B	50.14
Significant	***		***		***		***		***		ns

*: P < 0.05, **: P < 0.01, ***: P < 0.001, ns: Not Significant

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Effects of Rye Green Manure Application in Soil Physical and Chemical Characteristics in Maragheh Dryland Condition Zone

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ABSTRACT

In order to study of green manure application effects on soil physical and chemical characteristics in dryland condition, this project was carried out with 4 rye green manure treatments along with nitrogen factors included; 0, 26, 103 and 337 kg $N.ha^{-1}$ from urea fertilizer plus check (without green manure) treatment in 3 rotation system (green manure-wheat) in RCBD desigin with 4 blocks at 1999-2007 in Maragheh Dryland Research Station. Results showed that, althrough treatment effects on dryland wheat grain yield was not significant, but maximum grain yield with 2484 $kg.ha^{-1}$ obtained from application of rye green manure along with 26 kg $N.ha^{-1}$. This grain yield was 442 $kg.ha^{-1}$ (22 percentage) more than check (without green manure) treatment. Application of green manure without nitrogen factors increased soil pH, T.N.V.% and E.C ($dS.m^{-1}$), but decreased O.C%, P (av.), Fe (av.), Cu (av.), Mn (av.), Zn (av.), saturation% and sand% in soil. With application of nitrogen factors along with green manure increased saturation%, clay%, E.C ($dS.m^{-1}$) in soil, but decreased O.C%, P (av.), Cu (av.), Mn (av.), Zn (av.) sand% in soil. Soil moisture decreased 8% in green manure application treatment without nitrogen applicalion in 0-20 cm depth, but with nitrogen application along with rye green manure, soil moisture increased 6% compare to check. It can be concluded that, green manure application is useful in long term along with nitrogen fertilizer application. Green manure application in addition to increasing of soil moisture content, increase dryland wheat grain yield. Green manure application changes soil characteristics for example, increasing of soil T.N.V%. This problem is decreased of availability of some essential nutrient for dryland wheat, therefore in this condition dryland wheat fertilizer requirments must estimate via soil testing.

Key words: Rye green manure, soil physical and chemical characteristics, dryland condition

INTRODUCTION

For the long term productivity soil organic mater has great importance. Cultivation is expletive and reduces the content of organic matter. This decline is aggravated if follow is included in the rotation where the soil is cultivated to ensure no plant growth or where crop residues are removed (Brady, 1999; Feizisal and *et al.* 2005). Application of green manures in soils is considered as a good management practice for increasing soil organic matter. Such practice can increase cropping system sustainability by reducing soil erosion and ameliorating soil's physical and chemical properties (McGuire *et al*. 1998), by increasing organic matter and fertility level (Melero *et al*. 2006) and increases nutrient retention (Kapland and Estes, 1985).

It was reported that green manure increases soil water storage in dry lands by increasing water infiltration rate, declining evaporation and by soil structure amendment (Triplett *et al.* 1968; Zerega *et al.* 1995). Soil water storage is one of the important factors to crop production in arid and semiarid zones (Anger and McCala, 1980).

This project was fulfilled in Maragheh dry land condition zone to investigate the effects of Rye green manure with different nitrogen fertilizer levels on soil physical and chemical properties.

MATERIAL and METHOD

The study was conducted in research station of dryland agriculture research institute in Maragheh. The soil of the field experiment was a Clay loam (Fine Mixed Active, Mesic Typic Calcixerepts). Combined soil sampling before green manure cultivation derived from (0-25 cm) depth and general soil chemical and physical analysis measured in laboratory. Winter type Rye (*Secale cereale*) was cultivated in autumn and in spring Rye's green residues was added to soil along with nitrogen factors included: 0, 26, 103 and 337 kg N/ha from urea fertilizer plus check (without green manure) treatment. This level of N was added synchronous with Rye residue additional to soil. This study carried out in 3 rotation system (green manure –wheat) in PCBD design with 4 blocks at 1999 – 2007.

Soil water content measured (weigh moisture method) in wheat Growth stage (GS) by direct sampling from field experiment in two (0-20 cm and 20 -40 cm) soil depths.

Randomized 30 samples picked up from wheat field experiment and measured in laboratory For Plant characteristics observations. Statistical analysis of total data from this project carried out with Genstat software.

RESULTS

Dryland Wheat Yield

Mean comparison of for plant characteristics indicated that green manure application without N decreased biological yield, grain yield and straw yield respectively 10%, 14%, 7% in respect to the control. also this treatment decreased T.K.W, harvest index, productivity degree, Head Length, number of head m^{-2} and plant height respectively 15%, 5%, 6%, 3%, 8% and 8%. Whereas green manure application without N increased number of head and fertile tiller respectively 5% and 17% (table 1).

Application of green manure with nitrogen use in all level increased biological yield and grain yield respectively 5% and 12% respect to control. This treatment effect's on straw yield wasn't significant (Table1).

The highest grain yield 2484 kg.ha^{-1} present for green manure + 26 kg.ha^{-1} N (from urea) treatment and the lowest grain yield 1757 kg.ha^{-1} obtained from green manure without N use treatment. But this lowest grain yield from green manure treatment had 22% increase respect to control (table1). According to Fageria *et al.* (1991) it is important regarding to next plant production after green manure application. Pilipenko and Savoshchenko (1998) reported that application of green manure had not significant effect on barely production whereas Triplett *et al*. (1980) believed that organic matter application increase soil water content and plants grain production level progressively.

Table 1: Mean comparison for green manure treatment effects on wheat plant characteristic

Treatment	Biological yield	Grain yield	Straw yield	T.K.W	Harvests Index	Productivity degree	Spike length	No of head .m-^{2}	No of seed per spike	Plant height	No. of tillers
	(kg.ha^{-1})			(gr)			(cm)			(cm)	
Control	5944	2042	3901	40.9	0.336	41.6	5.9	422	19.6	72.2	1.40
0	5368	1757	3611	34.8	0.318	39.0	5.7	387	20.5	66.1	1.64
26	6645	2484	4161	42.1	0.406	49.7	7.5	444	18.9	73.2	1.57
103	6522	2282	4240	37.9	0.354	44.2	5.5	466	17.8	70.5	1.35
337	5540	2107	3433	41.7	0.414	49.1	6.2	438	20.9	74.0	1.74
LSD5%	1560.2	542.2	1117.1	8.3	0.08	8.3	2.1	94.8	7.1	11.2	0.29

Soil Physical and Chemical Characteristics

The statistical analysis of 3 period of wheat cultivation (green manure-wheat) showed that the effect of year was significant ($P<0.01$) on soil pH , %O.C, Fe, Cu, Mn, Zn, %sand, %clay and %silt (table 2).

And also the effects of treatment was significant on soil P, %SP, EC and on the $\%CaCO_3$ ($P<0.05$) table 2.

Table 2 shows that in the first year of experiment $\%CaCO_3$, Fe, Mn and Zn increased respectively 80%, 48%, 18% and 20% whereas P and Cu decreased respectively 8 % and 7%.

In the second year $\%CaCO_3$, Fe, Mn increased respectively156%, 35% and 23 % whereas P and Cu decreased respectively 14% and 4%.

In the third year $\%CaCO_3$, Fe, Mn and Zn increased 82%, 26%, 20% and 5% respectively whereas O.C decreased grain yield 19%.

However mean comparison of three years experiment in comparison with previous experiment showed that in the different treatments of green manure $\%CaCO_3$, Fe, Mn and Zn uptake increased 105%, 48%, 31% and 16% respectively whereas O.C, P and Cu decreased them 7%, 8 % and 3% respectively (table 3).

This result doesn't confirm Biswas and Mukherjee (1991) who is reported that green manure application increased soil O.C% and available P.

Mean comparison between different green manure treatments with control showed that application of green manure without nitrogen increased soil pH, $\%CaCO_3$, %Clay and EC 2%, 138%, 3% and 2% respectively. Whereas this treatment decreased %OC, P, total N, Fe, Cu, Mn and Zn 11%, 20%, 12%, 3%, 6%,13%, 5%, 2% and 5% respectively.

Mean comparison between different green manure + N treatments with control showed that these treatments increased %CaCO3, %SP and EC_e 72%, 3%, 6% and 24% respectively Whereas these treatments decreased %OC, P, total N, Cu, Mn, Zn and %sand 6%, 18%, 4%, 4%, 5%,3% and 10% respectively.

Table 2: The effects of Year on soil characteristics in 0-20 cm depth

	pH	O.C (%)	P (av.) ($mg.kg^{-1}$)	Total N (%)	T.N.V (%)	Fe (av.)	Cu (av.)	Mn (av.)	Zn (av.)	SP	Clay	Sand	Silt	EC ($dS.m^{-1}$)
						($mg.kg^{-1}$)				(%)				
first	7.94	0.617	14.7	0.062	4.0	7.1	2.10	13.9	0.60	58	44	13	43	0.77
second	7.68	0.634	13.7	1.089	5.7	6.5	2.16	14.5	0.50	59	21	23	56	0.68
third	7.89	0.511	15.8	0.575	4.0	7.8	2.33	17.9	0.64	63	31	20	49	0.66
LSD5%	0.12	0.05	2.60	0.05	1.61	0.59	0.10	1.8	0.05	1.9	2.2	4.1	3.4	0.13

Table 3: Combined analysis of variance for soil characteristics in different green manure treatments

		Mean square													
S.O.V	d.f	pH	O.C	P (av.)	Total N	T.N.V	Fe (av.)	Cu (av.)	Mn (av.)	Zn (av.)	SP	Clay	Sand	Silt	EC
Year	2	0.376**	0.090**	23.032ns	10.547**	19.89*	9.13**	0.28**	91.7**	0.104**	5.1ns	5273.0**	1046.5**	1621.80**	0.08ns
Residual	9	0.027	0.006	13.253	0.004	5.08	0.68	0.02	6.4	0.005	6.0	8.3	28.7	19.68	0.03
Treatment	4	0.033ns	0.017ns	27.900**	0.011ns	15.08*	0.28*	0.04ns	11.5ns	0.004ns	29.8**	4.6ns	9.7ns	5.09ns	0.39**
Year*Treatment	8	0.033ns	0.011ns	2.350ns	0.006ns	0.53ns	0.96ns	0.01ns	1.6ns	0.004ns	20.4ns	7.5ns	8.9ns	23.80ns	0.14**
Residual	36	0.028	0.019	3.216	0.006	5.09	0.50	0.03	7.1	0.005	10.5	7.4	11.0	10.57	0.02
C.V%	-	2.1	23.7	12.2	13.4	49.4	9.9	8.5	17.2	12.4	5.6	8.4	18.1	6.6	21.7

Soil Water Content

Combined soil moisture analysis of variance in each three years cultivation indicated tat there were significant effect of year, treatment, depth , effect of year × treatment and year × depth ($P<0.01$) whereas the effects of treatment × depth and year × treatment × depth was significant ($P<0.05$) (table 4).

Mean comparison of soil moisture for three years cultivation of wheat showed that the higher mean 28.7 % belong to third year and the lowest mean 12.5% related to first year of experiment.

Comparison of moisture (%) between second year and third year with first year showed increase of 74% that was significant.

It seems that increasing annual precipitation has important role on the soil moisture increase but this factor isn't parallel with annual precipitation in the second and third year of our experiment. Because increasing of soil moisture was 75% for second year and 130% respectively in comparison with first year. But the annual precipitation for these years was 104% for second year and 107% respectively for third year of experiment.

Although these results indicated 1% increase on annual precipitation between second and third year but increase in soil moisture was 32% among this years that confirm positive effect of green manure application on soil water (fig 1).

Mean comparison interaction effect treatment × sampling depth indicated moisture increasing 8% without N in green manure application comparison with control. Addition first level of N to green manure increased moisture 6% in the 0-20 cm depth. Whereas soil moisture variation had not significant effect between different levels of N + green manure treatments.

Application of green manure without N use decreased soil moisture (10%) in the 20-40 cm depth whereas use of N in all level decreased 6% in such depth comparison with control (fig 2).

These results indicated that application of Rye green manure with N use increased soil moisture in 0-20cm soil depth whereas decreased soil moisture in 20-40cm depth. These results agree with those of Trilett *et al* (1968), Black (1973), Zerega *et al*. (1995) and Pradit *et al.* (1993) who found that green manure application caused soil water content increase by increase of water infiltration rate, by decreasing evaporation rate and by improving soil physical characteristics.

Against these results Pikul *et al*. (1997) reported application of green manure has not increased soil water content.

Table4: Combined analysis of variance for soil moisture in different green manure treatments in two different depth 0-20 cm and 20-40 cm in wheat grain yield

S.O.V	d.f.	Sum of square	Mean square
Year	3	3266.9	1089.0**
Residual	4	57.4	14.4
T	4	46.9	11.7ns
Year*T	12	122.0	10.2ns
Residual	16	153.7	9.6
Depth	1	170.9	170.9**
Year*Depth	3	128.6	42.9**
T*Depth	4	14.3	3.6ns
Year*T*Depth	12	29.6	2.5ns
Residual	20	82.5	4.1
C.V%		10.5	

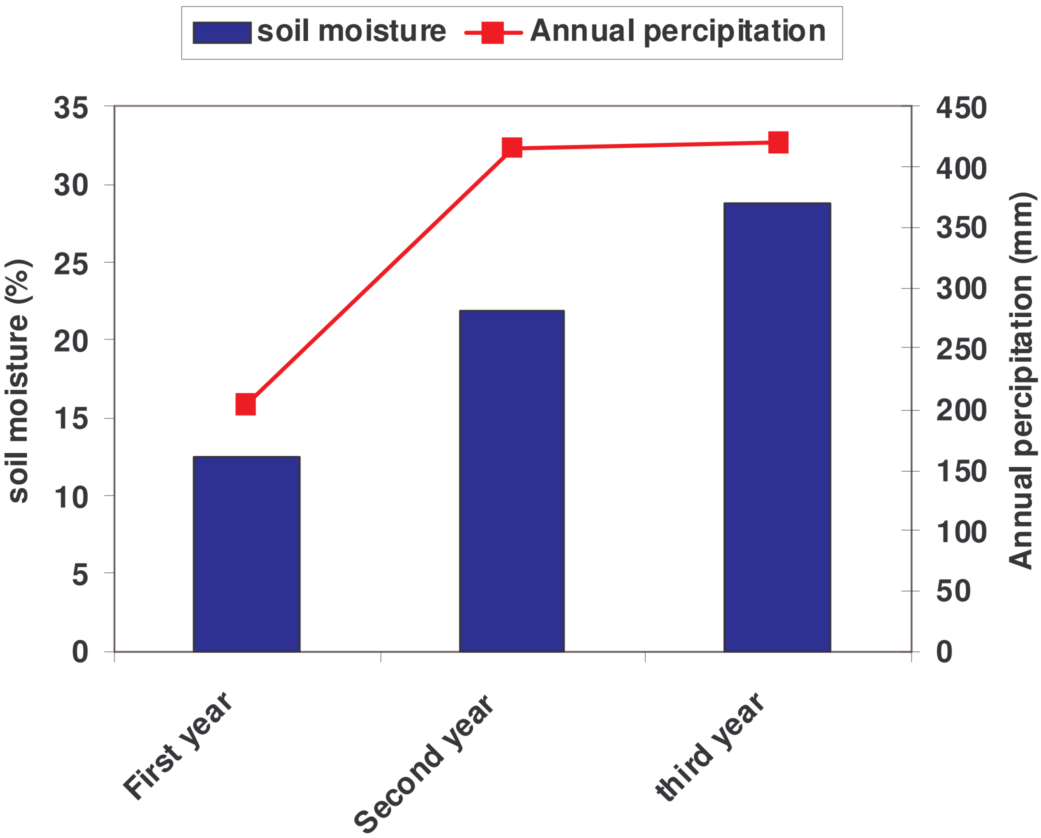

Fig 1: Variation of annual precipitation and soil moisture in 0-20 cm soil depth in three years in dray land wheat cultivation.

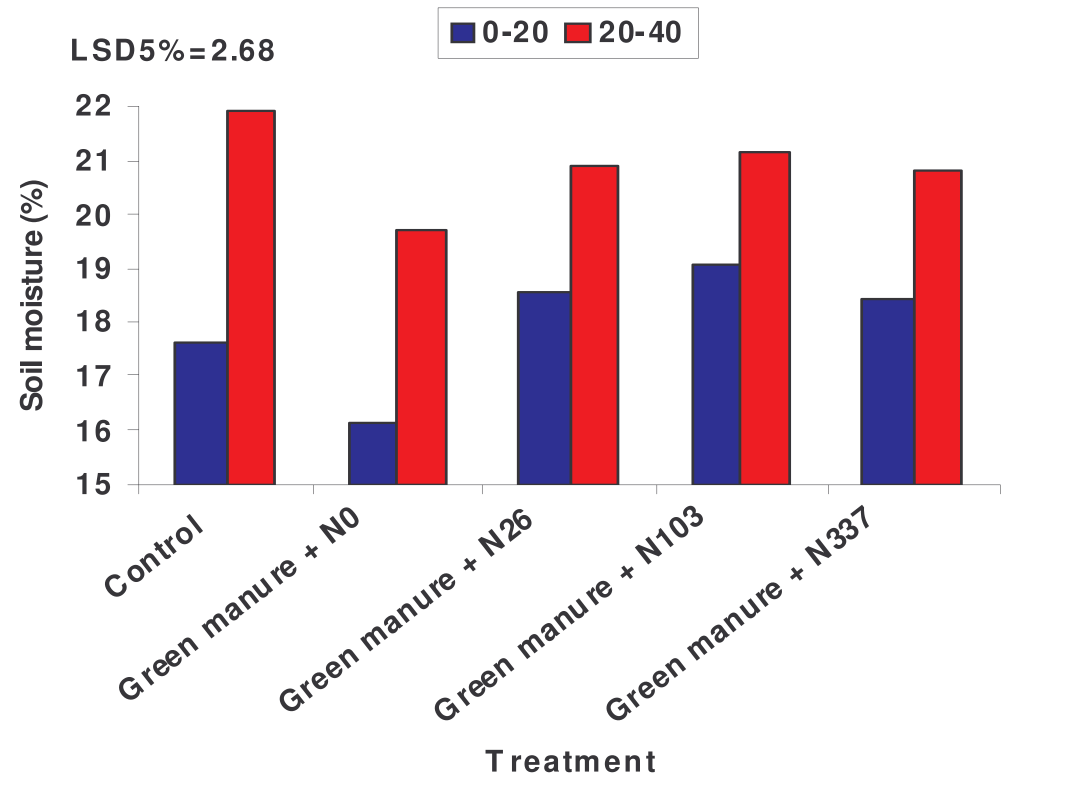

Fig 2: Mean soil moisture for average of three years in two different soil depths in wheat shooting stage.

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The Effects of Different Level of Nitrogenous and Phosphorus Doses on Herbage Yield and Yield Components of Silage Maize as the Second Crop under the Ecological Conditions of Tokat

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ABSTRACT

Nitrogen and phosphorus play a pivotal role in the crop growth and yield. This research was conducted to determine the effects of different nitrogenous (0, 60, 120, 180, 240 kg N ha^{-1}) and phosphorus doses (0, 60, 120 kg P_2O_5 ha^{-1}) on a plant length, leaf number, herbage yield, dry matter yield, harvest index, leaf nitrogen content, stalk nitrogen content, cob nitrogen content, leaf phosphorus content, stalk phosphorus content, cob phosphorus content, leaf crude protein content, stalk crude protein content, cob crude protein content in silage maize cultivar (MF-714 FAO 500) as the second crop in the experimental field of the Agricultural Faculty of Gaziosmanpaşa University in Tokat Conditions during the years of 2003-04. It was shown that nitrogen dose of 240 kg ha^{-1} and phosphorus dose of 120 kg ha^{-1} were a suitable combination for maximum herbage yield according to regression analysis.

Key Words: nitrogenous, phosphorus, silage maize.

INTRODUCTION

Maize is one of the alternative plants decreased excessive pasture in meadow pasture areas. Maize silage is important a crop provided roughage to ruminants. Nitrogen is an important nutrient that affects the yield and quality traits of this crop. (Russel and Balko, 1980). Maize, grows more rapidly in first growth stage and completes more early vegetatif growth if there was nitrogen in soil (Ülger, 1998; Uslu, 1999). Thus maize, is produce a high-quantity of dry matter, leaves and grain (Ülger et al., 1987). The reaction of silage maize to different nitrogen doses was studied by some researchers (Cox et al., 1993; Kara et al., 1999; Saruhan, 2002; Yılmaz, 2005). Yılmaz (2005) reported that the nitrogen dose had a significant effect on most of the yield component of silage maize and that the highest herbage yield, dry matter yield and harvest index was obtained at the nitrogen dose (200 kg N ha^{-1}). Phosphorus is another important nutrients that affects the yield and quality traits of silage maize (Kogbe and Adediran, 2003). Phosphorus has increased growth and development of cereals when uptake early stage in plants (Matarn and Brown, 1989). Maize that is grown on soils adequate in phosphorus is arrived earlier tasselling and silking stages and reached earlier harvest (Hofner and Krantz, 1951). The existence of sufficient phosphorus in soils in early growth stage of plant plays a pivotal role in forming of reproduction members (Güzel ve ark., 2002). Phosphorus taken in early stage by maize increase to harvest index and yield (Barry and Miller, 1989). Many researchers (Lönharn-Bary and Nemeth, 1989; Barriere and Traineau, 1986) have reported that leaf number increase with phosphorus application therefore that herbage yield increased. Öktem and Ülger (1998), evaluated the effects of 4 phosphorus doses (ranging from 40 to 160 kg P_2O_5 ha^{-1}) on the use efficiency of phosphorus in maize reporting that optimum crop growth appeared at phosphorus dose 80 kg P_2O_5 ha^{-1}. Kogbe and Adediran (2003), reported that increasing available phosphorus dose in soil decrease the use efficiency of phosphorus in maize. Selection of the most appropriate dose of N and P fertilization is a major two factor affecting the yield of corn (Cerrato and Blackmer, 1990).

The objective of this study was to evaluate the effects of nitrogen and phosphorus doses on yield and yield components of silage maize growing as a second crop under Tokat conditions.

MATERIAL and METHODS

This study was conducted in the experimental area Faculty of Agriculture, University of Gaziosmanpaşa, Tokat, (40^0 18' N, 36^0 34'E, altitude 608 m) Turkey during the 2003-2004 cultivation seasons. Weather conditions of the experimental area during the cultivation seasons are given in Table 1 (Anonymous, 2006). The soil of experimental area was a clay loam; pH: 7.49; available P: 6.7 kg P_2O_5 da^{-1}; organic matter: 0.75%, lime: 12.66%. The experimental design was a randomized complete block in a split plot arrangement with 4 replications. N rates (0, 60, 120, 180, 240 kg ha^{-1}) were the main plots, P rates (0, 60, 120 kg ha^{-1}) were the split- plots in the experiment. Phosphorus (as triple superphosphate) and half of the N (as ammonium nitrate) was added as a band at planting, and the other half of the N was added when the plants were about 50-60 cm high. All plots consisted of 5 rows that were 4 m long, with 60cm between row spacing. Sowing dates were July 9, 2003 in the first year; July 20, 2004 in the second year. Plants were collected by randomly selecting ten whole plants within the plot area at R3-R4 stage (Ritchie and Hanway, 1984) and were split into leaf, stalk and ear fractions. The samples were washed with deionized water, dried at 60 ^{0}C for 48 h, and ground using a silica grinder to pass a 0.5-mm sieve (Cox et al., 1993). The samples were dry-ashed and extracted with 0.3 N HCl solution to determine selected nutrients (Walsh and Beaton, 1973). Data were analyzed using the standard analysis of variance (ANOVA) technique and means were seperated using the comparisons based upon the least significant difference (LSD) using the MSTAT-C statistical analysis package. Also, regression equations were fitted for herbage yield, as a function of N dose and P dose by the General Linear Models (GLM) produce of Minitab.

Table 1. Monthly mean temperature accumulated precipitation and mean relative humidity in each site year in the maize growing seasons (May through October)

Month	Temperature (°C)		Precipitation (mm)		Relative humidity (%)	
	2003	2004	2003	2004	2003	2004
May	17.0	14.9	11.8	48.0	64.6	74.2
June	18.2	18.7	11.4	27.2	66.8	78.6
July	21.7	20.6	1.4	0.4	64.6	68.0
August	21.2	21.9	0.2	4.8	66.5	73.6
September	16.9	16.8	37.8	0	77.6	72.8
October	13.9	13.2	72	0.4	79.4	76.4
Average	18.2	17.7	134.6	80.8	69.9	73.9

RESULTS and DISCUSSION

The nitrogen application significantly increased the plant height in terms of the average of the two years (Table 2). The lowest plant height was obtained from the control (187.8 cm) while the highest plant height was obtained from application of 180 kg N ha^{-1} (231.7 cm). Some researchers have reported that the plant height increased with N application in silage maize (Flesch and Viera, 2000; Turgut, 2000; Kara, 2006). Phosphorus doses were also effect plant height. The values for plant height ranged from 214.2 to 221.4 cm. The highest plant height (221.4 cm) was obtained at application of 60 kg P_2O_5 ha^{-1}.

The leaf number values increased from the 0 (12.4 number $plant^{-1}$) to 180 kg N ha^{-1} (12.9 number $plant^{-1}$) nitrogen doses. The highest leaf number was obtained with of application 180 kg N ha^{-1} (12.9 number $plant^{-1}$, Table 2). Our findings are confirmed by Yılmaz (2005) , who concluded that increased N rates increased leaf number in silage maize. Phosphorus doses were not affected on leaf number.

Dry matter yield results are presented in Table 2. Considerable difference existed among N doses with respect to dry matter yield. The highest dry matter yield was obtained at nitrogen dose of 240 kg N ha^{-1} (1601.3 kg da^{-1}). The findings here support the data published by Cox et. al. (1993); Cox and Cherney (2001) who reported that rising nitrogen doses increase the dry matter yield. O'Leary and Rehm (1990) explained that there has been linear relation between dry matter yield and nitrogen doses. No differences occured among the phosphorus doses in dry matter yield (Table 2). The mean dry matter yield varied between ranged from 1291.1 to 1323.2 kg da^{-1}.

Table 2. The average values of two years results of plant height, leaf number and dry matter yield due to different nitrogen and phosphorus doses

N dose, kg ha^{-1}	P dose, kg ha^{-1}											
	Plant height(cm)				Leaf number (number/plant)				DM yield (kg da^{-1})			
	0	60	120	Aver.	0	60	120	Aver.	0	60	120	Aver.
0	188.7	190.3	184.5	187.8 B**	12.3	12.4	12.4	12.4 B**	821.6	730.5	716.7	756.3C*
60	210.4	218.4	217.4	215.4 A	12.5	12.7	12.8	12.6AB	1185.1	1111.1	1133.9	1143.4 B
120	219.3	231.0	223.4	224.6 A	13.0	12.7	12.8	12.8A	1340.5	1398.5	1441.5	1393.5 A
180	224.1	234.7	236.2	231.7 A	12.7	13.0	12.9	12.9A	1496.1	1498.3	1738.3	157.5A
240	228.5	232.3	233.5	231.4 A	12.8	12.8	12.8	12.8A	1612.1	1606.2	1585.6	1601.3 A
Aver.	214.2 B*	221.4 A	219.0 AB	218.2	12.7	12.7	12.7	12.7	1291.1	1268.9	1323.2	1294.4

* , **, indicates significance at 0.05 and 0.01, respectively.

Plant height (N LSD:19.0**; P LSD: 5.3*); Leaf number (N LSD: 0.4**); DM yield (N LSD:216**)

Increasing nitrogen doses would be caused by decreasing harvest index (HI) values (Table 3). The lowest harvest index was obtained from the application of 180 kg N ha^{-1} (% 8.1) while the highest harvest index was obtained from control (% 10.4). The phosphorus application significantly increased harvest index in terms of mean over two years. Harvest index tended to increase as the phosphorus dose increased. The control plots not receiving P fertilizer had the lowest value. The greatest harvest index was obtained from 120 kg P_2O_5 ha^{-1} (Table 3). Barry and Miller (1989) reported that uptake phosphorus by plant during the early stage increased harvest index and yield.

There was a significant difference in herbage yield with different N doses in terms of the average of the two years (Tablo 3). The application of nitrogen increased herbage yield when compared with the control (Table 3). Some researchers have reported that the herbage yield increased with N application in silage maize (Kara ve ark., 1999 ; Ülger ve ark, 1996). The lowest value (4198.1 kg da^{-1}) was obtained from control plots while the highest value (8386.2 kg da^{-1}) was at the 240 kg N ha^{-1}. When the mean results were taken into consideration, no significant difference was observed among phosphorus doses in terms of mean over two years. The values for herbage yield ranged from 6849.6 to 7045.2 kg da^{-1}.

The effect of nitrogen doses on herbage yield was founded 2 nd quadratic. According to results of this analysis the equation explaining this relationships $y = -9.015x^2 + 390.3x + 4211.2$ (Figure 1).

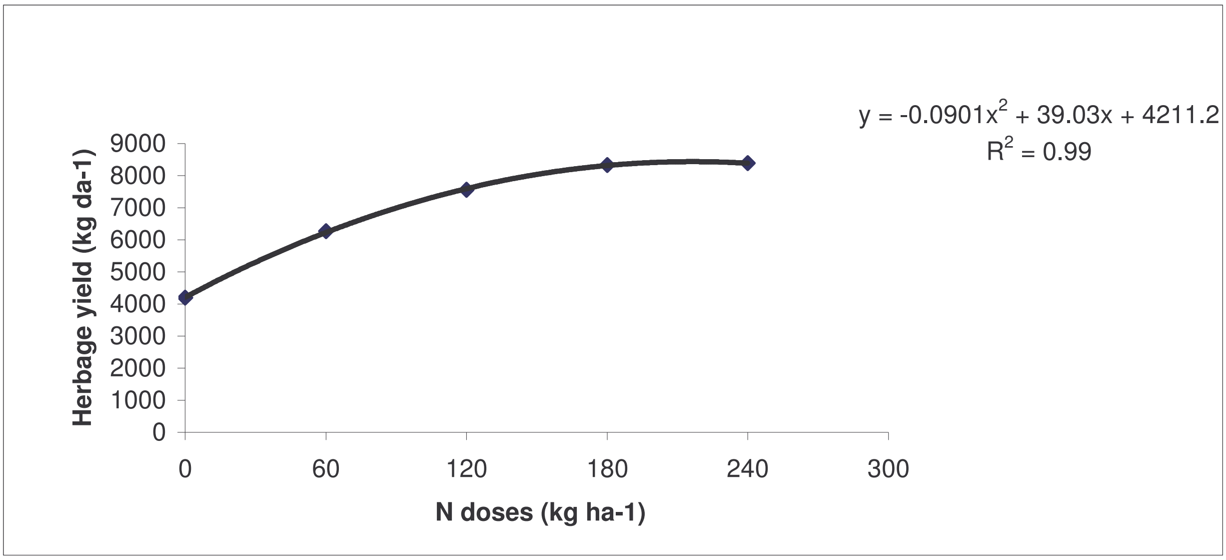

Figure 1. The relationship between nitrogen doses and herbage yield

The effect of phosphorus doses on herbage yield was founded significant at 2 nd quadratic (Figure 2). The equation was given below:

$y = 0.0408x^2 - 4.0878x + 6947.9$

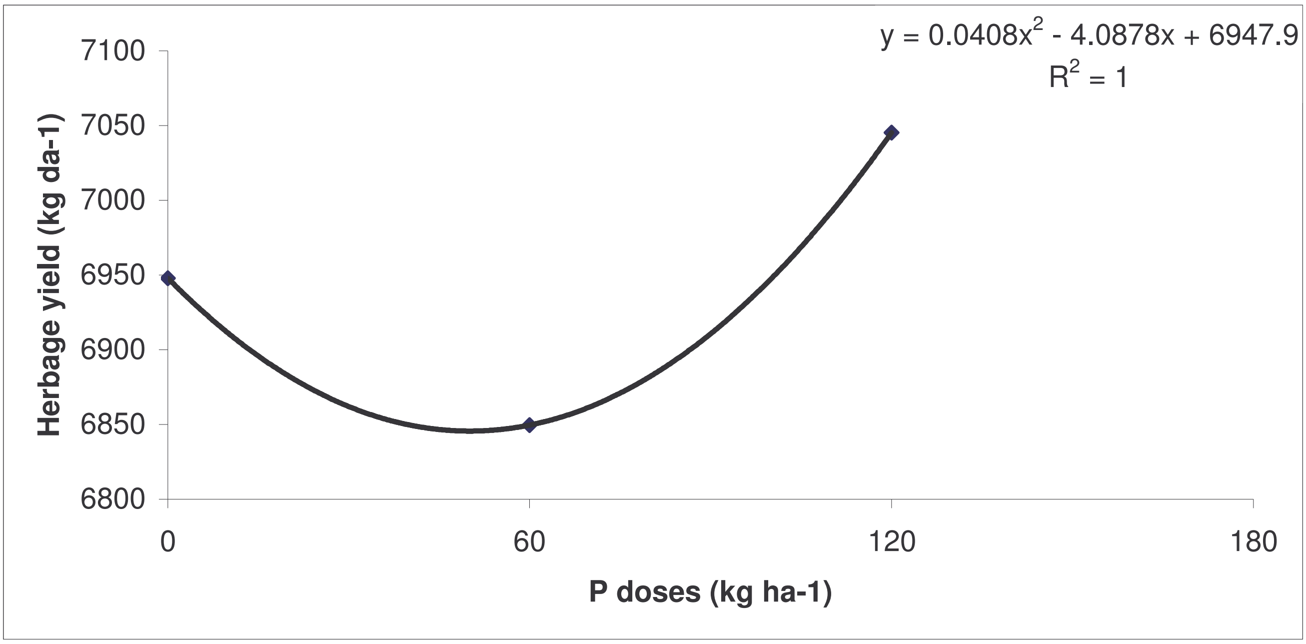

Figure 2. The relationship between phosphorus doses and herbage yield

Table 3. The average values of two years results of harvest index, herbage yield due to different nitrogen and phosphorus rates.

N dose, kg ha^{-1}	P dose, kg ha^{-1}							
	Harvest index (%)				Herbage yield (kg ha^{-1})			
	0	60	120	Aver.	0	60	120	Aver.
0	10.1	10.6	10.5	10.4	4456.9	4258.6	3878.7	4198.1 C**
60	7.8	8.6	10.1	8.8	6225.6	6216.8	6360.3	6267.6 B
120	7.0	8.4	9.8	8.4	7343.4	7695.4	7636.5	7558.4A
180	6.8	8.1	9.4	8.1	8213. 8	7978.5	8790.8	8327.7 A
240	8.2	9..3	10.1	9.2	8500.1	8098.7	8559.9	8386.2 A
Aver.	7.9 C**	8.9 B	9.9 A	8.9	6947.9	6849.6	7045.2	6947.6

**, indicates significance at 0.01

Harvest index (P LSD: 0.9**); Herbage yield (N LSD:1022**)

Leaf nitrogen content were not affected with both phosphorus and nitrogen doses (Table 4). The lowest leaf nitrogen content was obtained from the control (% 1.3) while the highest leaf nitrogen content was obtained from application of 180 kg N ha^{-1} (% 1.6). As phosphorus doses increased, leaf nitrogen content decreased.

A combined analysis over both years for stalk nitrogen content indicated that the stalk nitrogen content was affected neither by nitrogen nor by phosphorus doses (Table 4). The values for stalk nitrogen content ranged from % 0.5 to % 0.7 in the nitrogen doses. The highest stalk nitrogen content (% 0.6) was obtained at application of 120 kg P_2O_5 ha^{-1}.

Cob nitrogen content results are shown in Table 4. The lowest cob nitrogen content was obtained from the control (%1.4) while the highest cob nitrogen content was obtained from application of 180 kg

N ha^{-1} (% 1.6). Kaplan and Aktaş (1993) also reported that grain nitrogen content was effected positively with application of nitrogen dose. Phosphorus doses were not affected on cob nitrogen content.

Table 4. The average values of two years results of leaf nitrogen content, stalk nitrogen content, cob nitrogen content due to different nitrogen and phosphorus doses.

N dose, kg ha^{-1}	P dose, kg ha^{-1}											
	Leaf nitrogen content (%)				Stalk nitrogen content (%)				Cob nitrogen content (%)			
	0	60	120	Aver.	0	60	120	Aver.	0	60	120	Aver.
0	1.3	1.3	1.3	1.3	0.5	0.5	0.5	0.5	1.3	1.4	1.3	1.4
60	1.5	1.6	1.4	1.5	0.5	0.7	0.8	0.7	1.5	1.5	1.4	1.5
120	1.6	1.4	1.4	1.5	0.6	0.6	0.5	0.6	1.5	1.5	1.5	1.5
180	1.7	1.6	1.5	1.6	0.6	0.6	0.6	0.6	1.6	1.5	1.6	1.6
240	1.6	1.5	1.5	1.5	0.5	0.5	0.6	0.5	1.7	1.4	1.5	1.5
Aver.	1.5	1.5	1.4	1.5	0.6	0.6	0.6	0.6	1.5	1.4	1.5	1.5

Neither nitrogen application nor phosphorus application appeared to affect leaf crude protein ratio in terms of the average of the two years. The highest leaf crude protein was obtained with of application 180 kg N ha^{-1} (Table 5). These results are in agreement with those of many other workers (Cox et. al., 1993; Yılmaz, 1994; Yılmaz, 2005). As phosphorus doses increased, leaf crude protein ratio decreased.

No differences occured among the nitrogen doses in stalk crude protein ratio (Table 5). The lowest stalk crude protein ratio (% 3.5) was obtained from the control while the highest stalk crude protein ratio(% 4.4) was obtained from application of 60 kg N ha^{-1}. The increase of phosphorus dose up to 120 kg P_2O_5 ha^{-1} was observed.

Cob crude protein ratio increased with increase of nitrogen dose (Table 5). The lowest cob crude protein ratio (% 8.9) was obtained from the control while the highest cob crude protein ratio (% 10.2). was obtained from application of 180 kg N ha^{-1}. Rising nitrogen doses increase grain nitrogen and protein content (Lambert et. al., 1998). Phosphorus doses didn't affect on cob crude protein ratio. Cob crude protein ratio results are shown in Table 5.

Table 5. The average values of two years results of leaf crude protein ratio, stalk crude protein ratio, cob crude protein ratio due to different nitrogen and phosphorus doses.

N dose, kg ha^{-1}	P dose, kg ha^{-1}											
	Leaf crude protein ratio (%)				Stalk crude protein ratio (%)				Cob crude protein ratio (%)			
	0	60	120	Aver.	0	60	120	Aver.	0	60	120	Aver.
0	8.7	8.4	8.8	8.6	3.6	3.4	3.5	3.5	8.8	9.1	8.8	8.9
60	9.6	10.3	9.1	9.7	3.6	4.3	5.4	4.4	10.1	9.9	9.8	9.9
120	10.3	9.4	9.0	9.6	4.3	4.1	3.3	3.9	9.8	10.1	10.1	9.9
180	10.9	10.8	10.1	10.6	4.1	4.0	4.5	4.2	10.3	9.8	10.4	10.2
240	10.7	9.7	9.7	10.0	3.5	3.4	3.9	3.6	10.9	9.7	9.7	10.1
Aver.	10.0	9.7	9.3	9.7	3.8	3.8	4.2	3.9	9.9	9.7	9.8	9.8

Nitrogen doses didn't affect on leaf phosphorus contents (Table 6). The highest leaf phosphorus content was obtained from the control (Table 6). No differences occured among the phosphorus doses in leaf phosphorus content. The lowest leaf phosphorus content (% 0.17) was obtained from interaction 60 kg N ha^{-1}x 60 kg P_2O_5 ha^{-1} while the highest leaf phosphorus content (% 0.3) was obtained from interaction 0 kg N ha^{-1} x 60 kg P_2O_5 ha^{-1}

Table 6. The average values of two years results of leaf phosphorus content, stalk phosphorus content, cob phosphorus content due to different nitrogen and phosphorus doses.

N dose, kg ha^{-1}	P dose, kg ha^{-1}											
	Leaf phosphorus content (%)				Stalk phosphorus content (%)				Cob phosphorus content (%)			
	0	60	120	Aver.	0	60	120	Aver.	0	60	120	Aver.
0	0.21 bcd	0.31a **	0.26 ab	0.26 a*	0.23	0.28	0.28	0.26a**	0.35	0.41	0.43	0.40 **
60	0.19 bcd	0.17d	0.18cd	0.18 b	0.15	0.16	0.17	0.16 b	0.30	0.28	0.31	0.30 b
120	0.18 cd	0.21bcd	0.19 bcd	0.19 b	0.11	0.14	0.14	0.13 b	0.30	0.31	0.33	0.31 b
180	0.20 bcd	0.20bcd	0.18 cd	0.19 b	0.14	0.14	0.16	0.15 b	0.29	0.34	0.28	0.30 b
240	0.17 cd	0.19 cd	0.25 abc	0.20 ab	0.13	0.16	0.17	0.15 b	0.31	0.28	0.32	0.30 b
Aver.	0.19	0.21	0.21	0.20	0.15 b**	0.18 ab	0.19 a	0.17	0.31	0.32	0.33	0.32

**, indicates significance at 0.05 and 0.01

Leaf phosphorus content(N LSD: 0.06*; N x P int.LSD: 0.1**); Stalk phosphorus content (N LSD: 0.06**; P LSD: 0.03**); Cob phosphorus content (N LSD : 0.06**)

Both nitrogen application and phosphorus application appeared to affect stalk phosphorus content in terms of mean over two years (Table 6). The highest stalk phosphorus content was obtained from the control (% 0.3 Table 6). Stalk phosphorus content tended to increase as the phosphorus dose increased. Hajabbasi and Schumacher (1994) reported that phosphorus stimulated growth in maize. Nitrogen doses were effective on cob phosphorus content. The values for cob phosphorus content ranged from % 0.4 to % 0.3 (Table 6). The highest cob phosphorus content (% 0.4) was obtained from the control. No differences occured among the phosphorus doses in cob phosphorus content (Table 6).

Our results showed that 240 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} should be applied in the case of silage maize growing as a second crop under Tokat conditions.

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Potassium Fixation as Affected by Moisture Conditions in Some Soils of Azerbaijan

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ABSTRACT

Potassium is the third macronutrient provided in a complete fertilizer. Exhaustive cropping of potassium-demanding crops like potato, sunflower and sugar beet leads to depletion of soil non-exchangeable potassium and subsequent fixation of added potassium. In this study the effects of different soil moisture conditions on potassium fixation were investigated in some potassium-depleted soils of Azerbaijan province. For this purpose 6 soil samples were selected from among 17 locations where the amounts of boiling nitric acid extractable-K were considerably lower in cultivated soils compared to the adjacent non-cultivated soils. The amount of potassium added to the soils (250 mg K kg^{-1}) was equivalent to the amount of depleted K. Results showed that the amounts of K fixation were significantly (P<0.001) increased (14.5%) after air-drying. There was a significant (P<0.01) positive relationship between the amount of K fixation and clay content. Three soil samples with different amounts of K fixation were chosen from among six soil samples for subsequent studies. Early air-drying of the soils was significantly (P<0.01) caused more K fixation comparing to middle and late air-drying. According to the results obtained the effect of soil matric potential (-30, -100, -500 kPa) on K fixation was significant (P<0.001).The highest amount of K fixation was found for -100 kPa. Furthermore, K fixation during two months of incubation was significantly (P<0.001) elevated with the increase in the number of wetting-drying cycles (1, 5, 10 and 20 cycles). The amount of K fixation was increased by 23% with wetting-drying incubation (under 20 cycles) compared to constant field capacity incubation.

Key words: potassium fixation, wetting-drying cycles, soil matric potential

INTRODUCTION

Potassium (K) is the third macronutrient provided in a complete fertilizer. Exhaustive cropping of K-demanding crops like potato, sunflower and sugar beet leads to depletion of soil non-exchangeable K and subsequent fixation of added K. Potassium fixation influences the effectiveness of fertilization in soil-plant systems (Murashkina et al., 2007). Understanding the mechanisms responsible for K fixation is therefore fundamental for developing soil fertility management strategies (Olk et al., 1995). The expansible 2:1 layer silicates such as weathered micas, vermiculites, and smectites are the major clay minerals responsible for K fixation in soils. Weathered micas and vermiculites fix K under moist as well as dry conditions, whereas smectites fix K only under dry conditions. The amount of K fixation by smectites is very small unless their charge density is high. Some soil smectites have a higher charge density and likely have wedge sites near mica-like zones where K selectivity is high and K fixation can take place (Huang et al., 2005). The degree of K fixation in clays and soils depends on the type of clay mineral and its charge density, the degree of interlayering, the moisture content, the concentration of K^+ ions as well as the concentration of competing cations such as NH_4^+, and the pH of the ambient solution bathing the clay or soil (Sparks and Huang, 1985). Wetting and drying and freezing and thawing can significantly affect K fixation. The degree of K fixation or release on wetting or drying is dependent on the type of colloid present and the level of K^+ ions in the soil solution (Huang et al., 2005). Air drying generally causes significant fixation of recently added K (McLean and Watson, 1985). Without recent K addition, wetting-drying cycles can promote either fixation or release depending on the quantity of labile K (Tisdale et al., 1990). Two competing processes may occur during drying: fixation occurs in wedge zones while exfoliation of layers releases K. The net result could be K release or fixation, depending on the dominant process (Olk et al., 1995). In this study laboratory experiments were designed to determine the effects of air drying, time of air drying, soil moisture potential and wetting-drying cycles on potassium fixation in some K-depleted soils of Azerbaijan province.

MATERIALS and METHODS

To investigate the effects of moisture conditions on K fixation in some soils of Azerbaijan province, seventeen points spread throughout the area were collected randomly. Each point was located at the common border of a cultivated soil (under cultivation of potato, sunflower and sugar beet for several decades) and a virgin soil. Composite soil samples were analyzed and their texture, pH, EC, calcium carbonate equivalent and organic carbon determined. Chemical extraction procedures [1 M ammonium acetate (AEK) and 1 M boiling nitric acid (NEK)] were evaluated for measuring the changes in soil K as a consequence of exhaustive cropping (Knudsen et al., 1982). Six soil samples were selected from among 17 locations where the amounts of boiling nitric acid extractable-K were considerably lower in cultivated soils compared to the adjacent non-cultivated soils. These soils (in three replications) received 0 and 250 mg K kg^{-1} (equivalent to the amount of depleted K) as a solution of KCl with sufficient volume to achieve field capacity (33 kPa) condition. The samples were incubated at constant temperature ($20\pm1^{\circ}$) for two days. The amounts of NH_4COONH_4-extractable K (labile K) were determined by Olk et al.(1995) procedure before and after air-drying of the soils. Solution K was measured by flame emission using flame photometer. Added K that was not recovered by NH_4^+ was considered to be fixed. Three soil samples with different amounts of K fixation were chosen from among six soil samples for subsequent studies. To determine the effect of the time of air-drying during the incubation period on potassium fixation, air-dying was done in three different times: 1) early days of incubation period (2 days after the beginning of incubation), 2) middle of incubation period (14 days after the beginning of incubation) and 3) near the end of incubation period (28 days after the beginning of incubation). K fixation was determined at the end of one month incubation period. To investigate the effect of soil matric potential on potassium fixation an experiment was carried out as follows: 10 g of air-dried soils were packed into small plastic barrels (one centimeter in height). Barrels were allowed to soak in solutions containing different concentrations of KCl (to add 0, 100, 200 and 400 mg K kg^{-1}) and small amounts of thymol in a desicator for 8 hours. Barrels were then equilibrated at either -30, -100 and -500 kPa in a pressure plate apparatus. After equilibration, the soils were covered with several layers of parafilm and incubated at 20±1° for three months. The magnitude of fixed K was determined after the end of incubation time. To specify the effect of wetting-drying cycles on K fixation, zero and 200 mg K kg^{-1} were added to the soils. The samples were incubated at the above conditions for two months. Zero, 1, 5, 10 and 20 cycles of wetting and drying were done during the incubation period. K fixation was determined at the end of incubation time. Analysis of variance and comparison of means (using Dunan`s test,*P*<0.01) were performed with SPSS.

RESULTS and DISCUSSION

Selected physical and chemical properties of the soils investigated are given in table 1.

Table 1. Some physical and chemical properties of the soils

No.	Texture	$pH_{1:1}$	$EC_{1:1}$ (dS m^{-1})	CCE (g kg^{-1})	OC (g kg^{-1})	AEK (mg kg^{-1})	NEK(mg kg^{-1})
1	S.C.L	7.9	2.1	91	10.1	145	420
2	S.L	7.0	1.1	169	2.1	240	272
3	L	8.8	1.9	190	5.8	390	746
4	L	8.2	0.97	101	5.1	350	1137
5	C.L	8.3	0.50	127	9.4	360	894
6	L	8.1	1.4	94	11.4	230	925

Effect of Moisture Condition before Extraction on K Fixation:

Potassium fixation occurred in all soils. The amounts of K fixed were from 37.5 to 97.5 mg kg^{-1} (67.9 mg kg^{-1} (27.2%), on average) and from 60 to 147.5 mg kg^{-1} (104.2 mg kg^{-1} (41.7%), on average) for moist and air-dry conditions, respectively (Fig. 1). Therefore, the magnitude of K fixation was significantly (*P*<0.001) increased (14.5%) after air-drying as reported by other workers (Foth and Ellis, 1988). As soil dries, labile K becomes more concentrated in a small volume of soil solution which increases the concentration gradient and subsequent potassium fixation.

Potassium fixation in air-dry condition correlated with clay content (r=0.965*). This is in disagreement with the finding of Murashkina et al. (2007). According to this result, as clay content increases 10 percent, potassium fixation increases 17 percent. This strong correlation may be attributed to little variation in clay mineral composition between the soils. Nevertheless, the regression between K fixation and clay content for moist condition was not significant. This lack of correlation could be explained by the presence of vermiculites which fix potassium in moist condition, but do not be limited to clay particles (Fig. 2).

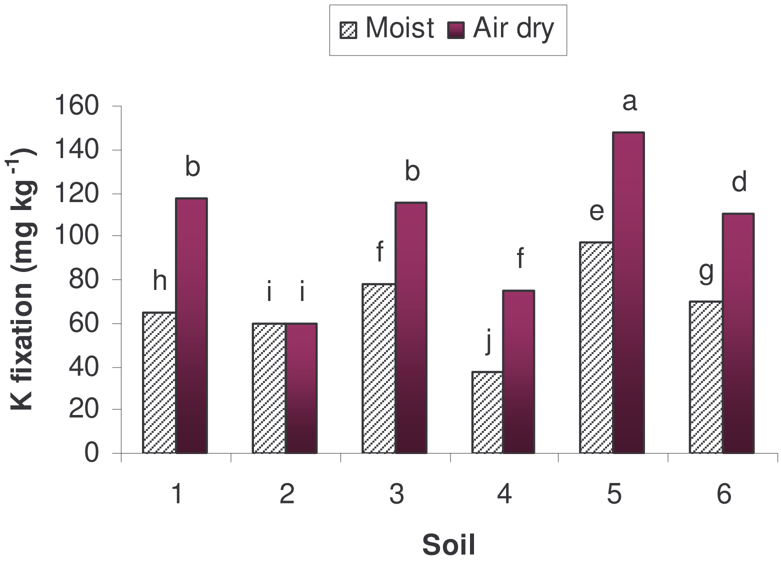

Fig. 1-Mean values of K fixation for moist and air dry conditions (P<0.01).

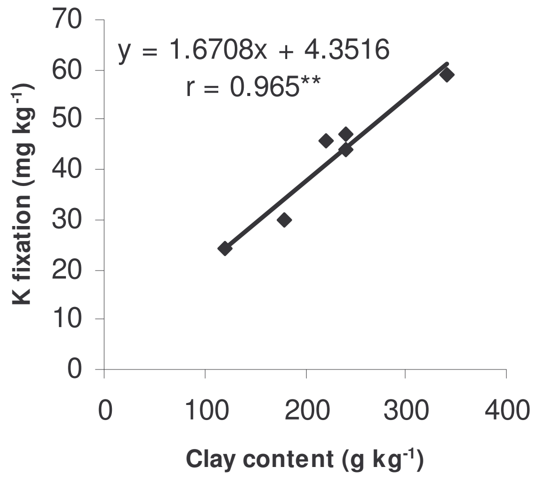

Fig. 2- Relation between K fixation and clay content.

Effect of the Time of Air Drying on K Fixation:

The amounts of K fixed after 2, 14 and 28 days of the beginning of incubation period were 10, 6.2 and 31.2 mg kg^{-1} (15.8 mg kg^{-1} on average) for soil 2; 57.5, 26.2 and 18.7 mg kg^{-1} (34.1 mg kg^{-1} on average) for soil 3; and 75.2, 72.1 and 53.5 mg kg^{-1}(66.9 mg kg^{-1} on average) for soil 5, respectively. In all soils, the magnitude of K fixation for three different times of air drying was in an order of (Fig. 3): early days of incubation (47.6 mg kg^{-1}) > middle of incubation (34.8 mg kg^{-1}) =near the end of incubation (34.5 mg kg^{-1}). Based on the above order, the magnitude of K fixation was greater when air drying was done in early days of incubation period. However, there was no difference between two other times of air drying ($P<0.01$). As noted before, two processes may occur during drying:1)K fixation in wedge zones and 2)K release while exfoliation of layers. It seems that the former mainly occurs in the first days of incubation and the latter mainly occurs in middle and near the end of incubation period.

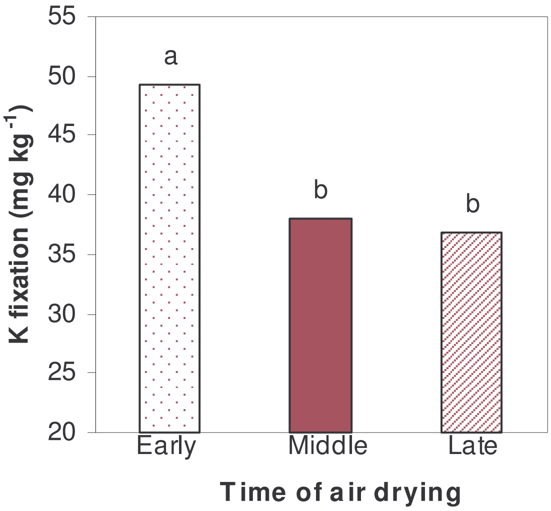

Fig. 3- Mean values of K fixation for three times of air drying (P<0.01).

Effect of Different Moisture Potentials on K Fixation:

As added K increases, K fixation increases linearly (Fig. 4). The data indicated that K fixation was greater at -100 kPa than at -30 and -500 kPa($P<0.001$). This may be explained as follows: lack of sufficient potassium concentration at -30 kPa causes low fixation. On the other hand, at -500 kPa, lack of sufficient moisture and presence of tortuous pathways retard K diffusion and subsequent K fixation (Fig. 5).

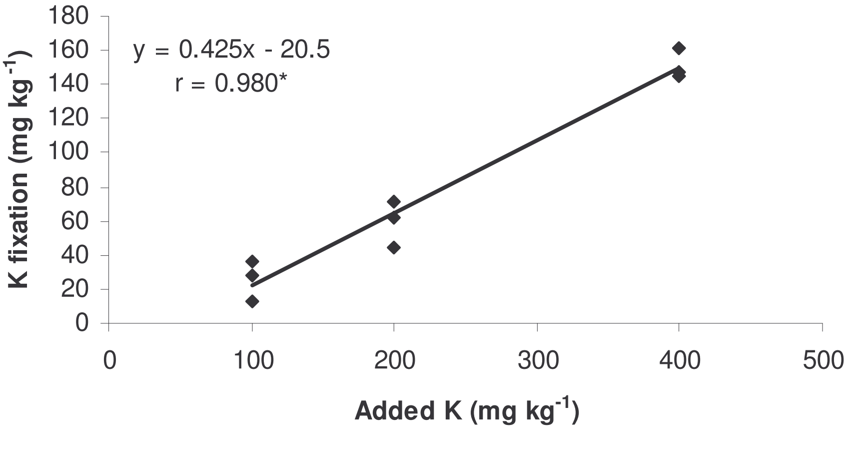

Fig. 4-Relation between K fixation and added K.

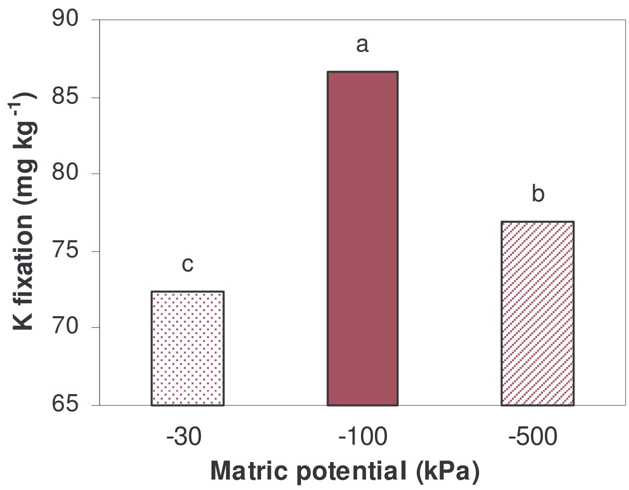

Fig. 5-Mean values of K fixation for different matric potentials (P<0.01).

Effect of Wetting-Drying Cycles on K Fixation:

Potassium fixation during two months of incubation was significantly ($P<0.001$) elevated with increasing the number of wetting-drying cycles (1, 5, 10 and 20 cycles). The amounts of K fixed by soils 2, 3 and 5 were 13, 20 and 35% (23% on average) more in the wetting-drying incubation (under 20 cycles) than in constant field capacity incubation, respectively (Fig. 6). Earlier reports propose that drying and rewetting cause a temporary exposure of new surfaces (Nevo and Hagin, 1966). Furthermore, air drying causes the movement of K ions from peripheral sites to deeper interlayer sites by an increased diffusion gradient (Sparks and Huang, 1985).

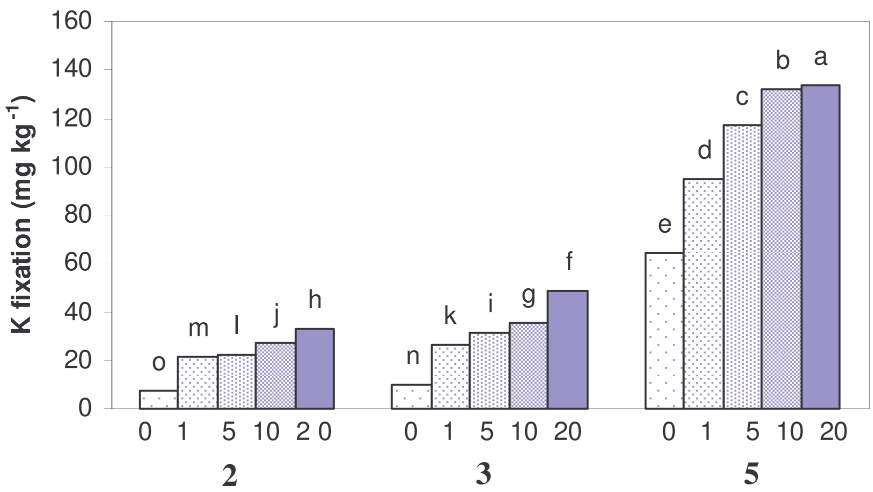

Fig. 6-Mean values of K fixation for different wetting-drying cycles (P<0.01).

Findings of this study reveal the significant effects of air drying, time of air drying, soil moisture potential and wetting-drying cycles on potassium fixation in some K-depleted soils of Azerbaijan province.

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Indigenous Knowledge and Approaches of Soil Fertility Management among Small Scale Farmers in Semi-Arid Areas of South Africa

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ABSTRACT

As is the case with many other countries in sub-Saharan Africa, crop production among small scale farmers, especially those in semi-arid regions of South Africa, is hampered by predominance of extreme climate (low, irregular & erratic rainfall), low inherent soil fertility and low use of mineral fertilizers. However, the small scale farmers have developed a range of indigenous knowledge and practices which have played a pivotal role in the management of soil fertility for sustaining crop productivity. This study sought to establish and document these strategies in four farming districts located in semi-arid areas of the country. It was found that farmers use locally adaptable and cost effective strategies including animal manure, ash from veld fire, agroforestry, fallow, *termitaria*, and earthworm castings to manage soil fertility. Some of these strategies were applied in specific niche locations and soils, times and crops. Furthermore, the farmers have developed local knowledge and criteria of classifying manure quality based on characteristics such as colour, wetness, presence of moulds and sand content that are used to make soil fertility management decisions. Analyses of samples of some of the organic resources used for soil fertility management confirmed their superior plant nutrient contents. The study concluded that research endeavors should recognize and build upon this wealth of indigenous knowledge and practices of soil fertility management by small scale farmers in these marginal environments of the country.

Keywords: Indigenous knowledge; nutrient management; semi-arid areas; small scale farmers; soil fertility, soil nutrients

INTRODUCTION

The sub-Saharan Africa is the only region of the world where per capita food production has remained stagnant for a long time (Sanchez, 2002). The majority of the resource poor people in this region reside in rural areas and agriculture is the principal economic sector upon which they depend for their livelihoods. Africa's food security is directly related to insufficient total food production. Low agricultural production results in low income, poor nutrition, low consumption, poor education, poor health and lack of empowerment (CIAT, TSBF & ICRAF, 2002). Although the low crop productivity is due to many factors, however, decline in soil fertility is considered to be one of the major factors for this situation (Smaling and Braun, 1996; Sanchez, et al., 1997). Soil fertility status is the foundation of cropping system productivity in the smallholder agriculture sector of Southern Africa (Snapp, 1998). Depletion of soil fertility often results in low yields which threatens household food security.

Consequently, household food security and nutrition issues are at the top of the planning agenda in many countries in sub-Saharan Africa (Babu, 2000).

Intensification of agricultural production is required to meet the food and income needs of the poor, and this cannot occur without investment in soil fertility (Laker, 1976). Although the use of mineral fertilizers is commonly applied to overcome nutrient depletion in soils, its use by the majority of small scale farmers in South Africa is still limited due various constraints (FSSA, 1997; Gerner and Harris, 1993). These farmers have some of the lowest rates of fertilizer use in the world (Smaling et al., 1997). Neither the majority of African farmers, nor African economies, can afford the financial resources needed to adequately fertilize their cropland with commercial fertilizers. In semi-arid areas that occupy about 23% of South Africa (Maraka, 1987) a combination of inadequate soil moisture and poor soil fertility presents one of the most challenging agricultural environments for crop production. Yet, soil fertility management has long been part of farming practice of local communities throughout the country. Small scale farmers have long recognized the need to enhance soil properties, including its structure, nutritional and water retention capabilities, by using soil amendments (Campbell et al., 1998). According to Edje, Semoka and Haule (1988), farmers in the region were generally organic in nature and used neither chemical fertilizers nor pesticides to support crop production. Using indigenous knowledge and experiences, farmers in the semi-arid environments have developed various practices of improving or maintaining soil fertility and systems (Mascarenhas, 2004).

Indigenous knowledge is unique to a particular culture and society and is the basis for local decision-making in agriculture and other activities (DST, 2005). Indigenous knowledge provides the basis for problem-solving strategies for local communities, especially the poor. Indigenous agricultural and environmental knowledge gained global recognition through the United Nations Conference on Environment and Development (UNCED) in 1992. Indigenous knowledge is an immensely valuable resource that provides insights on how to manage soils for sustainable crop production, and can contribute significantly to increased food availability household food security (Mascarenhas, 2004). Indigenous knowledge systems are being examined by academicians, development planners, and researchers as alternative approaches to development (World Bank, 1989). Given that the Green revolution aspects of agriculture have largely failed in many semi-arid areas of sub Saharan Africa, strengthening and building on the existing indigenous knowledge base through interfacing with modern technology may help reverse the declining trends in soil fertility.

The objective of this study was to document and quantify some of the indigenous knowledge and soil fertility management strategies used by small scale farmers in semi-arid areas of South Africa.

MATERIALS and METHODS

Location of Study Sites within the Semi-Arid Areas of South Africa

The study was conducted in four farming districts of the North West province in South Africa *viz* Mafikeng, Ditsobotla, Ganyesa and Taung all located in semi-arid regions. Semi-arid areas make about 23% of the country and it is estimated that approximately 14% of the population live in such areas. The areas are characterized by poor and erratic rainfall that ranges from 450-650 mm $annum^{-1}$. The probability of a 'normal' season occurring in these regions is 34-40% (Maraka, 1987). Although livestock production and cultivation of drought-resistant grain and fodder crops are emphasized, less-tolerant crops like maize are also dominant.

The soils in the study areas can broadly be categorized into two clusters consisting low infiltration rate, relatively high fertility clays and high infiltration rate, relatively low fertility sandy loams. The clays are either alluvial or derived from dolerite outcrops, while the sandy loams are derived primarily from granite. There are numerous intergradations within and between these broad types. The predominant soil profiles consist of an orthic topsoil with red apedal B-horizon which according to the local classification system belong to the Hutton form (Soil Classification Working Group, 1991).

Sampling Procedure and Data Collection

The study was collected during the summer (October 2006 to March 2007). A list of farmers involved in crop production in each of the study districts was obtained from the respective district offices of agriculture. A sample of 50 farmers in each area was randomly selected from the list. Visits were made to each farmer and a questionnaire was administered using a Participatory Rapid Appraisal (PRA) approach. The interview consisted of a combination of structured and open-ended questions. Information sought was related to the nature of indigenous knowledge, approaches used and their reasons, the source of knowledge and time of use. Physical observations were sued to verify the information.

Collection and Analysis of Soil Fertility Management Resources

In order to quantify the nutrient content and supplying capacity, samples of some resources used for soil fertility management (manure, ash, earthworm casts and termitaria) were collected from randomly selected farms visited during the study. The samples were analyzed for ash and organic matter content by igniting 5 g sample at $500^{o}C$ for 2 h (Okalebo et al., 1993). Ashed materials were extracted three times with 50% HCl and the dissolved material was analyzed for potassium and sodium by flame photometry; calcium, magnesium, iron, zinc and manganese by atomic absorption spectrometry. Nitrogen and phosphorous content of the materials were determined colorimetrically after digesting in sulphuric acid and hydrogen peroxide (IITA, 1979).

Data Analysis

Descriptive statistics for the socio-economic variables collected by questionnaires were analyzed using frequency counts, percentages, means and standard deviations using the SPSS software. A t-test and Least Significant Differences were used to compare means of the analytical values of the organic resources.

RESULTS AND DISCUSSION

Indicators of Soil Fertility Problems

Soil fertility problems were widely recognized by farmers in the study areas using various indicators (Table 1). Progressive decline in crop yields was associated more with soil fertility than rainfall. Most of the farmers could remember trends of yield declining in the monocropped cereals. Yellowing and other coloration of leaves during crop growth was also related to poor soil fertility although no specific nutrients would be indicated. Framers also clearly indicated that as a result of poor soil fertility, crop growth was stunted in most fields. Other notable indicators of low soil fertility included: lot of sand in the field, soil compaction and poor seedling emergence.

Animal Manure

Animal manure is of vital importance in maintaining soil fertility among small scale farmers in semi-arid areas of South Africa due to the low levels of use of inorganic fertilizer. The use of animal manure as a source of plant nutrients is a well-established practice especially among the small scale-farming sector in the study areas (Table 2). This is because keeping of livestock is an integral part of the households in semi-arid areas. It was clear from the responding farmers that they used manure because of its ability to improve soil fertility and crop yields (Table 3). Manure is used mainly as a source of N and P, which are nutrients that limit crop production in the majority of agricultural soils in South Africa. The main reason given by the respondent farmers for not using animal manure in managing soil fertility was that it encouraged weeds and pests. As a result, some of the farmers preferred to compost the manure before using it in order to kill the wed seed bank. Some of the farmers indicated that they did not have sufficient management knowledge to effectively use manure and feared that it could 'burn' their crops. In many of the areas, farmers were constrained from using manure because it was used as source of energy and decoration on the walls of their mud houses.

Another strategy of manure utilization involved the use of old cattle kraal sites for growing crops. Many farmers indicated that higher crop yields were obtained from those grown on previous kraal site compared with that grown away from the kraal site. Because of this, previous kraal sites are widely protected and used for crop production long after the kraal has been moved and/or abandoned. The better growth and yield of maize grown on previous kraal site was ascribed to improved soil structure which benefits the soil's water storage and nutrient availability.

Manure Quality

The quality of manure for soil fertility is determined by the chemical composition of the manure. High quality manure has low C:N ratio and releases nutrients rapidly during decomposition whereas low quality manure has a high C:N ratio and causes immobilization of nutrients during the early stages of decomposition. The study recognized that farmers in the study areas have different perceptions and indicators of manure quality (Table 4). Colour of manure, moisture content, texture and presence of moulds and un decomposed crop residues stood out as the most important indicators of manure quality. The farmer quality criteria were consistent across the study areas. A good quality manure was considered to be dark, moist, fine, with no sand, few moulds and has no crop residues. They also recognized that manure of high quality has a long residual effect and that it results in good soil moisture retention, crop germination and increased yields. Although it was established that the majority of farmers were aware that manure quality was affected by management and housing, there was very little being done to improve the quality. Consequently, the quality of most of the manure was lower compared to that from commercial farmers in the same areas (Table 5).

Generally, there was a large variation in the nutrient and sand contents of manure from the different households and villages. This was associated with differences in the management of the manure especially the housing, supplemental feeding and provision of bedding materials. The relatively high sand content of the manure samples was a concern as it reduced the quality of the manure.

Ash from Veld Fires

Fire has for a long time been considered a valuable tool in the management of savanna areas used for livestock and wildlife production in many parts of the semi-arid areas of South Africa (Tainton, 1988). The four main objectives for using fire in veld management include: to burn off unpalatable growth left over from the previous season; to stimulate growth during seasons when there is little young forage available on the veld; to destroy parasites, particularly ticks; and to control the encroachment of undesirable plants in the veld. Burning of the veld by farmers in the dry areas of South Africa is done in such a way that it coincides with the first spring rains because experience has shown that good spring rains accelerate regrowth of burnt veld (Teague et al., 1981; Trollope, 1978). Grass from regrowth of burnt veld has been shown to be more nutritious and acceptable to grazing animals than that which has been defoliated by grazing or mowing (Tainton et al., 1978). Small scale farmers in the study areas indicated the knowledge that veld which is burned early (June or July) recovers to an acceptable grazing stage no earlier (and indeed no later) than veld that is deliberately burned in August or early September just before or after the first spring rains.

In order to quantify the effect of veld fire on changes in nutrient concentration of a surface (0-5 cm) layer of a veld soil, we sampled soil from selected farms where the veld was subjected to burning before the rain. Table 6 shows that burning significantly increased the concentration of exchangeable Ca, Mg, K, Na, pH and extractable P but reduced the organic carbon and total N contents of the soil in both burnt plots. The amount of nutrients in the ash depended on the quantity of biomass available on the plot at the time of burning. Organic C and N were however significantly ($P < 0.05$) higher in unburnt than burnt plots. These results show that burning resulted in substantial increases of extractable P and exchangeable Ca, Mg, K and Na in the surface soil. The nutrients were bound in plant tissues before the fire and were therefore temporally unavailable for plant growth. The fire was considered to have provided a quick mechanism of releasing the nutrients locked up in the above ground biomass back to the soil surface (Stock and Lewis, 1986). Because of the increased concentration of nutrients and the raised pH in the surface layers of the soil, it may be possible that growth and productivity of grass in the veld will respond to burning through improved nutrient uptake.

Agroforestry

Agro forestry is a land-use system that integrates the production of woody perennials (trees and/or shrubs) with agricultural crops (food, fodder, fibre crops) with or without livestock simultaneously, sequentially, zonally or in relay on the same unit of land (Young, 1988). In parts of the semi-arid areas of South Africa, farmers have since time in memorial known, utilised the agroforestry potential of indigenous *Acacia* spp. trees in their landscape for crop production.

Acacia erioloba also known as Mpatsaka (Sotho), Mokala (Tswana), Kameeldoring (Afrikaans), Umwhohlo (Ndebele), Moghlo (Sepedi) and Camel Thorn (English) is an indigenous leguminous tree of the dry savanna environments of Southern Africa including Namibia, Angola, Zimbabwe, Botswana, South-western Zambia and South Africa (Smit, 1999). *A. erioloba* is found mostly on deep sandy soils of the semi-arid areas where it occurs in open savanna or on alluvial soils along dry river beds. The tree is evergreen to semi-deciduous and can grow up to 20 m tall with a wide spreading crown. Although not normally used for human food, *A. erioloba* trees provide many valuable products including fuel wood, wood for building, thorny branches for fencing, proteinaceous forage from its pods and shade for domestic livestock and people. Farmers generally recognize that crops grow better in the soil under *A. erioloba* than in areas outside the trees' influence. Consequently, the farmers protect the trees and cultivate crops under their canopies.

To further investigate the nutrient cycling by *A. erioloba* trees, we measured the concentration of nutrients in soils collected from under and beyond canopies of *A. erioloba* trees in two common local agroforestry practices in the study areas. Paired soil samples taken under and beyond *A. erioloba* tree canopies showed that there was a significantly higher ($P<0.05$) concentration of N, P, Ca, Mg, Zn and Mn in soils collected from under *A. erioloba* canopies compared with those collected beyond the canopies (Table 7). The nutrient concentrations were consistently higher in soil from trees that were located in grazing land than croplands. Except for Ca, the concentrations of all other nutrients were significantly higher ($P<0.05$) in soil from under *A. erioloba* canopies than in that from beyond. Soil pH was significantly lower ($P<0.05$) under than beyond tree canopies. The study concluded that the presence of *A. erioloba* trees improved the fertility of soils under the tree canopies in the agroforestry practices studied. The source of increased nutrients under *A. erioloba* trees was attributed to leaf fall, the organic matter added to the soil from grass and cattle dung, and urine from domestic livestock. This was consistent with reports of the ability of similar tree species (e.g. *Acacia albida*) to influence soil nutrient concentration, growth and yields of crops documented elsewhere on the continent (Gerakis and Tsangarakis, 1970; Weil and Mughogho, 1993; Buresh and Tian, 1998).

Fallow

Fallow is a cropland that is left without crops for periods ranging from one season to several years. There can be several reasons for fallowing. In the study, the number of farmers' fields which laid fallow were identified and visited. The proportion of small scale cropping land that had fallow is shown in Table 8. The farmers were asked the reasons for leaving the land fallow and the significance of the fallow (Table 9). The average land under fallow in the study areas was 31%. The main reason given as to why farmers had stopped cultivating was: Land tenure system; Lack of finance; Soil fertility management; Low & erratic rainfall; Lack of tractors & implements and High input costs. Some of the grass species that dominated the fallow fields included *Tagetes minuta, Sporobolus africanus, Eragrostis lehmanniana, Cynodon dactylon, Hyparrhenia hirts, Chenopodium carinatum,* and *Richardia brasiliensis*. There were Acacia bushes in most of the fields which the farmers said were kept to fasten the regeneration of soil fertility. The fallow periods ranged from 0-3 years (57%) and >3 years (43%). Overtime, it was suggested that the fallow period would increase the organic matter content of the soil; improve the soil structure including water holding capacity; recycle and trap nutrients from sub-soil; protect the soil from erosion and eliminate weeds, pests and diseases specific to the cropping system.

Termite Mound Soil-Termitaria

Many landscapes of South Africa, especially grazing lands (*veldt*), are dotted with small to large soil mounds constructed by termites. These are more often termed as "white ants", "termite mounds" or “anti hills”. The termites are closely associated with soil since they: ingest soil as source of food, construct nests and mounds, and break down organic materials/forage which they utilize as food sources. Consequently, the termite mound soil has superior properties for plant growth and yields. This unique attribute of mound soils has been recognized by many farmers in South Africa’s semi-arid areas as an agronomic resource for replenishing soil nutrients, as well as other parts of the Southern African Region (Mapfumo and Giller, 2001; Scoones et al., 1996).

In these areas, some of the mounds are broken down and the mound soil is spread over the other parts of the field as a soil amendment and fertilizer. The rate of application was quite variable and could be estimated at between 0.25 and 7 t ha^{-1} by individual farmers with a wide variation between farms. Crops such as water melon, butternut, green pepper, spinach and sweet sorghum cane which require good water supply and high nutrient levels are almost exclusively grown on termite mounds.

Farmers indicated that they used termitaria as an insurance against crop failure in the case when there is drought at critical stage in the development of the crop. Some farmers indicated that they applied the termitaria in small dollop holes close to the maize plant as is done with inorganic fertilizer. The rates of application were quite variable and could be from 0.25 to 10 t ha^{-1} on individual farms. In many instances, farmers traveled into the grazing area and bring back termite mound soil in a cart and mix it with the poor sandy soils to improve their fertility. It was claimed that this significantly increases the fertility and strength of the soil, and made it hold water better and longer. Availability of labour was the major constraint for using termitaria for soil fertility management.

Earthworm Casts,

Earthworms constitute a large proportion of soil mesofauna and are extremely important because they are involved in many key processes in the soil. Earthworms play a vital role in nutrient cycling through organic matter decomposition (Lee, 1985), and have the potential to significantly improve soil physical, chemical & biological properties (Lavelle et al., 1998). Through their feeding and burrowing, earthworms can improve soil aggregate stability, incorporate surface organic matter, lime and fertilizers, create macro porosity, increase soil microbial activity and enhance nutrient availability in the soil (Lee, 1985). Because of these key roles in soil ecosystem functioning, earthworm numbers and biomass have been used as indicators of soil quality and sustainable land management practices (Karlen et al., 1997). Apart from the population and size of earthworms, the species composition is also important as it influences the efficient functioning of earthworms in an ecosystem to which they are well adapted.

In respect of the chemical fertility, farmers in the study area were aware that worm-cast soil is superior to the surrounding non-casted soil and so claimed that this was responsible for the improved growth, in both field crops and veld grass, in areas where substantial amounts of casts were deposited by worms. Our analysis of the nutrient content of dry earthworm casts and corresponding non-casted soil confirmed the farmers claim (Table 10). It was therefore not surprising to note that some farmers in the study area used the casts like dressings of fertilizer by placing them in dollop holes close to the plant roots. The farmers also indicated that they preferred to use fresh casts as opposed to old casts since the former were easy to break and produced better results.

CONCLUSIONS

This study has shown small scale farmers in the study areas effectively utilize indigenous knowledge and available resources for soil fertility management in the semi-arid areas of South Africa. Indications are that, as the intensification of small-scale farming becomes higher due to the large numbers of emerging farmers in South Africa, these strategies and knowledge base will continue to play an important role as a way of maintaining soil fertility for sustainable crop productivity. Evidence from this study suggests that there are scientific basis for these approaches. It is therefore concluded that indigenous knowledge is vital in the technology adoption process and needs to be strengthened in the study areas.

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Table 1

Farmers' indicators of soil fertility problems

Rank	Indicator	Mafikeng	Ditsobotla	Ganyesa	Taung	Mean±SD
1	Low crop yields	73±5	81±4	78±2	75±5	77.8±6
2	Yellowing of leaves	68±4	61±3	65±2	67±5	62.3±3
3	Stunted growth of crops	61±3	60±6	59±4	64±8	61.0±2
4	Uneven growth of plants in field	56±2	57±6	60±4	53±2	56.5±3
5	Soil compaction	51±6	50±4	57±5	55±6	53.3±5
6	Poor soil structure	43±4	46±8	45±2	48±3	45.5±6
7	Lot of sand in the field	39±5	42±2	39±4	41±5	39.8±3
8	Poor emergence & stand	26±2	31±7	28±8	33±4	29.5±1
9	Disease and pest proliferation	11±6	19±3	22±7	15±6	16.5±4

Values are means ± SD, n=50

Table 2

Proportion of farmers using animal manure for soil fertility management in the study districts

District	Used manure	Did not use manure
Mafikeng	69	31
Ditsobotla	84	16
Ganyesa	77	23
Taung	81	19
Mean±SD	77.8±6.5	22.3±3.4

Table 3

Reasons given by farmers for using and not using manure for soil fertility management (in order of decreasing importance)

Rank	Using manure	Not using manure
1	Improves soil conditions	Encourages weed infest station in fields
2	Improves soil nutrients	Lack of labour
3	Increases soil moisture holding	Not enough manure (too few animals)
4	Better crop yields	Encourages worms and insects
5	No money to buy fertilizer	Bad smell
6	Health crops	Can not afford to purchase
7		Prefer fertilizers
8		Burns crops
9		Lack of knowledge in manure management
10		Alternative use as energy and decoration

Table 4

Manure quality indicators recognized by farmers in the study areas (in order of importance)

District	Quality indicators and criteria
Mafikeng	Presence of moulds; Moisture content; Presence of cow dung clods; Presence of crop residues; Compactness of manure; Manure odour.
Ditsobotla	Colour; Sand content; Compactness; Moisture; Presence of moulds; Cow dung clods; Presence of crop residues; Weight;.
Ganyesa	Colour; Texture of manure; Sand content; Odour; Cow dung clods
Taung	Moisture content; Colour; Presence of sand; Presence of moulds; Presence of cow dung clods; Compactness.

Table 5

Quality characteristics of cattle manure samples collected from selected farmers' fields in the study districts

District	Nutrient content (%) N	P	K	S	Moisture content (%)	Organic carbon (%)	Sand content (%)	C:N ratio
Mafikeng	1.15±0.92 (0.62-2.3)	0.19±.07 (0.05-0.31	0.63±.55 (0.27-2.01)	0.08±.02 (0.02-0.16)	9.7±4.6 (6.3-15.4)	17.6±3.2 (12.1-23.3)	52.6±6.1 (34.2-58.3)	15:1
Ditsobotla	0.98±1.01 (0.86-2.7)	0.25±.12 (0.03-0.34)	0.91±.83 (0.42-1.89)	0.23±.06 (0.16-0.45)	11.3±3.5 (7.1-14.8)	19.3±2.1 (14.2-24.1)	56.1±4.4 (39.2-61.5)	19:1
Ganyesa	1.22±2.01 (0.77-3.2)	0.13±.03 (0.06-0.27)	1.02±.37 (0.36-1.25)	0.14±.04 (0.08-0.29)	12.5±1.1 (8.4-14.6)	14.2±2.8 (11.4-18.6)	49.5±5.2 (42.4-54.7)	11:1
Taung	0.83±1.87 (0.56-2.5)	0.07±.15 (0.05-0.16)	1.17±..21 (0.60-1.63)	0.32±.07 (0.11-0.38)	15.7±2.7 (9.5-17.5)	16.5±3.3 (10.3-21.4)	39.4±10.3 (28.6-52.8)	19:1
Mean±SD	*1.02±.22*	*0.16±08*	*0.93±23*	*0.19±11*	*12.3±2.5*	*17.4±2.9*	*49.4±7.2*	
T-test	*	*	**	*	*	* *	**	**

Values are means ±SD; Numbers in parenthesis are ranges; **p*<0.05; ***p*<0.001

Table 6

Effect of burning frequency on soil nutrient pools in the 0-5 cm layer of a veld soil measured before (BB) and after (AB) burning of biomass at a site in Ganyesa district. The control treatment was not burnt

Soil Nutrient	Sampling time		Burning frequency No burning	Every year	Every 3 years	Mean	SE
Ca (mg kg^{-1})	BB		453±26 426±17	487±43 455	25		
	AB		-	528±24 559±31	544 16		
		Mean		477	523	500	
Mg (mg kg^{-1})	BB		81±5	93±3	99±10	91	7.0
	AB		-	107±5	111±7	109	2.0
		Mean		100	105		
K (mg kg^{-1})	BB		308±62 212±38	215±45 245	45		
	AB		-	285±49 301±51	294		
		Mean		249	259		
Na (mg kg^{-1})	BB		53±6	38±2	38±6	44	8.0
	AB		-	88±3	60±3	74	14
		Mean		63	49		
P (mg kg^{-1})	BB		9.9±2	6.5±.7	10.2±3	8.9	1.6
	AB		-	11.9±3	13.0±1.912.5	12.5	
		Mean		9.2	11.6		
Org. C	BB		1.36±.2 0.9±.13	1.14±.111.15	0.16		
(g kg^{-1})	AB		- 0.68±.08	0.93±.060.9	0.13		
		Mean		0.88	1.04		
Total N	BB		2.5±.3	1.67±.1 2.17±.2	2.11 0.3	(mg	kg^{-1})
	AB		- 1.04±.09	1.73±.331.39	0.21		
		Mean		1.34	1.95		
pH	BB		5.48±.065.52±.04	5.76±.025.57			
	AB		-	6.08±.236.28±.296.23			
		Mean		5.9	5.89		

Values are means of four determinations ! standard deviation
SE, standard error of the mean

Table 7

Soil nutrients and pH at different canopy locations of the *Acacia erioloba* tress in the selected study dry areas

Canopy Location	Total N (%)	Available P (mg kg^{-1})	Exchangeable cations (mg kg^{-1})					
			K	Ca	Mg	Zn	Mn	pH
Mafikeng (n=13)								
Beneath canopy	0.14±.01	15.1±.4.3	191.1±32	805.7±97	351±.102	3.9±.24	44.8±.17	6.2±.08
Beyond canopy	0.08±..02	11.5±.6.4	115.6±77	768.8±105	359±.84	2.2±.43	30.3±.9	6.5±.03
t-test	ns	*	**	ns	ns	*	*	*
Ditsobotla (n=27)								
Beneath canopy	0.24±.01	19.6±.2.3	213.1±21	904±47	332±67	2.9±.04	31.8±.83	6.6±.4
Beyond canopy	0.11±..01	11.5±.4.1	175.6±47	834.8±105	299±74	1.6±.33	29.6±.92	6.8±.3
t-test	*	*	*	ns	ns	**	ns	ns
Ganyesa (n=11)								
Beneath canopy	0.74±.05	26.4±.1.3	186±32	756±27	322±67	4.1±.34	56.7±.13	6.8±.3
Beyond canopy	0.38±.03	19.3±.3.4	132±77	742±76	289±84	3.6±.41	48.9±.66	6.2±.1
t-test	*	*	*	ns	*	*	*	*
Taung (n=21)								
Beneath canopy	0.51±.03	17.4±.2.3	224±32	645±47	210±42	2.7±.24	29±3.7	6.0±.8
Beyond canopy	0.23±.02	13.6±.1.4	193±27	578±12	184±.17	2.4±.43	21±1.8	6.3±..3
t-test	*	*	*	*	*	ns	*	*

Values are means ±SD; **p*<0.05; ns, not significant

Table 8

Proportion of farmers in the study districts with fallow on their cropping land

District	Average Farm size (ha)	Fallow (%)
Mafikeng	3.2	20
	(2-8)	
Ditsobotla	4.1	37
	(4-9)	
Ganyesa	3.5	41
	(1-5)	
Taung	7.6	26
	(3-15)	
Mean±SD	4.6±2.3	31±9.7

Numbers in brackets are ranges

Table 9

Reasons for leaving land fallow

Reason	Mafikeng	Ditsobotla	Ganyesa	Taung	Mean±SD
Lack of finance	73	77	69	75	73.5±3
Lack of tractors & implements	61	67	57	71	63.0±6
Low & erratic rainfall	68	64	55	65	63.0±4
Soil fertility management	63	56	50	46	53.8±7
Land tenure system	58	54	53	55	55.3±2
High input costs	50	48	45	53	49.3±4
Lack of farming knowledge	34	30	28	31	30.8±5
Lack of training & ext service	22	24	16	11	18.3±6

Table 10

Nutrient content of dry earthworm casts and corresponding non-casted surface soil from selected farmers' fields in the study areas

Material	pH-H_2O	Organic C (g 100 g^{-1})	Bray 1-P (mg kg^{-1})	Total N (g 100 g^{-1})	Exchangeable cations (mg kg^{-1})				
					Ca	Mg	K	Zn	Mn
Mafikeng (n=17)									
Worm-cast	6.4±0.2	1.47±0.32	17.4±5.2	1.25±0.12	890±65	185±31	537±78	8.3±0.3	19.4±2.3
Non-casted soil	5.7±0.4	0.89±0.03	4.1±1.5	0.22±0.03	603±37	97±18	288±56	1.7±0.1	8.6±0.8
T-test	*	*	**	*	*	*	*	**	**
Ditsobotla (n=11)									
Worm-cast	7.3±0.1	1.66±0.24	26.4±3.2	1.66±0.28	786±69	145±09	613±84	7.1±0.8	23.4±1.3
Non-casted soil	6.5±0.3	0.93±0.11	11.1±0.4	0.42±0.13	503±27	107±26	248±50	2.2±0.2	6.6±0.5
T-test	*	*	**	*	*	*	*	**	**
Ganyesa (n=9)									
Worm-cast	6.8±0.2	1.58±0.13	32.7±6.2	1.06±0.48	943±71	223±24	638±97	9.5±0.7	18.7±3.3
Non-casted soil	6.1±0.3	0.67±0.03	13.6±0.5	0.32±0.22	669±27	100±08	433±26	5.8±0.1	7.7±0.2
T-test	*	*	**	*	*	*	*	**	**
Taung (n=21)									
Worm-cast	6.7±0.5	1.92±0.22	21.4±4.2	1.27±0.31	708±49	143±23	501±88	6.1±0.4	21.4±1.3
Non-casted soil	5.9±0.2	0.77±0.13	9.9±1.1	0.66±0.16	567±58	121±12	312±46	3.9±0.1	12.6±0.5
T-test	*	*	**	*	*	*	*	**	**

Values are means ±SD, n=15; *$p<0.05$; **$p<0.001$

Effects of Composted Tobacco Waste and Farmyard Manure on Some Soil Physical Properties and Lettuce Yield

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ABSTRACT
This research was held in Agriculture Faculty of Ege University Menemen Investigation and Practise Farmyard. Tobacco waste gathered from cigarette industry were composted and applied to the soil together with farmyard manure. lettuce (*Lactuca sativa L. var. capitata*) was grown as test plant. No mineral fertilizers or pestisides were applied. The effects of composted tobacco wastes and farmyard manures on soil physical properties and lettuce yield were investigated. All application rates provided increasing effects on soil's physical properties at different percentages. Also, similar effects were determined for lettuce yield. Maximum yield was 102,7 ton ha^{-1} at the plots where % 100 composted tobacco wastes were applied. The results show that there are positive effects on all soil properties by the applications of the studied material; (thus) and this organic material source shouldn't be destroyed. Enviroment is also kept clean.
Keywords: Composted tobacco waste, farmyard manure, lettuce (*Lactuca sativa L. var. Capitata*), physical properties of soil

INTRODUCTION

Soil needs nutrients as every ecosystem. It has been known that organic matter which is a nutrient for soil organisms have got positive effects on soil's physical, chemical and biological properties. Protection of soil's natural efficiency is related to its content of organic matter .

Addition of organic materials to soil provides improving soil microorganism activity and increase aggreagation. As protection of soil and increasing plant productions belong to amelioration and protection of soil structure. Water movement, root development, water in soil and soil air are related to soil structure (Darwish et al., 1995).

Farmyard manure (FYM) which is the most useful organic manure as an organic matter is provided from various plant and animal wastes. Due to the fact that FYM is an expensive material and not found enough, other organic materials can be used instead of FYM to improve soil properties. Incorporation of these wastes to the soil is important to evaluate them as organic matter and also to prevent enviromental pollution (Kütük et al., 1995; Okur and Delibacak, 1996; Hati et al., 2006).

The Head Lettuce (Lactuca sativa L. var. capitata) is a main group of lettuce. Production of lettuces are 21 000 000 ton in 1 000 000 ha area in the world. In Turkey, there are 18 700 ha production area and approximetly 360 000 ton lettuce production and 60 000 tons of these productions are head lettuce (Anonymous, 2002).

In our country, lettuces are generally being grown in Ege, Marmara, and Mediterranen regions. They can be grown on not only sandy soils but also on clay soils. Due to the fact that acid soils aren't suitable for lettuces, they souldn't be grown in a soil which has less than 5,6 pH.

The aim of current work was to compare effects of composted tobacco waste (CTW) and FYM on physical properties of soil and lettuce yield. Moreover, if using tobacco waste has got positive effects, this material which has rich organic matter content won't be destroyed and will be stopped before it harms the enviroment and ensured to soils as organic matter.

MATERIAL and METHODS

Experimental Design

This research was carried out in Agriculture Faculty of Ege University Menemen Investigation and Practise Farmyard. The experiment was conducted a randomized block design with 3 replications and 6 treatments. Each plot had an area of 6 m^2 (3 x 2 m) and 30 plants. CTW were applied to the soil together with FYM. Lettuce (*Lactuca sativa L. var. capitata*) was grown as a test plant.

Tobacco wastes gathered from Izmir Kemalpaşa Socotab factory were composed and applied on parcels with composted FYM gathered from Agriculture Faculty of Ege University Menemen Investigation and Practise Farmyard. The effects of these materials on soil's physical properties and the yield of grown lettuce was investigated.

The experiment was conducted on loam texture soil, 7.52 pH with low alkaline reaction. Total soluble salt concentration was determined that without salt at a level of 0,085 %. Soil $CaCO_3$ amount was classified as average calcic (calcareous) at a level of 5.38 %. Other soil samples amounts are analyzed as 2,53 % organic matter and 17,3 mg $100g^{-1}$ cation exchange capacity are given in Table 1. Also some physical and chemical properties of CTW and FYM are given in Table 2 and 3, respectively.

Table 1. Some physical and chemical properties of experimental soil.

Soil Texture	Loam	Agregation (%)	29.11
Sand (%)	44.26	Structure stability Ind. (%)	10.88
Cilt (%)	44.13	Available Water (%)	9.7
Clay (%)	11.61	Total Porosity (%)	50.44
pH	7.52	Total-N (%)	0.129
Total Soluble Salt (%)	0.085	Available P (mg kg^{-1})	8.88
$CaCO_3$ (%)	5.38	Available K (mg kg^{-1})	447.29
Organic Matter (%)	2.53	Available Ca (mg kg^{-1})	2752.5
Bulk Density (g cm^{-3})	1.28	Available Mg (mg kg^{-1})	529.46
Particle Density (g cm^{-3})	2.58	Available Na (mg kg^{-1})	217.92
CEC (me 100 g^{-1})	17.3		

Table 2. Some physical and chemical properties of CTW

60 C° Water Content (%)	7.19	CaCO3 (%)	2.43
105 C° Water Content (%)	29.79	Total N (%)	2.18
pH	9.17	Available P (mg kg^{-1})	4900
EC (dS m^{-1})	40	Total K (mg kg^{-1})	26880
Organic Matter (%)	65.3	Total Na (mg kg^{-1})	2552
C/N	17.37	Total Ca (mg kg^{-1})	12870
Organic C (%)	37.87	Total Mg (mg kg^{-1})	6552

Table 3. Some physical and chemical properties of FYM

60 C° Water Content (%)	5.50	CaCO3 (%)	2.09
105 C° Water Content (%)	25.13	Total N (%)	2.35
pH	8.70	Available P (mg kg^{-1})	5800
EC (dS m^{-1})	38.5	Total K (mg kg^{-1})	30720
Organic Matter (%)	67.2	Total Na (mg kg^{-1})	2816
C/N	16.5	Total Ca (mg kg^{-1})	15210
Organic C (%)	39	Total Mg (mg kg^{-1})	6152

CTW was mixed with FYM at various ratios. Treatments were as follows:

Soil without fertilization (control)

% 25 FYM+ % 75 CTW

% 50 FYM+ % 50 CTW

% 100 FYM

% 100 CTW

%75 FYM+ % 25 CTW

At the beginning of the experiment, according to the results of the analyzed soil nutrients, 50 t ha^{-1} manure was applied to the soil because lettuce plant needs 50-100 kg N ha^{-1} (IFA, 1991). Except this, no mineral fertilizers and pesticides were applied. 540 lettuce seedlings were planted in I. vegetation period, on 1st September, 2005 by furrow watering and then watering method was changed as irrigation. First harvest was on the 11th November, 2005. During the II. vegatation period, again 540 lettuce plants were planted on 25th November, 2005 by watering and they were not watered until the end of harvest because of rainy season. II. period lettuce harvest was performed on the 14 th April, 2006.

Soil Sampling and Analyses

During the experiment, undisturbed and disturbed soil samples (0-20 cm) were taken from the center of each plot after one week of planting and before 1st and 2nd harvest. The samples were air-dried and sieved using 2 and 8 mm sieves. Undisturbed soil samples were taken by using a steel cylinder of 100 cm^3 volume (5 cm in diameter, and 5 cm in height). Bulk density and field capacity were determined from these soil samples. Wilting point was determined using disturbed soil samples sieved through a 2 mm sieve. Dry bulk density was measured by the core method (Blake and Hartge, 1986), particle density was determined by pycnometer method (Soil Survey Staff, 1951), particle size distribution was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962), nonaggregated silt+clay and total silt+clay were determined by using A.S.T.M. Soil testing cylinder (Soil Survey

Staff, 1972), structure stability index and aggregation percentage were calculated by formula (Soil Survey Staff, 1951). Total salt, OM concentration, calcium carbonate and pH were all determined according to Page et al., (1982). Available P was determined by the Mo blue method in a $NaHCO_3$ extract (Olsen et al., 1954). Available Ca, Mg, K and Na were analyzed with 1 N NH_4OAc extract method. Ca, K and Na were determined by flame emission spectrometry and Mg was determined by flame atomic absorption spectrometry (AAS) (Kacar, 1994). Some properties (total salt, OM concentration, calcium carbonate, pH, total N, P, K, Ca and Mg) of the experimental soil, CTW and FYM were also determined according to Page et al. (1982). Total porosity was calculated using bulk density and particle density values. Water retention capacity at -33kPa (field capacity) was determined in undisturbed soil samples and at -1500 kPa (permanent wilting point) in disturbed samples using a ceramic plate apparatus. Available Water Content (AWC) was calculated as the difference between water retained at -33kPa and at -1500 kPa (Klute, 1986).

Statistical Analyses

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 9 (SPSS, 1999). One-way analysis of variance was performed to determine the effects of CTW and FYM on some physical properties of Typic Xerofluvent soil, and Duncan test was used to find if differences in the treatments were significant at $P \leq 0.05$.

RESULTS

Effects of CTW and FYM on some physical properties of Typic xreofluvent soil and lettuce yield are given in Table 4.

Table 4. Effects of CTW and FYM on some physical properties of soil and lettuce yield.

Treatments	1st.sampling (After one week of planting) 1st.vegetation	2nd.sampling 1st.vegetation harvest	3rd.sampling 2nd.vegetation harvest
	Bulk Density (g cm^{-3})		
Control	1,28 A	1,26 A	1,28 A
25% M+75% CTW	1,25 AB	1,19 B	1,23 B
50%M+ 50% CTW	1,25 B	1,20 B	1,24 B
100%M	1,24 B	1,21 B	1,23 B
100%CTW	1,23 B	1,19 B	1,23 B
75%M+25%CTW	1,24 B	1,21 B	1,24 B

Means for CTW and FYM treatments applied in soil in the same period followed by the same letter are not significantly different (Duncan; $P \leq 0.05$)

Table 4. Effects of CTW and FYM on some physical properties of soil and lettuce yield (go on).

Treatments	1st.sampling (After one week of planting) 1st.vegetation	2nd.sampling 1st.vegetation harvest	3rd.sampling 2nd.vegetation harvest
	Particle Density(g cm^{-3})		
Control	2,58 A	2,64 A	2,61 A
25% M+75% CTW	2,57 A	2,58 B	2,58 AB
50%M+ 50% CTW	2,57 A	2,59 B	2,58 AB
100%M	2,57 A	2,57 B	2,57 B
100%CTW	2,57 A	2,56 B	2,56 B
75%M+25%CTW	2,57 A	2,58 B	2,56 B
	Total Porosity (%)		
Control	50,44 B	52,14 A	50,95 A
25% M+75% CTW	51,16 AB	53,93 A	52,18 A
50%M+ 50% CTW	51,48 AB	53,40 A	51,86 A
100%M	51,74 A	52,90 A	52,06 A
100%CTW	52,13 A	53,63 A	51,74 A
75%M+25%CTW	51,75 A	53,09 A	51,42 A
	Field Capacity (%)		
Control	18,73 C	18,65 B	18,27 B
25% M+75% CTW	21,38 A	21,68 A	20,33 A
50%M+ 50% CTW	20,30 B	20,97 A	20,07 A
100%M	20,83 AB	21,61 A	20,58 A
100%CTW	21,23 AB	21,90 A	20,69 A
75%M+25%CTW	21,35 A	21,14 A	20,43 A
	Wilting Point (%)		
Control	9,03 C	8,86 B	8,63 B
25% M+75% CTW	10,16 A	10,30 A	9,76 A
50%M+ 50% CTW	9,63 B	9,93 A	9,80 A
100%M	9,86 AB	10,23 A	9,90 A
100%CTW	10,06 AB	10,46 A	9,93 A
75%M+25%CTW	10,10 AB	10,00 A	9,86 A
	Available Water (%)		
Control	9,70 C	9,79 B	9,63 B
25% M+75% CTW	11,22 A	11,38 A	10,56 AB
50%M+ 50% CTW	10,67 B	11,04 A	10,27 AB
100%M	10,96 AB	11,37 A	10,68 AB
100%CTW	11,16 AB	11,44 A	10,76 A
75%M+25%CTW	11,25 A	11,14 A	10,56 AB
	Structure Stability Index		
Control	10,88 B	12,38 C	11,72 B
25% M+75% CTW	15,54 A	16,38 A	15,05 A
50%M+ 50% CTW	16,21 A	16,38 A	14,38 A
100%M	15,54 A	15,72 AB	14,38 A
100%CTW	14,88 A	14,38 B	15,05 A
75%M+25%CTW	14,21 A	15,72 AB	14,38 A
	Average Yield (t ha^{-1})		
	1st. vegetation	2nd. vegetation	Total
Control	50,7 B	31,0 C	81,7 B
25% M+75% CTW	60,8 A	38,0 AB	98,8 A
50%M+ 50% CTW	59,9 A	37,7 AB	97,6 A
100%M	60,9 A	37,4 AB	98,4 A
100%CTW	62,7 A	39,9 A	102,7 A
75%M+25%CTW	60,1 A	36,0 B	96,2 A

Means for CTW and FYM treatments applied in soil in the same period followed by the same letter are not significantly different (Duncan; $P \leq 0.05$)

DISCUSSION

Bulk density was decreased positively with increasing organic matter sources such as tobacco waste and manure. According to Hartge and Horne (1999), bulk density values are generally 1,67-1,19 g cm^{-3} for sandy soils, 1,96-1,19 g cm^{-3} for loam soils, 1,53-1,19 g cm^{-3} for silty soils, 1,32-0,92 g cm^{-3} for clay soils and 0,48-0,12 g cm^{-3} for organic soils.

High OM content of CTW and FYM decreased particle density of soil. OM, which weighs much less than an equal volume of mineral solids, decrease the particle density of soils. Some surface soils with high OM contents may exhibit particle density values of 2.4 g cm^{-3} (Tan, 1996).

Soil total porosity values were analyzed an measured as approximetly 50,44 % in experimental area soils. Depending on application of CTW and FYM, soil porosity increased. Especially after first harvest, total porosity of soil samples increased at a level of 7 % by 25 % FYM+ 75 % CTW treatment. Aggelides and Londra (2000) also found that organic compost application considerably improved soil physical properties by increasing soil porosity and changing distribution of pore sizes in loamy and clay textured soils.

Soil aggregation was significantly affected by the treatments. The highest value of soil agregation was found for 50 % FYM+ 50 % CTW treatment and 25 % FYM+ 75 % CTW treatment. Because of the fact that there is a strong correlation between structure stability and contents of high organic matter in CTW and FYM, application of these materials with different doses have increased soil aggregation and soil structure stability index. Aoyama et al. (1999) noted that manure and a combination of manure with N, P, and K fertilizers caused significant increases in the formation of water stable aggregates and soil organic matter; whereas, only N, P and K fertilizers application did not affect these soil properties.

The effect of organic treatments on water holding capacity was analyzed significantly. The CTW treatment was resulted in the highest values in both field capacity and available water capacity. Available water amount in soils related to soil is related to soil texture situation, structure and organic matter (Saatçı, 1975).

After application of CTW and manure, statistical differences on lettuce yield values were found. The highest yield was in 1st vegetation plants by application of 100 % CTW by 62,7 t ha^{-1}.

Due to the fact that II. vegetation period was winter season (Especially in December, January and February have been very cold) yield of Lettuce were decreased. Total yield of lettuce was determined on parcels which applicated % 100 CTW by 102,7 t ha^{-1}.

CONCLUSION

Application of CTW provided positive effects on soil physical properties at different percentages. It can be said that CTW is a soil conditioner. CTW is a nutrient and OM source, which increases the yield. These results demonstrate the importance of the incorporation of CTW in soil as an alternative organic amendment for improving soil properties in dryland and especially in Mediterranean soils, which are characterized by low organic matter content.

It is recommended that 50 t ha-1 CTW can be added for improving soil properties of Typic Xerofluvent soil, which are characterized by low OM content. In order to maintain and improve soil quality, further studies must be performed to confirm the positive long-term effects of CTW.

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Modeling Leaf Production and Senescence in Chickpea

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ABSTRACT

Quantitative information regarding leaf area development in chickpea (*Cicer arietinum* L.) is scarce. Data from four field experiments with a range of treatments including genotype, sowing date and plant density across 4 location-season combinations were analyzed to quantify main effects of temperature, photoperiod and plant population density on plant leaf area in chickpea. All experiments were conducted under well-watered conditions. Maximum rate of main stem node development was 0.72 nodes d^{-1}. Cardinal temperatures for node appearance were found as 6.0, 22.2 and 31.0 ^oC for base, optimum and ceiling temperatures, respectively. Plant density had no effect on cardinal temperatures for leaf appearance and phyllochron. Leaf senescence on the main stem started when the main stem had about 12 nodes and proceeded at a rate of 1.67% per each day increase in physiological day (a day with non-limiting temperature and photoperiod). Leaf production per plant versus main stem node number occurred in two phases; phase 1 when plant leaf number increased with a slower and density-independent rate (3 leaves per node), and phase 2 with a higher and density-dependent rate of leaf production (8-15 leaves per node). A close relationship was found between the fraction of senesced leaves per plant and the same fraction on the main stem. The average leaf size per plant increased from 4 cm^2 when there were 10 nodes on the main stem and stabilized at 10.8 cm^2 when there were 21 nodes on the main stem. Plant density and sowing date did not affect leaf size. Plant leaf area was also predictable directly from main stem node number. The relationships found in this study can be used in simulation models of chickpea.

Keyword: Leaf area development; Leaf senescence; Node appearance; Temperature; Model.

INTRODUCTION

Crop simulation models that predict plant growth, water use and yield are being used to understand the response of crops to the dynamics of climate-plant-water systems, to evaluate physiological traits for genetic yield improvement and to help make decisions that optimize use of available resources (Boote et al., 1996; Sinclair and Seligman, 1996; Hammer, 1998; Soltani et al., 2000; Soltani et al., 2001).

The ability to predict leaf area development is crucial for crop simulation models. Prediction of leaf area index is required to estimate interception of solar radiation and biomass production. It is also an important determinant of the partitioning of evapotranspiration between evaporation and transpiration.

Leaf area development involves the appearance of new leaves, expansion of newly emerged leaves and the senescence of old leaves (Hofstra et al., 1977; Ranganathan et al., 2001). Temperature can affect plant leaf area via its effects on rate of leaf appearance, on the rate and duration of individual leaf expansion, and on leaf senescence (Craufurd et al., 1997). Temperature and photoperiod can also regulate leaf area via their effects on the duration of leaf production period (Hammer et al., 1993). A range of approaches exist: from those dealing with appearance, expansion and senescence of individual leaves (e.g., Hofstra et al., 1977) to those predicting leaf area at the whole plant or crop level (e.g., Sinclair, 1984). Some others take a middle approach (e.g., Robertson et al., 2002).

There are no reports in the literature analyzing leaf area development in chickpea (*Cicer arietinum* L.) for the purpose of crop modeling except for the results of a 1-year study with only 2 treatments (sowing date) presented by Robertson et al. (2002). Furthermore, the effect of plant density has not been reported. Therefore, the objectives of this research were (1) to develop functional relationships to quantify main effects of temperature, photoperiod and plant population density on plant leaf area in chickpea, and (2) to evaluate the stability of the relationships and their parameters across different environmental conditions and agronomic practices. The present paper is a part of a comprehensive study (Soltani et al., 2004; Soltani et al., 2005; Soltani et al., 2006abc) aimed at improving chickpea modeling capabilities (Soltani et al., 1999; Robertson et al., 2002).

MATERIALS and METHODS

Field Experiments

Four experiments were conducted in the field to gather the data required for this study. Three of the four experiments were carried out at the Gorgan University of Agricultural Sciences Research Farm, Gorgan (36^o 85’ N, 54^o 27’ E and 100 m asl), and one experiment was conducted at Gonbad Agricultural Research Station, Gonbad (34^o 21’ N, 55^o 10’ E and 37 m asl), both in Iran. The soil was a deep silty loam (fine-silty, mixed, active, thermic, Typic Calcixerolls) at both sites. Some details about the experiments and weather conditions during the experiments are given in Table 1 and 2, respectively.

All the experiments were conducted under well-watered conditions. The plots were irrigated after 60-mm cumulative pan (class A) evaporation and irrigation amount was based on soil moisture depletion. Therefore, there was no effect of flooding or water deficit stresses. In all the experiments weeds were hand-controlled and if necessary appropriate chemicals were applied against *Ascochyta* blight (*Ascochyta rabiei*), fusarium diseases (*Fusarium* spp.), podworm (*Heliothis armiger*), leaf miner (*Liriomyza congesta*) and *Paramacella* spp., so the effect of diseases and pests were minimal. All experiments were over-sown at the correct spacing and thinned to desired density after emergence.

In the first experiment (Exp. 1) four chickpea cultivars (Beauvanij, 90-96c, Hashem and Jam – *kabuli* type) were sown at 11 sowing dates from December 2001 to August 2003 (details in Soltani et al., 2006b). For this study, main stem node number and total number of leaves per plant were measured on two cultivars (90-96c and Hashem) on only two sowing dates of 18 May and 17 June 2002.

The second experiment (Exp. 2) was conducted in Gonbad. The experimental design was single split plot with sowing dates in the main plot and plant densities in the sub plot, replicated four times. Plot size was 1.75 m (7 rows) by 7.0 m, row spacing of 25 cm and different intra-row spacings to achieve population densities of 15, 30, 45 and 60 plants m^{-2}. Chickpea cultivar was Hashem, a local cultivar.

The third (Exp. 3) and the fourth (Exp. 4) experiments were again conducted in Gorgan with the treatments as in Exp. 2, but the experimental design was a factorial arrangement of treatments based on a randomized complete block with four replicates. In Exp. 3, plot sizes were 6 m long with a row spacing of 25cm and included 20, 12, 10 and 8 rows for plant densities of 15, 30, 45 and 60 plants m^{-2}, respectively. In Exp. 4, plot sizes were 7 m long with inter-row spacing of 30 cm and included 16, 10, 8 and 7 rows for plant densities of 15, 30, 45 and 60 plants m^{-2}, respectively.

The chosen sowing dates in the field experiments do not necessarily reflect common practices, but were selected to create different growth environments with a range of temperature, photoperiod and solar radiation. December is the most common sowing date for chickpea in Gorgan and Gonad, but sometimes sowing might occur in late November, January and February.

Measurements

In all experiments, stages of development of emergence, flowering, first pod, beginning of seed growth (first-seed), first-maturity and full-maturity were recorded every 1-2 days (Fehr and Caviness, 1977; Soltani et al., 2006b).

Measurements regarding leaf production and senescence were the total number of nodes on main stem, the number of nodes on main stem with senesced leaves, the total plant leaf number (green + senesced), the number of primary, secondary and tertiary branches, and plant leaf area. Not all characteristics could be measured in all experiments. The measurements taken in each experiment and the frequency of the measurements are presented in Table 1. In Exp. 1 and 2, the measurements were conducted on 10 tagged plants, but in other experiments the measurements were done on 10 plants separated from bigger samples including 20-30 plants. Mean of the 10 plants measured was considered as an observation.

A leaf was counted when its leaflets were unfolded and a green leaf was considered a leaf with >50% green area. The number of fallen leaves was counted based on visible leaf scars. Leaf area was measured using an electronic planimeter (delta T devices).

In all experiments, daily maximum and minimum temperatures, sunshine hours and rainfall were measured at a standard weather station located a few meters (Gorgan) to a few hundered meters

(Gonbad) from the experimental units. Solar radiation was calculated from sunshine hours and extraterrestrial radiation. Photoperiod for each day was calculated from latitude and calendar day and included allowance for civil twilight when solar angle ≥ –4 ^{o} (Keisling, 1982; Soltani et al., 2006b).

Analysis

The data were analyzed based on functional and allometric relationships between environmental variables (mainly temperature and photperiod) and plant leaf area determinants. The appropriate relationships were captured from published work (Sinclair, 1984; Hammer et al., 1993; Robertson et al., 2002) when available or were developed when necessary. When there was no appropriate relationship, it was found by (1) examining scatter plots between the two considered variables, (2) fitting of promising equations to the data, and (3) selecting the most appropriate equation based on its simplicity and statistics such as coefficient of determination (R^2) and root mean square of deviations (RMSD). When possible, one equation was fitted to all data or a part of data rather than just a given treatment.

Physiological day per calendar day (PD_t) was calculated as (Soltani et al., 2006b):

$$PD_t = f(T)\ f(PP) \qquad (1)$$

where $f(T)$ is the temperature function and $f(PP)$ the photoperiod function. The $f(T)$ and $f(PP)$ were computed using dent-like and quadratic functions, respectively, as indicated by soltani et al. (2006b). From sowing to emergence and from flowering to maturity, the value of $f\ (PP)$ was fixed at 1, indicating no effect of photoperiod for these stages (Soltani et al., 2006b). Cumulative values of PD_t were used in present study. For example, starting at Stage 1, physiological days are accumulated until a threshold is reached. At this time, Stage 2 is predicted to occur. The threshold value is the physiological day requirement of Stage 1 to 2, that is, the minimum number of days from Stage 1 to 2 under optimal conditions for development.

Thermal day was also calculated from Eq. (1) by fixing $f\ (PP)$ at 1 for all phenological stages. Thermal day is a normalized form of thermal time.

RESULTS and DISCUSSION

Node Appearance and Senescence on Main Stem

The changes of main stem node number versus time, cumulative thermal day and physiological day were describable using a non-linear, segmented regression model. The segmented model consists of two intersecting lines, a sloping line for the linear increase in node number and a horizontal line, which determines maximum node number on the main stem (Fig. 1):

$$y = a + bx \qquad if \quad x < x_o \qquad (2)$$

$$y = a + b\,x_o \qquad if \quad x \geq x_o$$

where y is the main stem node number, x the time, thermal day or physiological day after sowing, a the intercept with the vertical axis ($x = 0$), b the rate of linear increase in node number (node d^{-1}), x_o the time of cessation of the linear increase in node number and $a + bx_o$ represents maximum node number on main stem. Eq. (2) was used to obtain estimates of the time of cessation of effective node production on main stem (TLG) and the maximum number of nodes on main stem. Using physiological day resulted in more stable estimates of x_o (data not shown). The sudden cessation of node production is a simplified but a satisfactory approximation of the data (Fig. 1). In some cases, a few nodes were produced after TLG, but in many cases no node was produced after the time. The calendar time from emergence to TLG was found and considered as an effective period of node production (ENPP). The linear increase in main stem node number versus thermal time has been reported in chickpea (Robertson et al., 2002), fababean (Dennett et al., 1979; Turpin et al., 2002), soybean (Sinclair, 1984) and pigeonpea (Ranganathan et al., 2001). However, Stutzel and Aufhammer (1991) reported that in fababean a quadratic equation best described this increase.

Estimates of TLG were stable for each experiment (Table 3). They averaged 39.8 physiological days for Exp. 1, 37.5 for Exp. 2, 36.4 for Exp. 3 and 38.0 for Exp. 4. Average across all experiments TLG was 38.0 physiological days, which was mid way between flowering and first-pod stages (Soltani et al., 2006b). Node production after TLG mainly depends on the carbon and nitrogen balance within the plant and the availability of extra assimilates for leaf production on the main stem. At each sowing date, the difference between cultivars in Exp. 1 and between plant densities in other experiments for ENPP was not considerable, but the difference was considerable between sowing dates (Table 3). Similarly, difference between cultivars in Exp. 1 and between plant densities in other experiments for maximum node number was not considerable. There was a significant correlation coefficient ($r = 0.44$; $P = 0.05$) between ENPP and maximum node number. The small difference between plant densities at each sowing date for TLG, ENPP and maximum node number is due to accelerated phenological development with increase in plant density.

For each treatment of Exp. 1 to 4, the rate of node appearance on main stem (d^{-1}) was calculated by dividing maximum node number by ENPP. Then, cardinal temperatures for leaf appearance were obtained by fitting the below model to data of node appearance rate versus mean temperature during ENPP (Fig. 2):

$$
\begin{aligned}
y &= 0 && \text{if} \quad T \le T_b \text{ or } T \ge T_c \\
y &= (T - T_b)/(T_o - T_b)\, R_{max} && \text{if} \quad T_b < T \le T_o \\
y &= (T_c - T)/(T_c - T_o)\, R_{max} && \text{if} \quad T_o < T < T_c
\end{aligned}
\qquad (3)
$$

where y is node appearance rate, T the temperature, T_b the base temperature, T_o the optimum temperature, T_c the ceiling temperature and R_{max} the maximum rate of node appearance at optimum temperature. A total of 94% of variation in node appearance rate was explained by Eq. (3). The estimated cardinal temperatures were 6.0, 22.2 and 31.0 ^oC for base, optimum and ceiling temperatures, respectively. According to Eq. (3) and its parameter estimates, phyllochron (thermal time period between emergence of successive leaves) in chickpea cv. Hashem is 23.8 ^oCd. This value has been reported as 42 ^oCd for cowpea (Craufurd et al., 1997), 55.6 ^oCd for soybean (Sinclair, 1984), 71.4 ^oCd for vigna (Pengelly et al., 1999), 56 ^oC d for peanut (Leong and Ong, 1983), 100 ^oCd for mungbean (Robertson et al., 2002), 31.5 ^oCd for pigeonpea (Ranganathan et al., 2001) and 54 ^oCd for fababean (Turpin et al., 2002). For chickpea the phyllochron number of 46 ^oCd has been reported by Robertson et al. (2002), which is significantly higher than the value found here. This difference is a result of higher base temperature in the current study (6 vs. 0^oC). However, the data of Robertson et al. (2002) indicate an R_{max} value of 0.65 node d^{-1} which is comparable with 0.73 node d^{-1} found here.

The base temperature of 6 ^oC is significantly different from a base temperature of 0 ^oC for leaf appearance reported for chickpea (Siddique and Sedgley, 1986), base temperature of 4.5 ^oC for emergence (Soltani et al., 2006a) and base temperature of 0 ^oC for development rate (Soltani et al., 2006b) reported for the same cultivar. The optimum temperature of 22 ^oC falls within the optimum temperature range of 20-29 ^oC for emergence (Soltani et al., 2006a) and 21-32 ^oC for development rate (Soltani et al., 2006b). The ceiling temperature of 31 ^oC is significantly lower than ceiling temperature of 40 ^oC verified for emergence rate and development rate towards flowering (Soltani et al., 2006ab).

No significant effect of plant density on cardinal temperatures and phyllochron, and similarity of the cultivars with respect to node production on main stem found in the present study (Table 3, Fig. 2), is in agreement with previous studies in fababean (Stutzel and Aufhammer, 1991; Turpin et al., 2002) and pigeonpea (Ranganathan et al., 2001).

The availability of assimilates can affect node appearance and leaf production (Stutzel and Aufhammer, 1991). The decline in node appearance rate with temperature increase over 22 ^oC might be due to limitation of assimilates for leaf growth.

Based on the results presented here, node production on the main stem can be simulated as influenced by temperature, photoperiod and assimilate availability. Photoperiod and temperature determine the time available for node production (TLG and ENPP) and the rate of node production during this period is determined by temperature. Further studies are needed to reveal the genotypic differences for cardinal temperatures of leaf appearance and R_{max}.

Examination of the fraction of senesced nodes on main stem (ratio of senesced to total nodes) versus thermal day and physiological day in Exp. 2, 3 and 4 indicated that the fraction follows the below model (Fig. 3):

$$y = 0 \qquad if \quad x \le x_o \qquad (4)$$
$$y = b(x - x_o) \qquad if \quad x > x_o$$

where y is the fraction of senesced node on main stem, x the thermal day or physiological day, x_o the time when senescence starts on main stem (^oCd or physiological day) and b the rate of increase in the fraction per unit increase in thermal day or physiological day. While there were some differences between sowing dates and densities with respect to b and x_o, these differences were not significant based on 99% confidence intervals of the parameters in each experiment (Table 4). Using physiological day compared to thermal day resulted in higher R^2, but the differences were not great. Leaf senescence on the main stem started after 15 physiological days (equivalent to 36 thermal days, 756 ^oCd and about 12 nodes on the main stem) and proceeded by 1.67% per each day increase in physiological day. Roberson et al. (2002) in their chickpea model (APSIM-chickpea) assumed that leaf senescence on main stem occurs as a linear function of thermal time after flowering and each node senesces after accumulation of 47 ^oCd.

Leaf Production and Senescence Per Plant

Leaf production and senescence per plant has been related to leaf production and senescence on the main stem (Leong and Ong, 1983; Hammer et al., 1993; Ranganathan et al., 2001; Robertson et al., 2002). Evaluation of data from Exp. 1 and 2 showed that leaf production per plant follows a 2-phase segmented model, which separates leaf production per plant into distinct phases; phase 1 when plant leaf number increases at a slower rate and phase 2 with a higher rate of leaf production per plant. Mathematically, the model may be expressed as (Fig. 4a):

$$y = b_1 x \qquad if \quad x \leq x_o \qquad (5)$$
$$y = b_1 x_o + b_2(x - x_o) \qquad if \quad x > x_o$$

where y is the total (green and senesced) number of leaves per plant, x the number of nodes on main stem, x_o the turning point between the two phases of leaf production, b_1 the rate of increase in plant leaf number in phase 1, and b_2 the same as b_1 for phase 2 of leaf production.

Parameter estimates of Eq. (5) for Exp. 2 are presented in Table 5. Leaf production rate in phase 1 was 3 leaves per node across plant densities. Plant density did not affect rate of leaf production in phase 1 probably because the plants are small and competition is still minimal. In phase 2, rate of leaf production ranged between 8 and 15 leaves per node (Table 5). This rate decreased linearly with increase in plant density up to 41 plants m^{-2} and then stabilized (Fig. 4b).

In Exp. 1, Eq. (5) also adequately described changes of plant leaf number versus main stem node number (data not shown). There was no significant difference between cultivars in each sowing date and estimates of x_o, b_1 and b_2 were 15.1, 2.12 and 7.82 for sowing on 8 May 2002 and 14.7, 1.62 and 2.24 for sowing on 17 June 2002. There was no significant difference between sowing dates in Exp. 1 and between Exp. 1 and 2 for x_o, b_1 and b_2 based on their 99% confidence intervals, except for b_2 at sowing date of 17 June 2002. The significantly lower value of b_2 for this sowing date was likely due to high temperatures (Table 2) and shortage of assimilates for leaf growth.

The increased rate of leaf production in phase 2 was related to the appearance of primary and secondary branches (Fig. 5). The branching pattern was similar for the 3 sowing dates and 4 sowing densities in Exp. 2; production of primary branches began after appearance of 2 nodes on the main stem and stopped when 3 primary branches had emerged. Then, after the appearance of 13-16 nodes on main stem, a second phase of branching started with a faster rate of appearance of primary and secondary branches. The number of secondary branches was approximately twice of the number of primary branches. Density had a major effect on branching; probably via assimilate availability, although the difference between plant densities of 45 and 60 was not significant. The number of tertiary branches was negligible.

In chickpea, a similar pattern of plant leaf production versus main stem node number has been reported by Robertson et al. (2002), but they assumed that in phase 1 plant leaf number was equal to main stem node number (3 here). They reported a leaf production rate of 13.4 leaves per node for phase 2 of leaf production at a plant density of 28 plants m^{-2}, which is comparable to the rate (11.0) found here for density of 30 plants m^{-2} (Table 5).

The fraction of senesced leaves per plant (ratio of senesced to total leaves) versus the same fraction on main stem in Exp. 2 also followed Eq. (5) (Fig. 6). The fraction of senesced leaves per plant increased 0.57% per each percent increase in fraction of senesced leaves on main stem until the fraction was less than or equal to 0.67 on main stem (equivalent to 55 physiological days, mid-way between beginning of seed growth (45) and R7 (67); Soltani et al., 2006b). After this, each percent increase in the fraction of senesced leaves on main stem resulted in a 1.88% increase in the fraction of senesced leaves per plant. There was no significant difference between sowing dates and densities (Fig. 6). In APSIM-chickpea, the rate of leaf senescence per plant is related to the number of senesced leaves on main stem (Robertson et al., 2002); senescence of each leaf on main stem results in senescence of 2% of plant leaves, obtained by calibration of the model against the observed post-flowering decline in leaf area. In pigeonpea, a close relationship has been reported between the fraction of senesced leaves per plant and the number of senesced leaves on main stem (Ranganathan et al., 2001).

Leaf Size

In this study, leaf size was not measured on the main stem and branches separately. Therefore, average leaf size was calculated by dividing green leaf area of the plant by the number of green leaves present as these two variables were measured in Exp. 3. The average leaf size increased from 4 cm^2 when there were 10 nodes on main stem and stabilized at 10.8 cm^2 when there was 21 nodes on main stem (Fig. 7). Plant density did not affect leaf size. This pattern of change in leaf size contradicts the pattern reported by Robertson et al. (2002) for chickpea, where leaf size declined after reaching its maximum on 15^{th} main stem node. However, leaf size of 4 cm^2 for 10^{th} main stem node and maximum leaf size of 11 cm^2 in both studies are similar. It has been reported that there is little genetic variation for leaf size in pigeonpea (Ranganathan et al., 2001). Leaf size in soybean and cowpea has been found to stabilize at about the 5th to 10th node (Hofstra et al., 1977; Littleton et al., 1979; Sinclair, 1984).

Plant Leaf Area

Potential plant leaf area can be predicted from the product of leaf appearance and senescence and the maximum size of leaves based on equations and parameter estimates shown in previous sections. However, some researchers have used allometric relationships between plastochron index (main stem node number) and total number of green leaves and plant leaf area to predict plant leaf area (Hesketh et al., 1973; Sivakumar, 1978; Sinclair, 1984; Hammer et al., 1993; Pengelly et al., 1999).

In Exp. 3, the total number of green leaves and plant leaf area were measured simultaneously. There was a simple, linear relationship between plant leaf area and the number of green leaves with an R^2 value of 0.91 (Fig. 8). The slope of the linear regression model was 10.5 cm^{-2} per leaf, indicating a total average leaf size. Sivakumar (1978) and Ogbuehi and Brandle (1981) reported a linear relationship for soybeans between the count of number of leaflets per plant and the plant leaf area.

Hammer et al. (1993) used a simple, power function to predict plant leaf area from plant leaf number in grain sorghum. The form of the function is:

$$y = x^{b} \qquad (6)$$

where y is the plant leaf area, x the plant leaf number (here, main stem node number) and b the coefficient of the equation. This function gave successful prediction of plant leaf area as a function of plastochron index in vigna (*Vigna trilobata* L.) (Pengelly et al., 1999).

The results of fitting the Eq. (6) to plant leaf area data versus main stem node number for each plant density treatment are presented in Fig. 9 (Exp. 4) and Table 6 (combined data of Exp. 3 and 4). When fitting the function, plant leaf area and main stem data up to 38 physiological days, when main stem node number approached its maximum (Table 3) were used. Plant leaf area ranged between 0 to 3000 cm^2 per plant. The function gave reasonable fits with R^2 values of 0.77 to 0.94. The coefficient of the function also indicated highly significant relationship with plant density (Fig. 9b). The effect of plant density on estimation of plant leaf area from main stem node number has not been reported before.

Therefore, plant leaf area in chickpea under well-watered conditions can be predicted using function (6) and its coefficient calculated from plant density. Based on this function plant leaf area can be predicted up to cessation of effective node production on main stem. For the senescence phase other approaches should be used. Sinclair (1986) and Sinclair et al. (2003) simulated plant leaf area in senescence phase based on nitrogen remobilisation from leaves.

CONCLUSIONS

Overall, the results of our study indicated that temperature and photoperiod modulate time available for leaf growth. However, the rate of node appearance on the main stem is controlled by temperature alone. Cardinal temperatures for node appearance were 6.0 ^oC for base, 22.2 ^oC for optimum and 31.0 ^oC for ceiling temperatures. Plant density had no significant effect on node appearance rate, cardinal temperatures for leaf appearance or phyllochron. Leaf production and senescence per plant were closely related to leaf production and senescence on the main stem. The average leaf size stabilized at 10.8 cm^2 when there were 21 nodes on the main stem. Plant density and sowing date had no effect on leaf size. Potential plant leaf area can be predicted from the product of leaf appearance and senescence and the maximum size of leaves, or directly from the number of nodes on main stem. The relationships presented in this study describe leaf production and senescence under well-watered conditions. They reflect the effects of carbon and nitrogen availability and remobilization under these conditions. They do not account for the effects of shortage of carbon, nitrogen or water on leaf development. Other relationships are required to predict these effects.

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Table 1.Summary of cultural practices and measurements in field experiments.

	Exp. 1	Exp. 2	Exp. 3	Exp. 4
Location	Gorgan	Gonbad	Gorgan	Gorgan
Growing season	2001-2002	2002-2003	2002-2003	2003-2004
Previous culture	Lettuce	Wheat	Fallow	Canola
Soil	Silty loam	Silty loam	Silty loam	Silty loam
Initial conditions	Electrical conductivity of 0.80 dS m^{-1}; pH of 7.6; organic carbon of 1.18%; total nitrogen of 0.15%; available P (Olsen method) of 5.1 mg kg^{-1}; available K (NH4AcO method) of 402 mg kg^{-1}	Electrical conductivity of 0.73 dS m^{-1}; pH of 8.1; organic carbon of 1.20%; total nitrogen of 0.12%; available P of 9.5 mg kg^{-1}; available K of 640 mg kg^{-1}	Electrical conductivity of 0.80 dS m^{-1}; pH of 7.7; organic carbon of 1.31%; total nitrogen of 0.13%; available P of 4.0 mg kg^{-1}; available K of 380 mg kg^{-1}	Electrical conductivity of 0.51 dS m^{-1}; pH of 7.9; organic carbon of 1.22%; total nitrogen of 0.14%; available P of 5.1 mg kg^{-1}; available K of 380 mg kg^{-1}
Fertilization (at sowing)	150 kg ha^{-1} triple super phosphate and 20 kg ha^{-1} urea	150 kg ha^{-1} ammonium phosphate	150 kg ha^{-1} triple super phosphate and 50 kg ha^{-1} urea	150 kg ha^{-1} triple super phosphate and 20 kg ha^{-1} urea
Treatments	2 sowing dates (18 May 02 and 17 June 02) × 2 cultivars (90-90c and Hashem)	3 sowing dates (7 Dec. 02, 23 Jan. 03 and 6 Mar. 03) × 4 plant densities (15, 30, 45 and 60)	3 sowing dates (5 Jan. 03, 6 Mar. 03 and 28 Apr. 03) × 4 plant densities (15, 30, 45 and 60)	3 sowing dates (6 Dec. 03, 20 Jan. 04 and 21 Mar. 04) × 4 plant densities (15, 30, 45 and 60)
Measurements [a]	Phenology, MSNN, TPLN	Phenology, MSNN, MSSNN, TPLN, TPSLN, BN	Phenology, MSNN, MSSNN, TGLN, PLA	Phenology, MSNN, MSSNN, PLA
Frequency of measurements	Until first-pod or first-seed; every 10 days	Whole season; every 7 to 10 days	Whole season; every 5 to 20 days	Whole season; every 5 to 10 days

[a] MSNN, the main stem node number; MSSNN, the number of nodes on main stem with senesced leaf; TPLN, the total plant leaf number; TPSLN, the total number of senesced leaves per plant; TGLN, the total number of green leaves per plant; BN, the number of primary, secondary and tertiary branches; PLA, the plant leaf area.

Table 2. Monthly means of solar radiation (SRAD, MJ m^{-2} d^{-1}), maximum temperature (TMAX, ^{o}C), minimum temperature (TMIN, ^{o}C) and monthly total rainfall (RAIN, mm) during the four field experiments. Locations and years of the experiments are indicated in Table 1.

	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Exp. 1									
SRAD	–	–	–	–	–	18.8	23.3	24.2	17.0
TMAX	–	–	–	–	–	25.0	31.6	34.7	32.8
TMIN	–	–	–	–	–	14.4	19.7	23.9	29.3
RAIN	–	–	–	–	–	23.5	38.1	4.5	44.6
Exp. 2									
SRAD	8.4	8.6	6.2	11.7	13.0	23.3	22.8	18.8	–
TMAX	11.6	13.8	12.9	13.6	18.8	27.0	31.9	33.9	–
TMIN	1.8	3.7	4.6	5.6	9.1	12.6	17.6	23.2	–
RAIN	54.6	28.3	56.5	90.1	71.7	39.4	8.5	5.4	–
Exp. 3									
SRAD	–	8.2	8.3	11.0	12.2	23.1	20.9	16.1	22.1
TMAX	–	13.8	13.1	12.8	18.8	26.2	29.1	31.0	33.9
TMIN	–	3.4	4.5	5.6	9.4	13.3	18.4	23.1	22.8
RAIN	–	11.8	2.2	110.9	56.2	50.9	53.8	6.2	30.0
Exp. 4									
SRAD	7.4	8.9	11.4	12.8	17.5	19.2	21.7	21.9	–
TMAX	15.1	15.3	16.8	18.3	20.8	26.9	31.6	30.4	–
TMIN	6.7	4.9	5.2	7.9	9.2	15.5	20.6	21.3	–
RAIN	56.4	51.4	10.7	101.8	52.6	30.4	14.5	73.8	–

Table 3. Time of cessation of node production on main stem (TLG, physiological day), duration of effective node production (ENPP, day), and maximum node number on main stem (MXN) for the field experiments.

	Exp. 1				*Exp. 2*		
Treatment	TLG	ENPP	MXN	Treatment	TLG	ENPP	MXN
8 May 02				7 Dec. 02			
90-96c	42.6	51	21.7	15	37.8	135	31.9
Hashem	39.5	47	21.0	30	35.1	133	30.0
17 Jun. 02				45	34.7	132	30.3
90-96c	36.1	45	19.8	60	34.5	132	30.1
Hashem	41.0	52	20.4	23 Jan. 03			
				15	39.2	110	28.1
				30	38.3	109	27.7
				45	38.0	109	27.1
				60	38.3	109	27.1
				6 Mar. 03			
				15	40.0	74	28.0
				30	38.5	73	26.4
				45	38.2	73	27.4
				60	37.0	71	25.5
	Exp. 3				*Exp. 4*		
5 Jan. 03				6 Dec. 03			
15	35.6	116	34.5	15	36.8	128	38.4
30	34.6	115	33.1	30	36.4	127	37.5
45	35.1	115	33.0	45	36.8	128	36.7
60	33.8	114	31.6	60	35.8	126	36.2
6 Mar. 03				20 Jan. 04			
15	38.2	71	33.3	15	39.6	104	35.8
30	39.0	72	32.1	30	39.3	104	35.9
45	35.2	68	30.8	45	38.7	100	34.1
60	35.7	68	30.4	60	37.8	101	35.1
28 Apr. 03				21 Mar. 04			
15	38.9	48	36.1	15	39.4	63	33.9
30	36.9	46	33.2	30	38.8	59	30.8
45	36.3	45	31.8	45	38.2	60	30.7
60	37.1	46	31.6	60	37.9	58	29.8

Table 4. Parameter estimates for the non-linear segmented model (Eq. 4) describing changes of fraction of senesced leaf number on main stem versus thermal or physiological days after sowing.

Experiment	R^2	b	x_o
Thermal day			
Exp. 2	0.90	0.0149 ± 0.0064	36.0 ± 1.59
Exp. 3	0.75	0.0128 ± 0.0040	35.0 ± 1.33
Exp. 4	0.68	0.0115 ± 0.0049	36.8 ± 1.62
Physiological day			
Exp. 2	0.96	0.0191 ± 0.0043	14.8 ± 0.59
Exp. 3	0.93	0.0142 ± 0.0040	14.6 ± 1.23
Exp. 4	0.93	0.0168 ± 0.0058	15.0 ± 0.95

Table 5. Parameter estimates for the non-linear segmented model (Eq. 5) describing changes of total leaf number per plant and number of nodes on main stem for different plant densities of Exp. 2. b^*_2 represents the value of b_2 after fixing b_1 at 2.98 and x_o at 14.4.

Plant density	R^2	b_1	x_o	b_2	b^*_2
15	0.99	3.1 ± 0.399	14.1 ± 0.73	14.7 ± 0.50	15.1 ± 0.22
30	0.99	2.9 ± 0.390	12.8 ± 1.02	10.1 ± 0.43	11.0 ± 0.21
45	0.99	2.9 ± 0.223	15.0 ± 1.16	7.8 ± 0.40	7.5 ± 0.15
60	0.98	3.0 ± 0.319	15.6 ± 1.32	8.9 ± 0.58	8.3 ± 0.22

Table 6. Parameter estimates for the power function (Eq. 6) describing changes of plant leaf area versus the number of nodes on main stem for different plant densities of Exp. 3 and 4.

Plant density	R^2	*B*
15	0.91	2.227 ± 0.0176
30	0.90	2.164 ± 0.0186
45	0.94	2.072 ± 0.0134
60	0.77	2.039 ± 0.0281

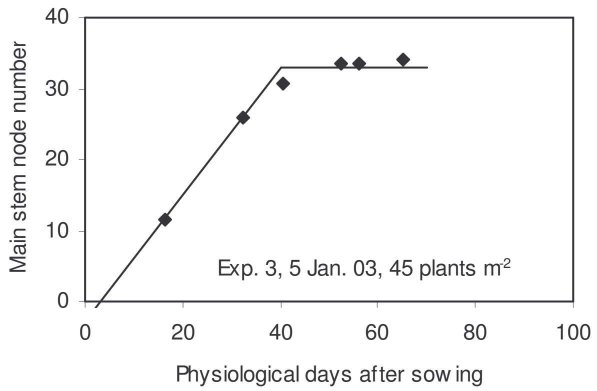

Fig. 1. Example fit of a segmented non-linear regression model to data of main stem node number versus physiological days after sowing.

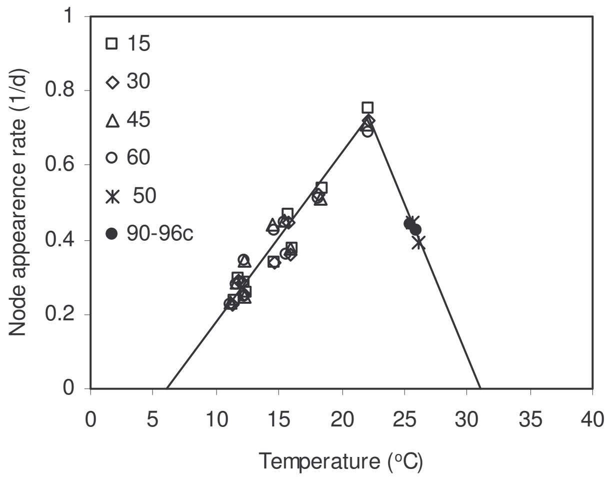

Fig. 2. Rate of node appearance on main stem as a function of temperature across the four field experiments. Numbers indicate plant densities. Filed circles belong to cv. 90-96c at plant density of 50 plants m^{-2}, other points belong to cv. Hashem at plant densities indicated in the figure.

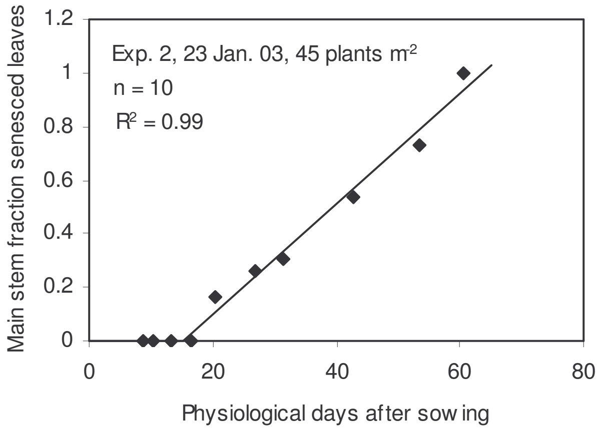

Fig. 3. Example fit of a segmented non-linear regression model to data of fraction of senesced leaf number on main stem versus physiological days after sowing.

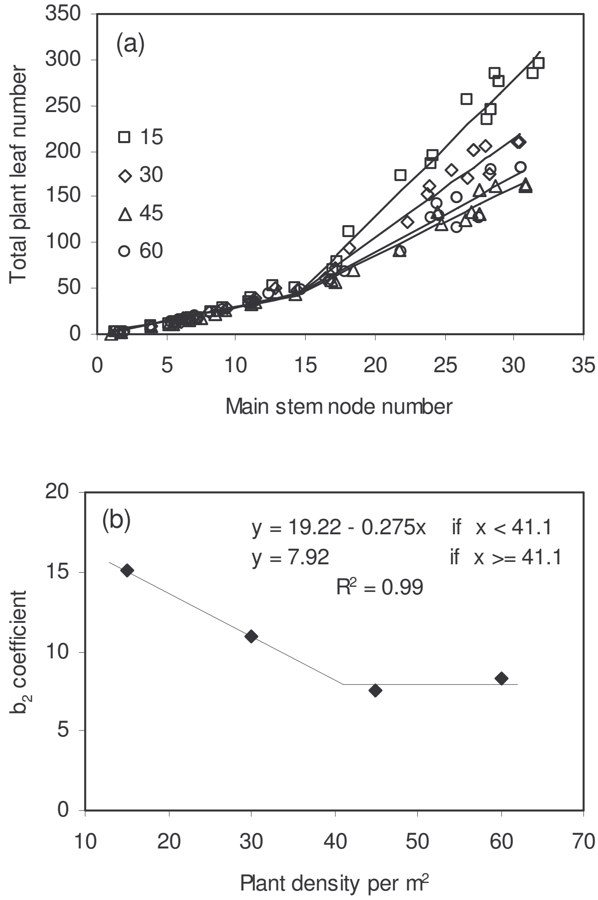

Fig. 4. (a) Changes of total leaf number per plant as a function of node number on main stem for different plant densities (numbers within figure). (b) Dependency of the rate of increase in plant leaf number during the second phase (b_2 coefficient-see Eq. 5) to plant density in Exp. 2.

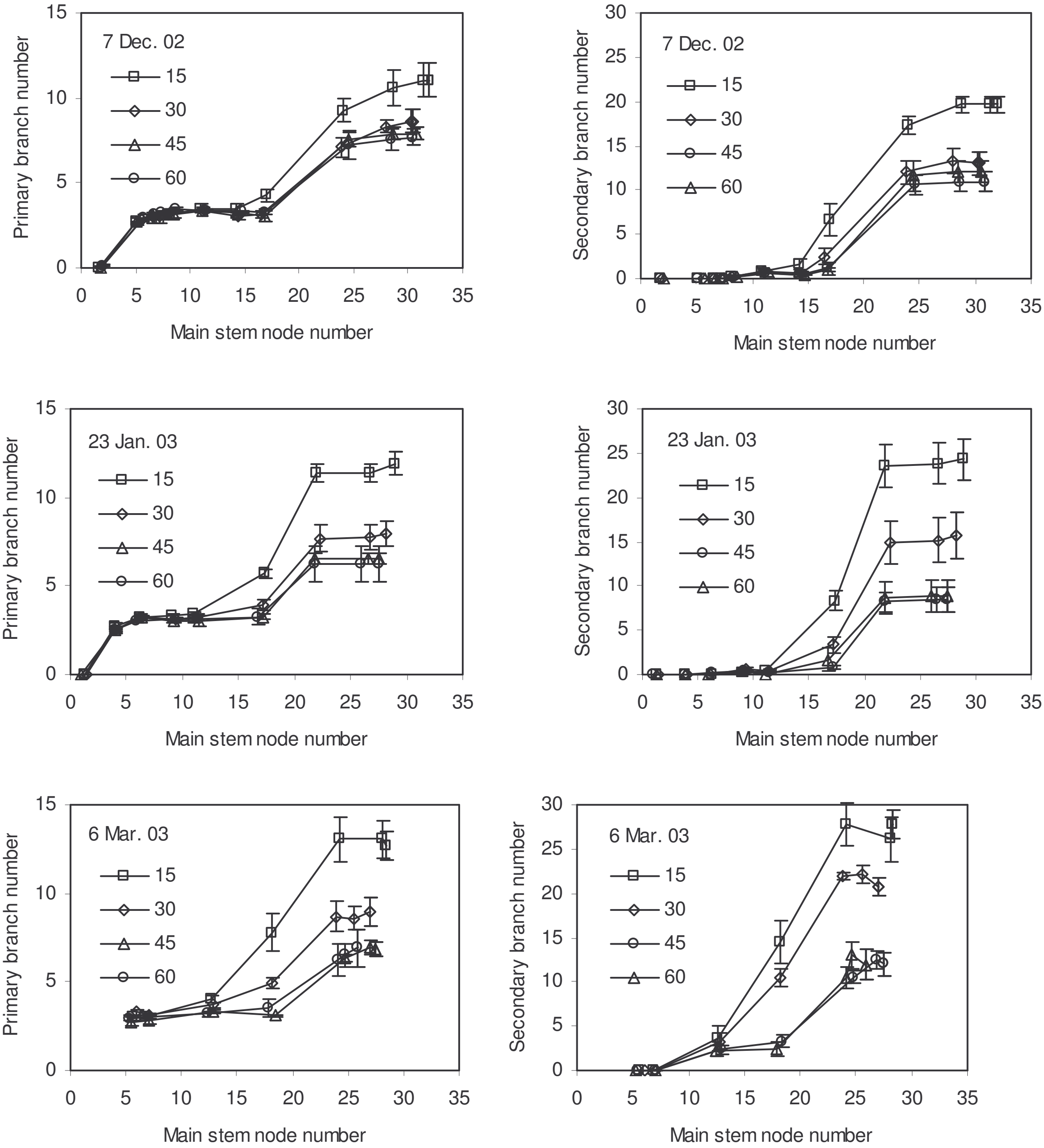

Fig. 5. Production of primary and secondary branches in relation to node number on main stem in Exp. 2. Numbers within figures indicate plant densities. Vertical bars indicate standard errors.

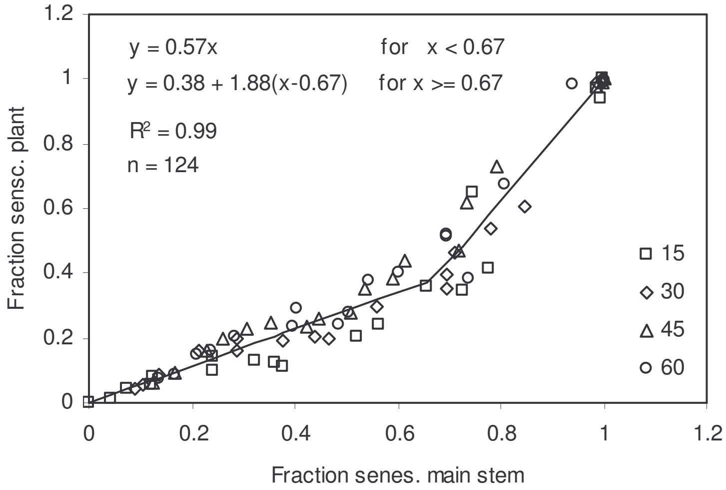

Fig. 6. Fraction of senesced leaf number per plant versus the fraction on main stem in Exp. 2. Numbers indicate plant densities.

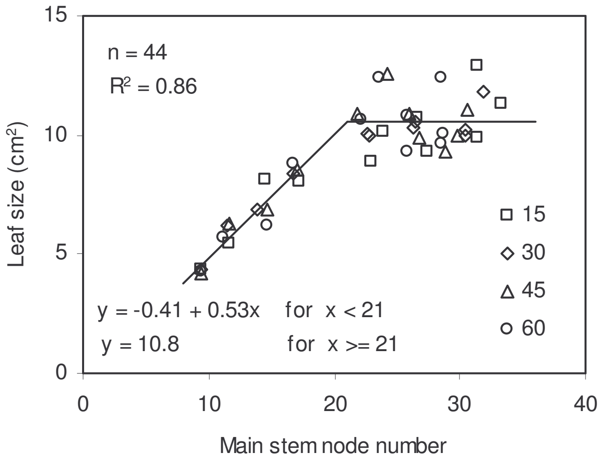

Fig. 7. Average leaf size as a function of main stem node number in Exp. 3. Numbers indicate plant densities.

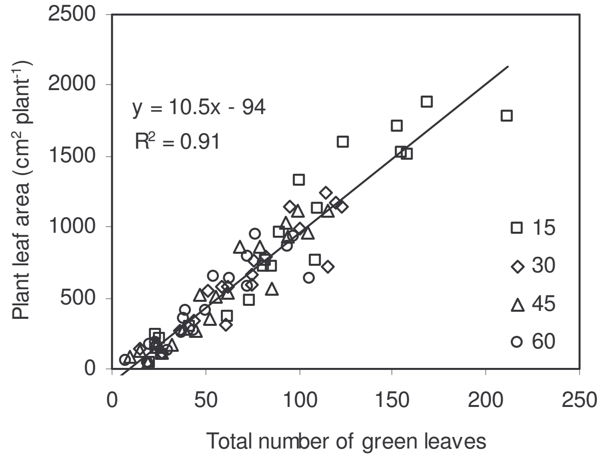

Fig. 8. Plant leaf area as a function of the number of green leaves per plant in Exp. 3. Numbers indicate plant densities.

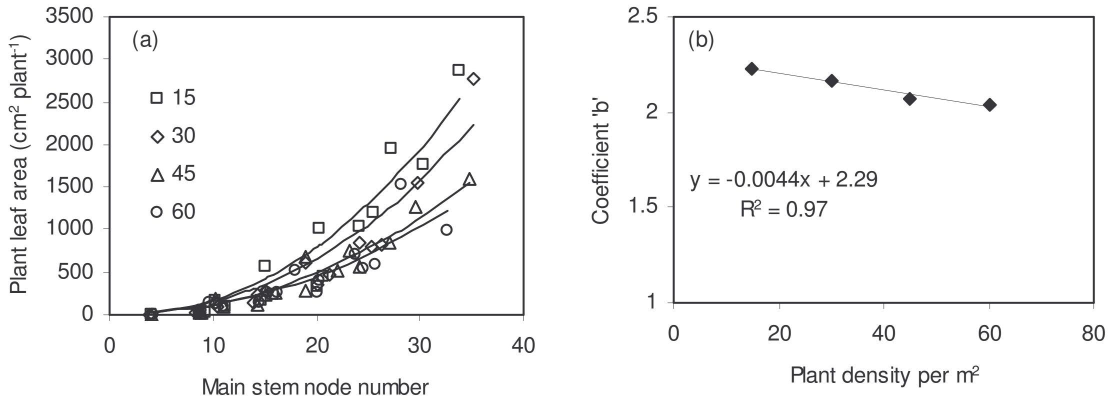

Fig. 9. (a) Plant leaf area as a function of main stem node number described by a power function as $y = x^b$ in Exp. 4. Numbers indicate plant densities. (b) Dependency of the coefficient of the power function on plant density.

Modeling Leaf Production and Senescence in Chickpea (*Cicer arietinum* L.): Leaf Lifetime

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ABSTRACT

Quantitative information regarding leaf lifetime in chickpea (*Cicer arietinum* L.) is scarce. Data from a field experiment with a range of planting date and density were analyzed to estimate leaf lifetime and its variation in chickpea. The experiment was conducted under well-watered conditions. An average leaf lifetime of 23.5 physiological days was estimated. A physiological day is a calendar day with no limitation of photoperiod and temperature for plant development. Planting date and density did not affect leaf lifetime. The results of this study can be used in simulation models of chickpea.

Keyword: Leaf; Leaf lifetime; Photoperiod; Temperature; Model.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the major pulse crops in the world with a total annual global production of 7.5 M tones from 10.3 M ha (FAO, 2003). It is cultivated on a large scale in arid and semiarid environments, and has considerable importance as food, feed and fodder.

Crop simulation models that predict plant growth, water use and yield are being used to understand the response of crops to the dynamics of climate-plant-water systems, to evaluate physiological traits for genetic yield improvement and to help make decisions that optimize use of available resources (Boote et al., 1996; Sinclair and Seligman, 1996; Hammer, 1998). The ability to predict leaf area development is crucial for crop simulation models. Prediction of leaf area index is required to estimate interception of solar radiation and biomass production. It is also an important determinant of the partitioning of evapotranspiration between evaporation and transpiration.

Leaf area development involves the appearance of new leaves, expansion of newly emerged leaves and the senescence of old leaves (Hofstra et al., 1977; Ranganathan et al., 2001). The concept of leaf lifetime has been used in some crop simulation models to quantify leaf senescence after the accumulation of a specified thermal time (e.g. Rickman et al., 1996).

There are no reports in the literature regarding estimates of leaf lifetime in chickpea for the purpose of crop modeling. Therefore, the objective of this research was to estimate this across different environmental conditions and agronomic practices.

MATERIALS and METHODS

The experiment was conducted at Gonbad Agricultural Research Station, Gonbad (34^{o} 21' N, 55^{o} 10' E and 37 m asl) in Iran. The soil was a deep silty loam (fine-silty, mixed, active, thermic, Typic Calcixerolls). Some details about the experiment and weather conditions are given in Table 1 and 2, respectively. The experiments was conducted under well-watered conditions. The experimental design was single split plot with sowing dates in the main plot and plant densities in the sub plot, replicated four times. Plot size was 1.75 m (7 rows) by 7.0 m, row spacing of 25 cm and different intra-row spacings to achieve population densities of 15, 30, 45 and 60 plants m^{-2}. Chickpea cultivar was Hashem, a local cultivar. The chosen sowing dates do not necessarily reflect common practices, but were selected to create different growth environments with a range of temperature, photoperiod and solar radiation. December is the most common sowing date for chickpea in Gonad, but sometimes sowing might occur in late November, January and February.

Stages of development of emergence (50% of plants with some parts at soil surface), flowering (50% of plants with at least one flower at any node, R1), first pod (50% of plants with a 0.5 cm pod at one of the 4 upper nodes with unfolded leaf, R3), beginning of seed growth (50% of plants with peas beginning to develop, R5), first-maturity (50% of plants with at least one pod yellowed, R7) and full-maturity (50% of plants with 95% pods yellowed, R8) were recorded every 2 days (Fehr and Caviness, 1977).

Table 1.Summary of cultural practices and measurements in the field experiment.

Location	Gonbad
Growing season	2002-2003
Previous culture	Wheat
Soil	Silty loam
Initial conditions	Electrical conductivity of 0.73 dS m^{-1}; pH of 8.1; organic carbon of 1.20%; total nitrogen of 0.12%; available P of 9.5 mg kg^{-1}; available K of 640 mg kg^{-1}
Fertilization (at sowing)	150 kg ha^{-1} ammonium phosphate
Treatments	3 sowing dates (7 Dec. 02, 23 Jan. 03 and 6 Mar. 03) × 4 plant densities (15, 30, 45 and 60)
Measurements [a]	Phenology, MSNN, MSSNN, TPLN, TPSLN
Frequency of measurements	Whole season; every 7 to 10 days

[a] MSNN, the main stem node number; MSSNN, the number of nodes on main stem with senesced leaf; TPLN, the total plant leaf number; TPSLN, the total number of senesced leaves per plant; TGLN, the total number of green leaves per plant.

Measurements regarding leaf production and senescence were the total number of nodes on main stem, the number of nodes on main stem with senesced leaves and the total plant leaf number (green + senesced). The frequency of the measurements are presented in Table 1. The measurements were conducted on 10 tagged plants. Mean of the 10 plants measured was considered as an observation. A leaf was counted when its leaflets were unfolded and a green leaf was considered a leaf with >50% green area. The number of fallen leaves was counted based on visible leaf scars.

Daily maximum and minimum temperatures, sunshine hours and rainfall were measured at a standard weather station located a few hundered meters from the experimental units. Solar radiation was calculated from sunshine hours and extraterrestrial radiation. Photoperiod for each day was calculated from latitude and calendar day and included allowance for civil twilight when solar angle ≥ –4 ^{o} (Keisling, 1982; Soltani et al., 2005a).

Physiological day per calendar day (PD_t) was calculated as (Soltani et al., 2006a):

$$PD_t = f(T) \times f(PP) \quad (1)$$

where $f(T)$ is the temperature function and $f(PP)$ the photoperiod function. Physiological day is similar to thermal time corrected for the effect of photoperiod. The $f(T)$ was obtained as:

$$\begin{aligned} f(T) &= (T - T_b)/(T_{o1} - T_b) && \text{if} \quad T_b < T < T_{o1} \quad (2) \\ f(T) &= (T_c - T)/(T_c - T_{o2}) && \text{if} \quad T_{o2} < T < T_c \\ f(T) &= 1 && \text{if} \quad T_{o1} < T < T_{o2} \\ f(T) &= 0 && \text{if} \quad T \leq T_b \ \ or \ T \geq T_c \end{aligned}$$

where T is temperature, T_b the base temperature, T_o the optimum temperature, T_{o1} the lower optimum temperature, T_{o2} the upper optimum temperature, and T_c the ceiling temperature (Soltani et al., 2006a). The $f(PP)$ was computed as:

$$\begin{aligned} f(PP) &= 1 && \text{if} \quad PP \geq Pc \quad (3) \\ f(PP) &= 1 - PS \times (Pc - PP)^2 && \text{if} \quad PP < Pc \end{aligned}$$

where PP is photoperiod (h d^{-1}), P_c the critical photoperiod below which development rate decreases due to short photoperiod, and PS the photoperiod sensitivity coefficient. From sowing to emergence and from flowering to maturity, the value of $f(PP)$ was fixed at 1, indicating no effect of photoperiod for these stages (Soltani et al., 2006a). The values of T_b, T_{o1}, T_{o2} and T_c were 4.5, 20, 29 and 40 ^{o}C for sowing to emergecne (Soltani et al., 2006b) and 0, 21, 32 and 40 ^{o}C for other stages (Soltani et al., 2006a). The value of P_c was 21 h and the value of PS was 0.00845 for Hashem (Soltani et al., 2006a). Cumulative values of PD_t were used in present study. Thermal day was also calculated from Eq. (1) to (3) by fixing $f(PP)$ at 1 for all phenological stages. Thermal day is a normalized form of thermal time.

RESULTS and DISCUSSION

Summary of weather conditions during the experiment is indicated in Table 2. To obtain an estimate of average leaf lifetime, a logistic regression model was used to describe changes of total and senesced plant leaf number versus thermal day and physiological day (Fig. 1):

$$y = y_{max} / [1 + exp(-a(x - b)]$$ (4)

where y is the total or senesced plant leaf number, x the thermal day or physiological day after sowing, a the steepness of increase in leaf number and b thermal day or physiological day when total or senesced leaf number reached to 50% of their maximums. When fitting Eq. (4) to data of senesced leaf number, the value of y_{max} was fixed to that found for total plant leaf number. The difference between b for senesced leaf number (b_2) and total leaf number (b_1) gives an estimate of average leaf lifetime ($b_2 - b_1$).

Table 2. Monthly means of solar radiation (SRAD, MJ m^{-2} d^{-1}), maximum temperature (TMAX, ^{o}C), minimum temperature (TMIN, ^{o}C) and monthly total rainfall (RAIN, mm) during the field experiment.

	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
SRAD	8.4	8.6	6.2	11.7	13.0	23.3	22.8	18.8
TMAX	11.6	13.8	12.9	13.6	18.8	27.0	31.9	33.9
TMIN	1.8	3.7	4.6	5.6	9.1	12.6	17.6	23.2
RAIN	54.6	28.3	56.5	90.1	71.7	39.4	8.5	5.4

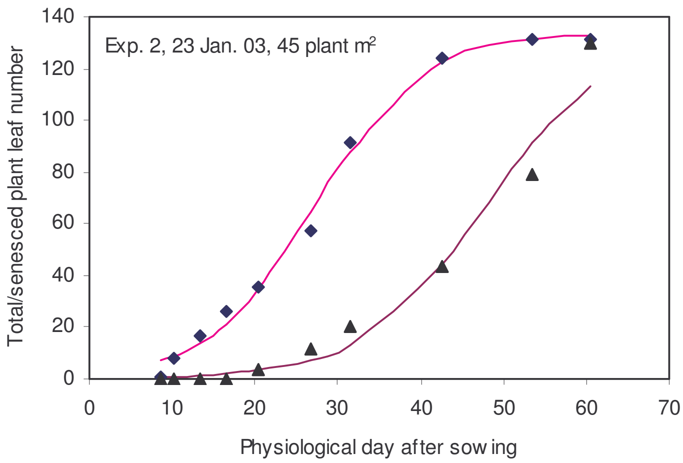

Fig. 1. Example fit of a logistic model to total (♦) and senesced (▲) leaf number per plant to determine average leaf lifetime.

Using physiological day resulted in stable estimates of leaf lifetime across sowing dates (Table 3), while leaf lifetime estimates based on thermal day were dependent on sowing date (data not shown), indicating a possible effect of photoperiod on leaf lifetime, probably due to linkage between phenology and the timing of carbon and nitrogen retranslocation (Prof. G.L. Hammer, personal communications). The logistic model gave a good description of leaf number changes versus physiological day with R^2 values higher than 0.98 and 0.94 for total and senesced plant leaf number, respectively. Regression of leaf lifetime versus plant density using a simple, linear model did not result in significant slope (data not shown). Average leaf lifetime across sowing dates and densities was 23.5 physiological days. This means that under optimal temperature and photoperiod a leaf in average lasts for 23.5 days.

Table 3. Parameter estimates for the logistic model (Eq. 4) describing total and senesced plant leaf number versus physiological day after sowing to obtain leaf lifetime (physiological days).

	Total leaves				Senesced leaves			
Treatment	R^2	*MxLN*	a_1	b_1	R^2	a_2	b_2	Lifetime
7 Dec. 02								
15	0.99	297 ± 6.5	0.227 ± 0.0208	25.9 ± 0.559	0.98	0.199 ± 0.0253	52.1 ± 0.765	26.1
30	0.99	214 ± 5.43	0.205 ± 0.0201	24.4 ± 0.676	0.97	0.127 ± 0.0157	49.4 ± 1.136	24.9
45	0.99	166 ± 4.675	0.203 ± 0.0220	23.0 ± 0.746	0.97	0.112 ± 0.0137	47.2 ± 1.355	24.2
60	0.99	186 ± 5.211	0.199 ± 0.0211	23.6 ± 0.750	0.97	0.121 ± 0.0139	47.2 ± 1.162	23.6
23 Jan. 03								
15	1.00	277 ± 6.388	0.204 ± 0.0207	30.0 ± 0.577	0.95	0.423 ± 0.1313	54.8 ± 0.690	25.0
30	1.00	179 ± 4.015	0.177 ± 0.0148	27.8 ± 0.593	0.94	0.148 ± 0.0329	50.6 ± 1.668	22.9
45	0.99	134 ± 3.272	0.155 ± 0.0128	27.3 ± 0.692	0.97	0.135 ± 0.019	47.8 ± 1.248	20.5
60	0.99	129 ± 3.061	0.156 ± 0.0125	27.2 ± 0.670	0.95	0.132 ± 0.0248	48.8 ± 1.659	21.6
6 Mar. 03								
15	1.00	244 ± 2.006	0.198 ± 0.0073	28.6 ± 0.222	1.00	0.126 ± 0.0069	53.4 ± 0.426	24.8
30	1.00	199 ± 4.883	0.179 ± 0.0186	28.0 ± 0.694	0.99	0.128 ± 0.012	51.5 ± 0.696	23.5
45	0.99	155 ± 5.377	0.152 ± 0.0202	28.4 ± 1.044	0.97	0.121 ± 0.0184	51.0 ± 1.267	22.6
60	0.98	146 ± 5.744	0.171 ± 0.028	27.3 ± 1.131	0.96	0.133 ± 0.0265	50.0 ± 1.485	22.7

MxLN: Maximum leaf number per plant.

Inverse prediction of Eq. (4) indicated that total plant leaf number reaches 95% of its maximum (y_{max}) when 43 physiological days have elapsed, which is the physiological day when first-pod occurs (Soltani et al., 2006a). This stage can be considered as when effective leaf growth terminates. The termination of leaf growth is important in some simulation models (Sinclair, 1986; Sinclair et al., 2003; Robertson et al., 2002).

Overall, average leaf lifetime was 23.5 physiological days. Plant density and sowing date had no effect on leaf size and lifetime.

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Path Analysis of Grain Yield with Its Components in Durum Wheat under Drought Stress

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ABSTRACT

This experiment was conducted in order to study the path analysis of grain yield with its components in durum wheat under potential and drought stress condition during 2005-2006 cropping season in Agriculture Research Station of Tabriz Islamic Azad University. 49 durum wheat line (6 line from Iran and 43line from other fount) was used for this purpose. Two separate simple lattic design (7×7) with two replications was conducted . In one experiment, the plants were commonly irrigated until physiological but in another experiment drought stress imposed in four different stages including; tillering, stem elongation, anthesis and grain filling. Correlations among traits after combining two experiments was calculated by SPSS software . Harvest index(r =0.849**), plant height(r =0.695**), and number of tiller (r =0.689**) had high correlation with grain yield. Back ward regressions was used for regressing grain yield on its components. Number of seeds per spike (0.432) , length of spike(0.407) and 1000 seed weight (0.385) had the highest direct positive effects on grain yield. Path analysis for 1000 seed weight, number of tillers per plant and number of seeds per spike showed that plant height (0.452), length of spike (0.857), days to flowering (0.345) were the most effective components of traits, respectively. Therefore, traits such as number of seeds per spike, spike length and 1000 seed weight could be used as a suitable indices in irrigated and dry farming conditions for obtaining durum wheat genotypes with high yield.

KeyWords: Correlation, Drought stress, Durum wheat, Path analysis.

INTRODUCTION

The insufficiency of water is the principle environmental stresses and to enter heavy damage in many part of the world for agricultural products (Volaire,2003;Yu and Setter,2003). Connies(1987) defined drought as a lack or leakage of rainful in part of time that cause decrease in growth of plant and thus economic production. The insufficiency of water in different growth stages, effect plant physiological activities until seed formation and seed and filling period. Yield components of cereal seeds consist of g number of spike per surface Area, number of seeds per spike and 1000 seed weight not only have compensational effect to each other, but they are most effective factors in grain yield of cereals(Rasmusson and Chanel,1970). Mohammedi (1998) reported that correlation between dry land wheat grain yield and 1000 seed weight, plant height, tiller no, length of last internode, seed no per spike and harvest index are significant and positive. also Darwinkal(1978) reported positive correlation between grain yield with 1000 seed weight and number of seed per spike in wheat.

According to path analysis in durum wheat genotypes, number of seeds per spike, 1000 seed weight and number of tillers have direct and positive affects yield(Gebeyehou et al, 1982;Monral et al,1997;Simane et al.1993). Kumar and Gupta(1984) reported direct positive but little affect of plant height, number of seeds per spike, 1000 seed weight and number of tiller on yield.

Objects of this experiment was to define correlations between traits correlated to grain yield in drought stressful condition and non stressful condition and also characterize traits that have highest direct and indirect effects on durum wheat yield in this condition.

MATERIALS and METHODS

This experiment conducted in Agriculture Research station of Tabriz Islamic Azad University during 2005_2006. 49 durum wheat line (6 line from Iran and 43 line from other countries) was used for this purpose. Two separate simple lattic design experiment (7×7) with two replications was conducted. In one experiment, the plants were commonly irrigated until physiological maturity but in another experiment drought stress imposed in four different stages including: tillering, stem elongation, anthesis and grain filling for study correlations among traits and also regression method and path analysis grain yield after combining two experiments was calculated buy Excel,Spss and Path2 software.

RESULTS and DISCUSSION

Correlation coefficients grain yield was significant and positive with plant height, length of spike, peduncle length, number of tiller per plant, harvest index and number of seed per spike.
Therefore increases in every traits mentioned above, result in increases in grain yield (table1).

Correlation between grain yield with harvest index were much more than correlation of grain yield with other trait($r= 0.849^{**}$), thus with increasing grain yield, other traits also increased but not in case of this increase in harvest index.

Correlation between yield and its components showed significant and positive correlation between yield components of number of tiller ($r = 0.689^{**}$) and number seed per spike ($r = 0.387^{**}$) with grain yield, also 1000 seed weight ($r = 0.013^{ns}$) don't show linear correlation with yield. Besides, according to results of table 1 that show correlation of two traits of seed per spike with 1000 seed weight significant and negative($r = -0.284^{**}$). Can conclude that by increasing number of seed per spike, 1000 seed weight decreases and reverse. Monral et al,(1997) reported significant and positive correlation between grain yield with number seeds per spike and 1000 seed weight.

In path analysis grain yield, number of seeds per spike have most coefficient and is first rate, length of spike is next rate regression coefficients. So this traits can cause increases of gain yield.(Table2). Darwinkal (1978) reported important direct effect of number seed per spike on grain yield.

1000 seeds weight direct effect on yield also was significant but number of seeds per spike and length of spike indirectly and by 1000seed weight can cause to yield losses that this can be due to negative correlation between 1000 seeds weight and seed no per spike ($r = -0.284^{*}$) and spike length ($r = -0.478^{**}$).

Path analysis for 1000 seed weight showed direct significant and positive affect plant height on 1000 seed weight. Results showed that 1000 seed weight increases is by increases in plant height(0.424) and flag leaf surface (Table 3).

Path analysis number of tiller showed that spike length (0.857) have highest significant and positive effect on number of tiller, Indirect effect of its by way of 1000 seed weight (-0.132) is less and negative (table4).

In path analysis number of seeds per spike basis direct effect days to flowering positive and was significant in 1% levels. Therefore can conclude that increase number of seeds per spike. 1000 seed weight direct effect(0.351) was significant and negative on number of seeds per spike that subject attentive negative correlation(r = -0.285) between this two traits is logical(table5).

Thus in this experiment condition three trait, number of seeds per spike, length spike and 1000 seeds weight respectively have direct effect most on grain yield. Therefore can in stress conditions use of two traits number of seeds per spike and length of spike index selection. Simane et al,(1993) reported effect number seeds per spike more than its components and to introduce that one selection index suitable in drought conditions.

Table 1. Correlation between traits for each two experiment

Trait	Plant height	Length of spike	Peduncle length	Number tiller	Harvest index	Number of seed per spike	1000 seed weight	Chlorophyl flag leaf	Surface flag leaf	Days to flowering
Length of spike	0.670**									
Peduncle length	0.714**	0.321*								
Number tiller	0.634**	0.746**	0.427**							
Harvest index	0.446**	0.365**	0.269	0.592**						
Number of seed per spike	0.126	0.113	-0.15	0.128	0.586**					
1000 seed weight	-0.4	-0.478	0.187	-0.252	0.068	-0.284*				
Chlorophyl flag leaf	-0.108	-0.404**	0.063	-0.373	-0.018	0.163	0.384**			
Surface flag leaf	0	-0.067	-0.059	-0.238	0.004	-0.01	0.401**	0.364*		
Days to flowering	0.218	0.227	-0.159	0.08	0.254	0.407**	-0.097	0.107	0.121	
Grain yield	0.695**	0.591**	0.466**	0.689**	0.849**	0.387**	0.013	-0.127	-0.03	0.241

** and * Significant at the 1 and 5% levels of probability, respectively

Table 2. Path analysis grain yield with its components for mean numbers of two experiment under stress drought and potential condition durum wheat.

Trait	Direct effect	Indirect effects: Length of spike	Peduncle length	Number tiller	Number of seed per spike	1000 seed weight	Correlation trait with yield
Length of spike	0.407**	---------	0.057	0.261	0.048	- 0.185	0.591**
Peduncle length	0.178**	0.13	--------	0.149	- 0.065	0.072	0.465**
Number tiller	0.352**	0.304	0.076	---------	0.055	- 0.098	0.689**
Number of seed per spike	0.432**	0.046	- 0.027	0.044	----------	- 0.11	0.386**
1000 seed weight	0.385**	- 0.195	0.033	- 0.089	- 0.123	--------	0.013

** and * Significant at the 1 and 5% levels of probability, respectively

Table 3. Path analysis for 1000 seeds weight in average two conditions stress and potential

Trait	Direct effect	Indirect effects: plant heights	Length of spike	number of tiller	number of seed per spike	Surface flag leaf	Correlation trait with yield
plant heights	0.424**	-----------	- 0.626	0.194	- 0.034	0	- 0.04
Length of spike	- 0.935**	0.284	----------	0.228	- 0.031	- 0.028	- 0.478**
number of tiller	0.306**	0.269	- 0.697	-----------	- 0.035	- 0.098	- 0.253
number of seed per spike	- 0.268*	0.053	- 0.106	0.039	----------	- 0.005	- 0.285*
Surface flag leaf	0.408**	0	0.062	- 0.074	0.002	-----------	0.4**

** and * Significant at the 1 and 5% levels of probability, respectively

Table 4. Path analysis for number of tiller in average two conditions stress and potential

Trait	Direct effect	Indirect effects: Length of spike	1000 seed weight	surface flag leaf	Correlation trait with yield
Length of spike	0.857**	---------	- 0.132	0.019	0.745**
1000 seed weight	0.274*	- 0.411	--------	0.117	- 0.253
Surface flag leaf	- 0.291**	- 0.058	0.11	-------	- 0.239

** and * Significant at the 1 and 5% levels of probability, respectively

Table 5. Path analysis for number of seeds per spike in average two conditions stress and potential

Trait	Direct effect	Indirect effects: 1000 seed weight	Chlorophyl flag leaf	days to flowering	Correlation trait with yield
1000 seed weight	- 0.351**	---------	0.1	- 0.034	- 0.285*
Chlorophyl flag leaf	0.261*	- 0.135	---------	0.036	0.163
days to flowering	0.345**	0.034	0.027	---------	0.407**

** and * Significant at the 1 and 5% levels of probability, respectively

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Comparative Physiological and Growth Responses of Tomato and Pepper Plants to Fertilizer Induced Salinity and Salt Stress under Greenhouse Conditions

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ABSTRACT

Fertilizer induced salinity adversely affects plant growth through its ionic and osmotic effects as in ordinary salinity caused by toxic ions (Na, Cl, etc.). In this study, to determine the ionic and osmotic effects of fertilizer induced salinity and NaCl salinity on growth, ascorbic acid, proline and hydrogen peroxide (H_2O_2) accumulation and stomatal resistance (SR), relative water content (RWC), malondialdehyde (MDA) contents of tomato and pepper plants subjected to different treatments (i.e. control, 40 mM NaCl salinity and excess fertilizer salinity) were investigated under greenhouse condition. The results of this study indicated that similar to NaCl salinity, fertilizer induced salinity significantly reduced the fresh and dry weights of tomato and pepper plants. Relative water content of the plants was decreased by NaCl salinity. Both NaCl and fertilizer induced salinity caused significant increases in proline, MDA, ascorbic acid and H_2O_2 accumulation, and stomatal resistance of the plants. Salinity achieved by NaCl and fertilizer altered plant growth and plant physiological processes ionically and osmotically in a similar manner.

Key words: ascorbic acid, malondialdehyde, proline, relative water content, H_2O_2, stomatal resistance

INTRODUCTION

Salinization plays a major role in soil degradation. It affects 19.5% of irrigated land and 2.1% of dry land agriculture existing on the globe (FAO, 2000). In many crop production areas, use of low quality water for irrigation and application of excess amounts of mineral fertilizer are the major reasons for increased salinity problem in cultivated soils. Due to very rapid accumulation of salts in soil under greenhouse conditions, salinity problem is also a critical constraint to vegetable production (Shannon and Grieve, 1999). Salinity effects are more conspicuous in arid and semiarid regions, where limited rainfall, high evapotranspiration and high temperature associated with poor water and soil management contribute to the salinity problem and become of great importance for agriculture production in these regions.

Salinity stress depresses plant growth and development at different physiological levels. The reduction in plant growth by salinity stress might be related to adverse effects of excess salt on ion homeostasis, water balance, mineral nutrition and photosynthetic carbon metabolism (Zhu, 2001;

Munns, 2002). The mechanisms by which salt stress damage plants are still a discussing matter due to very complex nature of the salt stress in plants.

Salt stress tolerance in plants is a complex phenomenon that may involve developmental changes as well as physiological and biochemical processes. Salinity can damage the plant through its osmotic effect, which is equivalent to a decrease in water activity, through specific toxic effects of ions and by disturbing the uptake of essential nutrients (Marschner, 1995; Dorais et al., 2001). In general, enzymes and metabolic activities in plants are highly influenced by both amount and type of salts. Salt resistance includes both avoidance and tolerance mechanisms (Levitt, 1980). The former may operate through active extrusion of ions by specific pumps, passive exclusion of ions due to membrane impermeability, or dilution by rapid growth associated with an increase in water content. An unavoidable consequence of growth in a solution containing a high salt concentration is the development of osmotic stress, which is followed by a loss of turgor. Tolerance to osmotic stress may operate either through dehydration tolerance, which permits the cell to survive without growing when the turgor decreases, or by avoiding dehydration through osmoregulation, which includes an increase of solute concentration in the cell and consequently rehydration. The solutes may be either salt ions, which can be sequestered in the vacuole and osmotically balanced by organic solutes in the cytoplasm, or organic substances. The latter occurs when salt ions are prevented from entering the cells (Tal, 1984). Salt-sensitive in which group most agricultural and horticultural crops belong respond to salinity with profound decrease in vegetative and reproductive growth (Greenway and Munns, 1980). These responses are highly due to osmotic effects. The inability of osmoregulation may result from either an insufficient uptake of salt ions or a lack of synthesis of organic solutes, which leads to growth disruption occasioned by reduced water uptake as well as reduced water potential in the soil, resulting to physiological water stress. In addition, salinity can cause injury by inorganic ions, which are absorbed by the cell, are not compartmentalized, and are accumulated at toxic levels in plant tissues. (Wahome, 2003; Neocleous and Vasilakakis, 2007).

Under oxidative stress conditions such as salinity, plants produce active oxygen species (AOS). To scavenge AOS; plants have evolved specific defense tactics involving both enzymatic and non-enzymatic antioxidant mechanisms. Several antioxidant enzymes participate in the detoxification of AOS. Superoxide dismutases react with superoxide radicals ($O2\bullet-$) to produce H_2O_2 (Bowler et al., 1992). In the absence of natural scavengers such as catalase and peroxidase, H_2O_2 accumulates in tissues to high levels. Accumulation of free proline is a typical response to salt stress. When exposed a high salt content in the soil (leading to water stress), many plants accumulate high amounts of proline, in some cases several times the sum of all the other amino acids (Mansour, 2000). Proline has been found to protect cell membranes of onion against salt injury (Mansour, 1998). Malondialdehyde (MDA) content, a product of lipid peroxidation, has been considered an indicator of oxidative damage (Zhua et al. 2004).

The aim of this work was an effort to investigate the ionic and osmotic effects of NaCl and fertilizer induced salinity to physiological, biochemical and growth parameters in tomato and pepper plants.

MATERIALS and METHODS

Growth Condition and Treatments

To determine the ionic and osmotic effects of salt stress on growth and physiological parameters of tomato (*Lycopersicon esculentum* L.) and pepper (*Capsicum annuum* L.) plants under stress conditions (NaCl and fertilizer induced salinity), an experiment was conducted in greenhouses under natural light conditions at the Faculty of Agriculture, Ankara university. For this aim, plants were grown three different treatments as a follow:

a) Control Treatment: Plants were grown with basic nutrient solution (BNS) contained as a mg kg^{-1}; 263 KH_2PO_4, 583 KNO_3, 1003 $Ca(NO_3)_2$ $4H_2O$, 513 $MgSO_4$ $7H_2O$, 171 Fe-EDDHA, 6.1 $MnSO_4$ H_2O, 0.39 $CuSO_4$ $5H_2O$, 0.37 $(NH_4)6Mo_7O_{24}$ $4H_2O$, 0.33 $ZnSO_4$ $7H_2O$ and 1.7 H_3BO_3

b) NaCl Treatment: BNS + 40 mM NaCl

c) Exceed Fertilizer Treatment: Basic nutrient solution (BNS) concentration increased three folds in order to achieve fertilizer induced salinity.

Tomato and pepper plants were grown in a glasshouse under natural light conditions. Three-week-old seedlings were transplanted at a rate of one plant per pot filled with 5000 g of air-dried soil. Some characteristics of the soil were as follows: texture loam, calcium carbonate (CaCO3) 6.02%, pH (1:2.5 water) 7.68, EC 0.2 dS m^{-1}, organic matter 0.76%, total N 0.20%. The concentration of ammonium acetate (NH4Oac)-extractable K, Ca and Na were as follows (mg kg^{-1}) 378, 4800 and 60 respectively. Sodium bicarbonate (NaHCO3)-available P was 14.25 mg kg^{-1}, and DTPA-extractable Zn, Fe, Cu and Mn were as follows (mg kg^{-1}); 0.57, 5.24, 0.48 and 33 respectively. After one day seedling transplantation, treatments were applied to have divided three for seedlings adaptation to stress conditions. For fresh matter used for assay, samples were taken fully matured leaves from tomato and pepper plants chosen at random. All the measurements with fresh matter were carried out during the last week before harvesting. After the 60 d of growing period, all plants were harvested with a knife by cutting at the joint point of fine roots to the main stem. The rest of the plants were weighed for the fresh weight determination. They were then dried in an air-forced oven at 65 ^{0}C until constant mass was reached, and then weighed dry weight determination.

Plant Measurement and Statistical Analyses

Stomatal Resistance Measurements

Stomatal resistance (SR) of the plants was measured by a ΔTAP4 Porometer (DELTA-T DEVICES, UK). The outer leaves were used in the SR measurements. Measurements were made on three leaves in each plant in the morning (10.30–11.30 a.m.) at a steady photon flux density (>250 mmol m^{-2} s^{-1}), while leaf temperature varied between 18 and 20 ^{0}C.

Determination of H_2O_2, Proline and Ascorbic Acid

Hydrogen peroxide was estimated with titanium reagent (Terenashi et al., 1974). Titanium dioxide (1 g) and 10 g of potassium sulfate were mixed, and boiled with 150 mL of concentrated sulfuric acid for 2 h on a hot plate. The digested mixture was cooled and diluted to 1.5 mL with distilled water, and used as titanium reagent. Sample preparation and H_2O_2 estimation was performed as described by Mukherjee and Choudhuri (1983). Leaf material (0.5 g) was homogenised in 10 mL of cold acetone (90% v/v). The homogenate was filtered through Whatman no. 10 filter paper. Titanium reagent (4 mL) was added to the filtrate, followed by 5 mL of concentrated ammonium solution to recipitate the peroxide– titanium complex. The reaction mixture was centrifuged in a refrigerated centrifuge for 5 min at 10.000g, $4^{0}C$, and the supernatant was discarded and the precipitate was dissolved in 10 mL of 2M H2SO4. It was re-centrifuged to remove the undissolved material and absorbance was recorded at 415 nm. Concentration of H_2O_2 was determined using a standard curve plotted with known concentration of H_2O_2.

Proline was determined as described by Bates et al., (1973). Leaf tissues (250 mg) were rinsed three times with distilled water and the stoppered tubes with 10 ml water placed in a boiling water bath for 10 min to extract the hot water-soluble compounds. An aliquot of water extract was treated with ninhydrin reagent. Toluene phase was decanted and the absorbance was recorded at 520 nm. The concentration of proline was calculated from a standard curve plotted with known concentration of L-proline as standard.

Ascorbic acid was estimated as described by Mukherjee and Choudhuri (1983). Leaf tissue (250 mg) was extracted with 10 ml of 6% TCA. An aliquot (4 ml) of the extract was mixed with 2 ml of 2% dinitrophenyl hydrazine (in acidic medium) followed by the addition of 1 drop of thiourea (in 70% ethanol). The mixture was boiled for 15 min in a water bath, and after cooling to room temperature, 5 ml of 80% (v/v) (0°C) H_2SO_4 was added to the mixture at 30°C (in an ice bath). The absorbance was recorded at 530 nm. The concentration of ascorbic acid was calculated from a standard curve plotted with known concentration of ascorbic acid.

Determination of Lipid Peroxidation and Relative Water Content (RWC)

The level of lipid peroxidation was measured in terms of malondialdehyde (MDA) content, a product of lipid peroxidation, leaf sample (0.5 g) was homogenised in 10 mL of 0.1% trichloro acetic acid (TCA). The homogenate was centrifuged at 15.000g for 5 min. To 1.0 mL aliquot of the supernatant 4.0 mL of 0.5% thiobarbituric acid (TBA) in 20% TCA was added. The mixture was heated at 95 1C for 30 min and then quickly cooled in an ice bath. After centrifugation at 10.000 g for 10 min, the absorbance of supernatant was recorded at 532 nm. The value for non-specific absorption at 600 nm was subtracted. The amount of MDA–TBA complex (red pigment) was calculated from the extinction coefficient 155 (mM^{-1} cm^{-1}) (Hodges et al., 1999).

All spectrophotometric measurements were carried out by spectrophotometer (Shimadzu UV-VIS, Japan).

For relative water content (RWC) determinations, the samples were also weighed immediately as fresh weight (FW), and then floated on distilled water for 4 h. The turgid leaves were then rapidly blotted to remove surface water and weighed to obtain turgid weight (TW). The leaves were dried in the oven at 60 ^{0}C for 24 h and then dry weight (DW) obtained. The RWC was calculated by formulae given in (Dhanda and Sethi, 1998): RWC (%) = (FW – DW)/(TW – DW)x100.

The experiments were designed as completely randomized with four replications. The experimental data were analyzed by ANOVA and the differences were compared by Least Significant Difference Test (LSD) at alpha 0.05.

RESULTS and DISCUSSION

Plant Growth

The ionic and osmotic effects of NaCl and fertilizer induced salinity on fresh and dry weight (g) of tomato and pepper plant are shown in Table 1. In tomato plant, NaCl and fertilizer induced stress caused to decrease plant fresh and dry weight creating significant differences compared to controls. In pepper plant, NaCl salinity significantly decreased fresh and dry weight, fertilizer induced salinity also decreased fresh and dry weight, however, was not found statistically significant compared to control. The growth reduction in fresh and dry weights of tomato plant occurred at approximately 80% and 73% decreases with NaCl treatment compared to control, and approximately 55% and 57% decreases with fertilizer induced salinity, respectively. The growth reduction in fresh and dry weights of pepper plant occurred at approximately 57% decreases with NaCl treatment compared to control, and approximately 27% and 18% decreases with fertilizer induced salinity, however, was not found statistically significant compared to control. The suppression of plant growth under saline conditions may either be due to osmatic reduction in water availability, which was supported by stomatal resistance values of the plants, or to excessive ions accumulation in plant tissues.

Salinity-induced growth reduction has been well documented in several plant species by many researchers; red raspberry (Neocleous and Vasilakakis, 2007), tomato and cucumber (Alpaslan and Gunes, 2001), lettuce (Eraslan et al., 2007a), pepper (Aktas et al., 2006), tomato (Maggio et al., 2007), and carrot (Eraslan et al., 2007b).

Proline, Lipid Peroxididation (MDA) and Ascorbic Acid Concentrations

The effect of NaCl and fertilizer induced salinity on proline, lipid peroxidation (MDA) and ascorbic asit concentrations of tomato and pepper plant are given in Table 2. Both NaCl and fertilizer induced salinity significantly increased proline concentration of tomato and pepper plants. Understanding the biosynthesis, degradation, transport and role of proline during stress and signaling events that regulate stress induced accumulation is vital in developing plants for stress tolerance. An increased proline level is a common response of plants to stress treatments by reported that Jaleel et al. (2007), Eraslan et al. (2007a and 2007b), and Turan and Aydin (2005).

Table 1. The effect of NaCl and fertilizer induced salinity on fresh and dry weight (g) of tomato and pepper plants

Treatment	**Fresh weight (g)**	**Dry weight (g)**
	Tomato	
Control	212.1 a[a]	28.30 a
NaCl	41.1 c	7.54 b
Fertilizer	94.3 b	12.16 b
F-test	**	**
	Pepper	
Control	40.23 a	5.36 a
NaCl	16.98 b	2.26 b
Fertilizer	29.14 a	4.35 a
F-test	**	*

*: $p<0.05$, **: $p<0.01$, [a]: values with the same letter are not statistically significant ($P<0.05$)

Lipid peroxidation (MDA concentration) of the tomato leaves increased statistically significant with fertilizer induced stress, but MDA concentration of the pepper leaves not affected by NaCl and fertilizer induced stress (Table 2). The increases in MDA concentration can be correlated whit the accumulation of ions and active oxygen species (AOS) production under salt stress. This is in agreement with the result of Jaleel et al. (2007), and Gunes et al. (2007).

Table 2. The effect of NaCl and fertilizer induced salinity on proline (mmol kg^{-1} FW), lipid peroxidation (MDA, nmol g^{-1} FW) and ascorbic asit (mmol kg^{-1} FW) concentrations of tomato and pepper plants

Treatment	**Proline (mmol kg^{-1} FW)**	**MDA (nmol g^{-1} FW)**	**Ascorbic Asit (mmol kg^{-1} FW)**
	Tomato		
Control	2.17 b[a]	4.90 b	10.66 b
NaCl	6.27 a	6.65 b	11.38 b
Fertilizer	6.23 a	9.42 a	14.73 a
F-test	**	**	**
	Pepper		
Control	1.54 b	7.55	14.83
NaCl	2.92 a	8.45	17.51
Fertilizer	3.50 a	8.04	19.02
F-test	**	ns	ns

*: $p<0.05$, **: $p<0.01$, ns: non significant, [a]: values with the same letter are not statistically significant ($P<0.05$).

The ascorbic asit concentrations of tomato plants increased significantly with fertilizer induced salinity compared to control. As for ascorbic asit concentrations of pepper plants increased with salt treatment, however this increase was found not to be significant (Table 2). Ascorbic acid, a non-enzymatic antioxidant, is associated with H_2O_2 scavenging via APX (Sairam et al., 1998), A role for increased ascorbic acid content in amelioration of oxidative stress has also been reported by Sairam et al. (2005) and Panda and Upadhyay (2003).

Relative Water Content (RWC), Hydrogen Peroxide (H_2O_2) Concentration and Stomatal Resistance (SR)

The ionic and osmotic effects of NaCl and fertilizer induced salinity on relative water content (RWC), hydrogen peroxide (H_2O_2) concentration and stomatal resistance (SR) of tomato and pepper plant are presented in Table 3. Both NaCl and fertilizer induced salinity were not affected statistically significant relative water content of tomato and pepper plants. Neocleous and Vasilakakis (2007) have reported that RWC was decreased only for higher salt concentration. Sairam et al. (2002) and Ghoulam et al. (2002) have concluded that salt treatment induced a reduction in leaves RWC.

Hydrogen peroxide (H_2O_2) concentration in the leaves of tomato and pepper plant significantly increased both NaCl and fertilizer induced salinity. Fertilizer induced salinity more increased than NaCl salinity H_2O_2 concentration of pepper plant (Table 3). Several studies have stated that H_2O_2 can act as a mobile signal, alerting the plant to various biotic and abiotic threats (Neill et al. 2002). Zhua et al. (2004) have reported that salt stress significantly increased H_2O_2 content in the leaves of cucumber plant. Similar reports were also given by Sairam et al. (2002), and Eraslan et al. (2007a).

Leaf stomatal resistance considerably increased with the both treatment in the leaves of tomato and pepper plant. NaCl salinity more increased than fertilizer induced salinity stomatal resistance in the leaves of tomato plant (Table 3). According to Gunes et al. (1996), measurement of leaf stomatal resistance provides determining the degree of stress in plants under salt stress. Stomatal resistance of the plants increased with the increasing NaCl in the nutrient solution that could be explained by the reduction of water use efficiency under saline condition. In our previous studies, leaf stomatal resistance increased under saline condition to have been reported (Eraslan et al. 2007a, 2007b).

As a conclusion, the results of this study showed that similar to NaCl salinity, fertilizer induced salinity significantly reduced the fresh and dry weights of tomato and pepper plants. Both NaCl and fertilizer induced salinity caused significant increases in proline, MDA, ascorbic acid and H_2O_2 accumulation, and stomatal resistance of the plants. Relative water content of the plants was decreased by NaCl salinity, but, was not found statistically significant. Salinity achieved by NaCl and fertilizer altered plant growth and plant physiological processes ionically and osmotically in a similar manner.

Table 3. The effect of NaCl and fertilizer induced salinity on relative water content (RWC, %), hydrogen peroxide (H_2O_2, mmol kg^{-1} FW) concentration and stomatal resistance (SR, s cm^{-1}) of tomato and pepper plants

Treatment	**RWC (%)**	**H_2O_2 (mmol kg^{-1} FW)**	**SR (s cm^{-1})**
		Tomato	
Control	84.0	14.92 b[a]	2.06 b
NaCl	77.4	22.70 a	8.01 a
Fertilizer	84.4	23.79 a	4.98 ab
F-test	ns	*	*
		Pepper	
Control	84.6	16.63 c	3.62 b
NaCl	81.2	21.14 b	14.13 a
Fertilizer	83.7	27.99 a	14.62 a
F-test	ns	**	**

*: $p<0.05$, **: $p<0.01$, ns: non significant, [a]: values with the same letter are not statistically significant ($P<0.05$)

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Tolerance of Five Azarbaijan Alfalfa Ecotypes to Salinity

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ABSTRACT

Breeding for salt tolerance in crop species, if possible, is an economical approach to overcoming the problem of soil salinity. However, the availability of appropriate genetic variation at the intraspecific level is a prerequisite for successful progress under selection. Genetic variation for NaCl tolerance at the seedling and mature plant stage was assessed in five Azarbaijan native alfalfa cultivars. A completely randomized design (CRD) with 5×4 factorial arrangements and three replication were used. Syah-Roud, Gara-Yonjeh, Hasht-Roud, Khor-Khor and Bash-Kand cultivars were used as a first factor and second were three levels of salt and a control. Salt levels were 3.07, 10, 20 and 30 mm mohs (Ec), which were achieved by adding 0, 1.062, 2.431 and 5.071 g kg^{-1} NaCl to pots soil. Total dry weight, leaves and shoot dry weight, height, number of leaves and leaf/stem ratio (TDW, LDW, SDW, H and NL) were measured. The results indicated that the response was significantly different among cultivars as well as NaCl levels. The NaCl effect was significant in reducing all measured traits of all five ecotypes. Bash-Kand had the highest; Syah-Roud and Gara-Yonjeh cultivars had the lowest yield reduction percentage, respectively. In general, Syah-Roud and Gara-Yonjeh had the highest tolerant to salinity.

Key words: *Medicago sativa*, Lucerne, alfalfa salt tolerance, Variation

INTRODUCTION

As the world population continues to increase and the amount of arable land decrease, a greater emphasis must be placed on bringing marginally productive and presently non-arable land under production. Much of the world's non-arable land is affected by salinity (Allen *et al*., 1985). Large amounts of formerly arable lands are being removed from crop production every year due to increasing soil salinity. Salinity limits crop yields on nearly one-third of the world's irrigated land and salinization continues to increase worldwide (McKell *et al*., 1986). Much of the cropland affected by salinity is in traditional alfalfa decreases 7.3% for each dS m-1(≈11mM NaCl) increase above a threshold of 2.0 dS m-1 (≈ 22 mM NaCl). Seedling alfalfa yield is decreased by 50% at 8.9 dS m-1 (≈97 mM NaCl) (Mass & Hoffman, 1977). Reclamation, drainage, and improved irrigation practices might reduce the severity and spread of salinization in some regions, but costs of these practices are generally prohibitive. Plant breeding may provide a relatively cost effective short-term solution to the salinity problem by producing cultivars able to remain productive at low to moderate levels of salinity (Johnson *et al*., 1993). However, breeding for improved salt tolerance in many crops plants, including alfalfa has progressed slowly (Blum, 1988; Johnson *et al*., 1992; Nobel *et al*., 1984).

Development of salt tolerance in crops depends ultimately on two factors. First, availability of genetic variation with respect to tolerance, and second, exploitation of available genetic variation by screening and selection of those plants with superior performance when exposed to such stress

(Epstein *et al*., 1980; Shannon., 1984). The presence of phenotypic variation for salt tolerance at the seedling stage was reported for 35 alfalfa cultivars (Al-Khatib., 1991). It might there fore be that selection of highly salt tolerant genotypes between and within cultivars could be expected to provide useful material for further breeding, and for experimental comparisons (Al-Khatib *et al*., 1993). Alfalfa (*Medicago sativa*) is one of the most important cultivated forage legumes in Iran, but the main alfalfa producing areas is Azarbaijan region in the north- west. There are very rich alfalfa germplasm, so more variation expected for traits. This research as a part of synthetic variety improvement project with polycross and progeny test was carried out with native alfalfa ecotypes. The objectives of this study were to determine: (i) phenotypic variation between cultivars at different salinity levels, and (ii) change in forage yield resulting from saline stress.

MATERIALS and METHODS

The experiment was carried out at East Azarbaijan Agriculture and Natural Resources Research Center (AZARAN), Iran. Five Azarbaijan native alfalfa cultivars, Syah-Roud, Gara-Yongeh, Hasht-Roud, Khor-Khor and Bash-Kand were used in this experiment. Five sterilized seeds of each five cultivars were sown in individual 40cm × 75cm pots containing 12 kg loamy sand soils, covered with sand to depth of 10mm (Assadian & Miyamoto., 1987). The saturation extract of this soil had a pH of 7.4 and an Ec of 3.07 (mm mohs). Four salt levels were 3.07, 10, 20 and 30 (mm mohs) that they achieved by adding 0, 1.062, 2.931 and 5.071 g kg^{-1} NaCl to pots soil, respectively.

All treatments were watered to field capacity daily with non-saline water (Assadian & Miyamoto., 1987). Forage from each plant was harvested at 10% bloom by clipping 4 cm above the crown, and total dry weight (TDW), leaves dry weight (LDW), shoot dry weight (SDW), height (H), number of leaves (NL) and dry leaf/stem ratio (DLS) were measured for each plant 59, 104, 137, 160 and 200d post-planting. In our experiment a completely randomized design with 5×4 factorial arrangements and three replication were used. Factors were ecotypes (Syah-Roud, Gara-Yongeh, Hasht-Roud, Khor-Khor and Bash-Kand) and salt levels (0, 1.062, 2.931 and 5.071 g kg^{-1} NaCl). All treatments were replicated four times.

RESULTS and DISCUSSION

An ANOVA (Table 1) indicated that the response was significantly different among germplasm sources ($P<0.01$) as well as NaCl levels ($P<0.01$) and the interaction effect of cultivar×NaCl wasn't significant for all measured traits, except for DLS. The total means of trails of five cultivars are given in Table 2.

Ecotypes had differing responses to increasing NaCl concentration. Syah-Roud, Gara-Yonjeh and Hasht-Roud cultivars had the highest yield in no-salt condition, respectively. Syah-Roud and

Gara-Yonjeh ranked higher in percentage yields than other cultivars; however, there was no significant difference between them. Bash-Kand cultivar ranked substantially lower than other cultivars.

The NaCl effect was significant in reducing all measured traits of all five ecotypes. All traits under the salt treatments were significantly lower ($P<0.01$) than no-salt condition for all cultivars. All cultivars yields reduced significantly ($P<0.01$) by the salt treatment(Tabel 3).

Clearly from the outcome of the study, genetic variation seems to exist between cultivars, which, as has been a requirement for breeding program to improve salt tolerance (Al-Khatib *et al*., 1993). The screening method used in this study for five cultivars was sufficient to isolate tolerant cultivars. Although tolerance to salinity at the germination and seedling stages is highly desirable (Raghra Ram & Nabors., 1985), tolerance of the resultant adult plants is of equivalent importance. The link between the detection of variation in response to salinity and the breeding of salt tolerant crop is the knowledge that the phenotypic variation observed has to at least some degree a genetic basis (Al-Khatib *et al*., 1993). It would seem likely from the data presented here about phenotypic variability in response to NaCl, and the implied genetic basis of that variability, that further significant advances in NaCl tolerance in alfalfa may be archived.

Table 1. Analysis of variance for total dry weight (TDW) leaves dry weight (LDW), shoot dry weight (SDW), height (H), number of leaves (NL) and dry leave/stem ratio (DLS) of five cultivars in four NaCl concentrations.

S.O.V.	df	MS					
		TDW (g)	LDW (g)	SDW (g)	H (cm)	NL	DLS
NaCl con. (C)	3	30.18**	17.86**	12.37**	148.79**	45.87**	0.29**
Cultivar (V)	4	4.27**	2.57**	1.81**	26.33**	2.53**	0.21**
C * V	12	0.42 n.s	0.43 n.s	0.17 n.s	3.03 n.s	1.85 n.s	0.18 **
Error	40	0.39	0.28	0.19	2.82	0.493	0.07

**, *, and ns, Significant at 0.01, 0.05 and non significant, respectively.

Table 2. The total mean of TDW, LDW, SDW, H and NL of five cultivars •

Cultivar	TDW (g)	LDW (g)	SDW (g)	H (cm)	NL
Syah-Roud	4.96	3.01	1.76	80.52	12.61
Gara-Yongeh	4.81	3.19	1.67	78.81	12.93
Hasht-Roud	3.45	2.06	1.34	72.02	11.48
Khor-Khor	2.42	1.54	0.85	56.28	9.39
Bash-Kand	2.18	1.48	0.67	49.83	9.19
LSD5%	0.30	0.25	0.21	0.80	0.47

•. The abbreviations in this table same as table 1.

Table 3. Forage parameters of five Lucerne ecotypes in salty treatments and control •

NaCl(Ec,mm mohs)	TDW (g)	LDW (g)	SDW (g)	H (cm)	NL
Control	8.63	5.22	3.31	110.04	470.45
10	4.23	2.86	1.38	76.91	200.78
20	1.52	0.96	0.54	45.29	47.45
30	1.46	0.95	0.47	45.15	53.61
LSD5%	0.269	0.226	0.188	0.715	3.144

•. The abbreviations in this table same as table 1.

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The Ameliorative Effect of Saline or / Sodic Water on Maize (*Zea Mays* L.)Production

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ABSTRACT

A pot experiment was conducted in green house to evaluate the performance of two maize genotypes using saline or / sodic water with and with out amendments. There were eight treatments T_1 (control with EC 1.07 dS m^{-1}, SAR 1.63, and RSC 0 me L^{-1}), T_2 (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}), T_3 (EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1}), T_4 (T_2+ Gypsum on irrigation water basis), T_5 (T_3+ Gypsum on irrigation water basis),T_6 (T_1+ FYM @ 20 Mg ha^{-1}),T_7 (T_2+FYM @ 20 Mg ha^{-1}),T_8 (T_3+ FYM @ 20 Mg ha^{-1}) . Saline or/ sodic water were prepared with the help of quadratic equation and recommended doses of NPK fertilizers were used. Chlorophyll content was recorded after 40 days of sowing and fully expanded younger leaf were collected and stored in separate polypropylene tubes for sap extraction. The experimental results showed that chlorophyll content, Leaf area $plant^{-1}$, plant height, fresh weight of plant, dry weight of plant of all genotypes decreased significantly with increasing levels of saline or /sodic water but this decrease was minimum when gypsum and FYM was applied. Na^+ concentration of all genotypes increased significantly and decreased with gypsum and FYM application. Potassium and K^+: Na^+ ratio of all genotypes decreased significantly with increasing levels of saline or / sodic water but increased when gypsum and FYM was applied. EC_e, SAR and pH_s in soils after harvesting of crop increased also significantly. The application of FYM and gypsum proved to much helpful in improving soil quality and crop productivity.

Key words: saline or sodic water, maize, gypsum, FYM, soil salinity

INTRODUCTION

Water is a basic necessity for sustainable life in universe. Functions of water are manifold and diversified. Among the versatile functions just a few are; maintenance of turgidity, opening and closing of leaf stomata, uptake and translocation of nutrients and metabolites, synthesis of proteins and other related products, sequestration of excessive salts and toxic material into vacuoles or out of tissue and serving as medium for all biochemical and bio-energy reactions. The Indus River system is the main surface water resource in Pakistan, which is 170 MAF out of which 108 MAF is diverted to canal for irrigation purpose. At present net water available at the farm gate is about 83.37 MAF against the crop irrigation requirement of 134 MAF (Anonymous 2002).

The excessive accumulation of salts in soils of arid and semi arid region is a potential threat to the productivity of irrigated agriculture. It is estimated that over 800 million hectares of land in the world are affected by both salinity and sodicity (Munns, 2005). According to an estimate, 6.67 mha of land in Pakistan has been affected by salinity (Khan, 1998), which is about $1/3^{rd}$ of the total cultivated land of Pakistan. About 70-75% of pumped ground water is unfit for irrigation due to high EC, SAR, and RSC, therefore adversely affecting the yield of wheat, rice and maize (Ghafoor, *et al* 2001). Therefore a supplemental source of water has to be made to meet this deficit from underground water. For this purpose about 0.53 million tube wells are pumping about 49.91 MAF underground water in Pakistan (Anonymous, 2002).During the recent drought years, the canal supplies further decreased which necessitated the utilization of even poor quality underground water for crops. This strategy although increased the water supplies, yet resulted in deterioration of soil physical and chemical properties (Sarwar *et al*., 2002). Soil solution SAR increased significantly in direct proportional to SAR_{iw} and irrigation with higher SAR water decreased the permeability of soil resulting in accumulation of salts (Ahmad, 2002).

Maize (*Zea mays* L.) is an important crop and provides raw material for agro-based industry. It is not only consumed by human beings in the form of food grains, but also provides feed for livestock and poultry. Maize is highly nutritive and its grains contain starch 72, protein 10, oil 4.8, fiber 8.5, sugar 3.1, and ash 3.1 on percent basis (Chaudhary, 1983). In Pakistan, it is grown on an area of 1022 thousand hectare with an annual production of 3560 thousand tones (Govt. of Pakistan. 2006). Maize is moderately salt tolerant crop; reduction in yield of maize is a common phenomenon because of poor quality irrigation water. Sufficient information is not available about the performance of different maize genotypes and changes in chemical and physical properties of soil under our field conditions by irrigated with brackish tube well water. Many scientists studied changes in physical and chemical properties of soil under control condition by using different EC, SAR and RSC levels, which were not correlated with naturally available brackish water in our local conditions. So that it is now essential to acquire more information about the effect of brackish water on chemical properties of soil and yield of different maize genotypes.

This work will help in successful planning of brackish water for maize production and helpful in selection of best genotype which can be economically grown by irrigating with brackish tube well water. Keeping in view these considerations, the present study was planned with following specific objectives.

1. To evaluate the performance of different maize genotypes irrigated with brackish water and selection of best genotype.
2. To see the effect of brackish water on chemical properties of soil in sandy clay loam texture.
3. To evaluate the technology for economic utilization of brackish water.

MATERIAL and METHODS

Growth Conditions and Experimental Technique

The seed of maize varieties (Sahiwal -2002 and Pak- Fagawi) were taken from Maize Millet Research Institute (MMRI) Yousafwala, Sahiwal. The experiment was conducted in partially green house having glass covered roof, sides with iron wire screen and no control of humidity, temperature and light.

Normal soil free from any salinity and sodicity hazards was collected from research area of Institute of Soil and Environmental Sciences, up to 0-15 cm depth. The soil was air dried, ground and passed through a 2 mm sieve and thoroughly mixed and analyzed for pre-requisite physiochemical characters like EC_e, pH_s, SAR and textural class, which are given in Table -1. Soil was filled in Glazed pots (30 cm high and 25 cm diameter) at the rate of 12 kg per pot.

Soil textural class was determined by Hydrometer methods (Moddie *et al*., 1959) and textural class was determined by using international soil classification system (ISSS). Electrical conductivity of soil extract was recorded with the help of EC meter (Method 3a and 4a, USDA Hand book No.60, 1954). Calcium and magnesium was determined by titrating the sample with standard versinate solution by using EBT as an indicator (Method 7 USDA Hand book No.60, 1954). Sodium was determined with the help of Sherwood 410 Flame photometer (Method 10a USDA Hand book No.60, 1954).

SAR was calculated by using the following formula (Method 20b USDA Hand book No.60, 1954).

$$SAR = \frac{Na^+}{\sqrt{Ca + Mg /2}}$$

The experiment was laid out in a Completely Randomized Design (CRD) with three repeats with following treatments

Treatments

There were eight treatments viz:

T_1 (control with EC 1.07 dS m^{-1}, SAR 1.63, and RSC 0 me L^{-1}),
T_2 (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}),
T_3 (EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1}),
T_4 (T_2+ Gypsum on irrigation water basis),
T_5 (T_3+ Gypsum on irrigation water basis),
T_6 (T_1+ FYM @ 20 Mg ha^{-1}),
T_7 (T_2+FYM @ 20 Mg ha^{-1}),
T_8 (T_3+ FYM @ 20 Mg ha^{-1})

The combination of four salts ($NaHCO_3$, Na_2SO_4, $CaCl_2.2H_2O$ and $MgSO_4.7H_2O$) was used to prepare the levels of saline or sodic water with the help of quadratic equation.

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Brackish water + Tap water were used alternatively for irrigation throughout the growing period. Calculations of salts for developing brackish water (EC along with SAR of water and RSC) made with the help of quadratic equation. Total No. of irrigations were 13, 7 with tap water and 6 with brackish water. The quantity of water per irrigation per pot was one litre and total amount of brackish water applied per pot was 6 litre (Table -2)

Lay out of the Experiment

A basal dose of N, P and K fertilizers was applied at the rate of 200, 150 and 200 kg ha^{-1}, respectively (1.2 g / 10 Kg, 0.9 g / 10 Kg, 1.2 g / 10 Kg, N, P_2O_5 and K_2O, respectively). Urea, DAP and K_2SO_4 were used as the sources of the N, P and K respectively. The amount of Urea, DAP and K_2SO_4 were used 2.607g, 1.956g and 2.4g respectively to fulfill the requirement of NPK. All the P and K were applied at the time of sowing and nitrogen was split into three doses, at sowing, with first irrigation and at flowering stage. FYM was applied at the rate of 20 Mg ha^{-1} at the time of pot filling. Gypsum requirement of irrigation water is calculated by the following formula.

$$\text{GR kg/Acre} = \frac{198 \text{ x } 30 \text{ x } 220 \text{ x } 30 \text{ x } 5 \text{ x RSC x } 86}{1000 \text{ x } 1000 \text{ x } 1000}$$

Initially ten seeds of each cultivar were sown per pot. Thinning was done after 16 days of sowing, keeping three plants per pot. The crop was raised up to 60days and harvested before cob formation. Recommended cultural operations such as weeding, hoeing etc. and plant protection measures like sprays were adopted during the experiment. The crop was harvested before the time of cob formation (after 60days).

Chlorophyll content was measured with a Chlorophyll meter after 40days of sowing with Minolta SPAD-502 DL meter Japan. Plant height was measured with a meter rod at the time of harvesting. Plant fresh weight was taken with the help of electrical weighing balance. Plants were kept in oven for three days at 65°C and then dry weight was taken with the help of electrical weighing balance. Leaf area of plants was measured at the time of harvesting with the help of ΔT Area meter MK_2.

Fully expanded younger leaves were collected in 1.5 cm^3 polypropylene tubes and stored at freezing temperature (Akhtar *et al*, 1998) for chemical analysis.Frozen leaf samples in polypropylene tubes were thawed and crushed using a stainless steel rod with tapered end and sap was extracted. The sap was collected in the other polypropylene tubes and centrifuged at 6500 rpm for 5 minutes. The supernatant sap was collected and used for ionic analysis (Na^+, K^+). The sap was diluted as required with distilled water. Sodium and Potassium were determined using Sherwood 410 Flame Photometer.

Data of the experiment was subjected to statistical analysis using Completely Randomized Design in factorial arrangement (Fisher *et al*., 1925).

RESULTS and DISCUSSIONS

Effect of Brackish Water on Leaf Area (cm^2) of Maize

Data regarding leaf area of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 3. The comparison of genotypes indicate that the difference in leaf area of S-2000 and Pak-Fagawi genotype, the reduction in leaf area due to different treatments and the interaction of genotypes with treatments were significant at different levels of saline/sodic water.

In control genotype Pak-Fagawi performed well rather than S-2000 and the addition of FYM @ 20 Mg ha^{-1} also resulted to improve the leaf area of Pak-Fagawi.

At, EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}, Sahiwal-2000 gave maximum leaf area (530.1 cm^2) which was 18% less than control and the Pak-Fagawi gave minimum leaf area (520.4 cm^2) which was 29% less than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave maximum leaf area (567.7 cm^2) which was 23% less than control and (628 cm^2) which was 15% less than control while Sahiwal-2000 gave minimum leaf area (559 cm^2) which was 14% less than control and (574.5 cm^2) which was 11% less than control, respectively.

At, EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1}, Sahiwal-2000 gave maximum leaf area (415 cm^2) which was 36% less than control and the Pak-Fagawi gave minimum leaf area (351.9 cm^2) which was 52% less than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave maximum leaf area (480.8 cm^2) which was 35% less than control and (471.7 cm^2) which was 36% less than control while Sahiwal-2000 gave minimum leaf area (452.9 cm^2) which was 30% less than control and (448.8 cm^2) which was 31% less than control, respectively.

The genotype Sahiwal-2000 gave the maximum leaf area than the Pak-Fagawi when no amendment was applied while the genotype Pak-Fagawi gave the maximum leaf area than the Sahiwal-2000 when amendments were applied. The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive effect on leaf area. The results are in accordance with the findings of Cicek *et al*. (2002), who reported that leaf area was decreased significantly with increasing levels of saline/sodic water and Ahmad *et al*. (2003), who reported that leaf area was increased when gypsum and FYM were applied along with saline-sodic water.

Effect of Brackish Water on Chlorophyll Content (mg g^{-1}) of Maize

Data regarding chlorophyll content of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 4. The comparison of genotypes indicate that the difference in chlorophyll content of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the reduction in chlorophyll content due to saline/sodic water irrigation was significant in different treatments. Maximum chlorophyll content (24.3) was found when FYM at 20 Mg ha^{-1} applied with control, followed by control (23.5). While the minimum chlorophyll content (16.5) was found where brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} with out any amendment was applied. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) reduced the chlorophyll content of maize by 13% over control(23.5) while application of gypsum and FYM in the same treatment reduced the leaf area by 8% and 4%, respectively over control. Similarly there was 30% reduction in chlorophyll content over control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 20% and 15% reduction was observed in the same treatment when gypsum and FYM was applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive effect on chlorophyll content The results are in confirmation with those of Cicek *et al*. (2002), who reported that chlorophyll content was decreased significantly with increasing levels of brackish water and Ahmad *et* a*l*. (2003), Chaudhary *et* a*l*. (2004) who reported that chlorophyll content was increased when gypsum and FYM were applied along with saline-sodic water.

Effect of Brackish Water on Plant Height (cm) of Maize

Data regarding plant height of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 5. The comparison of genotypes indicates that the difference in plant height of S-2000 and Pak-Fagawi genotype was significant at different levels of saline/sodic water and the interaction of genotypes with treatments was non-significant. On an overall average basis, the genotype Pak-Fagawi showed 6% (30.6cm) more plant height as compared to Sahiwal-2000 (28.8cm). While the reduction in plant height due to saline/sodic water irrigation was also significant in different treatments. Maximum plant height (34.5cm) was found when FYM at 20 Mg ha^{-1} applied with control, followed by control (34.4cm), without any amendment, while the minimum plant height (24.9cm) was found where we applied brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} with out any amendment. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) reduced the plant height of maize by 19% (34.4cm) over control while application of gypsum and FYM in the same treatment reduced the plant height by 13% over control. Similarly there is 28% reduction in plant height with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 18% and 20% reduction was observed in the same treatment when gypsum and FYM were applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive effect on plant height and the reduction in plant height was 30-35% less as compared to high EC-SAR-RSC irrigation water. The results are in confirmation with those of Cicek *et al.* (2002), who reported that plant height was decreased significantly with increasing levels of saline/sodic water while maximum height in gypsum and FYM treated plots was also reported by Murtaza *et al*. (2006), Chaudhary *et al*. (2004) in sugarcane and Sharma *et al*. (2001) in rice-wheat system.

Effect of Brackish Water on Fresh Weight (g) of Maize

Data regarding fresh weight of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 6. The comparison of genotypes indicate that the difference in fresh weight of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the reduction in fresh weight due to saline/sodic water irrigation was significant in different treatments. Maximum fresh weight (46.8g) was found when FYM at 20 Mg ha^{-1} applied with control, followed by control (46.3g). While the minimum fresh weight (30.2g) was found where brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied with out any amendment. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) reduced the fresh weight of maize by 27% over control (46.3g) while application of gypsum and FYM in the same treatment reduced the fresh weight by 20% and 19%, respectively over control. Similarly there is 35% reduction in fresh weight over control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 29% and 30% reduction was observed in the same treatment when gypsum and FYM were applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive effect on fresh weight and the reduction in fresh weight was 10-20% less as compared to high EC-SAR-RSC irrigation water. The results are in accordance with Cicek *et al*. (2002), who reported that fresh weight of plant was decreased significantly with increasing levels of saline/sodic water and the usefulness of gypsum and FYM in ameliorating the adverse effects of poor quality irrigation water and improving fresh weight of crop has been reported by Chaudhary *et al*. (2004) and Sharma and Minhas (2004).

Effect of Brackish Water on Dry Weight (g) of Maize

Data regarding dry weight of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 7. The comparison of genotypes indicate that the difference in dry weight of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the reduction in dry weight due to saline/sodic water irrigation was significant in different treatments. Maximum dry weight (18.3g) was found in control, followed by control + FYM at 20 Mg ha^{-1} (17.2g). While the minimum dry weight (11.6g) was found where we apply brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} with out any amendment. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) reduced the dry weight of maize by 30% over control (18.3g) while application of gypsum and FYM in the same treatment reduced the dry weight by 24% and 23%, respectively over control. Similarly there is 37% reduction in dry weight with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 30% reduction was observed in the same treatment when gypsum and FYM was applied.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive effect on dry weight and the reduction in dry weight was 10-18% less as compared to high EC-SAR-RSC irrigation water. The results are in accordance with Cicek *et al*. (2002), who reported that dry weight of plant was decreased significantly with increasing levels of saline/sodic water and Chaudhary *et al*. (2004) in sugarcane and Sharma *et al*. (2001) in rice-wheat system who reported the usefulness of gypsum and FYM in ameliorating the adverse effects of poor quality irrigation water and improving dry weight of crop.

Ionic Concentration in Leaf Sap

Na^+ Concentration in Leaf Sap of Maize

Data regarding Na^+ concentration in leaf sap of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 8. The comparison of genotypes indicate that the difference in Na^+ concentration in leaf sap of S-2000 and Pak-Fagawi genotype, the reduction in Na^+ concentration in leaf sap due to different treatments and the interaction of genotypes with treatments were significant at different levels of saline/sodic water.

At control Pak-Fagawi gave minimum Na^+ concentration (215.7) as compared to Sahiwal-2000 which gave maximum Na^+ concentration (287.3). But when FYM @ 20 Mg ha^{-1} was applied in control Pak-Fagawi showed 7% decrease in Na^+ concentration over control while Sahiwal-2000 showed 4% decrease in Na^+ concentration over control.

At, EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}, Sahiwal-2000 gave maximum Na^+ concentration (412.6) which was 44% more than control (287.3) while the Pak-Fagawi gave Na^+ concentration (403.7) which was 87% more than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave Na^+ concentration (367) and (382.7) which was 70% and 77% more than control, respectively while Sahiwal-2000 gave Na^+ concentration (394.6) and (378) which was 37% and 32% more than control, respectively.

At, EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1}, Sahiwal-2000 gave maximum Na^+ concentration (455) which was 58% more than control (287.3) while the Pak-Fagawi gave Na^+ concentration (439.3) which was 104% more than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave Na^+ concentration (388.3) and (399) which was 80% and 85% more than control, respectively while Sahiwal-2000 gave Na^+ concentration (416.3) and (408.7) which was 45% and 42% more than control, respectively.

The Na^+ concentration in leaf sap of maize genotypes was less when gypsum was added to the brackish water and further decrease in Na^+ concentration in leaf sap was observed in treatment having FYM. On an overall basis Pak-Fagawi had less Na^+ concentration in leaf sap compared to Sahiwal-2000.The results are in accordance with the findings of Ahmad *et a*l. (2003), Yaduvanshi *et al*. (2005) and Murtaza *et al*. (2006) who reported that Na^+ concentration in leaf sap increases with increasing levels of saline-sodic water and decreases when gypsum and farm yard manure was applied.

K^+ Concentration in Leaf Sap of Maize

Data regarding K^+ concentration in leaf sap of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 9. The interaction of genotypes with treatments was non-significant but the comparison of genotypes indicate that the difference in K^+ concentration in leaf sap of S-2000 and Pak-Fagawi genotype was significant at different levels of saline/sodic water. The genotype Pak-Fagawi showed less K^+ concentration in leaf sap in all treatments as compared to Sahiwal-2000. On an overall average basis, the genotype Pak-Fagawi showed 19% (258) less K^+ concentration in leaf sap as compared to Sahiwal-2000 (308.9). While the reduction in K^+ concentration in leaf sap due to saline/sodic water irrigation was also significant in different treatments. Maximum K^+ concentration in leaf sap was found when FYM at 20 Mg ha^{-1} applied with control, followed by treatment having EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}+FYM

(291.7) which was 1% more than control (289.2). While the minimum K^+ concentration (252.5) was found in treatment having EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} without any amendment which was 13% less than control. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) reduced the K^+ concentration of leaf sap of maize by 6% (271.2) over control while application of gypsum and FYM in the same treatment decreased the K^+ concentration by 4% and increased the K^+ concentration by 1%, respectively over control. Similarly there was 13% reduction in K^+ concentration with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 8% and 3% reduction was observed in the same treatment when gypsum and FYM was applied, respectively.

The K^+ concentration in leaf sap of maize genotypes was more when gypsum was added to the brackish water and further increase in K^+ concentration in leaf sap was observed in treatment having FYM. On an overall basis Pak-Fagawi had less K^+ concentration in leaf sap compared to Sahiwal-2000.The results are in accordance with the findings of Ahmad *et a*l. (2003), Yaduvanshi *et al*. (2005) and Murtaza *et al*. (2006) who reported that K^+ concentration in leaf sap decreases with increasing levels of saline-sodic water and increases when gypsum and farm yard manure was applied.

Effect of Brackish Water on K^+/Na^+ Ratio of Maize

Data regarding K^+/Na^+ ratio of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 10. The comparison of genotypes indicate that the difference in K^+/Na^+ ratio of S-2000 and Pak-Fagawi genotype, the reduction in K^+/Na^+ ratio due to different treatments and the interaction of genotypes with treatments were significant at different levels of saline/sodic water.

At control Pak-Fagawi gave maximum K^+/Na^+ ratio (1.2) as compared to Sahiwal-2000 which was (1.1). But when FYM @ 20 Mg ha^{-1} was applied in control Pak-Fagawi showed 6% increase in K^+/Na^+ ratio over control while Sahiwal-2000 showed 17% increase in K^+/Na^+ ratio over control.

At, EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}, Sahiwal-2000 gave maximum K^+/Na^+ ratio (0.7) which was 36% less than control (1.1) while the Pak-Fagawi gave K^+/Na^+ ratio (0.6) which was 49% less than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave K^+/Na^+ ratio (1) and (0.7) which was 22% and 43% less than control, respectively while Sahiwal-2000 gave K^+/Na^+ ratio (1) and (0.9) which was 31% and 23% less than control, respectively.

At, EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1}, Sahiwal-2000 gave maximum K^+/Na^+ ratio (0.6) which was 44% less than control (1.1) while the Pak-Fagawi gave K^+/Na^+ ratio (0.5) which was 57% less than control but when gypsum and FYM were applied in the same treatment the Pak-Fagawi gave

K^+/Na^+ ratio (0.6) and (0.6) which was 48% and 48% more than control, respectively while Sahiwal-2000 gave K^+/Na^+ ratio (0.7) and (0.8) which was 39% and 32% less than control, respectively.

The K^+/Na^+ ratio of maize genotypes was more when gypsum was added to the brackish water and further increase in K^+/Na^+ ratio was observed in treatment having FYM. On an overall basis Pak-Fagawi had less K^+/Na^+ ratio as compared to Sahiwal-2000.The results are in accordance with the findings of Ahmad *et al*. (2003), Yaduvanshi *et al*. (2005) and Sharma and Minhas (2004) who reported that K^+/Na concentration in leaf sap decreases with increasing levels of saline-sodic water and increases when gypsum and farm yard manure was applied.

Soil Analysis

After harvesting of crop the soil is tested for chemical analysis (EC_e, pH_s, SAR).

Effect of Brackish Water on EC_e (dS m^{-1}) of Soil

Data regarding EC_e of soil of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 11. The comparison of genotypes indicate that the difference in EC_e of soil of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the increase in EC_e of soil due to saline/sodic water irrigation was significant in different treatments. Maximum EC_e (16) was found when water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied followed by T_2 (15.3) where water of EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1} was applied. While the minimum EC_e (12.2) was found where FYM was applied with control. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) increased the EC_e by 13% over control(13.5) while application of gypsum and FYM in the same treatment increased the EC_e by 4.6% and 1.2%, respectively over control. Similarly there was 19% increase in EC_e of soil with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 7.5% and 2.5% increase in EC_e of soil was observed in the same treatment when gypsum and FYM was applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive decrease in EC_e of soil as compared to high EC-SAR-RSC irrigation water. Similar trend of increase in EC_e was observed by Murtaza *et al*. (1996), Niazi *et al*. (2000) and Chaudhary *et al*. (1990) who reported a significant increase in EC_e at different soil depths with the application of different levels of saline-sodic water and a significant decrease in EC_e at different soil depths with the application of different doses of gypsum and farm yard manure.

Effect of Brackish Water on pH_s of Soil

Data regarding pH_s of soil of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 12. The comparison of genotypes indicate that the difference in pH_s of soil of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the increase in pH_s of soil due to saline/sodic water irrigation was significant in different treatments. Maximum pH_s (8.9) was observed when water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied followed by T_5 (8.8) where water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied along with gypsum. While the minimum pH_s (7.3) was found where FYM was applied in control. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) increased the pH_s by 12% over control while application of gypsum and FYM in the same treatment increased the pH_s by 10% and 9% respectively, over control. Similarly there was 17% increase in pH_s of soil with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 14% and 15% increase in pH_s of soil was observed in the same treatment when gypsum and FYM was applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive decrease in pH_s of soil as compared to high EC-SAR-RSC irrigation water. A reduction in pH_s was observed by Zaka *et al.* (2003) with the application of organic amendments and gypsum. It reflects that gypsum along with FYM caused maximum leaching of Na^+ to affect a decrease in SAR of soil which in turn decreased pH_s (Hussain *et al.*, 1993). Similar results were reported by Murtaza *et al.* (1999) and Niazi *et al.* (2000) who found a significant decrease in pH_s with the application of gypsum and farm yard manure.

Effect of Brackish Water on SAR (mmol $L^{-1})^{1/2}$ of Soil

Data regarding SAR of soil of two maize genotypes as affected by different saline/sodic water and the ameliorative effect of gypsum, FYM are presented in Table 13. The comparison of genotypes indicate that the difference in SAR of soil of S-2000 and Pak-Fagawi genotype was non significant at different levels of saline/sodic water and the interaction of genotypes with treatments was also non-significant. On an overall average basis, the increase in SAR of soil due to saline/sodic water irrigation was significant in different treatments. Maximum SAR (52.5) was observed when water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied followed by T_5 (43) where water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied along with gypsum. While the minimum SAR (13.3) was found where FYM was applied in control. On percent basis application of brackish water (EC 2.4 dS m^{-1}, SAR 16 (mmol $L^{-1})^{1/2}$, and RSC 2.25 meL^{-1}) increased the SAR by 148% over control while application of gypsum and FYM in the same treatment increased the SAR by 64% and 98% respectively, over control. Similarly there was 258% increase in SAR of soil with respect to control when brackish water of EC 3.6 dS m^{-1}, SAR 24 (mmol $L^{-1})^{1/2}$, and RSC 4.5 meL^{-1} was applied while 193% and 190% increase in SAR of soil was observed in the same treatment when gypsum and FYM was applied, respectively.

The addition of gypsum and FYM to the high EC-SAR-RSC water had a positive decrease in SAR of soil as compared to high EC-SAR-RSC irrigation water. A reduction in SAR was observed by Zaka *et al*. (2003) with the application of organic amendments and gypsum. It reflects that gypsum along with FYM caused maximum leaching of Na^+ to affect a decrease in SAR of soil (Hussain *et al*., 1993). Similar results were reported by Murtaza *et al*. (1999) and Niazi *et al*. (2000) who found a significant decrease in SAR with the application of gypsum and farm yard manure.

CONCLUSIONS

Chlorophyll content, Leaf area $plant^{-1}$, Plant height, fresh weight of plant, dry weight of plant of all genotypes decreased significantly with increasing levels of brackish water but this decrease was minimum when gypsum and FYM was applied. Na^+ concentration of all genotypes increased significantly with increasing levels of brackish water but this increase was reduced when gypsum and FYM was applied. K^+ concentration of all genotypes decreased significantly with increasing levels of brackish water, but was increased when gypsum and FYM applied. K^+: Na^+ ratio of all genotypes decreased significantly with increasing levels of brackish water but increased when gypsum and FYM was applied. EC_e, SAR and pH_s in soils after harvesting of crop increased significantly with increasing levels of brackish water but decreased when gypsum and FYM were applied. It was concluded that maize crop could successfully be grown with brackish water using gypsum and FYM amendments.

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Table 1. Physical and chemical Characteristics of the Soil.

Determination	**Value**	**Unit**
pH_s	7.24	_
EC_e	2.08	$dS\ m^{-1}$
SAR	8.65	$(mmol\ L^{-1})^{1/2}$
Textural Class	Sandy Clay Loam	(Sand 67.75%,Silt 16.25% Clay 16%)

Table 2. Salts added per litter of irrigation water to irrigate one pot per irrigation

Treatments	Na_2SO_4 (g/L)	$NaHCO_3$ (g/L)	$MgSO_4.7H_2O$ (g/L)	$CaCl_2.2H_2O$ (g/L)
T1	-	-	-	-
T2	1.070	0.47	0.330	0.050
T3	1.720	0.6835	0.3578	0.0534
T4	1.070 + *Gyp	0.47 + Gyp	0.330 + Gyp	0.050 + Gyp
T5	1.720 + Gyp	0.6835 + Gyp	0.3578 + Gyp	0.0534+Gyp
T6	Control+**FYM	Control + FYM	Control + FYM	Control+ FYM
T7	1.070 + FYM	0.47 + FYM	0.330 + FYM	0.050 + FYM
T8	1.720 + FYM	0.6835 + FYM	0.3578 + FYM	0.0534 + FYM

* Gyp is applied on irrigation water basis** FYM was added in pots @ 20 $Mgha^{-}$

Table 3. Effect of brackish water on leaf area (cm^2) of maize

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*737.8±6.20	646.6±7.58	691.9
T_2 (EC 2.4, SAR 16 and RSC 2.25)	520.4±0.87 (-29)	530.1±4.22 (-18)	525.3 (-24)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	351.9±10.42 (-52)	415.0±1.26 (-36)	383.5 (-45)
T_4 (T_2+ Gypsum $_{iw}$)	567.7±10.38 (-23)	559.0±3.78 (-14)	563.4 (-19)
T_5 (T_3+ Gypsum $_{iw}$)	480.8±13.56 (-35)	452.9±10.82 (-30)	466.8 (-33)
T6(T1+ FYM @ 20 Mg ha^{-1})	878.9±12.87 (19)	691.9±10.51 (7)	785.4 (14)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	628.0±2.13 (-15)	574.5±2.45 (-11)	601.3 (-13)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	471.7±2.06 (-36)	448.8±4.61 (-31)	460.2 (-34)
Mean	579.6	539.8	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 4. Effect of brackish water on chlorophyll content (mg g^{-1}) of maize

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*23.0±2.32	23.9±0.53	23.5
T_2 (EC 2.4, SAR 16 and RSC 2.25)	20.1±0.21 (-13)	20.7±1.11 (-14)	20.4 (-13)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	15.6±2.27 (-32)	17.4±3.12 (-27)	16.5 (-30)
T_4 (T_2+ Gypsum $_{iw}$)	22.2±3.08 (-4)	21.2±0.32 (-11)	21.7 (-8)
T_5 (T_3+ Gypsum $_{iw}$)	19.6±0.55 (-15)	18.2±0.62 (-24)	18.9 (-20)
T6(T1+ FYM @ 20 Mg ha^{-1})	24.6±0.81 (7)	24.1±0.63 (1)	24.3 (4)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	23.4±0.23 (-3)	22.6±1.14 (-6)	23.0 (-4)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	20.6±0.83 (-11)	19.6±0.85 (-18)	20.1 (-15)
Mean	21.1	21.0	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 5. Effect of brackish water on plant height (cm) of maize

Treatments	**Pak- Fagwai**	**Sahiwal -2002**	**Mean**
T_1 (Control)	*36.6±0.74	32.1±0.91	34.4
T_2 (EC 2.4, SAR 16 and RSC 2.25)	27.5±1.25 (-25)	28.2±0.49 (-12)	27.8 (-19)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	24.4±0.60 (-33)	25.3±0.51 (-21)	24.9 (-28)
T_4 (T_2+ Gypsum $_{iw}$)	30.5±0.58 (-17)	29.6±0.73 (-8)	30.0 (-13)
T_5 (T_3+ Gypsum $_{iw}$)	29.4±0.67 (-20)	27.0±0.84 (-16)	28.2 (-18)
T6(T1+ FYM @ 20 Mg ha^{-1})	36.7±0.74 (0.3)	32.3±0.49 (0.7)	34.5 (0.5)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	30.8±2.56 (-16)	29.3±1.08 (-9)	30.0 (-13)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	28.8±2.18 (-21)	26.3±0.69 (-18)	27.6 (-20)
Mean	30.6	28.8	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table-6: Effect of brackish water on fresh weight (g) of maize

Treatments	**Pak- Fagwai**	**Sahiwal-2002**	**Mean**
T_1 (Control)	*48.9±1.28	43.6±3.11	46.3
T_2 (EC 2.4, SAR 16 and RSC 2.25)	32.9±2.81 (-23)	34.9±3.14 (-25)	33.9 (-27)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	29.4±0.85 (-40)	30.9±3.92 (-36)	30.2 (-35)
T_4 (T_2+ Gypsum $_{iw}$)	37.8±2.41 (-23)	36.4±2.15 (-21)	37.1 (-20)
T_5 (T_3+ Gypsum $_{iw}$)	33.6±2.65 (-31)	31.8±1.88 (-34)	32.7 (-29)
T6(T1+ FYM @ 20 Mg ha^{-1})	49.2±1.75 (0.5)	44.5±2.15 (2.6)	46.8 (1.3)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	38.4±0.88 (-22)	36.3±1.21 (-21)	37.3 (-19)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	32.7±2.70 (-33)	31.8±2.20 (-34)	32.3 (-30)
Mean	37.9	36.3	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 7. Effect of brackish water on dry weight (g) of maize

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*19.6±1.39	17.0±1.05	
T_2 (EC 2.4, SAR 16 and RSC 2.25)	12.3±1.65 (-37)	13.1±0.81 (-23)	
T_3 (EC 3.6, SAR 24 and RSC 4.5)	11.1±0.92 (-43)	12.1±0.05 (-29)	
T_4 (T_2+ Gypsum $_{iw}$)	14.0±0.68 (-29)	14.0±1.49 (-18)	
T_5 (T_3+ Gypsum $_{iw}$)	13.2±1.05 (-33)	12.4±0.47 (-27)	
T6(T1+ FYM @ 20 Mg ha^{-1})	20.0±0.78 (2)	17.1±0.27 (0.7)	
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	14.5±0.47 (-26)	13.8±1.19 (-19)	
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	13.1±0.93 (-33)	12.8±0.47 (-25)	
Mean	14.5	13.9	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 8. Effect of brackish water on Na^+ content (m mol/m^3) of maize

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*215.7±3.84	287.3±11.26	
T_2 (EC 2.4, SAR 16 and RSC 2.25)	403.7±7.54 (87)	412.6±6.01 (44)	
T_3 (EC 3.6, SAR 24 and RSC 4.5)	439.3±2.73 (104)	455.0±7.37 (58)	
T_4 (T_2+ Gypsum $_{iw}$)	367.0±10.41 (70)	394.6±5.13 (37)	
T_5 (T_3+ Gypsum $_{iw}$)	388.3±11.14 (80)	416.3±2.33 (45)	
T6(T1+ FYM @ 20 Mg ha^{-1})	201.0±6.93 (-7)	276.7±1.45 (-4)	
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	382.7±12.57 (77)	378.0±8.89 (32)	
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	399.0±10.41 (85)	408.7±9.33 (42)	
Mean	355.8	378.6	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 9. Effect of brackish water on K^+ content (m mol/m^3) of maize

Treatments	**Pak- Fagwai**	**Sahiwal -2002**	**Mean**
T_1 (Control)	*260.3±2.73	318.0±4.36	
T_2 (EC 2.4, SAR 16 and RSC 2.25)	247.0±5.51 (-5)	295.3±5.78 (-7)	
T_3 (EC 3.6, SAR 24 and RSC 4.5)	227.2±9.24 (-13)	277.7±8.19 (-13)	
T_4 (T_2+ Gypsum $_{iw}$)	253.3±5.21 (-3)	304.3±4.04 (-4)	
T_5 (T_3+ Gypsum $_{iw}$)	243.3±3.76 (-7)	287.4±8.09 (-10)	
T6(T1+ FYM @ 20 Mg ha^{-1})	320.7±6.57 (23)	358.3±5.78 (13)	
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	262.0±4.73 (1)	321.3±4.33 (1.0)	
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	250.3±3.71 (-4)	309.0±5.77 (-3)	
Mean	258.0	308.9	

Values in parentheses show % increase/decrease over control.

*Average of three replications ± S.E

Table 10. Effect of brackish water on K^+/Na^+ ratio of maize

Treatments	**Pak- Fagwai**	**Sahiwal -2002**	**Mean**
T_1 (Control)	*1.2±0.01	1.1±0.04	1.2
T_2 (EC 2.4, SAR 16 and RSC 2.25)	0.6±0.02 (-49)	0.7±0.02 (-36)	0.7 (-43)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	0.5±0.02 (-57)	0.6±0.01 (-44)	0.6 (-51)
T_4 (T_2+ Gypsum $_{iw}$)	1.0±0.03 (-22)	1.0±0.01 (-31)	1.0 (-26)
T_5 (T_3+ Gypsum $_{iw}$)	0.6±0.02 (-48)	0.7±0.02 (-39)	0.7 (-44)
T6(T1+ FYM @ 20 Mg ha^{-1})	1.3±0.04 (6)	1.3±0.02 (17)	1.3 (11)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	0.7±0.03 (-43)	0.9±0.03 (-23)	0.8 (-34)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	0.6±0.02 (-48)	0.8±0.02 (-32)	0.7 (-40)
Mean	0.8	0.9	

Values in parentheses show % increase/decrease over control.

*Average of three replications ± S.E

Table 11. Effect of brackish water on K^+/Na^+ ratio of maize

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*1.2±0.01	1.1±0.04	1.2
T_2 (EC 2.4, SAR 16 and RSC 2.25)	0.6±0.02 (-49)	0.7±0.02 (-36)	0.7 (-43)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	0.5±0.02 (-57)	0.6±0.01 (-44)	0.6 (-51)
T_4 (T_2+ Gypsum $_{iw}$)	1.0±0.03 (-22)	1.0±0.01 (-31)	1.0 (-26)
T_5 (T_3+ Gypsum $_{iw}$)	0.6±0.02 (-48)	0.7±0.02 (-39)	0.7 (-44)
T6(T1+ FYM @ 20 Mg ha^{-1})	1.3±0.04 (6)	1.3±0.02 (17)	1.3 (11)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	0.7±0.03 (-43)	0.9±0.03 (-23)	0.8 (-34)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	0.6±0.02 (-48)	0.8±0.02 (-32)	0.7 (-40)
Mean	0.8	0.9	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 12. Effect of brackish water on EC_e (dS m^{-1}) of soil

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*13.1±0.81	13.9±0.53	13.5
T_2 (EC 2.4, SAR 16 and RSC 2.25)	15.7±0.61 (20)	14.9±0.99 (7)	15.3 (13)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	16.0±0.68 (22)	16±0.50 (15)	16.0 (19)
T_4 (T_2+ Gypsum $_{iw}$)	14.3±0.17 (9)	14.0±0.26 (0.7)	14.1 (4.6)
T_5 (T_3+ Gypsum $_{iw}$)	14.0±0.96 (7)	15.0±0.28 (8)	14.5 (7.5)
T6(T1+ FYM @ 20 Mg ha^{-1})	12.2±0.66 (-7)	12.3±0.42 (-11)	12.2 (-9)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	13.6±0.08 (5)	13.6±0.20 (-2)	13.7 (1.2)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	13.5±0.26 (3)	14.2±0.63 (2)	13.9 (2.5)
Mean	13.9	14.0	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 13. Effect of brackish water on pH_s of soil

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*7.7±0.07	7.6±0.06	7.7
T_2 (EC 2.4, SAR 16 and RSC 2.25)	8.5±0.04 (11)	8.6±0.06 (14)	8.6 (12)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	8.9±0.12 (15)	8.9±0.25 (18)	8.9 (17)
T_4 (T_2+ Gypsum $_{iw}$)	8.6±0.08 (12)	8.4±0.14 (10)	8.5 (10)
T_5 (T_3+ Gypsum $_{iw}$)	8.8±0.17 (14)	8.7±0.20 (15)	8.8 (14)
T6(T1+ FYM @ 20 Mg ha^{-1})	7.2±0.11 (-6)	7.4±0.05 (-3)	7.3 (-5)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	8.3±0.12 (8)	8.5±0.19 (12)	8.4 (9)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	8.6±0.07 (11)	9.0±0.15 (19)	8.8 (15)
Mean	8.3	8.4	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

Table 14. Effect of brackish water on SAR $(mmol\ L^{-1})^{1/2}$ of soil

Treatments	Pak- Fagwai	Sahiwal -2002	Mean
T_1 (Control)	*15.0±0.90	14.3±0.75	14.7
T_2 (EC 2.4, SAR 16 and RSC 2.25)	36.7±1.94 (145)	36.1±3.06 (152)	36.4 (148)
T_3 (EC 3.6, SAR 24 and RSC 4.5)	52.9±1.69 (253)	52.0±1.69 (264)	52.5 (258)
T_4 (T_2+ Gypsum $_{iw}$)	24.2±1.04 (61)	23.8±0.84 (67)	24.0 (64)
T_5 (T_3+ Gypsum $_{iw}$)	43.3±1.44 (189)	42.6±1.86 (198)	43.0 (193)
T6(T1+ FYM @ 20 Mg ha^{-1})	13.3±0.45 (-11)	13.3±1.52 (-7)	13.3 (-9)
T_7 (T_2 + FYM @ 20 Mg ha^{-1})	29.5±0.77 (97)	28.5±0.70 (99)	29 (98)
T_8 (T_3 + FYM @ 20 Mg ha^{-1})	43.9±1.17 (193)	41.2±0.80 (188)	42.5 (190)
Mean	32.3	31.5	

Values in parentheses show % increase/decrease over control.
*Average of three replications ± S.E

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Evaluating the Effect of Crop Residue on Water Relations of Rainfed Chickpea in Maragheh, Iran, Using Simulation

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ABSTRACT

In no-till management, the crop residue is left on the soil surface. The effect of residue on water relations of soil, and subsequently that of plant are highly dependent on weather conditions. This study was aimed to evaluate the effect of maize residue (3.85 mg ha^{-1}) on water relations of rainfed chickpea, using model CYRUS. Firstly, this model was recoded in Qbasic programming; then a simple sub-routine was added to include the effect of crop residue; finally, it was run for long-term daily weather data (1961-2004) of Maragheh (winter-dominant rainfall), Iran. It was revealed that, as compared to control, the residue treatment results in that the value of fraction transpiration soil water in rooting depth [FTSW: ranges from 0 (wilting point) to 1 (field capacity)] to be 2.72% higher during emergence (E) to flowering (R1), 10.02% higher across R1 to pod initiation (R3), 7.59% higher for R3 to pod filling (R5), 1.82% higher during R5 to pod yellowing (R7) and 1.32% more over R7 to maturity (R8). Across the S-E, E-R1, and R1-R3 periods, the value of evapotranspiration (ET) was higher for non-mulching conditions, as compared to mulching conditions. On the other hand, across the R5-R7 and R7-R8 period, that of ET appeared to be higher for mulching than non-mulching conditions. The difference between named conditions for transpiration appeared to be negligible across R3-R5 period; while it was considerable over other periods. Across the E-R1 period, the transpired water from covered-soil was 56.89 mm, which is about 3.34 mm higher than that from bared-soil. This increasing effect of residue was 6.8% across R3-R5 period, 23.0% across R5-R7, and 35.1% across R7-R8. Considering the ratio of transpiration to evaporation, the mentioned beneficial impact of residue was more considerable across reproductive stages (R1-R8), than across vegetative stage (E-R1). The difference between bared- and covered-soil for named ratio was 0.14 over E-R1 period, 2.00 over R1-R3 period, 3.49 over R3-R5 period, 4.87 over R5-R7 period, and 2.98 over R7-R8 period.

Key words: Crop residue; water relation; chickpea; simulation

INTRODUCTION

There is a general consensus that global average surface air temperature has increased during the 20th century (Acia, 2004). Therefore, it is expected that in most cases the atmospheric demand for transpiration and evaporation to have an upwardly trend. Golubev et al. (2001) reported increasing evapotranspiration (ET) (measured empirically using massive weighing lysimeter data) during past decades in the former USSR where long-term data were available. A trend towards increasing ET is also inferred from continental-scale water balance studies that documented increases in precipitation that were substantially greater than increases in runoff during the period 1950–2000 in the conterminous United States (Milly and Dunne, 2001). Possible trends in evaporation over the oceans and their relation to precipitation and runoff have been addressed indirectly using salinity time-series data. Salinity in the surface 500–1000 m depth increased significantly between the periods 1955–1969 and 1985–1999 along a transect in the western basin of the Atlantic Ocean at latitudes between 40 ^{o}N and 20 ^{o}S (Curry et al., 2003). Curry et al. (2003) also reported systematic freshening poleward of these latitudes. The salinity increase was spatially coherent with measured warming of the sea surface (Curry et al., 2003). For 24 ^{o}N latitude (the salinity maximum), the evaporation minus precipitation (E–P) anomaly averaged 5 cm/year during the 40-year period (Curry et al., 2003).

Additionally, some reports indicate the declining trend in precipitation during past decades. An analysis of rainfall data since 1910 by Haylock and Nicholls (2000) reveals a large decrease in total precipitation and related rain days in southwestern Australia. Over the last 50 years, there has been a slight decrease in annual precipitation over China (Zhai et al., 1999), which is supported by a significant (5% confidence level) decrease in the number of rainy days (3.9% per decade). There have been marked decreases in precipitation in the latter part of the 20th century over sorthern Europe (Scho¨nwiese and Rapp, 1997). Since 1976, decreases in precipitation have occurred in South Pacific Convergence Zone (Salinger et al., 1996). There have also been significant decreases in rain days since 1961 throughout Southeast Asia and the western and central South Pacific (Manton et al., 2001). Hulme (1996) found significant decreases in precipitation being observed since the late 1970s. Using wavelet-based principal component analysis, Mwale et al. (2004) found that East Africa suffered a consistent decrease in the September–October–November rainfall from 1962 to 1997, resulting in 12 droughts between 1965 and 1997. Dore and Lamarche (2005) found evidence of a dramatic decline in precipitation in the Sahel, enough to characterize it as a ‘‘structural break’’.

More over the above mentioned problems, the value of runoff has been increased, which is good index for lower infiltration and storage of rain-water into the soil. Lins and Michaels (1999) found an increased runoff (stream flow) in United States. Georgievskii et al. (1996) also noted increases in stream flow and a rise in the level of the Caspian Sea over the last several decades over western Russia. Multidecadal stream flow data in Canada have revealed that there are apparent increases in runoff (Zhang et al., 2000). Published reports indicating that runoff from the Mississippi river increased by 22% from 1949 to 1997 (Milly and Dunne, 2001). Several analyses (e.g. Lettenmaier et al., 1999) have detected increases in stream flow across much of the contiguous United States. Stream flow data for major rivers in southeastern South America for the period 1901 to 1995 show that stream flow has increased since the mid-1960s (Garcia and Vargas, 1998).

The above mentioned reports reveal the necessity of focusing on the treatment (s), like mulching, which results in decreased soil evaporation and optimized rain-water-infiltration into the soil. The numerous positive impacts have been attributed to the leaving the crop residue on soil surface, like enhancing yield (Power et al., 1998), soil organic carbon (Clapp et al., 2000), soil nitrogen content (Kumar and Goh, 2000), and C/N ratio (Martens, 2000). In this simulation study, it was aimed to investigate the effects of crop residue on water relations at different development stages of rainfed chickpea.

MATERIAL and METHODS

Model Description

In this study, the CYRUS model was recoded in Qbasic programming language, and run to compare the residue-covered-soil with bared-soil for water relations across the different development stages of rainfed chickpea. This model was initially designed in 1999 by Soltani et al. (1999). Then it was developed for seedling emergence (Soltani et al., 2006d), for leaf expansion and senescence (Soltani et al., 2006c), for response of leaf expansion and transpiration to soil water deficit (Soltani et al., 2000), for response to photoperiod (Soltani et al., 2004a), for harvest index (Soltani et al., 2005), for phenological development (Soltani et al., 2006a), for nitrogen accumulation and partitioning (Soltani et al. 2006b), and for the effect of temperature and CO_2 (Soltani et al., 2007). The CYRUS has been used for evaluating yield of chickpea and its stability in dormant seeding (Soltani and Torabi, 2007), determining optimum phenology of chickpea for now and future (Rahimi-Karizaki and Soltani, 2007), potential effects of individual versus simultaneous climate change factors on growth and water use in chickpea (Gholipoor, 2007), evaluating the effect of future climate change on yield of rainfed chickpea in northwest of Iran (Barzegar and Soltani, 2007), comparing relative effects of temperature and photoperiod on development rate of chickpea (Gholipoor and Soltani, 2006), and optimizing the dormant sowing of chickpea (Gholipoor et al., 2006). The soil water balance sub model of this model with some little modifications has been applied for comparative evaluating the climate-related runoff production in slopped farms of Iran (Gholipoor, 2008), and to study the effect of past climate change on runoff in Gorgan, Iran (Gholipoor and Soltani, 2005).

Briefly, in seedling emergence sub model of CYRUS, emergence response to temperature is described by a dent-like function with cardinal temperatures of 4.5 (base), 20.2 (lower optimum), 29.3 (upper optimum) and 40 ^oC (ceiling temperature). Six physiological days (*i.e.* number of days under optimum temperature conditions; equivalent to thermal time of 94 ^oCdays) are required from sowing to emergence at a sowing depth of 5 cm. The physiological day's requirement is increased by 0.9 days for each centimeter increase in sowing depth. Snow cover effect is considered on the basis of daily maximum and minimum temperatures, as presented in Ritchie (1991).

In leaf sub model, cardinal temperatures for nod appearance are 6.0 ^oC for base, 22.2 ^oC for optimum and 31.0 ^oC for ceiling temperature. Leaf senescence on the main stem starts when the main stem has about 12 nodes and proceeds at a rate of 1.67% per each day increase in physiological day (a day with non-limiting temperature and photoperiod). Leaf production per plant versus main stem node number occurs in two phases; phase 1 when plant leaf number increases with a slower and density-independent rate (three leaves per node), and phase 2 with a higher and density-dependent rate of leaf production (8–15 leaves per node).

Phenological development is calculated using multiplicative model that includes a dent-like function for response to temperature, and a quadratic function for response to photoperiod. Photoperiod-sensitivity is considered to be different in various cultivars, and cardinal temperatures for phenological development are 21 ^{o}C for lower optimum, 32 ^{o}C for upper optimum and 40 ^{o}C for ceiling temperature. The cultivars require 25-31 physiological days from E (emergence) to R_1 (flowering), 8-12 from R1 to R3 (pod initiation), 3-5 from R3 to R5 (pod filling), 17-18 from R5 to R7 (pod yellowing) and 6 from R7 to R8 (physiological maturity).

The biomass production is calculated based on extinction coefficient (KS) and radiation use efficiency (RUE). It assumes that KS is not radiation- and plant density-dependent. The RUE assumes to be constant (1 g MJ^{-1}) across plant densities, but not across temperatures and CO_2 concentrations. After correction of RUE for temperature and CO_2 concentration, it is not affected by either solar radiation or vapor pressure deficit (VPD). The partitioning of biomass between leaves and stems is achieved in a biphasic pattern before first-seed stage. After this stage, the fixed partitioning coefficients are used for calculating biomass allocation.

Many simulation models assume linearity of harvest index increases as a simple means to analyze and predict crop yield in experimental and simulation studies (see Soltani et al., 2005 and related references for more detail). Despite of these models, the CYRUS model assumes that its increase is biphasic with turning point temperature equal to 17 ^{o}C. The similar approach has been proved to be appropriate for application in wheat (Soltani et al. 2004b).

The relation between total N and total biomass throughout the growth period is based on non-linear segmented model (with two segments/phases). Therefore, the rates of N accumulation during phase 1 and 2 are different, and the turning point between two phases of N accumulation is considered 218.3 g biomass per m^2. The distribution of N to different parts of plant is calculated using appropriate functions and coefficients.

In soil water balance sub model, daily soil water content is estimated as fraction transpirable soil water (FTSW, which ranges from 0 to 1) to calculate the degree of water limitation experienced by the crop. Similar to that described by Amir and Sinclair (1991), it accounted for additions from infiltration, and losses from soil evaporation, transpiration and drainage. Infiltration is calculated from daily rainfall less any runoff. Runoff is estimated using the curve number technique (Knisel, 1980). Soil evaporation

(Ev.) is calculated using the two-stage model as implemented in spring wheat model developed by Amir and Sinclair (1991). Stage I Ev. occurs when water present in the top 200 mm of soil, and FTSW for the total profile is greater than 0.5. Stage II Ev. occurs when the water in the top layer is exhausted or the FTSW for the total soil profile reaches to less than 0.5. In stage II, Ev. is decreased substantially as a function of the square root of time since the start of stage II. The calculation of Ev. is returned to stage I only when rain or irrigation of greater than 10 mm occurs. Like procedure of Tanner and Sinclair (1983) and Sinclair (1994), the daily transpiration rate is calculated directly from the daily rate of biomass production, transpiration efficiency coefficient (=5 Pa) and VPD. The calculation of VPD is based on suggestion of Tanner and Sinclair (1983) that it to be approximately 0.75 of the difference between saturated vapor pressure calculated from daily maximum and minimum temperatures.

Procedure of Calculating the Residue Effects, and Evaluated Attributes

The selected location was Maragheh (37° 22' 54" N and 46° 15' 15" E) from Iran, which has long-term (1961-2004) and reliable daily weather data. A simple sub-routine was added to CYRUS, to include the effect of crop residue. The sub-routine was based on the procedure of Stockle and Nelson (1994). In this method, the actual evaporation is function of residue and canopy cover. The effect of residue is mathematically calculated based on (1) area covered by one average straw per mass of one average straw (a crop parameter), and (2) the total residue mass per unit soil area. The residue mass was set to be 3.85 mg maize residue ha^{-1}.

The main calculated attributes were FTSW for top 20 cm soil, FTSW for top 60 cm soil, FTSW for rooting depth, transpiration, ratio of transpiration to evaporation and evapotranspiration. The value of FTSW lower than 0.34 at which the relative transpiration tends to be decreased (Soltani et al., 1999) was considered as drought.

RESULTS and DISCUSSIONS

The results regarding the value of fraction transpirable soil water in top 20 cm (FTSW-20) of bared- and residue-covered-soil were shown in Fig. 1. For both residue- and non-residue-conditions, the highest and 2nd highest FTSW-20 were found across sowing (S) to emergence (E) period, and E to flowering (R1) period, respectively. This is due to the fact that the studied location, like other locations of Iran, is a winter-dominant rainfall. So that, the considerable portion of precipitation is dropped during autumn and winter. Therefore, as chickpea grow, the soil-stored-water is lost, especially at upper layers of the soil. The difference between periods R1 to pod initiation (R3), R3 to pod filling (R5), R5 to pod yellowing (R7) appeared to be little for averaged value of FTSW-20 over residue- and non-residue-conditions. For period close to maturity, i.e. R7 to maturity (R8), it found no transpirable soil water for both residue and non-residue conditions. Across S-E, that of FTSW-20 was 0.559 for covered-soil, which is about 1.5 times higher than control (bared-soil). For period E-R1, it was 0.202 and 0.230 for bared- and covered-soil, respectively. Over R1-R3, R3-R5, and R5-R7, the value of FTSW-20 ranged from 0.013 to 0.023 for bared-soil, and from 0.018 to 0.030 for covered-soil. Generally, the top 20 cm layer of the soil is called "evaporative layer". The inhibitory effect of left crop residue on evaporation was more considerable at earlier stages of development of chickpea; at the end of growing period of rainfed-chickpea, the residue had not any benefit, which is due to lack of water for evaporation.

In top 60 cm of the soil, the wettest situation was expectedly found during period from sowing to emergence (Fig. 2). Considering the threshold value for experiencing the drought by chickpea, i.e. FTSW equal to 0.34, it could be concluded that in mentioned layer of the soil of Maragheh, Iran, there is enough stored-water for supporting the growth and development of rainfed-chickpea grown in both bared- and covered-soil until flowering. At S-E, leaving the residue on the soil surface caused that the value of FTSW-60 to be 7.3% higher than bared-soil. At E-R1, it was 0.525 and 0.582 for control and mulched-soil, respectively. For bared-soil (and for residue-covered soil) the FTSW-60 was 0.040 (0.069) at R1-R3, 0.013 (0.023) at R3-R5, 0.003 (0.004) at R5-R7, and 0 (0) at R7-R8. These results clearly indicate that there is serious drought in top 60 cm of the soil at reproductive stages of chickpea; mulching the soil can in some extend alleviate the drought.

In view point of growth and development of the rainfed-crops, like chickpea, the averaged value of FTSW across rooting depth of the crop (FTSW-Total) is more reliable than FTSW for top 20 cm and 60 cm of the soil. This is because of the fact that when the upper layers of the soil is dried due to transpiration, and especially evaporation, the lower layers are wetter, which is as result of much decreased evaporation; the roots can absorb the water from these deeper layers of soil, and hence the life-cycle of chickpea could successfully be completed. As seen in Fig. 3, the value of FTSW-Total across R7-R8 has never been declined to zero, which is in spite of FTSW-20 and FTSW-60 cases. Like FTSW-20 and FTSW-60 cases, the value of FTSW-Total tended to be the highest for period S-E. At this period, the beneficial effect of mulching reached to about 13% of the non-mulching situation. Across E-R1, the value of difference between bared- and covered-soil for FTSW-Total was 0.027 over E-R1 period, which is lower than that of difference over R1-R3 period (0.1). This difference was 0.076 over R3-R5, 0.018 over R5-R7, and 0.013 over R7-R8.

The comparative values of transpiration for mulching- and non-mulching-conditions are shown in Fig. 4. The difference between named conditions for transpiration appeared to be little across R3-R5 period; while it was considerable over other periods. Across the E-R1 period, the transpired water from covered-soil was 56.89 mm, which is about 3.34 mm higher than that from bared-soil. This increase in transpiration soil water proves the beneficial effect of residue on saving the water by decreasing the evaporation. This positive effect was 6.8% across R3-R5 period, 23.0% across R5-R7, and 35.1% across

R7-R8. Based on ratio of transpiration to evaporation (Fig. 5), it seems that the mentioned beneficial impact of residue to be more considerable across reproductive stages (R1-R8), as compared to vegetative stage (E-R1). The difference between bared- and covered-soil for named ratio was 0.14 over E-R1 period, 2.00 over R1-R3 period, 3.49 over R3-R5 period, 4.87 over R5-R7 period, and 2.98 over R7-R8 period.

Generally, it is hypothesized that the value of evapotranspiration (ET) may be the same for residue- and non-residue-conditions. Because, leaving the residue cause that evaporation to be decreased, but transpiration to be increased (due to saving the water in to the soil and hence enhancing stored-water for transpiration). The result of present study indicated that this hypothesis is true just for the R3-R5 period (Fig. 6). Across the S-E, E-R1, and R1-R3, the value of ET was higher for non-mulching conditions, as compared to mulching conditions; the difference between mentioned conditions was 8.67 mm across S-E, 3.65 mm across E-R1, and 0.66 mm across R1-R3. On the other hand, across the R5-R7 and R7-R8 period, that of ET appeared to be higher for mulching conditions, when compared with non-mulching conditions; the difference was 3.26 and 1.18 mm for named periods, respectively.

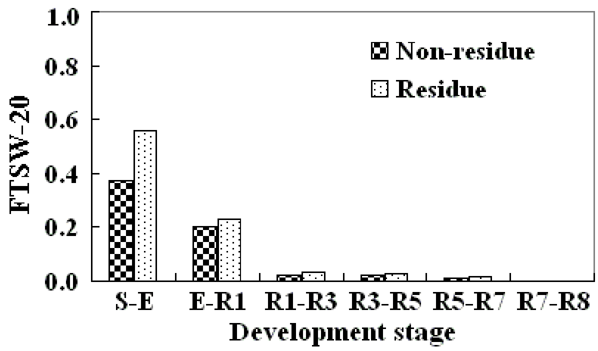

Fig. 1. The value of fraction transpirable soil water in top 20 cm (FTSW-20) of bared- and residue-covered-soil across different development stage of rainfed chickpea.

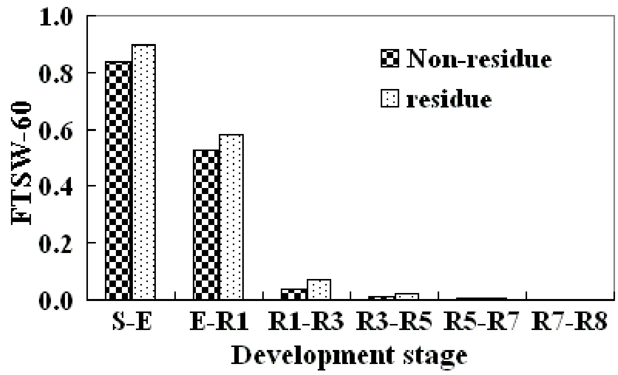

Fig. 2. The value of fraction transpirable soil water in top 60 cm (FTSW60) of bared- and residue-covered-soil over different development stage of rainfed chickpea.

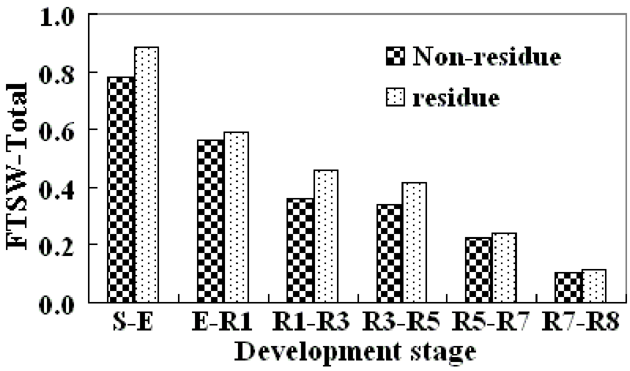

Fig. 3. The value of fraction transpirable soil water in rooting depth (FTSW) of bared- and residue-covered-soil across different development stage of rainfed chickpea.

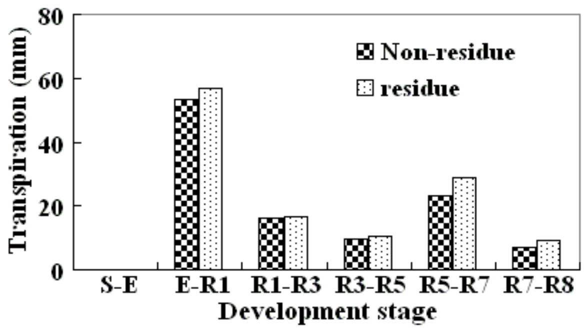

Fig. 4. The value of transpiration across different development stages of rainfed chickpea grown in bared- and residue-covered-soil.

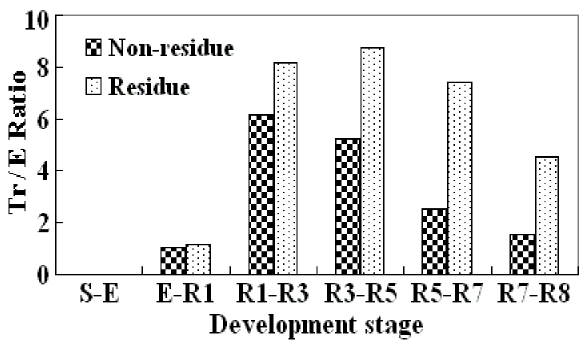

Fig. 5. The ratio of transpiration to evaporation (Tr/E) across different development stages of rainfed chickpea grown in bared- and residue-covered-soil.

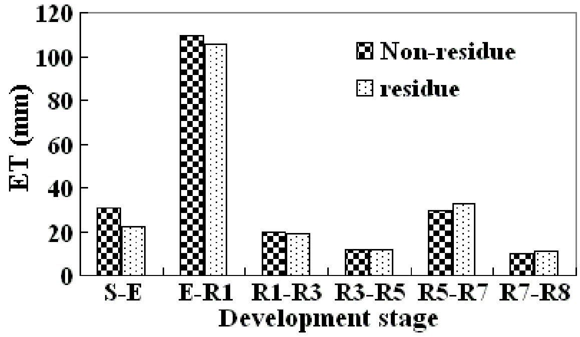

Fig. 6. The value of evapotranspiration (ET) across different development stages of rainfed chickpea grown in bared- and residue-covered-soil.

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Study on Relations Between Relative Water Content, Cell Membrane Stability and Duration of Growth Period with Grain Yield of Lentil Genotypes under Drought Stress and Non-Stress Conditions

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ABSTRACT

Drought is one of the most important abiotic stresses that limits crop production in arid and semi-arid regions of the world. Lentil (*Lens culinaris L.*), a valuable legume crop, is produced mainly rain-fed in Iran. An experiment was conducted to study the relationships between relative water content (RWC), cell membrane stability (CMS) and duration of growth period with grain yield of 11 advanced genotypes, varieties and a local genotype in the Ardabil Agriculture and Natural Resources research Station. Experimental design was a randomized complete block design (RCBD) with three replication under both rain-fed and irrigated conditions. Combined ANOVA showed significant differences among all the evaluated traits. Significant differences between characters reveals that there are high variation between the traits studied. Means for characters under study showed that grain yield, RWC, CMS and duration of growth period decreased in rain-fed condition but cell membrane leakage (electric conductivity) increased. Correlation coefficients showed strongly positive relation between grain yield with RWC ($r=+0.98^{**}$), strongly negative and non significant CMS ($r=-0.32^{ns}$) and strongly negative relation between grain yield and the days to maturity ($r=-0.78^{**}$). The results of the experiment also revealed that there weren't a strong relation between yield and calculated attributes for drought tolerance except RWC. Therefore, this character could be effective in evaluation of drought tolerance and identification of high yielding genotypes (ILL 6031, ILL 9893 and ILL 8095).

Key Words: relative water content, cell membrane stability, drought stress, grain yield, lentil

INTRODUCTION

Drought is the most important abiotic stress that limits crop production in arid and semi-arid regions of the world (Ferrat and Lovatt, 1999). Iran, with a mean annual rainfall of 250 m.m., is considered an arid to semi-arid country (Soltani et al., 2001). The limited available water during growing season in some regions, such as Ardabil, reduces crop yield considerably (Soltani et al., 2001; Yu and Stter, 2003).

Lentil (*Lens culinaris L.*) is traditionally grown as a rainfed crop under various cropping systems that often suffer from intermittent and terminal drought (Sarker and Erskine, 2005).

Lentil one of the valuable legume crops which is produced mainly as rain-fed in Iran (Mostafaei et al., 2006). Lentil contains large amounts of proteins, and has the ability to fix, symbiotically with certain bacteria, atmospheric nitrogen, and thus contribute greatly to soil fertility (Karim Mojein et al., 2003 and Anjam et al., 2005).

A considerable portion need of people in Iran is supplied through leguminous crops, including lentil. To produce the necessary protein needs of people in our country planting high yielding and drought tolerant lentil cultivars is of outstanding importance (Anjam et al., 2005 and Soltani et al., 2001).

Sometimes, relationship between leaves water potential (Ψ_w) and relative water content (*RWC*) of leaves used for evaluation of water deficit magnitude in the plant tissues and cells and predicting tissues resistant to desiccation resulted from water deficit (Aminzadeh and Eshghi, 2006; Ferrat and Lovatt,1999; Khan and Stoddard, 2005).

It seems that, tissues that able to maintain higher RWC with decreasing water potential are more resistant to drought conditions and desiccation resulted from this stress (Ferrat and Lovatt, 1999; Irigoyen et al., 1992; Schonfeld, 1988).

Neyestani and Azimzadeh (2003) reported that relative water content in lentil genotypes under drought stress is lower than non stress conditions.

Drought stress injure the plasma membrane, so cell content secrete to outside. Magnitude of this damage can be determinate with ionic secretion measurement (Ferrat and Lovatt,1999; Khan and Stoddard, 2005).

Neyestani and Azimzadeh (2003) in lentil and Vazan et al., (2005) in sugar beet, studied the relationship between plasma membrane stability (obtained from EC measurement) and grain yield in stress and non stress conditions and reported that plasma membrane stability in genotypes under stress was significantly lower than genotypes under non stress conditions.

The aim of this study was the identification relationship between relative water content (*RWC*), electrical conduction (*EC*), cell membrane stability and growth period and determination suitable factor for selection high yield in lentil genotypes under drought stress and non stress conditions at Ardabil.

MATERIALS and METHODS

In order to study the relationship between RWC, EC, cell membrane stability and growth period with grain yield in lentil genotypes under well-watered and stress conditions, compared 11 cultivar and promising genotypes and one genotype that selected from local genotypes of Ardabil at Agricultural research station in Ardabil. Climatically, the area placed in semi arid and cold zone (Alt

1350m; Long 48°20' E; Lat 38°15' N). Soil type was clay loam with pH about 7.7 and depth about 70cm.

The experiments were conducted in no drought (irrigated) and drought (rain-fed) conditions, in randomized complete block design with three replications. Seeds of genotypes were sown in 4 rows with 4m long and 25cm row spacing, in 13 April 2005. Plots in no drought conditions irrigated as required (2 irrigation) while, plots in drought conditions no irrigated.

For determinate the relative water content in 50% flowering (after drought stress), selected young and ripping leaves in each varieties and replications then, taken in plastic pockets and carried to laboratory, immediately. Afterward, determined the fresh weight of leaves and samples were taken in distilled water for 24h in refrigerator (about 5°C). After 24h recorded the turger weight of leaves. In order to determinate the dry weight of leaves, samples were taken in oven for 48h in 70°C. Relative water content of leaves calculated following modified formula of Wedrly .

$$RWC = \frac{wf - wd}{wt - wd} \times 100$$

Where:

RWC : relative water content of leaves (%)

Wf : fresh weight of leaves (g)

Wd : dry weight of leaves (g)

Wt: turger weight of leaves (g)

For measurement of electrical conductivity (*EC*) of leaves in end of flowering period (moisture stress) in all of replications, prepared 20 disk by punch from young leaves randomly, then put into 20cc distilled water. Afterward, these samples carried to refrigerator (about 5°C) and after 24h obtained samples EC by using sensitive EC meter. From these magnitudes subtracted distilled water EC (as control) and the EC of leaves were obtained.

In order to determine the number of days from planting to ripping, when one third of plant down was yellow and color of pods became yellow/green, recorded as ripping time.

Grain yield obtained from two middle rows (about $1.5m^2$).

To evaluate drought tolerance of lines under study we used the following equation (Fernandez, 1992).

SI= 1 – (Ys/Yp)

Where:

Ys = total yield mean in stress condition.

Yp = total yield mean in normal condition.

Analysis of variance and regression between studied traits were performed using MSTAT-C computer software package. The means were tested using the Duncans multiple range test in 5% level.

RESULTS and DISCUSSION

Combined analysis of variance of the data measured revealed that there were significant at 1% level of probability (Table1). Anjam et al. (2005); Beguom and Beguom (1996) and Mostafaei et al. (2006) in their studies of lentil reported the results similar to present study. Percent stress intensity was calculated to be 29 %(SI=29%). This shows that seed yield of lentils under drought stress in Ardabil decreases considerably. Percent yield reduction under the condition of this experiment would be 29 per cent.

Significant difference between studied traits indicated that there was high variation between studied traits that could be used in study of the stress resistance.

Mean of grain yield, number of days until ripping and relative water content in no-drought condition (no-stress) increased compared to drought condition (stress) while, EC under drought stress was more than the no-drought condition (Table 2). These results indicated that the lentil grain yield affected by water deficit and drought furthermore, lentil had high yield under optimal conditions.

The growth period of studied lentil genotypes affected by environmental conditions, so that water deficit and drought caused early ripping in lentil genotypes. Furthermore, under drought conditions relative water content of leaves decreased with decreasing soil moisture. Drought stress and water deficit destroy the cells membrane then, vacuoles content secret to outside and increase the concentration of solution. Under this condition, increasing the magnitude of EC and decreasing cell membrane stability, compared to no-drought stress.

The means of studied traits (Table 3) indicated that ILL 8095, ILL 9893 and ILL 6031 had the highest grain yield compared to other genotypes. Also, these genotypes had the highest relative water content. Thus, it seems that grain yield have positive relationship with relative water content. Furthermore, these genotypes were early ripping genotypes.

Correlation among grain yield and other studied traits (Table 4) indicated that grain yield had highly positive and significant relationship with relative water content. Positive and significant relationship between these traits indicates that genotypes that have high grain yield show more relative water content. Correlation among RWC and days number until ripping were found negative and significant. This indicated that early ripping genotypes had more relative water content than late ripping genotypes. These results are in agreement with Farat and Lavat (1999) in bean, Khan and Studdard (2005), Okarum et al. (2005) and Aminzadeh et al. (2008) in barley.

Correlation among the number of days until ripping and grain yield were found negative and significant. Mostafaei et al. (2006) reported same results. Grain yield showed negative and non-significant correlation with EC.

The results of the experiment also revealed that there weren't a strong relation between yield and calculated attributes for drought tolerance except RWC. Therefore, this character could be effective in evaluation of drought tolerance and identification of high yielding genotypes (ILL 6031, ILL 9893 and ILL 8095).

Table 1. Combined analysis of variance of traits among promising lentil genotypes studies

Mean Square					
Source	**df**	**seed yield ($kg.ha^{-1}$)**	**days to maturity**	**electric conductivity (µs/cm)**	**relative water content (%)**
Locetion	**1**	1175760.056*	470.222*	2130.521**	8462.138**
Error 1	**4**	146676.593	55.097	52.704	60.494
Factor A	**11**	323859.563**	74.040**	133.022**	145.783**
L * A	**11**	10636.578ns	12.040**	39.114ns	45.659**
Error 2	**44**	17853.383	5.646	41.578	15.993
Cv %		18.04	2.45	18.47	6.46

ns, * & ** : not significant, significant at the 5% & 1% levels of probability, respectively

Table 2. Mean comparison of promising lentil genotypes under rain-fed and irrigated condition (Combined analysis) based on DMRT

No. genotypes	**genotypes**	**days to maturity**	**electric conductivity (µs/cm)**	**relative water content (%)**	**Seed Yield ($kg.ha^{-1}$)**
1	**ILL 8173**	99.33 b	35.57 abcd	56.16 d	474.4 f
2	**ILL 9919**	98.33 b	31.28 bcd	61.91 bc	691.7 e
3	**ILL 9832**	104.2 a	27.67 d	56.14 d	456.6 f
4	**ILL 323**	98.17 b	34.20 bcd	60.98 cd	804.9 cde
5	**ILL 1878**	98.67 b	43.62 a	56.36 d	432.1 f
6	**ILL 8146**	97.00 bc	39.40 ab	56.38 d	476.6 f
7	**ILL 6031**	90.50 e	30.60 cd	65.52 bc	972.0 abc
8	**ILL 7677**	97.83 b	38.13 abc	62.50 bc	768.0 de
9	**ILL 9893**	94.50 cd	32.10 bcd	66.97 ab	1013.0 ab
10	**ILL 8095**	92.83 de	30.60 cd	70.99 a	1075.0 a
11	**ILL 8105**	97.50 b	35.87 abcd	63.38 bc	838.08 cde
12	**Native genotype**	94.50 cd	39.91 ab	65.78 bc	884.9 bcd
LSD 5%		2.764	7.503	4.635	155.500

Mean with the same letters in each column does not have significant difference at the 5% level of probability according to DMRT

Table 3.Total mean values for the traits of promising lentil genotypes under rain-fed and irrigated conditions

treittse	drought stress (rain-fed)	non-stress drought (irrigated)
days to maturity	94.389	99.500
electric conductivity	40.352	29.472
relative water content	51.081	72.763
seed yield (kg.ha^{-1})	612.906	864.483

Table 4. Simple correlation of traits among promising genotypes studied

traits	days to maturity	electric conductivity	relative water content	seed yield
days to maturity	-	0.01^{ns}	-0.77^{**}	-0.78^{**}
electric conductivity		-	-0.32^{ns}	-0.34^{ns}
relative water content			-	0.97^{*}
seed yield				-

ns, * & ** : not significant, significant at the 5% & 1% levels of probability, respectively

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Evaluation the Genetic Diversity of Advanced Lentil Genotypes under the Drought Stress and Non-Stress Conditions

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ABSTRACT

To evaluate genetic diversity of advanced lentil lines, screening quantitative indices of drought resistance, and identifying drought resistant lines, 11 varieties, one advanced lentil line and one selected genotype from Ardabil local mass in a randomized complete block design (RCBD) with 3 replications under both stress (rain-fed) and non-stress (irrigated) conditions in the Station of Agricultural and Natural Research of Ardabil. Based on yields obtained under irrigation (YP) and rain-fed (YS) conditions, several quantitative drought tolerance indices, like mean productivity (MP), tolerance index (TOL), geometric mean productivity (GMP), harmonic mean (HARM), stress susceptibility index (SSI) and stress tolerance index (STI) were used to evaluate the drought responses of these genotypes. Evaluation of quantitative indices of drought resistance and considering the means quantities and correlation coefficients between such indices, based on grain yield and under both rain-fed and irrigated conditions indicated that indices (MP), (HARM), (GMP) and (STI) are considered as the best indices of Lentil genotypes response with stress intensity of (SI = 0.29) under drought stress. In 3-D graph, it has been showed that with considering these indices and grain yield and under rain-fed and irrigated conditions, genotypes ILL 6031, ILL 9893 and ILL 8095 will be as the produced highest seed yields and drought resistant lines in group A. Multivariate Biplot graph indicated that genotypes ILL 6031, ILL 9893 and ILL 8095 were located next to the vectors of drought resistance indices, as: MP, HARM, GMP and STI. Distribution of the genotypes in the Biplot space indicated the presence of genetic diversity among the lines for drought stress. Diagrams obtained from cluster analysis based on above indices showed that the farthest genetic distance in related to drought resistant lines with highest seed yields (ILL 6031, ILL 9893 and ILL 8095) and drought susceptible lines and lowest seed yields (ILL 8173, ILL 9832, ILL 1878 and ILL 8146).

Key Words: Lentil (*Lens culinaris L.*), Seed yield, Drought sensitivity and tolerance indices, Biplot, Cluster analysis.

INTRODUCTION

From the initial agriculture activities, always drought has been an important factor, with reduction of performance has caused famine and fatality. Water shortage damage major agricultural products in most part of the world. (Yu and Stter, 2003). Iran, with a mean annual rainfall of 250 m.m., is considered an acid to semi-arid country (Soltani et al., 2001). The limited available water during growing season in some regions, such as Ardabil, reduces crop yield considerably (Soltani et al., 2001; Yu & Stter, 2003).

Lentil (*Lens culinaris L.*) contains large amounts of proteins, and has the ability to fix, symbiotically with certain bacteria, atmospheric nitrogen, and thus contribute greatly to soil fertility (Karim Mojein et al., 2003 and Anjam et al., 2005).

Lentil is a plant that can adapt itself to arid and semiarid climate (Karim Mojein et al, 2003). In Iran and most other countries of the world to assure their protein needs, use cereals such as pea, bean, vetch and lentil.Cultivating of these crops and gaining lines with maximum operation in shortage of water situation is an important problem in Iran to investigate about it (Soltani et al, 2001). So accessing genotypes which can tolerate drought, we can prevent reduction of crops significantly. In this regard selection of lentils that can tolerate drought by means of a suitable index which is able to distinguish these types of genotypes always has been a subject that breeders pay attention to it (Mostafaei, 1999).

Salehi et al., (2005) after studying resistance index said that, indexes such as "MP", "HARM", "GMP" and "STI" are the best indexes to screen lentil genotypes.

The goal of this project is evaluation of genetic diversity of lentil genotypes resistance to drought, in order to identify genotypes that can adapt themselves to both conditions of water tensity and without water tensity. This will be done by comparing some drought sensitivity and tolerance indexes to select high yielding and drought tolerant crops.

MATERIALS and METHODS

To study the response of as promising lentil lines, plus a native one as control, to drought an experiment was conducted at Ardabil Agriculture and Natural Resources Research Station in a Clay loam soil with a pH = 7.7 using a randomized complete block design with 3 replications under both drought stress (rain-fed) and non-stress (irrigated) conditions. Seed were planted in April, 13, 2005, in plots with 4 rows 4 meters long, spaced 25cm.

Evaluation of lentil genotypes was done on basis of dry farming (YS) and irrigation (YP), quantative indexes of drought tolerance such as mean of mean productivity (MP), tolerance index (TOL), geometric mean productivity (GMP), harmonic mean (HARM), stress susceptibility index (SSI) and stress tolerance index (STI).

1. Stress susceptibility index (SSI)(Fischer and Maurer, 1987):

$SSI = (1- (Ysi/Ypi))/SI$

Where:

Ysi =yield of genotype in stress condition.

Ypi = yield of genotype in normal condition.

SI = Stress Intensity

And SI= 1 – (Ys/Yp)

Where:

Ys = total yield mean in stress condition.

Yp = total yield mean in normal condition.

2. Tolerance index (TOL) (Rosielle and Hamblim, 1981):

TOL= Ypi – Ysi

3. Mean productivity (MP) (Rosielle and Hamblim, 1981):

MP= (Ypi – Ysi)/2

4. Geometric mean productivity (GMP) (Fernandez, 1992):

GMP= √Ypi – Ysi

5. Stress tolerance index (STI) (Fernandez, 1992):

STI= (Ypi – Ysi)/Yp^2

6. harmonic mean (HARM):

HARM = 2(Yp×YS)/Yp+Ys

Statistical calculations include combined analysis and calculation quantative index of drought sensitivity was done by MSTAT-C software and identification of simple correlation between above indexes, irrigation and dry farming were done using SPSS and Stat graphics softwares. Finally cluster analysis presented according to indexes and seed yield and UPGMA method and outcome was presented by a diagram.

RESULTS and DISCUSSION

Analysis of combined variance showed that there is significant difference between seed yielding and environment conditions (irrigated and rain-fed) that is about1% (Table 1). The intensity of tension in this test was 29 percent.

This issue shows that lentil crop will reduce by drought under condition of this test yield reduction was more than 29 percent.

Average values of grain yield and drought tolerance indexes (table 2) and simple correlation coefficients of indexes with irrigation and dry farm yield (table 3) showed that rating genotypes on basis of MP, HARM, GMP and STI indexes are equal, and grain yield on irrigation condition with index of SSI has a negative and significant correlation and with TOL index a positive and insignificant correlation, and on condition of dry farming showed a negative and significant correlation and with TOL a negative and insignificant correlation.

In 3 dimensional graph, referring to STI, GMP, MP and HARM indexes and grain yield in dry farming and irrigation condition, genotypes ILL 6031, ILL 9893 and ILL 8095 were identified as genotypes with high production and tolerant of intensed drought in group A (figure 1).

Actually these genotypes yielded the most in both irrigation and dry farming conditions.

had the highest grain yield in both of. Salehi et al., (2005) reach to the same output in study of resistance indexes against drought in lentil.

Multi variable Biplot showed that, genotypes ILL 6031, ILL 9893 and ILL 8095 are in adjacent refers related to, HARM, GMP, MP and STI indexes.

Lines distribution in Biplot spaces shows genetic diversity between researched lines in relation to drought.

cluster analysis of diagram on basis of GMP, MP, HARM and STI in figure 2 showed the most genetic differences between drought tolerant lines with high yield (ILL 6031, ILL 9893 and ILL 8095) and lines that are sensitive to drought and are low yield ILL 8173 ، ILL 9832, ILL 1878 and ILL 8146).

Using Biplot diagram and cluster analysis for selection of drought resistant items in lentil was assessed and confirmed by Salehi et al, (2005), Neiestani and Azimzadeh (2003), and Fernandz (1999) in bean and Farshadfar et al, (2001) in Chickpea.

In whole referring to outcome of indexes assessment MP, HARM, GMP and STI identified as the best indexes show interaction of lentil with intensity of tension in drought condition and genotypes ILL 8095, ILL 9893 and ILL 6031 as high yield and tolerant to drought and genotypes sensitive to drought.

Table 1. Combined variance analysis of grain yield of lentil genotypes in two irrigation and dry farming environment.

Source	df	Sum of Square	Mean Square	F
Location	1	1175760.056	1175760.056	8.0160*
Error 1	4	586706.373	146676.593	
Factor A	11	3562455.195	323859.563	18.1400**
L * A	11	117002.358	10636.578	0.5958ns
Error 2	44	785548.856	17853.383	
Total	71	6227472.838		
Cv %			18.04	

ns, * & ** : not significant, significant at the 5% & 1% levels of probability, respectively

Table 2. Average values of grain yield and drought tolerance and sensitivity indices in lentil genotypes.

genotypes No.	genotypes	Ysi (kg/ha)	Ypi (kg/ha)	SSI	TOL	MP	GMP	HARM	STI
1	**ILL 8173**	362.20	586.63	1.31	224.43	474.41	460.95	447.87	0.28
2	**ILL 9919**	655.53	727.73	0.34	72.20	691.63	690.69	689.74	0.63
3	**ILL 9832**	291.10	622.20	1.83	331.10	465.65	425.58	396.63	0.24
4	**ILL 323**	639.96	969.96	1/17	330.00	804.96	787.87	771.14	0.82
5	**ILL 1878**	275.52	588.86	1.83	313.34	432.19	402.79	375.40	0.21
6	**ILL 8146**	357.63	595.53	1.38	237/90	476.58	461.50	446.89	0.28
7	**ILL 6031**	842.20	1101.80	0.79	259.60	972.00	963.29	954.66	1.23
8	**ILL 7677**	617.73	918.33	1.14	300.60	768.03	753.18	738.62	0.75
9	**ILL 9893**	895.50	1131.66	0.72	236.16	1013.58	1006.68	999.82	1.34
10	**ILL 8095**	928.86	1220.30	0.83	291.44	1074.58	1064.65	1054.81	1.50
11	**ILL 8105**	666.60	1011.06	1.17	344.46	838.83	820.96	803.47	0.89
12	**Native genotype**	822.20	947.73	0.45	125.53	884.96	882.74	880.51	1.03

(Stress Intensity = 0.29%)

Table 3. Correlation factors among indices drought tolerance and sensitivity with grain yield under rain-fed and irrigated conditions

	YP	YS	SSI	TOL	MP	GMP	STI	HARM
YP	1							
YS	0.933**	1						
SSI	-0.581*	-0.825**	1					
TOL	0.117 ns	-0.239 ns	0.722**	1				
MP	0.984**	0.983**	-0.715**	-0.064 ns	1			
GMP	0.978**	0.988**	-0.735**	-0.093 ns	1.000**	1		
STI	0.977**	0.975**	-0.692*	-0.062 ns	0.993**	0.993**	1	
HARM	0.972**	0.992**	-0.753**	-0.119 ns	0.998**	1.000**	0.991**	1

ns, * & ** : not significant, significant at the 5% & 1% levels of probability, respectively

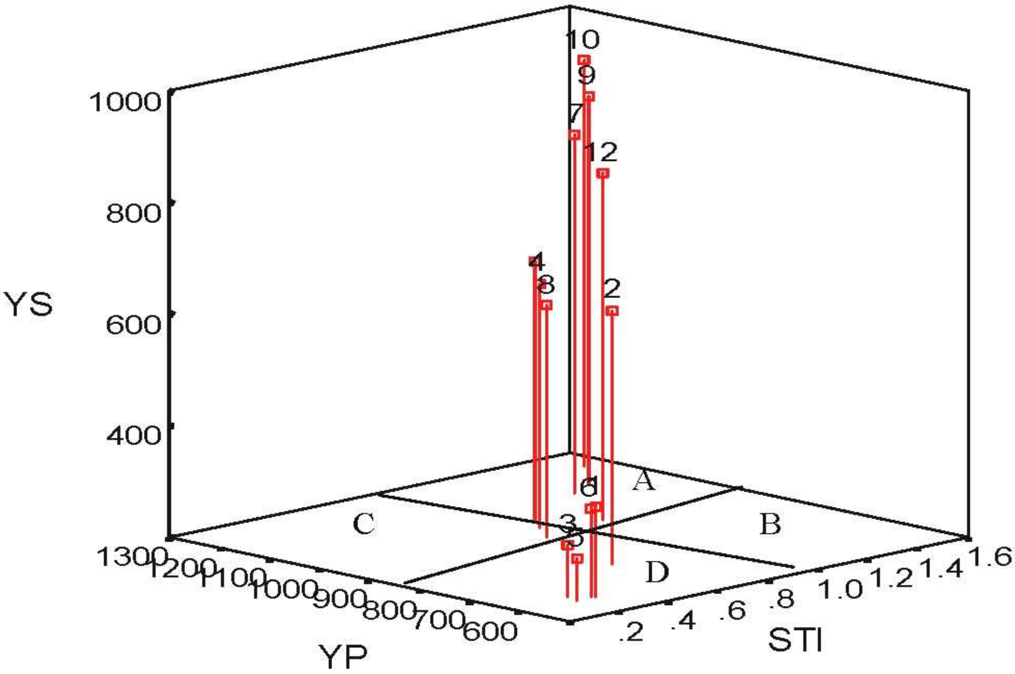

Figure 1. 3-D diagram for specifying the drought tolerance genotypes based on YP, YS and STI index.

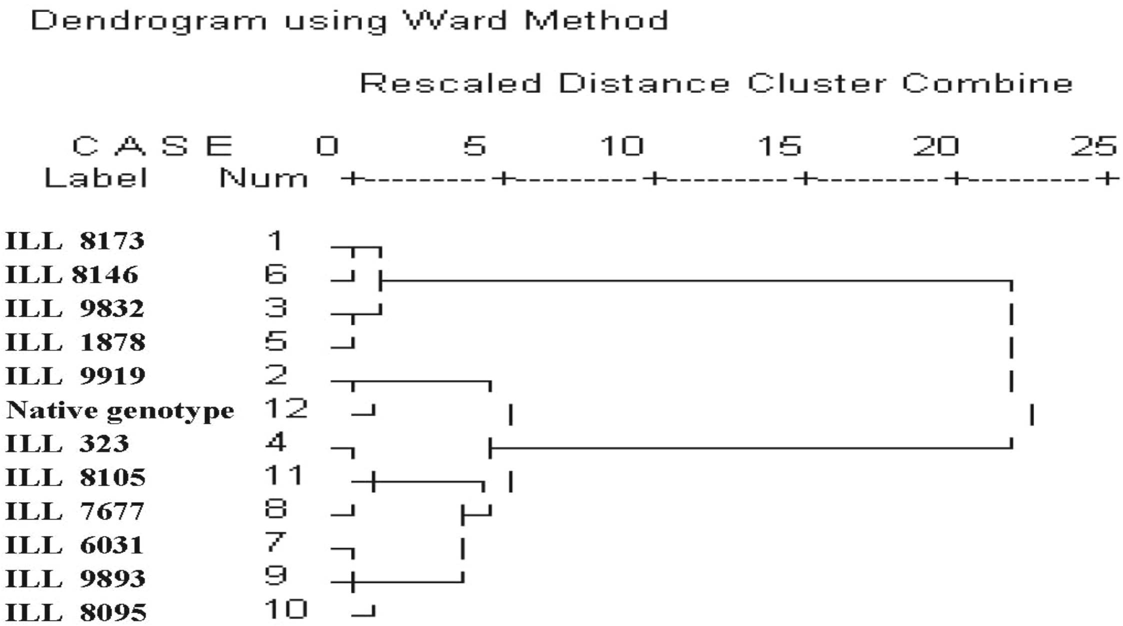

Figure 2. Grouping of 12 lentil genotypes based on MP, HARM, GMP and STI indices.

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The Investigation on Growth and Some Antioxidative Enzymes of the Maize (Zea mays L.) Plant under Salt and Water Stress

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Abstract

The present study was carried out to determine interactive effects of salinity and drought stress on growth and antioxidative enzymes such as superoxide dismutase (SOD), guaiacol peroxidase (POX), and polyphenol oxidase (PPO) in hydroponically grown plants of maize, *Zea mays* L.cv DKC647. Plants were treated two salt (NaCl) concentrations and PEG 6000 to create water stress The results obtained from this experiment show that high salinity reduced shoot and root dry and fresh weight but PEG treatment had no significant effect on this parameters. SOD, POX and PPO activities were increased with the increase in the intensity of NaCl stress, but PEG treatment in addition to NaCl had more significant effect on this enzyme activity. However, the interactive effects of salinity and water stress induced highest SOD, POX, and PPO activities compared to the other treatments in maize plants. These results suggest that maize plants may be increased the activity of antioxidant enzymes to have a better protection against reactive oxygen species (ROS) under salt and water stress.

Key words: Maize, Salinity and Water Stress, PEG 6000, Growth, Antioxidant enzymes (SOD, POX, PPO).

INTRODUCTION

Plants are immobile and therefore unable to escape stressful environments. Abiotic stresses such as salt excess (NaCl) and drought are among factors most limiting to plant productivity (Bohnert et al., 1995). In higher plants, exposure to abiotic stresses, *e.g.* water stress and high salinity, often results in different damages such as oxidative injury (Smirnoff, 1993, Fadzilla et al. 1997).

Salinity is a major abiotic stress reducing the yield of a wide variety of crops all over the world (Tester and Davenport, 2003, Ashraf and Foolad, 2005). The deleterious effects of salinity on plant growth are associated with low osmotic potential of soil solution, nutritional imbalance, specific ion effect, or a combination of these factors (Ashraf and Haris, 2004). On the other hand, water stress, one of the most common environmental limitations affecting growth and productivity of plants, causes many metabolic, mechanic and oxidative changes in plants (Kalefetoğlu and Ekmekçi, 2005).

Abiotic stresses such as salt excess (NaCl) and drought are among factors most limiting to plant productivity (Bohnert et al., 1995). Greenway and Munns (1980) suggested that reasons of growth reduction in plants under salt stress may be described as following i) Salinity can induce water stress as it increases the osmotic pressure of the soil solution, ii) High salinity may also result in too high an internal ion concentration (ion excess) and thus cause growth reduction. It is often difficult to assess the relative importance of ion excess and water stress as growth limiting factors (Marcelis and

Hooijdonk, 1999). Steduto et al., (2000) also suggested that the decline in productivity observed for many plant species subjected to excess salinity is often associated with a reduction in photosynthetic capacity. Salt may affect growth indirectly by decreasing the rate of photosynthesis (Meloni et al., 2003).

Many crop species are sensitive to high concentrations of salt with negative impacts on agricultural production. Maize (*Zea mays* L.) is considered a moderately salt-sensitive plant (Maas and Hoffman, 1977). In general, salinity tolerance mechanisms are described as cellular, organizational, and whole plant adaptations. But other additional means include cellular osmotic protection due to adjusting of internal osmotic balance by accumulation of compatible solutes and protection against consequences of endogenous oxidative stress (Levinsh, 2006).

Salt and water stress, like other abiotic stresses, also leads to oxidative stress through an increase in reactive oxygen species (ROS), such as superoxide ($O_2^{\bullet -}$), hydrogen peroxide (H_2O_2) and hydroxyl radicals ($OH^{\bullet}$) (Alscher et al., 1997; Mittler, 2002; Neill et al., 2002). ROS are highly reactive and in the absence of any protective mechanism they can seriously disrupt normal metabolism through oxidative damage to lipids, protein and nucleic acids (Rout and Shaw, 2001). Fortunately plants possess a number of antioxidant enzymes and antioxidants that protect them against the damaging effects of activated oxygen species (Dionisio-Sese and Tobita, 1998). In plant cells, one such protective mechanism is an antioxidant system, composed of both non-enzymatic and enzymatic antioxidants (Foyer et al., 1994). Plants have evolved mechanisms to protect cell and subcellular systems from the effects of these reactive oxygen radicals by using enzymes such as superoxide dismutase, catalase, peroxidase, glutathione reductase, polyphenol oxidase and non-enzymic ascorbate and glutathione (Agarwal and Pandey, 2004).

Superoxide dismutases (SOD, EC 1.15.1.1) since discovered by McCord and Fridovich (1969), attracted the attention of many researchers because they are essential component in an organism's defense mechanism (Badawi et al., 2004). The SOD (E.C. 1.15.1.1) is the first enzyme involved in the antioxidative process (Lee et al., 2001, Rubio et al., 2002). This enzyme converts superoxide radical to hydrogen peroxide (H_2O_2) and molecular oxygen (O_2) (Mhadhbi et al, 2004). Hydrogen peroxide can be removed by "non-specific" peroxidases (POX, E.C. 1.11.1.7) which use H_2O_2 as electron donor to metabolise phenolic compounds. These latter enzymes are ubiquitous and are involved in various processes such as cell growth control and tolerance to environmental stress (Quiroga et al., 2000). Polyphenol oxidase (PPO; E.C.1.10.3.1) is generally used as an indicator enzyme for the adequacy of heat treatment of fruit purees (Pointing et al., 1954; Williams et al., 1986). However, it is also used as an indicator for the salinity stress. For example, Agarwal and Pandey (2004) in senna and Demir and Kocaliskan (2001) in been seedlings studied the effect of salinity stress on this enzyme activity.

We hypothesized that increased activity of antioxidant enzymes; SOD, POX and PPO contributes to the protection of maize plants from salt and water stress. Therefore, the aim of this work was to evaluate the effects of salt and water stress on the activity of antioxidative enzymes, and dry and fresh weight in maize plants, in order to better understand salt and water stress effects and plant responses.

MATERIALS and METHODS

Plant Culture and Treatment Conditions

The experiment was conducted under greenhouse conditions in Mugla (Turkey) with maize (*Zea mays* L. cv., DK 647 F1). In the maize plant, grown at hydrophonic environment and under the conditions of greenhouse (at 25/20°C, 16/8h, 75±5%, and 300 µmol m^2 s^{-1} the mean temperature, day/night lenght, relative humidity, photoperiod and photosynthetic photon flux density were maintained, respectively); in this research where the stress conditions' effects on the development and accumulation, there formed settings including control, low-rate salt (5 dS m^{-1} NaCl) and high-rate salt (10 dS m^{-1}). These 3 settings each have been divided to two applications within themselves as normal watering and PEG6000. In order to create water stress, a certain amount of PEG6000 is used enough to create -1 MPa preassure. As a means of control, irrigation water and nutrition solution. In the experimentation conducted as a 3-repetation application, the accumulation levels of proline on the leaves were analysed and the changes occuring in the plants facing stress conditions were directly observed, and examined how they effected the development.

The basic nutrient solution used in this experiment was a modified Hoagland and Arnon formulation. All chemicals used were of analytical reagent grade, and composition of nutrient solution was (mg L^{-1}): 270 N, 31 P, 234 K, 200 Ca, 64 S, 48 Mg, 2.8 Fe, 0.5 Mn, 0.5 B, 0.02 Cu, 0.05 Zn and 0.01 Mo. The pH of nutrient solution was adjusted each time to 6.5 with 0.1 mM KOH. Each treatment was replicated three times in a randomised block design and each replicate included 6 plants (i.e., 18 plants per treatment).

Thirty day after germination different treatments were initiated. Treatments were: i) control (C) plant receiving nutrient solution, ii) low salinity treatment (C+S_L): plant receiving nutrient solution plus 5 dS m^{-1} NaCl, iii) high salinity treatment (C+S_H): plant receiving nutrient solution plus 10 dS m^{-1} NaCl, iv) PEG 6000 treatment (C+PEG): plant receiving nutrient solution plus PEG 6000 (a certain amount of PEG6000 is used enough to create -1 MPa preassure), v) low salinity and PEG treatment (S_L+PEG): plant receiving nutrient solution plus 5 ds/m NaCl plus PEG 6000 (a certain amount of PEG6000 is used enough to create -1 MPa preassure), vi) high salinity and PEG treatment (S_H+PEG): plant receiving nutrient solution plus 10 dS m^{-1} NaCl plus PEG 6000 (a certain amount of PEG6000 is used enough to create -1 MPa preassure). Each treatment was replicated three times and each replicated included 3 pots (i.e. 9 pots per treatment). The pH of the nutrient solution was adjusted to

6.5 with 0.1 m*M* KOH during the entire growing period. Plants were harvested 90 days after seedling emergence.

Experimental

In the analyses after the experiments, SOD, POX, PPO activities from antioxidative enzymes, and some plant growth parameters were determined.

Protein Content

Protein content in the enzyme extracts was determined according to Bradford (1976) using Bovine Serum Albumin V as a standard.

Enzyme Determination

Leaves (0.5 g) were homogenized in 50 mM sodium phosphate buffer (pH 7.0) containing 1% soluble polyvinyl pyrolidine (PVP). The homogenate was centrifuged at 20,000 *g* for 15 min at 4° C and the supernatant used for assays of the activities of POX and SOD. The activity of SOD was assayed by monitoring its ability to inhibit the photochemical reduction of NBT (Beauchamp and Fridovich, 1971). One unit of SOD was defined as the amount of enzyme necessary to inhibit the reduction of cytochrome c by 50%. The activity of POX was assayed by adding aliquot of the tissue extract (100 µl) to 3 ml of assay solution, consisting of 3 ml of reaction mixture containing 13 mM guaiacol, 5 mM H2O2 and 50 mM Na-phosphate (pH 6.5) (Chance and Maehly, 1955). An increase of the optical density at 470 nm for 1 min at 25°C was recorded using a spectrophotometer. POD activity was expressed as change in absorbance min-1 mg-1 protein. The increase in A470 was measured for 3 min and activity expressed as ΔA470/mg protein/min.

Polyphenol oxidase activity (PPO) activity was assayed with 4-methylcatechol as a substrate according to the method of Zaubermann et al. (1991). Half gram of fresh leaf was ground with 10 ml of 0.1 mol/l sodium phosphate buffer (pH 6.8) and 0.2 g of polyvinylpyrrolidone (PVP, insoluble). After centrifugation at 19 000g for 20 min, the supernatant was collected as the crude enzyme extract. The assay of the enzyme activity was performed using 1 ml of 0.1 mol/l sodium phosphate buffer (pH 6.8), 0.5 ml of 100 mmol/l 4- methylcatechol, and 0.5 ml enzyme solution. The increase in absorbance at 410 nm at 25 °C was recorded automatically for 5 min. One unit of enzyme activity was defined as an increase of 0.01 in absorbance per min per mg protein.

Dry Weight

Three randomly selected plants per replicate were divided into shoots and roots, and dried in a forced air oven at 70ºC for two days to determine dry weights.

Statistical analysis

The experiment was performed twice under the same environmental conditions. Statistical analysis (ANOVA) indicated that there were no significant differences in measurements between the two runs; data presented here are the averages of the two experiments. A two way analysis of variance was performed on all datas and the LSD was calculated at P≤0.05.

RESULTS

Plant Growth

In this experiment dry and fresh weight of both shoot and root was significantly inhibited by salt and water stress (Table 1). Reduction in total plant dry weight in high salinity (**C+S$_H$**: plant grown nutrient solution plus 10 ds/m NaCl) treatment was 52 % compared to the control (plant grown nutrient solution), while it was 56 % in high salinity and PEG 6000 (**S$_H$+PEG**:plant grown nutrient solution plus 10 ds/m NaCl plus PEG 6000). Inhibition on plant growth was not significantly affected by PEG 6000 in addition to NaCl treatment, but water stress had been effective on root and shoot dry weight. The high concentrations of NaCl were more harmful than PEG 6000 in maize plants. Total dry weight decreased with increasing concentration of the osmotic agents, with a drastic effect at the highest NaCl concentration.

Table 1. Effects of NaCl and PEG 6000 treatments on the fresh and dry weight of shoot and root of maize (*Zea mays* L.) plants.

	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)
C	250a	80a	20a	7,5a
C+PEG	203b	75a	19a	6,1b
C+S$_L$	195b	75a	14b	5,3c
S$_L$+PEG	134c	59b	11c	4,2d
C+S$_H$	94d	54b	9d	4,1d
S$_H$+PEG	90d	50b	9d	3,2e

Values followed by different superscript letters in each column differ significantly (LSD test, P ≤ 0.05).
C: Control**, C+PEG:** PEG 6000 treatment**, C+S$_L$:** 5 ds/m NaCl treatment**, S$_L$+PEG:** 5 ds/m NaCl treatment plus PEG 6000 treatment**, C+S$_H$:** 10 ds/m NaCl treatment**, S$_H$+PEG:** 10 ds/m NaCl plus PEG 6000 treatment.

Enzyme Activities

We report in Fig 1, 2, and 3 the effects of various salt concentrations and PEG 6000 on soluble protein content and antioxidant enzyme activities such as SOD, POX and PPO. The activity of SOD, which converts superoxide radical to H_2O_2, was higher in all leaf of maize plants under stress conditions compared to the control plants. SOD activity was observed to be significantly (p≤0.05) higher in high salt and PEG 6000 treated plants than in the only high salt treated plants, and activity was more pronounced in plants under NaCl stress than in the PEG 6000 treated plants. However, high salinity and PEG 6000 treated plants maintained higher (p≤0.05) SOD activity than all other treatments.

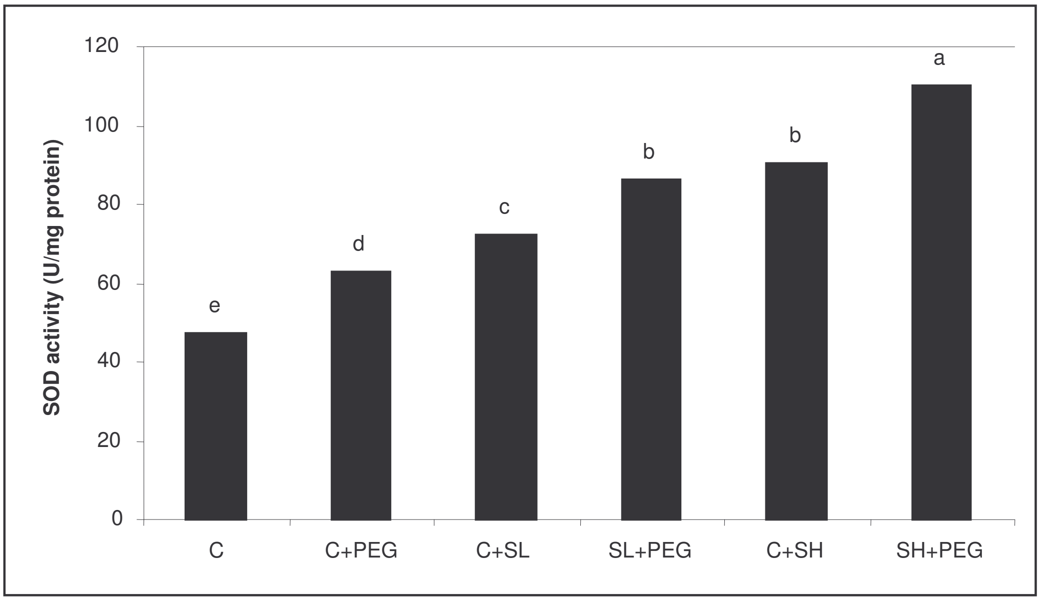

Figure 1. Effects of NaCl and PEG 6000 treatments on SOD activity of maize plants.

Values followed by different superscript letters in each column differ significantly (LSD test, $P \leq 0.05$); SOD, superoxide dismutase.

C: Control, C+PEG: PEG 6000 treatment, C+S_L: 5 ds/m NaCl treatment, S_L+PEG: 5 ds/m NaCl treatment plus PEG 6000 treatment, C+S_H: 10 ds/m NaCl treatment, S_H+PEG: 10 ds/m NaCl plus PEG 6000 treatment.

POX activity, which decomposes the H_2O_2 produced by SOD, also changes with respect to salinity and water stres. The activity of POX increased with increasing salinity and water stress. But POX activity was observed not to be significantly ($p \leq 0.05$) higher plants under water stress than the salinity treated plants. However maize plants exhibited an increase in POX activity with increasing magnitude of salinity and water stress conditions.

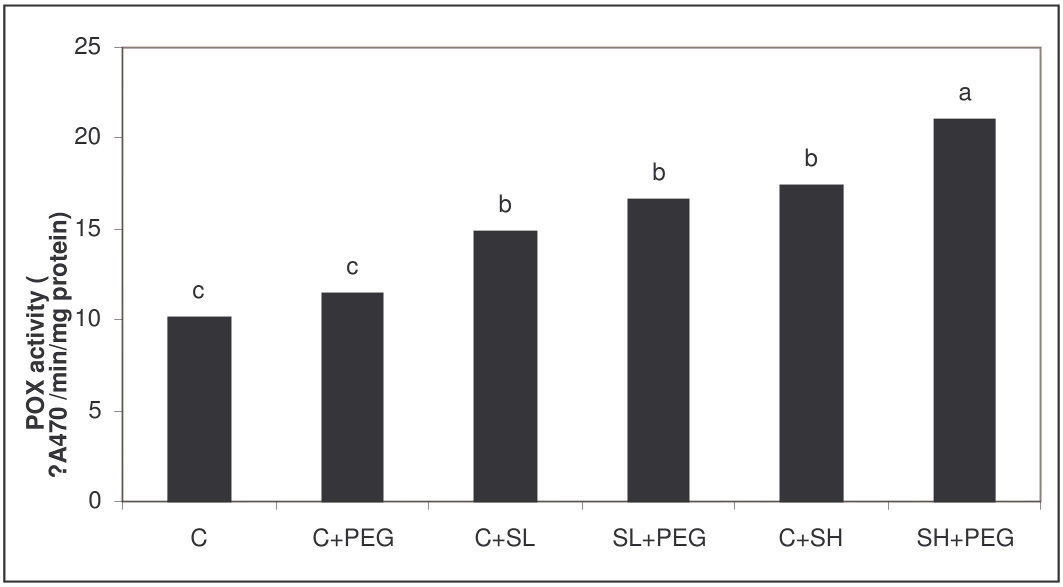

Figure 2. Effects of NaCl and PEG 6000 treatments on POX activity of maize plants.

Values followed by different superscript letters in each column differ significantly (LSD test, P ≤ 0.05); P0X, peroxidase.

C: Control**, C+PEG:** PEG 6000 treatment**, C+S_L:** 5 ds/m NaCl treatment**, S_L+PEG:** 5 ds/m NaCl treatment plus PEG 6000 treatment**, C+S_H:** 10 ds/m NaCl treatment**, S_H+PEG:** 10 ds/m NaCl plus PEG 6000 treatment.

The effect of increasing magnitude of salinity and water stress on PPO activity in the leaves of maize plants is shown in Fig 3. PPO activity showed an increasing trend with the increase in the NaCl concentrations. The highest PPO activity was found in high salinity and PEG 6000 treatment, whereas the lowest was determined in control plants. As POX activity, salinity was more effective than water stress in increase of PPO activity. However, the interactive effects of salt and water stress was found very significant on PPO activity.

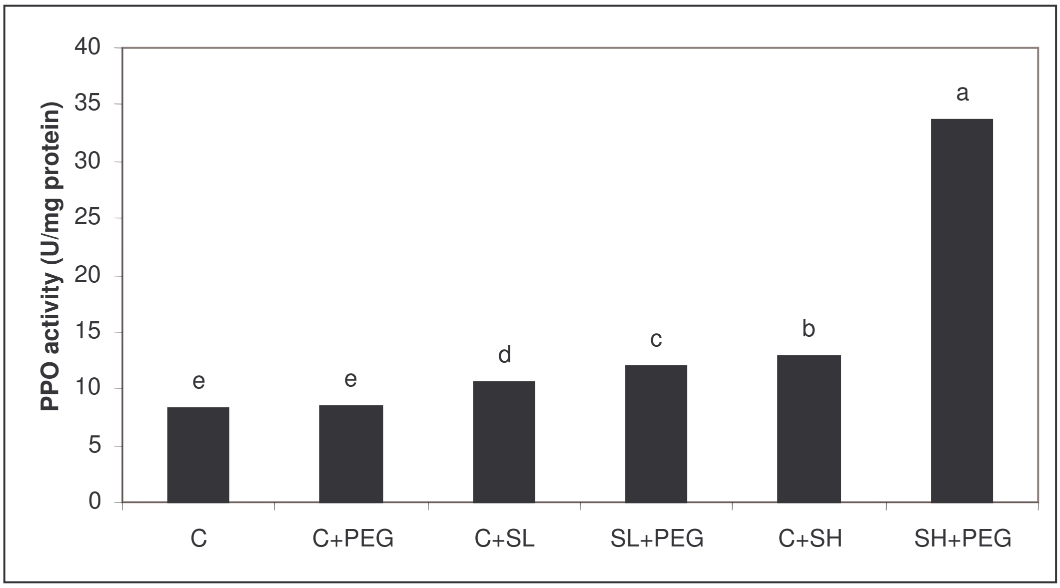

Figure 3. Effects of NaCl and PEG 6000 treatments on PPO activity of maize plants.

Values followed by different superscript letters in each column differ significantly (LSD test, P ≤ 0.05); PPO, polyphenol oxidase.

C: Control**, C+PEG:** PEG 6000 treatment**, C+S_L:** 5 ds/m NaCl treatment**, S_L+PEG:** 5 ds/m NaCl treatment plus PEG 6000 treatment**, C+S_H:** 10 ds/m NaCl treatment**, S_H+PEG:** 10 ds/m NaCl plus PEG 6000 treatment.

In the present study, in general salinity, was more effective on SOD, POX, and PPO than water stres in maize plants. However, it was found that the interective effects of salinity and water stress induced antioxidant enzymes such as SOD, POX, and PPO. Maize plants under salt and water stress were significantly increased the antioxidant enzymes compared to the control and only salt or PEG 6000 treated plants.

DISCUSSION

In this study, reduction in maize plants growth was more significant, because of water stress treatment in addition to NaCl. Similar results were reported in durum wheat plants by Almansouri et al. (2001). But it seems difficult to determine differences between salt and water stress detrimental effects on plant growth, because PEG 6000 treatment had also been decreased maize plants growth by reduce plant dry and fresh weight.

Antioxidant enzymes play important roles in adaptation to stress conditions (Misra and Gupta, 2006). Therefore, we hypothesized that increased activity of antioxidant enzymes; SOD, POX and PPO contributes to the protection of maize plants from salt and water stress. As a result of this study, it was found that maize plants under salt and water stress were increased antioxidant enzymes activity such as SOD, POX and PPO.

The activity of SOD enzyme, which converts superoxide radical to H_2O_2, was reported to increase under saline conditions in the maize and sunflower seedlings (Rios-Gonzalez et al., 2002), and in cotton (Meloni et al., 2003). Many workers found positive correlation between water stress and the abundance of SOD in plants (McKersie et al., 1996; Burke et al., 1985; Badawi et al., 2004). Our results are in conformity with these results.

It is know that high NaCl (Meloni et al., 2003) and PEG treatment (Li and Staden, 1998) induces POX activity in plants. The results of this study are similar to those reported results. High salinity and PEG 6000 treatment was more effective in increasing POX activity.

Demir and Kocaçalışkan (2001) was found that in bean plants treated with NaCl PPO activity gradually increased as NaCl concentrations increased. Some previous studies have also shown that PPO activity is induced during water stres (Shivishankar, 1988; English-Loeb et al., 1997). Similar results were obtained in this study.

In conclusion, the aim of this work was to evaluate the effects of salt and water stress on growth, the activity of antioxidative enzymes such as SOD, POX and PPO, in order to better understand stress condition's interactive effects on plant growth. The results obtained from this experiment show that high salinity and water stress enhanced antioxidant enzymes (SOD, POX and PPO) activity and salt stress was more effective than water stress on the stress parameters. However, interactive effects of salinity and water stress on growth, and antioxidative enzymes such as superoxide dismutase (SOD), guaiacol peroxidase (POX) and polyphenol oxidase (PPO) in hydroponically grown plants of maize, *Zea mays* L.cv DKC647 were more significant than only salt or water stress treatment. Certainly, the present study in *Zea mays* L. plants about its suffering from PEG 6000 and NaCl stresses is probably not sufficient. Nevertheless, these results suggest that maize plants may be increased the activity of antioxidant enzymes to have a better protection against reactive oxygen species (ROS) under salt and water stress.

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Automated Irrigation Scheduling Application of the North Dakota Agricultural Weather Network

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ABSTRACT

During the last 30 years, the development of agricultural weather networks and other technologies have made scientific irrigation scheduling much easier to apply and use. However, at the present time the most frequent complaints by irrigators about scientific irrigation scheduling is that it has a steep learning curve, takes too much time to gather all the bits of information and they just don't have the time during the growing season. To address these concerns a site-specific irrigation scheduling program, accessible through the North Dakota Agricultural Weather Network (NDAWN) website, was developed. The irrigation scheduling application has become one of the most popular agricultural applications on the NDAWN website (http://ndawn.ndsu.nodak.edu). It is designed to increase proficiency in water usage of irrigators by calculating site-specific water deficiency in soil. The soil-water deficiency is calculated based on a selected field and the growth stage of a selected crop. The application interfaces with a Geographic Information System (GIS) to select a specific field and thus obtain the geographic coordinates for the soil types and soil water holding capacity in the field. It also interfaces with the nearest NDAWN automated weather station to obtain meteorological information to automatically calculate crop water requirements on a daily basis of the crop in the selected field. The output is the daily checks and balances of the soil-water deficiency for the selected field.

Key words: irrigation scheduling, weather data, site specific, NDAWN, soil properties

INTRODUCTION

There are 15.9 million hectares (39.4 million acres) of farmlands in North Dakota, USA (USDA, 2002) . It makes up 87% of total land cover in the state (4th largest percentage in the United States). In 2007, North Dakota ranked number one in ten agricultural commodities in the nation including spring wheat, durum wheat, oats, barley, flaxseed, navy beans, pinto beans, lentils, sunflower and canola

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NDAWN: North Dakota Agricultural Weather Network
GIS: Geographic Information System
USDA: United States Department of Agriculture

(USDA, 2007). It is apparent that agriculture makes up a big portion of North Dakota's economic power. Small increases in yield due to farming practice (such as adaptation of irrigation farming) can translate into a significant statewide economic gain. The emerging importance and impact of climate change has raised the concern by policymaker, researcher, producer or consumer. This issue is recognized as a fundamental component of the world's future food, feed and fuel security. The state's annual average temperature rose 0.16°C per decade during the last 114 years in North Dakota. Unfortunately, precipitation regime since 1895 did not yield any significant trend in North Dakota. In fact, since the advent of the National Drought Monitor in 2000, North Dakota was exposed to extreme droughts (category 3 of a 4-category drought depiction with 4 being the most severe drought) at least once every year (NDMC, 2008). This raises 2 questions of concern:

1. How might cropping practices change in a changing climate, and how it might impact farmers' decisions on the best crop choices to suit today's climate?
2. How might changing climate impact our water resources, and what are the best practices to mitigate our vulnerability to extreme droughts?

Based on the 2007 census, United States Department of Agriculture (USDA) reported by the Farm Service Agency (FSA) over 105,000 hectares of land were irrigated in North Dakota (0.66% of total agricultural land). Installation and maintenance cost of irrigation systems, poor access to water resources and generally good dryland crop yields are the main reasons for lack of adaptation of irrigation in North Dakota. Amongst the most frequent complaints by irrigators who adopted the irrigation systems are the steep learning curve and complexity of the former scheduling systems. Up until the advent of the North Dakota Agricultural Network Irrigation Scheduling Application, irrigation scheduling was time consuming and required a significant effort to acquire the correct information to make good irrigation decisions.

Web-based irrigation scheduling has the potential to overcome many of the objections raised by irrigators. Singels and Smith, 2006, demonstrated that a web-based irrigation advisory service that reduced irrigation amounts by 33 percent reduced deep drainage by 64 percent and reduced irrigation costs for small-scale sugarcane producers. Thysen and Detlefsen (2006) have adapted a computerized irrigation decision support system for use on the web so that much of the data gathering is transparent to the user. Hillyer, et al. (2007) described a web-based irrigation advisory system for optimum irrigation management.

FSA: Farm Service Agency

MATERIALS and METHODS

The irrigation scheduling program can be activated from the NDAWN web site (http://ndawn.ndsu.nodak.edu/) by selecting the "Irrigation Scheduler" from the "Applications" menu on the left hand side of the web page (Figure 1). The irrigation-scheduling method uses a soil water balance algorithm to determine the soil water deficit in the effective root zone on a daily time step. Soil water deficit is zero when the moisture level in the effective root zone is at field capacity and is at 100 percent when all plant available water has been depleted (which should not occur under irrigated conditions). This method is explained in Lundstrom and Stegman (1988) where it is called the checkbook method. In the checkbook method water added to the soil (rain and irrigation) is treated as a deposit and water removed from the root zone (crop water use, runoff and deep drainage) is treated as a withdrawal, similar to a common bank checking system.

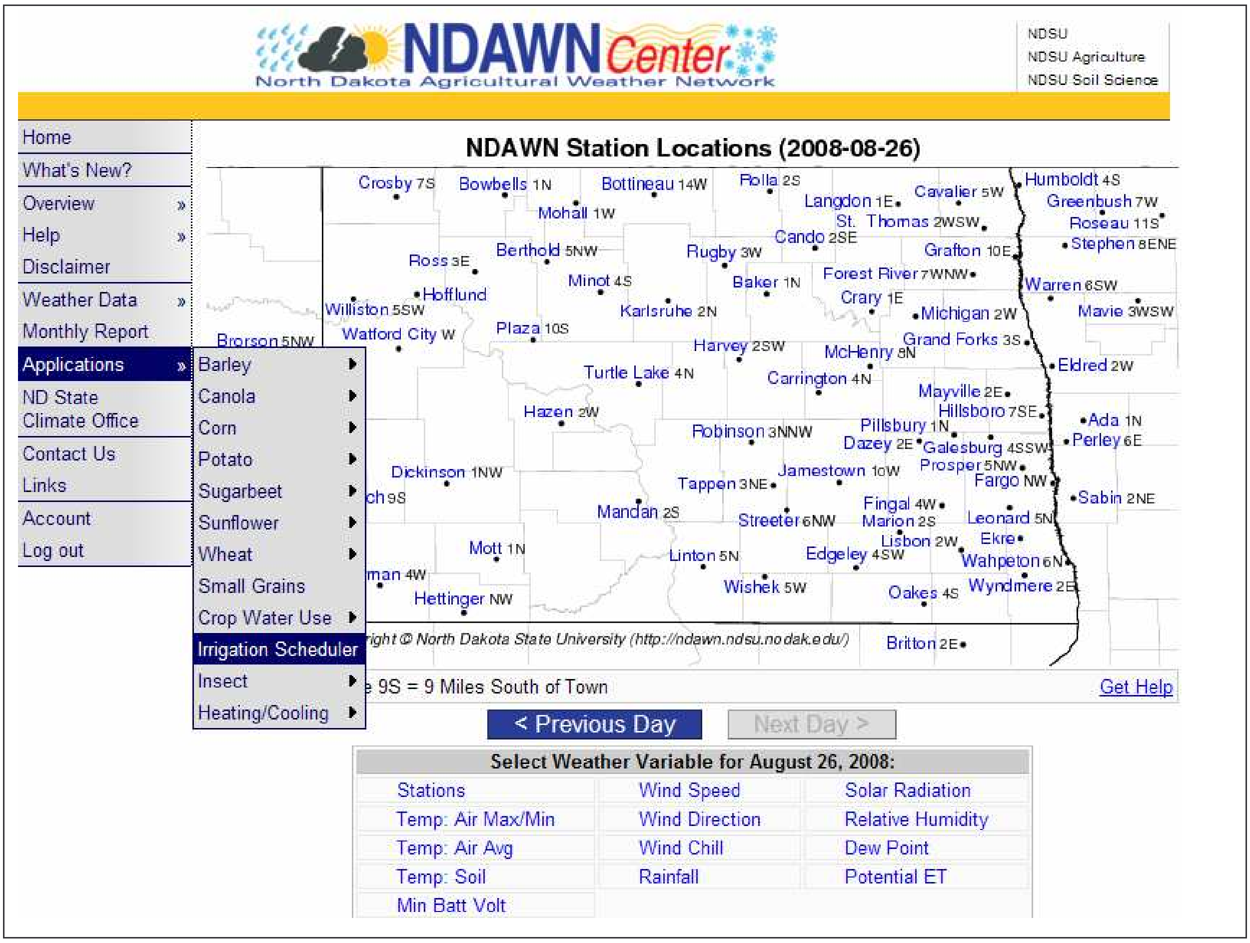
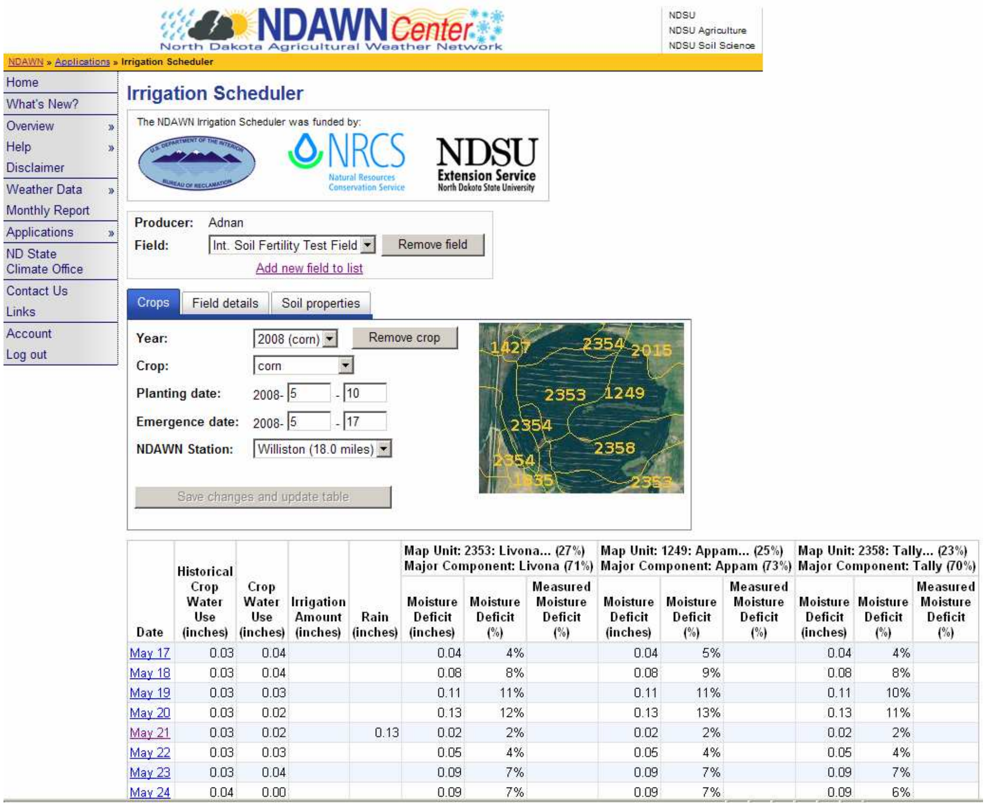


Figure 1. Accessing the North Dakota Agricultural Weather Network's Irrigation Scheduling Application.

Figure 2 is an example output for a test field that contains the picture of the irrigated field, soil information and the checkbook table with daily moisture deficit values for each soil type. In order to achieve the output seen in Figure 2, the user must select the field from aerial photos using a GIS interface and then field specific soil parameters are accessed from the USDA-Natural Resource Conservation Services (NRCS) digitized soil survey database. The user then selects the crop, planting date, emergence date and year. The user can then select one of the three nearest weather stations to be used to calculate crop water use estimates. The program automatically creates a soil water accounting sheet for each of the three major soils in the field (based on area). The user also has the choice to select the NDAWN weather station from the nearest station drop-down menu for the meteorological parameter calculations.



Date	Historical Crop Water Use (inches)	Crop Water Use (inches)	Irrigation Amount (inches)	Rain (inches)	Map Unit: 2353: Livona... (27%) Major Component: Livona (71%)			Map Unit: 1249: Appam... (25%) Major Component: Appam (73%)			Map Unit: 2358: Tally... (23%) Major Component: Tally (70%)		
					Moisture Deficit (inches)	Moisture Deficit (%)	Measured Moisture Deficit (%)	Moisture Deficit (inches)	Moisture Deficit (%)	Measured Moisture Deficit (%)	Moisture Deficit (inches)	Moisture Deficit (%)	Measured Moisture Deficit (%)
May 17	0.03	0.04			0.04	4%		0.04	5%		0.04	4%	
May 18	0.03	0.04			0.08	8%		0.08	9%		0.08	8%	
May 19	0.03	0.03			0.11	11%		0.11	11%		0.11	10%	
May 20	0.03	0.02			0.13	12%		0.13	13%		0.13	11%	
May 21	0.03	0.02		0.13	0.02	2%		0.02	2%		0.02	2%	
May 22	0.03	0.03			0.05	4%		0.05	4%		0.05	4%	
May 23	0.03	0.04			0.09	7%		0.09	7%		0.09	7%	
May 24	0.04	0.00			0.09	7%		0.09	7%		0.09	6%	

Figure 2. A Sample NDAWN Irrigation Scheduling Checkbook Output for a Test Field.

There are 3 main tabs under the field created by the user: "Crops", "Field details" and "Soil properties".

Crops: This is the default page that program returns upon saving the field, crop and date information. This is where crop moisture deficits are calculated for each soil type in the selected field. The calculations under the "Moisture Deficit" for each soil type utilizes the following equation (Scherer et al., 2008)

NRCS: Natural Resource Conservation Services

$$\mathbf{SWD_i = SWD_{i-1} + ET_c - (I + R)} \quad (1)$$

where:

SWD_i – soil water deficit at the end of day i (cm)

SWD_{i-1} – soil water deficit at the end of previous day [i-1] (cm)

ET_c – crop evapotranspiration on day i (cm)

I – irrigation amount on day i (cm)

R – rain amount on day i (cm)

i – day after crop emergence

The percent soil water deficit is calculated using the following equation:

$$SWD_i = \frac{100 * (PAWC_{rz} - AW_{rz})}{PAWC_{rz}} \quad (2)$$

where:

AW_{rz} – available water in the root zone on day i

$PAWC_{rz}$ – total soil-water holding capacity in the root zone on day i

Crop evapotranspiration values are obtained using daily weather data from the nearest NDAWN weather station. The farthest distance from any point in North Dakota to an NDAWN weather station is approximately 80km. In order to calculate the water deficits more accurately, precise precipitation data is necessary. Rainfall distribution in North Dakota can sometime be very variable in short distances especially during a summer thunderstorm event. Therefore, irrigators are encouraged to make on-site rainfall measurements. These observations are entered manually.

Field details: The field details contain the following information: total area, latitude, longitude and county. The field details also show the aerial photo of the field with soil types labeled. Figure 3 is a sample output for this test field showing the field details. The technology behind how this information is populated can be found in the following section.

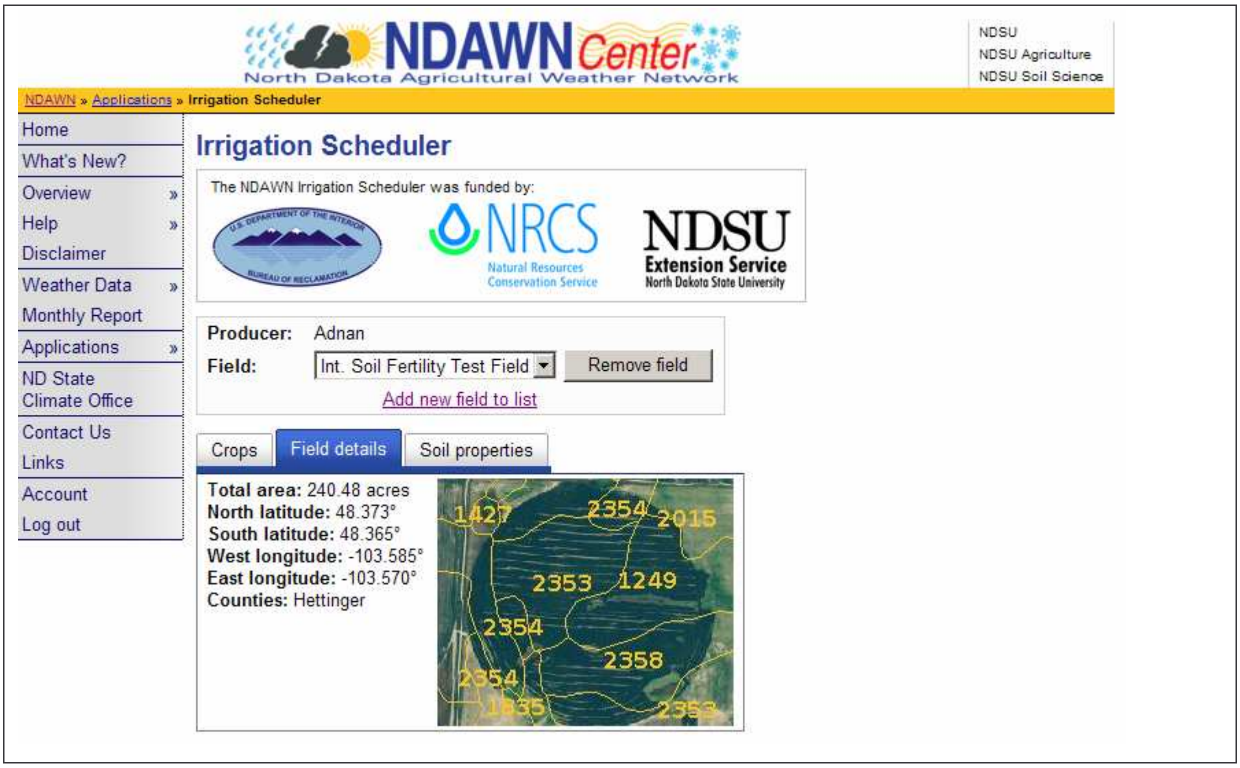


Figure 3. A Sample output of the NDAWN Irrigation Scheduling Field Details.

Soil Properties: The soil properties field contains information related to type of soils that occupies the field. Percent coverage, slope, soil-water holding capacity by depth are the information given in this section. Figure 4 is a sample output for this test field showing the soil properties. The technology behind how this information is populated can be found in the following section.

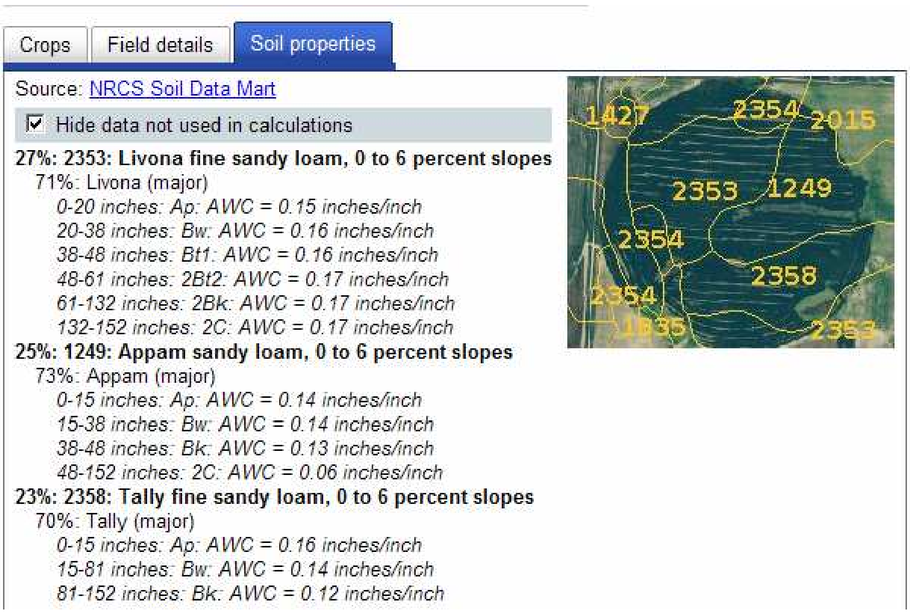


Figure 4. A Sample output of the NDAWN Irrigation Scheduling Soil Properties.

The Technology behind the NDAWN Irrigation Scheduler

The NDAWN irrigation scheduler is a web browser application with three separate pages. There are two pages for viewing and editing the schedule and a third page for setting up new irrigated areas (fields). The irrigation scheduler, like all NDAWN applications, is built on free and open source software. The web pages were created with a mixture of the jQuery [1], Yahoo User Interface (YUI) Library [2], and OpenLayers [3] software packages. jQuery is used for handling user interaction and manipulating the pages. YUI is used for its user interface components.

OpenLayers provides the Geographic Information System (GIS) functionality on the "field creation" page. Designing this page was a challenge because not only did the interface have to provide the tools necessary for users to find their irrigated plots on a map, but it also had to be easy to use for users who aren't familiar with GIS concepts. OpenLayers is a JavaScript library that runs in the web browser. It provides the functionality one would expect in a browser-based GIS application, such as zooming, panning, and manipulating maps, yet its interface is easy to use. On the server, NDAWN uses the University of Minnesota's MapServer [4] software to provide a single point of access for all of the map layers shown by OpenLayers. The aerial photograph, political boundary, and road layers are retrieved directly from the North Dakota GIS Hub (NDGIS) [5] via standard Web Mapping Service (WMS) queries. NDGIS provides North Dakota geospatial information in a centralized location and is a valuable resource for the irrigation scheduler. The soil map layers (the contours and their labels) are created from Soil Survey Geographic (SSURGO) [6] data stored in NDAWN's database. TileCache [7] runs between MapServer and an Apache Tomcat [8] HTTP server to cache map images to improve performance. MapServer's flexibility provides a powerful means of unifying map layers from different sources. The SSURGO soil data used by the irrigation scheduler is from the Natural Resource Conservation Service's Soil Data Mart [9]. The original shapefiles were imported into NDAWN's PostgreSQL [10] database using a technique similar to that the California Soil Resource Laboratory [11]. PostGIS [12] is used by MapServer for generating the soil data map layers. It's also used for storing the geographic coordinates of fields and for calculating the statistics shown in the irrigation scheduler, such as the total area of a field and the counties in which it exists. Table 1 (Scherer et al., 2007) shows the software development tools used to develop the irrigation scheduling application on the NDAWN website in the same order as mentioned in the text above.

YUI: Yahoo User Interface
WMS: Web Mapping Service
SSURGO: Soil Survey Geographic

Table 1. (Scherer et al., 2008) Software development tools used to develop the irrigation scheduling application on the NDAWN website (row numbers indicate the order in which they were cited in the text above)

1.	jQuery JavaScript Library:	http://www.jquery.com
2.	Yahoo! User Interface Library:	http://developer.yahoo.com/yui
3.	OpenLayers JavaScript GIS Library:	http://www.openlayers.org
4.	University of Minnesota MapServer:	http://mapserver.gis.umn.edu
5.	North Dakota GIS Hub:	http://www.nd.gov/gis
6.	Soil Survey Geographic:	http://www.soils.usda.gov/survey/geography/ssurgo
7.	TileCache:	http://www.tilecache.org
8.	Apache Tomcat HTTP server:	http://tomcat.apache.org
9.	NRCS Soil Data Mart:	http://soildatamart.nrcs.usda.gov
10.	PostgreSQL database:	http://www.postgresql.org
11.	Importing SSURGO data into PostgreSQL:	http://casoilresource.lawr.ucdavis.edu/drupal/node/369
12.	PostGIS, a GIS extension for the PostgreSQL database:	http://postgis.refractions.net

CONCLUSION

With changing climate, increasing demand in food, feed and fuel and increasing prices in commodities, irrigation will become more cost-effective by increasing efficiency in water use and reducing vulnerability to severe and extreme droughts. Farmers are going to adopt irrigation systems where benefits surpass costs. Irrigation would enable farmers to improve and maintain crop and pasture, develop healthier soils, and reduce wind erosion and the transfer of nutrients. The NDAWN irrigation scheduling application can make irrigation a science rather than guesswork, conserve water, reduce spending and increase earning through higher yield in North Dakota.

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The Effects of Irrigation Water Salinity, Potassium Nitrate Fertilization, Proline Spraying and Leaching Fraction on the Growth and Chemical Composition of Corn Grown in Calcareous Soil

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ABSTRACT

Two pot experiments were conducted to study the effect of irrigation with saline water in relation to KNO_3 fertilization, proline spraying and leaching fraction on the growth and Na^+, K^+, Cl^-, NO_3^- and proline contents of corn (*Zea mays* L.) plant grown on a nonsaline calcareous soil. The treatments included irrigation waters of different salinity (0.54, 3.36, 5.88 or 7.95 dS/m), three rates of KNO_3 (0, 4 and 8 g/pot) fertilizer and foliar application with three rates of proline (0, 100 and 200 mg/L). The first experiment was irrigated with the water to the field capacity with leaching fraction and the second without leaching fraction. The experimental design was a split split plot with three replications. Also, the effect of these parameters on salt accumulation in soil was discussed. The obtained results showed that the dry weight of shoots was decreased as salinity of irrigation water increased. The highest decreases were attained with waters of 5.88 and 7.95 dS/m as compared with dry weight due to irrigation with 0.54 or 3.36 dS/m water salinity. High salinity of water increased the shoot contents of Na^+, Cl^-, proline and decreased NO_3^- contents with or without leaching fraction, but the values without leaching fraction were higher than those of without leaching fraction. Also, increasing the salinity of irrigation water decreased K content in shoot which was higher with leaching than without leaching. On the other hand, KNO_3 fertilization or proline spraying decreased Na^+, Cl^- contents and increased K^+ or NO_3^- contents in plant shoot and their values without leaching were higher than with leaching. The EC values of soil were increased with both increasing salinity of irrigation water and KNO_3 fertilization. The decreased plant growth due to water salinity was partially offset by KNO_3 fertilization, proline spraying and leaching fraction application. Also, KNO_3 fertilization was more effective than proline for reducing the adverse effect of water salinity.

Key words: Water salinity ,potassium nitrate, proline , leaching fraction , fertilization.

INTRODUCTION

The utilization of various sources of water is necessary in Egypt due to increasing population and the consequent need of agricultural expansion. The main problem to be considered in using the different sources of water is the salinity hazards. Soil salinity is being progressively exacerbated by agronomic practices such as irrigation and fertilization, especially in arid regions. The effect of salinity on plant growth may be more related to the Na^+/K^+ ratio of the plant tissue than to absolute Na^+ concentrations. Thus the cultivars which have an ability to minimize this ratio may be more salt tolerant than those with lower K^+ concentration (Benzyl and Reuveni, 1994; Lingle, *et al*., 2000). Application of K improved growth and yield under water stress possibly by regulating photosynthesis (Gupta *et al*., 1989). Also, the plant growth may be related to Cl/NO_3 ratio in the plant tissue. There is ample evidence of root absorption competition between Cl and NO_3 for plants (Kafkafi *et al*., 1982; Savvas and Lenz, 1996; Fisarekis *et al*., 2001) and the inhibition of NO_3 uptake might occur by Cl. Plants which are dependent upon KNO_3 as a source of N are less sensitive to salt stress (Singleton and Bohlool, 1984).

Proline accumulation has been shown to be fast, and is thought to function in salt stress adaptation (Berteli *et al.,* 1995), through protection of plant tissue against osmotic stress and/or acting as enzyme protector (Solomon *et al.,* 1994; Liu and Zhu, 1997). Accumulation of proline in plants under stress may offer multiple benefits to the cell. Hong *et al.,* (2000) showed that free radicals are formed during osmotic stress, as measured by an increase in the malondialdehyde production. They also recorded that transgenic plants, which produce more proline, accumulate less malondialdehyde. It was concluded that Na^+ exclusion from the shoot was not correlated with salt tolerance and that free proline and glycinebetaine accumulation in the shoot was a possible indicator for salt tolerance in the maize genotypes studied (Mansour *et al*., 2005). Leaching is the key factor in controlling soluble salts in soils brought in by irrigation water. The amount of leaching required depends upon crop, salinity of water, soil characteristics, climate and management (Hoffman, 1990).

The objective of the present study was to determine the possibility of compensating the negative effect of irrigation water salinity by foliar application the plants with proline, potassium nitrate fertilization and leaching fraction application, on both the growth and chemical composition of corn plants and the salt accumulation in soil.

MATERIALS and METHODS

Pot experiments were carried out in the greenhouse of Faculty of Agriculture Saba Basha, Alex. Univ. using a calcareous soil (typical calciorthids). The main chemichal and physical characteristics of this soil was determined according to the methods outlined by Black (1965) and the obtained data are presented in Table 1. Four different qualities of irrigation water were used. The first one (S1) was tap water and the other three (S2, S3 and S4) were prepared by blending tap water with sea water. The main chemical compositions of these waters are given in Table 2. In this study, two experiments were carried out. The first one included leaching fraction application. This fraction was calculated (Rhoades and Merrill, 1976) for corn at 90% yield potential according to the salinity of irrigation water. The desired leaching fraction was added to the amount of water required to keep the soil moisture content at field capacity. The second experiment was carried out without applying the leaching fraction.

Experimental Layout: Ten Kgs air-dried soil were placed inside a plastic pot (25 cm in diameter and 30 cm depth) with a hole in its bottom for drainage. The soil in each pot was irrigated with tap water before planting the seeds of corn to achieve suitable seeding medium. The experimental design was a split split plot with three replicates. The water quality treatments were arranged at random in the main plots and three levels of potassium nitrate fertilizer (0, 4 and 8 gm/pot) were applied and arranged at random in the sub-plots. Each amount of this fertilizer was divided into three equal parts and applied during plant growth period (before sowing, after 3 and 5 weeks from sowing). Three levels of proline ($C_5H_9NO_2$) (zero, 100 and 200 mg/L) were applied as foliar and arranged at random within the sub-sub-plots. Superphosphate fertilizer was applied and mixed with the soil in each pot before planting at a rate of 2 g/pot and N as ammonium nitrate fertilizer at a rate of 1.5 g/pot was applied in two equal doses, before and after plant thinning. Five seeds of corn (*Zea mays* L.) cultivar S.C.10 were planted in each pot and irrigated with tap water. After 21 days from sowing, the plants were thinned to 2 uniform plants per pot. Irrigation treatments were applied, when the soil moisture content had reached 75% of the soil field capacity, to raise soil moisture content to the field capacity. The proline treatments were foliar applied, after adding "Tween 20" (0.05 %) as a wetting agent, using hand atomizer after 28 and 35 days from plant sowing.

Plant and Soil Sampling and Analysis: The plant shoots were collected after 60 days from planting, washed with tap water then by distilled water, dried in an oven at 65˚C for 48 hours and the dry weights were recorded. Sub-samples of plants were ground using stainless steal mill. The oven dried plant material was wet digested and the concentrations of Na, K were determined (Chapman and Pratt, 1961). In addition, the concentrations of Cl and NO_3 were determined according to the methods outlined by Chapman and Pratt (1961) and by Cataldo *et al*. (1975). The proline content in plant leaves was determined according to the method of Bates *et al*. (1973). After plant harvest, soil samples were collected from each pot and their salinity were determined (Black 1965). All data were statistically analyzed according to Gomez and Gomez (1984). The regression analysis was carried out by CoHort Software (1995).

RESULTS and DISCUTION

Shoot Dry Weight:

Table 3 showed that the corn shoots of plant dry weight was markedly decreased from 6.44 g/pot with water salinity of 0.54 dS/m to 6.36 g/pot with water salinity of 3.36 dS/m. However, with increasing water salinity to 5.88 and 7.95 dS/m, there were significant decreases of plant dry weights with or without leaching treatment. In this concern, it has been reported that salinity of 3.6 dS/m is water salinity marginal for corn production (Ayres and Westcot, 1985). It is also clear that the dry weight of corn plant had decreased significantly from 6.00 g/pot to 2.64 g/pot with increasing water salinity from 0.54 to 7.95 dS/m without leaching fraction treatment. These results clearly showed that applying leaching fraction at any salinity level had decreased the harmful effect of salinity of irrigation water especially at water salinity of 3.36 dS/m which is less than 3.60 dS/m, the marginal value of corn production according to Ayres and Westcot (1985). It is also clear that the harmful effect of salinity was greater in the treatment of without leaching. This is due to the accumulation of salts in the root zone, which did not occur with using the leaching fraction. Similar results have been also reported by Gendy and Hammed (1993), Radwan *et al.* (1993) and Abou Hussien *et al.*, (1994).

Table 3 and Fig 1 indicated a significant increase in the dry weight of corn plants, with or without leaching treatment, due to applying potassium nitrate fertilizer up to 8 g /pot. The relative increases in plant dry weights with potassium nitrate application (4 and 8 g/pot), and without leaching were 6.7 and 11.96% and with leaching were 2.57 and 5.94%, respectively. These data indicate the beneficial effect of appling potassium nitrate fertilizer for decreasing the harmful effect of salinity on plant growth. This is evident for plants grown without leaching treatment than with leaching treatment. Similar results were found by Badr and Shafei (2002) who reported that increasing K^+ application could be useful to overcome the adverse effect of salinity (NaCl) on the growth of wheat plant. It can be stated that the ability of plants to retain K^+ at high Na^+ concentration, of the external solution, may be involved in reducing the damage associated with excessive Na^+ concentration in plant tissue. In addition, the presence of N in the form of KNO_3 at this saline condition had improved the growth of corn plant. This was also found by Martinez and Cerda (1989) who indicated that increasing NO_3^- in the substrate decreased Cl^- uptake and accumulation in plant tissue which had improved the growth of tomato and cucumber plants grown in saline conditions. Table (3) and Fig 2 revealed that foliar application of proline increased significantly the dry weight of plant shoots, with or without leaching treatment. Foliar application of 100 or 200 mg proline /L increased the relative dry weight, without leaching treatment, to values of 2.06 and 3.67%, respectively while with leaching treatment these values were 1.17 and 2.33%, respectively. This points out that foliar application of proline (200 mg/L) significantly decreased the harmful effects of salinity with or without leaching treatment.The interaction effect between salinity of irrigation water(S) and potassium nitrate (K) on shoots dry weight, with or without leaching treatment, was highly significant (Table 3). The maximum dry weights with or without leaching were obtained with KNO_3 treatment of 8 g/pot, with each level of salinity of irrigation water. There was also a significant interaction effect between salinity of irrigation water and proline (S x P) on the dry weight of plant without leaching treatment only. The highest values of dry weight, without leaching treatment, were obtained when the plant was sprayed with 200 mg/L proline at each level of irrigation water salinity.

Multiple regression analysis between the dry weight (Y), KNO_3 (X_1) and proline (X_2), with or without leaching, are presented in Table 4. This relation showed that the dry weight was positively correlated with these two variables. The slope of each variable, in the equation, gives a quantitative expression of the efficiency of KNO_3 and proline for reducing the adverse effect of salinity. As a result, KNO_3 fertilizer showed higher efficiency for reducing the adverse effect of salinity on plant growth than proline.

Chemical Composition of Plants

Table 5 and Fig 3 showed that sodium concentration in the shoot of corn plant increased significantly from 0.41 % with irrigation by water of 0.54 dS/m to 1.07 % with irrigation by water of 7.95 dS/m, with or without leaching treatment. On the other hand, K^+ concentration in plant shoot decreased from 4.71 % to 1.82 %, with same treatment respectively. These results are associated with increasing Na/K ratio in plant from 0.09 to 0.58, respectively. Similar results were obtained by Santos *et al.* (1999) who reported that salinity decreased K^+ content in plants. On the other hand, applying KNO_3 fertilizer significantly decreased Na^+ and significantly increased K^+ concentrations in the shoot of corn plant, with or without leaching treatment. This increase of K^+ content had improved the Na – K balance in plant tissue which facilated plant growth as indicated in Table 3 and Figs 3, 4, 5 and 6. Foliar application of proline decreased the concentration of Na^+ in plant shoot. At the highest level of proline (200 mg/L), the relative decrease of Na^+ was 7.79 and 6.19% with or without leaching, respectively. In the same time, K^+ contents in shoot were increased and their relative increases were 4.73 and 6.52 %, respectively. Close results were obtained by Shaddad (1990) with *Raphanus sativus* grown under salinity stress.

Irrigation with 7.95 dS/m saline water produced the highest Na/K ratio with or without leaching (0.58 and 0.78, respectively). Similar results were found by Badr and Shafei (2002) who confirmed that decreasing the value of Na/K ratio may be involved in reducing the damage associated with excessive Na^+ levels in plant. It is clear from Table 5 that the Na/K ratio, with or without leaching, was decreased significantly with increasing KNO_3 fertilization. This relation was associated with increasing the dry weight of plant shoot. This points out to the beneficial effect of K^+ to overcome the adverse effects of salinity. The occurrence of high K^+ in plant had involved in reducing the damage caused by high Na^+ concentration. Table 5 also, showed that foliar application of proline decreased the Na/K ratio in plant shoot with or without leaching and this ratio was higher in plant grown without leaching than with leaching treatment. Highly significant negative correlation coefficients were found between dry weights and Na^+ contents in shoots of plant with or without leaching (r = -0.926** and -0.974** respectively). The corresponding correlations for Na/K ratio were -0.95** and -0.968**. On the other hand, highly significant positive correlation coefficients were found between shoot dry weights and K^+ contents in plant, with or without leaching treatment(r = 0.772** and 0.904** respectively).

Increasing salinity of irrigation water significantly increased Cl^- content and decreased NO_3^- contents in the shoot of corn plant (Table 6 and Figs 7, 8, 9 and 10). This decrease in NO_3^- content can be attributed to Cl^- competition with NO_3^- for binding sites on the plasma membrane which suppressed the influx of NO_3^- from the external solution (Balki and Padole, 1982 and Al-Uqaili, 2003). The ratio of Cl^-/NO_3^- in plant tissue increased with increasing salinity of irrigation water and was higher with leaching than without leaching treatment. This is due to low level of NO_3^- in plant tissue, with leaching treatment as compared without leaching. In the same time, proline contents in shoots significantly increased with increasing irrigation water salinity and were higher in plants grown without leaching than with leaching treatment (Table 6 and Figs. 11 and 12). It is clear that there were positive relations between proline contents in plant tissue and both Cl^- contents and Cl^-/NO_3^- ratio. It is also clear from Table (6) that chloride content decreased significantly with increasing KNO_3 application while NO_3^- content increased significantly with or without leaching. Foliar application of corn plant with proline significantly decreased Cl^- contents and increased NO_3^- contents in shoot with or without leaching treatment (Table 6). This could be due to the role of proline in minimizing the adverse effect of salinity which is associated with the decrease of both Na^+ content (Table 5) and Cl^- content (Table 6) and increase of both K^+ content (Table 5) and NO_3^- content (Table 6) in shoots (Figs 3, 4, 5, 6, 7, 8, 9 and 10). This effect was more pronounced with leaching than without leaching treatment. On the other hand, proline foliar application increased significantly NO_3^- contents in shoots and consequently decreased Cl^-/NO_3 ratio.

The interaction effects between irrigation water salinity and potassium nitrate fertilizerwere significant on K^+ and NO_3^- contents with leaching and on NO_3^- contents without leaching. Also, the interaction effects between irrigation water salinity and foliar application with proline were significant with Cl^- contents with leaching, and with NO_3^- contents without leaching. The interaction effect between potassium nitrate and proline was significant on NO_3^- content, with or without leaching. Several studies reported data indicated that increasing NO_3^- in the substrate decreased Cl^- content and its accumulation in plant (Bernstein *et al.*, 1974; Kafkafi *et al.*, 1982; Feigin *et al.*, 1987 and Martinez and Cerda, 1989). However, Cl^-/NO_3^- ratio were decreased significantly with increasing potassium nitrate with or without leaching. The same trend was found with increasing foliar application with proline. The highest values of Cl^-/NO_3^- ratio, with and without leaching (20.82 and 11.42), were found without proline spraying. This indicates that proline application could act well for reducing the accumulation of Na^+ and Cl^- in plant shoots.

Table (6) showed that proline content in plant significantly increased with increasing salinity of irrigation water and significantly decreased with increasing potassium nitrate, with or without leaching (Table 6 and Fig 11). It is obvious that proline plays an adaptive role in the tolerance of plant cells to salinity by increasing the concentration of osmotic active components in order to equalize the osmotic potential of the cytoplasm (Watad *et al.*, 1983). Anjum *et al.* (2005) also found that proline accumulation in the leaves of plants grown on salt affected soil was 8 times higher than in the control. Increasing levels of application foliar with proline significantly increased proline contents in the shoot of corn plant. The relative increases in proline content of corn plants, at 200 mg/L proline, were 103.16 and 72.41% with or without leaching treatment, respectively. Therefore, it can be pointed out that exogenous proline application might counteract the negative effects of high salinity on carbohydrate and nitrogen metabolism which consequently could promote the whole plant growth.

Salinity Build up in Soil

Table 7 showed that the salinity of soil increased significantly with increasing salinity of irrigation water, with or without leaching. This is due to the accumulation of salts in the soil from water of irrigation. Similar results were obtained by Hussan (1981) and Tomar and Yadev (1992) who found significant increases in soil EC when soil was irrigated with highly saline water. Also, EC values in soil were increased significantly with increasing application of KNO_3 fertilizer, with or without leaching (Table 7). Table 7 showed significant interaction effects between irrigation water salinity and potassium nitrate on the EC of soil, with or without leaching. It is clear, that the leaching fraction was effective in reducing the accumulation of salts in soil.

The EC (Y) values of soil, with or without leaching, were regressed against salinity of irrigation water (X_1), potassium nitrate levels (X_2) and proline levels (X_3). The data revealed that the EC of soil was positively correlated with (X_1) and (X_2), and negatively correlated with (X_3), with or without leaching. The multiple regression equations for these relationships were:

With leaching $Y = -1.17 + 0.77\ X_1 + 0.27X_2 - 0.0001\ X_3$

$R^2 = 0.842$ $(P < 0.01)$

Without leaching $Y = -2.16 + 1.02\ X_1 + 0.043\ X_2 + 0.0001\ X_3$

$R^2 = 0.794$ $(P < 0.01)$

The comparison of the slopes of each variable in the equation with leaching (0.77: 0.27: 0.0001) and without leaching (1.02: 0.043: 0.0001) gives quantitative estimate for the efficiency of each variable to the other.

In conclusion, the present study confirms the potential of foliar application with proline, soil application with potassium nitrate and leaching fraction treatment for improving the growth of corn under irrigation with saline water, especially at water salinity of 3.36 dS/m, which is less than the marginal value (3.6 dS/m) for corn production. Also, potassium nitrate fertilizer as a source for K and N had more adverse effects, due to salinity, on both plant and soil.

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Table 1. The main chemical and physical characteristics of the used soil.

Soil properties	value	Soil properties	value
pH*	8.2	**Particle size distribution**	
EC** (dS/m)	2.44	Sand (%)	63.1
Total $CaCO_3$ (%)	30.7	Silt (%)	15.2
O.C. (%)	0.34	Clay (%)	21.6
Field capacity (%)	16.0	Soil texture	Sandy Clay Loam

* In 1:2.5 soil water suspension ** In saturation paste extract

Table 2. Chemical composition of the irrigation waters.

Water quality	pH	EC_w dS/m	Cations, meq/L				Anions, meq/L			SAR
			Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3	
S1	7.98	0.54	1.83	1.07	1.60	0.55	1.50	2.46	0.63	1.33
S2	7.94	3.36	2.15	4.72	23.78	0.42	26.53	6.14	0.22	12.84
S3	7.84	5.88	4.57	8.63	39.27	0.78	44.67	11.63	0.34	15.29
S4	7.72	7.95	6.96	11.94	52.83	0.86	57.72	16.84	0.46	17.19

Table 3. Effect of irrigation water salinity, Potassium nitrate and proline on the mean dry weight of corn plants grown in soil with or without leaching.

Treatment	with leaching	without leaching
	Dry weight (g/pot)	
salinity of irrigation water (S), dS/m		
0.54	6.44	6.00
3.36	6.36	5.05
5.88	4.90	4.08
7.95	3.08	2.64
L.S.D $_{0.05}$	0.24	0.14
Potassium nitrate (K), g/pot		
0	5.05	4.18
4	5.18	4.46
8	5.35	4.68
L.S.D $_{0.05}$	0.05	0.10
Proline (P), mg/L		
0	5.14	4.36
100	5.20	4.45
200	5.26	4.52
L.S.D $_{0.05}$	0.05	0.04
Interactions		
S x K	N.S	0.19
S x P	N.S	0.08
K x P	N.S	N.S
S x K x P	N.S	N.S

Table 4. The multiple regression equations between dry weight (Y), potassium nitrate (X_1) and proline (X2) with irrigation water salinity.

salinity of irrigation Water (dS/m)	With leaching	R^2	Without leaching	R^2
0.54	$Y = 6.19 + 0.043 X_1 + 0.0008 X_2$	0.960	$Y = 5.47 + 0.096 X_1 + 0.0015 X_2$	0.983
3.36	$Y = 6.09 + 0.043 X_1 + 0.0010 X_2$	0.961	$Y = 4.64 + 0.076 X_1 + 0.0010 X_2$	0.994
5.88	$Y = 4.71 + 0.039 X_1 + 0.0004 X_2$	0.991	$Y = 3.86 + 0.042 X_1 + 0.0006 X_2$	0.992
7.95	$Y = 2.95 + 0.025 X_1 + 0.0003 X_2$	0.997	$Y = 2.47 + 0.035 X_1 + 0.0004 X_2$	0.980

Table 5. Effect of irrigation water salinity and potassium nitrate and proline with or without leaching, on the mean value of Na, K concentrations (%) and Na/K ratio in shoot of corn plants.

Treatment	With leaching			Without leaching		
	Na^+	K^+	Na/K	Na^+	K^+	Na/K
salinity of irrigation water (S), dS/m						
0.54	0.41	4.71	0.09	0.51	4.43	0.12
3.36	0.63	3.33	0.19	0.85	3.17	0.27
5.88	0.85	2.26	0.38	1.07	2.13	0.51
7.95	1.07	1.85	0.58	1.32	1.72	0.78
L.S.D $_{0.05}$	0.03	0.22	0.01	0.050	0.46	0.01
Potassium nitrate (K) , g/pot						
0	0.83	2.42	0.39	1.04	2.28	0.52
4	0.74	3.08	0.31	0.94	2.93	0.41
8	0.65	3.62	0.24	0.84	3.38	0.32
L.S.D $_{0.05}$	0.03	0.11	0.01	0.04	0.45	0.01
Proline (P), mg/L						
0	0.77	2.96	0.33	0.97	2.76	0.45
100	0.74	3.06	0.31	0.94	2.88	0.42
200	0.71	3.10	0.30	0.91	2.94	0.40
L.S.D $_{0.05}$	0.02	0.12	0.01	0.02	0.16	0.01
Interactions						
S x K	N.S	0.23	0.01	N.S	N.S	0.02
S x P	N.S	N.S	0.01	N.S	N.S	0.02
K x P	N.S	N.S	0.01	N.S	N.S	N.S
S x K x P	N.S	N.S	N.S	N.S	N.S	N.S

Table 6. Effect of irrigation water salinity, potassium nitrate and proline on Cl^-, NO_3^- contents, Cl/NO_3 ratio and proline contents of corn plants with or without leaching.

Treatment	with leaching				without leaching			
	Cl^-	NO_3^-	Cl/NO_3	Proline	Cl^-	NO_3^-	Cl/NO_3	Proline
	(mg g^{-1})							
salinity of irrigation water (S), dS/m								
0.54	3.77	1.40	2.98	0.87	4.82	3.08	2.13	1.60
3.36	13.77	1.37	10.81	1.41	15.63	2.01	8.70	1.98
5.88	16.50	0.92	19.91	1.85	19.22	1.76	11.86	2.29
7.95	19.58	0.66	39.81	1.88	22.69	1.20	19.62	2.60
L.S.D $_{0.05}$	0.51	0.01	0.16	0.05	2.87	0.04	0.18	0.04
Potassium nitrate (K), g/pot								
0	14.41	0.73	29.90	1.59	16.98	1.22	15.06	2.36
4	13.44	1.03	15.60	1.36	15.59	2.02	9.49	1.96
8	12.36	1.50	9.63	1.56	14.20	2.80	7.18	2.03
L.S.D $_{0.05}$	0.15	0.01	0. 08	0.02	1.56	0.04	0.10	0.03
Proline (P), mg/L								
0	13.74	1.03	20.82	0.95	16.04	1.90	11.41	1.45
100	13.40	1.10	18.00	1.64	15.61	2.04	10.54	2.40
200	13.06	1.14	16.32	1.93	15.13	2.10	9.78	2.50
L.S.D $_{0.05}$	0.04	0.01	0. 04	0.01	0.71	0.03	0.09	0.03
Interactions								
S x K	N.S	0.02	0.16	0.04	N.S	0.07	0.19	0.07
S x P	0.07	N.S	0.09	0.03	N.S	0.06	0.17	0.06
K x P	N.S	0.02	0.08	0.02	N.S	0.05	0.15	0.05
S x K x P	N.S	N.S	0.15	0.05	N.S	0.10	0.30	0.10

Table (7). Effect of irrigation water salinity, potassium nitrate and proline with or without leaching, on the *EC (dS/m) of soil collected after harvesting of corn plants.

Treatment	With leaching	Without leaching
salinity of irrigation water (S), dS/m		
0.54	0.91	1.15
3.36	1.28	1.80
5.88	4.48	5.32
7.95	6.27	8.67
L.S.D $_{0.05}$	0.45	0.45
Potassium nitrate (K), g/pot		
0	2.14	2.54
4	3.31	4.20
8	4.59	5.96
L.S.D $_{0.05}$	0.28	0.30
Proline (P), mg/L		
0	3.30	4.27
100	3.23	4.23
200	3. 18	4.20
L.S.D $_{0.05}$	0.19	0.23
Interactions		
S x K	0.56	0.60
S x P	N.S	N.S
K x P	N.S	N.S
S x K x P	N.S	N.S

*EC of soil-water extract (1:1 w/v) was measured

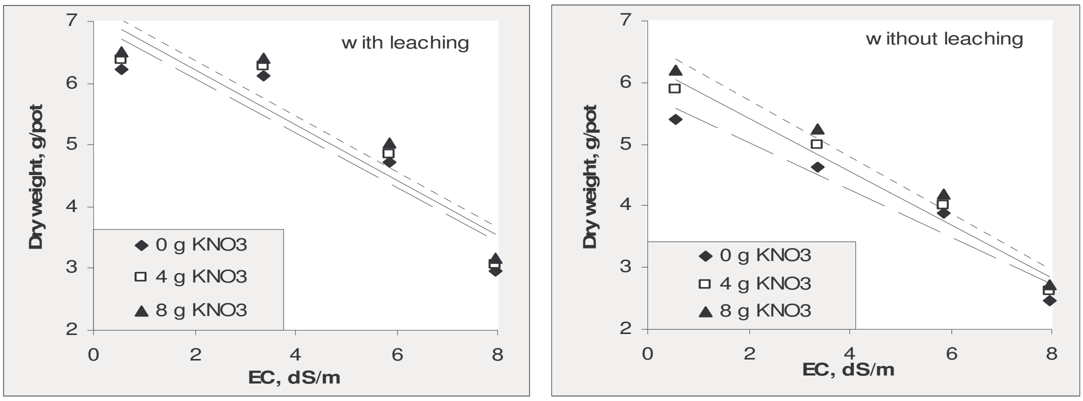

Fig 1. The relationship between the irrigation water salinity and the dry weight of corn shoot as affected by KNO_3 fertilization rate with or without leaching treatment

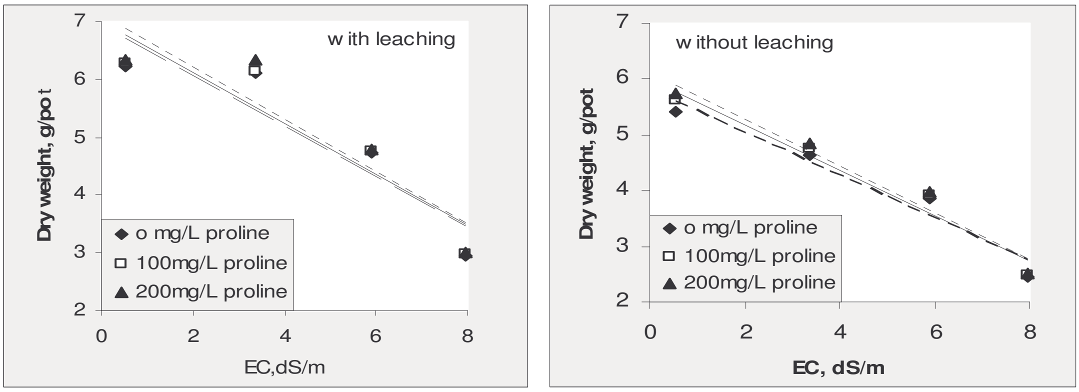

Fig 2. The relationship between the irrigation water salinity and the dry weight of corn shoot as affected by proline application rate rate with or without leaching treatment

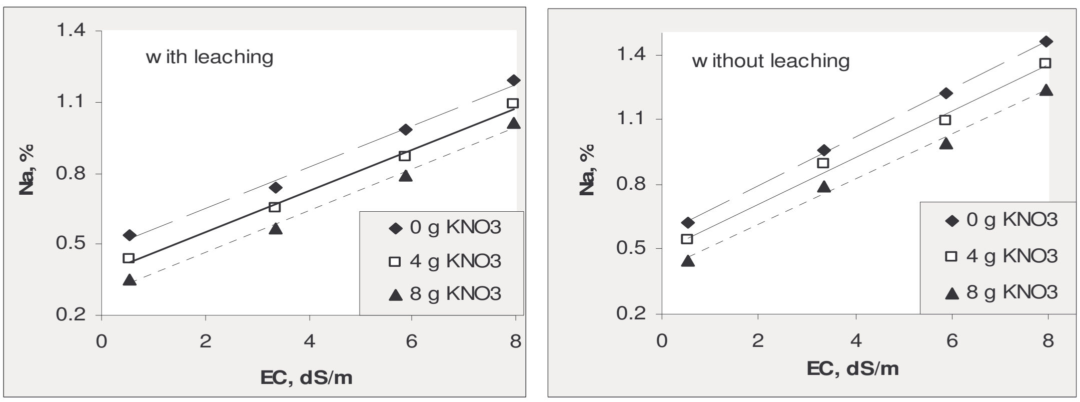

Fig 3. The relationship between the irrigation water salinity and the Na^+ contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

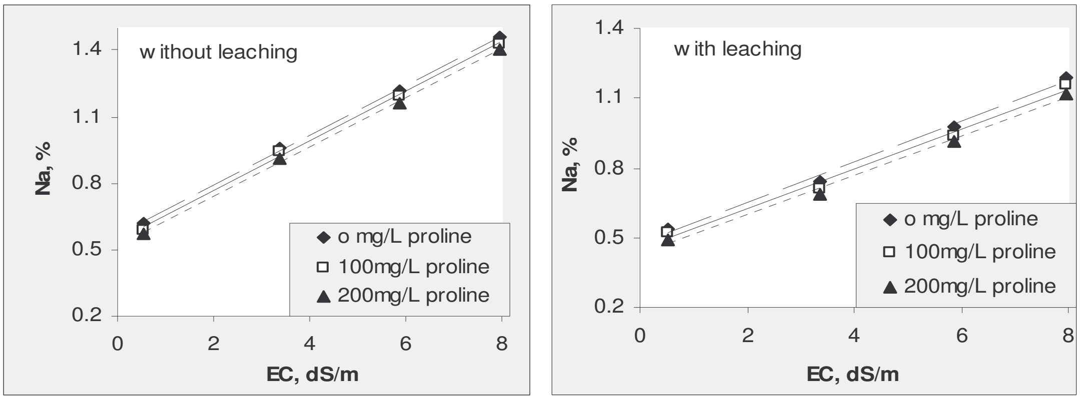

Fig 4. The relationship between the irrigation water salinity and the Na^+ contents in corn shoots as affected by proline application rate with or without leaching treatment

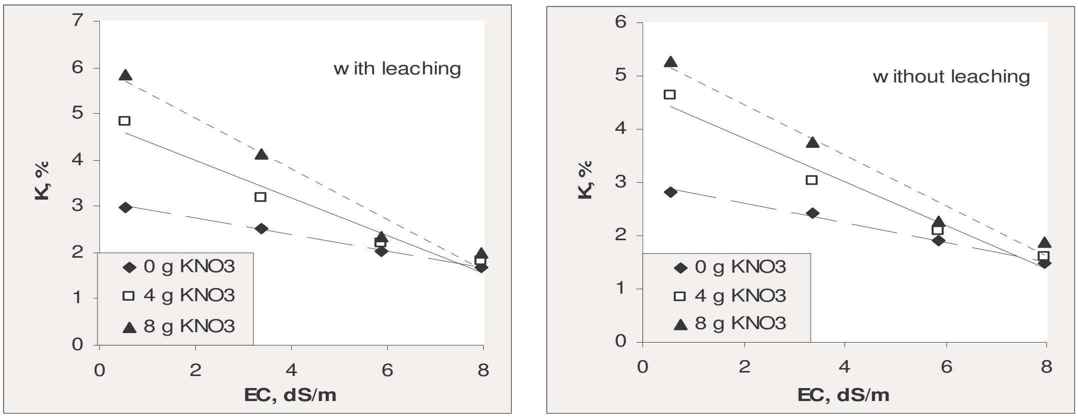

Fig 5. The relationship between the irrigation water salinity and the K^+ contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

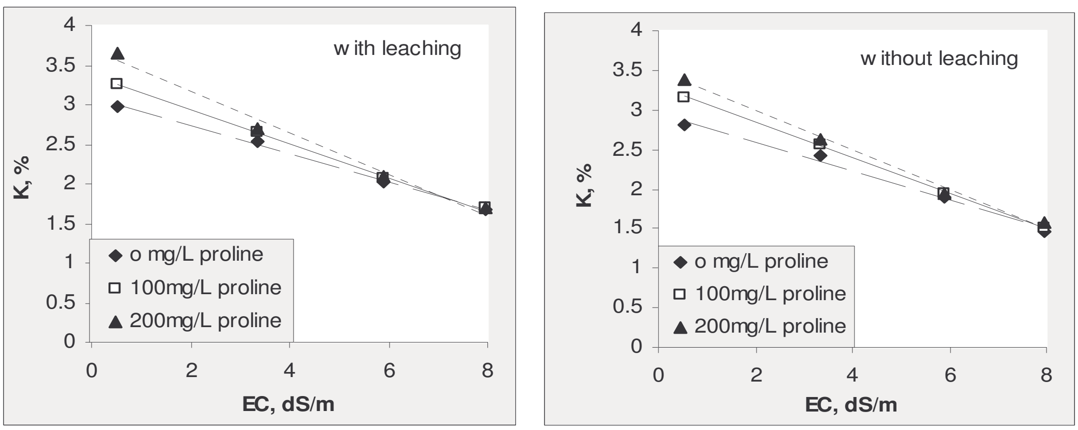

Fig 6. The relationship between the irrigation water salinity and the K^+ contents in corn shoots as affected by proline application rate with or without leaching treatment

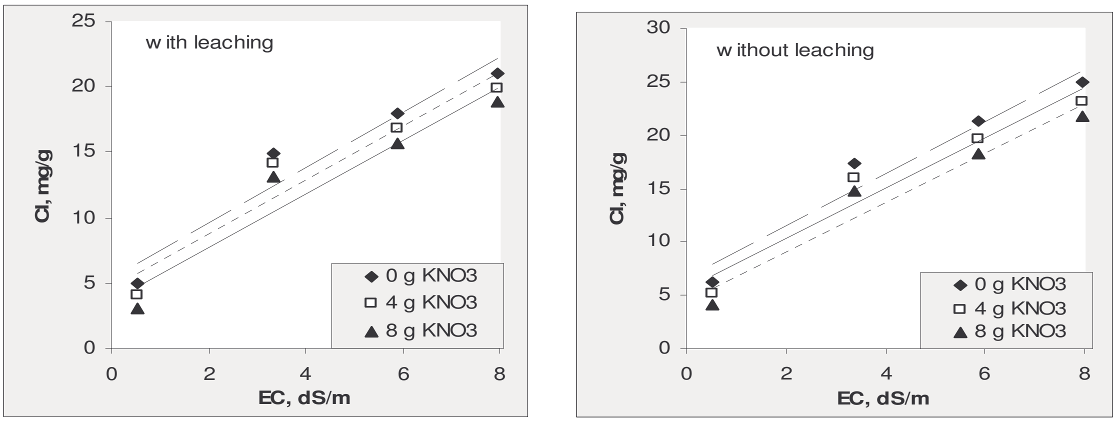

Fig 7. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

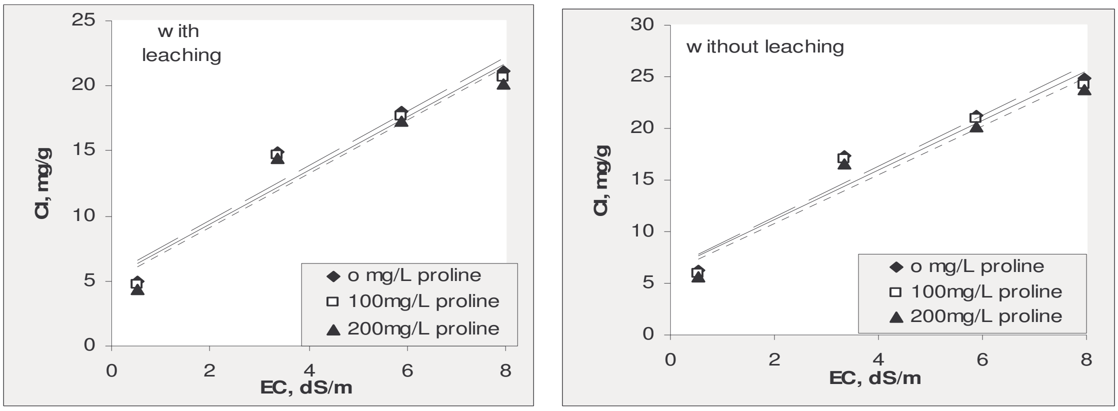

Fig 8. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by proline application rate with or without leaching treatment

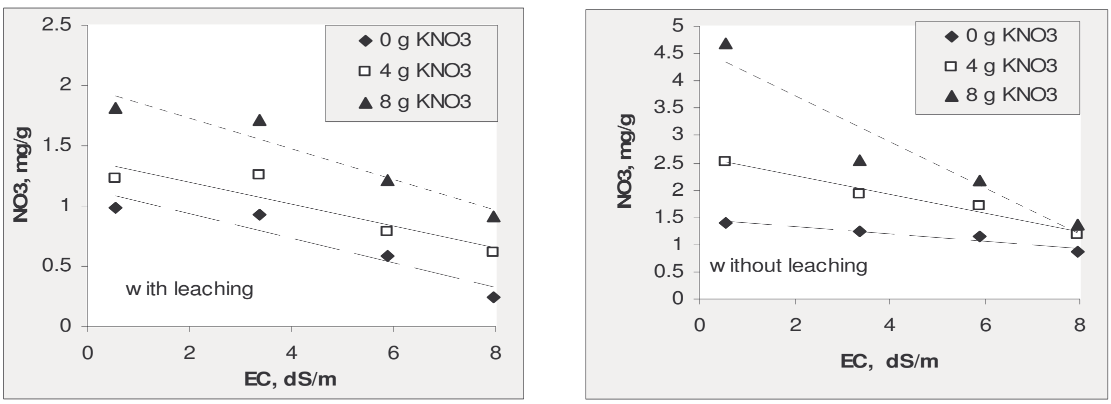

Fig 9. The relationship between the irrigation water salinity and the NO_3^- contents in corn shoots as affected by KNO_3 fertilization rate with or without leaching treatment

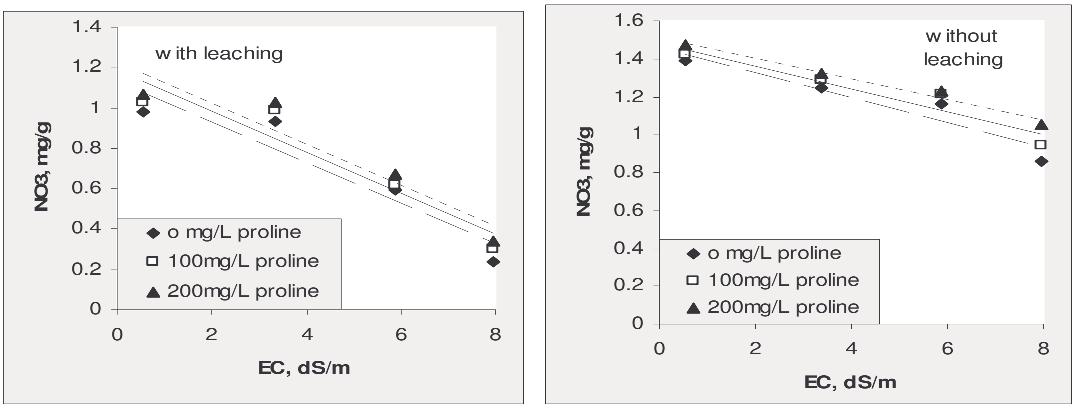

Fig 10. The relationship between the irrigation water salinity and the Cl^- contents in corn shoots as affected by proline application rate with or without leaching treatment

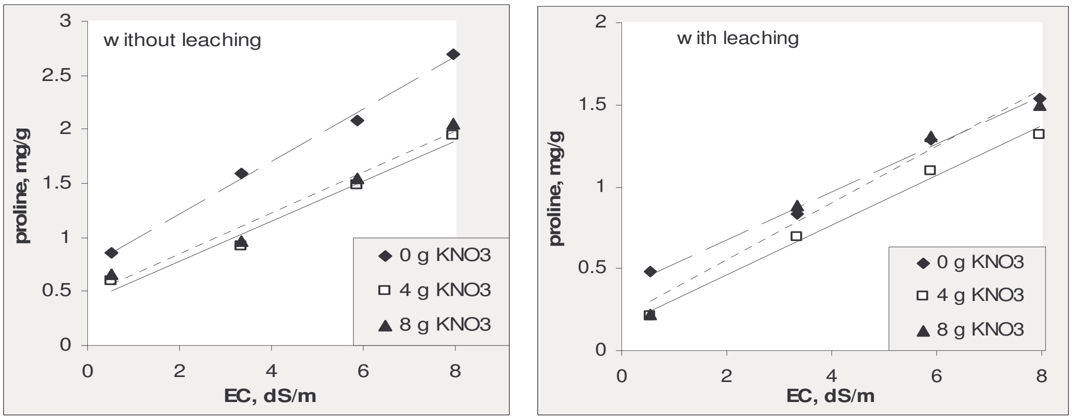

Fig 11. The relationship between the irrigation water salinity and the proline contents in corn leaves as affected by KNO_3 fertilization rate with or without leaching treatment

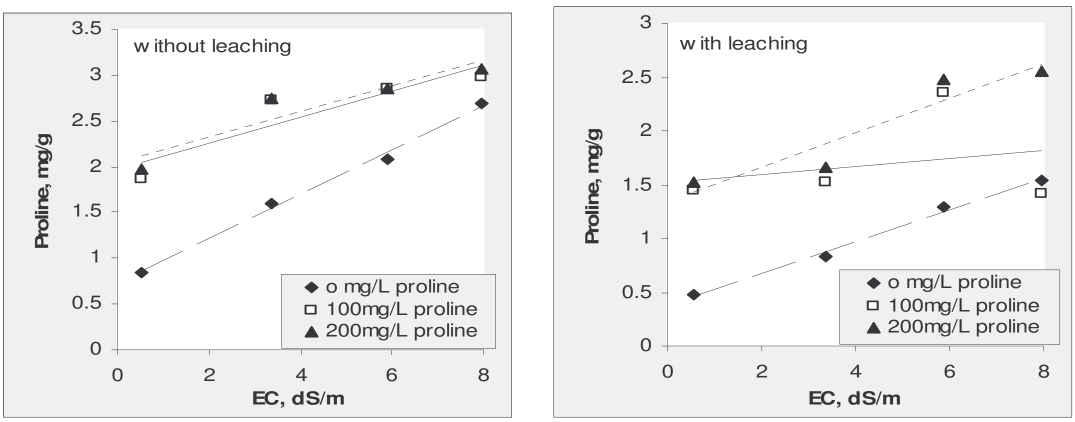

Fig 12. The relationship between the irrigation water salinity and the proline contents in corn leaves as affected by proline application rate with or without leaching

Determination of Crop Water Stress Index (CWSI) of Second Crop Corn in a Semiarid Climate

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ABSTRACT

This study was carried out to determine the relationship between the canopy-air temperature differential and vapor pressure deficit (VPD), which can be used to quantify the crop water stress index (CWSI) under fully irrigated (100 %) and maximum water stress (0 %) conditions of furrow irrigated corn. The effects of five different irrigation levels (100, 70, 50, 30 and 0 % replenishment of soil water depleted from the 0.90 m soil profile depth) on corn yields and the resulting CWSI were investigated. The highest yield and total water use were obtained under fully irrigated corn plots (100 % replenishment of soil water depleted). The trends in CWSI values were consistent with the soil water content induced by deficit irrigation. CWSI increased with increased soil water deficit. An average CWSI of 0.22 before irrigation time provided the highest grain corn yield. The yield was directly correlated with seasonal mean CWSI values and a second order polynomial equation "$Y = 59258CWSI^2 - 72051CWSI + 24060$" can be used to predict the grain yield of corn as a second crop under the semiarid climate.

Keywords: crop water stress index (CWSI), canopy temperature, lower baseline, corn

INTRODUCTION

Corn (*Zea mays* L.) grown mostly under irrigated conditions is a major commercial crop in the Aegean semiarid region of Turkey. During recent years, irrigated corn production has expanded rapidly in the Aegean semiarid region of Turkey. Corn has become a widely grown feed grain crop particularly as a second crop after wheat or barley. Almost no second crop corn production areas of Turkey have enough rainfall to reach the potential grain yield. Therefore, irrigation is necessary during the growing season to maintain and enhance crop growth and yield (Anac et al., 1999). Under these conditions farmers have to understand the water-yield relationship of corn and how to choose the most water efficient methods of irrigation scheduling (Anac et al., 1999; Orta et al., 2002).

Irrigation management is generally based on the estimation or measurement of evapotranspiration by measuring soil water content in the effective root zone or measuring some meteorological parameters. However, irrigation scheduling based on crop water status should be more advantageous since crops respond to both the soil and aerial environment (Yazar et al., 1999). Plant stress measurement with hand-held infrared thermometers (IRT) has become increasingly popular after 1980. This technique is based on the fact that transpiration cools the leaf surface. As water becomes limiting, stomatal conductance and transpiration decrease and leaf temperature increases (Reginato, 1983). Idso et al. (1981) determined an empirical approach for quantifying plant stress by determining "non-water stressed baselines" for crops. Under field conditions, they developed linear relationships for canopy-air temperature difference (Tc-Ta) versus vapor pressure deficit (VPD) of the atmosphere for a crop transpiring at its potential rate. This line, (Tc-Ta) versus VPD, represents the measured temperature difference when the crop is fully irrigated (no water stress). The upper limit (Tc-Ta) represents the temperature difference occurring when the crop transpiration rate approaches zero (maximum water stress) (Reginato, 1983).

Productivity response to water stress is different for each crop and this response is expected to vary with climate. Therefore, the critical values of CWSI should be determined for a particular crop in different climates and soils for use in yield prediction and irrigation management. Predicting yield response to crop water stress is important in both developing strategies and decision-making concerning irrigation management under limited water conditions by farmers and their advisors, as well as researchers. A range of empirical studies have reported on the determination of CWSI for different crops. Gardner et al. (1992a) suggested that baselines are strongly location dependent and perhaps species and variety dependent. Idso (1982) developed non-water stressed baselines for various crops. Steele et al. (1994) obtained the highest yield in the fully irrigated treatment with an average CWSI value between 0.2 and 0.4 for corn. Gencoglan and Yazar (1999) and Irmak et al. (2000) showed that the CWSI values could be used to determine irrigation scheduling and that irrigation should be applied when the critical CWSI values were about 0.21 and 0.22 for corn in the Mediterranean conditions of Turkey. Howell et al. (1984) determined that irrigation should be applied when the CWSI value for cotton is in the range 0.30-0.50. Yazar et al. (1999) and Kırnak and Gencoglan (2001) found critical average CWSI values of 0.33 and 0.25 in the Texas and in the GAP (Southesatern Anotolia Project) conditions, respectively.

The purpose of this study was to develop a baseline equation that could be used to calculate CWSI for monitoring water status and yield prediction of second crop corn under Aegean semiarid conditions of Turkey.

MATERIALS and METHODS

The experiment was conducted at the Agricultural Research Station of Adnan Menderes University, Aydın- Turkey, at 37^o 51' N latitude, 27^o 51' E longitude and 56 m altitude during the 2003 and 2004 growing seasons. The climate in this region is classified as semiarid and the average values of air annual temperature, air relative humidity, wind speed, sunshine duration per day and total annual precipitation are 17.5 ^{0}C, 63 %, 1.6 m s^{-1}, 7.6 h and 657 mm, respectively (Anonymous, 2003). The soil texture in the plot area was loam and sandy loam and the available water holding capacity within 0.90 m of the soil is about 0.16 m. Pioneer brand 3394 corn hybrid, the most popular hybrid as a second crop corn in the research area, was planted in rows at 0.70 m spacing during the last week of June (Day of year (DOY):178 in 2003; DOY:182 in 2004) of each experimental year. Corn plants were thinned leaving a plant every 0.25 m in all treatments. Corn plots were fertilized with 75 kg ha^{-1} of N, P and K (15 15 15 composite) before sowing and an additional nitrogen dose of 115 kg ha^{-1} of N was applied as Ammonium nitrate 33 % when the plant reached 0.3- 0.4 m in height.

The plots were arranged in a complete randomized block design with three replications. Each plot was 8.0 m by 4.2 m (6 rows, 0.7 m row spacing, 0.25 m inter plant spacing). There were 3.0 m spaces between the experimental plots in order to minimize water movement among treatments. Five irrigation treatments, differing in irrigation rate were evaluated. Irrigation was applied when approximately 50% of the available soil moisture was consumed in the root zone of the control treatment (T_1). The measured soil moisture content at the T_1 treatment was used to initiate irrigation during the growing season. In treatments T_2, T_3, T_4 and T_5, irrigation was applied at the rates of 70, 50, 30 and 0 % of T_1 on the same day, respectively. Closed-end furrow irrigation method was used in all treatments and a flow meter was used to measure the amount of water applied. The soil water content was measured at 9:00 am daily in the control treatment (T_1) and, if necessary, the plots were irrigated.

A neutron probe method (CPN, 503 DR Hydroprobe, Campbell Pacific Nuclear International, Martinez, CA, USA) was used to measure daily soil moisture level at depths of 0.60 to 1.20 m throughout the whole growing season. The soil moisture content in the fist 30 cm layer was measured by the gravimetric method since it was not possible to monitor it with the neutron probe method (Evett et. al., 1993). The water use (evapotranspiration) was calculated applying the water balance method to the upper 0.90 m soil layer. Evapotranspiration (ET) was calculated using the soil water balance method (Heerman, 1985);

$$ET = P + I - D \pm \Delta W$$

where P is the rainfall (mm), I is the irrigation applied to individual plots (mm), D is the deep percolation and ΔW is variation in water content of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was neglected.

Canopy temperatures (Tc) were measured using a hand-held infrared thermometer (IRT), (Raynger ST60 model Raytek Corporation, Santa Cruz, CA, USA). The instrument has a field of view of 3^0 and a 7.0 to 18 μm spectral band-pass filter. The infrared thermometer was operated with the emissivity adjustment set at 0.98. The IRT data collection was performed from August 1th (day of year (DOY) 213), when the percentage of plant cover was approximately 80-85 % until September 15th (DOY 258) in 2003 and from July 30th (DOY 212) until September 14th (DOY 258) in 2004, respectively. Canopy temperature was measured on four plants from four directions per plot and then averaged. For each measurement the IRT was held above the plant (0.50 m) at an angle of 20-30^0 below the horizontal so that soil background would not influence measurements.

The Tc, dry and wet bulb temperature measurements were made from 11:00 to 14:00 at hourly intervals under clear skies. Dry and wet bulb temperatures were measured with an aspirated pyschrometer at a height of 2.0 m in the open area adjacent to the experimental plots. The mean vapor pressure deficit (VPD) was computed using the corresponding instantaneous wet and dry bulb temperatures and the standard pyschrometer equation (Allen et al., 1998) using a mean barometric pressure of 101.7 kPa.

Using the upper and lower limit estimates, a CWSI can be defined as (Idso et al., 1981):

$$CWSI = \frac{\left[(T_c - T_a) - (T_c - T_a)_{ll}\right]}{\left[(T_c - T_a)_{ul} - (T_c - T_a)_{ll}\right]}$$

where, T_c is the canopy temperature (^{0}C), T_a the air temperature (^{0}C), the subindex ll indicates the non-water stressed baseline (lower baseline) and the subindex ul indicates the non – transpiring upper baseline.

From the above equation, the non-stressed baselines for canopy-air temperature difference (Tc-Ta) versus VPD relationship were determined using data collected from the control (100 %) treatment (T_1) a day after irrigation. The upper (fully stressed) baseline was determined based on the procedures suggested by Idso et al. (1981). To obtain the upper baseline, the canopy temperatures of the fully stressed crops (in T_5 treatment) were measured several times during the growing season.

Corn ears were harvested by hand from 7.5 m section of the two adjacent center rows (60 plants) of each plot, on 11 November 2003 (DOY:315) and on 8 November 2004 (DOY:313). Grain yields were converted to a standard grain water content of 15.5 % wet basis (Yazar et al., 1999). The data were analyzed by analysis of variance. The differences among treatments were evaluated using an F test in the yield results and the means were compared using Duncan's Multiple Test Procedure.

RESULTS and DISCUSSION

The seasonal water use of the T_1 treatment was the highest in both years, suggesting that the water applied was enough to meet the full crop water requirements. Therefore, the T_1 treatment was used to determine the lower (non-stressed) CWSI baseline. The lowest water use occurred in treatment T_5 since there was no irrigation water applied and presumably the highest water deficit in the crop root zone occurred in this treatment. The T_5 treatment was used, therefore, to determine the upper (fully-stressed) baseline. During the growing seasons, the upper and lower baselines as outlined by Idso et al. (1981) were determined using data taken from the T_1 and T_5 treatments using linear regression of the differences between Tc and Ta against VPD (Figs. 1 and 2). The resulting baselines were described by the following linear equations;

Tc-Ta = 2.90-2.18VPD ($r^2 = 0.89$, $p<0.01$, $S_{yx}= 0.55$) in 2003

Tc-Ta = 3.22-2.51VPD ($r^2 = 0.96$, $p<0.01$, $S_{yx}= 0.47$) in 2004 ; where Tc-Ta is in ^{o}C and VPD is in kPa.

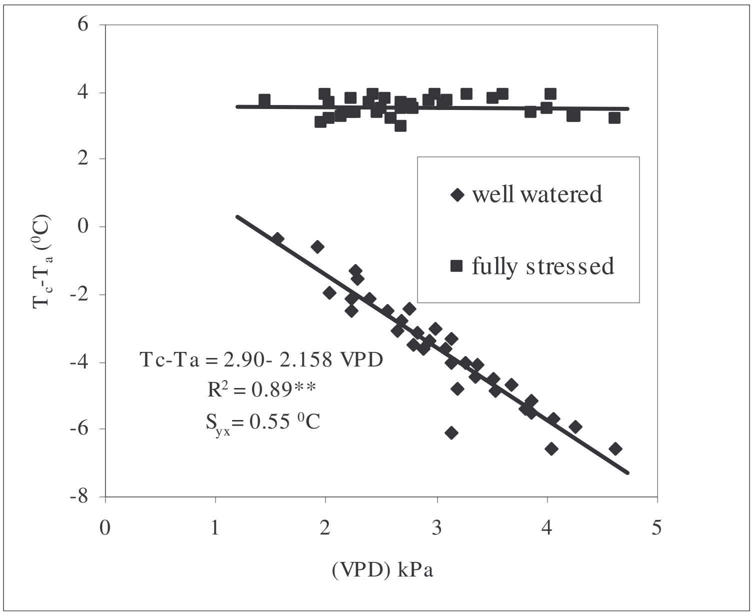

Figure 1. Canopy-air temperature differential (Tc-Ta) versus air vapor pressure deficit (VPD) for upper non-transpiring baseline and the lower non-water stressed baseline for corn in 2003.

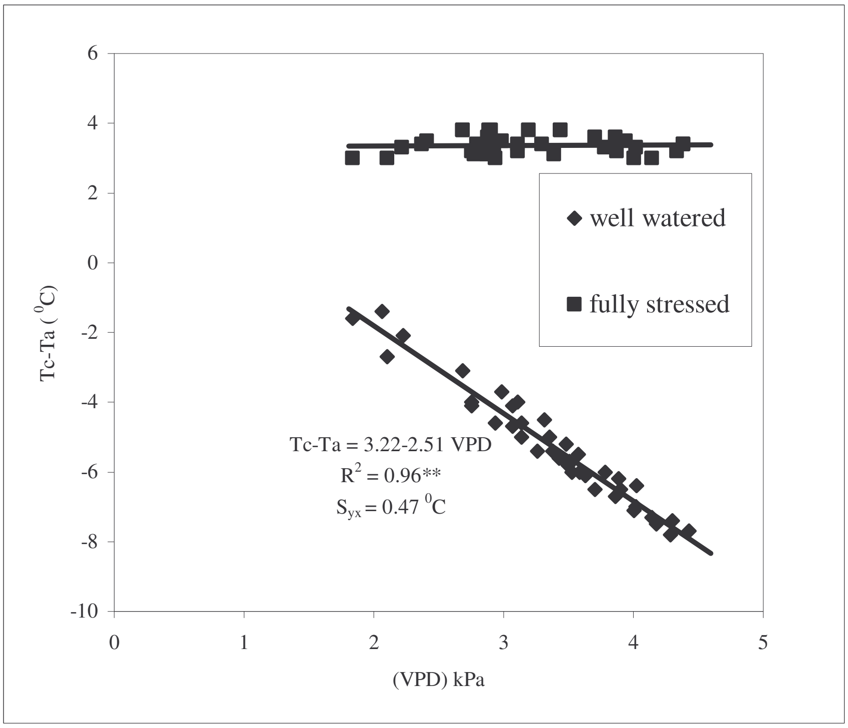

Figure 2. Canopy-air temperature differential (Tc-Ta) versus air vapor pressure deficit (VPD) for upper non-transpiring baseline and the lower non-water stressed baseline for corn in 2004.

These equations differ somewhat from those obtained for corn in previous studies. For example; Idso et al. (1982) found the equation Tc-Ta = 3.11-1.97 VPD in Arizona; Nielsen and Gardner (1987) obtained the equation Tc-Ta =2.67-2.059 VPD in Colorado; Steele et al. (1994) determined the lower limit equation of Tc-Ta= 2.14-1.97 VPD in Oakes. Yazar et al. (1999) reported the equation Tc-Ta = 1.06-2.56 VPD for the lower baseline for corn in Texas conditions. Gencoglan and Yazar (1999) determined the lower limit equations of Tc-Ta= 2.9-2.66 VPD and Tc-Ta= 2.41-2.045 in 1993 and 1994, respectively, under the Cukurova-Turkey conditions. Also Irmak et al. (2000) defined the lower limit equation of Tc-Ta= 1.39-0.86 VPD under Mediterranean conditions. Several factors such as the climate, soil type, IRT calibration and specific corn variety may have caused differences in the intercept and the slope of the lower baseline of this study.

Regarding to the upper baseline, the average value of (Tc-Ta) for the fully-stressed plants (treatment T_5) were 3.6 ^{0}C in 2003 and 3.3 ^{0}C in 2004. These values are similar to those reported in previous studies for corn. For example; Nielsen and Gardner (1987) reported an upper limit value of 3.0 ^{o}C, while Steele et al. (1994) reported a value of 5.0 ^{o}C. Howell et al. (1984) stated that the upper limit range was between 3 and 4 ^{o}C, and that the appropriate value depended on the intercept of the lower baseline and the air temperature of the region.

The seasonal course of CWSI values for the irrigation treatments studied in the years of 2003 and 2004 are shown in Figs. 3 and 4, respectively. In these figures, the arrows indicate the days of irrigation. The CWSI values in irrigated plots generally dropped following each irrigation application, and then increased steadily to a maximum value just prior to the next irrigation application as the soil water in the crop root zone was depleted. In 2003, the CWSI values ranged from 0.0 to maxima values of 0.78 (treatment T_1), 0.69 (treatment T_2), 0.77 (treatment T_3), 0.74 (treatment T_4), and 0.93 (treatment T_5). In 2004, these maxima values were 0.54 (treatment T_1), 0.54 (treatment T_2), 0.64 (treatment T_3), 0.67 (treatment T_4) and 0.92 (treatment T_5). Irrigations occurred when the CWSI on the previous day reached an average value of 0.44 and 0.45 (average 0.45) in T_1 treatment; 0.45 and 0.48 (average 0.47) in T_2 ; 0.50 and 0.55 (average 0.53) in T_3 ; 0.51 and 0.57 (average 0.54) in T_4 treatment, in the years of 2003 and 2004, respectively. The highest grain yield was attained in the T_1 treatment which had an average CWSI of 0.45 before irrigation. Gardner et al. (1992 b) stated that cotton, corn, and wheat crops tolerate increases of CWSI of 0.20 to 0.30 between irrigations without significant yield reductions. For the maximum water stressed (non irrigated) treatment, $T_{5,}$ the average CWSI values approached to 0.92 and stayed near this value.

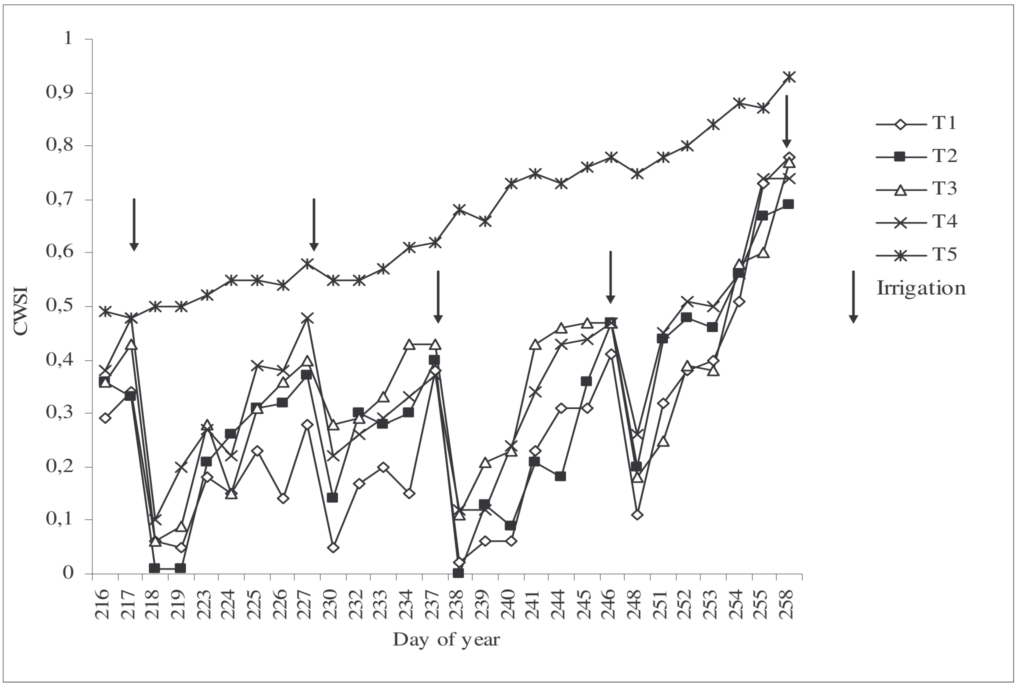

Figure 3. Seasonal variation of CWSI for each treatment in 2003.

The seasonal mean CWSI values for each treatment and the grain corn yields for the two studied years are presented in Table 3. Grain yield was significantly increased ($p<0.01$) by the irrigation level. The highest yield was measured for T_1 treatment in both years. The seasonal mean CWSI for treatment T_1 was 0.22 and 0.21 in 2003 and 2004, respectively. Results indicated that if the seasonal mean CWSI values were greater than the values mentioned above, grain corn yield would decrease. The relationship between yield and seasonal mean CWSI values was curvilinear within the range of mean CWSI for the two studied years (Fig. 5). This result agrees with many other studies for different crops (Reginato, 1983; Howell et al., 1984; Wanjura et al., 1990; Nielsen, 1994; Odemis and Bastug 1999; Yazar et al., 1999; Irmak et al., 2000).

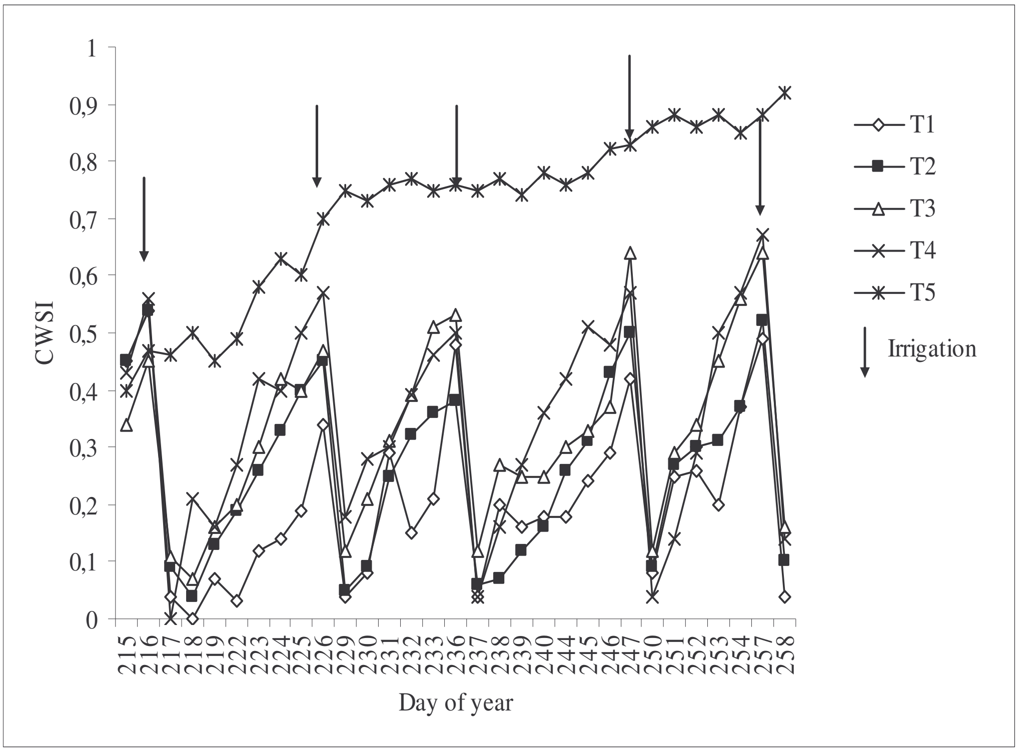

Figure 4. Seasonal variation of CWSI for each treatment in 2004.

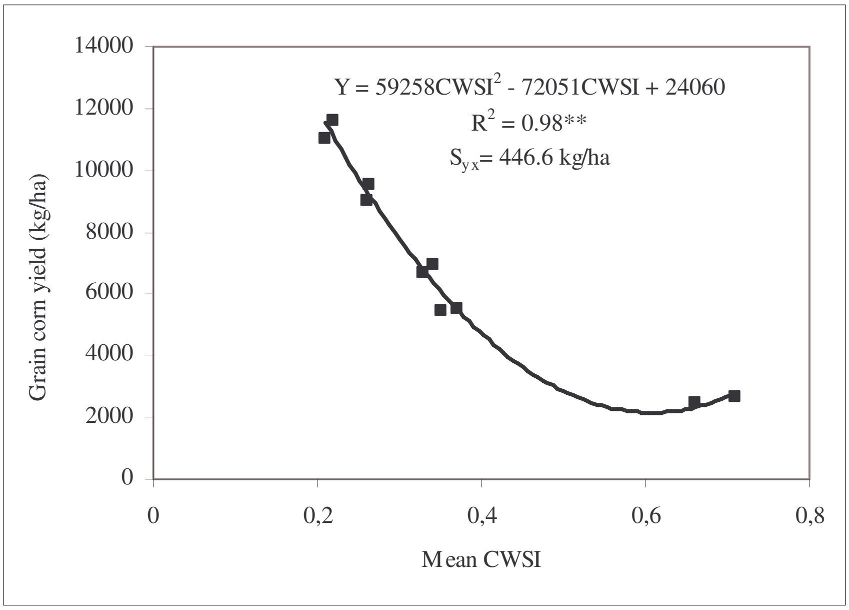

Figure 5. Relationship between corn grain yield and seasonal mean crop water stress index (CWSI).

Table 3. Corn grain yield and seasonal mean crop water stress index (CWSI) values for the different treatments of both growing seasons.

Year	Treatments	Grain corn yield (kg/ha)	Seasonal mean CWSI
2003	T_1	11630 a**	0.22
	T_2	10000 b	0.26
	T_3	7190 c	0.35
	T_4	5520 d	0.37
	T_5	3080 e	0.66
2004	T_1	11050 a**	0.21
	T_2	9000 b	0.26
	T_3	6670c	0.33
	T_4	4910 d	0.35
	T_5	2680 e	0.71

** Numbers followed by different letters indicate statistically significant differences at the 1 % level (Duncan's multiple range test).

CONCLUSIONS

In this research, the upper (water-stressed) and lower (non-water stressed) baselines and CWSI values determined empirically during this study in the years of 2003 and 2004 were slightly different. These differences can be due to several factors mentioned earlier. Based on these results the mean CWSI value before applying irrigation was 0.45 under non-water stress conditions. This CWSI value was consistent with the highest yield for corn in our study. However, we can not conclude that this CWSI value should be used for timing of irrigations for corn since we did not test irrigation scheduling using CWSI. Further studies are needed to reach such a conclusion. The critical value of CWSI that a farmer can use to determine when to irrigate corn in semiarid climate should be tested with long term experiments.

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Effect of Different Water Stress on the Yield and Yield Components of Second Crop Corn in Semiarid Climate

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ABSTRACT

The response of second crop corn (*Zea mays* L.) to different irrigation treatments in a semi arid climate was carried out in the field during the 2003 and 2004 growing season. Water stress was created at different development stages: early vegetative, vegetative, before tasseling, after tasseling, milk stage and after milk in order to determine the effect of irrigation treatments on vegetative growth, grain yield and yield components of corn. The effect of water stress at any stage of development on plant height, dry matter accumulation, kernel weight, kernel number per ear, ear length and ear diameter were studied. A rainfed (non-irrigated) treatment and 9 deficit irrigation treatments were applied to the Pioneer 3394 corn hybrid on a loam soil with 3 replications. Water stress significantly affected the corn grain yield. and yield components. The grain yield increased with irrigation water amount, and the highest average grain yield (11160 kg ha^{-1}) were obtained from the well irrigated treatment (K_1). Seasonal evapotranspiration increased with increased amounts of irrigation water applied. The highest seasonal ET (average of 650 mm) was determined at the (K_1) treatment. Water stress occurring during vegetative and tasselling stages reduced plant height. Total dry matter (DM) accumulation was accelerated after each irrigation application. Yield response factor (k_y) value of 1.02 were determined based on averages of two years. Significant linear relations were found for grain yield and seasonal evapotranspiration (ET). It is concluded that well irrigated treatment (K_1) could be used for the semiarid climatic conditions under no water shortage. In the case of more restricted irrigation, the limitation of irrigation water at the vegetative and tasselling stages should be avoided to maintain satisfactory growth.

Keywords: corn, water stress, growth stages, yield response factor (k_y), Aegean region.

INTRODUCTION

Corn (Zea mays L.) grown mostly under irrigated conditons, are a major commercial field crop in the Aegean region of Turkey. Especially corn has become a widely grown feed grain crop particularly as a second crop after wheat or barley in this region. Present corn production in Turkey is about 2.2 million tons of grain corn from 575.000 ha. The Aegean region of western Turkey produce 26 % of national corn production of the country (Anonymous, 2003). Long-term average annual precipitaton in the region is about 657 mm, with more than 89 % of it falling from October to March. Water loss by evapotanspiration is very high during the growing season. Therefore, irrigation is needed at this growing season to maintain and enchance crop growth and yield. Limited availability of irrigation water requires fundemental changes is irrigation management or urges the application of water saving methods. Generally applicable procedure is to assess the benefits of changing irrigation water management based on deficit irrigation which is the practice of deliberately under-irrigating. In order to implement deficit irrigation successfully, specific growth stages of the crops at which they can withstand water stress with no significant effect on plant growth and yield need to be well identified. Thus, it will be possible to develop optimum schedules for implementing deficit irrigation programmes (Anac et al., 1992). Water stress occuring during different growth stages may reduce final grain yield and the extent of yield reduction depends not only on the severity of the stress, but also on stage of the plant development (Claasen and Shaw, 1970). In the Texas conditions, Yazar et al. (1999) found that the highest grain yield, dry matter, kernel numbers and water use efficiency were obtained from well watered treatment in both years. Under severe water stress conditions leads to yield decrease, due to decreased vegetative growth including leaf expansion and dry matter accumulation (Pandey et al., 2000). Eck (1986) reported that water deficit during vegetative growth reduced kernel numbers but had little effect on kernel weight.

The vegetative and ripening periods are the most tolerant to water deficits. On the other hand, the flowering period is the most sensitive to water deficits that cause considerable grain yield decrease since less water became in the soil profile (Doorenbos and Kassam, 1979). Due to limited irrigation water, it is generally acceptable that deficit irrigation should be used in semiarid conditions. However, prior to explain this cultural practice, its effects on corn yield yield components and water usages should be carried out.

The purpose of this study was to evaluate the effects of water stress occurring at various growth stages of second crop corn yield and yield components. The results of this study will be provided a guideline to regional growers and irrigation agencies for water saving irrigation and optimum water management programs for second crop corn in the semiarid Aegean climate.

MATERIAL and METHODS

Field experiment of second crop corn were conducted at the Agricultural Research Station of Adnan Menderes Universty, Aydin-Turkey at 37° 51' N latitude, 27°51' E longitude and 56 m altitude during the 2003 and 2004 growing season. Climate in this region is semiarid with total annual precipitation of 657 mm. The climate in this region is classified as semiarid and the average values of air annual temperature, air relative humidity, wind speed, sunshine duration per day and total annual precipitation are 17.5 ^{0}C, 63 %, 1.6 m s^{-1}, 7.6 h and 657 mm, respectively (Anonymous, 2004). The soil series in the research area was Buyuk Menderes developed on aluvial meterials (Aksoy et al., 1998). The soils in the region were classified as Entisols and Fluvisols-Regosols according to soil Taxonomy (Soil Survey Staff, 1999) and FAO-UNESCO (1989), respectively. The soil type of the experimental area was loam and sandy loam in texture and the available water holding capacity within 0.90 m of the soil profile is approximately 162 mm.

Pioneer brand 3394 corn hybrid, the most popular hybrid as a second crop corn in the research area, was planted during the last week of June (DOY:178 in 2003; DOY:182 in 2004) of each experimental year. A row spacing of 0.70 m and a within-row spacing of 0.25 m were used. Corn plots were fertilized with 75 kg ha^{-1} pure N, P and K (15 15 15 composite) before sowing and additional nitrogen dose of 115 kg ha^{-1} was applied as Ammonium nitrate 33 % when the plant reached to 0.3-0.4 m in height. The experiments were set up randomised complete block design with three replications. At planting the plot sizes were 8 x 4.2 m , whereas the basic plot sizes harvested were 21.0 m^2. Closed-end furrow irrigation method was used and the amount of water applied was measured with a flow meter.

The experiment included 10 treatments in which soil water deficits were created by delaying irrigation for different combinations of growth stages. To determine the treatments, growth stages of corn such as early vegetative, vegetative, before tasseling, after tasseling, milk stage and after milk stages were taken into consideration (Doorenbos and Kassam, 1979). The irrigation treatments were based on soil water depletion replenishments. Control treatment "K_1" was designated to receive 100 % soil water depletion and irrigation was applied at each growth period with the amount of irrigation water required to fill the 0.90 m root zone to field capacity. Individual treatments were irrigated similarly except for delaying the irrigation applicaton at a given stage. The other treatments (K_8 and K_9) were the same as K_1, but a 50 % and 25 % of water deficit were applied at a given stages for K_8 and K_9 treatments, respectively. The same application was repeated for each individual growth period. for K_8 and K_9 treatments during the total growing season.

Soil water level was monitored by using the gravimetric method from the plots of the second replication of the various tratments. The amount of soil moisture in 0.90 m depth was used to initiate irrigation and the values within 1.20 m depth were used to obtain the evapotranspiration of the crop. (Heerman, 1985);

$$ET = P + I - D \pm \Delta W$$

where P is the rainfall (mm), I is the irrigation applied to individual plots (mm), D is the deep percolation and ΔW is variation in water content of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was neglected.

In order to detemine dry matter (DM) above the ground level, all corn plants within 0,5 m of a row section in each plot were cut at ground level at 15 day intervals. Collection of corn plant samples were started one week before first irrigation and continued until harvest. Corn leaves and rest of the plants were cut into pieces and then oven dried at 65 °C to a constant weight (Yazar et al., 2002)

Corn ears was harvested by hand from 7.5 m section of the two adjacent center rows (60 plants) on 11 November 2003 (DOY:315) and on 8 November 2004 (DOY:313). Grain yields were converted to a standard grain water content of 15.5 % wet basis (Yazar et al., 1999). The harvest data were analysed for grain yield per unit area as well as 1000 kernel weight, kernel number per ear. A calculated estimate for kernel numbers per ear have been determined from data obtained from kernel and ear numbers per plot. Twenty plants were randomly selected from the each plot (at maturity period of the plants) for measurement of plant height.

The effect of water stress during growing season and individual growth stages on fruit yield was investigated using Stewart's model (Doorenbos and Kassam, 1979) as follows:

$$(1- \frac{Y_a}{Y_m}) = k_y \, (1- \frac{ET_a}{ET_m})$$

where Y_a is actual harvested yield (kg ha^{-1}), Y_m is the maximum harvested yield (kg ha^{-1}), k_y is the yield response factor, ET_a is the actual evapotranspiration (mm), ET_m is the maximum evapotranspiration (mm) corresponding to Y_m, $1-(Y_a/Y_m)$ is the relative yield decrease and $1-(ET_a/ET_m)$ is the relative evapotranspiration deficit. WUE was calculated as yield (kg ha^{-1}) divided by seasonal evapotranspiration (mm). IWUE was determined as yield (kg ha^{-1}) per unit irrigation water applied (mm) (Howell et al., 1990).

Data on effects of treatments on the yield and yield components were submitted to analysis of variance (ANOVA) . The Duncan mean separation test procedure was used to compare and rank treatments (Gomez and Gomez, 1984).

RESULT and DISCUSSION

Water Use –Yield Relationship of Corn

The length of the total growing period for control treatment (K_1) was 139 days in 2003 and 132 days in 2004, respectively. The differences in the individual growth periods between the two years may be attributed to variations in climatic factors.

The total number of irrigation, irrigation water amounts applied and seasonal water use values of corn for the experimental years are presented in Table 1. A total of six irrigations were applied to all treatments for corn during the growing season. As shown in Table 5, the amount of irrigation water applied varied from 515 to 258 mm in 2003 and from 557 to 279 mm in 2004. Water demand during the tasseling stage (before and after tasseling) was more than that of other stages. In the control treatment K_1, the amount of total irrigation water applied was 515 mm in 2003 and 557 mm in 2004 respectively. As expected the highest seasonal water use occured in the full irrigation treatment (K_1) obviously owing to an adequate soil water supply during the growing season. Therefore, K_1 treatment had the highest total water use, 612 mm in 2003 and 687 mm in 2004. Other treatments underwent water deficits and gave lower seasonal water use. The lowest water use occured in the continuous stress treatment (K_0), 170 mm in 2003; 165 mm in 2004. The seasonal water use values are consistent with the ones obtained using furrow method in Menemen region 539,6 mm by Anac et al. (1992). Under surface irrigation applications, seasonal water use of corn was obtained by Kanber et al. (1990) as 605-474 mm in Çukurova conditions.

As shown in Table 2 data obtained from the two year study showed that corn grain yield was significantly ($P<0.01$) affected by irrigation treatments. The grain yield ranged from 11260 to 3100 kg ha^{-1} in 2003 and from 11060 to 2600 kg ha^{-1} in 2004 for the different irrigation regimes (Table 2).

Table 1. Irrigation treatments, seasonal irrigation water applied (I) and seasonal water use (ET)

Treatments	Early vegetative	Vegetative	Before tasseling	After tasseling	Milk stage	After milk stage	I (mm)	ET (mm)
2003								
K_1	30	85	110	100	110	80	515	612
K_2	30	85	113	92	118	-	438	567
K_3	30	85	112	108	-	90	425	551
K_4	30	85	100	-	160	70	445	536
K_5	30	85	-	146	105	65	431	523
K_6	30	-	165	90	110	75	470	592
K_7	-	100	110	100	126	60	496	603
K_8	15	43	55	50	55	40	258	387
K_9	23	64	83	75	83	60	388	508
K_0	-	-	-	-	-	-	-	170
2004								
K_1	40	80	105	124	130	78	557	687
K_2	40	80	99	130	125	-	474	581
K_3	40	80	85	125	-	115	445	573
K_4	40	80	102	-	170	75	467	561
K_5	40	80	-	149	105	85	459	534
K_6	40	-	130	110	150	60	490	569
K_7	-	95	110	125	145	60	535	607
K_8	20	40	53	62	65	39	279	407
K_9	30	60	78	93	98	59	418	520
K_0	-	-	-	-	-	-	-	165

Increasing water amounts resulted in a relatively higher yield. As would be expected, the highest yield was obtained from the K_1 treatment with 100 % irrigation and the lowest fruit yield was obtained from K_0 treatment with no irrigation. The grain yield for seasonal treatments (K_8 and K_9) was reduced from 14.2 % to 36.7 % in 2003 and from 14.1 % to 37.1 % in 2004. It was observed that ratio of decreases in grain yield for each percent of deficit rate was not constant. According to individual growth period's treatments, the highest decrease was obtained from the flowering and milk stage treatments (K_4, K_5, and K_3) and this decrease ranged from 18.6% to 34.4% in both years (Table 2) Water stress imposed during the early vegetative, vegetative and after milk stages had almost similar effects on grain yield. Average yield reduction during these stages were 11.9 and 18.1 %. Results obtained from our study concerning the effect of timing of water deficit on grain yield are comparable with those published earlier (Doorenbos and Kassam, 1979; Musick and Dusek, 1980; Eck, 1984; Ogretir, 1994; Yıldırım et al., 1996). Field trials showed that corn is very sensitive to water deficits at tasseling and silking stages and is more tolerant at milk stages (Ogretir, 1994).

Table 2. The effect of irrigation treatment on grain yield (Y), water use efficiency (WUE) and irrigation water use efficiency (IWUE) for the experiment period in 2003-2004

Year	Treatments	Y (kg ha^{-1})	Relative yield decrease (%)	WUE kg m^{-3}	IWUE (kg m^{-3})
2003	K_1	11260 a**	-	1.83	1.58
	K_2	9900 c	12.0	1.74	1.55
	K_3	9160 d	18.6	1.66	1.42
	K_4	7380 f	34.4	1.37	0.96
	K_5	8670 e	23.0	1.65	1.29
	K_6	9720 c	13.6	1.64	1.40
	K_7	10750 b	4.5	1.78	1.54
	K_8	7120 f	36.7	1.83	1.55
	K_9	9660 c	14.2	1.90	1.69
	K_0	3100 g	72.4	1.82	-
2004	K_1	11060a**	-	1.61	1.51
	K_2	9750 b	11.8	1.67	1.50
	K_3	8950 c	18.6	1.56	1.42
	K_4	7250 e	34.4	1.29	0.99
	K_5	8300 d	24.9	1.55	1.24
	K_6	9550 b	13.6	1.68	1.41
	K_7	10550a	4.6	1.74	1.49
	K_8	6950 e	37.1	1.70	1.55
	K_9	9500 b	14.1	1.82	1.65
	K_0	2600 f	76.4	1.58	-

**: Mean followed by different letters (a,b) indicate statistically significant differences at the level of 1 % for Duncan's Multiple Range Test

The relationship between seasonal water use and corn grain yield have been evaluated for each experimental year (Fig 1. and Table 2.). The relationship between seasonal water use and yield was linear ($P<0.01$) for two years. The linear relation of corn grain yield to water use is in agreement with other studies for corn in the Mediterranean region (Irmak et al., 2000); in the Çukurova region (Kanber et al., 1990); in the sountheast Turkey (Yazar et al., 2002).

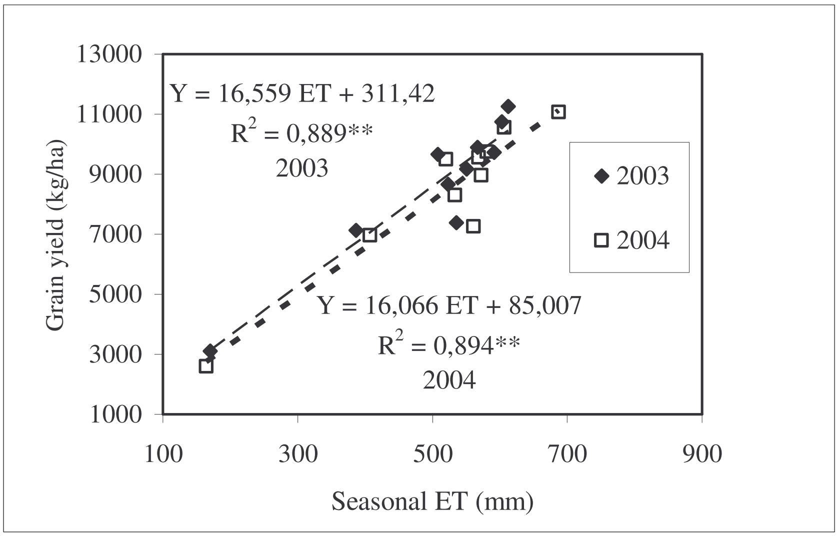

Figure 1. The relationship between grain yield and seasonal ET

Irrigation Water Use (IWUE), Water Use (WUE) Efficiencies and Yield Response Factor (k_y) for Corn

Water use and irrigation water use efficiency (WUE, IWUE) were listed in Table 2 . The WUE and IWUE were different depending upon the treatments and did not significantly change when irrigation amount increased. WUE values varied from 1.37 to 1.90 kg m^{-3} in 2003 and 1.29 to 1.82 kg m^{-3} in 2004, respectively. On the other hand, the highest WUE was obtained from K_9 treatment as1.90 kg m^{-3} in 2003 and 1.82 kg m^{-3} in 2004, respectively. However, the WUE values were lowest in K_4 treatment in both years. The WUE results are in agreement with those WUE values reported by Stone et al. (1996). The authors stated that grain yield increased with irrigation frequency and seasonal irrigation amount, and the WUE between treatments was not significantly different. WUE values of 1.83 and 1.61 kg m^{-3} from well irrigated treatment (K_1) in 2003 and 2004 are in agreement with those of 1.78-1.60 kg m^{-3} reported by Istanbulluoglu et al. (2002). The irrigation water use efficiencies (IWUE) of the treatments were lower than the water use efficiencies (WUE) in both years. This could be attributed to water used from soil stroge. IWUE values of 1.25-1.46 kg m^{-3} was obtained by Musick and Dusek, (1980) and 1.9 kg m^{-3} by Lyle and Bordovsky, (1995).

The corn yield response factor (k_y) was determined for the combined data from both years using the methods of Stewart et al. (1977). The relative yield decrease ($1-Y_a/Y_m$) increased linearly with relative evapotranspiration deficit ($1-ET_a/ET_m$). When data from both years were combined, the coefficient of determination (r^2) was 0.85; the relationship was statistically significant at the level of $P<0.01$; and the yield response factor (k_y) was 1.02. Similar relationships were obtained in other corn studies. For instance, the avarege k_y value of corn (1.02) obtained from the study is consistent with those of 0.98 determined by Kanber et al. (1990); 0.97 reported by Yıldırım et al. (1996).

Dry Matter (DM) Accumulation to Water Stress

Dry matter accumulation was significantly affected (*P*<0.01) by the water stress for corn. The highest dry matter of corn was obtained from K_1 treatment as 3.13 kg m^{-2} and 3.0 kg m^{-2} in 2003 and 2004, respectively (Table 3). In addition, the second highest dry matter of corn was recorded from K_7 treatment as 2.93 kg m^{-2} and 2.86 kg m^{-2} in 2003 and 2004, respectively. As could be expected, the most severe effect of water deficit on dry matter loss was observed from the non-irrigated treatments. The adverse effect of water stress on dry matter accumulation appeared under all water deficit treatments in the 2003 and 2004 experimental years. Serious decreases have been determined for corn plants exposed to water stress during the period of before and after tasseling stages (K_4 and K_5) and 50 % reduction of irrigation water amounts applied through multiple irrigation practices (K_8). Values of dry matter weight loss in those treatments were determined to vary in the ranges of 30-32, 30-27 and 29-30 % in 2003 and 2004 experimental years. Dry matter yield of 3.00-3.15 kg m^{-2} accumulated of our study under well irrigation conditions (K_1) is consistent with previous reports for second crop corn (Yazar et al., 2002). Corn dry matter accumulation and grain yield increased significantly by irrigation (Yazar et al., 1999).

Plant Height, Kernel Weight, Kernel Number per Ear, Ear Length and Ear Diameter to Water Stress

The average values of all corn yield components, namely plant height, kernel weight, kernel number per ear, ear length and ear diameter were summarized in Table 3 for the experiment period in 2003 and 2004. Statistically significant differences (*P*<0.01) were found between the different treatments for each year.

The development of plant height was slow from the emergence to the formation of 3-4 leaves and quite fast from this stage to the tasseling stage. Irrigation at all stages ($K_{1;}$ 257.6 cm) and limited

Table 3. The effect of irrigation treatment on vegetative growth and yield components data of corn for the experiment period in 2003–2004

Year	Treatment	Plant height (cm)	Kernel weight (g/1000)	Kernel number per ear	Ear length (cm)	Ear diameter (cm)	Dry matter yields (kg/m^2)
2003	K_1	262.3a**	391.8a**	656.6 a**	22.3 a**	5.31 a**	3.13 a**
	K_2	251.0 b	382.0 ab	605.6 ab	21.6 ab	5.27 ab	2.48 a
	K_3	245.3 cd	358.1 abc	575.7 bc	19.8 de	5.06 c	2.38 bc
	K_4	242.8 de	377.1 ab	504.3 d	19.9 cde	5.16 abc	2.15 d
	K_5	241.6 e	375.1 ab	554.3 bcd	19.7 de	5.10 bc	2.30 bcd
	K_6	237.6 f	370.0 ab	580.3 bc	20.6 bcd	5.24 abc	2.40 bc
	K_7	248.6 bc	372.2 ab	592.3 abc	21.2 abc	5.20 abc	2.93 a
	K_8	234.3 g	351.8 bc	531.3 cd	19.3 e	5.05 c	2.21 cd
	K_9	248.8 b	377.6 ab	602.7 ab	20.9 abc	5.20 abc	2.46 b
	K_0	149.3 h	325.2 c	408.0 e	15.8 f	4.80 d	0.80 e

	K_1	253.0 a**	387.1 a**	639.3 a**	21.8 a**	5.28 a**	3.00 a**
	K_2	245.1 b	375.1 ab	591.4 ab	20.9 ab	5.23 ab	2.35 b
	K_3	238.6 d	340.1 ab	559.0 bcd	19.5 bc	5.02 cd	2.28 bc
	K_4	237.0 de	349.1 cde	499.7 d	19.4 bc	5.11 abc	2.06 d
	K_5	233.8 ef	351.1 bcd	543.3 bcd	18.7 c	5.04 bcd	2.10 cd
2004	K_6	230.8 fg	349.7 bcd	558.0 bcd	19.6 bc	5.16 abc	2.20 bcd
	K_7	240.5 cd	350.2 bcd	570.0 abc	20.3 abc	5.12 abc	2.86 a
	K_8	227.8 g	330.5 de	514.7 cd	19.0 c	4.96 d	2.11 cd
	K_9	243.0 bc	357.5 c	582.7 ab	19.8 bc	5.13 abc	2.35 b
	K_0	143.8 h	314.3 e	391.3 e	15.3 d	4.67 e	0.70 e

**: Mean followed by different letters (a,b) indicate statistically significant differences at the level of 1 % for Duncan's Multiple Range Test

irrigation treatments (K_2, 248cm; K_9, 245.9 cm) produced the highest plants based on averages of 2 years. The shortest plants (146.5 cm) were obtained from non-irrigated (K_0) treatment. The most effective irrigation treatments on plant height were at vegetative and tasseling stages, respectively. These results indicate that full and limited irrigation applied at different growth stages significantly increased plant height in corn. Our results were in agreement with the results reported by Anac et al., (1992) and Istanbulluoglu et al. (2002). Irrigation treatments also significantly affected kernel weight. The highest average kernel weight in the ranges of 389.4-378.5 g was obtained from (K_1) and (K_2) treatments. The fact that kernel weight of these treatments were higher even than the other treatments showed the determinative effect of water availability in soil during the period forthcoming grain filling. Lower kernel weight of K_3 treatment could be explained with fewer kernel set due to water stress at flowering stage. These results were also in agreement with Kanber et al. (1990), Ul (1990) and Yıldırım (1993).

Significant differences in kernel number per ear were observed between irrigation treatments. Water stress at tasseling stages and milk stages decreased the kernel set on the ear. Much higher average kernel reduction (21-23%) were determined when plants were exposed to water stress at tasseling stages. Harder et al. (1982) reported that water stress after post-silking period decreased corn grain yield by up to 33% and the number of kernels per plant by about 15%. Yazar et al. (1999) reported that kernel number per ear is moisture dependent and concluded that kernel number decrease is the primary effect of water deficit on corn grain yield. Irrigation tratments had significant effect on the ear length and ear diameter and their average values varied from 19 to 22 cm, 5.0 to 5.2 cm, respectively. The lowest average ear length and ear diameter were obtained from the non-irrigated treatment as 15.9 cm and 4.7 cm, respectively. The highest ear length and ear diameter were obtained in K_1 and K_2 treatments. This implies that irrigation has a great influence on ear length and ear diameter formation. On the other hand, K_3, K_4, and K_5 treatments have a lower ear length and diameter than that of others. Thus, water stress should not be applied at tasseling and milk stage to obtain higher ear length and diameter. Our results are in close agreement with those of Ul (1990), Ogretir (1994) and Istanbulluoglu et al. (2002).

CONCLUSIONS

As a result of this 2-year field study, it can be concluded that corn yield and yield components were significantly affected by water stress. Full irrigation (K_1 treatment) and 25 % of its deficits (K_9 treatment) produced the highest grain yield. Full (K_1) and deficit irrigation (K_9) at all stages produced 74.0 % and 69.5 % (as an average) higher grain yield than the non-irrigated application. A close linear relationships between seasonal evapotranspiration rate and grain yield. The obtained average k_y value of corn is 1.02 which may be used to estimate grain yield from ET according to the Stewart's model. Total dry matter (DM) accumulation was accelerated after each irrigation application. Overall, results indicate that K_1 treatment (irrigation applied at all stages) could be optimal for corn grown in semiarid regions under no water shortage. When water is limited, K_9 treatment could be used because our results showed that this had the highest WUE (1.86 kg m^{-3}) and IWUE (1.67 kg m^{-3}) based on averages of two years. On the other hand, when considering deficit irrigation by omitting growth stages, tasseling stages (before and after tasseling) of second crop corn should be given priority for irrigation followed by vegetative and milk stages. When the water stress imposed at the tasseling (before and after tasseling), the yield decrease was 29.1 % parallel with the results of irrigation water saving of 16.0 % based on averages of two years. Therefore, corn sould not be stressed in these stages given above in order to maintain satisfactory growth. It was also found that, stress conditions created at early vegetative and after milk stage did not cause significant yield decrease.

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Water Quality Assessment of the Kopal River (IRAN)

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ABSTRACT

The Kopal River in the Khozestan province, IRAN, is the most important river on the plain and water capability for agriculture in this plain was provided from this river. It is planning to construct a reservoir on the river in the Haftgel area in order to supply the agriculture and drinking consumptions in that region. Therefore, the study on the water quality of this river is very important role in take any decision. In this paper the water quality parameters such as $HCO3^-$ ‛$SO4^{-2}$ ‛CL^{-1} ‛K^+ ‛Na^+ ‛Mg^{+2} ‛Ca^{+2} and $SO4^{-2}$ are evaluated base on the sampled data which taken in the Hydrometric station in the period from 1981-2001. In general, 162 series data are used. For assessment of the water the Wilcox diagram are used. Base on this criterion, the water of Kopal River has high harness and it is not suitable for dinking uses. Also the water is classified as C4S2, C4S3 and C4S4; therefore it is not suitable for the irrigation consumptions.

Keywords: Water Quality, Irrigation, Agriculture, Kopal River

INTRODUCTION

Intensifying water scarcity is now a global phenomenon. The water resources of many regions of the world are insufficient to meet the demands for food, municipal and industrial uses and environmental uses. Even countries that are relatively richly endowed with water may have to address regional or temporary water scarcity. The arid and semi- arid regions of the world are experiencing the most intense water scarcity. Agriculture is the largest consumptive user of water throughout the world. The productivity of irrigated agriculture is significantly higher than the productivity of rained agriculture, particularly in arid and semi-arid regions. The consequence is that agricultural uses of water are very important in generating the food needed to serve the populations of the region. Nevertheless, the growth in competing demands means that efforts will have to be made to manage agricultural water in the most efficient ways possible (Vaux, 2007, ref: Holliday, 2007).Irrigation of agricultural lands accounted for 70% of the water used worldwide. In several developing countries, irrigation represents up to 95% of all water uses, and plays a major role in food production and food security. Future agricultural development strategies of most of these countries depend on the possibility to maintain, improve and expand irrigated agriculture. On the other hand, the increasing pressure on water resources by agriculture faces competition from other water use sectors and represents a threat to the environment (Bauder et al., 2003).

Water Quality

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. For example, the physical and mechanical properties of the soil, soil structure (stability of aggregates) and permeability are very sensitive to the type of exchangeable ions present in irrigation waters. Defining background conditions of water quality is important for water and land managers in assessing the effects of human activities, such as land use, on water resources (Stoner et al., 1998). Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use. Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other, the better tasting water becomes the preferred supply. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely is any other factors considered important. Specific uses have different quality needs and one water supply is considered more acceptable (of better quality) if it produces better results or causes fewer problems than an alternative water supply. For example, good quality river water which can be used successfully for irrigation may, because of its sediment load, be unacceptable for municipal use without treatment to remove the sediment. Similarly, snowmelt water of excellent quality for municipal use may be too corrosive for industrial use without treatment to reduce its corrosion potential (Ayers and Westcot, 1985). There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Hopefully, each new set of guidelines has improved our predictive capability. The guidelines presented in this paper have relied on Wilcoks method to give more practical procedures for evaluating and managing water quality-related problems of irrigated agriculture. Irrigation water quality can best be determined by chemical laboratory analysis. The most important factors to determine the suitability of water use in agriculture are the following:

Salinity (EC or TDS)

Cations and Anions (Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Carbonate (CO^{--}_3), Potassium (K^{+}), Chloride (Cl^{-}) and Sulphate (SO_4^{--}))

Miscellaneous Effects (Bicarbonate (HCO_3), pH and Sodium Adsorption Ratio (SAR))

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water. Total dissolved solids (TDS) may be of interest for water supply and other uses. High TDS levels are undesirable for municipal and irrigation water supply. TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing (WHO, 2006).In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions, but does not tell us the nature or ion relationships. In addition, the test does not provide us insight into the specific water quality issues, such as: elevated hardness, salty taste, or corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water (Bauder et al., 2003). Salts, salinity, electrical conductivity (EC_w), or total dissolved solids (TDS), these terms are all comparable and all quantify the amount of dissolved "salts" (or ions, charged particles) in a water sample. However, TDS is a direct measurement of dissolved ions and EC is an indirect measurement of ions by an electrode. (Bauder et al., 2003). For classification of the agriculture water the Wilcox (1955) method is the most important method. Base on this method it can be classified the water in five categories as following (table 1):

Table 1. General classification of water based on EC values (after Wilcox 1955)

Classes of water	**Electrical Conductivity** (mmohs/ cm)
Excellent	EC<250
Good	250< EC<750
Permissible[1]	750< EC<2250
Doubtful	2250< EC<3000
Unsuitable	EC>3000

From a practical viewpoint, the degree of hardness can be interpreted as following (Zuane, 1997):

Table 2. General classification of water based on TDS values (after Zuane 1997)

Classes of water	**TDS** (mg/L)
Soft	0-50
Moderately hard	50-150
hard	150-300
Very hard	>300

pH and Alkalinity

The acidity or basicity of irrigation water is expressed as pH. Its scale is from 0 to 14. Values higher than 7 considered alkaline and values less than 7 are acid. Water pH regulates aquatic chemistry and can impact water use and habitat (Rabe and White, 1994). The normal pH range for irrigation water is from 6.5 to 8.4 (Ayers and Westcot, 1985). High PH's above 8.5 are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify sodic soil conditions (Bauder et al., 2003).

Sodium Hazard

Due to its effect on the soil and plant, sodium is considered to be one of the major factors governing ware quality. The EC value can also be used to predict soil structure stability in relation to irrigation water quality. The Sodium Adsorption Ratio (SAR) of irrigation water is also required for this (DeHayr et al., 2006). Wilcox (1958) submitted a diagram, illustrating the relation between the quality of irrigation water and the $Na^{+} : (Ca^{2+} + Mg^{2+})$ ratio. Based on this criterion the irrigation water can be classified in five groups as Low, Medium, High and Very high sodium water.

Table 3. General classification of water based on percent Sodium (after Wilcox 1955)

Classes of water	**Percent Sodium**
Excellent	<20
Good	20-40
Permissible	40-60
Doubtful	60-80
Unsuitable	>80

Also the sodium hazard can be expressed based on the sodium adsorption ratio (SAR) by the US Salinity Laboratory. This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample.

$$SAR = \frac{Na^{+}_{meq/L}}{\sqrt{\frac{(Ca^{++}_{meq/L}) + (Mg^{++}_{meq/L})}{2}}} \tag{1}$$

Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. General classifications of irrigation water based upon SAR values are presented in Table 3.

Table 4- General classification of water sodium hazard based on SAR values (after Bauder et al., 2003).

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very High	Generally unsuitable for use.

High concentrations of sodium in irrigation water can result in the degradation of well-structured soils. This will limit aeration and soil permeability to water, leading to reduced crop growth (DeHayr et al., 2006). Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler applied (Bauder et al., 2003).

Chloride

Since the chloride ion has no effect on the physical properties of a soil and is not adsorbed on the soil complex it has generally not been included in modern classification systems, it appears, however, as a factor in some regional water classifications. Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations (Table 4). Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation. Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days. Drop nozzles and drag hoses are also recommended when applying any saline irrigation water through a sprinkler system to avoid direct contact with leaf surfaces (Mass, 1990).

Table 5- Chloride classification of irrigation water (after Bauder et al., 2003)

Chloride (ppm)	Effect on Crops
Below 70	Generally safe for all plants
70-140	Sensitive plants show injury
141-350	Moderately tolerant plants show injury
Above 350	Can cause severe problems

Usual range of Chloride in irrigation water is Chloride 0-30 me/l (Ayers and Westcot, 1985)

Sulfate (SO_4^{2-})

Usually, sulfate ion exists in the total of natural water. The sulfates of sodium, magnesium, potassium are easily soluble in the water, but sulfate calcium has low capability. The presence of sulfate in the soil is rarely a problem, except at very high concentrations where high sulfate may interfere with uptake of other nutrients. As with boron, sulfate in irrigation water has fertility benefits (Bauder et al., 2003).

Calcium (Ca^{++}) and Magnesium (Mg^{++})

Calcium and Magnesium (Ca, Mg) are cations (positively charged ions) which are present in water. They are widely distributed in ores and minerals. They are also very chemically active; therefore they are not found in the elemental state in nature. Calcium and Magnesium ions are of particular importance in water pollution. They may contribute to water hardness. In most cases the sum of Ca and Mg are reported in mill-equivalents/liter. Together Ca + Mg may be used to establish the relationship to total salinity and to estimate the sodium hazard (Wilkerson, 2008).

Szabolcs and Darab consider that one of the most important qualitative criteria is the Mg content of the irrigation water, calculated by formula (FAO, 1973):

$$\frac{[Mg^{++}]}{[Ca^{++}]+[Mg^{++}]}100 \qquad (2)$$

High magnesium affects the soil unfavorably; a harmful effect on soil appears when the above ration exceeds 50.

MATERIALS and METHODS

Kondok river basin is situated in the Southern Western part of Iran. The main river originates from the slopes of mounts Haftgel and Ghalegiri. This river is a water source for the city of Haftgel in Khozestan Province. The major tributary of this river is Gazin. After 23km this river joined with the Kopal River. The river basin measures 1848 km^2. There is a hydrometric station on this river which constructed in the 1982. Figure 1 shows a map of the watershed. River water pollution hinders the socio-economic development of the Iran (Ye et al., 2006), discourages tourism and reaction and degrades the quality of life of local people (Najafpoor et al., 2007).

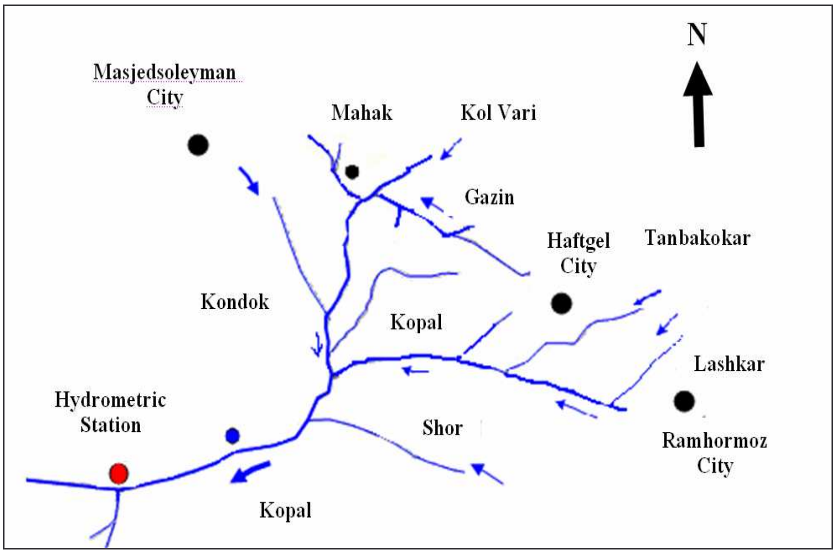

Figure 1- A schematic of the tributaries of the Kondok and Kopal River

The methodology of river water quality monitoring conducting by KWPA, covers measurements that are applied one to twelve times each year, on the hydrometric station, in the period from 1981- 2004. The KWPA staffs have been collecting water samples. Methods (sampling, handlings of samples) used for river monitoring were conformed to the international standard or equivalent national methods. As it is mentioned earlier it is planning to construct a reservoir on the river in the Haftgel area in order to supply the agriculture and drinking consumptions in that region. Therefore, the study on the water quality of this river is very important role in take any decision. The parameters which measured were PH, EC, total dissolved solids (TDS), HCO_3^-, SO_4^{-2} ،CL^- ،K^+ ،Na^+ ،Mg^{++} ،Ca^{++} and $SO4^{-2}$ and S.A.R. For this purpose the sample data which collected from the hydrometric station from 1981 to 2001 are used. Improvement of the river water quality management is still needed in Iran, for a better quality of life of its inhabitants and to line up with the WHO environmental standards. Table 7 shows the statistical parameters of the measured water quality of the Kopal River at Hydrometric station.

Table 6 – The statistical parameters of the measured water quality of the Kopal River at Hydrometric station

Parameter	T.D.S	E.C.*10^6 25 c°	PH	Na^+	S.A.R	K^+	Na	Mg^{+2}	Ca^{+2}	$So4^{-2}$	Cl^-	$Hco3^-$	$Co3^{-2}$
	mg/lit	mmhos/cm		%	-	meq/lit				meq/lit			
Maximum	9728.0	14520.0	8.5	55.6	14.9	0.6	80.0	33.3	41.5	68.0	78.0	4.0	0.6
Mean	4801.5	6788.8	8.0	45.1	7.8	0.2	36.3	15.3	27.1	39.8	36.5	2.5	0.0
Minimum	1712.0	2265.0	7.3	29.0	1.0	0.0	3.8	1.8	14.5	4.8	3.5	0.9	0.0
Standard Deviation	1234.6	1919.2	0.2	8.5	2.3	0.1	13.3	5.8	4.0	9.1	13.0	0.6	0.1
Variation %)	25.7	28.3	2.9	18.8	29.9	45.0	36.7	37.7	14.6	22.9	35.6	24.6	561.7

RESULTS and DISCUSSION

Water Quality Variation based on TDS and EC.

To know the variation of Water Quality from 1981-2001, 162 collected data at the Kopal River at Hydrometric station have been used for analysis. Based on the measured values of the TDS (table 7), the minimum and maximum value of the TDS are 1712 and 9728. As the TDS values are more than 300, from the drinking view the degree of hardness is very hard. Also the minimum and maximum value of the EC are 2265 and 14520. As the EC values are more than 2250, based on the Wilcox method the water of this river classified in the Doubtful and Unsuitable category.

A line graph trend line has been plotted for TDS and EC values versus discharge of the river as shown in following figures 2 and 3. As it observed from these figures the decreasing of the discharge would caused the increasing of TDS and EC. As at the discharge less than 0.1m^3/s, the amount of TDS and EC would be more than 6500 mg/L and 9000 micro mhos/cm, respectively. In the other words, reduced flows can cause accelerated increases total dissolved solids (TDS) concentrations and EC in downstream reaches of the river.

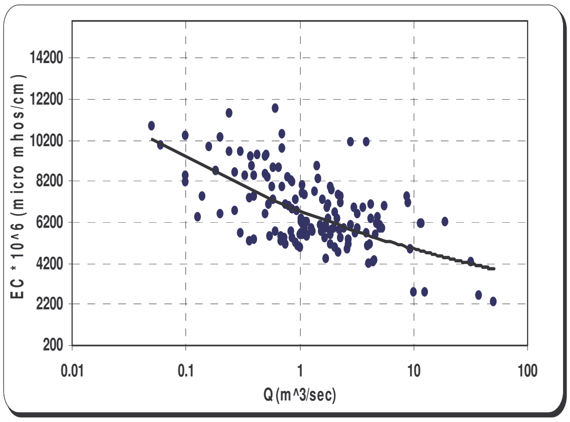

Figure 2- The variation of T.D.S versus EC of the Kopal River

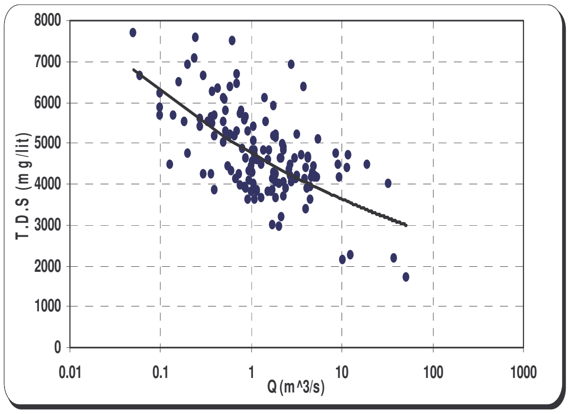

Figure 3- The variation of EC versus discharge of the Kopal River

Sodium and Sodium Adsorption Ratio (SAR)

The measurement of the sodium of the sample data shows that the minimum and maximum values of the sodium percentage are 29 and 55.6. Base on the Wilcox method the water of this river classified in permissible category (table 2). Also the sodium hazard can be expressed based on the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. The calculated value of the SAR shows that the minimum, mean and maximum values of this parameter are 1, 7.8 and 14.9. In comparison to the criteria of table 3 this water has low sodium hazard.

pH

As it is mentioned earlier the acidity of irrigation water is expressed as pH. The measured values of the PH show that the min and max values of it range 7.3 to 8.5. In other word the water of this river from the viewpoint of irrigation consumption is normal.

Calcium (Ca^{++}) and Magnesium (Mg^{++})

Calcium and Magnesium (Ca, Mg) are cations which are present in water. Szabolcs and Darab(FAO, 1973) consider that one of the most important qualitative criteria is the Mg content of the irrigation water, calculated by equation 1. The calculated of this parameter show that the minimum, mean and maximum percentage values of this parameter are 11, 36 and 44. As the maximum value of this parameter is below 50, therefore it has not harmful effect on soil.

Chloride

As it is mentioned earlier the chloride ion has no effect on the physical properties of a soil and is not adsorbed on the soil. Chloride is essential to plants in very low amounts; it can cause toxicity to sensitive crops at high concentrations. The measurement of chloride shows that the minimum and maximum values of the chloride are 3.5 and 78. In comparison with the criteria which mentioned in the table 5 (Bauder et al., 2003), the amount of chloride is nearly low and it is generally safe for all plants.

Wilcox diagram

The gathered water quality data of the Hydrometric station on the Kopal River are plotted on the Wilcox diagram (Figure 4). As it is observed from this figure the water of this river has bad condition and it is not suitable for drinking consumption.

From the view point of agriculture using the water of this river classified C4S2, C4S3 and C4S4. In other word the water of this river has the bad condition and it is not suitable for agriculture.

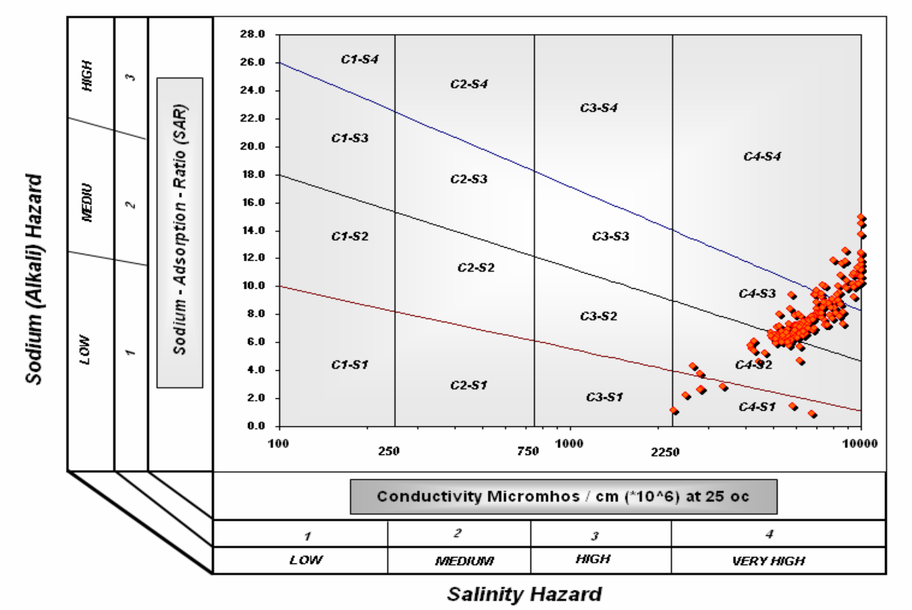

Figure 4- The Wilcox diagram of the Kopal River

CONCLUSION

The purpose of this study was to compile and analyze the available water-quality data on Salinity (EC or TDS), Cations and Anions (Calcium, Magnesium, Sodium, Carbonate, Potassium, Chloride, Sulphate), Miscellaneous Effects (Bicarbonate, pH, Sodium Adsorption Ratio) in the Kondok River which covers 1848 km^2 and encompasses parts of Southern Iran, Khozestan. Our data indicates that water quality conditions in the Kopal River didn't meet the target water quality standard for drinking and agriculture using.

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Performance Benchmarking In Irrigation and Drainage Systems

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ABSTRACT

Due to the rapid growth in world population, increasing numbers of people especially those who are living in arid and semi-arid regions are suffering from shortage of water and food, and this is the driving force for improving irrigation and drainage systems' efficiency. As irrigated agriculture is a consumer for over 75% of world fresh water supplies, using the water allocated to the agricultural sector more efficient and then releasing the surplus of water for other sectors' use seems to be the only solution for coping with water scarcity. Irrigation and drainage infrastructure is the indispensable element of irrigated agriculture. The level of irrigation and drainage services maintained in the irrigation area is directly affecting the quantity of crop production. Improving irrigation system efficiency / performance in aspects of Management - Operation - Maintenance (MOM) tasks has become a major concern for stakeholders and system managers, but monitoring and evaluating the performance of irrigation systems by using performance indicators have been a major concern for the researchers in this area. The term "Irrigation system performance evaluation" refers to what extent the targets and objectives have been achieved. Benchmarking implies comparison either internally with previous performance and desired future targets, or externally against similar organizations, or organizations performing similar functions. The overall aim of benchmarking is to improve the performance of an organization as measured against its mission and objectives. This paper emphasizes on the concept of benchmarking and its applications in irrigation and drainage systems.

Keywords: Benchmarking, performance evaluation, irrigation and drainage systems

INTRODUCTION

Main destination for developing new areas for irrigated agriculture worldwide or introducing irrigation to dry agricultural lands is to meet the food needs of increasing population. Securing food and water should be the main challenge of mankind in order to sustain himself. "Getting more crop per drop" is the goal of modern irrigated agriculture in the world struggling with global climate change and diminishing water resources.

Due to declining per capita production of food grains and increasing numbers of people living in poverty and hunger, there is a growing need worldwide to identify and develop new lands with adequate agricultural potential (Hargreaves and Olsen, 1999).

The question is whether there will be enough freshwater to satisfy the growing needs of agricultural and non-agricultural users. FAO expects that the withdrawal of irrigation water in the 93 countries of its study will grow during the period 1998–2030 by only about 14%, a small increase compared to the projected increase in the irrigated area. Crop water consumption per unit of area is expected to decrease by 3%, and gross crop water use by 16%. FAO explains most of this difference by an expected improvement in irrigation efficiency, that should result in a reduction in the water withdrawals per unit of irrigated area. The FAO model is based on the assumption that 2.5% of the existing irrigated area is rehabilitated or substituted by new irrigation systems each year, an activity that would commit a considerable investment in irrigation hardware and technology (Playán and Mateos, 2006).

Concerns and problems over water scarcity will certainly affect irrigated agriculture. The rate of increase in irrigation withdrawals will not be the same as over the last 25-year period. From 1995 to 2025, FAO forecasts a growth in irrigation withdrawals of 14%, while IWMI sees a 17% growth in withdrawals for irrigation. But food production from irrigated lands during the same period should grow by at least 40% to meet the needs of a 33% increase in population, and to satisfy trends for improved nutrition. There is increasing competition for water. Water is increasingly being transferred from irrigated agriculture to higher valued industrial and urban uses, and irrigated land is going out of production from urban sprawl. Water quality problems increase with rising industrialization and inefficient irrigation water use, leading to pollution and salinization. There is a call for more water to be reserved for environmental uses. It is not clear how much land is going out of production due to salinization, but it is clearly a threat to irrigated food production systems (Bos et al., 2005).

Performance Assessment in Irrigation and Drainage Systems

The concept of benchmarking in irrigation and drainage systems has emerged from the previous performance evaluation studies which constitute a basis and a background for the researchers in this area. Clemmens (2006), stated that without a clear understanding of the link between irrigation system operations and the resulting system performance, one cannot develop a rational plan for implementing needed changes, nor where to start.

Irrigation water, once applied, becomes part of the hydrologic system and is difficult to trace. When determining irrigation performance, it is usually necessary to make assumptions about what happened to all the applied water (Clemmens, 1999).

Many irrigation systems, particularly in developing countries, perform below their potential. Head-tail problems, leaky canals, and malfunctioning structures because of delayed maintenance, leading to low water use efficiency and low yields, are some of the commonly expressed problems. A large part of low performance may be due to inadequate water management at system and field level (Çakmak et al, 2004).

Performance of a system is represented by its measured levels of achievements in terms of one or several parameters, which are considered as indicators of system's goals (Mondal and Saleh, 2003). Performance assessment enables verification of the degree to which targets and objectives are being realized. It also provides different stakeholders (system managers, farmers and policy makers) with a better understanding of how a system operates. It can help determine problems and identify ways and means of improving system performance (Çakmak et al, 2004).

The need for higher levels of performance in the irrigation and drainage sector is driven by several factors:

- Increasing population leading to a need for greater agricultural production

- Growing water scarcity within river basins leading to a need for irrigated agriculture to produce ‘‘more crop per drop’’

- Higher expectations from farmers and their families in terms of their livelihoods

- Higher expectations by farmers in relation to the level of service required from the irrigation and drainage agency

- Changing perceptions, attitudes and practices within government on provision of public services (Malano et al., 2004).

Irrigation performance assessment had been focused on internal evaluation of each individual irrigation system and the methods were given in detail in Rao (1993). Malano et al., (2004), mentioned that the work on the comparative performance of irrigation schemes, which lies at the heart of benchmarking came primarily from International Irrigation Management Institute (Perry, 1996; Molden et al., 1998; Kloezen and Garces-Restrepo, 1998; Sakthivadivel et al., 1999).

The process of performance assessment hinges around the capacity of the managers of an organization to answer two simple questions:

- "Am I doing things right?", which asks whether the intended level of service (that has been set and agreed upon) is being achieved. This is the basis for good operational performance.
- "Am I doing the right thing?", a question that aims at finding out whether the wider objectives are being fulfilled, and fulfilled efficiently. The latter is part of the process of assessment of strategic performance (Bos, 1997).

The organizations responsible for irrigation and drainage systems can be very helpful in providing information about system performance, assuming they have a well-established monitoring and evaluation program and an efficient management information system. In this respect it is also useful to clarify who are the actors in the field of agricultural water management (Figure 1) (Schultz and de Wrachien, 2002).

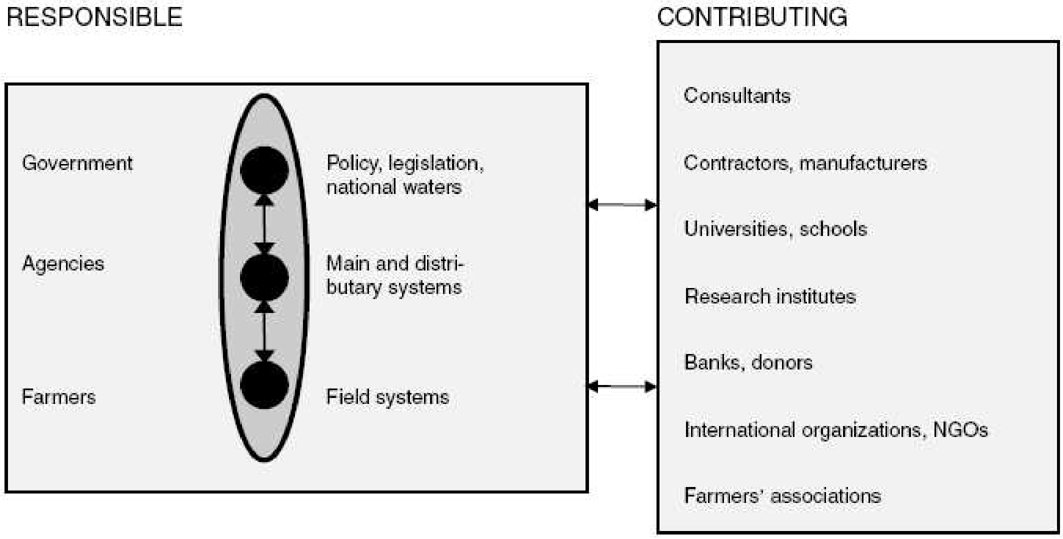

Figure 1. Indicative schematization of actors in agricultural water management (Schultz, 2001)

The Concept of Benchmarking

Benchmarking is a fundamental business skill that supports quality and excellence and since the early 1990s has become widely regarded as a skill that should be communicated and utilized in day-to-day private and public business operations. Recent developments are utilizing the technique for government operations in municipal and state services for example. Benchmarking has also broad applications in problem solving, planning, goal setting, process improvement, innovation, reengineering, strategy setting, and in various other contexts (Gonzalez, 2000).

Benchmarking is a process whereby organizations pursue enhanced performance by learning about their own organisation through comparison with their own historical performance and with the practices and outcomes of others (Alexander, 2002).

Benchmarking and performance assessment are related but different in several ways. Benchmarking is essentially an externally focused activity. In benchmarking the specific aim is to identify key competitors/comparable organisations, and find best management practices for that organisation. These then become standards and/or norms against which to assess an organisation's own performance. Performance indicators are specifically identified to enable the comparison, and to monitor progress towards closing the identified performance gap (Malano and Burton, 2001).

Benchmarking is a management tool based on indicators that enable managers to know the relative position of an organization with respect to others (external benchmarking) or to compare different sections within an organization for their performance over time (internal benchmarking) (Rodríguez-Díaz et al., 2004).

Benchmarking in Irrigation and Drainage Sector

As defined in preliminary IPTRID (International Program for Technology and Research in Irrigation and Drainage) documents, benchmarking is a systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards. The overall aim of benchmarking is to improve the performance of an organization as measured against its mission and objectives. Benchmarking implies comparison either internally with previous performance and desired future targets, or externally against similar organizations, or organizations performing similar functions. Benchmarking is in use in both the public and private sector (Burt and Styles, 2004).

The first evidence of benchmarking in the irrigation and drainage sector, rather than performance assessment, being applied as a management process in the irrigation and drainage sector was its use by the Australian National Committee of the International Commission on Irrigation and Drainage (ANCID). Upon the request of the World Bank to the Consultative Group of the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) in December 1999, a research study to develop guidelines for benchmarking in the irrigation and drainage sector was launched by IPTRID. The study was carried out as a joint initiative of the IPTRID partner institutions, namely, World Bank (WB), Food and Agriculture Organization of the United Nations (FAO), International Water Management Institute (IWMI) and the International Commission on Irrigation and Drainage (ICID) and coordinated by the IPTRID Secretariat. The IWMI (International Water Management Institute) has developed an on-line programme called the On-line Irrigation Benchmarking System (OIBS), in which users can introduce data and establish a benchmarking procedure using existing data (Malano, 2002; Cornish, 2005; Malano and Burton, 2001).

Performance indicators are a powerful tool for identifying deficiencies in irrigation district management and determining which measures should be taken to improve them. This process is known as benchmarking. Until now, analysis has been based on direct comparisons of performance indicators from different irrigation districts. However, this procedure does not provide an overall view of the actual performance of each district in relation to others. Furthermore, on some occasions irrigation districts are compared with very different ones and best practices cannot be adapted to organisations having lower performance (Rodríguez-Díaz et al., 2008).

Benchmarking is a continuous process that involves (a) internal assessment of the organisation, (b) comparing it with the best practices of more successful similar businesses in the market, (c) determining performance gap between current practice and best practice, and (d) selecting best practices, tailoring them to fit the organisation and implementing them (Figure 2). The cycle of improvement continues.

Benchmarking does not substitute other diagnostic and appraisal analyses, but rather complements them (Malano and Burton, 2001).

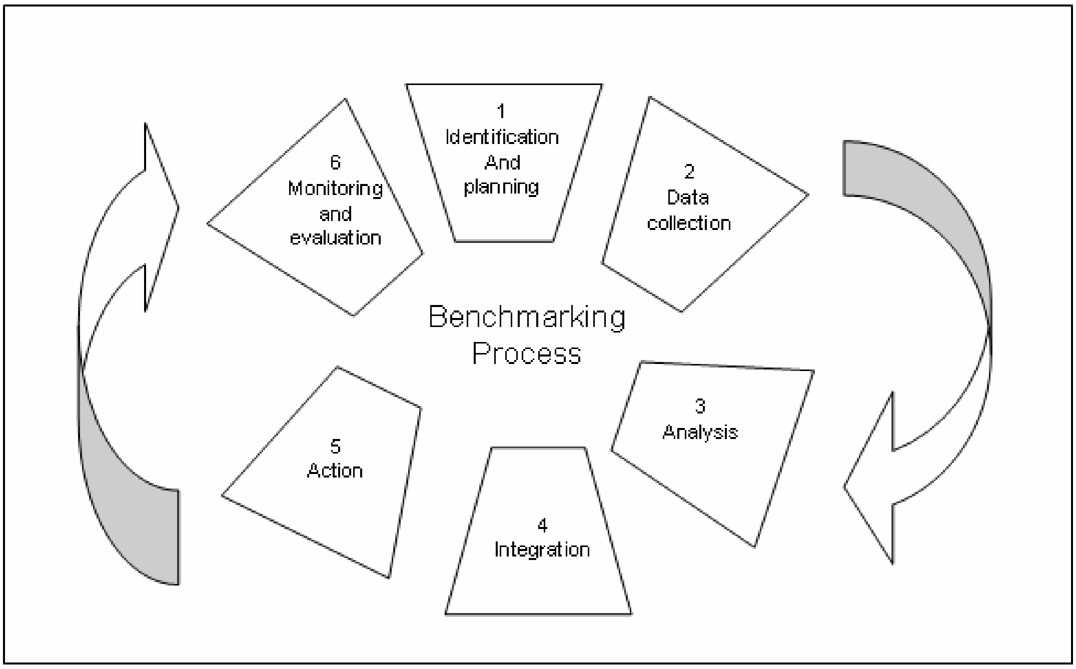

Figure 2. Stages of the benchmarking process (Malano and Burton, 2001)

In approaching benchmarking for the irrigation and drainage sector there are three characteristics that need to be borne in mind:

- Irrigation and drainage service providers operate in a natural monopoly environment
- Irrigation and drainage entails complex and interacting physical, social, economic, political, technical and environmental processes
- Performance of irrigation and drainage schemes is site specific (Malano and Burton, 2001).

A significant problem with benchmarking and performance assessment of irrigation and drainage schemes is the complexity and thus variety of types of scheme. Some schemes are farmer-managed, some are private estates with shareholders, some are gravity fed, some fed via pressurized pipe systems, etc. There is as yet no definitive methodology for categorizing irrigation and drainage schemes, therefore there will always be discussion as to whether one is comparing like with like (Burton et.al, 2000.)

A distinctive feature of irrigation and drainage schemes is their site or region specified nature. In order to allow comparisons between irrigation and drainage schemes they need to be categorised into similar types. There are a variety of ways this can be done. Following are the categorization headings that will be used for benchmarking:

- type of control (fixed proportional division, manual control, automatic control);

- type of management (government agency, private agency, farmer managed);
- method of allocation and distribution (supply, arranged-demand, demand);
- climate (humid, arid)
- predominate crop type (rice, non-rice, subsistence/cash cropping);
- water availability (abundant, scarce)
- water source (surface water, groundwater);
- socio-economic setting (gross domestic product, degree of industrialization, developing / developed nation);
- size (large, small)
- location (Asia, Africa, Americas) (Malano and Burton, 2001).

The extent of the benchmarking exercise needs to be identified and the boundaries defined. The extent/boundaries can be categorized into five key dimensions, such as; spatial (numbers of schemes to be considered), temporal (duration of the exercise and temporal extent of the data), system(s) to be assessed, processes to be assessed, level (primary, secondary, tertiary, field; village, district, national) (Burton et al., 2000).

Benchmarking can be carried out by a variety of organisations, including private companies, government organizations, regulatory/supervisory organizations, management consultants, independent agencies (Table 1). In all cases the benchmarking exercise will be initiated within the organisation and may be executed in the main by personnel within the organisation (Malano and Burton, 2001).

Table 1. Examples of for whom, from who's viewpoint and by whom benchmarking and performance assessment might be carried out? (Burton et al., 2000)

For whom?	**From whose viewpoint?**	**By whom?**
Government regulatory body	Water users Irrigation service provider Society (use of resources)	Government regulatory body Irrigation service provider (data provision)
Irrigation service provider	Irrigation service provider Water users	Irrigation service provider Consultant (possibly)
Water users	Water users	Consultant
Academic community	Irrigation service provider	Research institute University

The application of benchmarking techniques to improve irrigation district performance is a relatively recent phenomenon. The main objective of this technique is to enhance the performance of a given irrigation district by comparing its current performance with that of other districts. In this way, it is possible to determine which practices lead to better performance in a district and subsequently adapt these practices to irrigation districts that perform less efficiently. Similarly, irrigation districts that perform more poorly will be able to determine which aspects are in need of improvement and take the necessary steps to achieve better performance. Performance indicators are the main tool in a benchmarking process. A performance indicator is a ratio that relates variables (i.e. irrigated area, volume of irrigation water applied or productivity) in such a way that a large amount of information can be reduced to a single number. By comparing performance indicators it is possible to determine when an irrigation district is more or less efficient than another and take the necessary measures to correct any existing deficiencies (Rodríguez-Díaz et al., 2008).

In the water sector benchmarking has an important potential to contribute to improve the services and the efficiency of the operations. It has successfully been applied in the water supply and sanitation in different conditions. The objective is to compile, analyze and compare a core database of irrigation projects, which are or should be available in the files of well managed irrigation agencies. The data will not fulfill the needs of all involved in irrigation, the idea is to identify the most important processes and cost centers and to start with simple indicators that could describe the improvement of a system in time and the comparison of similar systems (Gonzalez, 2000).

The simple comparison of indicators involves subjective judgment-making which provides little information about the global position of an organization with respect to others. In order to address this problem, data envelopment analysis (DEA) techniques were applied. DEA is a nonparametric frontier method for the study of production functions. The use of DEA analysis based on inputs and outputs of an irrigation system enables us to determine the relative efficiency of an organization or a productive function within an organization and to determine its position in relation to the optimal situation by providing a numerical quantification of the direction in which the organization must direct its efforts in the future (Rodríguez-Díaz et al., 2004).

In order to facilitate the use of performance indicators, a computer application called IGRA, (Application of Irrigation Performance Indicators), is developed. This application facilitates the calculation of indicators and defines them using a wide range of zone descriptors and irrigation year variables, allowing comparisons to be established between different zones and irrigation years. IGRA also takes into account certain phases of the benchmarking procedure. The programme is used in this study to calculate and compare performance indicators for several irrigation zones in Andalusia-Spain (Pérez et al., 2004).

The rapid appraisal process (RAP) of irrigation projects as a key part of benchmarking was introduced in a joint FAO/IPTRID/World Bank publication Water Reports-19 (Burt and Styles, 1999). The Rapid Appraisal Process (RAP) for irrigation projects is a 2 week process of collection and analysis of data both in the office and in the field. The process examines external inputs such as water supplies, and outputs such as water destinations. It provides a systematic examination of the hardware and processes used to convey and distribute water internally to all levels within the project (from the source to the fields). External indicators and internal indicators are developed to provide (i) a baseline of information for comparison against future performance after modernization, (ii) benchmarking for comparison against other irrigation projects, and (iii) a basis for making specific recommendations for modernization and improvement of water delivery service (Burt and Styles, 2004).

CONCLUSION

Irrigated agriculture makes an important contribution meet the food demand of the world population and irrigation and drainage infrastructure is the indispensable element of this system. The benefits expected to obtain from irrigation is subject to the productivity, efficiency and sustainability of irrigated agriculture. Implementation of performance evaluation techniques and benchmarking in irrigation and drainage systems help system managers and policy makers in diagnosing the deficiencies of the system and improving its efficiency.

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Effect of Seed Priming with Growth Promoting Rhizobacteria at Different Rhizosphere Condition on Growth Parameter of Maize

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ABSTRACT

In this experiment the effects of three rhizobacteria named *Azotobacter*, *Azospirillum* and *Pseudomonas* at different rhizosphere condition on growth parameters were evaluated as a factorial experiment.10 straines of rhizobacteria include: P_1=*P.putida* strain R-168, P_2=*P.flurescens* strain R-93, P_3=*flurescens* strain 50090, P_4= *P.putida* DSM*291,* P_5=*Azotobacter chroococcum* strain 5, P_6=*Azotobacter chroococcum* DSM 2286, P_7=*Azospirillum lipoferum* strain 21, P_8=*Azospirillum lipoferum* DSM 1691, P_9=*Azospirillum brasilense* DSM 1690 and P_{10} = non- inoculation(control) were tested in both sterile and non-sterile soils. The results showed the interaction of two factors on stem and total fresh weight also on total dry weight and leaf area were significant. Results of this study revealed that soil natural condition had the higher effects on growth parameter than soil sterile condition.

Key words: pgpr , maize, growth, rhizosphere

INTRODUCTION

Colonization of plant roots by bacteria has been observed for a long time, but only lately has its importance for plant growth and development become clear. Plant Growth-Promoting Rhizobacteria (PGPR) are beneficial bacteria that colonize plant roots and increased plant growth (Glick, 1995). PGPRs are able to enhance plant growth by different mechanisms such as nitrogen fixation, production of phytohormones or status nutritional of plants (Kloepper, 1994; Glick, 1995; Cleyet-Marcel et al., 2001) which can improve the extent or quality of plant growth directly or indirectly. Several of these bacteria have been described as increasing plant water and nutrient uptake (Okon and Labandera-Gonzalez, 1994; Jacoud et al., 1999). PGPR can also enhance the plant competitiveness and responses to external stress factors as well as inhibiting soil-borne plant pathogens through antifungal activity (Sharma and Chahal, 1987) and siderophore production (Neiland, 1981; Suneja et al., 1996).

In last few decades a large array of bacteria including species of *Pseudomonas, Azospirillum, Azotobacter, Klebsiella, Enterobacter, Alcaligens, Arthobacter, Burkholderia, Bacillus* and *Serratia* have reported to enhance plant growth (Kloepper et al., 1989;and Glick, 1995). Several studies clearly showed Inoculation of maize and wheat with *Azotobacter* , *Azospirillum* and *Pseudomonas* increased plant growth, nutrient uptake and yield (Tilak et al., 1982; Dobbelaere et al., 2001; Okon and Labandera- Gonzalez, 1994). Different strains of *Pseudomonas putida* and *Pseudomonas fluorescens* could increase root and shoot elongation in canola, lettuce and tomato (Hall et al., 1996; Glick et al., 1997). It has also been reported that wheat yield increased up to 30% with *Azotobacter* inoculation and up to 43% with Bacillus inoculation (Kloepper et al., 1991). Inoculation of plants with *Azospirillum* can result in a significant change in various growth parameters, viz. increase in plant biomass, nutrient uptake, tissue N content, plant height, leaf size, tiller numbers, root length and volume in different cereals (Okon,1985;Wani, 1990). Keeping the above information in view, the present experiment was planned to evaluate the effects of *Azotobacter*, *Azospirillum* and *Pseudomonas* inoculants on growth characteristics of Zea mays by means of a pot study.

MATERIALS and METHODS

For the evolution of growth promotion with PGPRs under pot conditions a laboratory study was carried out at research laboratory of Shahrood University of Technology in 2007. 10 levels of rhizobacteria include: P_1=*P.putida* strain R-168, P_2=*P.flurescens* strain R-93, P_3=*flurescens* strain 50090, P_4= *P.putida* DSM291, P_5=*Azotobacter chroococcum* strain 5, P_6=*Azotobacter chroococcum* DSM 2286, P_7=*Azospirillum lipoferum* strain 21, P_8=*Azospirillum lipoferum* DSM 1691, P_9=*Azospirillum brasilense* DSM 1690 and P_{10} = no inoculation were tested in both non-sterile and sterile soils. All treatments (bacterial inoculation× soil type) consisted of 60 plots i.e., 3 replicates with 20 pots per replication and a double seed per pot. Treatments were arranged in a factorial experiments based on completely randomized design. The plastic pots had a size of 15cm in diameter and capacity to hold 2Kg of soil (for sterile and non-sterile factors used autoclaved and natural soil respectively). The soil was silty clay loam in texture, having pH, 7.8; EC, 3.9ds.m-1; 0.75% of organic carbon; 0.04% N, 6.4 and 320 ppm of available P and K respectively. Seeds of maize (*Zea mays*, hybrid SC.647) were surface-sterilized with 0.02% sodium hypochlorite for 2 min, and rinsed thoroughly in sterile distilled water. For inoculation Seeds were coated with 20% gum arabic as an adhesive and rolled in to the suspension of any bacteria (10^8 cfu ml-1) with perlit mixture until uniformly coated. Seeds treated with sterile distilled water amended with gum arabic served as the non treated control. Seedlings were watered daily, and no artificial fertilization was used. After 30 days, fresh weight was determined by weighing the uprooted plants and dry weight by drying plants in an oven at 75℃ until the weight remained constant. The area of each expanded leaf area was calculated as $K \times$ length $\times$ width, where k =0.75 (Ruget et al., 1996).

All data in the present study were subjected by analysis of variance (ANOVA) using the Statistical Analysis System computer package (SAS system Ver.9). Least significant difference test (LSD) was applied to make comparisons among means at the 0.05 level of significance.

RESULTS and DISCUSSION

Inoculation of seeds with bacterial strains in different soil type did not stimulate leaf fresh weight, leaf and stem dry weight significantly (Table 1). Stem fresh weight and total fresh weight significantly increased with bacterial inoculation in this experiment. The highest stem fresh weight were recorded from *A.brasilense* DSM1690 in sterile (5.62 g) and non sterile(5.39 g)soil, followed with *A.lipoferum* DSM1691 (5.4g) and *A.lipoferum* strain21(5.34g) in non sterile soil.

A.lipoferum DSM1691 in sterile soil and *A.brasilense* DSM1690 in both soil conditions produced more total fresh weight than other treatments. Stem and total fresh weight in *A.lipoferum* DSM1691 strongly decreased in sterile soil. Total dry weight were significantly ($p<0.05$) enhanced by bacterial inoculation and soil type. Application of *A.brasilense* DSM1690 in sterile soil had the highest effect on total dry weight as compared to control (Table 1).

Application of bacterial strains had significant effect on leaf surface area under both soil types. The results revealed that inoculation of maize seeds with *A.lipoferum* strain21 and *A.lipoferum* DSM 1691 in non sterile soil had the most leaf area (352.5 and 349.9 cm 2, respectively).

Experiment results indicated that the PGPR promote plant growth during the early stages of growth after sowing. This is the period when young seedlings and plants are so vulnerable to environmental stresses. This present investigation confirms the earlier work that showed Bacterial inoculants are able to increase plant growth, seed germination rate, improve seedling emergence, protect plants from disease and external stress factors (Lugtenberg et al., 2002). responses to external stress factors Findings were reported by Dobbelaere *et al.,*(2002), who assessed the inoculation effect of PGPR *A. brasilense* on growth of spring wheat, revealed that inoculated plants resulted in better germination, early development and flowering and increase in dry weight of both the root system and the upper plant parts. The mechanisms by which PGPRs promote plant growth are not fully understood, but one of the main action happend by effects of plant growth regulators such as auxins (Gutierrez Mañero et al., 2003). Kloepper et al.,(1986) reported PGPR synthesize phytohormones can promote plant growth at various stages.

Inoculation of maize seeds with *Azospirillum* strains compared with *Pseudomonas* strains and control under experiment conditions resulted in a more visible increase in shoot development, especially during the establishment of the plant. Kravchenko and Makarova(1993) shwed that PGPR strain of *Pseudomonas fluorescens* was not able to colonize the wheat root in non-sterile soil, and after 6 days only a small number of introduced bacteria were present at the root base, and practically none at the root elongation zone and at the apex. At the same time in sand this strain showed very good colonization of the same wheat genotype. However, *A. brasilense* can induce acidification of the rhizosphere (Carrillo et al., 2002) . *Azospirillum* spp. may change root physiology and patterns of root exudation (Heulin et al., 1987). Woodard and Bly(2000) reported that the corn inoculated with *A. brasilense* increased shoot dry matter.

Results indicate that application of *A. chroococcum* strain 5 sterile soil had more effect on growth parameters in sterile soil compared to non sterile soil. Martinez-Toledo (1988) showed that the numbers of *Azotobacter* decreased as plant growth continued in non-sterile agricultural soils, while the numbers of *Azotobacter* associated with maize roots grown in sterile agricultural soils remained similar to those of the original inoculums. In contrast for *A.chroococcum* DSM 2286 higher enhancement observed in non sterile soil. This may imply that this strain had more competitive ability to survive and affect the growth of inoculated plants in the presence of indigenous micro flora.

It is concluded that in *Zea mays* different bacterial strains stimulated significantly growth parameters at both soil conditions (especially in non-sterile soil), when compared with that of control. Increase in growth parameters could associated with the ability to produce phytohormons, asymbiotic N2 fixation, antagonism against phytopathogenic microorganisms and solubilisation of mineral phosphates and other nutrients. Hence the strains used in the present study can be used as biofertilizer for the improvement of growth parameters of commercially cash crop i.e. maize.

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Table1.Effect of bacterial inoculation on growth characteristics of maize seedlings at 30 days after sowing in two different soils

Treatments	Fresh weight (g)						Dry weight (g)						Leaf area (cm^2)	
	Leaf		Stem		Total		Leaf		Stem		Total			
	non sterile	Sterile	non sterile	Sterile	non sterile	Sterile	non sterile	Sterile	non sterile	Sterile	non sterile	Sterile	non sterile	Sterile
P.putida strain R-168	5.28	3.58	4.55ab	3.20bcde	9.84abc	6.77cdefg	0.28	0.27	0.62	0.57	0.90abcde	0.84abcde	250.6abcd	173.1def
P.fluorescens strain R-93	5.04	1.42	4.48ab	1.15 e	9.53abc	2.56 g	0.33	0.11	0.61	0.38	0.94abcde	0.49efg	274.6abcd	109.3ef
P.fluorescens DSM50090	5.09	4.32	4.31ab	3.80abc	9.41abc	8.12abcde	0.27	0.26	0.59	0.55	0.86abcde	0.81bcde	244.1abcd	169.2def
P.putida DSM29*1*	5.28	3.56	4.55ab	2.89bcde	9.83abc	6.45cdefg	0.34	0.17	0.65	0.43	0.99abcd	0.60defg	252.4bcde	166.7def
A.chroococcum strain 5	4.26	4.85	3.63abcd	4.15abc	7.9abcde	8.99abcd	0.41	0.26	0.52	0.67	0.92abcde	0.93abcde	221.6abcd	247.8abcd
A.chroococcum DSM 2286	5.11	5.09	4.19abc	3.9abc	9.29abc	9.01abcd	0.28	0.27	0.70	0.61	0.99abcd	0.88abcde	255.0cdef	227.2abcde
A. lipoferum Strain 21	5.82	4.01	5.34a	3.2bcde	11.17ab	7.22bcdef	0.50	0.20	0.71	0.47	1.22ab	0.67cdef	352.5a	148.8def
A.lipoferum DSM 1691	6.13	1.50	5.40 a	1.56 de	12.20 a	3.07 fg	0.51	0.07	0.61	0.20	1.13abc	0.28 fg	349.9ab	87.50 f
A.brasilense DSM 1690	6.32	6.64	5.39a	5.62 a	11.72a	12.27 a	0.36	0.37	0.72	0.92	1.08abc	1.30 a	267.3abcd	325.4 a
Control	2.47	2.45	1.41 e	2.13cde	3.88efg	4.58defg	0.04	0.18	0.12	0.36	0.17g	0.54defg	196.3cdef	170.0def

Soil, Vegetation and Vicunas in Apolobamba (Bolivia): Conservation of Biodiversity

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ABSTRACT

High-grasslands in the Andes Mountain Range are the natural habitat of many species such as vicuna (*Vicugna vicugna*), endangered specie recognized by The World Conservation Union. These ecosystems are especially weak and suffer, in many cases, over-exploitation processes due to the cattle raising. The National Area of Apolobamba Integrated Management (ANMIN-A) is located northwest of Bolivia and there, government and indigenous people carry out a vicuna sustainable management programme in the aim of the conservation of this specie and its natural habitat. The objectives of this work were to study different zones with diverse vicuna and other domestic camelid populations in Apolobamba in order to evaluate: (i) soil conservation degree through the analysis of physical and chemical properties, (ii) vegetation characterization and (iii) the relationship soil-plant system. Some soil and plant samples were taken in different sampling plots according to vicuna and domestic camelid population densities. Moreover, it was taken into account the geo-morphological and landscape characterization. Results showed differences between soil characteristics and fertility qualities, and plant covert, vegetation species identification and palatability. Results discussion exhibited that the studied zones had different degradation processes, mainly, due to the vegetation modification. In conclusion, in Apolobamba there were differences in the study zones with diverse vicuna and domestic camelid population densities, related to soil and vegetation conservation degree. On the other hand, some zones need specially protection measures associated to the cattle raising impacts and the soil-plant system degradation.

Keywords: soil conservation, camelid population, soil-plant system

INTRODUCTION

Grazing intensity and grassland degradation problems have been studied around the world; ecosystem degradation is commonly assessed, based on soil and vegetation conditions (Chunli et al., 2008). Grazing reduces soil water-holding capacity (Pietola *et al*., 2005) which increases surface runoff (Heathwaite et al., 1990), decreases soil macro-porosity (Singleton *et al*., 2000) and increases the risk of soil nutrients loss (Kurz et al., 2005). On the other hand, an intensive grazing may lead to the destruction of vegetation and incorporation of plant residues into the soil (Bilotta *et al*., 2007), which alter carbon storage and nitrogen levels in rangeland ecosystems (Derner *et al*., 2006; McNauughton *et al*., 1997; Frank and Groffman, 1998; Milchunas and Lauenroth, 1993). Some researchs show that soil and vegetation degradation on grassland is caused mainly by livestock grazing (Keya, 1998). However, the effect of overgrazing on vegetation and soil properties is not well understood (Chunli *et al*., 2008).

In many cases, ecosystems in the *puna* or grasslands in the Altiplane are degraded as a consequence of anthropogenic activities (Rocha and Saenz, 2003), in addition to excessive grazing. Vicuna is an endangered species recognized by The International Union for Conservation of Nature (IUCN, 2008) The National Apolobamba Integrated Management Area (ANMIN-A) in Bolivia is a high altitude grassland (above 4,000 m.a.s.l.), located in the Northwest of La Paz (Fig. 1). ANMIN-A provides a natural habitat for a high number of camelids. Aymara and Quechua indigenous communities live in Apolobamba and their main economical activity is to raise camelids. These ethnic groups present a poverty index of about 98% (Instituto Nacional de Estadística, 2001). According to the Servicio Nacional de Áreas Protegidas (SERNAP), Apolobamba area hosts more than 10,000 vicunas (*Vicugna vicugna*) and 130,000 alpacas (*Lama pacos*), approximately 34% of the total alpacas in Bolivia and other domestic camelids; they are distributed in about 120,000 ha (SERNAP, 2005). Vicuna management in the Apolobamba area is an example of sustainable management in indigenous communities (Agencia Española de Cooperación Internacional, 2004). The objectives of this study were to determine: (i) soil conservation degree through the analysis of physical and chemical properties, (ii) the vegetation characterization and (iii) the relationship soil-plant system.

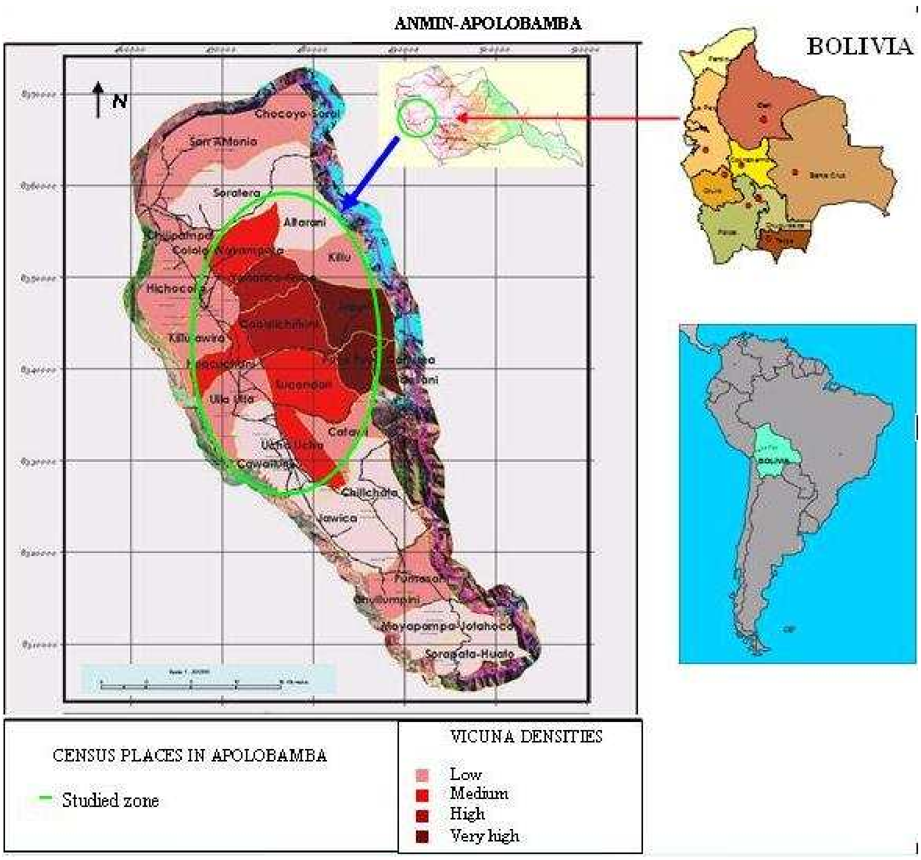

Figure 1. Location map of the ANIMN-Apolobamba and the studied zone.

MATERIALS and METHODS

The research was carried out in the *puna* of Apolobamba, the vicuna habitat. The study zone is characterized by udic and frigid soil moisture and temperature regimes (Soil Survey Staff, 2003) with an annual average temperature of 4.5 ºC and total precipitation of 505 mm which is concentrated in five months, between November and March (SERNAP, 2006). Considering Rivas-Martinez (2004) bioclimatic model and Navarro and Maldonado (2002) bioclimatic map of Bolivia, the study area would be classified as orotropical. It could be also identified by two vegetation units (altoandine and *puna*), according to Beck et al. (2002) classification. García et al. (2002) recognize three sub-units grasslands; with altitude ranges between 4,000 and 5,200 m.a.s.l., and some variations described by several investigators (Ribera, 1992; Kessler and Beck, 2001; Beck et al., 2002; Navarro and Maldonado, 2002).

Soil quality and conservation degree was evaluated through a physical-chemical characterization. Vicuna population density was the main reason to select studied zones (Fig.1). Other characteristics that were determined include: (i) alpaca densities, (ii) vegetation species, (iii) geo-morphological, and (iv) hydrological landscape elements. Eight census places, or areas with stable vicuna populations separated by geographic accidents, were selected (Tables 1, 2 and Fig. 1).

Table 1. Vicuna and alpaca densities in the Apolobamba area.

Vicunas			Alpacas	
Density	**Nº**	**Nº/ km^2**	**Density**	**Nº**
Low	139-412	2.1-9.4	Low	1569-2542
Medium	413-691	9.4-16.5	Medium	2543-4004
High	692-1383	16.5-23.1	High	4005-6641
Very High	1384-2119	23.1-58.1	Very High	6642-15300

(Catari and Fernandez, 2003)

Table 2. Vicuna and alpaca densities in selected census places.

Census places	Vicuna density 2003 [(1)]	Vicuna density 2004	Vicuna density 2005 [(3)]	Alpaca density [(3)]
Ulla-Ulla	Low	Low	Low	High
Killu	Low	Low	Low	Medium
Ucha-Ucha	Medium	Medium	Medium	Very high
Wakampata	Medium	Medium	Medium	Medium
Caballchiñuni	High	High	High	Medium
Sucondori	Medium	High	High	
Puyo-Puyo	Very high	Very high	High	Medium
Japu	Very high	Very high	Very high	

[(1)] Catari and Fernández (2003); [(2)] SERNAP (2004);[(3)] SERNAP (2005).*In 2006 and 2007, the census was not carried out.

Soil Sampling

Three representative plots of 5 x 5 m were selected in each census location or studied area. Since most of the soil organic matter is located in the surface layer (Ganjegunte et al., 2005), three replicates, surface and sub-surface soil samples, were collected per plot: 0-5 cm and 5-15 cm. Samples were placed in plastics bags, which were sealed and then transported to the laboratory. Soil samples were air-dried and passed through a 2 mm sieve to remove gravels, plant remains and root fragments.

The following soil analysis were carried out: organic carbon was analysed on TOC Analyser (Shimadzu 5000, Kyoto, Japan); total nitrogen was determined using Duchafour (1970) method; pH (Peech, 1965), electrical conductivity in 1:5 (w/v) aqueous solution, texture (pipette Robinson) using FAO-ISRIC (1990).

Statistical analyses were determined using mean values and the standard error of means (n=9) was calculated taking into account three replicates per plot. Through the analysis of residuals distribution (normal probability plot) data normally distributed was studied. Variance-ANOVA (Fisher, 1935) and Tukey´s Test were used to determine significant differences in physico-chemical variables in studied zones.

Sampling of Vegetation

Plant covert percentages were determined in each plot according Huss et al. (1986) method, modified using a sampling grid (50 x 50 cm) and needles inserted with 90 º. This way 72 sampling points were located per plot and the mean value was determined for each census place. In addition, vegetation samples of the most representative species were collected on each plot (UNESCO, 1973); they were identified in the Herbario Nacional de Bolivia. Flora samples were taken from around the plots in order to prevent these plots from any disturbance (Yager et al., 2007). The vicuna and alpaca palatability degree of plants was also studied (Catari and Fernandez, 2003). Soil and vegetation samples were collected in the dry season (June-November).

RESULTS

Soil

According to surface and sub-surface samples data, Tables 3 and 4 show different physico-chemical variables mean values analysed in each studied zone. Normal probability plot analyses showed normal data distributions and ANOVA ($p<0.001$) exhibit significant differences in surface and sub-surface results in all physico-chemical variables in the studied zones.

Table 3. Physico-chemical variables. Mean and standard error (n=9) in surface samples (0-5 cm) in studied zones (different letter indicates significant differences).

Variable	Ulla-Ulla	Killu	Ucha-Ucha	Wakampata	Caballchiñuni	Sucondori	Puyo-Puyo	Japu
O.C. (g kg^{-1})	51.5 ± 6.4	58.9 ± 5.2	55.0 ± 3.1	91.7a ± 5.6	45.9 ± 2.3	37.3d ± 2,0	72.7 ± 3.8	61.1 ± 5.9
TN (g kg^{-1})	4.3 ± 0.4	5.0b ± 0.2	4.6 ± 0.3	7.2a ± 0.4	3.9 ± 0.1	3.3d ± 0.2	5.2b ± 0.3	5.2b ± 0.4
C/N	11.9 ± 0.6	11.7 ± 0.8	12.1 ± 0.5	12.7 ± 0.2	11.9 ± 0.4	11.7 ± 1.0	14.3 ± 0.9	11.5 ± 0.3
CEC ($cmol_+ kg^{-1}$)	13.9 ± 0.6	20.9 ± 0.4	16.3 ± 0.8	23.5a ± 1.5	12.3e ± 0.6	14.2 ± 1.1	18.3 ± 0.9	17.2 ± 1.4
pH H_2O	5.0c ± 0.1	5.9a ± 0.1	5.6a ± 0.2	4.9c ± 0.2	4.9c ± 0.1	5.4b ± 0.1	4.9 ± 0.0	4.2d ± 0.1
pH KCl	4.0c ± 0.1	4.9a ± 0.1	4.8a ± 0.1	4.0c ± 0.0	4.0c ± 0.0	4.4b ± 0.1	4.2 ± 0.0	3.7d ± 0.0
EC (µS cm^{-1})	22.1d ± 1.6	66.5 ± 4.1	227.0a ± 73.6	192.5 ± 78.0	28.4d ± 5.4	56.6 ± 14.2	184.2a ± 16.5	99.8 ± 16.2
Sand (%)	69a ± 2	40d ± 4	61 ± 3	45 ± 1	66a ± 1	63 ± 4	52 ± 2	50 ± 3
Silt (%)	20c ± 2	42a ± 3	23 ± 3	41a ± 1	23c ± 1	26c ± 3	34 ± 1	36a ± 2
Clay (%)	11 ± 0	18a ± 2	16 ± 1	14b ± 1	11d ± 1	11 ± 2	14 ± 1	14b ± 1

The highest organic carbon contents (O.C.) in surface samples was observed in the Wakampata area (91.7±5.6 g kg^{-1}) and the lowest in Sucondori (37.3±2.0 g kg^{-1}). Related to total nitrogen (TN), Table 3 show the highest value in Wakampata (7.2±0.4 g kg^{-1}) while Sucondori presented 3.3±0.2 g kg^{-1}, the lowest TN content in studied zones, and Killu, Puyo-Puyo and Japu exhibited similar contents. Carbon-nitrogen relation (C/N) presents maximum value in Puyo-Puyo (14.3±0.9). Wakampata showed highest Cation Exchange Capacity (CEC) value (23.5±1.5 cmol+ kg^{-1}) in front of Caballchiñuni (12.3±0.6 cmol+ kg^{-1}). Soil acidity conditions in surface samples are showed in Table 3: Killu and Ucha-Ucha exhibit uppermost pH H_2O and KCl values (5.9±0.1 and 4.9±0.1 in Killu, and 5.6±0.2 and 4.8±0.1, respectively, in Ucha-Ucha); least values were observed in Japu (4.2±0.1 and 3.7±0.0, respectively). Ulla-Ulla, Wakampata and Caballchiñuni areas present similar soil acidity conditions. Electrical conductivity (EC) results indicated low soil salinity in surface; highest value was detected in Ucha-Ucha (227.0±73.6 µS cm^{-1}). Texture data presented the maximum clay percentage in Killu (18±27%) and the least sand percentage (40±4%). Ulla-Ulla presented highest sand percentage (69±2%).

Table 4. Physico-chemical variables. Mean and standard error (n=9) in sub-surface samples (5-15 cm) in studied zones (different letter indicates significant differences).

Variable	Ulla-Ulla	Killu	Ucha-Ucha	Wakampata	Caballchiñuni	Sucondori	Puyo-Puyo	Japu
O.C. (g kg^{-1})	44.5 ± 4,0	47.8c ± 2.0	38.8 ± 2.2	56.2 ± 2.0	57.3a ± 2.7	30.0d ± 2.1	50.4 ± 2.5	43.9 ± 4.0
TN (g kg^{-1})	3.3c ± 0.2	4.7 ± 0.1	3.4c ± 0.1	5.3a ± 0.2	4.4 ± 0.2	2.3d ± 0.2	3.8 ± 0.2	3.9 ± 0.4
C/N	13.5a ± 0.9	10.0c ± 0.2	11.4 ± 0.7	10.6 ± 0.1	13.1a ± 0.7	12.3 ± 0.6	13.1a ± 0.3	11.3 ± 0.2
CEC ($cmol_+ kg^{-1}$)	12.0b ± 0.8	19.2a ± 1.0	10.6b ± 0.6	17.7a ± 0.6	12.4b ± 0.7	10.5b ± 1,0	11.8b ± 0.7	13.5b ± 1.5
pH H_2O	4.7d ± 0.1	6.0a ± 0.1	5.7 ± 0.1	5.5 ± 0.0	4.7d ± 0.1	5.5 ± 0.1	5.1c ± 0.1	4.3d ± 0.1
pH KCl	4.0 ± 0.0	4.7a ± 0.1	4.6a ± 0.1	4.1 ± 0.0	4.0 ± 0.1	4.5 ± 0.1	4.3 ± 0.0	3.8e ± 0.1
EC (µS cm^{-1})	32.3c ± 1.9	35.5c ± 3.6	78.1a ± 12.6	47.5 ± 2.8	38.8c ± 2.9	33.9c ± 3.5	63.5 ± 3.1	48.5 ± 5.8
Sand (%)	78 ± 2	40 ± 5	67 ± 3	45 ± 2	72 ± 2	69 ± 3	67 ± 3	58 ± 4
Silt (%)	14d ± 2	40a ± 3	18 ± 3	41a ± 2	18 ± 1	22 ± 2	23 ± 2	29 ± 3
Clay (%)	8e ± 1	20a ± 2	15 ± 0	14 ± 1	10 ± 1	9 ± 1	10 ± 1	13 ± 1

Table 4 shows sub-surface samples data. Maximum OC content was presented in Caballchuñuni (57.3±2.7 g kg^{-1}) conversely to Sucondori with 30.0±2.1 g kg^{-1}. Total nitrogen exhibited the same situation than OC in the Caballchiñuni and Sucondori area, showing the highest and lowest values (5.3±0.2 and 2.3±0.2 g kg^{-1}, respectively). Ulla-Ulla and Ucha-Ucha exhibited similar TN contents. Carbon-nitrogen relation was the maximum in Ulla-Ulla (13.5±0.9) and Caballchiñuni (13.1±0.7). In sub-surface samples CEC data were homogeneous in studied zones: Killu presented the highest CEC value (19.2±1.0 µS cm^{-1}) followed by Wakampata (17.7±0.6 µS cm^{-1}); however, Ulla-Ulla, Ucha-Ucha, Caballchiñuni, Sucondori, Puyo-Puyo y Japu exhibited similar values. In addition, pH H_2O and KCl results showed highest values in Killu (6.0±0.1 and 4.7±0.1, respectively) and the lowest in Japu (4.3±0.1 and 3.8±0.1, respectively). Ucha-Ucha presented maximum EC value (78.1±12.6 µS cm^{-1}) and Ulla-Ulla, Killu, Caballchiñuni and Sucondori areas exhibited low and similar values (Table 4). The highest sand percentage in sub-surface samples was detected in Ulla-Ulla (78±2%) corresponding to the least clay percentage (8±1%); conversely, Killu presented maximum clay percentage (20±2%) and the lowest sand content (40±5%).

Vegetation

Fig. 2 reports mean values of the plant cover in the studied zones (n=3). The highest percentage was observed in the Puyo-Puyo (78.7±1.8%) area, whereas Japu presented the second highest density (68.1±11.9)%. The lowest one was in the Caballchiñuni (41.2±2.3%) and it was related to the low number of species identified (6). About 10 species were identified in the Sucondori and 9 in the Ucha-Ucha zone (Fig. 4), corresponding with low plant cover percentages (50.5±6.0 and 49.6±8.2%, respectively). Most of the identified plant species showed that studied census places presented *Pycnophyllum* grassland. However, in Ulla-Ulla and Killu, census places with low vicuna density and high and medium alpaca density, respectively, there were some species such as *Senecio spinosus*, which were related to vegetation community changes due to environment alterations (García et al., 2002).

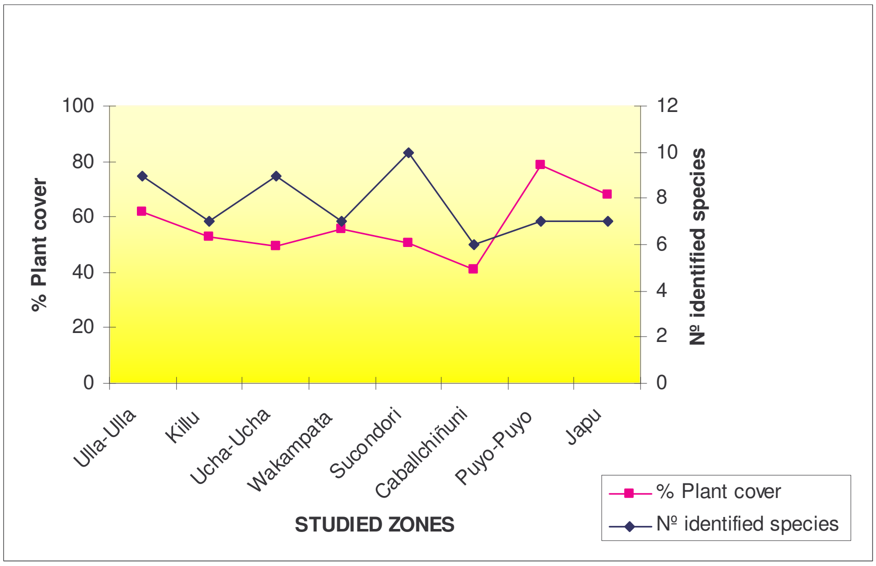

Figure 2. Mean values of plant cover percentage and identified species in studied zones

Species palatability to vicuna and alpaca was studied as well. It was identified one species (*Aciachne acicularis*) with low alpaca palatability, although it was not described for vicuna. Ulla-Ulla exhibited 4 vicuna and alpaca unpalatable species while 2 species were identified in Puyo-Puyo and Wakampata. Puyo-Puyo and Sucondori showed the highest number of identified vicuna palatable species, 5 in each studied zone, while the Sucondori presented highest number of identified alpaca palatable species (5), and 4 for Puyo-Puyo, Wakampata, Ucha-Ucha, and Ulla-Ulla.

DISCUSSION

Soil study reports wide range of OC contents in the studied zones. Wakampata area presented maximum OC values and having medium alpaca and vicuna densities while Sucondori exhibited least OC contents with high vicuna and medium alpaca density. Areas with high and very high vicuna density and medium alpaca density (Puyo-Puyo and Japu) showed high OC contents and similar TN values. Studies on the effect of grazing on semiarid grasslands have shown inconsistent results with soil OC variations; it could be due to the large fraction of highly stable humic substances in soil that are not very responsive to grazing (Galantini and Rosell, 2006; Ganjegunte et al., 2005; Chunli et al., 2008). Carbon-nitrogen relation is similar in most of the studied zones and indicates mineralization and humification equilibrium, apart from Puyo-Puyo, which reported intensive humification processes (Cobertera, 1993). Cation Exchange Capacity presents maximum values in Wakampata and Killu, above 20 $cmol_+ kg^{-1}$; some natural soils can exhibit humic horizons with CEC average of around 30-40 $mEq\ 100\ g^{-1}$ (Cobertera, 1993). These areas reports medium and low vicuna densities and medium alpaca densities, respectively. pH values indicated that soils are strongly acid in H_2O and extremely acid in KCl (Soils Survey Division Staff, 1993) and no saline (USDA, 2005). Texture analyses showed sandy-loam and loam soils (FAO-ISRIC, 1990) and it is no related to vicuna and alpaca densities in each zone.

The study of vegetation showed more plant cover percentage in very high vicuna density census areas, Puyo-Puyo and Japu, with medium alpaca density; Caballchiñuni, Sucondori and Ucha-Ucha areas presented the lowest plant cover: Caballchiñuni had high vicuna and medium alpaca densities, as well as Sucondori, whereas Ucha-Ucha presented medium vicuna density and very high alpaca density. Sucondori and Ucha-Ucha areas exhibited the highest number of identified plant species. Some plant species indicated that there was degradation in the *Pycnophyllum* grasslands (García et al., 2002). Palatability data pointed out that the vicuna and alpaca palatability, in the studied species, were very similar.

CONCLUSIONS

In conclusion camelid density in these areas is not correlated to physico-chemical studied soil properties. There is a balance between mineralization and humification processes and texture conditions. Results show that, nowadays, soil conservation degree is suitable to camelid grazing in studied areas. On the other hand, the vegetation studies have shown a loss in the plant cover and grassland degradation in some zones, which they could be due to an excessive grazing. Areas with high-quality plant cover are matched with those with high soil organic carbon and cation exchange capacity and loam texture. However, other zones exhibited low plant cover and little soil organic carbon; consequently it is necessary to carry out soil and plant protection actions in order to preserve soil quality and biodiversity in Apolobamba.

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Studying of Structure-functional Features of Halophytic Vegetation in depend on Degree of Soil Salinity (The South Part of Central Siberia, Khakasia)

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ABSTRACT

Field investigations of yields of halophytic meadow plant communities were performed in the coastal area of Lake Kurinka in the central part of the Republic of Khakasia in 2003 – 2008 years. Salinity plant communities play important role for agricultural practice of Khakasia. Five plant communities *Festuca – Elytrigia* (PC.1.), *Artimisia – Puccinellia* (PC.2.), *Suaeda* (PC.3.), *Carex* – herbs (PC.4.), herbs – *Phragmites* (PC.5.) were investigated (2004-2008) on the north-west coast in depend on degree of salinity soil. Each plant community locates on soils of different types with different degree of salinity, resulting in changing in structure. Results of investigation can be used for distributing dynamic halophytic meadow vegetation to quality estimate its dependence on environmental factors with construction mathematical model.

Keywords: halophytes; plant communities; temperature; salinity level of the soil.

INTRODUCTION

The important factor influencing change of soil salt concentration and change of vegetation structure are weather conditions of a vegetative season. In the coast zone of salt-lake (besides air temperature and precipitation sum) a special role play change of altitude above the sea and concentration of readily soluble salts in the soil. This parameter determines species plant distribution on plant communities and influence, consequently, on their productivity.

There is very little published information on the relationships between agricultural crop yields and such soil factors as the depth of the salinity maximum and the amounts and composition of the soil salts.

Halophytic plants are capable to exist on soil with high salt concentration. Different researchers (Lee et al., 2005) observed beneficial effects of moderate salinization on life processes of halophytic plants. Particularly, increasing of ferments strength, responsible for a salt exchange, maximal growth, etc was observed. However, high concentrations of soluble salts in the soils had negatively impact on plants. Soil salinity is a major abiotic stress in plant agriculture worldwide (Zhu et al., 2001). In addition, toxic salts action depends on chemical compound of salts and depends on salt tolerance of plant. It was established, that toxic sequence of widespread in nature soluble salts are $MgSO_4$ --- Na_2SO_4 --- $MgCl_2$ --- $CaCl_2$ --- NaCl --- Na_2CO_3 --- $NaHCO_3$. Thus, toxicity increases from sulfates to chlorides and further to carbonates (Martin et al., 2006.).

MATERIALS and METHODS

The study was performed on plants of halophytic meadows in the coastal area of Lake Kurinka in central part of the Republic of Khakasia (53°26'01"N, 91°34'85"W). The common mineralization is changing from 72 to 108 g l-1 (Krivosheev, 1991). Field investigations were conducted during 2003–2008. Harvest was gathered during the time period of May to September, on the same days of every month. Three plant communities were studied: meadow fescue-couch grass (Festuca pratensis Huds., Elytrigia repens (L.) Nevski) – PC. 1, sagebrush-puccinellia (Artemisia nitrosa Web., Puccinellia tenuissima Litv. ex V. Krecz.) – PC. 2, and seablite (Suaeda linifolia Pall.) – PC. 3. Carex – herbs - PC. 4., Every plant community grew on the soil of a different level of salinity – the amount of the solid residue of the saline soil aqueous extract (Table 1). The type of salinity is sulfate-sodic. Theoretical results are compared with the field data of the first three months of active growth of plant communities (May, June, and July). The field data were processed statistically (Dospekhov, 1973).

Determination of Plant Productivity

Plant productivity was determined in the growth period in 2004 - 2007 year. Three permanent study plots (10×10 m 2) were located on soil with different degree of salinity. The occurrence of each vascular species, its coverage, density and mean height was recorded in each plot. Plant productivity calculations were based on alive aboveground biomass from samples that were harvest from a 1 × 1 m area in four replications in the center of each plot. Raw material was separated into five botanical-functional groups: gramineous plants, sedges, beans, sagebrush, herbs. All reproductive shoots were weighed, dried from air-dry state (at 80°C) and weighed again (Voronov, 1973).

Determination of the Solid Residue of the Saline Soil Aqueous Extract

It was measured 30 g of soil samples and scooped of soil into a 300-ml conic flasks. Then, in conical vessel was added 150 ml of distilled water. The soil samples and water was stirred in during 3 min and was leave the solution to settle for at least 5 min. After that an extract filter, using double folded filters, and place in porcelain cup. Previously, porcelain cup was dried up and weighed with a margin error no more 0,001g. After that porcelain cup was put up on a water-bath for evaporation of a filtrate. Then a cup was weighed again (with a margin error no more than 0,001g). The mass fraction of solid residue of the saline soil aqueous extract (total dissolved solid (TDS) was calculated under the formula:

$$TDS = (A - B)*1000 / V$$

where:

A = weight of dried residue + dish, mg, and

B = weight of dish, mg.

V= sample volume, ml (Schukin, 1985).

RESULTS and DISCUSSION

The purpose of this work is to study of structure-functional features of halophytic vegetation in depend on degree of soil salinity (the south part of Central Siberia, Khakasia). Five plant communities Festuca – Elytrigia (PC. 1.), Artimisia – Puccinellia (PC.2.), Suaeda (PC. 3.), Carex – herbs (PC. 4.), herbs – Phragmites (PC. 5.) were investigated (2003 - 2008) on the north-west coast in depend on degree of salinity soil (table 1).

Table 1.Structure of plant communities and soil salinity level

Plant community	Plant community structure	Soil salinity, %
PC.1	Elytrigia repens Elymus junceus	0.1
PC.2	Puccinellia tenuissima Artemisia nitrosa	1.84
PC.3	Puccinellia tenuissima Suaeda linifolia	3.58
PC.4.	Carex enervis Halerpestes salsuginosa	1,29
PC.5.	Phragmites australis Juncus gerardii Triglochin maritimum	0,6

These plant communities include 36 species, which belong to 15 families. Most of them from family Chenopodiaceae (19.4 % from all species). Each plant community locates on soils of different types with different degree of salinity, resulting in changing in structure (table 2).

Table 2. The characteristics of soil nearest coastal zone Lake Kurinka

№	Plant community	Soil type	pH
1	PC.1	medium loam meadow soil	7,7-8,9
2	PC.2	meadow sandy loam saline soil	8,5-8,4
3	PC.3	medium meadow loam saline soil	9,2-8,3
4	PC.4.	heavy loam meadow-swamp saline soil	8,2-8,7
5	PC.5.	heavy loam meadow-swamp saline soil	7,8-8,2

PC. 1. growth on medium loam meadow soil with low salinity level of 0.25%, pH varies from 7.7 to 8.9 along profile soil. Vertical stratification of this plant community have three layers. The first layer has height 85 – 90 cm and occupies by dominant species Elytrigia repens and subdominant

Festuca pratensis. The second layer is presented by Artemisia nitrosa and rarely Potentilla inclinata, Limonium gmelinii. The third layer is occupied by Suaeda linifolia (the coverage lower then 2%).

Artimisia – Puccinelia plant community locates also on meadow sandy loam saline soil with degree salinity changing from 0.6 to 1.8%. The increase of sulfate-ions up to 0.24% and appearance chloride (the pH values changing from 8.3 to 8.5 along profile soil). Plant community structure also varies. PC. 2. has three layers such as PC. 1., but first layer is presented by dominant Puccinellia tenuissima. Subdominant Artemisia nitrosa occupies the second layer. It is registered logical increasing size of Suaeda and Salicornia – spot.

PC.3. has boundary status. It has specific second-layers structure due to enhance degree salinity up to 3.58%. Soil type is medium meadow loam. The value of pH has maximum in near-surface zone (0 – 5 cm) and composes 9.2%. The first layer has height 25 cm and is presented by dominant species Suaeda linifolia and subdominant Suaeda corniculata. Salicornia europapaeae does not grows here, as it associate with chloride land.

Carex – herbs (PC. 4.) and herbs – Phragmites (PC. 5.) plant communities locate nearest to coast and have great species diversity including mesohalophyte, halomesophyte and also swamp species. It has significant degree of similarity (up to 95% in 2005 year). However, PC. 4. has second-layers vertical stratification and associate with heavy loam meadow-swamp saline soil with degree of salinity 1.29%, pH values increases with depth from 8.2 to 8.7. The first layer of plant community is significantly saturated and includes subdominant Carex enervis and also prevailing herbs: Triglochin maritimum, Tripolium vulgare, Iris biglumis. The second layer is presented by salt marsh species Halerpestes salsuginosa, Glaux maritime and others. The structure of PC. 5. has third-layers due to appearance of dominant Phragmites australis.

In addition, our research display, that plant community productivity change correlate with increasing of degree salinity soil (Fig.1. and Fig.2.).

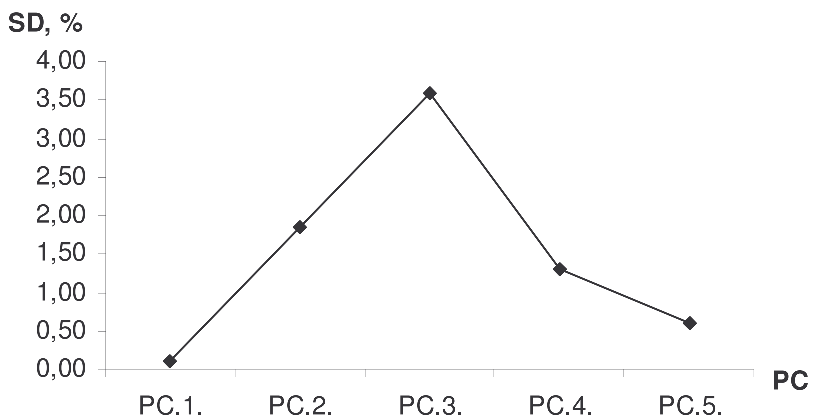

Fig.1. The sum salt concentration of plant community (SD – salinity degree, %)

In accordance with the diagram are changes productivity of the presented communities. All communities locates at one height concerning a coastal line, therefore change of a soil salinity degree is a primary factor which defines plant productivity halophytic meadows. As a whole, plant communities productivity is high enough, as climatic features of Khakassia allow to pass all physiological cycle.

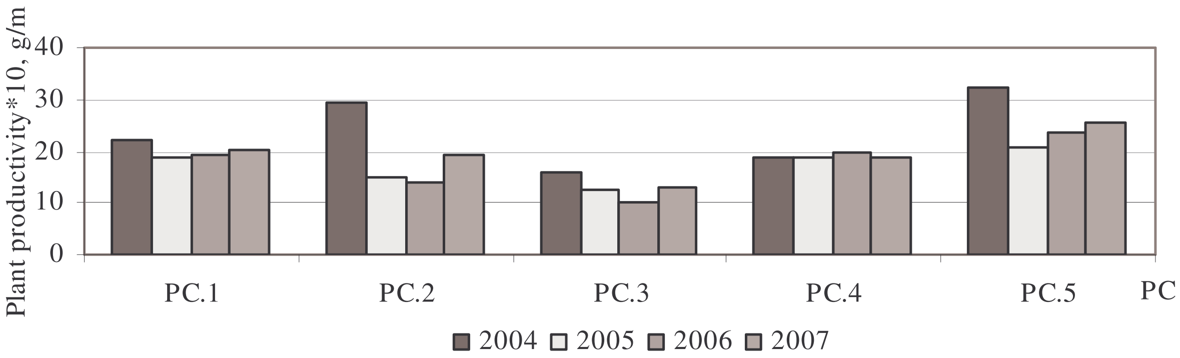

Fig.2. Plant productivity (dry mass) of halophytic meadows for 2004-2007 years

The similar analysis allows to estimate features of functioning of plant communities (in our case – halophytic vegetation) in depend on climatic conditions of a vegetative season and change of a degree soil salinity. The quantitative estimation of stability plant community will help to reveal mechanisms due to which stability plant community to constantly varying conditions of environment is formed.

Results of research can be used for the description of dynamics of productivity of vegetation halophytic meadows with the purpose of a quantitative estimation of its dependence on environmental factors of with construction of mathematical model.

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Natural Occurrence and Distribution of Soil borne Entomopathogenic Fungi in Shahrood Region, Northeast of Iran

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ABSTRACT

The study investigated the occurrence of soil borne entomopathogenic fungi (EPF) in potato, wheat, sugar beet, alfalfa fields and orchards. A total of 150 soil samples were collected and EPF were isolated using Galleria method. Soil pH was rages from 6.8 to 8.1 and soil texture was sandy, loam, sandy- loam, clay and sandy-loam-clay. Soil borne EPF occurred at 78% of soil samples from which 40% *Beauveria bassiana*, 21% *Metarhizium anisopliae* and 17% had both species. Occurrence and distribution of EPF was not significantly affected by pH and texture of soil samples. Although Shahrood region is located at dry climate but this study showed that its soil is rich of EPF. Fungal pathogens collected from this soil survey will serve as a source of potential biological control agents of soil borne pests.

Keywords: Entomopathogenic fungi, soil borne, *Beauveria bassiana, Metarhizium anisopliae*

INTRODUCTION

Microbial life within the soil ecosystem is a fascinating aspect of soil biology, and has recently caught the attention of microbiologists. High populations of beneficial soil borne organisms are characteristics of healthy soils (Magdoff, 2001). Microbial assemblages in agricultural soils are important for ecosystem services in sustainable agricultural systems, including pest control (Altieri, 1999). Soil-borne pests are serious enemies of some plants and chemical control of these pests can damage to soil ecosystem and reduce its fertility. Isolating entomopathogens from soil provides insight into the naturally occurring pathogen biodiversity and provides a pool of potential biological control agents (Bruck, 2004). The soil environment constitutes an important reservoir for a diversity of entomopathogenic fungi, which can contribute significantly to the regulation of insect populations (Keller and Zimmerman, 1989). Many fungal species belonging to Hypocreales (Ascomycota) inhabit the soil for a significant part of their life cycle. Of these, *Beauveria spp*., *Metarhizium anisopliae* (Metschnikoff) Sorokin and *Paecilomyces spp*. are especially common (Keller and Zimmerman, 1989). There is evidence for higher population levels of entomopathogenic fungi in soils of organically farmed fields as opposed to conventionally farmed fields (Klingen *et al*., 2002). Our knowledge about local species composition and distribution is important if the indigenous populations of entomopathogenic fungi in the soil are to be managed in ways to facilitate the control of pest insect populations within the agroecosystem.

MATERIALS and METHODS

Soil Sampling

Soil samples were collected with a garden spade to a depth of about 15 cm after removal of surface litter at potato, wheat, sugar beet, alfalfa fields and orchards of Shahrood region, north east of Iran during 2006-2007. A total of 150 (30 from each field) soil samples were collected. Soil texture and PH of samples were determined by soil laboratory.

Insect Culture

Galleria mellonella larvae used in this study were obtained from infested beehives in Shahrood and were used to initiate a continuous culture on natural wax.

Baiting Procedure

Each soil sample was thoroughly mixed and approximately 40 ml soil, moistened with distilled water (if the soil was too dry), was placed in glass Petri dishes (diameter 9 cm). Larvae of third or fourth instars (approximately four weeks after hatching) were used for baiting the soil samples. Prior to baiting, the larvae were immersed in 56 oC water for 15 sec. to minimize their ability to produce silk webbing in the soil (Woodring and Kaya, 1988). No food was provided for the larvae during the bait experiment. Each soil sample was baited with 10 larvae and incubated in the dark in closed cardboard boxes at ambient room temperature (20– 25 oC). During the first two weeks of baiting the Petri dishes were frequently shaken, inverted and left upside down. Once a week the soil was inspected for dead larvae. All dead larvae or pupae were washed three times in distilled water and transferred individually to Petri dishes provided with moist filter paper and incubated at room temperature. Incubated cadavers were inspected for presence of external fungal growth. The fungi were identified morphologically both by low magnifying stereomicroscope of cadavers and by preparing slides for light microscopy. Analyses were made of frequencies of occurrence the fungal isolates between the surveyed fields by standard chi-square tests.

RESULTS and DISCUSSION

A total of 143 fungal isolates were obtained from the 150 soil samples baited. EPF were found in 78% (117 out of 150) of soil sampled (Table-1). The fungal species isolated were M. anisopliae and B. bassiana. Out of 143 EPF isolated, 86 isolates were B. bassiana and 58 isolates were M. anisopliae (Table 2). Although the number of B. bassiana in the soil samples was higher than M. anisopliae (except of potato fields) but there was no significant differences between their frequencies in the different fields (figure1and table 2). These results are in agreement with findings of other studies. Klingen et al (2002) in their study found three EPF from soil samples including Tolypocladium cylindrosporum, M. anisopliae and B. bassiana. They mentioned that 35% of soil samples had EPF. Sosa-Gomez et al. (2001) found M. anisopliae, B. bassiana and Paecilomyces lilacinus in soybean fields. Three EPF including B. bassiana, M. anisopliae and P. tenuipes were found in Pacific Northwest nursery soils by Bruck (2004). Some of important agricultural pests spend at least one stage of their life cycle in the soil and some of them feed on underground parts of plants. Chemical control of soil-born pests is difficult and has side effects on soil ecosystem. An alternative control method is to use soil-born entomopathogenic fungi. Although entomopathogenic fungi need high relative humidity to cause infection and their use in dry climates is limited but soil environment can provide enough moisture for them. The results of this study revealed that entomopathogenic fungi are occur naturally in agricultural soils of Shahrood region which has dry climate therefore can provide good resources for biological control of soil-born pests.

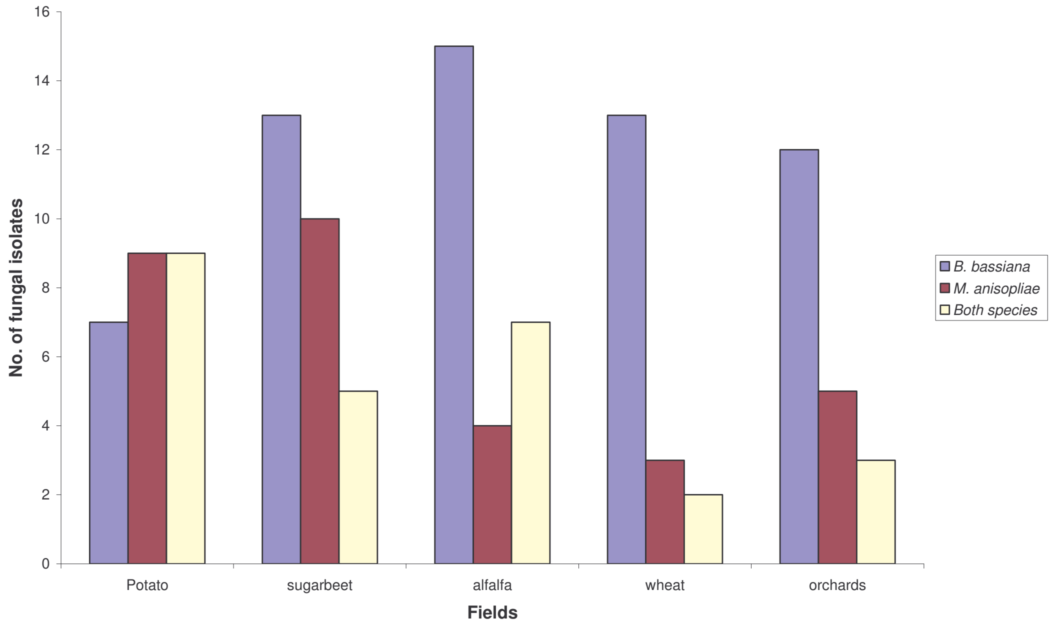

Figure 1: Occurrence of *B. bassiana* and *M. anisopliae* in soil sampled from different fields

Table 1: Soil properties, samples having fungi and number of fungal isolates collected from different fields

Fields	Soil texture	Soil pH	No. of soil samples having fungi	No. of fungi isolated
Potato	sandy, loam, sandy-loam-clay	6.8-8.1	25	34
Sugar beet	sandy-loam-clay	7.38-7.85	27	33
alfalfa	sandy-loam-clay	7.64-7.9	26	33
Wheat	sandy, loam, sandy-loam	6.8-7.8	18	20
Orchards	sandy- loam	7.55-7.93	21	23
Chi-square			2.44 $^{n.s}$	4.93 $^{n.s}$

n.s: Not significant

Table 2: Frequencies of occurrence of entomopathogenic fungi in soil samples from different fields

Fields	Samples having only *B. bassiana*	Samples having only *M. anisopliae*	Samples having both species	No. of *M.anisopliae* isolates	No. of *B.bassiana* isolates
Potato	7	9	9	18	16
Sugar beet	13	10	5	15	18
alfalfa	15	4	7	11	22
Wheat	13	3	2	5	15
Orchards	12	5	3	8	15
Chi-square	2.99 $^{n.s}$	6.25 $^{n.s}$	6.30 $^{n.s}$	9.15 $^{n.s}$	1.52 $^{n.s}$

n.s: Not significant

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Comparative Analysis of *Pseudomonas* Population in Oil-Contaminated Soils in Serbia and Plant-Pathogenic *Pseudomonas*

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ABSTRACT

Pseudomonas species are remarkable for their capacity to colonize almost all terrestrial and aquatic ecological niches. This genus includes species of ecological, economic and health-related importance. Although they are globally active in aerobic decomposition and biodegradation, *Pseudomonas* includes species pathogenic for humans, domestic animals and cultivated plants. The aim of this study was to identify members of the *Pseudomonas* species from oil-polluted soil, investigate their diversity and compare it to phytopatogenic strains isolated from host-plants near marked site.

Isolates were described phenotypically according to carbon assimilation, fluorescence on King B medium and susceptibility patterns to 5 different heavy metals. In addition, they were characterized genotypically using plasmid profile and fingerprints obtained with the $(GTG)_5$ primer.

We have observed high heterogeneity within the *Pseudomonas* strains collected from oil- contaminated soils. Phenotyping and $(GTG)_5$ pattern showed that similarities between strains ranged from 55% to 94%, with some strains showing high level of similarity with plant-pathogens.

Key words: *Pseudomonas*, polluted soil, heavy metals, BOX-PCR

INTRODUCTION

Pseudomonas sp. encompasses a group of saprophytes that colonize soil, water and plant surface environments. It is an obligate aerobe, except for some strains that can utilize NO_3 as an electron acceptor in place of O_2. Some of *Pseudomonas sp.* strains produce fluorescent pigments, particularly under conditions of low iron availability. *P. fluorescens* produces a soluble, greenish fluorescent pigment, while *P. aeruginosa* strains produce two types of soluble pigments: fluorescent pyoverdin and blue pyocyanin (Cody and Gross, 1987). Fluorescence on King B medium under ultraviolet light is helpful in early identification of *P. aeruginosa* colonies.

Pseudomonas has simple nutritional requirements and grows well in mineral salts media supplemented with any of a large number of carbon sources. *Pseudomonads* are noted for their metabolic diversity and are often isolated from enrichments designed to identify bacteria that partially or completely degrade pollutants such as styrene, TNT and polycyclic aromatic hydrocarbons (Timmis, 2002).

Pseudomonas is tolerant to a wide variety of environmental conditions, including temperature. It is resistant to high concentrations of salts, dyes, weak antiseptics, many commonly used antibiotics, and tolerant to heavy metal ions and metalloids (Silver, 1996). Although an excess of metals is generally toxic, some of them are essential in trace amounts (Cu, Mn, Zn, etc.). Microorganisms use a number of mechanisms to maintain the correct equilibrium, including the uptake, chelation and extrusion of metals (Robinson *et al*., 2001, Cánovas et al., 2003). Various microbial species, including *Pseudomonas,* have been shown to be tolerant and relatively efficient in bioaccumulation of uranium, copper, lead, and other metal ions from polluted effluents, both as free-swimming or immobilized cells (Lovely et al., 1991).

The aim of this study was to isolate, identify and characterize *Pseudomonas* strains indigenous to oil-polluted soils in different locations in Serbia, and compare them to plant-pathogenic *Pseudomonas* strains isolated from the same locations.

METHODS

Indigenous *Pseudomonas sp.* were isolated from two different locations of polluted soils and labeled DZI and DmZI according to the location. Isolates from surfaces of different plants were labeled DBP. Isolates were tested for fluorescence on King B medium (Moragrega et al., 2003). Pathogenicity of isolates was tested following the protocol of Moragrega et al. (2003). Substrate utilization of crude oil and mineral oil was tested as described by Toledo et al., (2006). For susceptibility patterns to heavy metals, isolates were grown on NA with addition of 200µg/ml of Zn and Co, 50µg/ml of Mo, 20 µg/ml of Hg or 25µg/ml of Cd. Plasmid profiles were obtained by method of Wheatcroft and Williams (1981). rep-PCR analysis using BOX type $(GTG)_5$ primer was performed as recommended by de Bruijn (1992). Similarity was estimated by means of the simple matching coefficient (*S*SM) and clustering was based on the unweighted pair group arithmetic average-linkage algorithm using STATISTICA 5 software .

RESULTS andSCUSION

We have examined *Pseudomonas* species indigenously growing on two locations with soil polluted with petrol and mineral oil. We have been able to isolate 27 different bacterial isolates from polluted soil, 6 of which were identified as *Pseudomonas* sp (DZI2, DZI3, DZI5, DmZI1, DmZI4, DmZI6). Three plant-pathogenic *Pseudomonas* strains were isolated from plant leaves near one of the locations (DBP1, DBP2, DBP3). Pathogenicity of the isolates was confirmed as described in Methods.

Phenotypic analysis of the strains was performed as described in Methods, and the results are summarized in Table 1. All strains except DmZI1 and DZI2 were fluorescent on King B medium.

Isolates	Fluorescence on King B medium	Plasmid number	Heavy metals (µg/ml)					Substrate utilization (0,5%)	
			Hg 20	Mo 50	Zn 200	Co 200	Cd 25	Crude Oil	Mineral Oil
DmZI1	-	1	±	+	+	+	+	+	+
DZI2	-	1	-	±	+	-	±	±	+
DZI3	+	nd	+	+	+	+	+	+	+
DmZI4	+++	2	+	+	+	+	+	+	+
DZI5	++	2	+	+	+	+	+	+	+
DmZI6	+++	1	+	+	+	+	+	+	+
DBP1	+	1	+	+	+	+	+	+	+
DBP2	++	1	±	+	+	+	+	+	+
DBP3	+	nd	±	-	-	±	-	-	+

Table1. Phenotypic analysis and plasmid profiles of investigated *Pseudomonas* isolates. Fluorescence on King B medium, plasmid number, heavy metal tolerance and substrate utilization of *Pseudomonas sp*. isolates. n.d.-not detected

Strain DBP3 showed high sensitivity to investigated heavy metals, strain DZI2 was moderately sensitive, and the rest of the strains were highly tolerant to investigated concentrations of Mo, Zn, Co and Cd. High tolerance to heavy metals was previously reported for *Pseudomonas* strains. Nakahara et al. (1977) tested 787 clinical *Pseudomonas* isolates on four metals (Hg, Cd, As, and Pb), and showed that 99.8% were tolerant to metals, with most (99.5%) showing multiple tolerance.

Strains DmZI1, DmZI4, DmZI6, DZI3, DZI5, DBP1and DBP2 were tolerant to 200µg/ml of Zn and Co, which is higher than the concentration reported in a similar study (100 mg/l of Cu, Pb, Cd, Zn, Malekzadeh et al. 1996). In addition, investigated strains showed resistance to 50µg/ml of Mo, 20 µg/ml of Hg and 25µg/ml of Cd. Multiple resistance to investigated heavy metals is probably regulated by metal-dependent members of COG0789 (Permina et al., 2006), that include mercury detoxification (MerR), resistance to zinc (ZntR), copper (CueR and HmrR), cadmium (CadR) and a number of other toxic metals (Rouch et al., 1997, Brown et al., 2003, Hobman et al., 2005)

Seven of the nine examined strains were able to grow on both mineral oil and crude oil as only source of carbon, while strain DZI2 grew well on mineral, but only poorly on crude oil. Phytopathogenic strain DBP3 grew well on mineral oil, but showed no growth on crude oil. *Pseudomonas* growth in the presence of different PAHs was previously reported by Hubert et al., (1999), Baldwin et al (2000), Barathi et al., (2001) and Toledo et al. (2006).

Genotypic analysis was performed by plasmid profile and rep-PCR. Plasmid profile analysis placed examined strains in 3 groups: strains DZI3 and DBP3 had no plasmids, DmZI4 and DZI5 had two plasmids, and the other five strains had one plasmid in their plasmid profile (Table 1).

Rep-PCR (BOX) pattern obtained with $(GTG)_5$ primer (Figure 1) revealed highest level of similarity between DZI3 and DBP1 (94%) (Figure 2). Similarity of these two strains with DBP3 was 83.5%, same as the similarity between DmZI4 and DZI5. The rest of investigated strains showed less than 67% of similarity in BOX patterns.

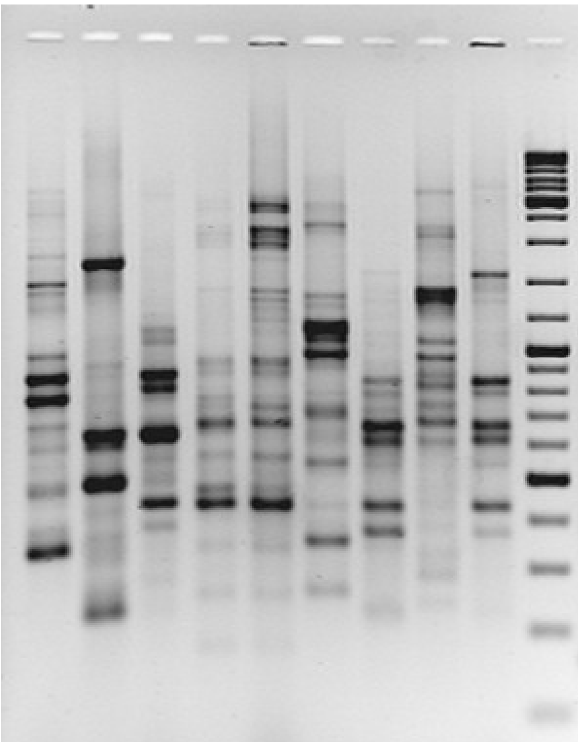

Figure 1. Rep-PCR (BOX) profiles of investigated *Pseudomonas* isolates. Lane 1-9: isolates DmZI1, DZI2, DZI3, DmZI4, DZI5, DmZI6, DBP1, DBP2, DBP3 respectively. Lane 10: GeneRuler DNA Ladder mix SM0331 (Fermentas)

This study represents preliminary data on diversity of indigenous *Pseudomonas* strains in oil-polluted soils in different locations in Serbia. Investigation of microorganisms that indigenously live in polluted soils is of potential ecological and economic importance. Microorganisms that have high affinity for metals can be effective in sequestering heavy metals, and have been used to remove metals from polluted industrial and domestic effluent on a large scale (Silver, 1996). Further investigations will demonstrate the capabilities of *Pseudomonas* strains identified in this study in removing Zn, Co, Mo, Hg, Cd, and possibly other toxic metals from polluted sites.

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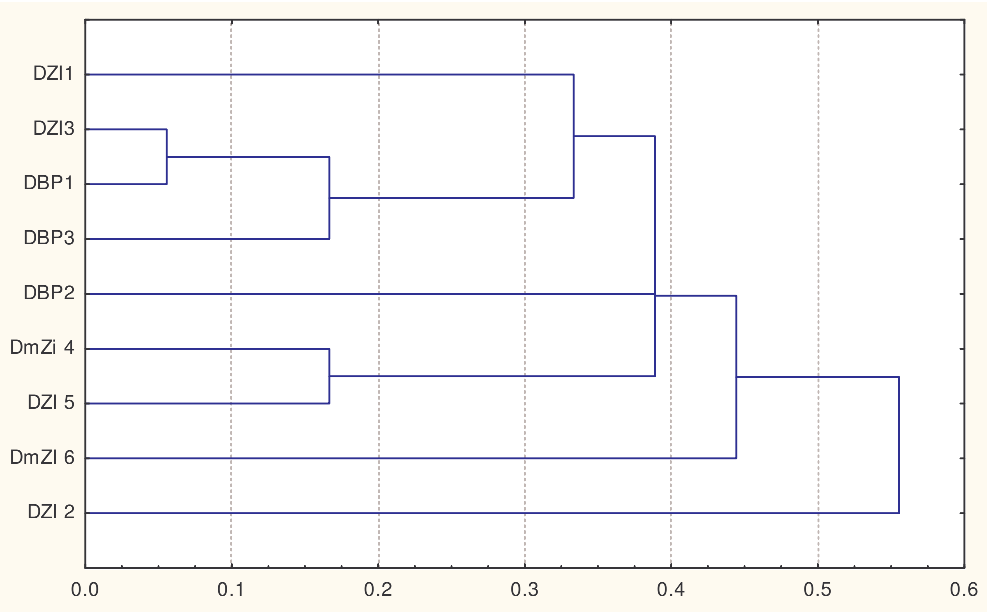

Figure 2. Tree Diagram for *Pseudomonas sp.* isolates rep-PCR: BOX analysis with $(GTG)_5$ primer. X-axis: percent disagreement.

The Study of Azotobacter-chroococum Inoculation on Yield and Post Harvest Quality of Wheat (*Triticum aestivum*)

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ABSTRACT
In order to evaluation of the effect of Azotobacter-chroococum on two varieties of wheat grown under field conditions, an experiment was carried out in Agricultural Research Station of Shahrood University of Technology during 2004-2006. results showed that wheat yield was affected when cultivars inoculated. Inoculation resulted in improving post harvest seed germination and nitrogen content of the seed.
Keywords: Inoculation, wheat, yield, germination

INTRODUCTION

Positive interactions between free-living nitrogenfixing rhizosphere bacteria belonging to the genera Azotobacter and Azopirillum and a variety of field grown crops have been frequently re+corded(Okon, 1985; Pandey and Kumar, 1989). The beneficial effects on plant growth are not only through nitrogen fixed in the rhizosphere, but are also related to the ability of these bacteria to synthesize antibiotics and growth- promoting substances including phytohormones, siderophores and the ability to solubilize phosphates (Brown and Walker, 1970; Harper and Lynch, 1979; Okon and Kapulnik, 1986; Fallik et al., 1989; Pandey and Kumar, 1990. Application of beneficial microbes in agricultural practices started 60 years ago and there is now increasing evidence that these beneficial microbial populations can also enhance plant resistance to adverse environmental stresses, e.g. water and nutrient deficiency and heavy metal contamination (Shen 1997). A group of bacteria are now referred to plant growth-promoting rhizobacteria (PGPR), which participate in many key ecosystem processes such as those involved in the biological control of plant pathogens, nutient cycling and seedling establishment, and therefore deserve particular attention for agricultural or forestry purposes (Weller and Thomashow, 1993; Glick, 1995; Elo et al., 2000). PGPR may colonize the rhizosphere, the surface of the root, or even superficial intercellular spaces of plants (McCully, 2001). It has been revealed that the effect of nitrogen fixation induced by nitrogen fixers is not only signification for legumes, but also non-legumes (Doeberiner and Pedrosa, 1987). Phosphate (P) - and potassium (K) - solubilizing bacteria may enhance mineral uptake by plants through solubilizing insoluble P and releasing K from silicate in soil (Goldstein and Liu, 1987). Some successful examples of inoculation with PGPR have been achieved both in laboratory and field trials. It has been reported that wheat yield increased up to 30% with Azotobacter inoculation and up to 43% with Bacillus inoculation (Kloepper et al., 1991). Soil microorganisms are important components in the natural soil subecosystem because not only can they contribute to nutrient availability in the soil, but also bind soil particales into stsble aggregates, which improve soil structure and reduce erosion potential (Shetty et al., 1994).

Azotobacter sp. Is free-leaving aerobic bacteria dominantly found in soils. A large number of experiments have been performed to investigate the effects of inoculation of cereals with Azotobacter sp. Results of these studies showed that in many cases grain, yield and N concentration in plants increased by inoculation with Azotobacter sp. (De Freitas, 2000; Kumar et al., 2001 a, b; Emtiazi et al., 2004) A. chroococcum is the most prevalent species found but other species described including A. agilis, A. vinelandii, A. beijerinckii, A. insignis, A. macrocytogenes and A. paspali (FAO,1982). Cereal plants inoculated with A. chroococcum increased number of root hairs, tillering ratio, dry matter concentration, N uptake or yields of wheat (Haahtela et al., 1988; Ishac et al., 1986; Rai and Gaur, 1988). Several studies have shown that A. chroococcum as soil inoculant is not only effective in N fixation but also has other properties such as production of growth hormones (Remus et al., 2000), production of fungicidal substances (Lakshminarayana, 1993), siderophore production (Suneja et al., 1994) and the property to solubilize phosphate (Kumar and Narula, 1999; Narula et al., 2000).

MATERIALS and METHODS

Pure culture of A. chroococcum used for inoculation. Wheat seed were placed in bacteria suspension for 30 min before sowing and then transferred to soil. The soil was clay loam. Experiment was carried out as Factorial based on Randomized complete Block Design with four replications. Firs factor included 2 cultivars of wheat (Pishtaz and) and second factor included inoculated and un inoculated of wheat cultivars. Seeds were hand sown on 2* 8 mt plots so as to give 450 seeds/ m^2 . Plants in plots were harvested 220 days after sowing. At the end of the experiments plants were collected from plots. Studied plant parameters were grain yield, straw yield N concentration in grain and straw. Statistical analysis.

RESULTS

Analysis of variance (mean of square) results showed in table (1). As showed in table (1), Grain yield Biological yield, Harvest index, plant height, Number of spike per m, Number of seed per spike traits was different between cultivars and Inoculation and non inoculation factor significantly affected cultivars traits.

Table 1.Analysis of Variance

S.O.V	Grain yield	Number of spike/m^2	Biological yield	Plant height	Harvest ndex
Cultivars (A)	ns	**	ns	ns	ns
Inoculation (B)	**	ns	*	**	**
(A*B)	**	*	*	*	*

*, ** Significant at 5 and 1%
ns : Non significant

Interaction between cultivars and Inoculation was significant for grain yield (Fig 1) and grain yield increased when cultivars inoculated.

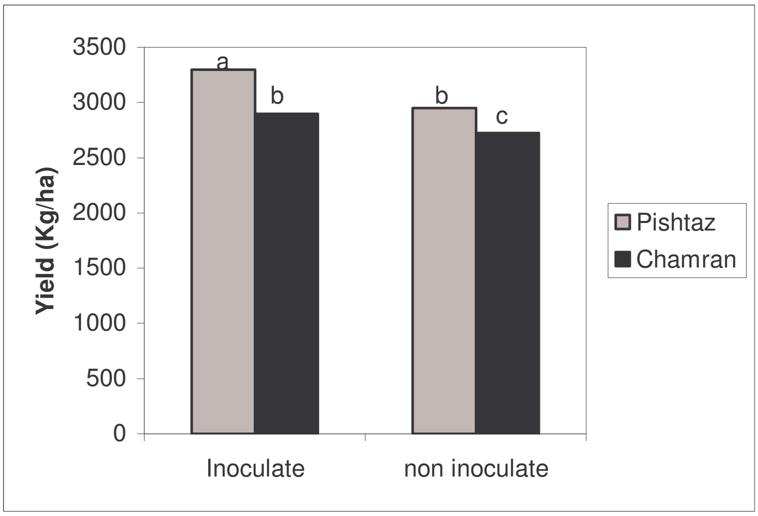

Figure 1. Interaction between cultivars and inoculation on grain yield

Number of spike per m^2 significantly affected by inoculation factor and this trait increased when cultivars Inoculated (Fig 2). Biological yield between cultivars was different and was affected by inoculate factor (Fig 3).

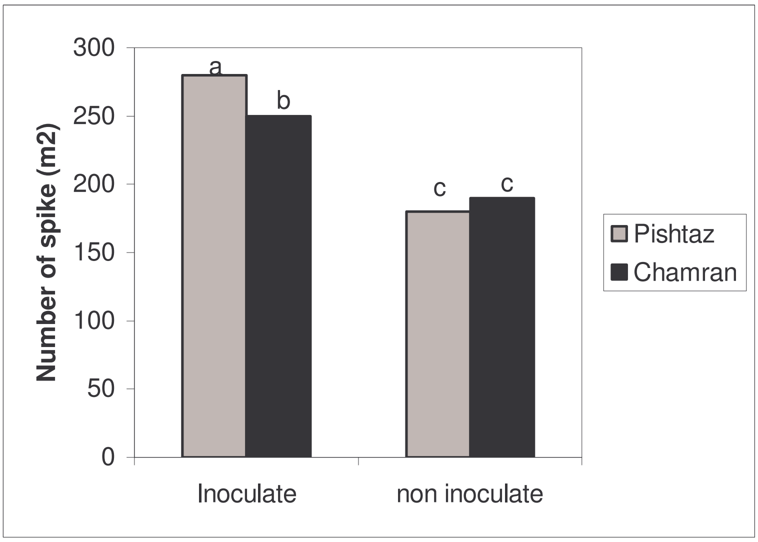

Figure 2: Interaction between cultivars and inoculation on Number of spike per m^2

Biological yield between cultivars was different and was affected by inoculate factor (Fig 3).

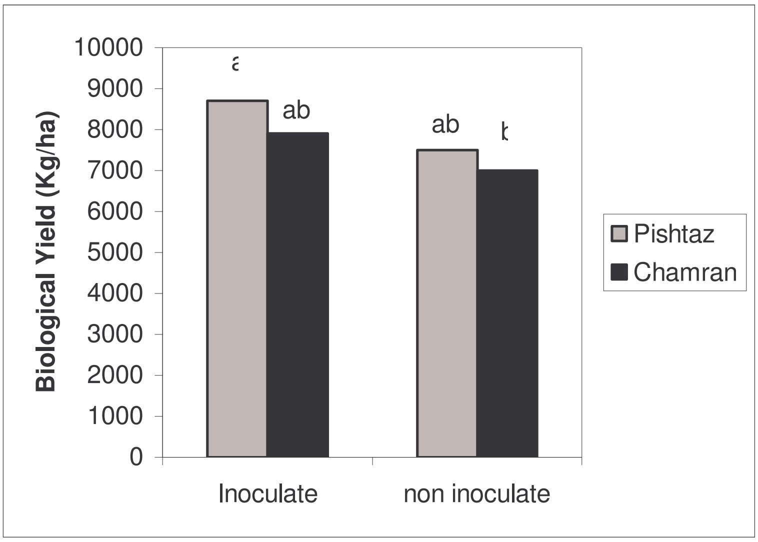

Figure 3: Interaction between cultivars and inoculation on biological yield

Interaction between cultivars and inoculation factors was significant and plant height increased when cultivars Inoculated (fig 4).

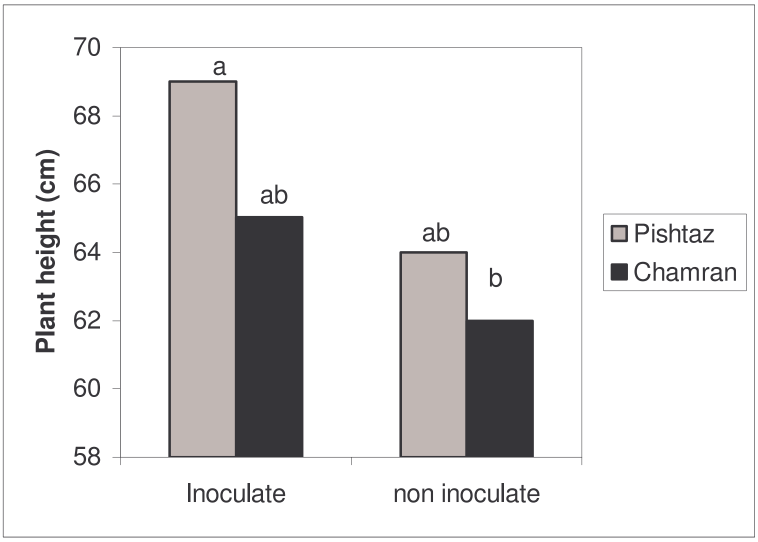

Figure 4: Interaction between cultivars and inoculation on plant height

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The Effect of PGPR Inoculation on the Growth of Wheat

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ABSTRACT

Many agricultural soils of Iran have high pH, resulting in low availability of Fe and Zn. The potentials of non-symbiotic plant growth-promoting rhizbacteria (PGPR) for stimulating plant growth have been extensively used during recent decades. This experiment was carried out in growth chamber to evaluate the effects of siderophore-producing Pseudomonads on the growth as well as Fe and Zn uptake of wheat. A randomized complete block design experiments was conducted using with Alborz genotype (an efficient phytosiderophore-producing bread wheat) treated with either 7NSK2 strain as a siderophore positive (*sid*$^+$) or with MPFM1 mutant strain of the same isolate as a siderophore negative (*sid*$^-$) treatments with three replications. The potentials of these strains for auxin production and phosphate solubilizing activity were evaluated by standard methods. The results showed that inoculation with *sid*$^+$ strain increased dry matter production in shoots as compared with the control (sterile condition) or with s*id*$^-$ strain. Likewise, the concentration of chlorophyll *a* in leaves of *sid*$^+$ and *sid*$^-$ treatments were 1.27 and 0.41μg mg^{-1} of fresh weight, respectively, and the concentration of chlorophyll *b* were measured to be 1.09 and 0.35 μg mg^{-1} of fresh weight, respectively, indicating significantly more chlorophyll formation due to inoculation with *sid*$^+$ as compared with s*id*$^-$. The uptake of Fe by roots and its rate of translocation to the shoots were greater for the *sid*$^+$ treated plants as compared with the *sid*$^-$ treated ones, indicating that siderophores increased the rate of Fe uptake by wheat. The effect of microbial inoculation on shoot Zn was not significant, but increased the concentration of Zn on roots compared with control. The results suggested that the siderophores of Pseudomonads may involve on increasing bioavailability of iron.

Keywords: Plant Growth Promoting Rhizobacteria (PGPR); Siderophore; Fluorescent Pseudomonads; Iron; Zinc

INTRODUCTION

Plant growth-promoting rhizobacteria (PGPR) are of agronomic importance. Indeed, they produce metabolites such as plant growth regulators that directly promote growth and facilitate nutrient uptake by plants. There is widespread distribution of PGPR that flourish in different geographical habitats (Hafeez et al., 2005). These rhizobacteria significantly affect plant growth not only by increasing nutrient cycling, also by suppressing pathogens by producing antibiotics and siderophores or by bacterial and fungal antagonistic substances and / or by other plant hormones. A divers array of bacteria including *Pseudomonas, Azospirillum, Azotobacter, Bacillus, Klebsilla, Entrobacter* and *Serratia* have been shown to promote plant growth (Khalid et al., 2004). Among these bacteria, fluorescent pseudomonads have high efficiency in host root colonization and plant growth metabolites production as well (Rasouli Sadaghiani, 2005). These bacteria are an important component of the rhizosphere of many plants, and are known to colonize the rhizosphere of wheat, potato, maize, grasses, pea and cucumber (Cakmakci et al., 2006; Khalid et al., 2004; Howie and Echandi, 1983; Brown and Rovira, 1976). *Pseudomanas* inoculants significantly increased root dry weight in spring wheat (Walley and Germida, 1997) and colonized winter wheat roots (De Freitas and Germida, 1992). Rhizosphere fluorescent pseudomonads are known to be antagonists to plant pathogens via siderophore production (Kloepper et al., 1980). Khalid et al. (2004) screened PGPR for improving growth and yield of wheat and concluded that the strains which produced the highest amount of auxins caused maximum increase in growth as well as yield of wheat.

PGPR improve plants efficiency in iron acquisition. In calcareous soils the availability of Fe is very low due to the high pH of the soil solution and its buffering capacity that may impede Fe uptake mechanisms of many plants. Plants grown in such soils may suffer from sever Fe deficiency (Marschner et al., 1986). In order to avoid Fe deficiency, various graminaceous plants seem to rely on excretion of phytosiderophores by the roots and their uptake as a Fe complex by a highly specific uptake system that is enhanced by Fe deficiency (Marschner et al., 1986).

Microbial siderophores form Fe complexes with high stability constants and therefore play a role in the Fe uptake by microorganisms (Neilands, 1995). Siderophores were found in soil solutions at concentrations that may influence the Fe nutrition of plants. Soil microbial activity is essential for Fe acquisition by soil-grown rape. Similarly, sorghum which is able to release phytosiderophores from the roots requires soil microbial activity to ensure satisfactory Fe supply (Rroco et al., 2003). Furthermore, some strains of *Pseudomonas* and *Bacillus* could be able to solubilize sparingly Zn compounds. These bacteria have been introduced as ZSB (Zinc Solubilizing Bacteria) (Saravanan et al., 2003). Disimine et al. (1998) isolated a strain of *Pseudomonas fluorescens* from forest soil which showed high efficacy in solubilizing insoluble Zn compounds.

Pesudomonas aeruginosa strain 7NSK2, isolated from barley roots (Iswandi et al., 1987), has been genetically marked with a lac element (MPB1) for ecological studies (Hoft et al., 1991). MPFM1 is a pyoverdin-negative mutant of 7NSK2 obtained by Tn5 mutagenesis. In the case of PGPR strain 7NSK2, the fluorescent siderophore pyoverdin plays an important role in plant growth stimulation (Hoft et al., 1991).

The aim of this study was to evaluate the efficiency of siderophore producing PGPR and its siderophore negative mutant. We, therefore, investigated the effectiveness of previously identified strains (7NSK2 and MPFM1) on growth, Fe and Zn uptake in bread wheat.

METHODS and MATERIAL

Microbial Inoculation and Properties

Bacterial strains used were *P. aeruginosa* 7NSK2 as siderophore positive (sid^+) and its siderophore negative mutant *P. aeruginosa* MPFM1 (sid^-) and were prepared by Monika Hoft, Gent University, Belgium. Bacterial inoculations were produced from 48 h culture grown in King's B broth medium on a rotary shaker at 28°C. Seeds were bacterized by the method of seed inoculation on bacterial culture (ca. 10^8 cfu ml^{-1}) for 15 min. Un-inoculated jars considered as control treatments.

Plant growth-promoting properties of the strains were confirmed with their ability to produce siderophore, indole acetic acid and phosphate solubilization. The potentials of these strains for siderophore production were evaluated by chrome azorel-S assay (CAS blue agar) through color change (Schwyn and Neilands, 1987). Auxin production by the strains was determined by colorimetry. For this purpose sterilized broth of glucose peptone agar medium was put in glass tubes and inoculated at 28 °C for 24 h with occasional shaking. The contents of the tubes were filtered before measuring auxin production as Indole acetic acid (IAA) equivalents. In measuring the IAA equivalents, 3 ml of the filtrate were pipetted into test tubes and 2 ml Salkowski reagent (2 ml 0.5 M $FeCl_3$ + 98 ml 35% $HClO_4$) were added to it. The tubes containing the mixture were left for 30 min for color development. Intensity of the color was measured spectrophotometrically at 535 nm. Similarly, color was also developed in standard solutions of IAA and standard curve was established by measuring the intensity of this color (Asghar et al., 2002). Phosphate solubilization ability was evaluated according to the method of Sperber (1958).

Pltan Culture

Seeds of wheat (*Triticum aestivum* L. cv. Alborz) were surface sterilized for 1 min in 70 % ethanol and then treated in 5 % Na hypochloride solution for 40 min, followed by rinsing the seeds six times with autoclaved distilled water. Wheat genotype was Fe-efficient in terms of phytosiderophore producing (Rasouli Sadaghiani et al., 2007). Bacterized seeds then planted and were grown on sterilized fine sand-derived from Caspian Sea beaches in sand culture method. Pots (Leonard jars) consisted two part, upper part filled with sand and a cotton-based strip in center and lower part included nutrition solution sink with corresponding strip. Nutrient solution was sterilized and containing: 2 mM $Ca(NO_3)_2$, 0.25 mM KH_2PO_4, 0.1 mM KCl, 0.88 mM K_2SO_4, 1 mM $MgSO_4$ 7H2O, 1 µM H_3BO_3, 0.2 µM $CuSO_4$ $5H_2O$ and 0.2 µM $(NH_4)_6MoO_{24}$. Fe and Zn were supplied in sparingly soluble forms as Fe_2O_3 (5 mg kg^{-1} soil) and ZnO (1 mg kg^{-1} soil), respectively. Solution pH was adjusted at 7.1 by adding HCl or NaOH. Plants were cultivated in growth chamber and at aseptic condition. The growing period lasted 32 days and growing condition included 26 °C day (16 h) and 20 °C night temperature (8 h).

At the end of experiment plants were harvested, shoot and root dry weights were determined and their Fe concentration was recorded. Also the concentration of chlorophyll a and b were measured in leaf samples according to the method of Sharma et al. (2003).

RESULTS and DISCUSSION

To evaluate the effects of strains 7NSK2 and MPFM1 inoculation on wheat growth in presence of sparingly soluble compounds of Fe and Zn, an experiment was designed using F_2O_3 and

ZnO. *Pseudomonas* strain 7NSK2 despite from MPFM1 produced high amount of siderophore which determined through CAS blue agar assay. Neither 7NSK2 nor MPFM1 did solubilize insoluble phosphate compounds. Both strains produced auxines (Table 1). The results showed that inoculation with *sid*$^{+}$ strain increased dry matter production in shoots as compared with the control (sterile condition) or with s*id* $^{-}$ strain. Shoot dry weight in 7NSK2 inoculated plants (2.13 g pot^{-1}) were approximately 18% higher than the MPFM1 and were statistically in the same group as the control (1.97 g pot^{-1}). The 7NSK2 treatment (0.47 g pot^{-1}) gave a 46% and 30% increase in root biomass compared to MPFM1 and control treatments, respectively (Fig. 1).

Table 1. Production of plant growth regulators by *Pseudomonas* strains

Isolates	IAA equivalents mg l^{-1}	Phosphate solubilizing ability	Siderophore production
7NSK2	2.27	-	+
MPFM1	2.18	-	-

The control (sterile) plants were comparable to 7NSK2 (sid^{+}) inoculated plants and it was as effective as 7NSK2 in terms of shoot dry weight (Fig. 1). Uninoculated control plants showed higher whole plant dry weight compared to MPFM1 treatments (data not shown). Tabasi genotype has shown to produce large amount of phytosiderophores on Fe deficient condition and classified as efficient wheat genotype (Rasouli Sadaghiani et al. 2007). It seems this genotype could better uptake and utilize nutrients in such condition.

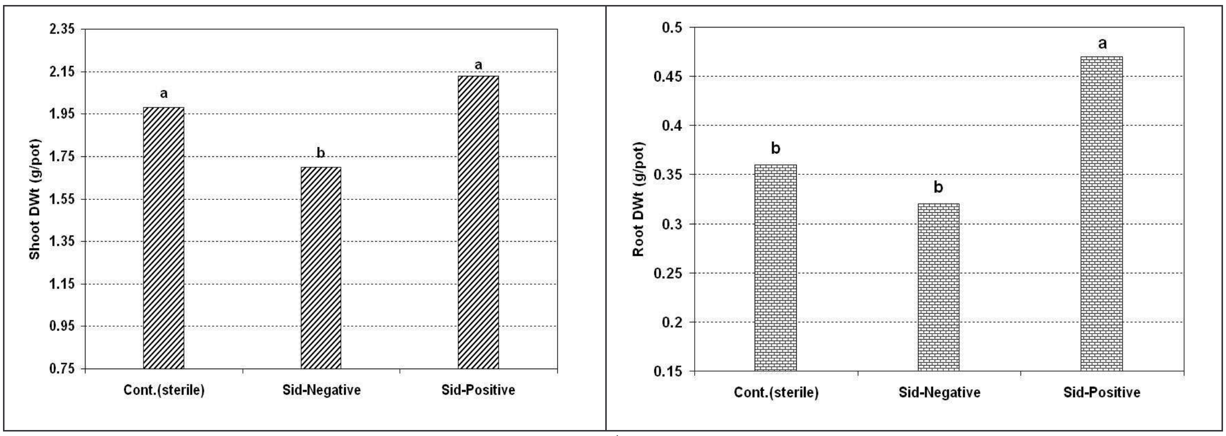

Figure1. Effects of *Pseudomonas* strains 7NSK2 (Sid^{+}) and MPFM1 (Sid^{-}) on shoot and root dry weights

Plant inoculated with MPFM1 showed lower degree of iron chlorosis, which was visualized as interveinal yellowing of wheat leaves. In 7NSK2 treatment along with control plant, a significant (at $P \leq 0.05$) increase in chlorophyll a chlorophyll b and total chlorophyll content was observed as compared to MPFM1 inoculated plants (Table 2). Treatment with 7NSK2 was effective in reducing chlorosis as evident in increased chlorophyll components. Seong et al. (1992) reported that bacterization of soil with the siderophore producing strain 7NSK2 resulted in a significant dry weight increase in maize compared to MPFM1 strain. In this study, the siderophore-deficient mutant MPFM1 did not affect shoot dry weight as well as chlorophyll content, although its root Zn uptake amount was not impaired (Fig. 1; Table 2). Chlorophyll a, chlorophyll b and total chlorophyll content was correlated with higher iron acquisition (Katyal and Sharma, 1980). The concentration of chlorophyll *a* in leaves of *sid*$^{+}$ and *sid*$^{-}$ treatments were 1.27 and 0.41μg mg^{-1} of fresh weight, respectively, and the concentration of chlorophyll *b* were measured to be 1.09 and 0.35 μg mg^{-1} of fresh weight, respectively, indicating significantly more chlorophyll formation due to inoculation with *sid*$^{+}$ as compared with s*id*$^{-}$. These results may also indicate that siderophores of strain 7NSK2 involved in Fe uptake.

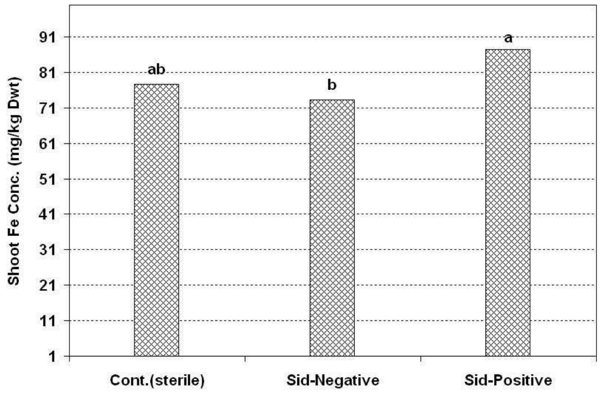

Figure 2. Effects of *Pseudomonas* strains 7NSK2 (Sid^{+}) and MPFM1 (Sid^{+}) on shoot Fe concentration

Table 2. Effects of *Pseudomonas* strains 7NSK2 and MPFM1 on Fe, Zn and chlorophyll concentration

Inoculation conditions	Fe conc. (mg kg^{-1})		Zn conc. (mg kg^{-1})		Chlorophyll cont. (mg g^{-1} Fresh wt)		
	Shoot	Root	Shoot	Root	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Control (no inoculation)	77.75 ab	3606 b	48.50 a	151 b	1.40 a	0.83 a	2.23 a
7NSK2 (Sid^{+})	87.50 a	5586 a	51.87 a	185 a	1.27 a	1.08 a	2.35 a
MPFM1 (Sid^{-})	73.25 b	3871 b	47.75 a	180 ab	0.41 b	0.35 b	0.76 b

Data presented in Table 2 shows that in 7NSK2 inoculated plants Fe uptake enhanced (approx. 20%) compared to negative siderophore strain (MPFM1). However, plant with no inoculation (sterile) was also showed relatively high amount of Fe in shoots. It is surprising that although control plant did received pgpr inoculants, its effect on shoot dry weight and chlorophyll content was prominent. This increased Fe uptake resulted from high efficiency of wheat genotype in phytosiderophore release in Fe deficient condition. Rasouli Sadaghiani et al. (2007) showed that Tabasi genotype as bread wheat released high amount of root exudates mainly phytosiderophores in Fe and Zn deficiency conditions. Therefore, the uptake of Fe by roots and its rate of translocation to the shoots were greater for the *sid*$^+$ treated plants as compared with the *sid*$^-$ treated ones, indicating that siderophores increased the rate of Fe uptake by wheat.

Microbial siderophores are used as Fe chelating agents that can regulate the availability of iron in the plant rhizosphere. It has been assumed that competition for iron in the rhizosphere is controlled by the affinity of the siderophore for iron (Loper and Henkels, 1999). Interestingly, the binding affinity of phytosiderophores for iron is less than the affinity of microbial siderophores, but plants require a lower iron concentration for normal growth than do microbes (Meyer, 2000). In this study, the effect of microbial inoculation on shoot Zn was not significant, but increased the concentration of Zn on roots compared with control. Disimine et al. (1998) reported that a strain of *Pseudomonas fluorescens* from forest soil showed high efficacy in solubilizing insoluble Zn compounds.

The data presented in this study explores microbe-plant interaction in terms of iron uptake from particularly the insoluble oxide form of iron and supports the mechanisms of heterologous iron uptake in wheat system via microbial siderophores. Chlorophyll content may be used as marker of iron availability to the plant system. For calcareous soils which prevalent in Iran, strains like 7NSK2 will be of great interest to combat iron chlorosis and additionally improve strategic crop yield.

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The Effect of Soil Management Systems on Microbial Activity

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ABSTRACT

The objective of this study was to evaluate basal (BR) and specific respirations (qCO_2) of soils under native pasture and long-term cultivated soils at semiarid climate of the northern Turkey. In addition, the dependencies of BR to soil water content and the relationship between microbial biomass C (C_{mic}) and qCO_2 were determined in the both ecosystems. Soil samples were collected from 0-5, 5-15, and 15-30 cm layers of native pasture and long-term cultivated soils. Soil microbial biomass was determined using fumigation incubation method. Specific respiration was calculated as BR/C_{mic}. BR varied through growth season in the both ecosystems and native pasture generally had greater BR than long-term cultivated soil. The highest BR was observed in October at native pasture. However, qCO_2 was generally greater in long-term cultivated soil compared to native pasture. qCO_2 and C_{mic} were negatively correlated at all layers of both management systems. There was not a significant dependency between soil water content and BR in Fluvaquentic Haplustolls. Thus, long-term cultivation increased qCO_2 which varied through growth season. Soil organisms under stress condition increased qCO_2 compared to native pasture.

Key words: Basal respiration; specific respiration, native pasture; long-term cultivation.

INTRODUCTION

The function of soil microorganism in a soil is the decomposition and transformation of soil organic materials. Soil organic materials, above and below ground plant residue, are used as an energy source of microorganisms. Hence, soil microorganisms play a critical role in nutrient turnover, carbon cycling and the production of trace gasses (Ananyeva et al., 2008).

Soil microbial activities, population and communities structure are managed by soil type and texture, temperature, moisture, pH (Cavigelli et al., 2005), and soil management systems such as cultivation practices and crop rotation (Salinas-Garcia et al., 1997). Soil organisms under different soil type, management, and climate region have been acting variable through a year. Researchers still need to better evaluate the effect of land management, soil type and different climate region in the northern Turkey. The study site is on a passing zone between humid and arid climate region. Annual precipitation around 446 mm and most of the precipitation fall in the winter and spring seasons.

Soil microbial activity is an index of the actual (basal respiration) and the potential microbial respirometric activity. Soil microbial biomass and activity are key parameters for transformation of soil carbon pools in various ecological scenarios (Bailey et al., 2002; Wardle, 1992). Soils developed under different ecology have different potential to store soil organic matter and nutrients. The improvement of ecosystem productivity depends mainly on the organic matter dynamics and soil microbial biomass (Valpassos et al., 2001). Soil microbial biomass, the active and living part of soil organic matter, is responsible for releasing nutrient from organic matter and functions as a sink or source for plant nutrients (Smith and Paul, 1990). The amount of microbial biomass does not provide any information about soil microbial activity. However, microbial respiration provides estimate of soil microbial activity and reveals the impact of different soil type, land management systems and climate conditions. Microbial activity in soils is a measurement of active microbial cell and most frequently used parameters for quantifying microbial activity in soils (Anderson and Domsch, 1990). Soil microbial activity responds differently to soil management systems and soil environmental factors. The effects of environmental factors on soil microbial activity vary under different soil management systems through plant growth season.

The aim of this study was to evaluate microbial respiration activities of soils under different management systems (native pasture and long-term cultivated land) at semiarid climate of the northern Turkey. The other point was to determine the dependencies of microbial respiration activities to soil water content through plant growth season.

MATERIALS and METHODS

The study was carried out at Yeşil river basin of the northern Turkey. The area has two different land managements adjacent to each other. The two land managements include native pasture and long-term cultivated sites which cover about 10 ha area. The soils developed on an alluvium over lacustrine material with a flat topography at an elevation of 640 m. The annual average precipitation is 446 mm with 12.4 ^{o}C average temperature. Soils were classified as fine, smectitic, mesic, Fluvaquentic Haplustolls according to soil taxonomy (Durak et al., 2006). The native pasture has been under heavy grazing of cattle without any fertilizer. The study area with high clay content and poor drainage system, which leads to high ground water level approaches to 2 m at spring. The cultivated site has been under continuous wheat production with conventional tillage system including plowing at spring and disking two or three times before planting.

The soil samples were collected monthly from 0 – 5, 5 – 15, and 15 – 30 cm depths of four randomly selected locations of the each land use. The samples were stored at 5 ^{o}C until analysis. A 4-mm mesh was used to separate plant materials and to homogenize the soils. Soil dry weigh was determined gravimetrically by drying at 105 ^{o}C for 24 h. The some soil physical end chemical properties were presented in Table 1 (at publication).

Soil microbial biomass was determined by fumigation and incubation method (Horwath and Paul, 1994). Soil microbial respiration was determined by using actual (basal) respiration method at *in situ* water content. A 20 gr soil samples were placed in a mason jar with 10 mL of NaOH. Soil CO_2 was trapped inside the alkaline solution and titrated using a diluted HCl solution. Soil respiration was measured during 48 h and the respiration rates were determined through the depth of the two management system. Soil water contents were determined to evaluate the effect of soil water content on soil respiration.

The experimental design was randomized block design with four replications. The data were analyzed based on analysis of variance and means were compared by the Duncan test at $\alpha = 0.05$. The significances of regression were determined using Sigma Plot 8.0 (Systat Software Inc.).

RESULTS and DISCUSSION

Soils under different management systems represented different basal respirations (BR) (Fig. 1). The basal CO_2 respiration represents an estimation of heterotrophic microbial respiration at standardized laboratory condition and provides evidence of soil carbon availability to soil microorganisms (Ananyeva et al., 2008). The greater basal respirations were observed at 0-5 and 5-15 cm depths and BR decreased at 15-30 cm depth. The greater BR at the surface of soils could be the result of the higher level of soil organic C and nutrient sources. BR of soils was significantly correlated with soil organic carbon and nitrogen content (Alvarez et al., 1995; Ananyeva et al., 2008). Long-term cultivation decreased BR compared to native ecosystem. Consequently, long-term cultivation resulted in a dramatic reduction of microbial activity compared to natural ecosystem. Basal respiration varied through the year at the both ecosystems. The variation of soil respiration can be associated with soil chemical and physical properties and environmental factors. The soil studied in this study, Fluvaquentic Haplustolls, developed on alluvial materials with frequently river charge. Therefore, soils have poor drainage and clay texture had slightly lower microbial activity. Generally, the greatest BR occurred in October and the lowest BR occurred on May at both management systems. This could be the result of competition for nutrients between plants and soil organisms during most active plant growth season. However, at the end of growth season, harvest residue and plant senescence stimulated microbial activity and BR. The lowest BR at 15-30 cm depth can be attributed to the lower root biomass as consequences less organic C. Most of the root biomass in the native pasture occurred up to 15 cm depth while less root biomass was observed blow 15 cm depth due to lower aeration and heavy compaction.

Table 1. Physical and chemical properties of pasture and long-term cultivated soils.

Soil Properties	Depth (cm)	Pasture	Cultivated	*p*
pH	0 - 5	7.7 (0.0)	8.2 (0.2)	**
	5 - 15	7.8 (0.0)	8.2 (0.2)	*
	15 - 30	7.9 (0.1)	8.3 (0.2)	*
Clay ($g\ kg^{-1}$)	0 - 5	325 (25.6)	315 (68.0)	Ns
	5 - 15	392 (23.0)	326 (81.0)	Ns
	15 - 30	479 (21.6)	333 (79.2)	Ns
Silt ($g\ kg^{-1}$)	0 - 5	330 (10.4)	363 (24.1)	Ns
	5 - 15	265 (24.7)	355 (31.7)	Ns
	15 - 30	273 (15.9)	350 (28.1)	Ns
Sand ($g\ kg^{-1}$)	0 - 5	345 (22.8)	322 (62.2)	Ns
	5 - 15	343 (42.1)	319 (58.3)	Ns
	15 - 30	248 (16.5)	317 (56.8)	Ns
$CaCO_3$ ($g\ kg^{-1}$)	0 - 5	186 (29.9)	122 (17.9)	Ns
	5 - 15	216 (23.9)	128 (10.8)	*
	15 - 30	191 (16.5)	129 (17.9)	*
Organic C ($g\ kg^{-1}$)	0 - 5	36 (2.0)	10 (1.0)	**
	5 - 15	36 (1.0)	5 (0.1)	**
	15 - 30	22 (7.0)	4 (1.0)	*
Total N ($g\ kg^{-1}$)	0 - 5	5.3 (0.1)	0.5 (0.0)	**
	5 - 15	4.1 (0.1)	-	
	15 - 30	4.6 (0.0)	-	

Ns, not significant. Each value represent mean (n = 4), S.E. of means are included in parenthesis.

* $p < 0.05$.

** $p < 0.001$.

The effect of long-term cultivation on soil microbial properties was evaluated in this study. Soil microbial biomass C and BR decreased in the long-term cultivated land compared to native pasture. The previous studies stated that C_{mic} was greater in forest, grassland compared to arable land (Wardle, 1992; Dyckmans et al., 2003). The main reason for decreased C_{mic} contents in arable soil is attributed to a decrease of available substrate due to tillage and removal of plant residues (Ananyeva et al., 2008).

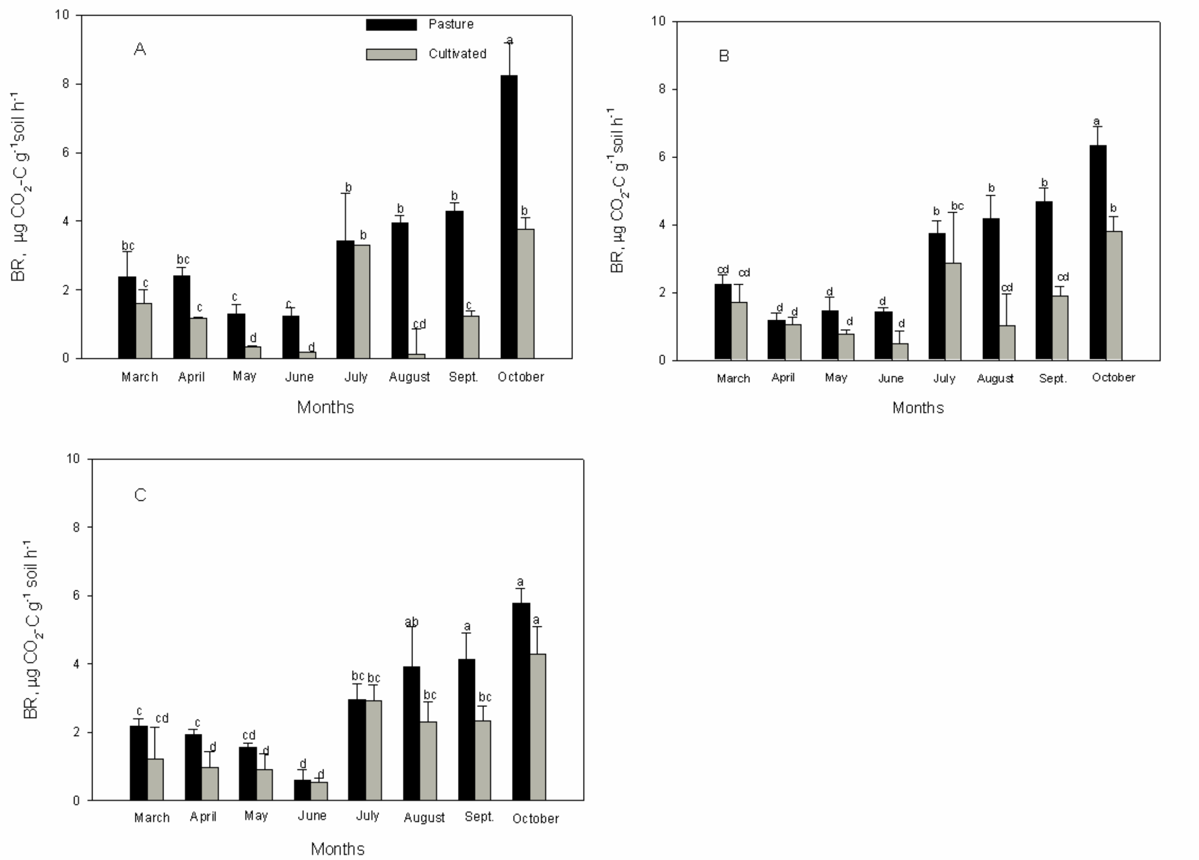

Fig. 1. Basal respirations (BR) of pasture and long-term cultivated lands through plant growth at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths. The bars represent standard error (n = 4). The different letters indicate significant difference at $\alpha = 0.05$.

The relationship between soil water content and BR was determined through the soil profile. There was not a significant relationship between soil water content and BR in both soil managements (data not presented). This may suggest that other than soil water content some factors may control BR in the poor drained and high ground water soils. The general trend was the increases of water content decreased BR from a point where soil water content limited soil aeration. Thus, soil water content is not an important determining factor for BR at Fluvaquentic Haplustolls. However, some researchers found significant correlation between BR, organic C ($r = 0.68$), and C_{mic} ($r = 0.71$) in a study of arable soils from 12 regions in the United States (Insam, 1990).

Table 2. Specific microbial biomass respiration (qCO_2) at 0 – 5, 5 -15, and 15 – 30 cm depths of pasture and long-term cultivated lands through plant growth season.

	Pasture			Cultivated		
	0 – 5	5 - 15	15 - 30	0 – 5	5 – 15	15 - 30
Months	$\mu g\ CO_2 – C\ mg^{-1}\ C_{mic}\ h^{-1}$					
March	3.19 ± 2.09*	2.49 ± 0.29	2.78 ± 0.87	3.65 ± 0.34	3.68 ± 0.92	3.51 ± 0.09
April	4.24 ± 1.17	3.18 ± 0.52	3.26 ± 0.68	4.03 ± 0.16	4.65 ± 0.26	3.79 ± 0.32
May	5.31 ± 0.64	4.70 ± 1.44	4.36 ± 1.14	4.31 ± 0.26	5.08 ± 0.78	4.05 ± 1.55
June	2.76 ± 0.76	3.21 ± 0.31	1.50 ± 0.65	5.00 ± 0.21	2.15 ± 0.36	4.37 ± 0.24
July	5.17 ± 2.12	8.21 ± 1.34	3.11 ± 1.26	5.07 ± 0.18	4.14 ± 2.54	5.44 ± 0.43
August	4.40 ± 0.70	6.30 ± 0.12	7.20 ± 0.63	7.39 ± 8.97	3.04 ± 1.79	3.98 ± 0.17
September	6.73 ± 0.65	6.87 ± 0.42	6.79 ± 0.72	7.02 ± 0.48	5.49 ± 0.81	4.86 ± 0.53
October	8.72 ± 0.20	8.60 ± 4.82	8.17 ± 2.12	8.09 ± 7.98	8.10 ± 4.16	9.34 ± 0.46

* Means ± standard error of four replications.

In this study, the specific respiration (qCO_2) values ranged from 1.50 up to 9.34 µg CO_2-C mg^{-1} C_{mic} h^{-1} (Table 2). The qCO_2 values in the soils were varied through a year and between the soil layers. In the 0-5 cm soil layer the qCO_2 ranged from 2.76 up to 8.72 µg CO_2-C mg^{-1} C_{mic} h^{-1} in the pasture, but the qCO_2 was slightly higher in the cultivated land, ranging from 3.65 up to 8.09 µg CO_2-C mg^{-1} C_{mic} h^{-1}. The specific respiration of soil microbial biomass provides information of substrate quality and availability (Insam et al., 1996) and in addition, physiological stage of soil microbial community (Dilly et al., 1997; Dilly and Much, 1998). Overall, the qCO_2 values was generally greater in the cultivated land compared to the native pasture at the all the layer. The average qCO_2 at the native pasture (5-15 cm) ranged from 2.49 up to 8.60 µg CO_2-C mg^{-1} C_{mic} h^{-1} while ranging from 2.15 up to 8.10 µg CO_2-C mg^{-1} C_{mic} h^{-1} in the long-term cultivated land. Long-term cultivation decreased microbial biomass and resulted greater qCO_2 values compared to native pasture. However, after harvest of wheat and cultivation with plowing slightly decreased qCO_2 compared to native pasture in August. This could be the results of increases of nutrient sources with harvest residue and the changes in the soil environment with plowing and disking. The variation of qCO_2 from March through October may be associated with the changes in soil environmental factors and nutrient availability. Some researcher indicated that high qCO_2 may be related to stress response (Odum, 1985; Anderson and Domsch, 1993). However, soils from different climatic region of European part of Russia did not show difference in qCO_2 (Ananyeva et al., 2008).

The functional relationship between changes of qCO_2 and C_{mic} for native pasture and long-term cultivated land was presented in Fig. 2 and Fig. 3. There was a negative relationship between C_{mic} and qCO_2 in the all layers of the both management systems except 0 – 5 cm of long-term cultivated site, where the relationship was not significant. Specific microbial biomass respiration decreased with increases of microbial biomass C. The similar results were observed at native and arable ecosystems of European Russia (Ananyeva et al., 2008). These results suggest that the amount of microbial biomass C can be used as a good index to estimate specific respiration of soil under different management systems.

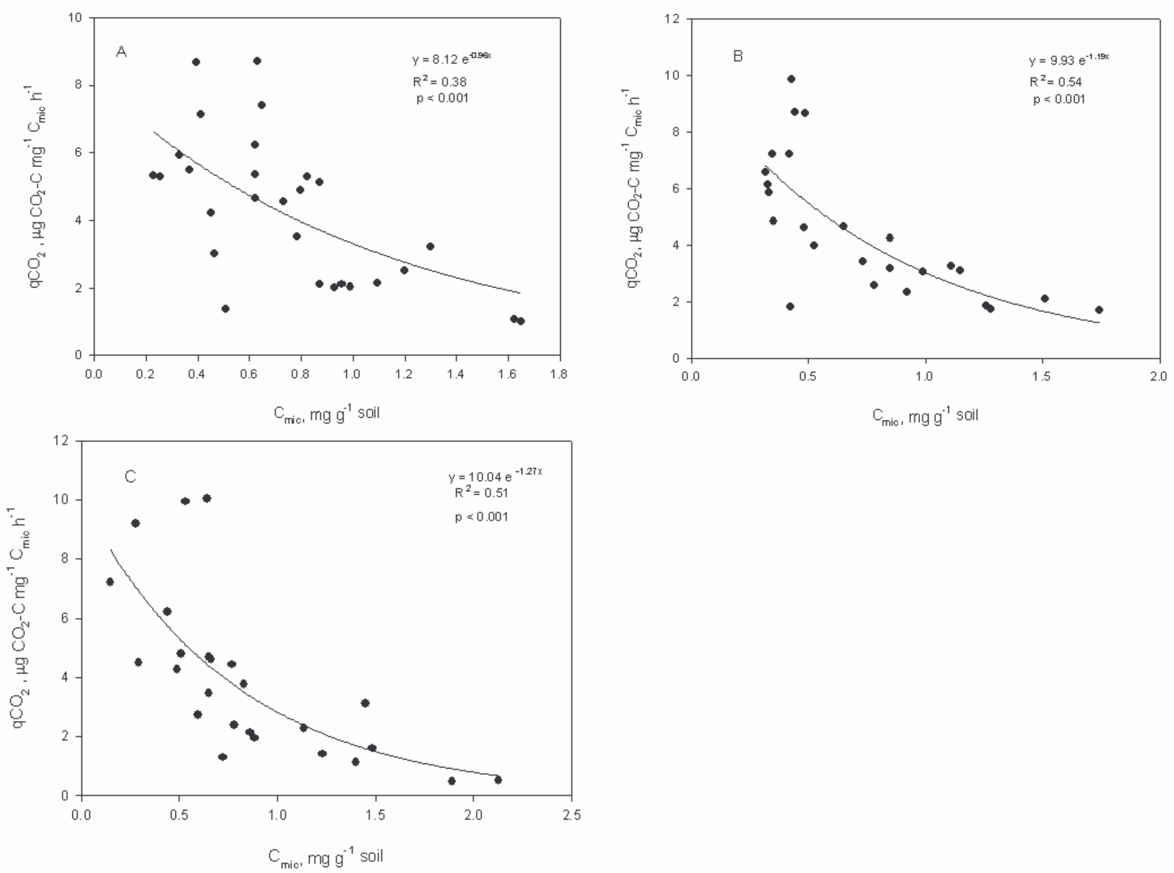

Fig. 2. The relationships between microbial biomass C (C_{mic}) and specific respiration (qCO_2) in pasture at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths.

As consequences, the long-term cultivated land had a lower microbial activity with lower BR and generally higher qCO_2 compared to the native pasture. Hence, cultivation caused significant reduction of microbial activity and soil organic C pools. There was not significant correlation between soil water content and BR at the all the layers of the soils. Basal respiration varied through plant growth season in the cultivated and native pasture. It was clear that the qCO_2 was significantly greater in long-term cultivated land compared to native pasture. The correlation between qCO_2 and C_{mic} was negatively significant in the both managements. The increases of microbial biomass decreased specific respiration, which indicates that soil organism under stress condition increases specific respiration.

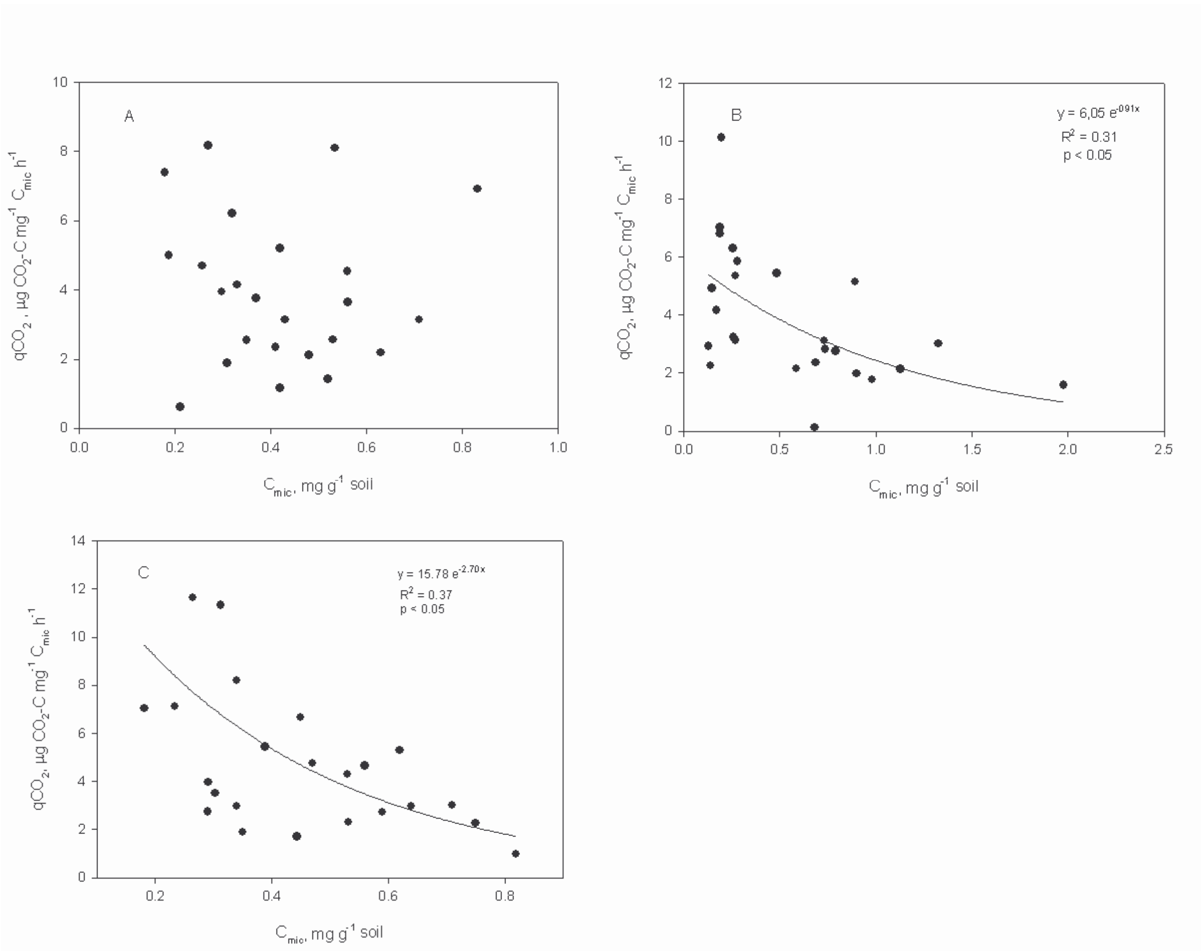

Fig. 3. The relationships between microbial biomass C (C_{mic}) and specific respiration (qCO_2) in long-term cultivated land at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths.

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Effects of Different Application Doses of Sewage Sludge on Microbial Biomass and CO_2 Production of Soil and Earthworm *Lumbricus terrestris* Cast

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ABSTRACT

This study was carried out in order to determine the effects different application doses of sewage sludge (0, 2, 4, 6, 8 and 10 %) on microbial biomass C, CO_2 production, organic C and total N of soil and earthworm *Lumbricus terrestris* casts. Experimental design was randomized plot design with three replications. The moisture content in soil was maintained around 60 % of maximum water holding capacity by weighing the pots everyday. Changes in the microbiological properties and total C and N were determined in the soil and earthworm casts samples taken in 15, 30, 45, 60, 75 and 90 days after the experiment was conducted.

At the end of the experiment, earthworm casts had higher microbial biomass C, CO_2 production, total organic C, and total N levels than the surrounding soils at all incubation periods and sewage sludge applications significantly (P<0,001). Increases in application doses of swage sludge caused increases in microbial biomass C and CO_2 production, significantly (P<0,001). It was determined that the microbial parameters of soil and earthworm casts were not significantly changed after the 45th and 60th days of the experiment.

Key words: Sewage sludge, soil, earthworm cast, microbial biomass C, CO_2 production

INTRODUCTION

Organic wastes are added to agricultural soils for increasing plant nutrition and soil fertility and also for soil amendment. It has been added not only plant and animal wastes but also sewage sludge that to provide with refining of urban wastes to agricultural soils for organic matter added. Previous studies have demonstrated favorable plant yield responses to the application of sewage sludge (King and Morris, 1972). In contrast, the effects of sewage sludge on biological process in soil have been questioned by some authors (Knight et al., 1997; Banerjee et al., 1997; Kızılkaya and Bayraklı, 2004). Most papers concerned with the results of sewage sludge studies deal with the influence of sewage sludge on soil biological characteristics. Knight et al. (1997) observed a decrease of soil biological activity such as microbial biomass and enzyme activities, due to sewage sludge application. Conversely, Sastre et al. (1996) and Banerjee et al. (1997) found that the sewage sludge amendment increased soil microbial activity and CO_2 production. These differences might be a result of the some toxic metal content of sewage sludge and of the sewage sludge stability (Tam and Wong, 1990).

In soils, earthworms are known to incorporate organic wastes into soil and casts. Additionally, earthworms enhance the formation of soil structure, incorporation and transformation of soil organic matter, and their importance in improving soil physico-chemical and biological properties are generally accepted (Lee, 1985; Kızılkaya, 2008). In general, earthworms are known to incorporate organic wastes such as plant and animal residues into soil and casts. The nutrient contents of the casts have higher than non-ingested soil (Sharpley and Syers, 1976; Scheu, 1987; Daniel and Anderson, 1992; Parkin and Bery, 1994). Additionally, higher microbial biomass and their activities in casts than the corresponding topsoil were recorded in a range of several studies (Tiunov and Scheu 1999; Kızılkaya and Hepşen, 2004). However, little information is available on the effects of sewage sludge on some biological characteristics in earthworm casts and surrounding soil. Soil biological activity plays an important role in regulating soil fertility and/or soil sustainability. Several biological parameters, such as microbial biomass and CO_2 production have been used to define the status and sustainable development of productivity in soils, and are used as bio-indicators for soil quality and health in environmental soil monitoring (Rogers and Li, 1985). Microbial biomass C is measured to give an indication of the response of soil microbiota to management, environmental change, site disturbance, and soil pollution (Kandeler, 2007). Soil respiration, as measured by the net heterotrophic production of CO_2, is an important measure of aerobic microbial activity and carbon flux through terrestrial ecosystems (Coleman, 1973). The CO_2 produced from the soil results from the mineralization of organic matter, a process in soil microflora play a dominant role (Satchell, 1983).

The objective of this study were to determine the effects of different application doses of sewage sludge on microbial biomass C, soil respiration organic C and total N of soil and *Lumbricus terrestris* earthworm cast.

MATERIAL and METHOD

Soil, Sewage Sludge and Earthworms

Surface soil (0-20 cm) was taken from the horticultural soil in Merzifon. The site is located in the Black Sea Region, Northern Turkey (Latitude, 40º 52' N; longitude, 35º 20' W). The climate is semi-arid and the annual average precipitation and temperature are 470.6 mm and 6.6 ^{0}C in February to 23 ^{0}C in August. Sewage sludge obtained from a wastewater facility setup by Ankara Wastewater Treatment Plants, Ankara, Turkey. Sewage sludge used was dried at 65 ^{0}C prior to collection and was sieved (< 2 mm) before analysis. Selected soil and sewage sludge physical-chemical properties were determined by standard methods (Black, 1965; Rowell 1996).

Lumbricus terrestris L. was collected from the site which the soil sample was taken. Earthworms were washed with distiled water and capt for 2 weeks before starting the experiment in containers with soil-sewage sludge combinations at 20 ± 0.5 ^{0}C.

Experimental Procedure

The soil samples (500 g air-dried soil) were placed in 1 L cylindirical plastic containers. The sewage sludges were mixed as homogenous with the soil at a rate equivalent to 0, 20, 40, 60, 80 and 100 g kg^{-1} on an air-dried weight basis. Then, four individuals of *Lumbricus terrestris*, were placed in the sewage sludge-amended soil. The containers were incubated for 90 days in the incubater at 20 ^{0}C and samples were taken from containers per 15 days. The moisture content in soil was maintained at 60% water holding capacity in soil trough out the incubation period. Three replicates per treatment were established. At the end of the each incubation period, samples were collected by hand from earthworm casts deposited on the soil surface and from bulk soil.

Total organic C and Total N Analysis

Total organic C levels of soil and casts were determined by the Walkley-Black method, and total N concentrations were determined by using the Kjeldahl method (Black, 1965; Rowell, 1996).

Biological Analysis

Microbial biomass carbon was determined by the substrate-induced respiration method of by Anderson and Domsch (1978). A moist soil sample equivalent to 100 g oven-dry soil was amended with a powder mixture containing 400 mg glucose. The CO_2 production rate was measured hourly using the method described by Anderson (1982). The pattern of respiratory response was recorded for 4 h. Microbial biomass carbon (C_{mic}) was calculated from the maximum initial respiratory response in terms of mg C g^{-1} soil as 40.04 mg CO_2 g^{-1} + 3,75. Three replicates of each sample were tested. Data are expressed as mg CO_2-C 100 g^{-1} dry soil.

Basal soil respiration at field capacity (CO_2 production at 22 ^{0}C without addition of glucose) was measured, as reported by Isermayer (1952); by alkali ($Ba(OH)_2.8H_2O + BaCl_2$) absorption of the CO_2 produced during the 24h incubation period, followed by titration of the residual OH^- with standardized hydrochloric acid, after adding three drops of phenolphthalein as an indicator. Three replicates of each sample were tested. Data are expressed as μg CO_2 g^{-1} dry soil.

Statistical Analysis

All data were analyzed using SPSS 11.0 statistical software. Analysis of variance (ANOVA) was performed to compare the means of different doses of sewage sludge-amendment; were significant F-values were obtained. Pearson correlation coefficient and P values were calculated for all possible variable pairs. The asterisks, *, **, and ***, indicate significance at $P < 0.05$, 0.01, and 0.001, respectively.

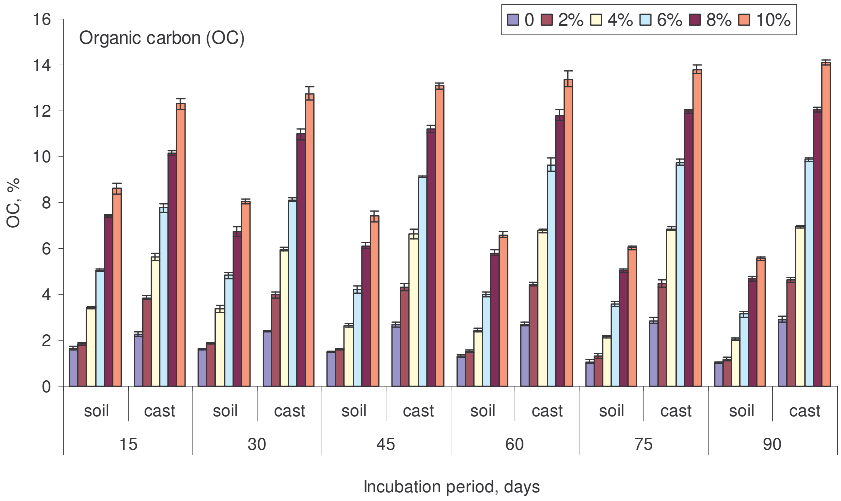
RESULTS

Physical Chemical Properties of Sewage Sludge and the Soil

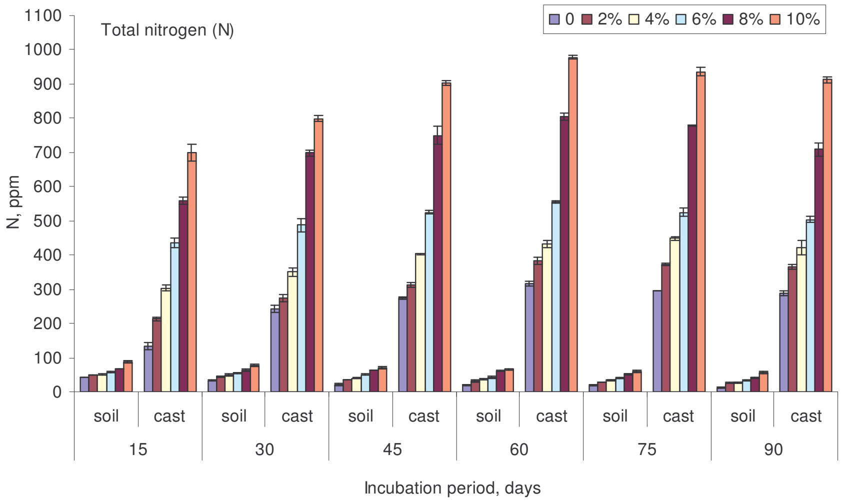
The sewage sludge is composed of approximately 37% weight of oxidable organic matter. The organic fraction comprises 21.2% C and 2.3% N. The pH in water, lime content and C/N ratio were 7.2, 15.8%, and 9.22, respectively. The soil contained 14.1% clay, 10% silt, and 75.9% sand. Soil texture can accordingly be classified as sandy. The pH in water, organic matter content, lime content and C/N ratio were 8.1, 3.29%, 22.5% and 28.1, respectively.

Organic Carbon and Nitrogen Contents in Soil and Casts

The changes of total organic C and total N in earthworm *L.terrestris* casts and surrounding soil during the incubation periods are shown in Figure 1. Organic C and total N in *L.terrestris* casts were generally increased compared to the control treatment at all incubation periods and all sewage sludge doses.



(a)



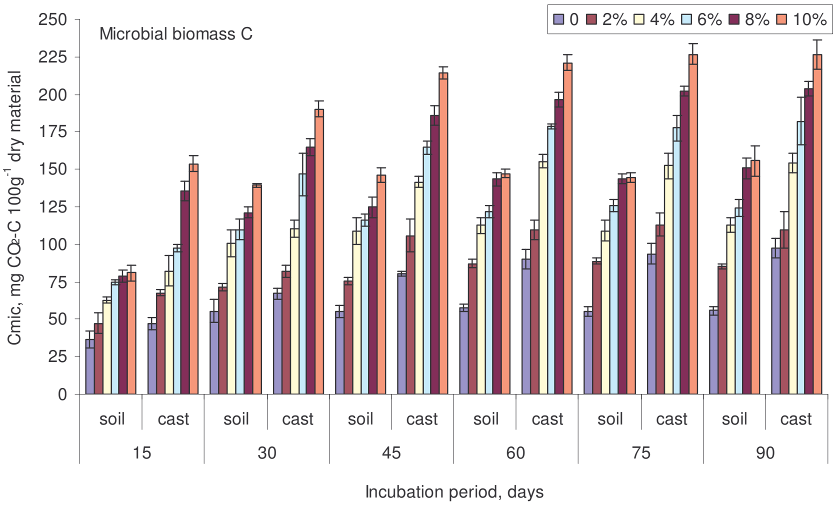
(b)

Figure 1. Changes in C and N of soil amended with sewage sludge during the incubation period. Vertical bars indicate standard error of mean of three replicates at 95 % confidence level
(a) Total organic carbon (b) Total Nitrogen

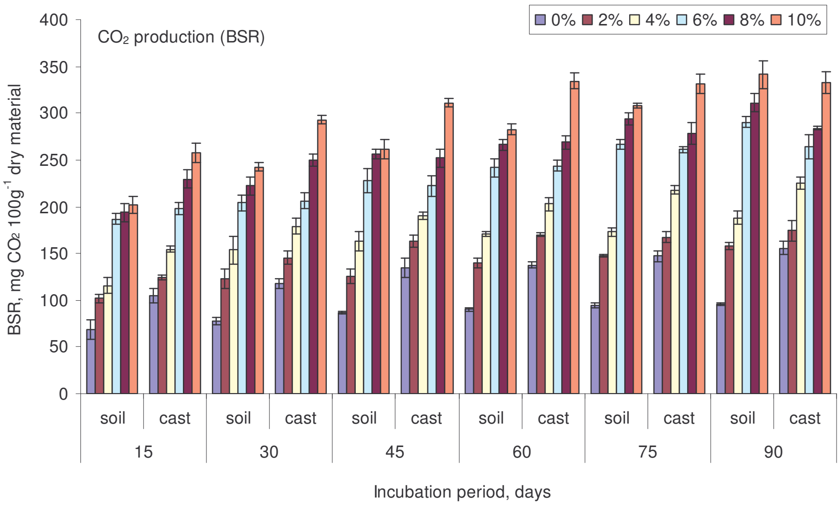
The variations in soil and earthworm casts Organic C and N were statistically significant (Table 1). A marked increase in soil and cast N were found for each increase dose of sewage sludge from 2 to 10%. The highest organic C and total N in soil and casts were obtained with 10% sewage sludge application to soil, and the lowest organic C and total N were found in the control treatment.

Microbial Biomass C and CO_2 Production in Soil and Casts

The changes of microbial biomass C (Cmic) and CO_2 production (BSR) in earthworm *L.terrestris* casts and surrounding soil during the incubation periods are shown in Figure 2.



(a)



(b)

Figure 2. Changes in biomass C and BSR amended with sewage sludge during the incubation period. Vertical bars indicate standard error of mean of three replicates at 95 % confidence level
(a) Microbial biomass carbon (b) CO_2 production

Considerable variations in Cmic and BSR were found for the different doses of sewage sludge and different sampling times. Statistically significant variations were found in C mic and BSR at various application rates. Biological properties were also affected by incubation period. The analysis of variance of the results obtained in our experiment on the periodic sampling times with sewage sludge showed that all factors (sewage sludge doses, incubation periods) significantly influenced Cmic and BSR (Table 1). After sewage sludge addition a rapid and significant increase in Cmic and BSR was observed in sludge amended soils followed by a stable in the Cmic and BSR in soils and earthworm casts. At the end of the incubation, the Cmic and BSR measured in treated soils and casts were statistically different from those measured in the control soils.

Table 1. Analysis of Variance (ANOVA)

	Organic C	Total N	Cmic	BSR
Material (cast or soil)	48381.081***	174410.363***	2440.156***	627.643***
Incubation period (IP)	14.738***	495.510***	458.993***	537.360***
M x IP	736.838***	786.759***	19.288***	13.789***
Sewage sludge doses (D)	20434.538***	8751.207***	1487.319***	3649.125***
M x D	1646.809***	6695.104***	78.806***	74.232***
IP x D	6.326***	17.184***	6.430***	12.011***
M x IP x D	30.927***	16.673***	1.986**	6.948***

DISCUSSION

At the end of this study, It was determined that organic C, N, Cmic and BSR levels increased depending on increasing doses of sewage sludge treatment compared to the control. This situation may be related to the organic matter and nutrient concentrations in sewage sludge.

In some researches it was determined that the sewage sludge application to soil has significantly increased the biological characteristics, nevertheless at the other researches that the sewage sludge application to soil has destructed the biological characteristics (Sastre et al, 1996; Knight et al, 1997; Kızılkaya and Bayraklı, 2004).The differences among the data that to carry in conclusion of studies completely depend on sewage sludge characteristics (organic matter content, C/N ratio, nutrient content etc.) and soil physico-chemical characteristics (Hinesly et al. 1972; Kızılkaya and Bayraklı, 2004). It was determined that organic C, N, Cmic and BSR levels of earthworms casts into both sewage sludge treated and no treated pots is higher than the surrounding soil. Similarly most of the experiments reported that the earthworm casts contain higher level of organic matter and nutrient than soil and thus contain biological characteristics like biomass and BSR at higher levels (Lee and Foster, 1991; Scheu and Parkinson, 1994; Haynes and Fraser, 1998; Kızılkaya and Hepşen, 2004, 2007). Nevertheless, Zhang et al. (2000) determined some earthworm species' casts contain lower level microbial activity. This is due to that some earthworm species feed some microorganisms such as fungal spores and bacteria. In this incubation experiment, organic C, N, Cmic and BSR in cast and soil increased until 30th and 45th days depend on increasing doses of sewage sludge, but there is not a significantly increase after 45th day. This situation probably interests in lack of nutrient sources in order to earthworm feeding (Lee, 1985) and stabilization of biological characteristics in earhworm growing media.

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Characterization of Indigenous *Bacillus* Isolates from Stabilized Sludge in Petrochemical Industry

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ABSTRACT

Bacillus species are rod-shaped, endospore-forming aerobic or facultatively anaerobic, Gram-positive bacteria; in some species cultures may turn Gram-negative with age. The many species of the genus exhibit a wide range of physiologic abilities that allow them to live in every natural environment. The spores are resistant to heat, cold, radiation, desiccation, and disinfectants. *Bacillus* species are used in many medical, pharmaceutical, agricultural, and industrial processes that take advantage of their wide range of physiologic characteristics and their ability to produce a host of enzymes, antibiotics, and other metabolites. Certain *Bacillus* species are important in the natural or artificial degradation of waste products.

We isolated 15 indigenous *Bacillus* isolates from stabilized sludge in petrochemical plant in Serbia (FOV – HIP "Petrohemija", Pancevo) and investigated their morphological and biochemical characteristics, emulsification activity and sensitivity to antibiotics and heavy metals. In addition, we estimated the genetic diversity of isolates by RAPD and rep-PCR.

Three of 15 isolates showed very strong emulsification ability of xylol (E_{24} from 95 to 100). Six isolates showed strong emulsification of mineral oil (E_{24} from 78 to 100). All isolates were tolerant to 100µg/ml of Zn and Co, 10µg/ml of Hg and Mo, while eleven isolates showed tolerance to 10µg/ml of Cd and six isolates to 100µg/ml Hg. Only one isolate was sensitive to trimethoprim (5 µg). All isolates were sensitive to bacitracin (40U), cephalexin (30 µg), clindamycin (2 µg) and neomycin (120µg), while five isolates were resistant to novobiocin (5µg) and two to bacitracin (40U). Based on PCR analysis, we assessed genetic similarity of investigated *Bacillus* isolates.

Key words: *Bacillus* sp., hydrocarbon utilization, heavy metal tolerance, emulsification activity, BOX PCR, RAPD

INTRODUCTION

Safe disposal of oil sludge generated during the processing of crude oil is big problem in petroleum industry and oil refineries. The petroleum hydrocarbons from oil sludge have adverse effects on ecosystem and lead to environmental pollution. Oil sludge is a complex mixture of specific compounds such as alkane, aromatic, asfaltene fraction and heavy metals, and soil contamination may be caused by improper disposal. More than seventy microbial genera contain species able to degrade almost all fractions of hydrocarbons present in oil sludge, but degradation capability depends on many factors (Ryu et al., 2006). Isolation of indigenous microbial population from contaminated site may help the bioremediation process because indigenous microorganisms can degrade specific constituents and have a higher tolerance to toxicity. Soil microorganisms are typically associated with organic fractions of the soil microenvironment and they participate in the metal dynamics typically ascribed to these fractions. Bacteria have a high surface-to-volume ratio and should have a high capacity for sorbing metals from solution (Beveridge, 1988). Metal binding by gram-positive and gram-negative bacterial cell walls has been evaluated (Marquis 1976, Doyle et al., 1980, Beveridge et al., 1985). Soil bacteria utilize and solubilize a variety of hydrocarbons by producing a variety of surface active agents named biosurfactants. Wide spectra of microbial compounds (glycolipids, lipopeptides, fatty acids, polymeric biosurfactants) have been found to have surface activity (Morikawa et al., 2000).

The heavy metals and hydrocarbons from oil sludge act as stress or selection agents and give rise to resistant and even hyper-resistant bacterial populations in the polluted areas. Considering that hydrophobic pollutants present in petroleum hydrocarbons require solubilization before being degraded by microbial cells, it is necessary to select appropriate microorganisms with environmental compatibility. In this work, we assessed the natural abiotic selection leading to resistant microbial population in the contaminated sites and investigated indigenous *Bacillus* (as the most abundant) population in stabilized sludge of HIP "Petrohemija", Pancevo, Serbia. The present study applies commonly used molecular techniques as rep-PCR and RAPD to estimate diversity of this population.

METHODS

Sensitivity of bacterial isolates to six antibiotics was assessed by agar diffusion method with followed antibiotics: novobiocin (5µg), trimethoprim (5 µg), bacitracin (40U), cephalexin (30 µg), clindamycin (2 µg) and neomycin (120µg). The investigated heavy metals were added in nutrient agar (NA) in following concentrations (µg/ml): 10, 20 cadmium sulphate (Cd); 100 cobalt sulphate (Co); 2, 4, 10, 15, 20 mercuric chloride (Hg); 100 zinc sulphate (Zn) and 50 sodium molybdate dihydrate (Mo). Substrate utilization of hydrocarbons was tested as described by Toledo et al. (2006). Biopolymer production and emulsification ability of xylole, toluene and mineral oil was carried out as described by Cooper and Paddock (1983). rep-PCR analysis using BOX type $(GTG)_5$ primer was performed as recommended by de Bruijn (1992), while RAPD analysis was done according to Dooley et al. (1993). Similarity was estimated by means of the simple matching coefficient (*S*SM) and clustering was based on the unweighted pair group arithmetic average-linkage algorithm (STATISTICA 7 software).

RESULTS and DISCUSION

In situ bioremediation using indigenous microorganisms is the most widely used technique for decontamination of affected sites, and reintroduction of indigenous isolates after enrichment is frequently used for this process (Mishra et al., 2001). We have isolated indigenous population of bacteria from stabilized sludge and polluted soil, for characterization and selection of isolates for possible use in bioremediation process.

Bacillus population was the most abundant, with 15 of 25 isolates, and it was compared with two strains previously isolated from oil polluted soil (BZi1 and BZi2). All isolates showed high sensitivity to applied concentrations of antibiotics, except to trimethoprim. All isolates were sensitive to cephalexin (30 μg), clindamycin (2 μg) and neomycin (120μg), while five isolates were resistant to 5μg novobiocin (BZi1, BZi2, 5B, 6B and 8B). Only one isolate was sensitive (BZi2) to 5 μg trimethoprim. Isolates BZi1 and 6B showed intermediate sensitivity to 40U bacitracin and 5 μg trimethoprim.

Tested *Bacillus* isolates were tolerant to 50 μg/ml Mo, 100 μg/ml Zn and Co, except isolate 10B. Isolate 17B was sensitive to 10 μg/ml Cd, while other isolates grew well on this concentration, but showed differences on 20 μg/ml Cd (Table 1.). All isolates showed tolerance to 2 μg/ml Hg. Nine isolates were tolerant to 4 and 10 μg/ml Hg, while 7 showed tolerance to 15 and 20 μg/ml Hg. Results showing significant differences in tolerance of isolates to heavy metals are presented in Table 1.

Isolate	heavy metals (μg/ml)			substrate utilization				emulsification activity (E_{24})		
	Hg 10	Hg 20	Cd 20	toluene 1%	xylole 1%	mineral oil 0,5%	crude oil 0,5%	toluene	xylole	mineral oil
BZi1	-	-	-	-	+	+	+	74.42	62.50	78.05
BZi2	-	-	-	-	-	+	-	67.44	65.00	89.74
5B	+	+	+	±	-	+	±	90.30	75.61	80.03
6B	+	+	+	+	±	+	±	97.62	95.12	80.49
7B	+	+	+	±	±	+	±	97.67	82.50	78.05
8B	+	-	+	±	±	+	±	95.35	97.56	75.61
9B	-	-	-	±	±	-	+	95.45	98.12	78.05
10B	-	-	-	±	-	-	-	88.10	49.98	78.51
11B	-	-	±	±	±	-	-	nd	71.00	99.80
12B	+	+	-	+	+	+	+	97.67	73.17	87.50
15B	+	-	+	-	-	+	+	78.05	58.54	85.71
16B	-	-	-	-	-	-	±	64.29	58.62	85.37
17B	-	-	-	±	-	-	±	71.43	78.05	88.10
18B	±	±	+	+	+	+	+	45.45	85.37	78.05
19B	±	-	+	+	+	+	+	90.70	85.00	99.12
23B	-	-	-	+	+	+	+	90.48	65.00	92.68
25B	+	-	+	-	±	-	-	57.14	65.00	73.14

(-) no growth; (±) poor growth; (+) good growth; (nd) not detected

Table 1. Substrate utilization, emulsification activity and heavy metal tolerance of *Bacillus sp.* isolates

Fourteen tested *Bacillus* isolates from stabilized sludge and two from oil-polluted soil showed multiple tolerances to heavy metals. Obtained results were in agreement with several previous reports (Silver and Phung, 1996). Bacteria have developed a variety of resistance mechanisms to counteract heavy metal stress. These mechanisms include the formation and sequestration of heavy metals in complexes, reduction of a metal to a less toxic species, and direct efflux of a metal out of the cell. In bacteria, efflux systems are a more common resistance mechanism for dealing with heavy metals. One type of efflux systems found in gram-positive bacteria pumps out Cd^{2+} and Zn^{2+} by using a phospho-aspartate intermediate (Nies, 1999, Outten et al., 2000) and enables multiple tolerances.

Utilization of toluene, xylole, mineral and crude oil as a sole carboin source added to Bushnell-Hass (BH) medium is shown in Table 1. Four isolates exhibited abundant growth on all substrates, three isolates grew on all substrates but with different efficiency, and two isolates could utilize only three substrates. Four isolates grew only on one substrate. Growth of different *Bacillus* strains in the presence of different PAHs was previously reported by Hubert et al., (1999), Baldwin et al (2000), Barathi et al., (2001) and Toledo et al. (2006). *B. macroides* strain exhibited a degradation ability of mixed hydrocarbon consisting of benzene, toluene and xylole, while *B. pseudomegaterium* degraded mixture of toluene and naphthalene (Green et al., 2000).

Hydrophobic pollutants present in petroleum hydrocarbon require solubilization before being degraded by microbial cells. Many bacteria produce extracellular compounds that can emulsify or disperse this phase and make it available for utilization. Some *Bacillus subtilis* strains produced high yields of active surfactant when the growth medium contained a hydrocarbon as only carbon sources, while *Corynebacterium fascians* was able to stabilize emulsions of water and hydrocarbons even if grown on medium which did not contain hydrocarbon (Cooper and Paddock, 1983). In our investigation, we tested emulsification activity of soluble extracellular agents from cell-free broth as recommended by Cooper and Paddock (1983). E_{24} index (percent of emulsified volume after 24h) ranged from 45.45 to 97.67 for toluene, 49.98- 98.12 for xylole and 73.14 to 99.80 for mineral oil. Isolates from polluted soil had significantly lower index then many isolates from stabilized sludge. Many isolates showed very high emulsification activity on all investigated substrates (5B, 6B, 7B, 8B, 9B, 12B, 19B, 23B) and were also able to utilize them. Similar results for emulsification activity of *B.subtilis* strains were described by Toledo et al., (2006): 65.6 on xylole, 70 on toluene, 42.6 on mineral oil and 75.9 on crude oil. Our isolate 11B showed almost 100% emulsification of mineral oil, but wasn't able to degrade it. Contrary to conventional arguments that microbial emulsifiers are produced solely to facilitate the uptake of water-insoluble substrates, Cooper and Paddock (1983) described the yeast strain *Torulopsis petrophylum* effective at generating surface-active agents, but without possibility to uptake hydrocarbons. The complex physiological roles of biosurfactants (bacterial motility, signaling, differentiation, biofilm formation, toxicity) and roles in bioremediation were reviewed by Van Hame et al. (2003).

Repetitive sequence-based PCR (rep-PCR) genomic fingerprinting is used for species and strain specific fingerprinting of different bacteria (Versalovic et al., 1994; Laguerre et al. 1996; Jussila et al., 2006). DNA primers corresponding to BOX elements sequences and repetitive trinucleotide $(GTG)_5$ as one of them were the most useful methods for monitoring the diversity of culturable bacteria during in situ bioremediation (Jussila et al., 2006). In our investigation, $(GTG)_5$-PCR produced clear and well-separated fingerprints consisting of short and long PCR products in most of the isolates (Figure 1). Results derived from $(GTG)_5$ -genotyping are presented as dendrogram in Figure 2. One group of isolates (9B, 10B, 12B and 18B) showed only small-size bands and clustered separately with 75% dissimilarity from the other cluster. The similarity level in second cluster varied from 42 (isolate 25B) to 100% (isolates 5B and 8B; 16B and 17B). Isolates from polluted soil were distinguished into two subclusters: BZi1 isolates was in one cluster with 67% similarity to 19B and 23B, while BZi2 isolate was in the second cluster and showed lower similarity (58%) to subgroup of 8 (71% similar) isolates.

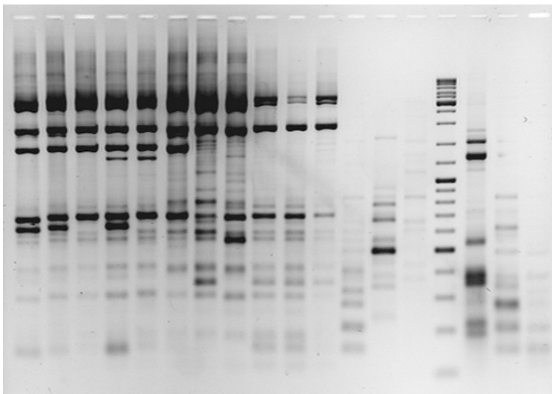

Figure 1. $(GTG)_5$ -PCR fingerprinting of some *Bacillus* isolates from stabilized sludge in petrochemical plant in Serbia (lane 1-5: **5B; 8B; 7B; 6B; 15B;** lane 9-11: **16B; 17B; 11B;** lane 16-18: **25B; 19B; 23B**, respectively) and from polluted soil (lane 12: **BZi1**; lane 14: **BZi2**). Lane 15: Molecular marker GeneRuler DNA Ladder mix SM0331 (Fermentas)

To confirm that isolates 5B and 8B, and 16B and 17B are genetically identical as obtained by $(GTG)_5$ -genotyping, we used additional PCR methods- Random Amplified Polymorphic DNA (RAPD) fingerprinting. This method has already been used to differentiate several related species and strains of bacteria (Nakamura, 2000) and closely related *Bacillus sphaericus* strains (Woodburn et al., 1995). Results of RAPD analysis of fifteen sludge isolates and two isolates from polluted soil using SPH1 primer are shown on Figure 3.

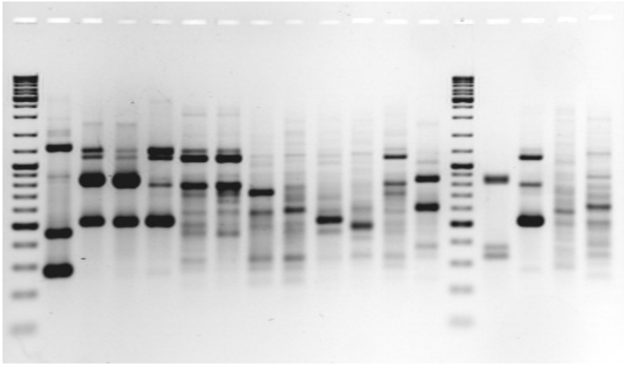

Figure 3. RAPD fingerprinting of some *Bacillus* isolates from stabilized sludge in petrochemical plant in Serbia (lane 3-8: **5B; 8B; 6B; 16B; 17B; 9B;** lane 10-13: **7B; 10B; 11B; 12B;** lane 15-18: **14B; 15B; 18B; 19B** , respectively) and from polluted soil (lane 2: **BZi2**; lane 9: **BZi1**). Lane 1 and 14: Molecular marker GeneRuler DNA Ladder mix SM0331 (Fermentas)

Isolates were grouped in tree clusters with 55 and 67% similarity between clusters (Figure 4.). Isolates 23B and 25B formed one cluster (45% differences) that was distant from all other isolates (72%). The level of similarity for isolates in the other two clusters ranged from 67 to 94%.

Genetic identity between isolates 5B and 8B was confirmed by RAPD analysis. Isolates 16B and 17B, identical by $(GTG)_5$ -genotyping, showed very high similarity level (94%) by RAPD, but were not identical. These isolates also exhibited differences in toluene utilization and very small differences in emulsification activity. In contrary, isolates 5B and 8B, genotypically identical, showed different tolerances on 20 µg/ml Hg and utilization and emulsification of xylole. It might be necessary to apply more then one RAPD primer to confirm genetic identity of these isolates.

The grouping results derived from two PCR methods were generally in good agreement. Group of isolates (5B, 8B, 6B and 11B) showed 67% similarity by SPH1 and 71% by $(GTG)_5$ primer. Isolates 9B, 10B and 18B also clustered together with both primers, while isolates 25B, 12B, 23B, BZi1 and BZi2 grouped differently. These results are comparable to data reported by Jussila et al. (2005) which grouped 5 *B. macroides* strains in 3 groups by $(GTG)_5$ genotype, and Woodburn et al. (1995) with 15 to 84% similarity levels of *B. sphaericus* isolates assessed by RAPD method.

Characterization of *Bacillus* isolates obtained by using two different primers, different substrate utilization and emulsification ability, and sensitivity to heavy metals, represents the first step towards selection of the most tolerant and active isolates for future bioremediation applications.

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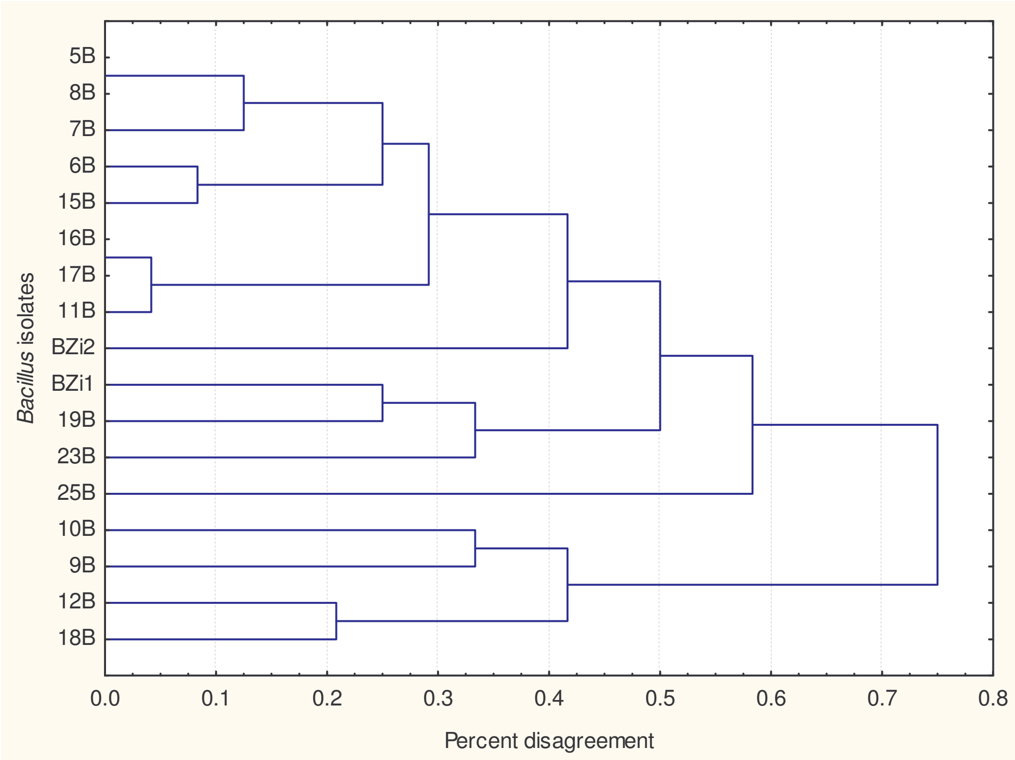

Figure 2. Dendrogram of $(GTG)_5$ -PCR fingerprinting of *Bacillus* isolates from stabilized sludge in petrochemical plant in Serbia and from polluted soil (BZi1 and BZi2)

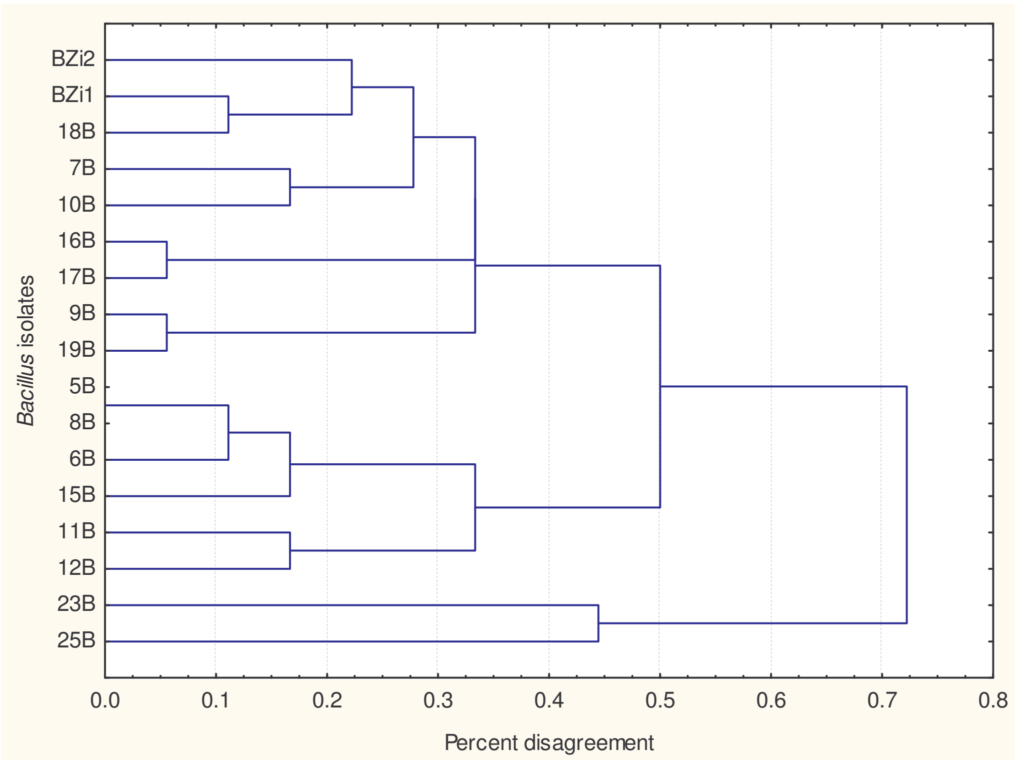

Figure 4. Dendrogram of RAPD fingerprinting of *Bacillus* isolates from stabilized sludge in petrochemical plant in Serbia and from polluted soil (BZi1 and BZi2)

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RAPD Fingerprinting of Indigenous *Lysinibacillus fusiformis* Isolates from Stabilized Sludge and Oil-Polluted Soil

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ABSTRACT

The *Lysinibacillus* group are motile Gram-positive bacilli, with oval or spherical spores, oxidase and catalase positive, not grouped in strict chains, with strictly oxidative metabolism and very similar to *Bacillus sphericus* group.

Two indigenous isolates of *Lysinibacillus fusiformis* from oil-polluted soil near gas station and stabilized sludge from petrochemical plant in Serbia (FOV – HIP "Petrohemija", Pancevo) were tested on IAR and HMT and showed high sensitivity to neomycin, cephalexin and bacitracin, and were resistant to trimethoprim. Both isolates were tolerant to 100µg/ml of Zn and Co, 10µg/ml of Mo, but they differed in tolerance to 20µg/ml of Cd and 10µg/ml of Hg. The isolate from stabilized sludge showed moderate emulsification ability of xylol (E_{24} 65.8) and mineral oil (E_{24} 75.6). The isolate from oil-polluted soil showed very strong emulsification ability of xylol (E_{24} 87.2) and moderate of mineral oil (E_{24} 72.7). RAPD fingerprinting showed clear differences between the two *Lysinibacillus fusiformis* isolates.

Keywords: *Lysinibacillus fusiformis*, polluted soil, sludge, heavy metals, emulsification ability, RAPD fingerprinting

INTRODUCTION

Mesophilic, strictly aerobic, spore-forming bacilli that are capable of producing spherical endospores have been designated *Bacillus sphaericus*. These bacteria metabolize a variety of organic and amino acids but cannot metabolize sugars, leading to negative results for many of the traditional phenotypic tests used in the classification of members of the genus *Bacillus* (Baumann et al., 1991). The diversity of these bacteria was demonstrated by Krych et al. (1980), who identified five distinct DNA homology groups among the 50 strains using DNA hybridization techniques. Strains belonging to DNA homology group IIA are of particular interest as pathogenic for the larvae of certain species of mosquitoes. The homology IIB group consists of nonpathogenic strains that exhibit 60 to 66% homology with the group IIA reference strain. In a study of 91 *B. sphaericus* strains in which 155 phenotypic tests were used, strains belonging to homology group IIA clustered with strains belonging to homology group IIB at a Jaccard similarity level of 85.5%. In 1988, Priest et al. described species *Bacillus fusiformis,* which is homologue to IIB group according to Krych. Urea-hydrolysing capability of *Bacillus fusiformis* differentiated it from *B. sphaericus*. Later studies based on random amplified polymorphic DNA (RAPD) probing (Woodburn *et al.*, 1995) and ribosomal gene restriction fragment length polymorphism (RFLP) analyses (Aquino de Muro *et al.*, 1992) confirmed the separate groupings. Phylogenetic analysis based on 16S rDNA sequences from 58 *B. sphaericus* strains Nakamura (2000) was used to examine the genetic heterogeneity of the taxon. Data showed that *B. sphaericus* was genetically and phenotypically a highly heterogeneous taxon comprised of at least seven genetically distinct taxa, one of which encompassed *B. sphaericus* insect-pathogenic strains and another *B. fusiformis*.

Lysinibacillus fusiformis is described by Ahmed et al. (2007) as spore-forming, Gram-positive, motile, rod-shaped and boron-tolerant (up to 150 mM boron) bacterium isolated from soil, which can tolerate 5 % (w/v) NaCl and has growth range 16–45 °C and pH range pH 5.5–9.5. In contrast to the type species of the genus *Bacillus*, *Lysinibacillus fusiformis* strains contain peptidoglycan with lysine, aspartic acid, alanine and glutamic acid. Comparative analysis of the 16S rRNA gene sequence demonstrated that isolated *Lysinibacillus fusiformis* strains were closely related to *Bacillus fusiformis* DSM 2898^T (97.2 % similarity) and *Bacillus sphaericus* DSM 28^T (96.9 %). DNA–DNA relatedness was greater than 97 % among three isolated strains and 61.1 % with *B. fusiformis* DSM 2898^T and 43.2 % with *B. sphaericus* IAM 13420^T. Based on the distinctive peptidoglycan composition, phylogenetic analyses and physiology, the strains were assigned to a novel species within a new genus, for which the name *Lysinibacillus boronitolerans* gen. nov., sp. nov. was proposed. It was also proposed that *Bacillus fusiformis* and *Bacillus sphaericus* be transferred to this genus as *Lysinibacillus fusiformis* comb. nov. and *Lysinibacillus sphaericus* comb. nov., respectively (Ahmed et al., 2007).

The aim of this study was to characterize and compare the two *Lysinibacillus fusiformis* strains indigenous to oil-polluted soil and stabilized sludge from petrochemical plant in Serbia.

METHODS

Indigenous isolates of *Lysinibacillus fusiformis* from oil-polluted soil (marked BZi) near gas station (BZi4) and stabilized sludge (BMi) from petrochemical plant in Serbia (FOV – HIP "Petrohemija", Pancevo) (BMi3) and *Bacillus sp.* isolates, BMi 9 and BMi12, were tested and compared to isolates BZi1 from oil-polluted soil near gas station, previously identified as *Bacillus sp*. The isolates were collected by the Institute of Soil Science, Belgrade, Serbia. Working stock cultures were incubated at 28 °C on nutrient agar amended with 5 mg $MnSO_4$x $2H_2O$ until sporulation occurred and then stored at 4 °C. Isolates were tested on nutrient agar (NA) supplemented with different antibiotics: novobiocin, neomycin, cephalexin, bacitracin, trimethoprim and clindamycin. Isolates were tested to 100 and 200µg/ml of Zn and Co, 10and 50µg/ml of Mo, 4,10 and 12 µg/ml of Hg and 20µg/ml of Cd added to NA. Emulsification ability of xylole, toluene and mineral oil was assessed as described by Cooper and Paddock (1983). Substrate utilization was tested on BH medium with 1% of toluene and xylole and 0.5% mineral and crude oil (Toledo et al., 2006). RAPD analysis was performed as recommended by Dooley et al. (1993). Similarity was estimated by means of the simple matching coefficient (*S*SM) and clustering was based on the unweighted pair group arithmetic average-linkage algorithm (STATISTICA 7 software).

RESULTS and DISCUSION

Two indigenous *Lysinibacillus fusiformis* isolates from stabilized sludge (BMi3) and oil polluted soil (BZi4) were assessed for antibiotic resistance and heavy metal tolerance and compared to *Bacillus sp*. (BMi9 and BMi12) from stabilized sludge and *Bacillus thurangiensis* (BZi1) from polluted soil. The results are summarized in Table 1. Isolate BMi3 was more sensitive to novobiocin and bacitracin than other isolates, except for BZi1 which was very sensitive to all investigated antibiotics. BMi3 isolate was tolerant to Cd (20 µg/ml), but showed low tolerance to Mo, Zn, Co and Hg. Isolates BZi4, BMi9 and BMi12 showed high tolerance to heavy metals, especially BMi12, which was tolerant to Hg 12 µg/ml.

Isolate	antibiotic (µg/ml)						heavy metal (µg/ml)						
	Nov 5	Clin 2	Neo 120	Bac 40U	Ceph 30	Tmp 5	Mo 50	Zn 200	Cd 10	Cd 20	Co 200	Hg 2	Hg 10
BMi3	S	I	S	S	S	R	-	-	+	+	-	+	-*
BZi4	I	S	S	I	S	R	+	+	+	-	+	+	+
BZi1	S	S	S	S	S	I	+	+	+	-	+	+	+
BMi9	R	S	S	I	S	R	+	+	+	-	+	+	+
BMi12	R	S	S	I	S	R	+	+	+	-	+	+	+**

-* - isolate sensitive to 4 µg/ml Hg; +**- isolate tolerant to Hg 12 µg/ml
R- resistant, S- sensitive, I- intermediate

Table1. Antibiotic resistance and heavy metal tolerance of *Lysinibacillus fusiformis* and *Bacillus sp.* isolates

Isolate	substrate utilization				emulsification activity		
	toluene 1%	xylole 1%	mineral oil 0,5%	crude oil 0,5%	toluene	xylole	mineral oil
BMi3	+	+	-	-	75.64	65.79	75.61
BZi4	+	±	-	±	92.68	87.18	72.74
BZi1	-	+	+	+	74.42	62.50	78.25
BMi9	±	±	±	+	95.45	99.72	78.40
BMi12	+	+	+	+	97.67	83.82	89.62

Table2. Substrate utilization and emulsification activity of *Lysinibacillus fusiformis* and *Bacillus sp.* isolates

Large number of *Bacillus* strains, including *B. fusiformis*, capable of degrading different hydrocarbons have been isolated from oil-contaminated soils (Bento et al., 2003). Our investigation showed no growth of isolate BZi1 on toluene, but good growth on other substrates (Table 2). None of *Lysinibacillus fusiformis* isolates were able to grow on mineral oil as only source of carbon, while isolate BZi4 grew poorly on crude oil and xylole and well on toluene. *Bacillus sp*. isolate BMi9 grew poorly on all substrates except crude oil, while BMi12 showed ability to utilize all examined substrates.

Microorganisms growing on hydrocarbons frequently produce biopolymers with emulsifying or surfactant activity (Ron and Rosenberg, 2002), that can facilitate the availability of hydrophobic substrates. Emulsifying biopolimers can stimulate growth of hydrocarbon degrading bacteria and improve their ability to utilize these compounds (Toledo et al., 2006). In this study, the capacity of isolates to produce extracellular biopolymers with bioemulsifier activities was assayed. Emulsification activity of *Lysinibacillus fusiformis* isolate BMi3 ranged from 65.79 (xylole) to 75.64 (toluene), and it was lower for BZi4 isolate (72.74 for mineral oil and 92.68 for toluene). Isolate BZi1 from polluted soil was the least effective, while *Bacillus sp.* isolates BMi9 and BMi12 from activated sludge were highly effective in emulsification, especially BMi9 on xylole (99.72) and BMi12 on toluene (97.67). Previous reports on different microorganisms showed variable values of emulsification of hydrocarbon by cell-free broth after 24h: 10-70 *Torulopsis petrophilum* (Cooper and Paddock, 1983), 25-68 *Bacillus sp*. IAF343 and 70 *B.cereus* on pH 2-7 (Cooper and Goldenberg, 1987). E_{24} value for *Lysinibacillus fusiformis* isolates from this work were similar to previously reported, except for BZi4 isolate on toluole as investigated solvent that showed higher emulsification values. The two *Bacillus sp.* isolates from stabilized sludge investigated in this work also showed high emulsification activity, suggesting that they produced high amount of biopolymers that act as good emulsion stabilizers.

The RAPD method is very useful in fingerprinting of bacteria because previous sequence information is not necessary (Williams et al., 1990). Woodburn et al. (1995) used the ability of RAPD fingerprinting data to indicate heterogeneity within the *B. sphaericus* isolates. RAPD analysis in this work was performed to confirm differences between two *Lysinibacillus fusiformis* isolates and to determine genetic distance of investigated isolates. Results of genotypic analysis (Figure 1) and similarity level are shown as dendrogram in Figure 2.

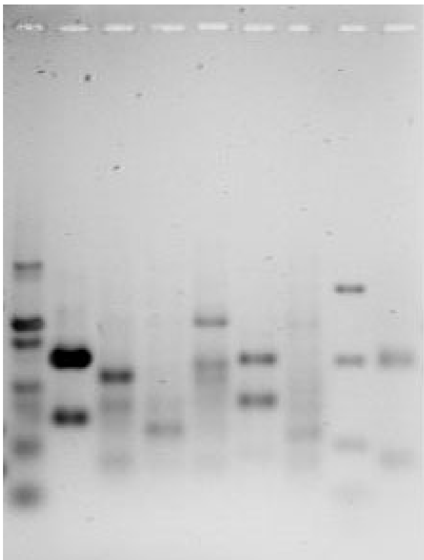

Figure 1. RAPD band patterns generated by using SPH1 primer and DNAs from indigenous *Lysinibacillus fusiformis* (lane 1- BMi3 and lane 2- BZi 4) and *Bacillus sp.* isolates (lane 3- BMi9; lane 6- BMi12 ;lane 9- BZi1). Marker: lane 8 -FastRuler Low Range DNA Ladder SM1103 (Fermentas) with 1500; 850; 400 and 200 bp bands

The results of RAPD fingerprinting support the results of phenotypic analysis that two *L. fusiformis* isolates are quite different. The similarity level between them obtained with SPH1 primer was only 30%. *Bacillus sp*. isolates formed a cluster with 78% of similarity. BZi4 isolate showed highest similarity level to *Bacillus* group, then to *Lysinibacillus fusiformis* BMi3. Anandkumar and Maruthamuthu (2008) who investigated manganese oxidizing strains from orthodontic wires by 16S rRNA sequencing, described two *Lysinibacillus boronitolerans* strains that were phylogenetically diverse from *Lysinibacilus fusiformis* strain.

Genotypic and phenotypic analysis showed significant differences between two *Lysinibacillus fusiformis* isolates investigated in this study. Ability to tolerate heavy metals, to grow on toluene, and to produce a biopolymer with high emulsification activity gives the isolate BZi4 potential for use in bioremediation process. *Bacillus* isolates BMi9 and BMi12 could also potentially be used in bioremediation.

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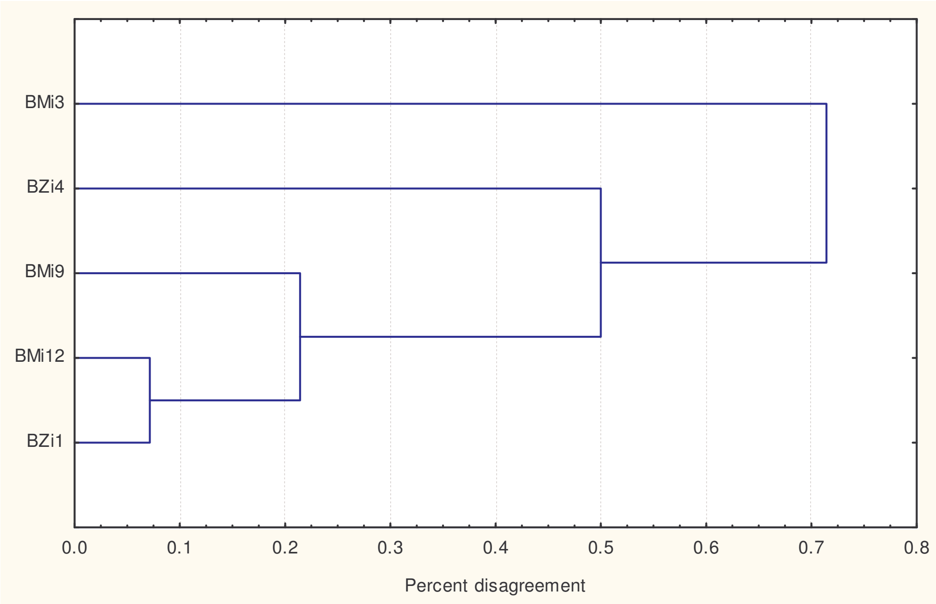

Figure 2. Dendrogram of RAPD generated by SPH1 primer on *Lysinibacillus fusiformis* and *Bacillus sp.* isolates

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Modeling Phytoextraction of Heavy Metals at Multiply Contaminated Soils with Hyperaccumulator Plants

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ABSTRACT

Soils and waters contaminated with heavy metals pose a major environmental and human health problem that needs an effective and affordable technological solution. Phytoextraction offers a reasonable technology which uses plants to extract the heavy metals from soils. However, the effectiveness of this new method needs to be demonstrated by means of mathematical modeling. The phytoextraction models also are needed to manage the contaminated soils. A thorough literature review indicates that very few models have yet been developed for phytoextraction due to complexities involved within the soil-water-chemicals-plant system, even for a single metal contamination in the laboratory scale. Furthermore, the complexity increases in the field scale problems where the soils are multi-contaminated and also are with high heterogeneity involved in soil physico-chemical properties. On the other hand, in the case of hyperaccumulator plants there are a great deal of data spread worldwide because of the attentions that have been made to test the phytoextration technology in the last years. Consequently, analysis of the existing database of measured phytoextraction data for hyperaccumulators may result in simple models. The objective of this study was to develop a simple model for phytoextraction of heavy metals at multi-contaminated soils. The more preferable input parameters to derive the phytoextraction models were selected by reviewing the literature. Using the published data of Cd and Zn phytoextraction with *Thlaspi caerulescens*, some reasonable models were derived. The model calculations suggest that phytoextraction using *T. caerulescens* is not feasible even when the soil is only moderately contaminated with both Cd and Zn.

Keywords: Heavy Metal, Hyperaccumulator, Modeling, Multi-Contaminated Soils, Phytoextraction

INTRODUCTION

Soil pollution has recently been attracting considerable public attention since the magnitude of the problem in our soils calls for immediate action (Garbisu and Alkorta, 2003). Soils may be polluted by a wide range of contaminants from industrial activities, sewage sludge disposal, agricultural inputs, mining, metal processing, and energy production. Among these contaminants, heavy metals are primarily a concern because of their immutable nature (Garbisu and Alkorta, 2003).

Soils contaminated with heavy metals create major environmental and human health problems that need effective and affordable technological solutions. More often, conventional remediation approaches that mostly resort to excavation and either landfilling or soil washing followed by physical or chemical separation of the contaminants are both expensive and intrusive to the ecosystem. Phytoextraction has been proposed as a suitable alternative to those destructive and high-cost engineer-based techniques. It involves growing plants that hyperaccumulate heavy metals on contaminated sites, harvesting the plants, recycling the biomass both for energy and metal, or disposing of them as hazardous waste (Cunningham et al., 1995). While the cost of conventional remediation methods range from \$10 to \$1000 m^{-3} of treated soil material, phytoextraction is estimated to cost about \$0.05 m^{-3} of treated soil material (Cunningham et al., 1997). Although phytoextraction offers cost advantages and is comparable to in situ bioremediation and natural attenuation, but the trade off is the time needed to achieve the treatment. Furthermore, the technology has not been demonstrated conclusively at many sites to date, and it remains to be seen if it is effective at full scale. Therefore, mathematical or statistical modeling is necessary to demonstrate the effectiveness of the technology to regulatory agencies. Phytoextraction models also could be used to calculate the time needed to soil remediation, economical assessment of biomass recycling for metals, and to manage the contaminated soils.

A thorough literature review indicates that very few models have yet been developed for phytextraction due to the complexities involved within the soil-water-chemicals-plant system. Plant uptake models that originally have been developed for nutrients are well established for the supply of solutes from soils (Barber, 1995; Tinker and Nye, 2000), have been used to provide a quantitative knowledge of the effect of the plant on metal concentrations in adjacent soil (Whiting et al., 2003; Mullins and Sommers, 1986; Adhikari and Rattan, 2000; Schnepf, 2002; Lehto et al., 2006). Plant uptake models have evolved from simple diffusion and mass flow based models (Bouldin, 1961; Barber and Cushman, 1981; Olsen et al., 1962; Lehto et al., 2006) to more complex models that incorporate quantifiable processes in the rhizosphere for both nutrients and even for heavy metals (Barber and Cushman, 1981; Kirk et al., 1999, Puschenreiter et al., 2005; Klepsh et al., 2006). A list of these models and two samples of their mathematical equations have been published in Lehto et al. (2006). Although, this modeling has been useful in quantitative understanding the relevant rhizosphere processes, however, as they have not consider the plant yield changes as a result of soil metal concentration, they are of less help in management uses. Furthermore, the soil/plant-oriented parameters in the models are somehow hard and time-consume to be measured immediately for urgent management needs.

Attempts have been made, so far, to developed a model for coupled transport of water, heat, and solutes in the soil–plant–atmosphere continuum (Boersma et al., 1988a,b and 1991; Lindstrom et al., 1990) or to simulate uptake of contaminants into plants (Trapp and McFarlane, 1995) and also for Pb and Cd uptake in agricultural lands (Jorgensen, 1988). However, most of these models are to predict the nutrient uptake or to predict the contamination of agricultural products and there are just a few simulation models for phytoremediation process. Although the current realistic or mechanistic simulation models almost exclusively discuss uptake of minerals or metals (Silberbush, 1996; Rengel, 1993), but for the purpose of phytoextraction the mechanistic models are not well developed and the realistic models are not reasonably efficient (Tudoreanul and Phillips, 2004).

Zhao et al. (2003) assessed the potential for Zn and Cd phytoextraction by *Thlaspi caerulescens*. They provided some regression models to predict the shoot concentration and bioaccumulation factor of Zn and Cd with soil total concentration of the metals. They assumed the potential for phytoextraction to be dependent on plant biomass, the bioaccumulation factor and the soil mass that requires remediation. Assuming the average yield of the plant to be 5 (an achievable average biomass with optimized agronomic inputs) and 10 (an ideal average biomass expected to be achieved by plant breeding) t ha^{-1}, they calculated the number of crops needed to achieve the remediation targets. But, they did not consider the effect of heavy metal stress and also the other soil parameters on the plant biomass yield and plant metal uptake and the model does not suit the multi-contaminated soils.

Yanai et al. (2006) investigated the effect of soil characteristics on Cd uptake by *T. caerulescens.* They provided some regression equations to predict the Cd and Zn concentration of shoots and their uptake by the plant based on the total soil Cd or Zn concentration and some other soil parameters, such as pH, OC and soil clay content. However, the models were not aimed in phytoextrction at multi-contaminated soils. Furthermore, they did not consider the possible effect of other metals on the uptake of metal of interest by plant.

In spite of all the attempts have been made to develop a phytoextraction model, so far, there is no model to serve reasonably for multi- and even for single-contaminated soils. Indeed, the high-variable nature of soil physico-chemical properties prevents scientists to develop a general phytoextraction model for soils. However, due to the fact that in the two last decades a great concerns have been made to assess the potential phytoextraction of multi-contaminated soils in field trials with hyperaccumulator plants, there are a great deal of data for these kind of plants spread worldwide (e.g. Hammer and Keller, 2003, Zhao et al. 2003, Yanai et al., 2006, Kaysar et al, 2000, Felix, 1997). Therefore, as an alternative for other modeling approaches it is rewarding to analyze the existing database of measured phytoextraction data in multi-contaminated soils to derive some simple regression models. These models will quantify the relationships between available and missing phytoextraction data. The models will finally translate data *we have* to data *we need*. However, to derive such models it is necessary to overcome the problem of selecting more preferable or necessary input parameters which are needed to be included in a heavy metal phytoextraction model.

Soil properties have a large influence on metal bioavailability to plants. Matter of fact, the metal uptake by plants and the magnitude of stress expected to be risen from a given metal is dependent on a fraction of the total concentration of metal exists in the soil solution, more commonly known as bioavailable concentration, rather than the total soil metal concentration. However, neglecting the difficulties associated with detecting the metal available fraction in the soil, it is not a routine parameter to measure in the phytoextraction experiments and also it may be determined by different methods. On the other hand, the soil total metal concentration is not only available more readily in the publications but also the methods to its measurements are more unique.

In the soil, metals undergo reactions with ligands in soil solution and with surface sites on the solid material. Metal sorption to the solid matrix results in a reduction in the dissolved concentration of metal and this affects the overall rate of metal availability to plants. For a given soil, the soluble and adsorbed contaminants are related by the soil sorption distribution coefficient K_{SD}. For a particular metal, K_{SD} values in soil are dependent upon various geochemical characteristics of the soil and its pore-water. The main soil characteristics which affect the K_{SD} are soil pH and organic carbon content (Drgryes et al., 2006).

Soil pH significantly influences heavy metal concentrations in both soil and plant tissues. The effect of soil pH on mobility of heavy metals is a well-researched topic (Cataldo *et al.* 1981; Chen *et al.* 1997; Peles *et al.* 1998; Li and Wu 1999). Robinson et al. (1998) found an inverse correlation between plant metal content and soil pH. Brown et al. (1994) found the soil pH as a major factor controlling heavy metal bioavailability in soil, so that decreasing the soil pH increases the uptake of Zn by *T. caerulescens*. As the soil pH decreases, metals are desorbed from organic and clay particles, enter the soil solution and, become more mobile (Li and Wu 1999). When the pH is higher (i.e., >7), metals remain adsorbed and what metals in solution precipitate out in the form of salts (Chen *et al.* 1997). Variability in pH also affects the amount of Cd assimilated by the plant. John and VanLaerhoven (1972) showed that higher pH resulted in lower Cd uptake. Peles *et al.* (1998) concluded that the addition of lime to contaminated soils (essentially increasing the pH) decreased the uptake of heavy metals. However, increased levels of soil soluble Cd in low pH soils may adversely affect plant development, led to low total uptake of metal at low pHs. Khan and Frankland (1983) reported that extremely high concentrations (180 $\mu g\ g^{-1}$) of Cd in soil adversely affected plant development. Increasing in heavy metal uptake by plants will also led to trace metal deficiencies in plants (Khan and Frankland 1983) that may decreases the plant yield production. Furthermore, increased levels of Ca^{2+} (as in high ph soils) can decrease the amount of Cd that is assimilated by plants (Larlson *et al.* 2000). A higher affinity for the essential trace metal Ca results in the decreased uptake of Cd into the plant.

Yanai et al. (2006) found the soil pH, soil OC, soil clay content and soil metal concentration to be the most important factors affecting the metal uptake by plant.

Khan and Frankland (1983) reported that extremely high concentrations (180 µg g-1) of Cd in soil adversely affected plant development. Therefore, it sounds to be reasonable to use a combination of soil total concentration of metal of interest, soil pH, soil OC and also the concentration of other metals exist in the soil to derive the model for each metal in a multi-contaminated soil.

The objective of this study was to develop a simple model to account for phytoextraction of heavy metals at multi-contaminated soils.

MATERIALS and METHODS

A literature survey was conducted to obtain the data for phytoextraction of Cd and Zn in multi-contaminated soils by hyperaccumulator plants. The published data (26 data points) for phytoextraction of Cd and Zn by *T. caerulescens* ecotype *Ganges* (southern France) was used to derive the models (Lombi et al., 2001; Yanai et al., 2006). *T. caerulescens* ecotype *Ganges* known for both Zn and Cd hyperaccumulation (Cosio et al., 2005).

Stepwise multiple regression analysis (MINITAB, Release 14.20) was performed to obtain the optimal models for predicting plant relative yield and Cd and Zn concentration in *T. caerulescens*. Combining plant yield model with those of plant concentration of Cd and Zn, a model was derived to predict the total metal uptake by each crop of *T. caerulescens*. The accuracy of the model was tested, quantitatively. Using the model, then the number of crops needed to remediate the Cd and Zn below the remediation targets was simulated at a multi-contaminated soil for an initial concentration of soil Cd of 20 mg kg^{-1} and soil Zn of 1000 mg kg^{-1}, and soil Cd of 5 mg kg^{-1} and soil Zn of 500 mg kg^{-1}.

RESULTS and DISCUSSIONS

Table 1 shows the range of some soil physical and chemical properties used to derive the models. The values in Table (1) can be used to avoid the extrapolation while we are using the derived models to predict the phytoextraction data needed for other sites.

Table 1- The range of some soil physical and chemical properties[§] used to derive the models

pH	OC (%)	Zn_t (mg kg^{-1})	Cd_t (mg kg^{-1})
4.4-7.7	1.5-14.6	53-27413	0.5-314.8

§ pH: soil pH, OC: soil organic carbon content, Zn_t: soil total Zn concentration, Cd_t: soil total Cd concentration.

A set of the regression equations were obtained to estimate the plant relative yield and Cd and Zn concentration in *T. caerulescens*. A number of 26 data points were used to derive all the equations. The most important soil factors affecting the plant yield and Cd and Zn uptake by *T. caerulescens* were selected among soil pH, soil OC and soil total concentration of Cd and Zn by stepwise regression analysis in such a way that the largest R^2_{adj} and the smallest standard deviation of the error term in the model, *S*, were obtained (MINITAB, Release 14.20). According to the stepwise regression analysis the most important factors affecting the relative yield of *T. caerulescens* are the soil pH and Soil total Zn concentration. However, the most important factors determining the shoot concentration of Cd and Zn were the soil total Cd and Zn concentrations and soil total Zn concentration, respectively. Soil OC was not entered in any model. The derived regression equations and their statistics are given below:

$$\frac{Y}{Y_{\max}} = -0.106 + 0.0577\,pH + 1.8\times10^{-5}\,Zn_t \qquad (1)$$

$R^2_{adj} = 69.5, \qquad S = 0.1$

$$Cd_{shoot} = 75.4 + 6.69Cd_t - 0.0367Zn_t \qquad (2)$$

$Zn_{shoot} = 854 + 0.150Zn_t$

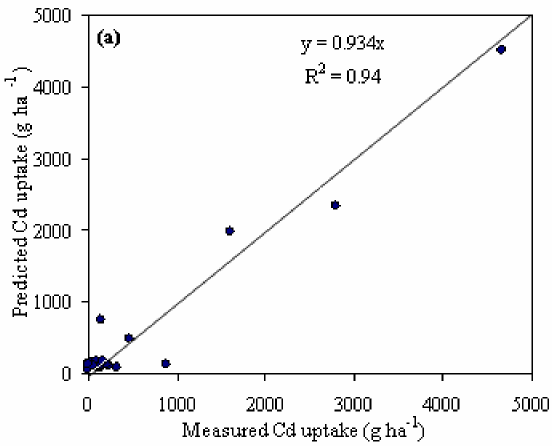
$R^2_{adj} = 80.7, \qquad S = 104.9$

(3)

$R^2_{adj} = 58.0, \qquad S = 918.8$

where Y and Y_{max} are the plant yield at a given concentration of Cd or Zn in the soil (t ha^{-1}) and maximum yield of plant (in this study it assumed to be 5 t ha^{-1}), respectively, $\frac{Y}{Y_{\max}}$ is the relative yield, Zn_t and Cd_t are the soil total concentration of Zn and Cd (mg kg^{-1}), respectively, and Cd_{shoot} and Zn_{shoot} are the plant shoot concentration of Cd and Zn (mg kg^{-1}), respectively. R^2_{adj} is a modified R^2 that has been adjusted for the number of terms in the model. If unnecessary terms been included in the model, R^2 can be artificially high. Unlike R^2, R^2_{adj} may get smaller by adding terms to the model (MINITAB, Release 14.20). All the obtained regression equations appeared to be significantly correlated at $p = 0.001$.

Combining Eq. (1) with Eqs. (2) and (3) and assuming Y_{max} to be 5 t ha^{-1}, the plant uptake of Cd and Zn by one crop of *T. caerulescens* was predicted, respectively. Fig. (1) shows the comparison between measured total uptake of Cd and Zn by each crop of *T. caerulescens* with those predicted by the models. The models predictions showed the significant correlation with measurements ($p = 0.001$) both for Cd and Zn uptake with *T. caerulescens*.



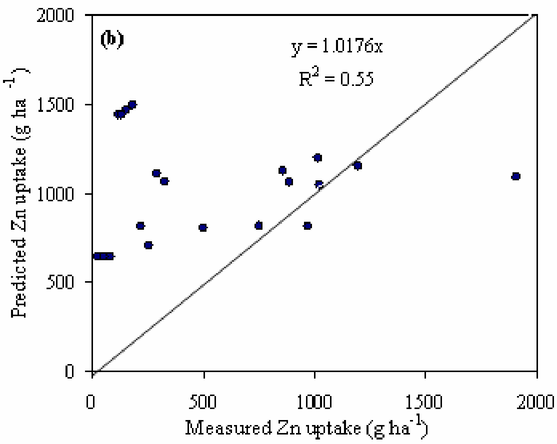


Figure 1. Comparison of measured total uptake of Cd (a) and Zn (b) by each crop of *Thlaspi caerulescens* with those predicted by combining Eq. (1) with Eq. (2) for Cd and with Eq. (3) for Zn and assuming Y_{max} to be 5 t ha^{-1}. The solid lines indicate the 1:1 diagonal.

Using the models then the number of crops needed to remediate the Cd and Zn below the remediation targets was simulated in different pHs at a multi-contaminated soil. Fig. (2) shows the Simulated concentrations of Cd and Zn in a multi-contaminated soil with pH values of 4.5 and 7.5 for an initial concentration of soil Cd of 20 mg kg^{-1} and soil Zn of 1000 mg kg^{-1} and soil Cd of 5 mg kg^{-1} and soil Zn of 500 mg kg^{-1} after successive crops of *T. caerulescens*. For an initial concentration of soil Cd of 5 mg kg^{-1} and soil Zn of 500 mg kg^{-1}, it would take 32 and 16 crops of *T. caerulescens* to phytoremediation of soil Cd to 3 mg kg^{-1} with soil pH of 4.5 and 7.5, respectively (Fig. 2a). At the same level of soil Cd and Zn contamination, it would take 299 and 145 crops of the plant to reduce the soil Zn to 300 mg kg^{-1} with soil pH of 4.5 and 7.5, respectively (Fig. 2b).

However, when the soil is more contaminated with an initial concentration of soil Cd of 20 mg kg^{-1} and soil Zn of 1000 mg kg^{-1}, it would take 200 and 100 crops of *T. caerulescens* to phytoremediation of soil Cd to 3 mg kg^{-1} with soil pH of 4.5 and 7.5, respectively (Fig. 2a).

Phytoremediation of soil Zn to soil Zn concentration of 300 mg kg^{-1} at the same level of soil Cd and Zn contamination would take 975 and 477 crops of the plant with soil pH of 4.5 and 7.5, respectively (Fig. 2b).

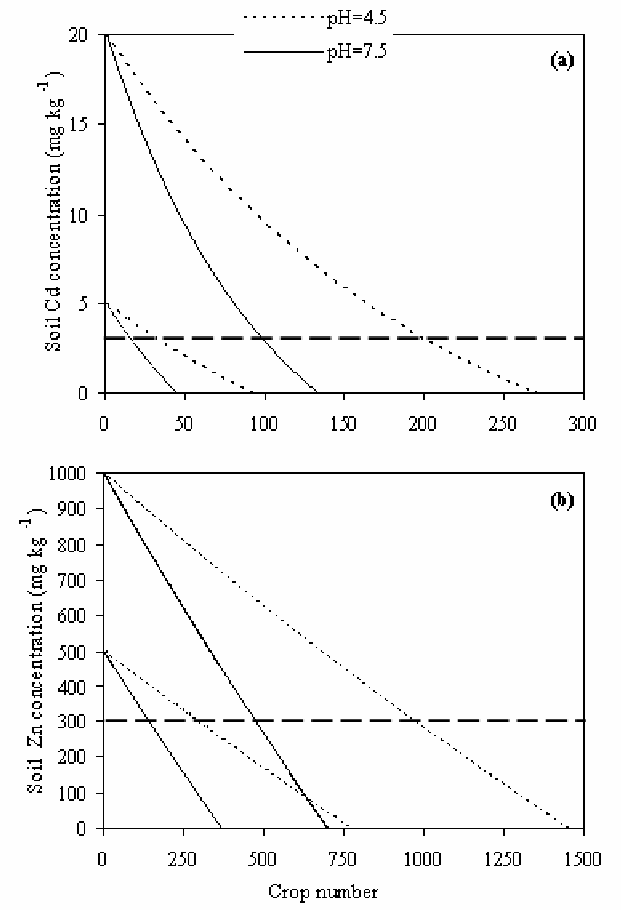


Figure 2. Simulated concentrations of Cd (a) and Zn (b) in multi-contaminated soils with different pH values (for an initial concentration of 1- soil Cd of 20 mg kg^{-1} and soil Zn of 1000 mg kg^{-1}, and 2- soil Cd of 5 mg kg^{-1} and soil Zn of 500 mg kg^{-1}) after successive crops of *Thlaspi caerulescens*. Horizontal dashed lines represent the targets for remediation.

The results showed that the number of crop needed to remediate the both soil Cd decreases by a factor of ≈ 2 with increasing soil pH from 4.5 to 7.5. The reason may be relied upon the fact that, although the Cd and Zn bioavailability to plant decreases with increasing of soil pH (Yanai et al., 2006; Degryse et al., 2006) in the case of *T. caerulescens* the increasing of the yield as a result of soil pH increasing (Yanai et al., 2006) may preponderate to result in a more total metal uptake. The results also showed that the number of crops needed to reduce the unit concentration of soil Cd is between 5.9-16 (Crop/ $mg_{Cd}\ kg^{-1}{}_{Soil}$) and for Zn is between 0.7-1.5 (Crop/ $mg_{Zn}\ kg^{-1}{}_{Soil}$). No matter how much is the magnitude of hazard risen from a unit level of contamination of soil Cd and Zn, the results revealed the more ability of *T. caerulescens* to extract the soil Zn contamination than that of Cd. However, owing to the fact that the absolute concentrations of Cd in soil are generally two orders of magnitude lower than those of Zn (Zhao et al., 2003), the phytoremediation of Cd seems to be more feasible than that of Zn.

Comparing the results above with those of Zhao et al. (2003) for the very same initial concentrations of soil Cd and Zn revealed that in a soil contaminated with both Cd and Zn, it may take 1.8-5 times more crops to soil Cd remediation to a same target than that of a single-contaminated soil. In the case of soil Zn decontaminations it is 4-9 times more crops in compare to a soil contaminated only with Zn.

The above model simulations suggest that phytoremediation using *T. caerulescens* is not feasible even when the soil is only moderately contaminated with both Cd and Zn, simultaneously. It calls more attempts to improve the metal hyperaccumulation and biomass production of *T. caerulescens* by means of plant breeding and/or genetic engineering to overcome the globally increasing problem of soil heavy metal pollution.

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The Effects of Natural Zeolite on Ions Adsorption and Reducing Solution Electrical Conductivity I) Na and K Solutions

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ABSTRACT

Natural zeolites are crystalline alominosilicate minerals with three dimensions. In general, three important factors, structure, texture, chemical composition as well as economic value of natural and synthetic zeolites have made them as valuable materials. Zeolites as catalysts in oil and petrochemical industries, fire distinguishing industries and agricultural industries are just some of their applications. Zeolites are also valuable as soil fertilizer, soil moisture holder, municipals as well as industrials wastewater treatment, harmful and toxic chemicals eliminator metals and gases adsorptive. Zeolites are very effective minerals to decrease the risk of toxic cations as well as anions. In a series of experiments different mixtures of soil with zeolite were prepared using 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight. The constant amounts of mixtures were treated with constant volumes of solutions containing NaCl, $NaNO_3$, KCl and KNO_3. The electrical conductivity of each solution was 0, 5, 10, 15 and 20 dS/m. All samples were replicated two times and each batch of experiment was containing 60 samples with total number of 240 samples for the whole experiment. Mixtures of soil with zeolite were treated with different salt solutions and were shake for two hours prior to analysis. All suspensions were filtered and their electrical conductivity was measured at constant temperature. The results showed that electrical conductivity of filtered solutions was lower in mixtures containing zeolite compared to soil. Also the electrical conductivity of the filtered solutions was considerably lower in K solutions compared to Na. It concluded that zeolite could probably reduce the electrical conductivity of soil solutions by adsorption of ions from the primary solutions and it seems that zeolite would tend to adsorb more K ions compared to Na ions from the solutions resulting lower electrical conductivity of K containing compared to Na containing solutions.

Keywords: Zeolite, Cations, Soil, Electrical conductivity, Adsorption

INTRODUCTION

Zeolites are crystalline alumino silicate minerals. They are generally formed in nature when water of high pH and high salt content interacts with volcanic ash causing a rapid crystal formation. The framework of zeolites is open and contains channels and cavities in which cations and water molecules are located. The channel structure of zeolites is responsible for their function as a molecular sieve, but is also important for selective cation exchange. The selectivity for different ions is determined by several factors such as the size and state of solvation of the ions, the charge and geometry of the framework, the number of cation sites available for occupation inside the framework, and the temperature (Dyer, 1988).

Natural zeolites have been used for a long time to improve soil quality. Farmers add the zeolites to the soil to control soil pH and to improve ammonium retention (Dwyer and Dyer, 1984). Natural zeolites are also used in wastewater treatment to remove ammonium ions and heavy metals (Zamzow et al., 1990). Weber et al. (1984) investigated the effect of a natural zeolite (clinoptilolite) on heavy metal uptake by plants from an agricultural field. They did not observe a reduction in heavy-metal uptake in sorghum even at an addition rate of approximately 6.5%. Other studies concerning the addition of natural zeolites to soil also show little or no effect on the availability of metals (Mineyev et al., 1990; Chlopecka and Adriano, 1996; Chlopecka and Adriano' 1997; Baydina, 1996).

In situ immobilization of metals in contaminated soils is a technique to improve soil quality. Zeolites are potentially useful additives to bind metals. In a research, free ionic concentration of Cd and Zn strongly decreased after the addition of zeolites, which might explain the reduction in metal uptake observed in plant growth experiments. Pretreatment of zeolites with acid (to prevent a pH increase) or Ca (to coagulate organic matter) suppressed the dispersion of organic matter, but also decreased the metal binding capacity of the zeolites due to competition of protons or Ca. (Oste et al, 2001). Similar results were also found by Garau (2007).

Li et al (2000) reported that zeolites have also large cation exchange capacities, which enable them to be modified by cationic surfactant to enhance their sorption of organic and anionic contaminants. In this study, the influence of quaternary ammonium surfactants on sorption of five metal cations (Cs^+, Sr^{2+}, La^{3+}, Pb^{2+}, and Zn^{2+}) onto a clinoptilolite zeolite was investigated. Generally, the metal cation sorption capacity and affinity for the zeolite decreased, indicating that presorbed cationic surfactants blocked sorption sites for metal cations, as the surfactant loading on the zeolite increased.

Binary exchange reactions (Ca^{2+}–K^+, Ca^{2+}–NH_4^+, and K^+–NH_4^+) were also conducted on two soils and with combinations of these soils with bentonite or zeolite added. Binary exchanges were used to predict ternary exchanges (Ca^{++} - K^+ - NH_4^+). The results showed that K^+ and NH_4^+ were preferred over Ca^{2+}, and K^+ was preferred over NH_4^+ in all soils and soils with amendments. Generally, the addition of bentonite did not change cation selectivity over the native soils, whereas the addition of zeolite did. Although additions of bentonite or zeolite may not help increase the NH_4^+ selectivity of a liner material, increases in the overall cation exchange capacity (CEC) of a soil will ultimately decrease the amount of soil needed to adsorb downward-moving NH_4^+ (DeSutter, and Pierzynski, 2004). Other workers were also found similar results (Weber et al, 1982; Fishman and Mumpton, 1977).

Other studies were conducted to quantify apatite and phillipsite (zeolite) sequestration of selected metal contaminants. The results revealed that zeolite was more effective than apatite at sorbing aqueous

Ba^{2+}. Zeolite additions significantly enhanced plant growth and reduced Cd, Pb, and Zn concentrations in all analyzed tissues (grain, leaves, and roots). Sequential extractions of the soil indicated that the Cd, Pb, and Zn were much more strongly sorbed onto the amended soil, making the contaminants less phytoavailable (Knox et al, 2002).

Other finding revealed that zeolite could be useful to decrease negative effects of high salinity. Soil salinity is a major abiotic factor limiting crop production but an amendment with zeolite may mitigate effects of salinity stress on plants. The objective of the study was to determine the effects of zeolite on soil properties and growth of barley irrigated with diluted seawater. Barley was raised on a sand dune soil treated with calcium type zeolite at the rate of 1 and 5% and irrigated every alternate day with seawater diluted to electrical conductivity (EC) levels of 3 and 16 dS m^{-1}. Irrigation with 16 dS m^{-1} saline water significantly suppressed plant height by 25%, leaf area by 44% and dry weight by 60%. However, a substantial increase in plant biomass of salt stressed barley was observed in zeolite-amended treatments. The application of zeolite also enhanced water and salt holding capacity of soil. Post-harvest soil analysis showed high concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) due to saline water especially in the upper soil layer but concentrations were lower in soils treated with zeolite. Zeolite application at 5% increased Ca^{2+} concentration in salt stressed plants; concentrations of trace elements were also increased by 19% for iron (Fe^{2+}) and 10% for manganese (Mn^{2+}). The overall results indicated that soil amendment with zeolite could effectively ameliorate salinity stress and improve nutrient balance in a sandy soil (Al-Busaidi et al, 2008).

The object of this study was to investigate the effects of natural zeolite on solution electrical conductivity and some selected metal adsorption under the condition of this experiment.

MATERIALS and METHODS

In a series of experiments different mixtures of soil with zeolite were prepared using 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight. The constant amounts of mixtures were treated with constant volumes of solutions containing NaCl, $NaNO_3$, KCl and KNO_3, separately. The saline solutions were prepared using different concentrations of each salt to make the final electrical conductivity of each solution as 0, 5, 10, 15 and 20 dS/m (Rowell, 1994). All samples were replicated two times and each batch of experiment was containing 60 samples with total number of 240 samples for the whole experiment. Mixtures of soil with zeolite based on the ratio of 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight (equal to 0, 0.1, 0.2, 1, 2, and 20 grams of zeolite per 20 grams of soil-zeolite mixtures, respectively) were treated with different salt solutions and were shake for two hours prior to analysis. All suspensions were filtered and their electrical conductivity was measured at constant temperature. The concentrations of Na and K ions were also determined in the equilibrated solutions using flame photometry method (Page, 1982). The data processing and graphs were performed using Excel computer program.

RESULTS and DISCUSSIONS

The results showed that, generally, application of zeolite to the soil significantly decreased the electrical conductivity of the equilibrated solutions in the mixtures of soil-zeolite (Figures 1 to 6). However, comparing the results of Na salts with K salts revealed that there were differences between K and Na salts in terms of zeolite effects. For example, in EC equal to 20 dSm^{-1}, application of zeolite by the rates of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures in $NaNO_3$ solutions, decreased the electrical conductivity by 0%, 3%, 25%, 20% and 8%, respectively, compared to the control treatment (no zeolite added to the soil) (Figure 1). At the same conditions, the corresponding data for KNO_3 showed that, zeolite decreased the electrical conductivity by 47%, 54%, 52%, 53% and 65%, respectively (Figure 2), showing greater decrease in electrical conductivity in K salts compared to Na.

Although, the magnitudes of zeolite effects are found to be different between different levels of salinity in terms of decreasing electrical conductivity (Figures 1 and 2), however, mean pooled data for salinity levels showed that application of zeolite by the rate of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures in $NaNO_3$ solutions, decreased the electrical conductivity by 2%, 6%, 15%,18% and 16%, respectively, compared to the control. The corresponding data for KNO_3 salt were 13%, 33%, 31%, 49% and 52%, respectively (Figure 3), showing greater effects of zeolite in K solutions compared to Na even if pooled data are examined.

Other data for K and Na salts in chloride solutions were also showed relatively similar results which were already found for nitrate solutions (Figures 4 and 5). However, the data showed some disintegrates specially at the lower levels of salt concentrations. Most of data at the higher levels of salinity (such as EC equals to 15 and 20 dSm^{-1}) were found similar trends to the previous nitrate solutions data. As an example, in NaCl solutions and EC equal to 20 dSm-1, application of zeolite by the rates of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures, decreased the electrical conductivity by 2%, 0%, 16%, 2% and 23%, respectively, compared to the control with no added zeolite (Figure 4) while the corresponding data for KCl solutions were found to be 2%, 19%, 5%, 10% and 33%, respectively (Figure 5). However, again if mean pooled data are considered for salinity levels, the effects of zeolite to decrease salinity would be stronger in K solutions compared to Na solutions (Figure 6).

Greater decrease in salinity when K salts are used could be explained by preference of K adsorption compared to Na by zeolite. The results from analysing equilibrated solutions for K and Na also supported the evidence as K concentrations were found to be lowered in the solutions after mixing with zeolite, compared to Na concentrations, indicating more adsorption of K compared to Na (data were not shown here). Although no any clear reason is mentioned for this process in the literatures, but smaller hydrated K ions compared to Na could be one the reason which would influence the adsorption phenomena to adsorb more K over Na. However other workers have also reported the preference of K adsorption over NH_4^+ by zeolite in soil (DeSutter, and Pierzynski, 2004).

In overall, the results from the experiment suggested that zeolite is an effective additive in order to improve soil salinity in both K as well as Na solutions. However the data suggested stronger effect of zeolite in K solutions compared to Na. Since zeolite has relatively large capacity to adsorb cations from the soil solutions (Li et al, 2000), decrease salinity is expected due to application of zeolite to the soil. This would be important properties since in additions of salinity control it could be used as a good source of plant nutrients (Dwyer and Dyer, 1984).

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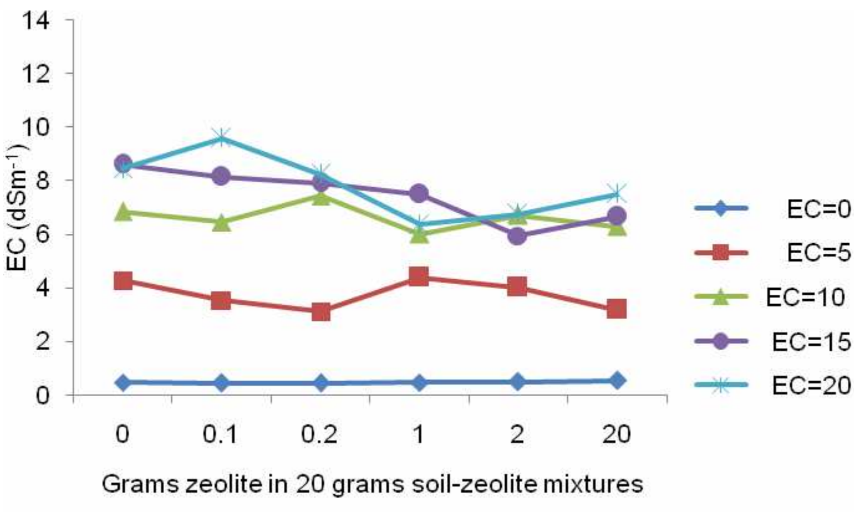

Figure 1. The effects of zeolite on electrical conductivity of soil using $NaNO_3$

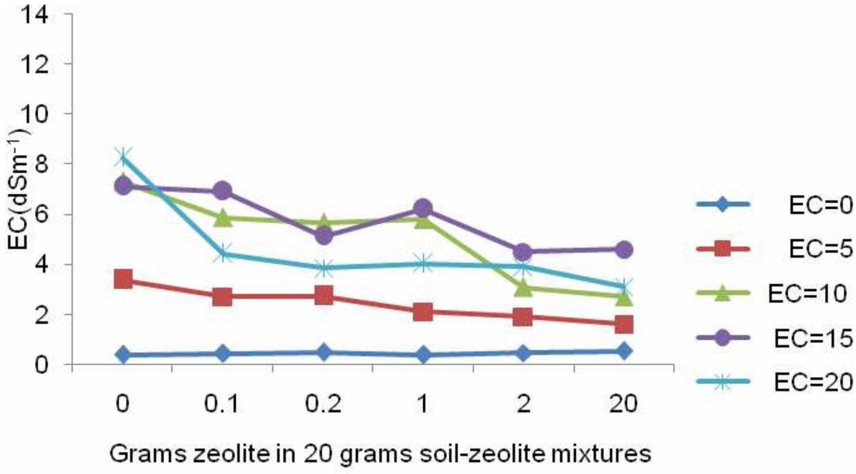

Figure 2. The effects of zeolite on electrical conductivity of soil using KNO_3

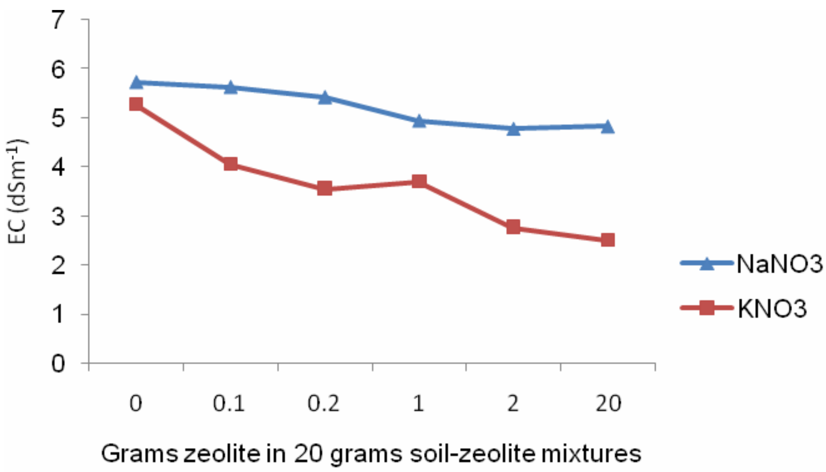

Figure 3. The effects of zeolite on electrical conductivity (pooled mean values for Na and K in nitrate solutions)

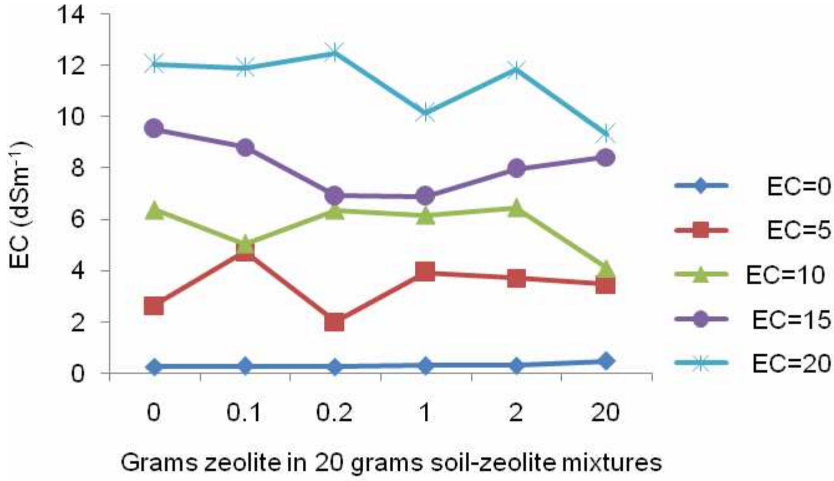

Figure 4. The effects of zeolite on electrical conductivity of soil using NaCl

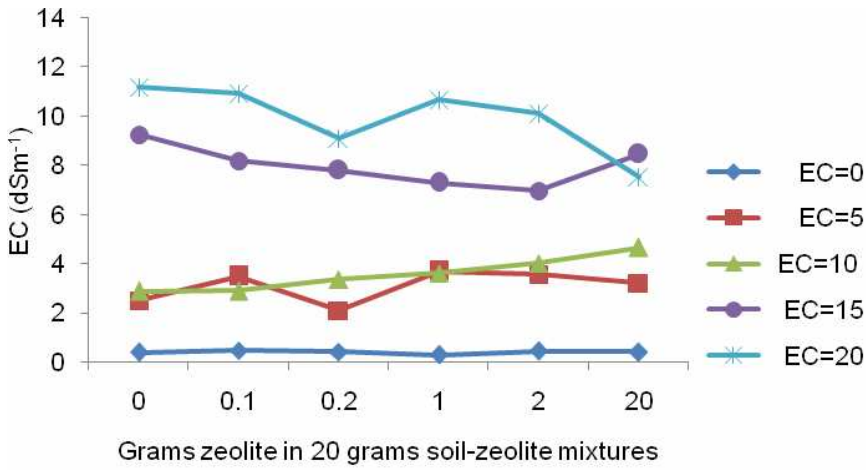

Figure 5. The effects of zeolite on electrical conductivity of soil using KCl

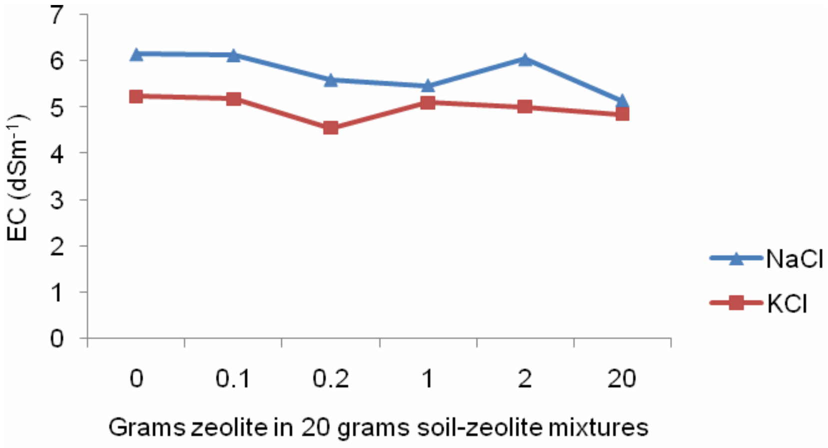

Figure 6.The effects of zeolite on electrical conductivity (pooled mean values for Na and K in chloride solutions)

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Geophagia, a Soil - Environmental Related Disease

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ABSTRACT

Geophagia or geophagy is a habit for an uncontrollable urge to eat earth that commonly is occur in poverty-stricken populations and particularly there are in children under three years of age and pregnant women. The custom of involuntary or deliberate eating of soil, especially clayey soil, has a long history and is amazingly widespread. Some researchers have described an anomalous clay layer at a prehistoric site at the Kalambo Falls in Zambia indicating that clay might have been eaten by hominids. Von Humboidt reported from his travels in South America in early 18th century that clay was eaten to some extent at all times by the tribe in Peru. In the mid 19 century it was customary for certain people in the north of Sweden to mix earth with flour in making bread whether the clay effected an improvement in taste. In Iran, geophagia has seen in some of children and pregnant which that is solved with eating starch daily. For example, some reports are shown that there has been geophagia disease in some parts of Fars province, around Shiraz city which have been made different health as well as environmental complications. Clay with a large cation exchange capacity that is also fairly well saturated can release and supplement some macronutrients and micronutrients such as Cu, Fe, Mn and Zn. Deficiency of these elements led to dwarfism, hypogonadism, anemia, hepatosplenomegaly and skin problems. Almost all of these health complication evidences are seen in most of people who has been suffered from geophagy in Iran. However, geophagia has a history of 2000 years and the effects of soil and environmental chemistry on human health have been studied for hundreds years ago in China. In this review it has tried to introduce the geophagia as a nutritional and environmental complication in Iran as well as in the world which could be a serious health risk for human.

Keywords: Geophagia, Soil, Iron, Zinc, Anemia, Environment

INTRODUCTION

Soil can influence the human health and caused diseases by different ways (Oliver, 1997). Geophagy or geophagia is the way which soil is normally eaten by human and is digested in the stomach. This is a habit for an uncontrollable urge to eat earth that commonly is occur in poverty-stricken populations and particularly there are in children under 3 years of age and also in pregnant women.

The simplest form of mineral element intake from the environment is “geophagia” or direct eating of soil by human beings. Geophagia is widely reported in literature and can vary from undeliberate taking in of soil, e.g., by playing children to deliberate eating of soil either pure or mixed in other food substances. Geophagia is common among traditional societies, e.g., in sub-Saharan Africa. Soil may be directly eaten from the ground, but in many situations there is a cultural preference for soil from "special sources" such as the walls of termite nests or in traditional herbal–soil mixtures. These are taken as a "special remedy" during pregnancy and by children when micronutrient requirements are increased (Smith et al., 2000).

Despite occurring in a wide variety of taxa, deliberate soil consumption is a poorly understood behavior. In humans, geophagy is sometimes considered as a sign of metabolic dysfunction. However, geophagy is normally assigned an adaptive function in nonhuman primates and various other organisms such as a wide diversity of mammals (Simon, 1998; Krishnamani and Mahaney, 2000). For humans, adaptive benefits must eclipse the costs of ingesting geohelminths (Saathoff et al., 2002) and soil-based toxins, such as lead, copper and potassium (to a hyperkalemic extent) (Simon, 1998). Despite such costs, an adaptive function is probable given its persistence in human history.

In Iran, geophagia has seen in some of children and pregnant which that is solved with eating starch daily (Ronaghy et al, 1968). Clay with a large cation exchange capacity that is also fairly well saturated can release and supplement some macrominerals, and trace elements such as Cu, Fe, Mn and Zn. Deficiency of this elements led to dwarfism, hypogonadism, enemia, hepatosplenomegaly and skin problems. In this review it has tried to introduce the geophagia as a nutritional and environmental complication in Iran as well as in the world which could be a serious health risk for human.

History

Geophagy was first reported by Aristotle and further described by Dioscorides and Avicenna in 40 BC and 1000 AD, respectively (Halstead, 1968). One of the first reports on geophagia is from Von Humbolt, who writes in his travel reports from South America between 1799 and 1804 that clay was eaten to some extent at all times by the Otomac tribe along the Orinocco River, and in Peru he saw mothers give their children lumps of clay to keep them quiet (Halsted, 1968).The habit can be traced back to ancient times, in the days of the philosophers Aristotle and Hippocrates, whose interest had been in the danger of the excessive consumption of ice-water and snow (Walker et al, 1997). The Roman physician Soranus is also noted for describing how geophagia was used to alleviate the unpredictable appetite and other symptoms associated with pregnancy. He noted that some unusual food items, were being consumed by pregnant women and that the craving for such unusual items began around the fortieth day of pregnancy and persisted for at least four months (Coltman, 1969). Soranus identified that these unusual foods could harm both the mother and child if not checked (Coltman, 1969).

Geophagia can also be traced back to the 18th century when it was learned that the Sultan of Turkey ate a special clay from the island of Lemnos; this resulted in Europeans adopting the product as a health food (Deutsch, 1977). In Africa, explorers and missionaries reported on clay eating dating from the 18th to the early 20th century as observed in Nigeria, Ghana and Sierra-Leone (Hunter, 1993). In the early part of the

20th Century, miners in Austria were reportedly eating earth and mountain tallow, which they spread onto bread as a substitute for butter and in Southern Germany, quarrymen developed “ stone butter” derived from Clay and used as a food supplement (Hawass et al, 1987).

World Spread

Some people around the world eat clay, dirt and or other pieces of the lithosphere for a variety of reasons. Commonly, it is a traditional cultural activity, which takes place during pregnancy, religious ceremonies or as a remedy for disease (Jordan and Rowntree, 1990). Many studies on geophagia have been conducted over the years and around the world. As early as 1825, it was reported as a health hazard in the Southern States of North America (Makhobo, 1986).

In Asia, some comprehensive research on geophagia had also conducted which was very common in few villages around Shiraz city in Fars province of Iran (Ronaghy et al, 1968; Sayar et al, 1975). Geophagia is still exists in some parts of Iran especially among the pregnant women as well as children. In these areas it is a habit which is strongly favored by them and is going beyond a habit and mostly considered as a disease. In 1992 a study was conducted on the dietary habits of rural Jamaican women during pregnancy and 15 out the 38 pregnant women questioned reported cravings, common amongst which were cravings for cigarette ash and drinking soda (Melville and Francis, 1992). In Australia, some aborigines eat white clay found mostly in the billabounds of the coastal areas of the North territory, fresh water springs and riverbeds mainly for medicinal purposes (Beteson and Lebroy, 1978)

Many reasons exist for geophagia around the world. In the Southern parts of the United States of America, pregnant women who traditionally ate substances like clay, corn starch and baking soda believed that such substances helped to prevent vomiting, helped babies to thrive, cured swollen legs and ensured beautiful children (Mcloughlin, 1987). In Malawi, it is reported to be surprising for a pregnant woman not to practice geophagia since it is their way of identifying if she is really pregnant. The taste of clay is claimed to diminish the nausea, discomfort and vomiting in “morning sickness” during pregnancy. Clay eating in this case is seen as normal during pregnancy and not between pregnancies (Hunter, 1993). The practice of geophagia is widespread in Africa and is associated with medicinal treatment and spiritual and ceremonial behavior (Walker et al, 1997). Clay eating is wide spread among women in five African countries namely Malawi, Zambia, Zimbabwe, Swaziland and South Africa, an estimated prevalence level in the rural areas of these countries is 90% (Walker et al, 1997). Poverty, starvation and famine have also been associated with geophagia practice (Hawass et al, 1987), in which case the substances function as a bulking agent to supplement insufficient food or a poor diet (Mclouglin, 1987).

Medical and Nutritional Effects

Intake of soil is usually associated with risk of human diseases. Examples are pathogens such as tetanus (Clostridium tetani), worm infections such as hookworm (Ancyclostoma duodenale, Necator americanua) or even non-filarial elephantiasis, which may enter through skin abrasions. In traditional societies where geophagia is common practice, parasite-causing soil-born pathogens are important to understand the etiology of certain human diseases. The nonfilarial elephantiasis or podoconidiosis is an interesting case: small worms in soil cause swelling of the legs by blocking lymph nodes! The disease is common in tropical highland areas on basaltic volcanic geology on "fine reddish brown soils"—most likely Nitisols (Nachtergaele et al., 2000). Price (1988) reports on the ecological niche of this disease. It seems to occur in well populated regions between 1250 and 2500 m altitude, with moderate mean annual temperature around 208C, and with more than 1000 mm of rain in the hot season. This covers areas such as the volcanic Highlands in Ethiopia, Kenya, Tanzania, Burundi and Cape Verde (Price and Plant, 1990). Very small particles of kaolin, amorphous silica and some quartz and iron were found in phagosomes of macrophages. The specific role of these soil minerals is still not yet clear and should be further investigated.

Mineral nutrient supplementation is the historical and intuitive basis for geophagy (Jones and Hanson, 1985). Indeed, sodium acquisition reportedly explains the phenomenon in organisms ranging from butterflies to babirusas (Clayton and MacDonald, 1999). In humans, however, investigators have largely discounted the hypothesis that geophagy is a physiological response to a need for nutrients, such as iron. The tendency to infer that anemia elicits soil consumption (Abrahams, 1997) is confounded by the fact that geophagy often leads to, rather than corrects, iron, zinc, or potassium deficiencies (Reid, 1992). The phenomenon is exacerbated when clays with high cation-exchange capacities are ingested. Moreover, mineral nutrients are usually sufficient in an animal's routine diet (Gilardi et al., 1999); and, among primates, elements are similar between unconsumed soils and those consumed selectively and repeatedly (Mahaney et al., 1995). Furthermore, in soils consumed by chimpanzees, only Fe was present in high concentrations (range 6-17%; Mahaney et al., 1997). However, available Fe was only partially soluble in conditions modeling the chimpanzee stomach (oxalic acid at pH 2.0), indicating it was an improbable cue. Finally, it is notable that dissolved salts in some soils may render calcium oxalate soluble. To our knowledge, this hypothesis has never been tested despite the importance of Ca to vertebrate reproduction. In plants, Ca exists principally as oxalate crystals (Prychid and Rudall, 1999), which readily cross intestinal epithelia (Hatch and Freel, 1995). It is perhaps significant that primates incurring high reproductive costs consume soil despite considerable risk of predation (Heymann and Hartmann, 1991).

In 1958, a 21 year old male patient in the Iranian city of Shiraz presented with dwarfism, hypogonadism, hepatosplenomegaly, rough and dry skin, mental lethargy, geophagia, and iron deficiency anemia (Prasad, 2003). This patient had an unusual diet. His intake of animal protein was negligible, and he ate only unleavened bread. In addition, he consumed 0.5 kg of clay daily. His total intake of calories and protein (cereal) was adequate, and except for iron deficiency no other deficiency in micronutrients was documented consistently. In the following three months 10 more patients with a similar illness were seen in the same hospital. The growth retardation and testicular hypo function in all these patients could not be explained on the basis of iron deficiency—these manifestations are not observed even in iron deficient animals. In animals, among the transitional elements known to have adverse effects on health due to deficiency (Cr, Mn, Co, Cu, and Zn), only zinc deficiency was known to cause growth retardation and testicular hypo function.

In many studies, quoted in Smith et al. (2000), geophagia is considered as "good for health," especially for strengthening the blood and promoting growth and physical strength. It is not 100% clear what the precise reasons are for a beneficial effect of geophagia—are mineral elements exchanged from the CEC-complex under the acidic conditions in the stomach? Exchange reactions may also explain absorption on the clay surface of possible dietary toxins such as alkaloids, tannins and bacterial toxins. For instance, Johns and Duquette (1991), describe clay being eaten a.o. by Pomo Indians to detoxify bitter potatoes (Solanum spp.). The clay fraction of ingested soils could also protect the gastrointestinal epithelium by cross-linking with glycoproteins in the intestinal mucosa (Rateau et al., 1982). Because toxins and tannins cross or afflict the epithelium (Gee and Johnson, 1988), the adsorption of such dietary compounds is the leading hypothesis for geophagy in some animals (Gilardi et al., 1999). Clays with high cation-exchange properties also adsorb diarrhea-causing enter toxins (Brouillard and Rateau, 1989). Practitioners of geophagy are often socially disadvantaged cultural and ethnic groups living in the tropics (Simon, 1998). Under such conditions, geophagy may facilitate exploitation of marginal plant foods and concomitantly reduce the energetic costs of diarrhea. Given the selective benefits to pregnant women and children, it is unsurprising that they are the principal consumers of soil (Wiley and Katz, 1998). In fact, humans use clay explicitly to render tanniniferous acorns and alkaloid-rich potatoes edible (Johns and Duquette, 1991).

In the other studies in Iran some researchers found significant clinical results on geophagia. A six years study on the patients in the area with geophagia habit showed that 9 of 13 patients with the syndrome of dwarfism, hypogonadism, iron-deficiency anemia, geophagia, and hepatosplenomegaly studied in Iran in 1959-1960 were traced in 1966. In this study, those who were able to consume a good diet the abnormalities had disappeared or had become much ameliorated. In those who were unable to maintain an adequate diet the syndrome continued unabated. These findings indicate that the syndrome is of nutritional origin and is reversible (Ronaghy et al, 1968). Other studies in Iran also showed that geophagia characterized by, severe, anemia, dwarfism, hypogonadism and hepatosplenomegaly is sometimes seen in young patients (and children) in Iran; Hematological aspects of the syndrome are those of, severe, iron deficiency anemia; Gastric biopsies and histological findings revealed superficial or atrophic gastritis showing some resemblance to those seen in pernicious anemia; Hematological features, anemia and many of the clinical signs of the syndrome were improved after appropriate iron therapy; and histological changes of gastric mucosa improved, in 5 patients, 6 months after correction of the anemia (Sayar et al, 1975). Also, one of the first descriptions of zinc deficiency in man was made by Prasad, Halsted and Nadimi (1961) in adolescent boys in Iran who had been clay-eaters since childhood. It was a syndrome of dwarfism, sexual retardation and iron-deficiency anemia and the first two of these responded to zinc therapy.

Although the incidence of geophagy is decreasing, the practice remains common in many cultures. For example, a single Nigerian village produces 500 tons of soil yearly for consumption across West Africa (Vermeer and Ferrell, 1985). Moreover, children consume considerable quantities of soil regardless of geography and socio-economic status. Ingestion varies from the incidental to the incredible, ranging from 75 mg day-1 in Amherst, USA (Stanek and Calabrese, 1995) to 650 g reported in vivo in a single Gambian boy (Collinson et al., 2001). Accordingly, understanding and quantifying the adsorptive capacity of clay continues to be important. To date, modeling of dietary compound adsorption by clays has been investigated only in Amazonian parrots (Gilardi et al., 1999). Here we model the human gastrointestinal system and test the capacity of kaolin to adsorb a toxin (quinine) and tannins, both condensed (quebracho) and soluble (tannic acid). Furthermore, we evaluate the solubility of calcium oxalate in the presence of kaolin

The practice of geophagia and more specifically clay eating is strongly connected to folk medicine, social customs and obsessive-compulsive behavior (Crosby, 1976). The eating of some clays have been used as a remedy for diarrhea and stomach discomfort a practice that has been attributed to the presence of kaolin in these clays and it's absorptive ability (Morgan 1984). Clay has been identified as having the ability to absorb dietary toxins and bacterial toxins associated with gastro-intestinal disturbances that arise during pregnancy (Hunter, 1993). In some third world countries, clay is eaten to 'line the stomach' before eating yam or fish which may be poisonous, to reduce hunger and treat hook-warm infestation.

In a study conducted on 156 primary school children in Western Kenya by Geissler et al (1998), the proportion of anemic and iron depleted children was significantly higher among those with geophagia than in those without it. Geophagy among 204 primary school children aged between 10 and 18 years and relationship with helminthes (Ascaris lumbricoides, Trichuris trichiura, Schistosoma mansoni and hookworm) load was studied and results showed that 77% of the children ate soil daily and 48% of all soil samples were contaminated with eggs of the round worm - Ascaris lumbricoides (Geissler et al, 1998).

Geophagia, especially clay eating has often been associated with lead poisoning abdominal problems, hypokalemia, hyperkalemia, phosphorous intoxication and dental injury. The high aluminium content of the clays eaten may increase the risk for Alzheimer's disease (Alzheimer's Society, 2002). A study in Washington DC among Afro-American women reported that large quantities of ice and freezer frost, about half to two cups a day, were consumed by women at a frequency of between one and seven times a week, resulting in low serum ferritin levels among those who are pregnant especially in the second and third trimesters (Edwards et al, 1994).

In a study conducted on 553 African American women admitted to prenatal clinics in Washington, geophagia was not observed. However, pagophagia (the ingestion of large quantities of ice and freezer frost) was reported. Some of the women were found to consume as much as 2 cups of frost a day (Edwards et al, 1994). In this study, the findings were well correlated with that of more recent ones by the likes of Geissler et al (1998) and Tayie and Lartey (1999). The serum ferritin concentrations for women with geophagia habit were significantly lower during the second and third trimesters of pregnancy; the average values for three trimesters of pregnancy for both ferritin and mean corpuscular hemoglobin were lower in geophagia women than their non-geophagia counterparts (Edwards et al, 1994).

The types of clay eaten in most countries could contribute some mineral nutrients. About 100g of white copper belt clay could contribute 15mg of calcium, 48 mg of iron, 42mg of zinc and small amounts of copper, chromium nickel and molybdenum, which may be significant amounts where deficiency exists (Hunter, 1993).

In South Africa as in other parts of Africa, the eating of clay is mostly observed among pregnant women. The prevalence of geophagia among urban and rural South African women was reported to be 38.3% and 44.0% respectively as compared to the prevalence among the Indian, colored and white women at 2.2%, 4.4% and 1.6% respectively (Walker et al, 1997). In some studies such as that reported by Vermeer and Frate (1979), the average daily intake of clay consumed by women in rural Holmes County, Mississippi, was 50g.

In Malawi, geophagia habit is used as a marker for pregnancy (Walker et al 1997). In a recent cross sectional study at in an antenatal clinic at Kilifi District Hospital, Coast Province, Kenya, low iron status and high anemia prevalence was present among 154 out of 275 pregnant women (56%) and were reported to eat soil regularly (Geisslier et al, 1998). In an accompanying interview on the said study at Kilifi District hospital, soil eating was found to be more than just a physiologically induced practice and involved a rich cultural practice favored by most females with strong relations to fertility and reproduction (Geissler et al, 1999). Geophagia is a natural habit among infants who crawl and eat whatever they can pick up and though usually the total amount of earth eaten is small and insignificant, carelessness or indifference on the part of parents may contribute to the continuation of this habit as the child matures (Hawass et al 1987). The phenomenon of geophagia is reported to be more prevalent than commonly believed. Women at high risk of geophagia are more likely to be of African origin, to live in rural areas, and to have a family history of geophagia.

CONCLUSION

Geophagia is defined as deliberate consumption of earth, soil, or clay[1]. From different viewpoints it has been regarded as a psychiatric disease, a culturally sanctioned practice or a sequel to poverty and famine. In view of the high prevalence of geophagia in many regions of the world, it is hypothesized that ancient medical texts would also contain reports of the disorder. To our surprise, geophagia was indeed reported by many authors ranging from Roman physicians to 18th century explorers. All the concepts of geophagia—as psychiatric disorder, culturally sanctioned practice or sequel to famine—fall short of a satisfying explanation. The causation is certainly multifactorial; and clearly the practice of earth-eating has existed since the first medical texts were written. The descriptions do not allow simple categorization as a psychiatric disease. Finally, geophagia is not confined to a particular cultural environment and is observed in the absence of hunger. Might it be an atavistic mode of behavior, formerly invaluable when minerals and trace elements were scarce? Its re-emergence might then be triggered by events such as famine, cultural change or psychiatric disease. However, geophagia now is a world wide disorder which needs to be addressed more than in the past.

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Evaluation of Nitrate Concentration in the Groundwater Resources of Gorgan

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ABSTRACT

Nitrogen is vital for plants and influences the amount as well as the quality of yield. However, in the absence of proper management, it's excessive in the water resources could have negative impact on water quality and may cause environmental as well as health complications. To evaluate the nitrate concentrations in groundwater resources in Gorgan area, north of Iran, 47 water samples were taken from different groundwater resources of shallow and deep wells as well as streams. The results showed that nitrate concentrations varied from 0.44 to more that 36 mgL^{-1}showing different pattern in different resources. In deep wells (wells with the depth of more than 50 meter), nitrate concentrations varied from 1.77 to 12.4 mgL^{-1} with an average of 5.8 while nitrate concentrations in shallow wells (wells with the depth of less than 50 meter) varied from 0.44 to 36.32 with an average of 13.37 mgL^{-1} . The corresponding data for streams was found to be varied from 3.54 to 27.9 mgL^{-1} with an average of 15.84. The results showed that nitrate concentrations was clearly greater in shallower groundwater resources compared to deeper ones showing increase of nitrate accumulation risks due to intensive agricultural activities in these area. The trends of nitrate accumulation showed that water resources is becoming more susceptible since they are the main drinking as well as agricultural source of water in the area. It seems that proper management in terms of fertilizers use and irrigation would be necessary to decrease the risk of nitrate accumulation in water with more emphasis to shallow water resources in the area.

Keywords: Nitrate concentration, Groundwater, Gorgan.

INTRODUCTION

Nitrate is an essential plant nutrient and a natural constituent of any soil. It is an important source of nitrogen for plant growth. However, if the soil contains more nitrate than plants can use, then the excess nitrate can be leached from the soil and contaminate groundwater. Most nitrate leaching occurs over the winter months, when plant growth is slow, soils are wet and rainfall is plentiful. As a result, nitrate concentrations in groundwater are highest in the winter and springtime. In the summer and autumn, plants are growing and taking nitrate and water from the soil, so nitrate leaching rates are lower. As a result, nitrate concentrations in groundwater generally decrease in summer and autumn. Mahvi et al (2005) found a few different between groundwater mean nitrate contents, during spring and summer 2004, in each sub-regions of Andimeshk and Susa plains of Iran, because the water table in these plains has very low fluctuations during the year.

Obviously the more nitrogen fertilizer a farmer uses the greater the chance of nitrate pollution of groundwater. Farmers still consider nitrogen fertilizer as s cheap insurance against crop failure (Looker, 1991; Mahvi et al, 2005). Even if farmers cut down on nitrogen fertilizer, there will still be some nitrate leaching. Although sustainable practices may not eliminate nitrates, it might lower them to a safe level. Obviously, if there is a chance of nitrogen pollution when no fertilizer is applied, the chance of pollution is greatly increased when a large amount of fertilizer is applied. However, some conditions such as riparian ecosystems, through their unique position in the agricultural landscape and ability to influence nutrient cycles, can potentially reduce NO_3 loading to surface and ground waters (Davis et al, 2006).

Some researchers have reported nitrate movement from waste application fields in shallow ground water, and soil, hydrologic, and biological factors influencing the amount of nitrate in the adjacent stream (Israel et al, 2004; Karr et al, 2001). The seasonal changes in the relative impact of nitrate sources on ground water contamination were also reported to be related to such factors as source distribution, the aquifer confining condition, precipitation rate, infiltration capacity, recharge rate, and the land use pattern (Jun et al, 2003). It has also reported that noncontrollable factors such as precipitation and mineralization of soil organic matter and manure have a tremendous effect on drainage losses, nitrate concentrations, and nitrate loadings in subsurface drainage water (Randall and Mulla, 2000; Dauden et al, 2004)**.** The elevated level of nitrate in groundwater is also a serious problem in Korean agricultural areas (Kaown et al, 2006).

The United States Environmental Protection Agency is currently establishing National Primary Drinking Water Regulations for over 80 contaminants under the Safe Drinking Water Act (Vogt and Cotruvo, 1987). The goal is to reduce the contaminant concentrations of all drinking water to levels near those prescribed in the Maximum Contaminant Level Goals (MCLGs) previously established by the EPA (Vogt and Cotruvo, 1987). MCLGs are "non enforceable health goals" at which "no known or anticipated adverse effects on health of persons occur and which allow an adequate margin of safety" (Vogt and Cotruvo, 1987). The Maximum Contaminant Levels (MCLs) are to be set as close to the MCLGs as possible (Vogt and Cotruvo, 1987). In the case of nitrate concentrations, the MCL has been set at 10 mgL-1 as nitrogen which is also the proposed MCLG (Vogt and Cotruvo, 1987). For many contaminants, carcinogenicity is the primary characteristic which determines the MCL; however, because there are no conclusive epidemiological studies which link nitrate to cancer in humans, carcinogenicity was not taken into account in the establishment of the MCL for nitrate (Kamrin, 1987). The determining factor in the EPA's decision to set the MCL at 10 mgL-1 was the occurrence of methemoglobinemia in infants under of six months. The MCL reflects the levels at which this condition may occur (Kamrin, 1987). Although the MCL for nitrogen was set at 10 mgL-1 nitrate - nitrogen, in 1976 the EPA suggested that water having concentrations above 1 mgL-1 should not be used for infant feeding (Rail, 1989). This guideline is very conservative and nitrate concentrations below 10 mgL-1 are probably harmless as well. However, because concentrations this low are common, the EPA hopes this guideline will induce people in rural areas to have their wells tested so that severe nitrate contamination is detected and serious health problems are avoided in the future.

However, there is substantial disagreement among scientists over the interpretation of evidence on the issue. There are two main health issues, the linkage between nitrate and infant methaemoglobinaemia, also known as blue baby syndrome (Comly, 1987), and finally cancers of the digestive tract. The evidence for nitrate as a cause of these serious diseases remains controversial. On one hand there is evidence that shows there is no clear association between nitrate in drinking water and the two main health issues with which it has been linked, and there is even evidence emerging of a possible benefit of nitrate in cardiovascular health. There is also evidence of nitrate intake giving protection against infections such as gastroenteritis. Some scientists suggest that there is sufficient evidence for increasing the permitted concentration of nitrate in drinking water without increasing risks to human health. However, subgroups within a population may be more susceptible than others to the adverse health effects of nitrate. Moreover, individuals with increased rates of endogenous formation of carcinogenic N-nitroso compounds are likely to be susceptible to the development of cancers in the digestive system. Given the lack of consensus, there is an urgent need for a comprehensive, independent study to determine whether the current nitrate limit for drinking water is scientifically justified or whether it could safely be raised (Powlson et al, 2007).

Gorgan is located in north of Iran where there have been extensive agricultural activities for a long time in the area. Since the main source of agriculture as well as drinking water of the area is mostly groundwater, the object of this study was to determine the nitrate concentrations in groundwater and some other different sources of water in the studied area.

MATERIALS and METHODS

The research was conducted in Gorgan a part of Golestan province located in the north of Iran. To evaluate the risk of nitrate concentration in water resources of Gorgan, 47 water samples were taken from different groundwater resource including shallow as well as deep wells. In general, 20, 18 and 9 water samples were taken from deep wells, shallow wells and streams, respectively. Shallow and deep wells were referred to the wells with less and more than 50 meter in depth, respectively. Few water samples were also taken from the streams at the surface. Well's water samples were taken after an hour the water pump was turned on. All samples were taken using polyethylene plastic tubes which were already been truly washed and were kept in the fridge for nitrate analysis. Nitrate concentrations were measured in the water samples straightaway using spectrophotometer methods (Rowell, 1994). All data processing and graphs were prepared using Excel computer software.

RESULTS and DISCUSSIONS

The results are generally shown in Figures 1 to 4. In deep wells nitrate concentrations were ranged from 1.77 to 12.4 mgL-1 (Figure 1). The corresponding data for shallow wells and streams were from 0.44 to 36.32 mgL-1 (Figure 2) and from 3.54 to 27.9 mgL-1 (Figure 3), respectively. The results showed that there were relatively high variations between the points for nitrate concentrations which seem to be due to different crops and farms managements which were quite obvious in the studied area. Since the farmers would like to apply their own management to their private lands, nitrate concentrations in soil as well as in the water resources would be affected under different management strategies. Different rates of N fertilizers along with Soil as well as climate conditions are also reported to be important factors controlling nitrate leaching and concentrations in soil and water resources (Jun et al, 2003; Randall and Mulla, 2000; Dauden et al, 2004). Although, precipitation rate was relatively similar across the area, but different soil properties were found in different points. The results showed that higher nitrate concentrations in water sources were found in the areas with lighter soil textures with higher infiltration rates and vies versa.

The variations in nitrate concentrations were also found to be higher in shallow wells and streams compared to deep wells (Figures 1-3) showing greater effects of soil properties in shallow wells and streams compared to deep wells suggesting safer water in deep wells especially in the heavier soil textures. However, the general data showed that the risk of nitrate concentration would be greater in shallower water sources as mean values of nitrate concentrations were increased by 2.3 and 2.7 times in shallow wells and streams compared to deep wells, respectively (Figure 4).

The results showed that although most of deep waters contained low nitrate concentrations with only few samples higher than 10 mgL-1 nitrate, but more than 55% of the samples in shallow wells and more than 66% of the samples in streams were found to contain more than 10 mgL-1 nitrate concentrations with the maximum of as high as 36.32 mgL-1 in shallow wells (Figure 5).

The data are generally suggest that the risk of nitrate concentration would increased in shallower water resources and it would enhanced by light texture soils as well as higher N fertilizer applications by farmers in the studied area. In these situations nitrate would easily leached and enter to groundwater and would increased the health risk (Kamrin, 1987; Mahvi et al, 2005). The findings are in agreement with others who are also reported higher risk of nitrate contamination in the similar conditions (Israel et al, 2004; Karr et al, 2001; Jun et al, 2003). Although the data did not showed high risk of nitrate concentration in most of water resources in the studied area, fair considerations should be taken into account to prevent future risk especially in shallower resources across the areas with high N fertilizer application.

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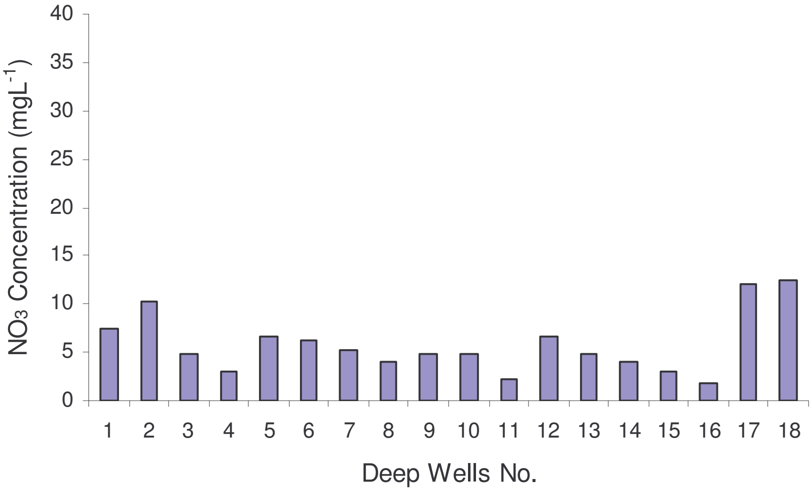

Figure 1. Range of nitrate concentrations in deep wells

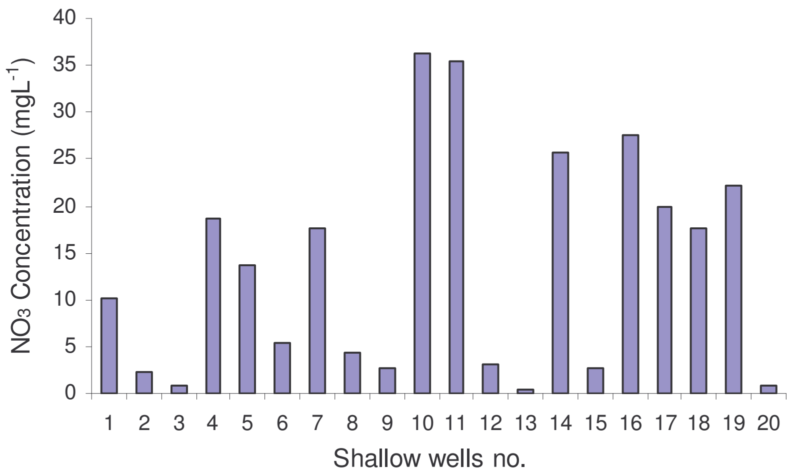

Figure 2. Range of nitrate concentrations in shallow wells

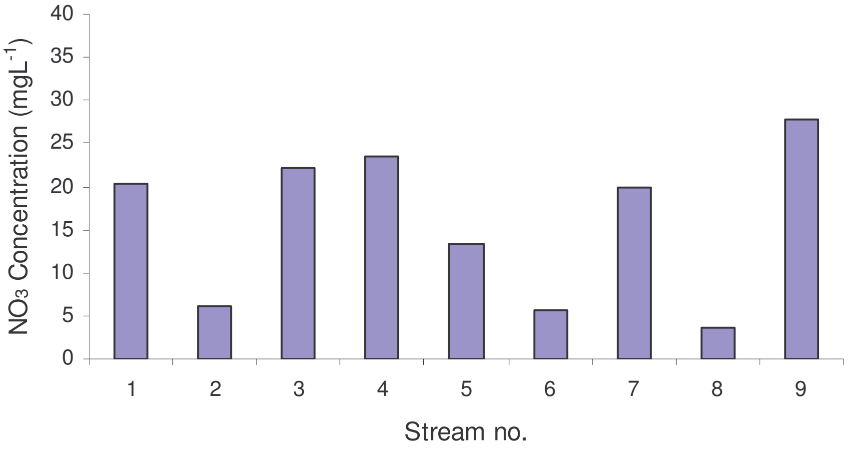

Figure 3. Range of nitrate concentrations in streams

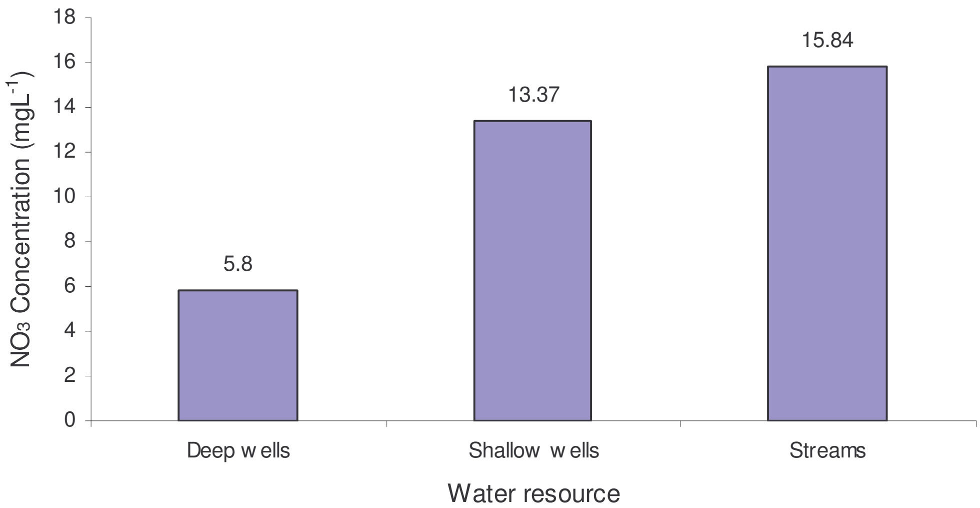

Figure 4. Mean values of nitrate concentrations in different water resources of Gorgan

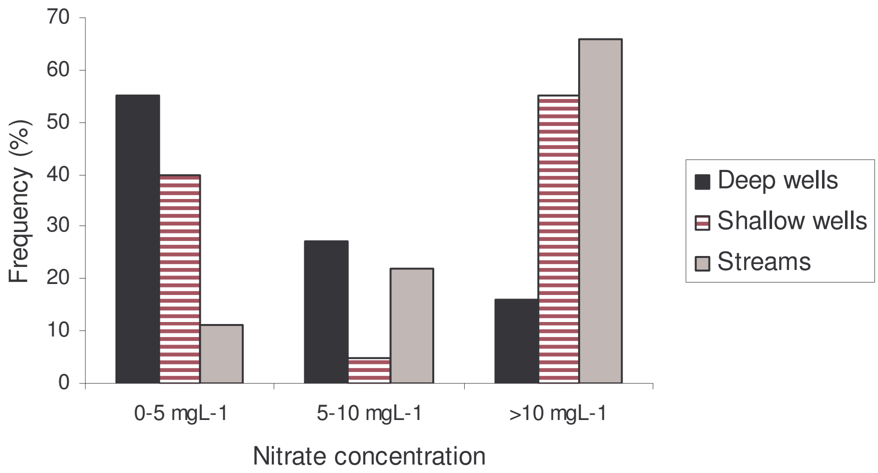

Figure 5. Nitrate frequencies in different water resourses

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The Effects of Natural Zeolite on Ions Adsorption and Reducing Solution Electrical Conductivity II) Cl and NO_3 Solutions

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ABSTRACT

Zeolites can change soil solution compositions due to having high capacity of adsorption as well as water holding capacity. Zeolite are able to decrease fertilizer losses and their leaching from the soil and also able to adsorb the environmental pollutants such as heavy metals and toxic elements from the wastewaters. Some soil solutions are rich of different metals as well as anions which may potentially be harmful for the organisms and the environment. Natural zeolites such as clinoptilolite, analcime, laumomtite, phillipsite, mordenite are crystalline alominosilicate minerals and are effective minerals to decrease the risk of toxic cations as well as anions. In a series of experiments different mixtures of soil with zeolite were prepared using 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight. The constant amounts of mixtures were treated with constant volumes of solutions containing NaCl, $NaNO_3$, KCl and KNO_3. The electrical conductivity of each solution was 0, 5, 10, 15 and 20 dS/m. All samples were replicated two times and each batch of experiment was containing 60 samples with total number of 240 samples for the whole experiment. Mixtures of soil with zeolite were treated with different salt solutions and were shake for two hours prior to analysis. All suspensions were filtered and their electrical conductivity was measured at constant temperature. The results showed that electrical conductivity of filtered solutions was lower in mixtures containing zeolite compared to soil. Also the electrical conductivity of the filtered solutions was considerably lower in NO_3^- solutions compared to Cl^-. It concluded that zeolite could probably reduce the electrical conductivity of soil solutions by adsorption of ions from the primary solutions and it seems that zeolite would tend to adsorb more NO_3^- ions compared to Cl^- ions from the solutions resulting lower electrical conductivity of NO_3^- containing compared to Cl^- containing solutions.

Keywords: Zeolite, Anions, Soil, Adsorption, Electrical conductivity.

INTRODUCTION

Zeolite is a naturally occurring crystal formed from volcanic ash over 300 million years ago. This crystalline compound has a cage-like, honeycomb structure, which is negatively charged and therefore attracts and captures harmful substances. Britannica Concise Encyclopedia explain zeolites as any member of a family of hydrated aluminosilicate minerals that have a framework structure enclosing interconnected cavities occupied by large metal cations (positively charged ions) generally sodium, potassium, magnesium, calcium, and barium and water molecules. The ease of movement of ions and water within the framework allows reversible dehydration and cation exchange, properties that are exploited in water softeners and molecular sieves for pollution control, among other uses (Britannica Concise Encyclopedia, 2008).

More than 150 zeolite types have been synthesized and 48 naturally occurring zeolites are known. Natural zeolites form where volcanic rocks and ash layers react with alkaline groundwater. Zeolites also crystallized in post-depositional environments over periods ranging from thousands to millions of years in shallow marine basins. Naturally occurring zeolites are rarely pure and are contaminated to varying degrees by other minerals, metals, quartz or other zeolites. For this reason, naturally occurring zeolites are excluded from many important commercial applications where uniformity and purity are essential (Wikipedia, 2008).

Although many researchers have reported relatively high Cation adsorption capacity for zeolites (Mineyev et al, 1990; Zamzown et al,1990; Weber et al, 1982; Li et al, 2000; Oste et al, 2001), there are some reports on the adsorption of anions by zeolites (Zhang et al, 2006; Sullivan et al, 2003; Yousofi and Sepaskhah, 2005).

Zhang et al (2006) investigated the potential of using surfactant (hexadecyltrimethylammonium)-modified zeolite (SMZ) as an inexpensive sorbent for removing perchlorate (ClO_4^-) from contaminated waters in the presence of competing anions. They found, in batch systems, the presence of 10 m*M* OH^- (i.e., pH 12), CO_3^{2-}, Cl^-, or SO_4^{2-} had little effect on the sorption of ClO_4^- by SMZ, indicating that the sorption of ClO_4^- by SMZ was very selective. The presence of 10 m*M* NO_3^-, however, reduced the sorption of ClO_4^- at low initial concentrations. The maximum sorption capacity for ClO_4^- by the SMZ remained relatively constant (40–47 mmol kg^{-1}), in the absence or presence of the competing ions. In flow-through systems, ClO_4^- broke through the SMZ columns much later than other anions present in an artificial ground water. The affinity of the anions for SMZ followed the sequence of $ClO_4^- >> NO_3^- > SO_4^{2-} > Cl^-$. The exchange of ClO_4^- with NO_3^- corroborated results of the batch tests where NO_3^- was shown to compete with ClO_4^- sorption on the zeolite surfaces. In a similar work, Yousofi and Sepaskhah (2005) found that application of 2, 4 and 8 gKg^{-1} zeolite to the soil, were decreased the amounts of NO_3^- leached down out of the soil columns to 87.7%, 74.7% and 63%, compared to 95% for control, respectively, indicating clear evidence for zeolite to adsorb NO_3^- anions.

Reviewing the literatures shows that new types of soil amendments are being considered to reduce the leaching losses of N fertilizers. One such potential soil amendment is clinoptilolite, which is a natural zeolite (Weber et al, 1982). Clinoptilolite zeolite has a high CEC (160 cmol kg^{-1}), a large affinity for NH^+_4 ions and water molecules that may reduce N leaching on sand based putting greens. In an experiment, the impact of CZ amendment of sand putting greens on N leaching was determined. The lysimeter method was used to determine NO_3^- and NH^+_4 leaching potential and fertilizer N use efficiency. The results showed that sand plus zeolite had a lowered concentration of NO^-_3 and NH^+_4 in leachate while doubling the water retention capacity and increasing CEC 200 fold. The greatest reduction of N leaching was found from lysimeters amended with zeolite at the highest N rate. Nitrate and NH^+_4 leaching were 86 and 99% lower, respectively, than the unamended sand lysimeters. The N fertilizer use efficiency was improved by 16 to 22% with the addition of zeolite to sand, depending on N application rate. Amendment of sandy rooting media with clinoptilolite promoted better fertilizer N uptake efficiency and reduced N leaching from a highly leachable soil (Huang and Petrovic, 1992). Similar results were also found by others (Weber et al, 1982).

Soil salinity is a major abiotic factor limiting crop production but an amendment with synthetic zeolite may mitigate effects of salinity stress on plants. In a research, a substantial increase in plant biomass of salt stressed barley was observed in zeolite-amended treatments. The application of zeolite also enhanced water and salt holding capacity of soil. Post-harvest soil analysis showed high concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) due to saline water especially in the upper soil layer but concentrations were lower in soils treated with zeolite. Zeolite application at 5% increased Ca^{2+} concentration in salt stressed plants; concentrations of trace elements were also increased by 19% for iron (Fe^{2+}) and 10% for manganese (Mn^{2+}). The overall results indicated that soil amendment with zeolite could effectively ameliorate salinity stress and improve nutrient balance in a sandy soil (Al-Busaidi et al, 2008).

Other researchers have also reported other ions such as Arsenic (Sullivan et al, 2003), Chromate, CO^{2-}_3 and HCO^-_3 (Li, 1996) on surfactant-modified zeolites. Zeolites have also been shown to have the potential to control NH_3. Because of their properties it is also expected that zeolites could effectively adsorb NH_3 and odor (Cai et al, 2006) Zeolite adsorption of ethylene and other gases for use in the purification of natural gas has also been well characterized (Peiser and Suslow. 1998).The poultry manure was treated with various amendments which included two natural zeolites, clay, $CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, and $Al_2(SO_4)_3$. The zeolite amendments were proposed to be the most suitable for reducing NH_3 losses during composting of poultry manure (Kithome et al, 1997).

The object of this study was to investigate the effects of natural zeolite on solution electrical conductivity and some selected anions sorption under the condition of this experiment.

MATERIALS and METHODS

In a series of experiments different mixtures of soil with zeolite were prepared using 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight. The constant amounts of mixtures were treated with constant volumes of solutions containing NaCl, $NaNO_3$, KCl and KNO_3, separately. The saline solutions were prepared using different concentrations of each salt to make the final electrical conductivity of each solution as 0, 5, 10, 15 and 20 dS/m (Rowell, 1994). All samples were replicated two times and each batch of experiment was containing 60 samples with total number of 240 samples for the whole experiment. Mixtures of soil with zeolite based on the ratio of 0, 0.5, 1, 5, 10 and 100 percent of zeolite by weight (equal to 0, 0.1, 0.2, 1, 2, and 20 grams of zeolite per 20 grams of soil-zeolite mixtures, respectively) were treated with different salt solutions and were shake for two hours prior to analysis. All suspensions were filtered and their electrical conductivity was measured at constant temperature. The data processing and graphs were performed using Excel computer program.

RESULTS and DISCUSSIONS

The results showed that, generally, application of zeolite to the soil significantly decreased the electrical conductivity of the equilibrated solutions in the mixtures of soil-zeolite (Figures 1 to 6). However, comparing the results of NO_3^- salts with Cl^- salts revealed that there were differences between NO_3^- and Cl^- in terms of zeolite effects. As an example, in NaCl solutions and EC equal to 20 dSm-1, application of zeolite by the rates of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures, decreased the electrical conductivity by 2%, 0%, 16%, 2% and 23%, respectively, compared to the control with no added zeolite (Figure 1). The corresponding data for $NaNO_3$ solutions were 0%, 3%, 25%, 20% and 8%, respectively, compared to the control (Figure 2). Mean pooled data for salinity levels also showed that application of zeolite by the rate of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures in $NaNO_3$ solutions, decreased the electrical conductivity by 2%, 6%, 15%,18% and 16%, respectively, compared to the control (Figure 3). At the same conditions for pooled data, the corresponding values for NaCl showed that zeolite decreased the electrical conductivity by 0%, 9%, 12%, 2% and 17%, respectively showing greater decrease in electrical conductivity in NO_3^- salts compared toCl^-(Figure 3). Since all the conditions in the experiment were the same, and also both salts were contained Na as their cations, the differences between these salts could be due to the difference between their anions which are NO_3^- and Cl^-.

Other data for NO_3^- and Cl^- salts in potassium solutions were also showed similar but much stronger results compared to which were already found for sodium solutions (Figures 4 and 5). As an example, in KNO_3 solutions and EC equal to 20 dSm-1, application of zeolite by the rates of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures, decreased the electrical conductivity by 47%, 54%, 52%, 53% and 65%, respectively, compared to the control with no added zeolite (Figure 4) while the corresponding data for KCl solutions were only 2%, 19%, 5%, 10% and 33%, respectively (Figure 5). However, mean pooled data for salinity levels showed that application of zeolite by the rate of 0.1, 0.2, 1, 2 and 20 grams per 20 grams mixtures in KNO_3 solutions, decreased the electrical conductivity by 13%, 33%, 31%, 49% and 52%, respectively, compared to the control (Figure 6). The corresponding data for KCl salt were only 2%, 14%, 2%, 4% and 8%, respectively (Figure 6), indicating much greater effects of zeolite in NO_3^- solutions compared to Cl^-, even if pooled data are examined. Again, similar to sodium salts, since all the conditions in the experiment were the same, and also both salts were contained K as their cations, the differences between these salts could be due to the difference between their anions which are NO_3^- and Cl^-

Although there are plenty reports to reveal high cation adsorption capacity for zeolites (Mineyev et al, 1990; Zamzown et al,1990; Weber et al, 1982; Li et al, 2000; Oste et al, 2001), however, the affinity of zeolite to adsorb some anions were also been reported (Zhang et al, 2006; Sullivan et al, 2003; Yousofi and Sepaskhah, 2005). The findings in this research were in agreement with other findings who have also reported NO_3 adsorption by zeolites (Huang and Petrovic, 1992, Yousofi and Sepaskhah, 2005). They found that application of 2, 4 and 8 gKg^{-1} zeolite to the soil, were decreased the amounts of NO_3^- leached down out of the soil columns to 87.7%, 74.7% and 63%, compared to 95% for control, respectively (Yousofi and Sepaskhah, 2005), and also, the greatest reduction of N leaching was found from lysimeters amended with zeolite at the highest N rate where nitrate and NH^+_4 leaching were 86 and 99% lower, respectively, than the unamended sand lysimeters (Huang and Petrovic, 1992), indicating clear evidence of NO_3^- adsorption by zeolite.

Lower salinity when NO_3^- salts are used could be explained by preference of NO_3^- adsorption compared to Cl^- by zeolite. Although the equilibrated solution samples were not analysed for NO_3^- and Cl^- concentrations in this stage, however, significant lower electrical conductivity in NO_3^- solutions compared to Cl^- in the presence of both sodium as well as potassium cations, supported the idea that more adsorption of NO_3^- has been probably occurred compared to Cl^- using zeolite. Although it may not be the only reason to explain this response, but anions competition for adsorption on zeolite could be an explanation. Other workers were also found similar results that NO_3^- was shown to compete with ClO_4^- sorption on the zeolite surfaces (Zhang et al, 2006). They also showed that the affinity of the anions for zeolite followed the sequence of $ClO_4^- >> NO_3^- > SO_4^{2-} > Cl^-$, indicating greater affinity of NO_3^- for adsorption compared to Cl^- (Zhang et al, 2006)

The results of this research suggested that zeolite is an effective soil amendment in order to improve soil salinity in both NO_3^- as well as Cl^- solutions. However the data suggested stronger effect of zeolite in NO_3^- solutions compared to Cl^- to decrease the solution electrical conductivity. Since NO_3^- could be leached down easily in soils especially in sandy textures, zeolites would be useful materials to prevent the loss of N fertilizers in soil and to supply good source of N to the roots.

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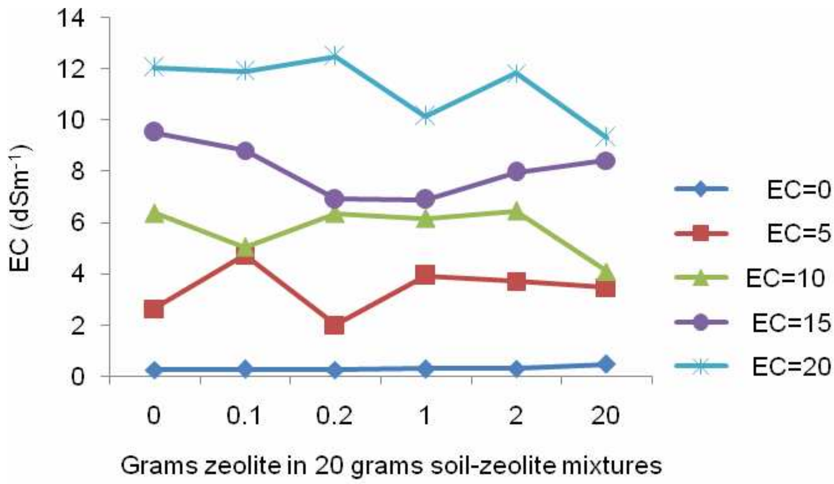

Figure 1. The effects of zeolite on electrical conductivity of soil using NaCl

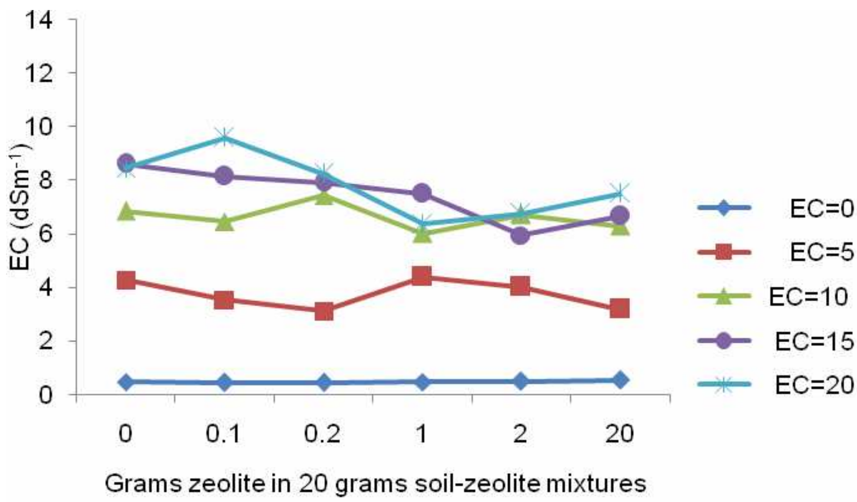

Figure 2. The effects of zeolite on electrical conductivity of soil using $NaNO_3$

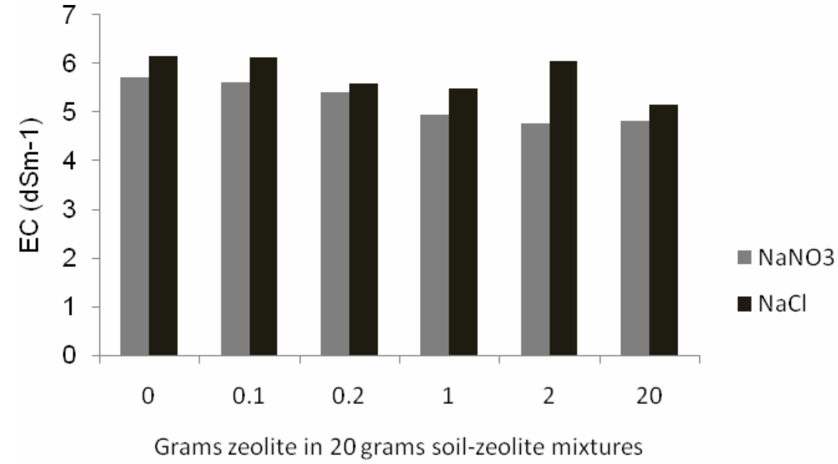

Figure 3. The effects of zeolite on electrical conductivity (pooled mean values for NO_3 and Cl in sodium solutions)

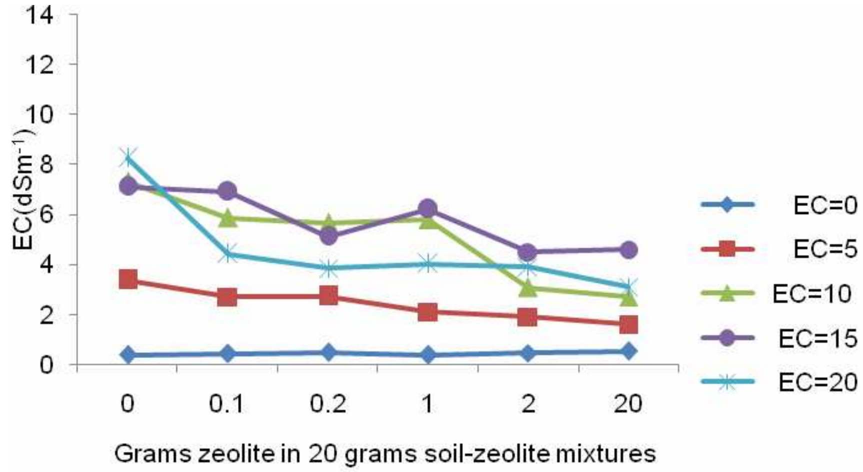

Figure 4. The effects of zeolite on electrical conductivity of soil using KNO_3

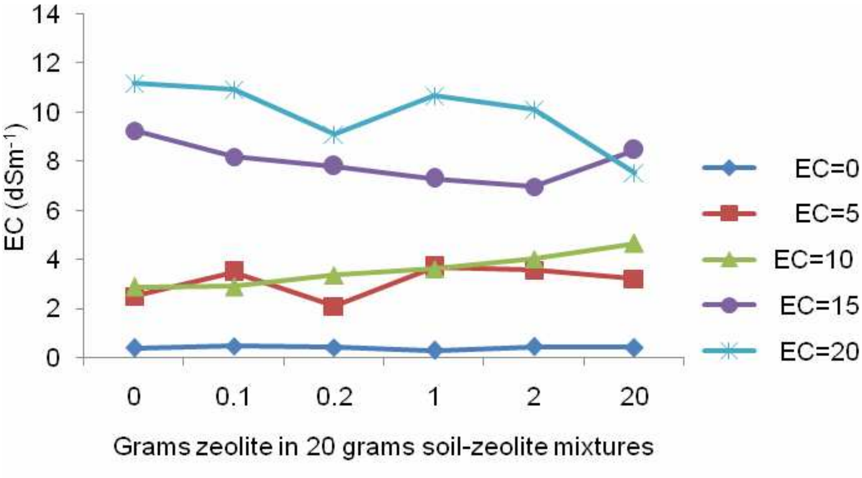

Figure 5. The effects of zeolite on electrical conductivity of soil using KCl

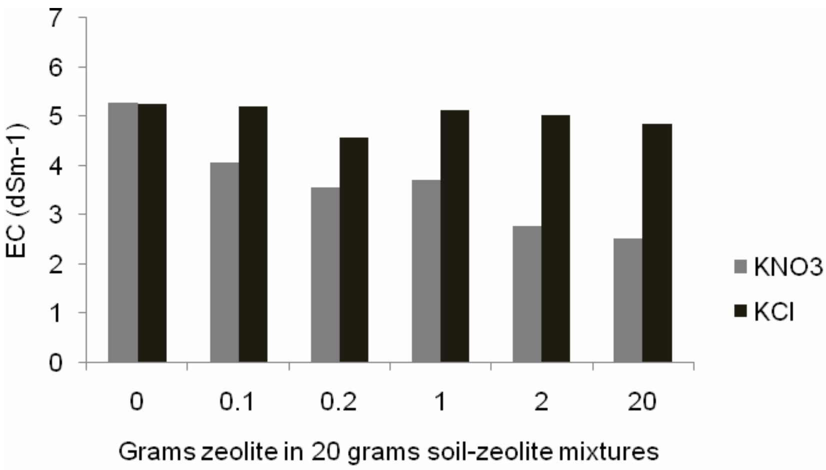

Figure 6. The effects of zeolite on electrical conductivity (pooled mean values for NO_3 and Cl in potassium solutions)

Factors Controlling the Bioavailability of Potentially Harmful Metals in Wastewater Treated Soils

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ABSTRACT

Sewage sludge contains significant proportions of nitrogen, phosphorus and organic matter. It therefore has a similar fertiliser value to animal manures and slurries. Typical applications can provide a significant contribution to the nitrogen and phosphate requirements of arable and grassland crops. In addition, sludge can contain potentially harmful substances, including pathogens, persistent organic pollutants and toxic metals. It is therefore necessary to control the use of sewage sludge in order to protect human and animal health and to maintain soil fertility and crop yields. The bioavailability of heavy metals can be affected by several factors. Some of these factors are related to soil and some others may be related to plant characteristics. Soil pH, organic mater content, redox status, carbonate content, chloride content, moisture, source and form of metals and plant genotype may be the most important. However, investigation of any factors which may reduce or enhance the availability of heavy metals in soil and uptake by plants would be crucial. Such knowledge and information on these factors could be used and would help the authorities to manage and control the environmental problems which are concerned with sludge application to agricultural land and could threaten the human health. This paper is going to review and describe the factors and circumstances of which the bioavailability of potentially harmful metals would reduce or enhance in soil.

Keywords: Heavy Metals, Bioavailability, Soil, Sewage sludge.

INTRODUCTION

Application of sewage sludge to soil can influence the chemical, physical and biological properties of the soil. After loading of sewage sludge to soils, regardless of the sources, a series of chemical and biological processes will be initiated. Some of these processes, such as those microbiologically-related and adsorption processes may be rapid, but some others such as physical properties may take some time. Nonetheless, these may be beneficial, particularly in arid and semi-arid regions where soils normally have poor physical characteristics due to low organic matter. However, application of sewage sludge in these regions would also raise the risk of increasing metal availability in soil solution because many of these soils have high salinity and chloride concentrations in the soil solution. Application of sewage sludge could also influence the chemical and biological properties of the soil. There may be changes in soil cation exchange capacity, soil pH and soil metal concentration, as well as changes in soil biological activity. Of course, change in any of these factors would result in changes in the bioavailability of potentially toxic metals and their uptake by plants.

In recent years, sewage sludge has been used as a soil fertiliser. In addition, the organic matter content of sludge can improve the water retaining capacity and structure of some soils, particularly when applied in the form of dewatered sludge cake (MAFF 1996). Although, some benefits support the sewage sludge application to soils, some other factors may limit its utilisation (Alloway and Jackson 1991). In order to reduce the hazards involved with sludge application to agricultural land, governmental agencies have set up rules which restrict the sludge application to control disadvantages. To achieve the minimum harm and the maximum benefit of sewage sludge, Sludge Regulations and Code of Practice for Agricultural Use of Sewage Sludge have been prepared to provide guidance and requirements on the application of sludge to agricultural lands (MAFF 1996)

Since potentially toxic metals are frequently found in sewage sludge and application of sewage sludge to soil and agricultural lands has significantly increased recently, the behaviour of heavy metals in soils treated with sewage sludge has received a marked attention. In the past few years, a large number of projects have been conducted on heavy metals, sewage sludge and their potentially toxic impact to environmental ecosystems. Human health risks as well as environmental pollution implications could be the main reasons for this attention.

Soil pH and Carbonate Content

One of the factors that has received the most attention is soil pH. This can markedly affect the bioavailability and consequently the plant uptake of metals. The effect of pH on the solubility and plant-availability of different metals is greater for some than others (Smith 1996). It is also found that pH has a greater influence on the extraction of heavy metals with chemical solvents than on their uptake from the soil by plants. This may be due to an increased efficiency in the process of plant uptake at higher pH values. Apparently, there are also some differences in the influence of pH on the uptake of native and applied metals. The availability of most metals decreases with increase in pH (Sillanpaa 1976, Ross 1996, Alloway and Jackson 1991) but the availability of Mo and elements with anionic species increases with increasing soil pH (Sillanpaa 1976, Smith 1996). Most researchers have found that the bioavailability of cationic forms metals to plant from sludge-treated soils decrease as the pH is increased either by liming or applying calcareous sludges (Alloway and Jackson 1991).This effect can be due to both a pH effect and / or an increase in Ca^{+2}ions (due to lime) (Alloway and Jackson 1991).

Jackson and Alloway (1991) showed that liming soils (to pH 7) which had been heavily amended with sewage sludge reduced the Cd concentration in crops. Similar results were found by Hooda and Alloway (1996). They found that liming the soils to pH 7 prior to sowing significantly reduced metal concentrations in carrot and spinach. This reduction was greater for Cd, Ni and Zn than Cu and Pb. The effect of sewage sludge on crops when used alone or in combination with mineral fertilizers or lime was studied by Merzlaya (1995). He reported that sewage sludge had a greater effect on yield whereas sewage sludge + lime were ineffective and N and P fertilizers had practically no effect. The effect of lime on crops and bioavailability of heavy metals have been studied by many other researchers. Metal mobility decreases with increasing soil pH due to precipitation as insoluble hydroxides, carbonates and as organic complex adsorption on to clay minerals and organic matter is also raised by increasing soil pH value (Smith 1996). Some metals such as Zn, Ni and Cd tend to be influenced strongly by soil pH whereas Cu, Pb and Cr are little affected by changes in soil pH (Smith 1996). Hooda et al (1997) showed that the surest way to control the accumulation of metals in food plants is by controlling their concentrations in the soil. They found that soils with a non-acidic pH and clayey texture tended to achieve better control of metal accumulation in food plants compared to those with an acidic reaction and a course texture.

The Effect of Organic Amendments

Any change in the amount of organic matter may result in a noticeable change in soil cation exchange capacity. In soils with greater CEC, lower concentration of metals may be expected in an extracted solution. In particular, DTPA extractable metals have been found to be lower in soils with a higher CEC compared to lower CEC (Korcak and Fanning 1985). In sludge-treated soils or soils with high organic matter content (e.g. organic soils), increasing organic matter would increase not only the soil CEC but also it would act as a specific absorbent. In these conditions, the effect of CEC, itself, may become unclear due to domination of adsorption and complexation reactions introduced by organic matter. The effect of organic matter on the availability of metals will be discussed separately.

Soil Organic Matter

Organic matter is a very important adsorptive source of metals in soils. Organic matter has a high cation exchange capacity and can adsorb a high concentration of heavy metals. Sludges contain a lot of organic products so they adsorb metals. In addition to the organic matter, sludges contain Fe and Mn oxides that can adsorb other metals (Alloway and Jackson 1991). In some cases, adsorption of metals by organic matter may be great enough to cause deficiency (Sillanpaa 1976). Many metals form insoluble complexes with the soil organic matter and can be efficiently sorbed in relatively unavailable form (e.g. Pb and Cu) (Alloway 1997). Increasing the complexing capacity of soil and the formation of stable organo-metallic complexes by applying sewage sludge, reduces the mobility of metals in soil and thus lowers their availability to plants (Smith 1996). However, in addition to the solid-state organic matter acting as a sink for metals in sludge-treated soils, soluble low molecular weight organic molecules produced during the microbial decomposition of sludge in the soil form soluble complexes with metals. These complexes are more mobile, less readily adsorbed and possibly more readily taken up by plants than free metal ions (Alloway 1997, Antoniadis 1998).

There are some differences between the reactions of various metals with different organic compounds. Humus holds di- and tri-valent metallic cations more firmly than alkaline metal cations. Some researchers showed that Cu forms rather strong complexes with organic compounds and is more likely than Mn to be fixed in humus (De Mumbrum and Jackson 1956). Sometimes plants seem to be able to adsorb organically complexed heavy metals and it appears that many of the metal deficiency cases found in peat soils are not due to the low degree of bioavailability but to the inadequate total metal sources in these soils (Sillanpaa 1976).

Organic matter differs widely in composition and degree of humification and consequently there are different decomposition rates which can affect availability of metals and uptake by plants. Pascual et al (1998) examined the changes in organic matter mineralization when six amendment rates of municipal solid waste, sewage sludge and compost were added to an arid soil. They found that potentially mineralizable C in municipal solid waste-amended soil was significantly higher than in the soil amended by sewage sludge and compost and it increased as the amendment rate of compost and sewage sludge increased. The results also showed that the CO_2 loss:TOC (total organic carbon) ratio differed with amendment rate between fresh and composted wastes. Other results showed that sewage sludge increased the Zn, Cu, Pb, Cd, Ni and Cr content of soil and plants. They indicated that differences in metal content of various composts are generally related to differences in their composition and soil-climate management system in which they are used (Pinamonti 1998, Pinamonti et al 1997).

The effect of temperature on organic matter decomposition and availability of metals and nutrients have also been studied.The behaviour and bioavailability of Cd and Pb from two soils mixed with sewage sludge was studied at two temperatures (15 and 25 ^{o}C) by Hooda and Alloway (1993). They found that Cd and Pb concentration in ryegrass was significantly higher in the warmer temperature compared to lower temperature. Similar results were found by Antoniadis and Alloway (2001).

Hydrous Oxides

Al, Fe and Mn hydrous oxides can adsorb metals (Alloway and Jackson 1991, Alloway 1997). Kuo et al (1985) found that the hydrous Fe oxide content of soils was an important factor in the prediction of metal uptake by Swiss chard. Hue et al (1988) reported that soils contain volcanic ash had the greatest adsorptive capacity for heavy metals and P.

Source and Form of Metals

The form of metals from different sources has an important effect on their availability. It has been found that metals originating from sewage sludge applied to soil tend to be less available than those from many inorganic sources. Tills and Alloway (1983) using liquid chromatographic fractionations found that Cd^{+2} predominated in the solutions of Cd-polluted soils. Around 13% of the total Cd in the soil solution from a sludged soil was found in organic compounds. Ghorbani (2003) found that the addition of the metals to soils as either sewage sludge or metal salts resulted in increased concentrations of these metals in ryegrass tissue but accumulation was greatest from the metal-spiked soils. Similar results were also reported by Hooda (1992) and Antoniadis (1998).

Redox Status

Redox conditions can affect the behaviour of metals. In the reducing environment hydrous oxides of Fe and Mn dissolve and release any metals which were adsorbed or co-precipitated with them thus increasing the availability of several metals (Alloway 1997). Obviously the availability of Mn and Fe is more affected by oxidation and reduction than other metals. Reduction caused by high moisture content or flooding can increase the availability of S, Cu, Mo, Ni, Zn, Pb and Co . The low availability of Mn and Fe in oxidized conditions is usually explained in terms of the lower solubility of the tri-valent as compared with the reduced di-valent form (Sillanpaa 1976). However, oxidation - reduction processes are usually accompanied by changes in soil pH, which may complicate the picture as well as interactions between Fe and Mn and other elements.

Some metals such as Cd tend to form insoluble sulphides with reduced sulphate ions in saturated soils (Alloway 1997). Change in soil conditions such as a fluctuating water table or seasonal changes causes a change in the redox status, and this has been linked to the availability of many metals (Sillanpaa 1976, Alloway 1997). Soil with a fluctuating water table will often have a lower adsorptive capacity for metals such as Cd and As which are strongly sorbed by hydrous oxides of Fe and Mn . The availability of Cd in rice grown-soils can be affected by oxidation-reduction conditions. In flooded conditions, CdS will be formed which is insoluble but in oxidising conditions the Cd^{+2} and SO_4^{-2} will be the main ions. The SO_4^{-2} will cause the soil pH to decrease and consequently Cd will be more available (Alloway 1997).

Antagonistic Effects of Other Metals

Several elements can have antagonistic effects on the availability of metal to plants. Some researchers have found that excessive phosphorus fertilisation has reduced the availability of Cu and Zn (Bingham 1963, Bingham and Garber 1960). Several possible explanations for P-induced Zn or Cu deficiency have been given, including the immobilisation of the metals within the plant by abnormal amounts of P being present, precipitation by P-Zn antagonism within the roots and reactions occurring outside the physiologically active roots, so reducing the uptake of Cu and Zn . Some other antagonistic effects between metals have been reported by some other researchers. Antagonistic effect of Zn/Cu, Zn/Cd, Ca/Cd, Ca/Pb and Mo/Cu are some of them (Alloway 1997).

Salinity

Many factors influence Cd uptake by plants, but the identification of salinity as an important determinant of Cd concentrations in field crops (Li et al 1994, McLaughlin et al 1994) has encouraged further investigation of the effects of Cl on Cd uptake by plants (Smolders and McLaughlin 1996a, Smolders and McLaughlin 1996b).

In an experiment (Smolders and McLaughlin 1996b) the ability of Cd-Cl complexes to be taken up by plants was investigated using Swiss chard in resin-buffered nutrient solutions. The results showed that as solution Cl concentration increased, Cd concentrations in plant shoots also increased from 6.5 to 17.3 mg/kg and in roots from 47 to 106 mg/kg. Since the activity of Cd^{+2} in solution was well buffered during the plant growth using the resin system, complexation of Cd with Cl, increased soluble Cd in culture solution while no significant changes were found in Cd^{+2} activity with increased Cl concentration. Based on these findings, it was concluded that enhancement of Cd uptake by Cl need not to be related only to enhanced diffusion of Cd^{+2} through soil to the roots, but that (i) Cd-Cl complexes species would be available (in addition to Cd^{+2} species) and / or (ii) Cl enhances diffusion of Cd^{+2} through the unstirred liquid layer adjacent to the root surfaces or through the apoplast to sites of Cd uptake within the root itself. It was also mentioned that mechanism (i) is more likely to be the main explanation for increased Cd plant uptake with increased Cl concentration in the solutions.

Cabrera et al (1988) have also reported that Cd uptake by barley was enhanced in NaCl solutions compared to $NaNO_3$ in the presence of humic acid. However they reported more Cd uptake in $NaNO_3$ in the absence of humic acid in the solutions. Although they finally concluded that Cd^{+2} was the preferred species to be taken up by roots over the Cd-Cl species, the effect of Cl in enhancing the Cd uptake in the presence of humic acid could not be ignored. In fact, humic acid may act as a buffer to control Cd^{+2} activities in the presence of Cl in the solution.

Ghorbani (2003) also showed that increased Cl concentration in the soil solution can significantly increase the concentration of Cd in ryegrass as well as spinach. Cadmium speciation in the solutions using $MINEQL^+$ computer model programme, showed that the plants have strong affinity to uptake Cd-Cl complexes as well as Cd^{+2} free ions. Other experiments (Ghorbani 2003) also showed that ionic strength, inorganic complexation, index cation as well as pH are the most factors affecting the adsorption of Cd in both soil and sludge-treated soil. He finally concluded that Cd uptake could be affected by Cd complexation in soil and in the solutions through change in Cd^{+2} activity as well as plant absorption of Cd-Cl complexes.

Bingham et al (1984) evaluated the effect of salinity on the availability of Cd by Swiss chard. They found that there was an important relationship between the calculated chemical speciation of Cd in the soil solution and Cd availability to Swiss chard as judged by leaf Cd concentration. Bingham et al (1986) also studied the effect of sulphate salinity on availability of Cd in soil. They reported that the absence of a statistically significant effect of SO_4 on leaf Cd may be associated with the general lack of the effect of SO_4 treatment on total free Cd ions (Cd^{+2}) in the soil solution. This behaviour contrasts with that reported by Bingham et al (1984) for the effect of Cl treatment which tended to increase total Cd in soil solution and was highly significant in affecting leaf Cd in Swiss chard. The authors concluded that these differences are due to differences in speciation of SO_4 and Cl with Cd in solution. In contrast with the above results, some other workers reported the significant effect of SO_4 on Cd uptake by Swiss chard. They found that increasing SO_4 concentration in nutrient solution and soil solution causes increased Cd uptake. They concluded that the $CdSO_4$ complex is clearly as available to plant as Cd free ions (McLaughlin et al 1998a and McLaughlin et al 1998b). Increasing Cd uptake with increase in Cl concentration in soil solution in Potato tubers, Swiss chard and Sunflower kernels have also been reported by others (McLaughlin et al 1994, Bingham et al 1983 and Yin-Ming Li et al 1994).

Plant Species and Genotype

It is recognised that metal concentrations in plants grown on the same soil can vary up to 100-fold between different species but mostly between 4 and 20-fold. However, inter-varietal differences within plants of the some species may vary between 1 and 4 fold (Alloway 1997).

Some researchers have worked on the effect of plant species on metal uptake. Alloway and Morgan (1986) found that there are some differences between species in metals uptake. They reported the following order for Cd and Ni accumulation by lettuce, cabbage, carrots and radish (Alloway 1997):

Cd : lettuce > cabbage > carrots > radish

Ni : radish > lettuce > cabbage > carrots

Jackson and Alloway (1991) reported that the component of the diet which made a major contribution to the overall exposure to the metal and which were also sensitive to changes in soil Cd concentration were : cereal grain, potatoes, root vegetables and leafy vegetables (Alloway 1997). Some differences between cultivars have also been reported. McLaughlin et al (1994) found that 15 cultivars of potato varied widely in Cd concentrations on the same soil with ranges of 9-39 µg/kg on one site and 29-56 µg /kg at others (Alloway 1997).

Genotype variations in metal uptake by plants may be partly due to differences in root morphology and biochemistry. The rhizosphere which is the zone surrounding plant roots at the interface with the soil seems to have an important role in this. The zone contains a very active and diverse population of micro organisms and organic materials from roots. Some metals and micronutrients can become more available in the rhizosphere. As the composition of the rhizosphere may differ in plant species, it has been reported that some species may be able to take up different amounts of metals by roots (Alloway 1997). The differences between plant genotypes in term of Cd uptake have also been reported (Hocking and McLaughlin 2000).

Other Factors

The main factors affecting availability of metals in soils have already been discussed. There are some other factors such as soil texture, soil moisture, soil temperature and soil aeration which may contribute to metal availability. The effect of theses factors is likely to be indirect. Clay content can directly influence the soil CEC and contribute to the adsorption of metals in soils. The effect of other factors such as temperature and soil moisture may be through their effect on the soil microbial activity or qualifying the chemical reactions in solution. The availability of all metals seems to be greater in the presence of adequate moisture (e.g. near to field capacity) due to existence of better mass flow and diffusion of metals and their complexes (Alloway 1997). Soil aeration is also important for biological activity and decomposition processes in soils.

Plant Uptake and Accumulation of Metals

The amount of metals taken up by plants may be significantly influenced by their ability to be absorbed and accumulate in a particular plant part. For example, spinach, lettuce, celery and cabbage are known as high accumulators of Cd while potato and maize are low Cd accumulators (Pais and Jr 1997). Such characteristics are useful for selecting those crop plants best situated for soils that have a particular metal content, thereby avoiding the potential of introducing the metal concerned into the food chain (Chaney 1983). Also, some plant parts tend to accumulate more metal than others. For instance, it is widely accepted that for most plants, cadmium is accumulated much more in roots than in leaves.

When the soil substrate is ready to be assimilated by plant roots, and the mineral salts, including metals, are mobile, it could be expected that the proportion of the metals absorbed by plants would be the same as their proportion in the soil solution, but this is not normally so. In fact, plants selectively absorb certain metals in definite proportions (Ermolenko 1972). The entry of mineral substrates into the plants is determined by electrolyte concentration in the soil solution, ion exchange, permeability of membranes, Donnan equilibrium, membrane potential, etc. As a result minerals and water are supplied to the cells, while the decomposition products are eliminated from the cells. While diffusion is possible into and out of the cells, such a cell is not in equilibrium with the surrounding medium; the cell is controlling the biological migration of different ions. It has been established by work using radioactive isotopes that when ions are absorbed by roots from the surrounding medium, both diffusion and active migration of specific ions take place (Ermolenko 1972).

Thus, the selective sorption of specific ions by plants is due to the metabolic activity of the cells. The theory of active migration of ions in the organism by way of carriers was found to be applicable to most of the cations and anions, even though the selective absorption of some ions can be explained in other ways. The transfer of oxygen by haem to the cells of living organism is an excellent example of an element being transported on a carrier and not by diffusion. It is also noticeable that haemoglobin selectively absorbs oxygen rather than nitrogen from the air, even though the amount of available nitrogen in the atmosphere is more than three times larger than that of oxygen. Similar selectivity is shown in plant uptake mechanisms.

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Research on Pollution Caused by Thermal Power Plants in Muğla

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ABSTRACT

The paper studies the heavy metal pollution caused by Gökova (210 MWx3), Yeniköy (210 MWx2) and Yatagan (210 MWx3) Thermal Power Plants in Mugla. For this purpose, the heavy metal level of the leave and soil samples taken in each season from olives is stated. The minimum heavy metal level is found in Yatagan, and the maximum in Yeniköy. The heavy metal level of the soil samples generally increases in autumn. The level of the leave samples has generally its highest levels in winter. Because Lignite includes low calorie and high sulphur and ash and especially Yatagan becomes demoded, the pollution continues to pose a serious threat in the precinct.

INTRODUCTION

Thermal Power Plants produce energy by ignited fossil fuels such as coal, petrol or gas. The 60 percent of World electricity production is supplied by fossil fuels. Thermal Power Plants contribute the country's 60 percent of energy production. Yatagan (3*210 MW), Yeniköy (2*210 MW) and Kemerköy (Gökova) (3*210 MW) Thermal Power Plants all of which have 1680 MW power of Thermal Power Plants with 10.794 MW power which are settled in the country and regularly produce electricity for the national power allocation system are in Mugla.

Considering the importance of the tourist receipts for our developing country, the importance of electricity production for the precinct, which has an intensive tourism potential, is apparent. However, at the same time it cannot be ignored that the precinct has foremost *Pinus brutia* Ten. and *Pinus pinea* L. forests, a quite rich forest potential, and a high agricultural production potential. This prosperity is in jeopardy. In precinct, olive (*Olea europea* L.) is harvest vegetation raised intensively and from which oil is produced. Due to the fact that lignite used in Thermal Power Plants is burnt in elevated temperatures, several heavy metals in the lignite turns into ash. Some of the ashes accrue with un-burnt organic matter while most of the ashes are moved through chimney with hot gases and it is released to the atmosphere. Forests and vegetation around Thermal Power Plants are negatively influenced long terms by heavy metal particulates and ashes. The heavy metal content directly related to the increase in the ash level of the coal used as an energy resource changes from source to source. The ash ratio produced by Yatagan Thermal Power Plant which uses Yatagan-Eskihisar lignite including % 20-27 ash and has 3 working units is stated as 1-1.4 million tone/year.

The anatomic and morphological changes on vegetation because of air pollution have been studied in many researches. According to a study executed in Mugla Yatagan Thermal Power Plant region, the scrub which constitutes the forest substratum is preserved whereas red pines which constitute the upper crust of the forest are destroyed by the pollution caused by Thermal Power Plant and forest area which gets dry is 3047 acres (Nuhoğlu et. al.1996). The observations done in the same region for 22 years shows that the width of the pines rings has decreased annually about 07-28 mm. (Tolunay, 2003). The pollution caused by Thermal Power Plants damaged not only aboveground but also the subterranean waters. In a research which studies the effect of Mugla Yatagan Thermal Power Plant on aboveground and subterranean waters, it is reported that Ca_2^+, Cd_2^+, Pb_2^+ and Sb_2^+ metals in water samples taken from 2 barrage, 5 surface and 21 ground water are above the boundary value (Baba et. al., 2003). Another study reports that the effects of the ashes from Yatagan Thermal Power Plant are geochemistrically evaluated and it is required to create precautions and a detailed program to prevent soil contamination in the region intensively affected by ashes (Baba, 2003). In a study to determine some features of fly ash and heavy metal contents from Soma and Tuncbilek Thermal Power Plants, it is stated that the environmental problems caused by the lignite which is used as a fuel in Thermal Power Plants are not only the result of gas emission but also the problem of fly ash storage. The main problem about fly ash results from the heavy metal remains in fly ash storage. The important point in the study is when fly ash comes together with water, it can be resolved. So that it can cause soil pollution (Baba and Kaya, 2004). Some prominent features of lignite coal used as a fuel in certain Thermal Power Plants settled in Turkey and its heavy metal content is examined. It is found that lignite used in Çayırhan, Seyitömer, Tunçbilek, Orhaneli, Soma, Yatagan, Yeniköy, Elbistan, Kangal and Çatalagzi plants contains high moisture (% 14-47), high ash (% 23-64) and % 0.4-4.8 sulphur. It is reported that energy level of lignite is about 1370-4980 kcal/kg. It is noted that coals have such minerals as not only clay but also quartz, feldspat, calcite, dolomite, pyrite and gyps. In addition to these, it contains siderite, aragonite, and zealot. It is also reported that coals are rich in Cr, Cs, Mo, Ni, Rb, Th, U and V metals and according to As, Co, Cu and Mn, coals excess the global standards (Karayigit et. al. 2000).

Considering the environmental reasons mentioned above and the electricity production of our country, this study aims to search the effects of 3 Thermal Power Plants settled in Mugla on soil and vegetation. In this study, pervasively growing olive orchard is used as a material. Each season, leave and soil samples are taken from the olives around each of 3 Thermal Power Plants. In all the leave and soil samples, there are 9 heavy metals (Fe, Cu, Mn, Zn, Ni, Cd, Pb, Co, Cr) and the results are examined.

MATERIAL and METHOD

The research materials are made of the leave and soil samples taken each season from the olive plantations around Gökova (Kemerköy), Yeniköy and Yatagan Thermal Power Plants in Mugla.

After soil samples are turned into air dry in laboratory, they become ready for analyzing process by being sieved in a fine sieve (2 mm) (Jackson, 1967). In the soil samples, heavy metals and certain trace elements (Fe, Zn, Mn, Cu, Cd, Co, Cr, Ni, Pb) king water (HNO_3+HCl) are found by extraction method in Atomic Absorption Spectrometer (AAS) (Kick et al., 1980).

Leave samples taken from young olive trees around each of the 3 Thermal Power Plants are brought to laboratory in freezing compartments. After they are turned into air dry in 65 ^oC, they are ground and analyzable (Kacar,1972). After heavy metals and certain trace elements (Fe, Zn, Mn, Cu, Cd, Co, Cr, Ni, Pb) in the leave samples are turned in to ashes in 550 ^oC by dry-blowing method. They are found in vegetation samples extracting with 2N HCl by Atomic Absorption Spectrometer (AAS) (Isaac and Kerber, 1969; Kacar, 1984).

RESULT and DISCUSSION

The Heavy Metal Levels in the Soil Samples taken from Olive Plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants

The heavy metal levels in the soil samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants are defined and average results are shown in the Table 1.

Table 1. The heavy metal levels in the soil samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants

Plants	Fe (%)	Zn	Mn	Cu	Cd	Co	Cr	Ni	Pb
Gökova	1.9	87.4	544.7	24.6	0.90	17.6	50.7	66.3	23.3
Yeniköy	2.2	84.0	560.0	25.3	1.12	24.2	44.7	65.6	29.8
Yatagan	1.7	75.9	487.7	22.4	0.98	16.8	35.8	42.4	33.7
Average	**1.9**	**82.4**	**530.8**	**24.1**	**1.00**	**19.5**	**43.7**	**58.1**	**28.9**

The findings in Table 1 are in rapport with many researchers' findings. All the metals examined (except for nickel) are in normal boundaries. Saatçı et al. (1988) in Izmir Hakerlerler et al. (1992) in Harran Plain, Scheffer ve Schachtschabel (1989) in Germany have found total iron value in these lands is min. % 0.5, max. % 5.0. Kloke (1980) and Pendias and Pendias (1984) see 70-400 mg kg^{-1} Zn ve 1500-3000 mg kg^{-1} Mn concentration as criterion on lands. Kloke (1980) ve Pendias ve Pendias (1984) finds 60-125 mg kg^{-1} as boundary level for Cu, 0.01-2.00 mg kg^{-1} as normal boundary and 3-8 mg kg^{-1} as critical boundary for Cd. They also find 25-50 mg kg^{-1} as critical boundary for Co. Shacklette et al. (1971) finds about 37 mg kg^{-1} Cr in 863 soil samples. Cr and Pb value of soil on which olive is raised has the same critical values Kloke (1980) ve Pendias ve Pendias (1984) gives. Ure and Berrow (1982) find that the average concentration of Ni is 93 mg kg^{-1}, proposing Nickel pollution. Considering Kloke (1980)'s 50 mg kg^{-1} Ni concentration, it is apparent that Gökova and Yeniköy Thermal Power Plants' soil is polluted by Ni.

In soil samples taken from olive orchard around each of the 3 Thermal Power Plants, the lowest heavy metal level (Fe, Zn, Mn, Cu, Co, Cr ve Ni) is around Yatagan Thermal Power Plant. The highest is around Gökova (Zn, Mn, Cr, and Ni) and Yeniköy (Fe, Cu, Co, Cr). Especially Mn, Cr and Pb vary more than any other elements. According to .the heavy metal criterion given by Kloke (1980), it is found that only Gökova and Yeniköy's soil are polluted by Ni (Ni>50 mg kg^{-1}).

Table 2. The heavy metal levels in the soil samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants in different seasons (mg kg^{-1})

Seasons	**Plants**	**Fe (%)**	**Zn**	**Mn**	**Cu**	**Cd**	**Co**	**Cr**	**Ni**	**Pb**
Spring	Gökova	1.7	94.7	554.7	21.8	0.38	13.8	40.5	47.9	11.4
	Yeniköy	2.5	77.4	606.0	15.6	0.62	20.2	33.6	52.1	17.9
	Yatagan	1.7	73.3	451.4	16.6	0.90	12.3	16.5	34.7	18.8
Spring Average		**2.0**	**81.8**	**537.4**	**18.0**	**0.63**	**15.4**	**30.2**	**44.9**	**16.0**
Summer	Gökova	1.4	59.7	485.9	21.1	0.76	15.6	68.5	72.8	24.4
	Yeniköy	1.6	54.3	479.4	18.3	1.18	26.8	84.4	74.6	34.7
	Yatagan	1.4	57.2	446.8	18.3	1.34	15.2	77.4	46.6	31.2
Summer Average		**1.5**	**57.1**	**470.7**	**19.2**	**1.10**	**19.2**	**76.8**	**64.6**	**30.1**
Autumn	Gökova	2.5	94.0	701.4	34.1	1.27	25.1	45.3	81.9	29.7
	Yeniköy	2.5	100.8	604.4	44.7	1.70	34.8	36.0	58.0	36.8
	Yatagan	2.0	76.1	624.4	36.2	0.86	25.4	24.2	50.9	35.6
Autumn Average		**2.3**	**90.3**	**643.4**	**38.3**	**1.28**	**28.4**	**35.2**	**63.6**	**34.0**
Winter	Gökova	2.1	101.1	436.9	21.4	1.19	15.9	48.4	62.5	27.6
	Yeniköy	2.2	103.5	550.3	22.6	0.98	15.0	24.9	77.8	29.8
	Yatagan	1.7	97.1	428.0	18.6	0.81	14.2	25.0	37.3	49.4
Winter Average		**2.0**	**100.6**	**471.7**	**20.9**	**0.99**	**15.1**	**32.8**	**59.2**	**35.6**

The result of analysis of the soil samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants in different seasons are shown in Table 2. The total soluable metal contents of soil samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants in different seasons are compared by seasons. It is found in soil samples that: Fe is the lowest in summer, the highest in autumn. Zn is the lowest in summer, the highest in winter. Mn is the lowest in winter, the highest in autumn. Cu is the lowest in spring, the highest in autumn. Cd is the lowest in spring, the highest in autumn. Co is the lowest in winter, the highest in autumn. Pb is the lowest in spring, the highest in winter. Cr is the lowest in spring, the highest in summer. the values of the soil samples taken during seasons are report with the values given by Bowen (1979), Kloke (1980), Pendias and Pendias (1984), Scheffer and Schachtschabel (1989), Hakerlerler et al. (1992)'

By total Ni values, the lowest Ni value is found in spring, the highest in summer. The total Ni value in GAP (South East Anatolia Project) region is found 60.23-111.37 mg kg^1 (Hakerlerler et al., 1992). Therefore, considering Kloke (1980)'s 50 mg kg^{-1} total Ni value, it is realized that the lands around Yeniköy and Gökova Thermal Power Plants are polluted by Ni in all 3 seasons except for spring. The lowest heavy metal level of the soil samples taken from the olive plantations is generally found in spring (Cu, Cd, Cr, Ni and Pb), the highest is in autumn (Cu, Cd, Cr, Ni ve Pb) .

The Heavy Metal Levels in the Leave Samples taken from Olive Plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants

The heavy metal levels in the leave samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants are defined and average results are shown in the Table 3.

Table 3 The heavy metal levels in the leave samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants (mg kg^{-1})

Plants	Fe	Zn	Mn	Cu	Cd	Co	Cr	Ni	Pb
Gökova	263.4	22.8	47.9	7.0	0.30	2.1	1.8	3.6	6.3
Yeniköy	221.1	22.1	38.9	7.1	0.27	2.0	2.3	4.4	9.9
Yatagan	240.3	20.9	39.2	6.7	0.26	2.4	2.1	3.7	8.7
Average	**241.6**	**21.9**	**42.0**	**6.9**	**0.28**	**2.2**	**2.0**	**3.9**	**8.3**

The findings given in table are in rapport with many researchers' findings. Bouat (1971) states that 460 mg kg^{-1} Fe, 84 mg kg^{-1} Zn, 164 mg kg^{-1} Mn and 78 mg kg^{-1} Cu levels are high for olive leaves. In leave samples taken from olive plantations near the fertilizer factory, Hakerlerler and Höfner (1984) finds 1800-8875 mg kg^{-1} Fe, 23-38 mg kg^{-1} Mn, 0.5 mg kg^{-1} Cd, 2.8-11.5 mg kg^{-1} Cr, 6.3-16.0 mg kg^{-1} Ni, 13-88 mg kg^{-1} Pb. Scheffer ve Schaektschakel (1989) finds 0.04-0.5 mg kg^{-1} Cd, 0.1-1.0 mg kg^{-1} Cr, < 3 mg kg^{-1} Ni ve 0.1-6.0 mg kg^{-1} Pb concentration in normal boundaries. In addition, our findings for Cu are in rapport with the values given by Chapman (1966), for Cd with the values given by Kloke (1973) and Bowen (1979). The metals in leave samples Fe, Zn, Mn, Cu, Cd, and Co are in normal boundaries. However, Cr, Ni and Pb metals are in high limit. It can be concluded that lignite used in Thermal Power Plants may profusely include these metals. Sauerbeck (1982) states that the concentration level of Cr which may have toxic effect on vegetation is 1-2 mg kg^{-1} Cr. According to this level, it can be inferred that there is Cr pollution around Yeniköy and Yatagan Thermal Power Plants. Bowen (1979) notes that the normal Ni concentration level is 0.02-5.0 mg kg-1 whereas Schaffer and Schachtschabel (1989) note that it is 3 mg kg^{-1}**.** Considering these levels**,** there is Ni pollution not only around each of the 3 Thermal Power Plants but also in each Thermal Power Plant. According to Sauerbeck (1982), the critical lead concentration level is 10-20 mg kg^{-1} Pb for vegetation. Considering 10 mg kg lead concentration level, there is a Pb pollution danger around Yeniköy and Yatagan Thermal Power Plants. The lowest heavy metal level of the leave samples taken from olive plantations around each of 3 Thermal Power Plants are equally shared by elements. The highest heavy metal level is found in the olive leaves taken from Gökova (Fe, Zn, Mn and Cd) and Yeniköy (Cu, Cr, Ni and Pb) Thermal Power Plants precinct.

Table 4. The heavy metal levels of the leave samples taken from olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants in different seasons. (mg kg^{-1}).

Season	Plants	Fe	Zn	Mn	Cu	Cd	Co	Cr	Ni	Pb
Spring	Gökova	196.2	5.6	30.7	3.4	0.21	1.2	0.8	2.7	2.8
	Yeniköy	191.3	7.0	31.8	3.7	0.19	1.0	0.7	2.5	2.8
	Yatagan	219.6	8.3	34.9	4.2	0.21	1.4	0.9	2.8	3.3
Spring Average		**202.4**	**6.9**	**32.5**	**3.8**	**0.20**	**1.2**	**0.8**	**2.7**	**3.0**
Summer	Gökova	249.4	19.0	33.3	5.0	0.26	1.1	3.0	2.3	11.3
	Yeniköy	148.9	15.6	30.4	5.7	0.24	1.7	4.3	3.4	13.3
	Yatagan	144.8	15.5	31.1	5.6	0.19	2.0	4.3	2.9	10.3
Summer Average		**181.0**	**16.7**	**31.6**	**5.4**	**0.23**	**1.6**	**3.8**	**2.8**	**11.7**
Autumn	Gökova	229.8	27.1	52.5	8.0	0.30	3.6	0.8	3.3	4.4
	Yeniköy	158.5	25.5	39.7	7.6	0.33	3.6	0.6	5.3	4.9
	Yatagan	175.9	21.1	29.8	7.5	0.27	3.7	0.8	3.4	4.3
Autumn average		**188.0**	**24.5**	**40.7**	**7.7**	**0.30**	**3.6**	**0.8**	**4.0**	**4.5**
Winter	Gökova	378.4	39.4	75.2	11.6	0.45	2.4	2.7	6.4	6.5
	Yeniköy	385.6	40.2	53.7	11.4	0.34	1.7	3.5	6.6	18.7
	Yatagan	420.9	38.9	60.9	9.6	0.36	2.5	2.4	5.7	16.8
Winter Average		**394.9**	**39.5**	**63.3**	**10.9**	**0.38**	**2.2**	**2.8**	**6.2**	**14.0**

The heavy metal levels of leave samples taken from olive plantations in different seasons are shown in Table 4 by seasons. As it is seen in table, the level of Fe is lowest in summer, the highest in winter. The level of Cr is lowest in spring and autumn, the highest in summer. The level of Zn, Mn, Cu, Cd, Co, Ni and Pb is the lowest in spring, the highest in winter. The reason why metals appear mostly in wintertime can be the increasing necessity of heating and electricity energy causing Thermal Power Plants to overwork. According to Bouat (1971), the heavy metal level of olive leaves is high. The level of Fe is 460 mg kg^{-1}, Zn is 84 mg kg^{-1}, Mn is 164 mg kg^{-1} and Cu is 78 mg $kg^{-1.}$ Hakerlerler and Höfner (1984) finds 1800-8875 mg kg^{-1} Fe, 23-38 mg kg^{-1} Mn, 88-313 mg kg^{-1} Cu, 0.5 mg kg^{-1} Cd, 2.8-11.5 mg kg^{-1} Cr, 6.3-16.0 mg kg^{-1} Ni and 13-88 mg kg^{-1} Pb in the leave samples taken from fertilizer factory precinct. Apart from these values, Reuter and Robinson (1986) finds the level of Zn is 10-30 mg kg^{-1} and the level of Mn is 20 mg kg.$^{-1}$ Chapman (1966) gives the value of 5-19 mg kg^{-1} for Cu. Kloke (1973) ve Bowen (1979) gives min-max value of 0.1-3.0 mg kg^{-1} for Cd. Macnicol ve Beckett (1985)' min level of Co is 4 mg kg.$^{-1}$ Considering these values, Fe, Zn, Mn, Cu, Cd and Co levels of the leave samples are in normal boundaries. According to Macnicol and Beckett (1985), the

Cr concentration level which causes %10 loss of efficiency on vegetation is 2-18 mg kg^{-1}. For Sauerbeck (1982), the Cr concentration level which has toxic effect on vegetation is 1-2 mg $kg.^{-1.}$ Referring to 2 mg kg^{-1} Cr concentration, it can be proposed that there is Cr pollution on leave samples. For Ni (Nickel), Schaffer and Schabel (1989) find its level below 3 mg kg^{-1} Bowen (1979) finds it normally between 0.02 mg kg^{-1} and ^{5} mg kg^{-1} on the leave samples. Considering 5 mg kg^{-1} Ni concentration, there is Ni pollution in wintertime. Bowen (1979) notes that there is 0.2-20.0 mg kg^{-1} Pb on vegetation while Sauerbeck (1982) notes that the critical lead concentration on vegetation is 10-20 mg kg^{-1} Pb. As it is stated, considering 10 mg kg^{-1}' lead concentration, it is acceptable that there is a Pb pollution in summertime and wintertime. To examine the heavy metal pollution level of soil and vegetation caused by Thermal Power Plants in Gökova, Yeniköy and Yatagan in Mugla, soil and leave samples are taken around Thermal Power Plants and examined. The results are given below: It is notable in the soil samples taken from the olive plantations around Gökova, Yeniköy and Yatagan Thermal Power Plants that some of the average heavy metal concentrations (Fe, Zn, Cd, Co and Ni) are alike while some (Mn, Cu, Cr and Pb) vary.

The lowest heavy metal level in olive plantations is found in Yatagan (Fe, Zn, Mn, Cu, Co, Cr, Ni) and the highest is found in Yeniköy (Fe, Mn, Cu, Cd, Co). The average of Mn, Cr and Pb varies more than any other elements. Ni level in olive plantations in Gökova and Yeniköy (>50 mg kg^{-1} Ni) is the evidence of Ni pollution. The lowest heavy metal level (Cu, Cd, Cr, Ni ve Pb) of soil samples taken from olive plantations in different seasons is generally found in spring and the highest (Fe, Mn, Cu, Cd, Co) in autumn. The highest levels of heavy metal on olive leaves are generally found in the samples taken from Gökova and Yeniköy. The Cr, Ni and Pb levels are especially found in leave samples taken around Yatagan and Yeniköy Thermal Power Plants and these levels are found in little-high limit. The lowest heavy metal levels of the leave samples taken around Thermal Power Plants in different seasons are generally found in the samples (Zn, Cu, Cd, Co, Ni and Pb) taken in springtime and the highest heavy metal levels are generally found in the samples (Fe, Zn, Mn, Cu, Cd, Ni and Pb) taken in wintertime.

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Continuous Monitoring of Suspended Sediment in Rivers by Use of New Methods

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ABSTRACT

Traditional sampling methods are restrictive for spatial and temporal monitoring of suspended sediment in river. Application of these methods is simple but labour intensive to collect and process. For this reason, the use of new technological methods has recently gained importance. These methods are commonly based on the scattering of sound or light in water. Acoustic methods involve propagating sound at around the Megahertz frequency range through the water column. Short bursts of high frequency sound are transmitted from a transducer and directed towards the measurement water sample. Sediment in suspension will scatter a part of this sound back to the transducer. Another method, laser scattering, directs a laser beam through the sample of water where particles in suspension will scatter, absorb and reflect the beam. The scattered laser beam is received by a ring detector that allows measurement of the scattering angle of the beam. Particle size and volumetric concentration can be calculated from knowledge of this angle. In addition to these methods, optical turbidimeters supply an estimate for suspended sediment concentration through measuring either the backscatter of the light or the attenuation of a light beam passing through a water sample. In this paper, these methods were presented and advantages and limitations of each were given for comparison.

Keywords: Suspended sediment, Acoustic, Optical sensor, Laser diffraction

INTRODUCTION

Correct measurement of amount of sediment load is crucial in the design and management of water resources projects for determining the economical life of the facilities. The sediment load carried by river may lead to reduction in useful storage of a dam and congestion in water inlet. Transportation of sediment load not only causes decrease in economical life of facilities but also harm agricultural areas. The suspended sediment yield is the main parameter for hydrological studies and has spatial and temporal variability depending on many factors such as the hydraulic characteristic of the stream, geomorphologic conditions of the catchments, and the climatic regime of the area and the presence of vegetation. Measurement of sediment concentration in a river for long term requires taking periodic water samples for laboratory analyses and it is necessary for specific studies to monitor sediment concentration along the entire storm hydrograph to predict loads (Nakato, 1990 ; McBean et al. 1988).

Suspended sediment data from rivers can be measured by different techniques. However, despite many attempts, field data is still limited and will continue to be so because of sheer difficulty in making field measurements. In this paper, acoustic, laser scattering and turbidimetric methods as well as the traditional methods were presented, and advantages and limitations were given for comparison.

Suspended Sediment Measurement Methods

Water Sampling Method

The primary traditional measurement method has been to take periodic water samples for laboratory analyses. Two different sampling methods are used in rivers to determine the suspended sediment. Point integrating samplers are designed to be lowered to a specific depth within the water column. By this means, a time averaged sample is taken that represents a specific point in the water column. Taking a series of measurements at different depths allows an analysis of suspended sediments with height above the bed. Depth integrating samplers are lowered and raised through the entire water column and accumulate a sample which integrates all points, thus giving a sample which reflects the entire content of the water column, but does not indicate the distribution of the contents within the column. The velocity at the entrance of the intake tube should be equal to the local stream velocity for an ideal suspended sediment sampler (ASCE, 1975).

Acoustic Method

The acoustic method is based on the evaluation of the backscatter signal from suspended particles in water and described as an acoustic backscatter system (ABS). This method involves the propagation of sound from 0.5 MHz to 5 MHz through the water column. The high frequency sound beams transmitted from transducers are directed towards the measurement volume. Sediment in suspension scatters a portion of this sound back to the transducer. The strength of the backscattered signal allows the calculation of sediment concentration. The backscatter amplitude depends on the concentration, particle size, and acoustic frequency. (Wren et al., 2002; Thorne et al., 1991; Hay and Sheng, 1992)

Since the acoustic backscatter system is an indirect method of measurement, an inversion algorithm is required for determining of sediment concentration with measured backscattered signal strength. The acoustic backscatter equations provide the basis for the development of such an algorithm. (Clay and Medwin, (1997), Thorne and Meral (2007)). This method has been demonstrated and utilised successfully under laboratory and field conditions by several investigators. Results showed that sediment concentration and particle size can be measured relatively non-intrusive, with high spatial and temporal resolution with acoustic backscatter systems. (Thostenson and Hanes (1998). Thorne et al. (1993))

Commercially available three or four frequency acoustic backscatter systems, such as the AQUAscat developed by the Aquatec Group, contain separate transducers to estimate the mean sediment sizes along the water column. Each transducer operates both as a transmitter and as a receiver (Fig. 1).

Fig 1. An acoustic backscatter system (AQUAscat 1000) with transducers

Laser Scattering Method

In recent years, the application of laser scattering techniques has opened new possibilities for the measurement of sediment concentration and size distribution. The LISST-100 (Laser In Situ Scattering Transmissometry) which is developed by Sequoia Scientific Inc. using the laser scattering technique (Fig. 2), directs a laser beam through a sample of water where particles in suspension will scatter, absorb and reflect the beam. The diffracted laser beam is received by a ring detector that allows measurement of the scattering angle of the beam. Particle size and volumetric concentration can be calculated from knowledge of this angle (Agrawal and Pottsmith 1994, Pedocchi and Garcia 2006).

Gartner et al., 2001 have reported that laboratory and field measurements indicate the potential of the LISST as a powerful research tool for sediment measurement studies and the instrument is capable of determining size distribution and volume concentration within acceptable limits. Traykovski et al. (1999) performed several experiments with natural sediments in the laboratory to compare LISST results to traditional sieving, filtering and weighing techniques. They found the LISST was able to adequately determine the particle volumetric size distribution of two different natural sediments. van Wijgaarden and Roberti (2002) have used LISST for the measurement of the particle size and settling velocity of suspended sediment in calm fresh water and Thonon et al. (2005) have used LISST on river floodplains. Both of these authors report a greatly expanded capacity for the collection of the spatial and temporal variability of suspended sediment in these conditions.

Fig. 2 . The LISST-100 devices for sediment measurement with laser scattering technique

A disadvantage of the LISST instrument is its large size, which causes a significant flow obstruction. Another disadvantage is the design of the LISST laser mount, which is sensitive to impacts that can easily throw it out of alignment. The high energy regime of the surf zone could easily provide impacts of such magnitude (Battisto, 2000).

Turbidimetric Method, TM

Turbidity measurements are being used to generate continuous records of suspended sediment concentration in rivers. Turbidity is described as, 'an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample‘. Turbidity, an index of light scattering by suspended particles, has been widely used as a simple, cheap, instrumental surrogate for suspended sediment that also relates more directly than mass concentration to optical effects of suspended matter (Ziegler, 2002). The Seapoint Turbidity Meter, manufactured by Seapoint Sensors Inc, is a sensor that measures turbidity by detecting scattered light from suspended particles in water (Fig 3). Its small size, very low power requirement, high sensitivity and wide dynamic range allow this sensor to be used in most applications where turbidity or suspended particle concentrations are to be measured.(Seapoint Sensors Inc., 2008)

Fig 3. The Seapoint Turbidity Meter sensor

The use of turbidity values for sediment monitoring generally requires the user to get a statistical relationship between the turbidity and suspended sediment concentration (SSC). This relation is often expressed in a linear regression or a non-linear equation or as a polynomial function (Sun et al., 2001).

Minella et al. 2007 investigated the relationship between suspended sediment concentration and turbidity values with two calibration methods. The first calibration relationship was derived with the turbidity readings during flood events in a river. With the second method, the calibration was based on the readings obtained from the turbidity meter with the probe immersed in samples of known concentration prepared using soils collected from the catchment. They reported that the first calibration method corresponded closely with the conventionally measured sediment concentrations.

Pavanelli and Bigi (2005) reported that the relation of SSC with nephelometric turbidity units (NTU) for high sediment concentrations range is not completely investigated yet. They prepared water samples with 12 different sediment concentrations (1.5 - 30.0 gL^{-1}) for calibration of a turbidimeter and obtained very good correlation between sediment concentration and NTU values.

Besides sediment concentration, the sediment size, colour, and mineral composition have an effect on turbidity value. These effects probably should be calibrated with suspended-sediment samples collected over the range of turbidity conditions at the same time that continuous turbidity measurements are made (Ziegler, 2002). Gravimetric analysis with water sampling is the most reliable tool to estimate SSC and is essential to properly calibrate measurements of the various surrogates in spite of its limitations.(Gray et al., 2002).

DISCUSSION and CONCLUSION

The requirement for monitoring of suspended sediment concentration with temporal and spatial resolution has led to the development of sediment measurement. At the present time many methods exist for the measurement of suspended sediment in water. Four methods are reviewed above; in addition, a summary of the advantages and disadvantages of these methods is given in Table 1.

Table 1. The comparison of different suspended sediment measurement methods

Methods	Advantages	Disadvantages
Water Sampling	1. Simple and cheap method 2. No calibration needed 3. Not sensitive to grain size	1. Labour and time intensive to collect and process 2. Can not sample an "instantaneous" concentration or a time series 3. Difficulties of balance between the velocity entrance of the intake bottle and stream velocity
ABS	1. Can sample a full concentration profile with a single instrument 2. Most non-obtrusive of all sensors 3. More sensitive to larger grain size than fine grain size 4. Multiple frequencies can estimate mean sand size	1. Signal highly susceptible to absorption and scattering by air bubbles 2. Flow depth limitation for shallow rivers 3. Software difficult to learn and data processing labour intensive 4. Expensive when compared to TM
LISST	1. Ability to measure time series of size distribution 2. Can make measurement without calibration 3. Easy to operate commercial software package	1. Large and would cause flow obstruction if deployed underwater 2. Laser mount sensitive to bumps 3. Expensive when compared to TM 4. More difficult to set up and operate than TM
TM	1. Relatively inexpensive 2. Easy to install and operate 3. Relatively insensitive to bubble entrainment because of short signal path length	1.colour, and mineral composition effect on turbidity value 2. Sensitive to grain size 3. Requires calibration for each condition

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Identification of *Helianthus annuus* Proteins that are Upregulated when Exposed to Heavy Metals

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ABSTRACT

Plants have evolved the ability to extract, transport and use micronutrients from the soil. Many plants utilize this mechanism to accumulate toxic metals from the soil without incurring toxic effects. As a result, phytoremediation is gaining interest as a remediation technology. The study of model plants has shown that plants use a large amount of its genome to deal with stress, including heavy metal uptake and protection from the toxic effects. Although many genes have been identified, knowledge of the basic mechanisms of remediation is limited. Hydroponic and soil based experiments were conducted with two different dwarf sunflowers to identify what proteins were up-regulated as a response to heavy metal exposure. Two-dimensional gels of *Helianthus annuus* have isolated four proteins that were upregulated when the plants were exposed to arsenic or lead. This paper will discuss total metal uptake and translocation of arsenic and lead as well as the proteins that were upregulated as a result of metal sequestration.

Key Words: Phytoremediation, *Helianthus annuus*, proteins, arsenic, lead

INTRODUCTION

Consumption of contaminated drinking water has led to a global epidemic of arsenic poisoning with increased occurrences of cancer and Blackfoot disease in Taiwan, Argentina, Chile, and Bangladesh (Tripathi et al., 2007; Ultra et al., 2007). The toxic forms of As include arsenite (AsO_2^-), which is reactive towards thiol groups and acts on proteins and cofactors (lipoic acid) and arsenate (AsO_4^{3-}), an analogue of phosphate that interferes with phosphorylation. Arsenate is apparently transported by PO_4 transporters and reduced to arsenite in plants by an arsenate reductase (Singh and Ma, 2007).

The most well-known As hyperaccumulators are members of the order of Pteridales: *Pteris vittata* (Chinese brakefern) and *Pityrogramma calomelanos* (silver fern) (Wei and Chen, 2006). Other ferns with the ability to hyperaccumulator As include: *P. ensiformisk, P. umbrosa, P. multifida, P. cretica* and *P. argyraea* (Baldwin and Butcher, 2007; Gonzaga et al., 2006; Wang et al., 2007). Only two studies have documented the ability of dwarf sunflowers, *Helianthus annuus,* to hyperaccumulate As (January et al., 2008; Raab et al., 2005). The hyperaccumulation of Pb has been more widely studied than that of As. The most common Pb hyperaccumulators include *Brassica juncea*, *B. napus* (Marchiol et al., 2004), *Pelagorium spp., Sesbanon drummondi*, *Nicotiana tabacum* (Evangelou et al., 2006), and *H annuus* (Solhi et al., 2005).

There are two classes of peptide families associated that facilitate metal homeostatis and tolerance in plant systems – phytochelatins (PC) and metallothioneins (MT) (Yang et al. 2005). In both cases metal-binding is mediated by thiol groups in the peptide. PCs are synthesized by a PC synthase, which is constitutively present in the cytoplasm of plant cells. PCs are involved in As transport, it appears that this is not the major transportation mode in sunflowers (Raab et al. 2005). A similar observation was made for Cd, which is in roots bound to thiol groups and transported to the vacuole, but GSH and PC appear not to participate in transport to the shoot (Piechalak et al, 2002).

Experiments with two strains of *Helianthus annuus* were conducted under hydroponic conditions as well as in soil. Hydroponic experiments were conducted first to eliminate bioavailability issues that would be present in soil. Each cultivar was exposed to As alone, As in combination with Cd, Cr, and Ni, Pb alone, and Pb with Cd, Cr, and Ni.

MATERIALS and METHODS

Cultivar Source, Preparation, Harvesting and Analysis:

Helianthus annuus was used based on its ability to uptake and translocate heavy metals (Chen and Cutright, 2001). Sundance sunflower (*H. annuus* strain 3508) and Teddy Bear sunflower (*H. annuus* strain 03505) seeds were purchased from the Harris Seed Company (Madison, WI). For hydroponic experiments seeds were initially grown in Rockwool in a greenhouse illuminated with natural light. The average greenhouse temperature was 28 ^{o}C (winter) or 35 ^{o}C (summer) in the day and 20 ^{o}C at night. Seedlings were allowed to grow for 4 wk using a nutrient solution containing 250 mg N (NH_4NO_3), 109 mg P (KH_2PO_4) and 207 mg K (KH_2PO_4) per 1 L distilled water. After the growth period, seedlings of similar size were transferred to troughs in their individual Rockwool compartment to initiate the greenhouse experiment.

Seven sunflowers were utilized per chamber, with two chambers used simultaneously per experiment (one for Sundance and one for Teddy Bear sunflowers). . Both chamber received contaminated solution at a complete recycle rate of 1.59 L h^{-1}. After 17 days of exposure, the plants were harvested for analysis. Half of the biomass was transported on dry ice for protein analysis. The other half of the biomass was dried prior to determining the metal content.

Heavy Metal Source and Determination of Metal Content in Plant Biomass:

The metals were applied as As^{5-} ($Na_2HAsO_4{\cdot}7H_2O$), Pb ($Pb(NO_3)_2$) alone or in combination with Cd^{2+} ($CdSO_4{\cdot}8H_2O$), Cr^{3+} ($CrCl_3{\cdot}6H_2O$), and Ni^{2+} ($NiSO_4{\cdot}6H_2O$). Each compound was added to supply 30 mg of the target element to yield a 30 mg/L water or 30 mg/kg soil concentration.

The roots, leaves, and stems were rinsed with distilled water (to remove any metal-contaminated dust), sectioned and dried in a convection oven at 70 °C for 3 days. Dried tissues were weighed and milled with mortar and pestle. The crushed tissue sections were then digested according to Zheljazkov and Erickson (1996) and analyzed with flame atomic absorption spectroscopy (Buck 200 AA). The detection limit with the extraction procedure and AA analysis was 0.2 mg/L for each metal. Blind samples and certified reference samples (Supelco) were also analyzed for quality control.

Protein Analyses

Protein Extraction Electrophoresis and in-Gel Tryptic Digestion:

The plant tissues were mashed with mortar and pestle in liquid nitrogen, and 100-200 mg were placed in extraction buffer. The plant extraction solution Focus^{TM} Plant Proteome (G-Bioscience, St. Louis, MO) was used following the manufacturer's instructions, then centrifuged for 20 min at 15,000 x g. Supernatants were collected and the protein concentrations were measured using the Bradford method with albumin as the reference protein solution. One dimensional SDS-PAGE was performed as described (van Keulen et al., 2008). Gels were stained with Coomassie Brilliant Blue.

Two dimensional (2D) gel electrophoresis was performed as described in van Keulen et al. (2008). 2-D SDS-PAGE was performed in NuPAGE Novex 4-12 % Bis-Tris ZOOM gradient Gel (Invitrogen) with IPG wells following manufacturer's instructions. Protein molecular weight marker was applied to the well provided on the gel for calibration of the molecular weight. Gels stained with SimplyBlue, run with an electrophoresis buffer and electrophoresis was performed at 200 V for 35-40 min.

LC-MS/MS:

The digested protein samples were analyzed using an EsquireHCT Brucker Daltonics mass spectrometer equipped with a standard Agilent electrospray (ESI) ion source. Samples were loaded in 10 µl aliquots onto the column as described in van Keulen et al. (2008).

DNA and RNA Methods:

RNA was isolated by modified standard methods. Plant material was ground in liquid nitrogen, and RNA was purified using the Ambion RNA-aqueous mini preparation method. Reverse transcription coupled polymerase chain reaction (RT-PCR) was used to amplify cDNA from total RNA (0.5 µg) using a gene specific antisense primer (see below), and Moloney Murine Leukemia virus reverse transcriptase (Epicentre, Madison, WI) according the manufacturer's protocol. The primers were designed based on homology of the amino acid sequence with TC15508 of chitinase in the Sunflower Gene Index and were, sense: 5' TATCCCACAACATG*GaATtC*ACTCATC and antisense: 5' TCG*CTcgAG*GACTAGTTTATACTGCCT. The lower case letters stand for mutations introduced to provide restriction enzyme recognition sequences, indicated in italics as *Eco*RI and *Xho*I, resp. The putative thaumatin gene was amplified using a sense primer:

5’ATGACTTGTGCCAAAAACCTTCTACTC and antisense: 5’ ATATACTTAAAGAGTTTATGGACAGAAC designed based on TC15998 in the Sunflower Gene Index. The cDNA (10% of the sample) that was obtained by reverse transcription of RNA using the antisense primer was then subjected to the polymerase chain reaction (PCR) using these gene specific primers and *Taq* polymerase as described (van Keulen et al., 1998). As loading control primers were used to amplify part of the 23S rRNA. Primers were designed to amplify the entire open reading frame and DNA fragments were eluted from agarose gels, purified and ligated into pGEM-T Easy vector (Promega, Madison, WI) for sequence analysis. Plasmids were purified by the alkaline miniprep procedure using the Invitrogen plasmid preparation kit (Invitrogen). The DNA sequence was determined using a Beckman CEQ 8000 Genetic Analysis System.

DNA was purified using the DNeasy plant genomic DNA purification kit using the manufacturer’s instructions (Qiagen, La Jolla, CA). The same primers as described above were used for amplification of genomic DNA, which was cloned into the pGEM–T Easy vector and sequenced.

Antiserum Production:

Antiserum was prepared in rabbits against a synthetic peptide located at the C-end of the sunflower chitinase with sequence: CRFYDKQSGYSDAIK and attached to Keyhole Limpet protein (Sigma-Genosys, The Woodlands, TX). Western Blot analysis was as described (Lopez et al., 2003) using a 1:750 dilution of the antiserum and a 2 h incubation at room temperature. A goat anti-rabbit secondary antibody conjugated with horse-radish peroxidase was used and the signal detected with SuperSignal West Pico (Pierce).

Statistical and Data Analysis:

MINITAB statistical software was used to compare experimental. Statistical significance was determined using Tukey’s Honestly Significant Different comparisons. P-values < 0.05 were considered statistically significant. The translocation factor (TF) is defined as the metal shoot concentration divided by the root concentration. In order for phytoremediation to be considered effective the TF should be greater than one. Selectivity is the preferential uptake of one heavy metal over another.

RESULTS and DISCUSSION

Metal Uptake of as Alone or in Combination with Cd, Cr, Ni:

Analysis of metal distribution indicated that more metals were sequestered in roots than either stems or leaves under the experimental conditions. When As was the only contaminant (Fig 1), the root, leaves and stems concentrations were 1.52, 0.52, and 1.04 mg As g^{-1} biomass, respectively with no statistical difference in sequestration location. When Cd, Cr, and Ni were also present, As concentration was still highest in the roots at 1.54 mg g^{-1} biomass. There was no difference between the arsenic concentration in the leaves or stems. The presence of the other metals did not appear to alter the As uptake. It is also apparent that uptake of Cr and Cd were significantly greater than Ni or As. These results suggested that the process of accumulating arsenic in *H. annuus* is governed by mechanisms that are distinct from those of other metals.

For soil experiments, Sundance cultivar accumulated 0.96 mg, 0.77 mg, and 1.22 mg As for spiked (no chelator), 0.1 g/kg EDTA, and0.3 g/kg EDTA, respectively. Shoot concentrations for each condition were 999, 1000, and 1776 mg As/kg biomass, thus Sundance achieved hyperaccumulator status.

Similar studies were performed with the Teddy Bear cultivar. The uptake patterns in this strain resembled those of Sundance in that more metals were sequestered in the roots than other tissues. In addition, Cr levels, when compared to other metals, were higher. However, the degree of total metal content in Teddy Bear varied with that of Sundance (**Table 1**). For instance, the metal uptake was Ni>Cr>Cd>As in Teddy Bear whereas the order in Sundance was Cr>Ni>Cd>As.

Metal uptake of Pb alone or in combination with Cd, Cr and Ni:

Figures 2 and 3 contain the uptake for Sundance and Teddy bear sunflowers, respectively exposed to either Pb alone or in combination with Cd, Cr, and Ni. For both cultivars, when Pb was the only contaminant the concentration was significantly higher in the roots. The root, stem, leaves concentration for Sundance were 3.18, 0.04, and 0.04 mg g^{-1} respectively. With teddy bear the root, stem and leaves contained 0.284, 0.11, and 0.12 mg g^{-1} Pb. When Cd, Cr, and Ni were also present, the majority of Pb was still retained in the roots. However the Pb concentrations in each biomass section was significantly higher. This would indicate that the presence of the other metals decreased the toxic effects of Pb leading to a higher uptake.

Teddy Bear accumulated less Pb than Sundance (Table 2), regardless of whether Pb was the sole contaminant or present with other metals. This was not due to a difference in biomass since there was no statistical difference in biomass weight for the Teddy Bear experiment or with Sundance-mixed metals. In terms of total mg metals, Sundance performed better. In addition, it exhibited a better translocation factor than the Teddy Bear (Table 2). The selectivity with Sundance was Cd>Pb>Cr>>Ni. Selectivity with Teddy Bear cultivar was Cr>Pb>Cd>>Ni.

Protein Analysis:

Protein extracts were size fractionated by 1-D polyacrylamide gel electrophoresis (PAGE-SDS) under denaturing conditions to determine protein distribution in both the control and metal exposed plants (leaves). A comparison between the extracts indicated that protein induction was visible (Figure 4). One protein was clearly present in As-treated plants but was not present in control plants or those treated with Cd, Cr, and Ni (data not shown).

The protein indicated with the arrow was excised, subjected to LC/MS/MS and identified as a type III, family 18 chitinase. This chitinase was truly upregulated in plant leaf samples when all metals including As was present as shown by RT-PCR. Primers were designed to amplify this chitinase, which was detected in the Sunflower Gene Index using the obtained amino acid data from LL/MS/MS.

Figure 5 shows the semi-quantitative RT-PCR that was performed with RNA isolated from leaves of control plants (lanes 1, 2 and 7, 8), leaves from plants treated with all metals except As (lanes 3, 4) and leaves from plants treated with all metals including As (lanes 5, 6). The even-numbered lanes represent 35 cycles of PCR the others 20 cycles. The 1000 basepair (bp) band in lane 6 is the chitinase DNA amplified from the chitinase cDNA. The identity of the DNA was confirmed by DNA sequence analysis. The results demonstrate that the proteomics approach followed by verification via RT-PCR is a valuable approach. In addition, antibodies were generated against a C-terminal peptide of this chitinase. The antiserum showed a high degree of specificity and confirmed the induction of this enzyme by As using Western Blots as described (van Keulen et al., 2008).

A protein dot blot (Figure 6) using several tissues from Sundance plants as source of protein was screened using the anti-chitinase serum. It showed strong signals when leaf proteins of plants exposed to Cd, Cr, Ni and As or As alone were loaded, but no signal when plants were not exposed to metals or to metals without As. Chitinase was also detected in 2-D gels of leaf proteins extracted from plants exposed to Cd, Cr, and Ni plus Pb (spot 1, Figure 7). The mass spec data show 8 peptides covering 21% of the protein sequence. This protein was identical to the one observed after As induction and using 1-D gels. In addition to chitinase, three other proteins appear to be upregulated and are not visible in samples from plants exposed to Cd, Cr, and Ni or no metals. One spot, indicated by number 3 appeared to be a heat-shock protein, belonging to the 70 kDa family with 16 peptides covering 29% of the protein sequence. RT-PCR however failed to confirm this. However, spot 2, which appeared to be a thaumatin-like protein with 6 peptides found to be identical to the database sequence, covering 43% of the sequence. RT-PCR using primers designed to amplify the entire open reading frame, the same approach as described for the chitinase, showed a clear upregulation at the RNA level (Figure 8). Not only was the RNA detected in Cd, Cr, and Ni plus Pb treated samples but also, though at a lower level, in Cd, Cr, and Ni plus As treated samples.

CONCLUSIONS

Both cultivars achieved hyperaccumulator status when As was present as a soil contaminant. Furthermore, the uptake and translocation of As was not impacted by the presence of the other heavy metals. Neither Sundance nor Teddy Bear achieved hyperaccumulator status when Pb was present. However the presence of Cd, Cr, Ni did appear to decrease Pb’s toxicity, leading to a higher Pb uptake for the mixed metal treatment. Overall, Sundance was more effective at uptaking Pb (1.1 mg) than Teddy Bear (0.75 mg). Sundance also exhibited a significantly higher Pb uptake with the mixed metal condition (2.37 mg versus 0.16 mg with Teddy Bear). Both As and Pb were found to induce proteins that were not present within the controls or with just Cd, Cr and Ni.

Chitinase was first found to be upregulated in the leaves and roots of Sundance sunflowers when exposed to As or As in combination with Cd, Cr, and Ni. Chitinase was not induced in the controls or when As was not present. Teddy bear sunflowers were found to also induce Chitinase when As was present. When experiments were repeated with Pb, four protein spots were upregulated. The fourth spot is believed to be a metal ion binding protein, however this has not been externally verified since there was no match to this protein that has a high degree of identify to an *Arabidopsis* protein, with any known sequence in the Sunflower Gene Index. Two of the proteins were externally verified to be chitinase and thaumatin. These results clearly indicate that chitinase and thaumatin were upregualted in Sundance and Teddy bear sunflowers only when As or Pb was present.

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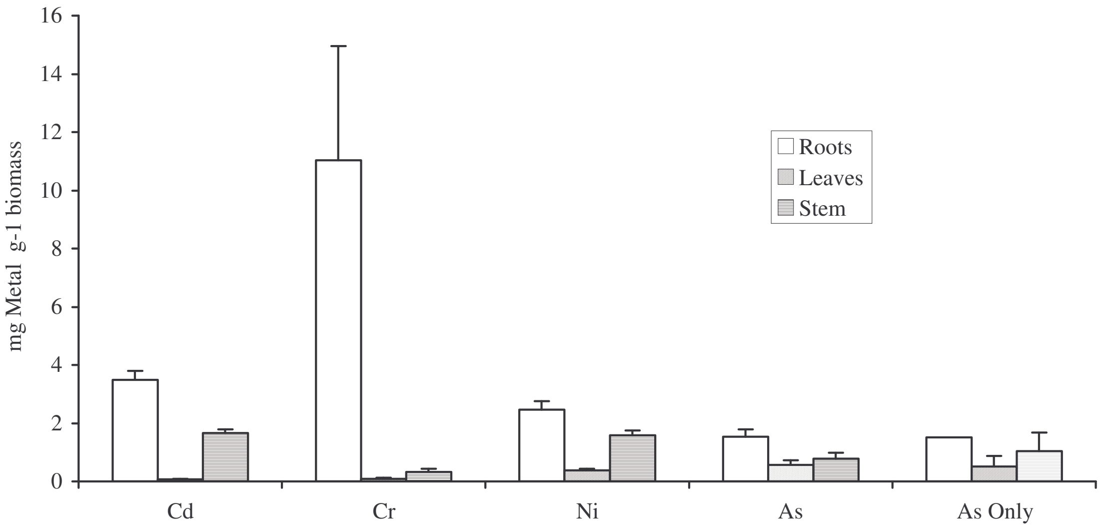


Figure 1 Sundance hydroponic As alone or mixed with Cd, Cr, Ni

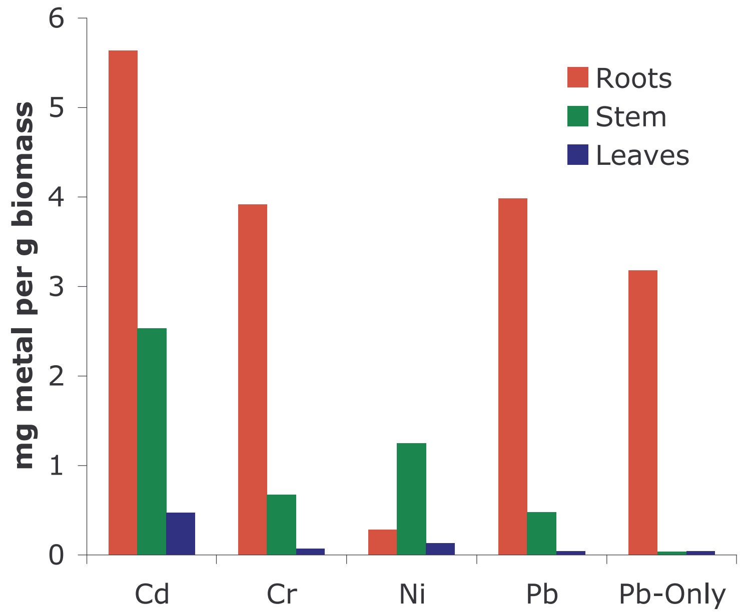


Figure 2 Sundance hydroponic 30 mg/L Pb alone or with Cd, Cr, Ni

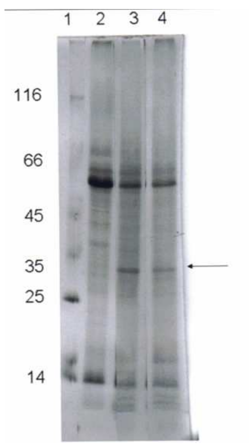


Fig 4. PAGE-SDS of leaf proteins
Lane 1 . Molecular weight markers from 116 to 14 kDa. Lane 2. Control leaves, supernatant. Lane 3. All metals treated plants. Lane 4. Leaves from plants treated with As only.

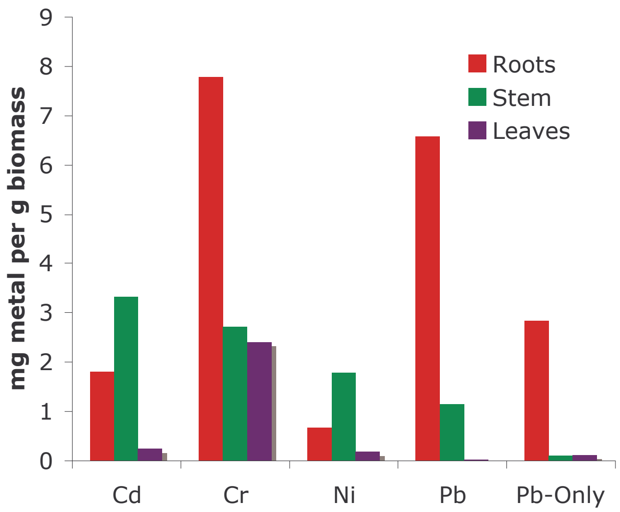


Figure 3 Hydroponic Teddy Bear Pb alone or with Cd, Cr, Ni

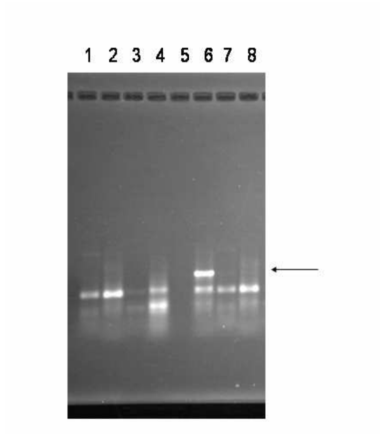


Fig. 5 RT-PCR of Sundance sunflower RNA

Table 1. Total metal uptake, biomass and translocation factors for hydroponic Sundance and Teddy Bear sunflowers in the presence of As.

Cultivar		Total	Metals (mg)				Total
		Biomass g	As	Cd	Cr	Ni	Metal
Sundance	As Cd Ni Cr	2.682	1.95	2.40	3.92	2.55	10.82
	As Only	2.129	1.59				1.59
Teddy Bear	As Cd Ni Cr	4.757	3.34	0.57	3.00	3.59	10.50
			Translocation Factors				
Sundance	As Cd Ni Cr		0.4	0.16	0.02	0.3	
	As Only		0.44				
Teddy Bear	As Cd Ni Cr		0.20	0.13	0.05	0.17	

Translocation factors =shoots (stems and leaves) divided by the metal ion concentration in roots.

Table 2. Total metal uptake, biomass and TFs for hydroponic Sundance and Teddy Bear sunflowers with Pb.

Cultivar		Total	Metals (mg)				Total
		Biomass g	Pb	Cd	Cr	Ni	Metal
Sundance	Pb Cd Ni Cr	1.246	2.37	3.91	2.43	0.42	9.13
	Pb Only	2.21	1.10				1.10
Teddy Bear	Pb Cd Ni Cr	1.198	0.16	0.11	0.41	0.06	0.733
	Pb Only	1.176	0.751				0.751
			Translocation Factors				
Sundance	Pb Cd Ni Cr		0.042	0.52	0.04	0.93	
	Pb Only		0.008				
Teddy Bear	Pb Cd Ni Cr		0.028	0.38	0.32	0.01	
	Pb Only		0.042				

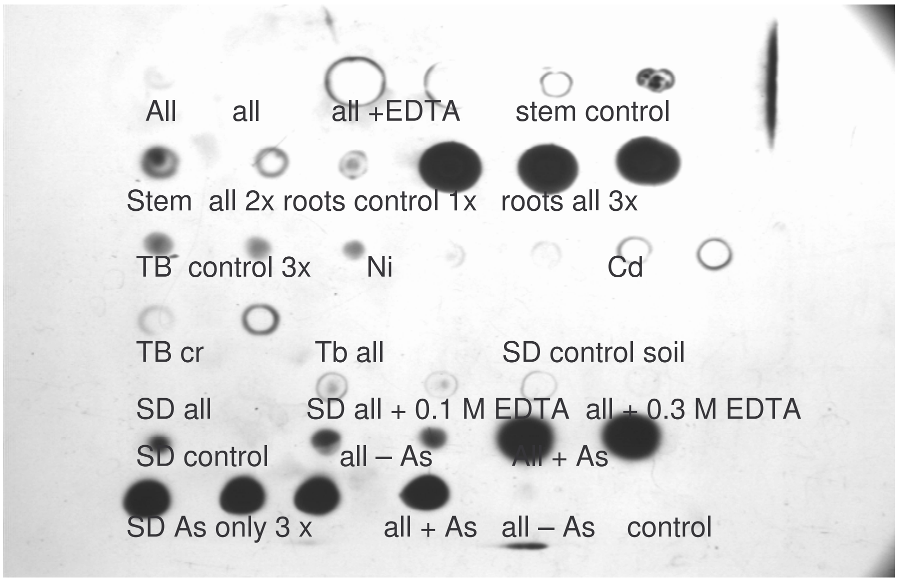
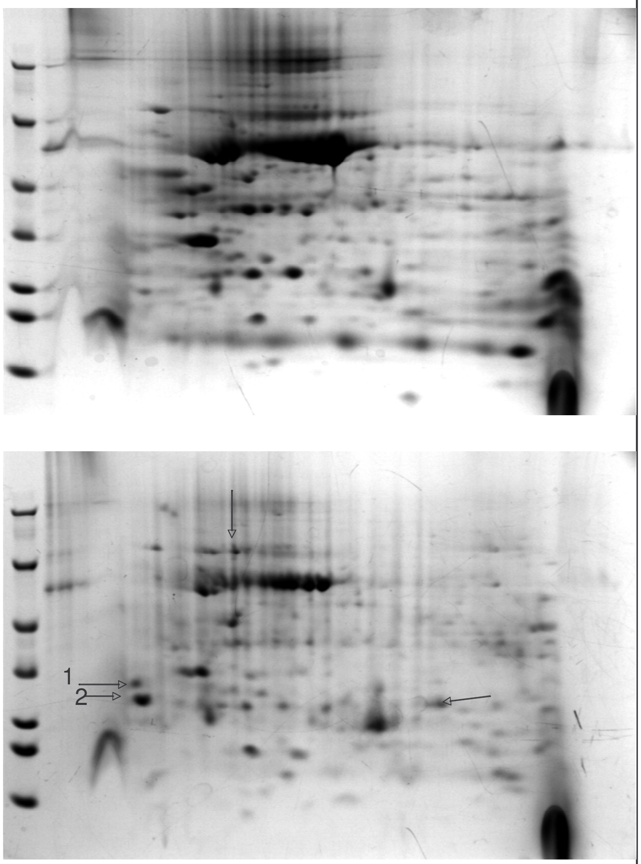


Figure 6. Dot Blot analysis of protein samples in triplicate probed with anti-chitinase serum. Sudance (SD) samples in bottom two rows are hydroponic plants, all others are soil based



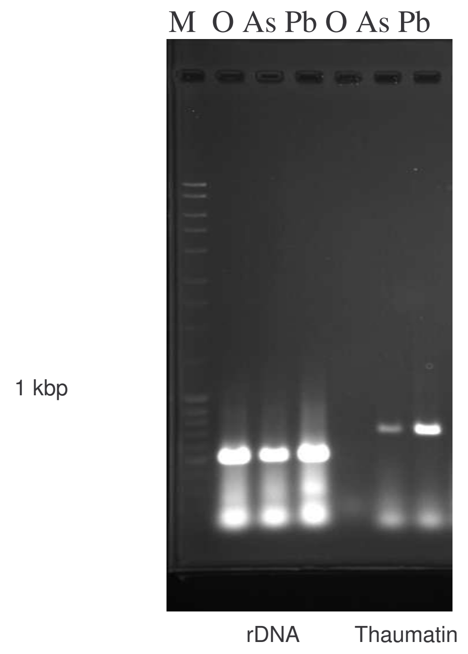


Figure 8. Confirmation by RT-PCR that Thaumatin is upregulated
M- marker DNA, O-control, As: all metals + As, Pb- all metals +Pb

Figure 7. Two-D gel leaves of plants (a) control and (b) treated with Cd, Cr, Ni and Pb. Note the extra proteins 1-chitinase and 2 - thaumatin

Potential Use of Olive Oil Solid Waste in Agriculture

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ABSTRACT

Olive (*olea europea*) orchards are dominant crops in Mediterranean countries. The main use of olive fruits is the extraction of olive oil. The remaining Olive oil solid waste (OSW) can be a good and available source for soil organic matter in Turkey. One method to use OSW in agricultural practices can be making compost. OSW and OSW compost were evaluated for agricultural use. Olive solid wastes were mixed with soil at the rates of 0, 3, 5 and 7% with and without additional nitrogen and phosphorous sources. Sunflower and corn plants were grown in the pots for two months. Additionally changes in soil physical and chemical properties were observed. Results showed that OSW compost can be used as and organic source for plant growth. This research was supported by TUBİTAK TOVAG project number 106O371.

Keywords: olive oil solid waste, compost, sunflower, corn, nitrogen, soil

INTRODUCTION

During the olive oil production large volumes of wastes are generated that vary in composition depending on which of the three olive oil production systems is used. Approximately volume of olive solid waste is about 50 to 60% of the olive fruit after oil processing. There are two centrifugation technologies during oil olive extraction, which are three-phase and two-phase systems. Three phase system generates oil, waste water and olive oil solid waste (OSW), while the two-phase system produces olive oil and a semisolid by-product called two-phase olive mill waste. Approximately 50-60% of olive by volume is solid waste. This waste or pomace must also be disposed of appropriately. It can be used as stock feed if it is dry and destoned, it can be used as a mulch or separated olive stone can be utilised as a fuel source (Anonymous, 2001). Application of raw olive oil solid waste (OSW) increased soil aggregate stability. Application of OSW at the rate of 8% has significantly increased soil total organic nitrogen contents. OSW applications at the rate of 8% (w/w) significantly increased both mean SOC content (3.5%) and aggregate stability (88%) after 2 months of incubation (Kavdir and Killi, 2008). Another possible use of olive oil solid waste is biosorption of pollutants. In this article possible use of OSW in agriculture will be discussed

Olive Oil Solid Waste Compost and Plant Growth

There are several researches in Mediterranean countries to evaluate effects of OSW compost on plants. Alberuque et al (2007) reported ‘alperujo’’ compost had no phytotoxicity, had considerable greater organic matter and lignin contents than the other two organic amendments tested. ‘Alperujo’’ compost which is a solid by-product of the two-phase centrifugation method also had a considerable content of potassium and organic nitrogen but was low in phosphorus and micronutrients. It can be used as an efficient organic amendment, for growing pepper.

In Greece Papafotiou et al. (2004) investigated the possibility of using olive-mill waste compost (OWC) in the production of ornamentals replacing part of the peat in the growing medium. They reported that OWC can replace up to 25% of the peat in a medium with perlite in the production practice of poinsettia. The quality of the plants produced in OSWC medium was as good as that of the control.

Ehaliotis et al., 2005 evaluated the potential of leaves and pomace derived from olive-oil mills to provide root-zone heating for organically grown cucumber plants via a composting process carried out under the plant rooting system during the cultivation period. The process resulted in over 10^{o}C increase in rhizosphere temperature lasted over 2 months without any phytotoxic effects to a variety of cucumber cultivars.

Peredes et al (2005) applied olive mill water (OMW) compost to soil which did not show phytotoxic effects on Swiss chard plants. Plants produced similar yields as those grown in compost without OMW and the inorganic fertilizer. Soil fertility increased with increasing OMW compost application rates. However, the higher dose of OMW compost (60 tonnes ha^{-1}) application increased the soil salinity, and that could be the major concern regarding the use of OMW compost at high rates in soil.

Olive oil solid waste composts were made with different compositions to evaluate in the agriculture in Turkey (TUBİTAK TOVAG 106O371). Three different ratios of OSW were mixed with manure, alfalfa and straw to make compost under controlled conditions (Kavdir et al., 2007). One of the most important factor for successful compost making is C.N ratio (Poincelot, 1977) and C:N ratio must be 25:1-30:1 while C.N ratios between 20:1-40:1 is also acceptable (Rynk, 1992). Nitrogen contents of OSW showed 38.5% increment after composting where final N concentration of OSWC was 2%. On the other hand, carbon (C) content reduced 13.4% after composting and became 35.8%. As a result C:N ratio of OSWC decreased up to 54.2% compared to initial OSW' s C:N. The final mature compost had black color with sufficient amount of nutrients. In this research initial OSW's C:N ratio was 50 however it reduced up to 18:1 after composting (Figure 1)

Effect of uncomposted OSW on sunflower growth was evaluated by Kavdir et al. 2008. The results showed that direct application of OSW to soil inhibited plant growth. Plant height, sunflower leaf numbers and stem thickness were greater in control (soil with no OSW) treatments than other treatments in the last measurement date. Addition of inorganic sources such as N and P fertilizers did not improve negative effects of OSW. Similarly positive effects of OSWC on corn growth has been observed. Corn development was greater in compost added treatments compared to those in control and OSW treatments (Figure 2 and Tables 1 and 2).

OSW and OSW compost effects on tomatoes growth was evaluated by Killi (2008). Application of OSWC increased tomatoes growth, plant chlorophyll content in Sandy and Loamy soils. The best compost rate was %4 w/w. Compared to olive solid waste, OSWC increased plant length, dry and fresh weight significantly. OSW application significantly increased aggregate stability of Loam soils compared to control treatment. Increase of soil aggregate stability after addition of OSW compost was lower than those of OSW (Figure 3).

Killi (2008) evaluated OSW and OSW compost effects on physical properties of coarse textured soils (Sandy Loam and Loamy Sand). Compost application reduced soil bulk density, increased aeration capacity, field capacity, available water content, hydraulic conductivity. On the other hand OSW application increased soil aggregate stability.

CONCLUSION

Composting is a good alternative method for olive oil solid waste management around olive oil factories and farms. Despite the negative effects attributed to direct use of OSW, results of recent literatures and researches indicated that, applications of olive oil solid waste compost have generally positive effects on plant growth.

ACKNOWLEDGMENTS

This research was supported by TUBITAK (Project TOVAG 106O371).

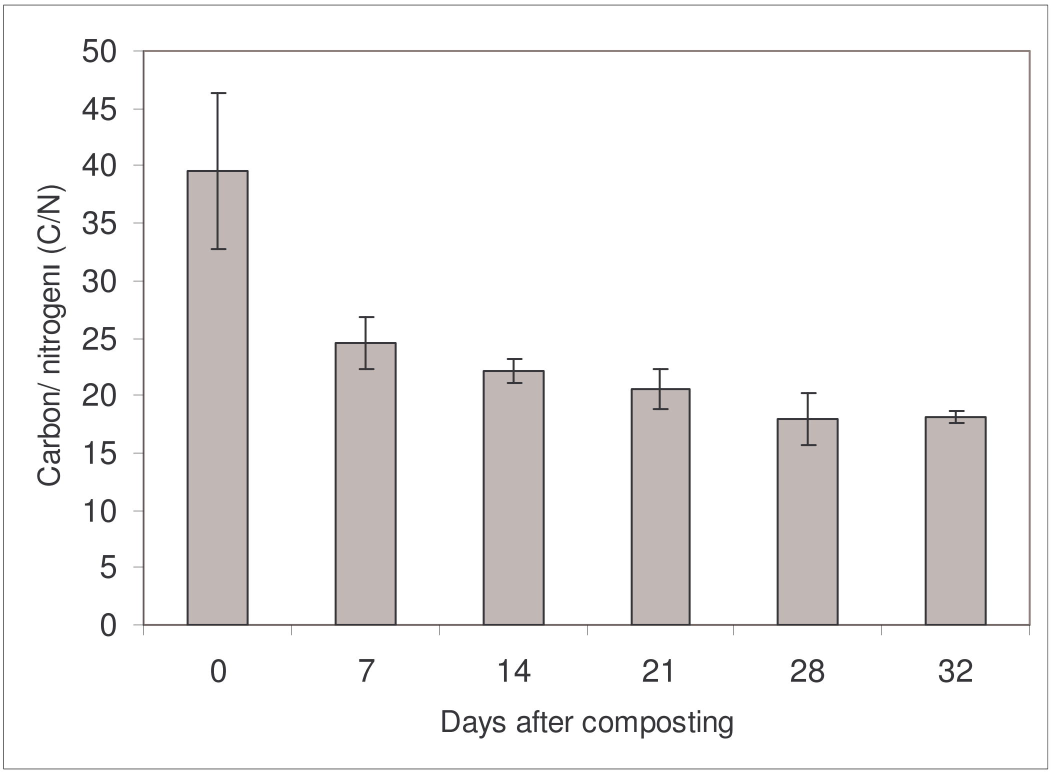

Fig. 1. Changes in carbon (C) and nitrogen (N) contents during OSW composting.

Fig.2. Corn plant development . 1: OSWC application 2: OSW application 3: Control (from left to right)

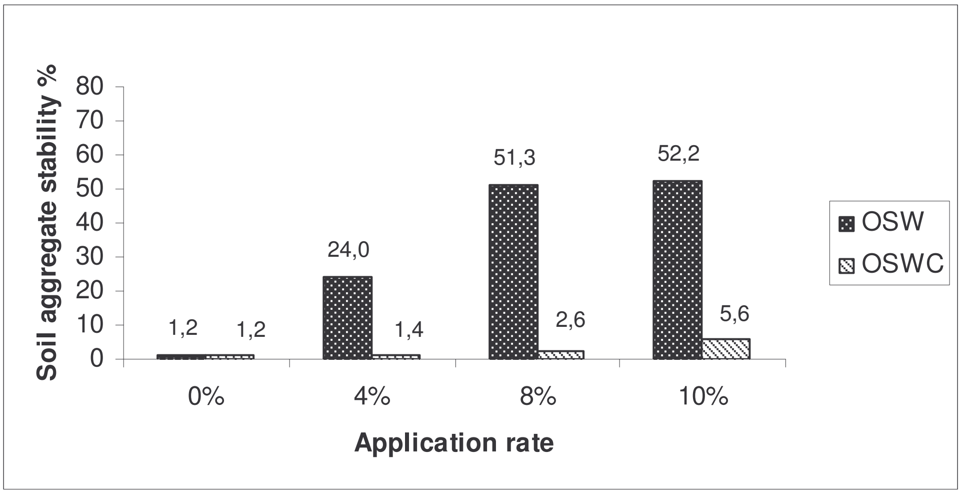

Fig.3. Effects of OSW and OSWC application on soil aggregate stability

Table 1 . Effects of OSWC application on corn development.

Treatments	Plant height (cm)	Stem thickness (cm)	Fresh weight (gr)	Dry weight (gr)	Leaf numbers
Control	40,10 ± 3,09	6,69 ± 0,43	5,87 ± 1,31	0,64 ± 0,14	6,00 ± 0,00
3% OSW Compost	56,28 ± 0,22	13,19 ± 0,19	25,45 ± 1,25	2,63 ± 0,11	7,50 ± 0,29
5% OSW Compost	56,88 ± 1,72	13,97 ± 0,33	25,22 ± 2,69	2,71 ± 0,26	7,75 ± 0,25
7% OSW Compost	53,30 ± 0,64	12,88 ± 0,47	23,52 ± 2,74	2,49 ± 0,32	7,25 ± 0,25

Table 2 . Effects of OSW application on corn development.

Treatments	Plant height (cm)	Stem thickness (cm)	Fresh weight (gr)	Dry weight (gr)	Leaf numbers
Control	40,10 ± 3,09	6,69 ± 0,43	5,87 ± 1,31	0,64 ± 0,14	6,00 ± 0,00
3% OSW	33,33 ± 4,02	5,36 ± 0,47	3,26 ± 0,85	0,34 ± 0,09	5,25 ± 0,25
5% OSW	38,56 ± 1,50	5,17 ± 0,40	3,37 ± 0,59	0,34 ± 0,06	5,75 ± 0,25
7% OSW	32,75 ± 3,07	5,06 ± 0,33	2,57 ± 0,42	0,27 ± 0,04	5,25 ± 0,25

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Geostatistical Analysis of a Water Well Field for Determination of Land Management Constraints

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ABSTRACT

Soil spatial variability and heterogeneity is a tough but very important matter in the field-scale description of soil properties, such as soil electrical conductivity, soil saturated hydraulic conductivity, and soil salinity. Geostatistics is a useful tool to study spatial distribution of soil properties and optimum sampling strategies in field. Estimating soil salinity, EC and Ks is a vital issue in soil fertility and management. Geostatistical methods, kriging and cokriging, were applied to estimate spatial distributions of the variables that were collected from a large size water well field for the surface soil, rather than entire bore-hole profile of the soil. The results suggested that estimation can be improved using cokriging , rather than kriging. Comparing to kriging results, cokriging reduced the mean squared error and improved the estimation of EC by 2-100% depending on cross-correlated variables. Using the cokriging prediction maps of the soil properties, the soil can be managed cell by cell with prescribed appropriate management strategies such as irrigation and manure application to mitigate soil salinity in the region.

Key words: Geostatisctics, salinity, kriging, cokriging.

INTRODUCTION

Soil salinity, soil electrical conductivity and other soil fertility parameters are on a regular timely basis determined in field and laboratories for arid and semi arid areas in southern Turkey. Excessive soil salinity may result in a large amount of crop loss and eventually land degradation (Lesch et al., 1992). Inappropriate management of low saline and high saline areas due to their non-homogeneous distribution on the landscape is known as the same input of tillage, irrigation water, fertilizer and pesticide application, seed spreading on indiscriminately selected agricultural lands although no economic yield return is very well known in these areas (Halvorson and Rohades, 1976). From the same study, the salinity problem is observed to influence the soil in two principle ways. Soluble salts bring about a high ESP (content of exchangeable sodium) and high osmotic potential, which are collectively unfavorable physical conditions for a soil to be fertile for a plant species. The attempts were made to remediate high saline areas by biological methods and by pinpoint site specific irrigation of good quality of water, gypsum addition, and leaching (Szabolcs, 1989; Mankin et al., 1997). Maintaining upgrade data of soil salinity requires high cost of densely sampling of a soil. This adds to saline soil irrigation or reclamation costs to be more expensive. Therefore, geostatistics provides appropriate tools to reduce the cost of soil sampling and maintenance of management practices, such as irrigation system in a field. As a result, soils are mapped in terms of soil properties using some estimation techniques such as kriging and cokriging, numerical methods, and fuzzy set analyses. In this study, kriging and cokriging are used to map the pattern of the spatial distribution of a large water-well area growing cash crops of every kind, except citrus fruits. Kriging is used by Tabor et al. (1984, 1985) to determine spatial variability of nitrate in cotton plants and soil nitrate was correlated with nitrate content of cotton seedlings. Similarly, Yates et al. (1993) used kriging and cokriging in determination of salt affected soils, while Istok and Cooper (1988) applied kriging to study groundwater contamination. Zhang et al. (1995) applied kriging and cokriging to estimate trace elements of soils and plants and Yates and Warrick (1987) utilized cokriging to estimate soil water content with standby data of bare soil surface temperature and sand content. In this study, kriging and cokriging were applied to predict spatial variability of soil electrical conductivity (EC), hydraulic conductivity (Ks), Total Dissolved Solids (TDS), pH, and elevation and cokriging was compared to kriging in improvement of the estimation accuracy. The main goal is to determine soil constraints to agriculture in the studied basin.

MATERIALS and METHODS

Sampling and Analysis

A total of 49 water wells and soil profiles at the same location in the Harran Plain, Turkey, have been sampled for the purpose of monitoring salinity**.** Sampling scheme and locations are given in Figure 1. Soil pH, electrical conductivity (EC: µmhos/cm) and Total Dissolved Solids (TDS: mg/l) of water wells have been determined according to Richards (1954). Soil saturated hydraulic conductivity (Ks: cm/day) has been measured according to constant head method (Klute and Dirksen, 1986). Elevation at each location in the study area has been recorded using a GPS instrument.

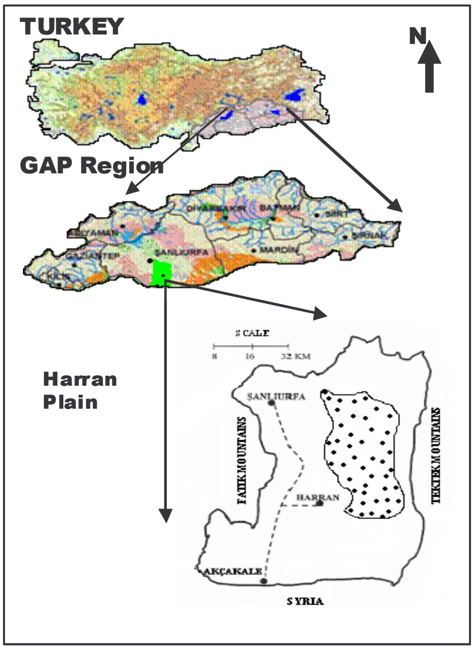

Figure 1. Study area and sampling locations.

Geostatistical Modeling

Kriging, as a linear spatial interpolation method, estimates the quantities of soil properties at unsampled locations by assigning weights to each neighbor location based on their distance from the location being estimated. Weights sum up to one. Kriging can be formulized as:

$$Z^*(x_0) = \sum_{i=1}^{n} w_i Z(x_i)$$

where $Z^*(x_o)$ is the kriging estimation at an unsampled location (x_o), n is the number of samples in a search neighborhood, w_i are the weights assigned to the ith observation $Z(x_i)$. Weights are determined using a semivariogram that measures spatial correlation and covariance structure between data points for each variable. It is computed using following equation (Journel & Huijbregts,1981):

$$\hat{\gamma}(h) = 0.5n \sum_{i=1}^{n} \left[Z(x_i + h) - Z(x_i) \right]^2$$

where $\hat{\gamma}(h)$ is the semivariance between two observation points, $Z(x_i)$ and $Z(x_i+h)$, separated by a distance h, and n is number of pairs at the distance h.

Cokriging (COK) uses a secondary variable, (Z_2), which is spatially cross correlated with the primary variable (Z_1). It is formulated as:

$$Z_{COK}^*(x_0) = \sum_{i=1}^{n1} w_i Z_1(x_i) + \sum_{j=1}^{n2} w_j Z_2(x_j)$$

where $Z^*_{COK}(x_o)$ is the cokriging estimate at an unsampled location (x_o), w_i and w_j are cokriging weights associated with the primary variable $Z_1(x_i)$ and the secondary variable $Z_2(x_j)$ at i^{th} and j^{th} locations, respectively, which are obtained based on the cross-semi variogram:

$$\hat{\gamma}_{Z_1 Z_2}(h) = 0.5n\sum_{i=1}^{n}\left[Z_1(x_i+h)-Z_1(x_i)\right]\left[Z_2(x_j+h)-Z_2(x_j)\right]$$

RESULTS and DISCUSSION

Table 1. Descriptive statistics of the random variables.

Variable	Count	Max.	Min.	Mean	Stdev	Skewness	Kurtosis	1st Quart.	Median	3rd Quart.
EC (μmhos/cm)	49	3450	412	1071	654	1.92	6.48	693.8	885	1150
pH	49	8.85	7.95	8.3	0.47	0.74	1.55	8	8.38	8.85
Ks (cm/day)	49	6.63	0.39	1.571	1.4	1.58	6.136	1	4.03	2
Elevation	49	399	368	379.3	6.7	0.77	3.39	374.7	378	382.3
TDS (mg/l)	49	27.5	3.7	11.8	5.6	0.9	3.16	7.75	10	15

Table 1 shows descriptive statistics of the data set used in spatial analysis. It is clear that the soil EC has the highest variability than the rest of the variables. The soil EC proves the highest asymmetrical distribution with the highest skewness on comparison to the other variables. Similarly, the second highest skewed variable is Ks. All the variables are positively skewed. This pattern is the same for standard deviation which is the highest for EC and the lowest for soil pH. This statistics is strongly influenced by outliers in the data set. Since the data showed positive skewness, all mean values are greater than median values of the data. This positive skewnes and larger standard deviations may be due to a limited number of the data points in the sampling field. The greater number of samples is likely to result in the lower variance and standard deviation in the data set and the distribution can be much like normal distribution.

Table 2 shows the correlation coefficients and p-values in parentheses for the intervariables. Elevation is always negatively correlated with the variables in the study. This may mean increases in elevation points in the water-well field always result in decreases in the values of random variables. In other words, the highest values of the EC, TDS, pH, and Ks are likely to be found on the foothills and valley bottoms. The elevation and soil EC correlation is significant and may be an indicative of high amount of leaching of soil salts from high elevations to low elevation points by the seasonal precipitation events that may cause accumulation of salts in the foothill slopes of the landscape. Ks negatively correlated with pH and TDS, while soil EC holds a positive correlation with Ks.

Table 2. Correlation matrices of variables (p values in parenthesis).

Variables	TDS	pH	Ks	Elevation
EC	0.471 (0.001)	-0.254 (0.078)	0.133 (0.362)	-0.288 (0.045)
TDS		-0.537 (0.000)	-0.024 (0.872)	-0.145 (0.319)
pH			-0.052 (0.722)	-0.064 (0.661)
Ks				-0.006 (0.969)

Another negative significant relationship exists between pH and soil EC at 10% significance level, whereas TDS and pH are negatively correlated and the relationship is significant at any p-value. The negative pH-EC correlation may be attributed to salt hydrolysis in the soil, result of which doesn't always cause incremental pH in soil. On the other hand, the more salinity doesn't mean the higher pH in soil. Similarly, pH and TDS don't increase and lower as conjugates. The other significant relation occurs between soil EC and TDS ($p < 0.05$) and this relationship is positive. This may be due to the fact that totals dissolved solids contribute in larger part to the soil EC and therefore, very commonly in the soilscape, EC-TDS combination for positive correlation remains valid.

Spatial variability

All the variables were analyzed spatially with kriging, whereas only strongly correlated parameters were analyzed by cokriging on the data set. Generally speaking, all the variables used in kriging tended to be more easily predictable than in cokriging. Cokriging not only calculates the semi-variance of each variable, but also calculates cross-variogram for two or more variables in the cross-autocorrelation process. Cross-variogram model parameters mostly came out of anisotropic spatial distributions. There may be multiple reasons for this. First of all, sampling techniques and sampling times are not known whether to be consistent and locations of the samples are assumed to be the same. Secondly, the variables are not correlated very well with one another and correlation coefficients are generally very low and generally negative. The correlation matrices of the data showed that 2 out of 10 correlations were positive and lower than 50%.

If two random variables are negatively correlated, the rate of increase in cross-variogram is expected to decrease in distance. On the other hand, if cross-vaiogram of two or more variables increases, the random variables are said to be positively correlated. In this data set, anisotropy and trend for all variables prevail. Fortunately, ArcGIS eliminates the trends and computes the spatial semivariance model first. At the end of the model computation, the eliminated trend is added back to the data. This process adds more reliability to ArcGIS geostatistical analyses because in the semivariance model computation process the trend is not involved and model is computed safely.

Kriging models

Figure 2 illustrates spatial distribution of TDS in the study area Total dissolved solids in the water well field are described spacially according to the spherical variogram model. The TDS concentrations reach at the sill value 30 in 1835 m range.

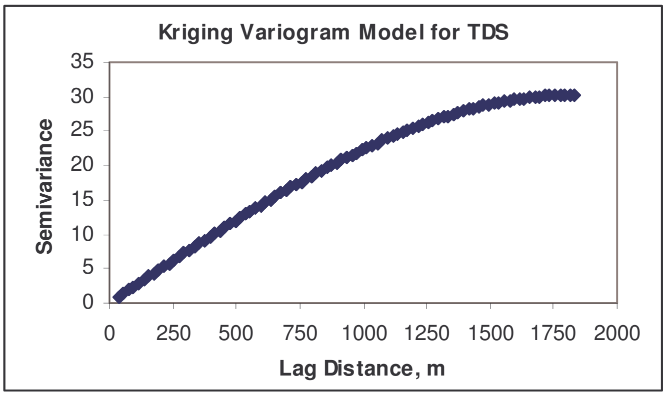

Figure 2. TDS variogram model ($\gamma_{(h)} = 30.3(1.5(h/1835)-0.5(h/1835)^3)$).

Figure 3 illustrates spatial distribution of soil EC in the study area. The soil EC distributes according to spherical variogram model as was the TDS. The range and sill values for the soil EC are 10070 m and 70093 x 10^{-5}. The variability of the soil EC is the highest among the other variables analyzed. The variation coefficient is greater than 40% for soil EC, while this was lower for the soil TDS (not given).

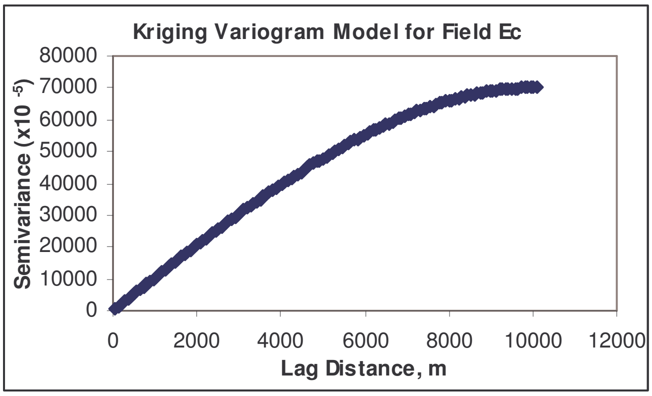

Figure 3. Field variogram model for EC
($\gamma_{(h)} = 70093 \times 10^{-5}(1.5(h/10458)-0.5(h/10458)^3)$).

Like the other variables of the soil, saturated hydraulic conductivity has also distributed according to spherical model with a sill and range value, 0.392 and 10458 m, respectively (Figure 4).

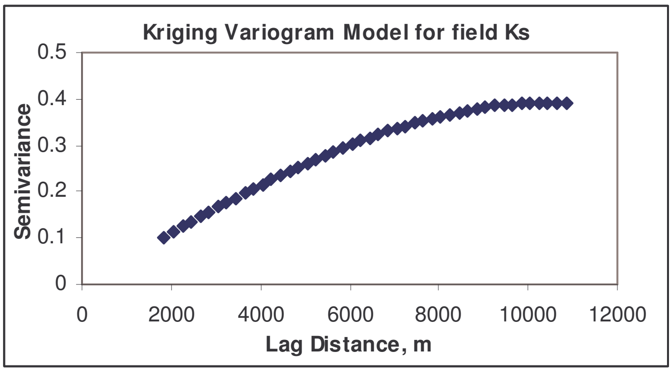

Figure 4. Variogram model for the field saturated hydraulic conductivity ($\gamma_{(h)}$ = 0.023+0.392(1.5(h/10458)-0.5(h/10458)^3).

Comparisons of Kriging Predictions with Cokriging Estimations

The comparisons of cokriging to kriging for some of the significantly correlated parameters of the data set were made. The following method was used to compare results estimated by kriging and cokriging. Relative improvement, or relative reduction of estimation accuracy, is defined by:

$$R_E = 100\%(|MES_R|) - (|MSE_E|)/(|MSE|) \qquad \text{(Pozdnyakova and Zhang, 1999)}$$

where R_E is percentage of improvement or reduction, (positive R_E improvement, negative R_E reduction), MSE_R kriging mean squared error, and MSE_E is cokriging mean squared error. If the R_E is positive, the evaluated method (cokriging) is better than reference method (kriging). On the other hand, negative R_E corresponds to evaluated method that is worse than reference method. The results are given in table 3.

Table 3. Comparison of kriging to cokriging by R_E factor.

Kriging variables	MSEkrig	MSEcokrig	RE %	Cokriging variable
Ks	22.01	19.6	11.04	Ks-Elevation
EC	448505.3	441266	0.02	EC-Elevation
EC	448505.3	38.45	100	EC-TDS
TDS	41.2	38.45	0.067	EC-TDS

Table 3 shows that mean squared errors for the random variables are generally greater for kriging than the ones for cokriging. Depending on the cross-variogram model, the accuracy and improvement of the prediction maps developed in a large range. The improvement of the predictions ranged between 2 and 100 % for the variables that were used in cokriging. For example, if the field EC was predicted by

EC-Elevation cokriging model, the improvement was 2%, while EC –TDS cross-variogram improved field EC prediction as 100%. This shows that cokriging is better to estimate unknown sample locations of EC in the field, rather than kriging.

The cross-variogram is computed as the following;

$\gamma_{12} = 0.5*(\gamma^{+}_{12} - \gamma_{11} - \gamma_{22})$ (Zhang et al., 1995)

where, γ_{12} is cross-variogram of Ks and elevation; γ_{11} is variogram of Ks; γ_{22} is variogram of elevation; γ^{+}_{12} is the variogram of Ks + elevation.

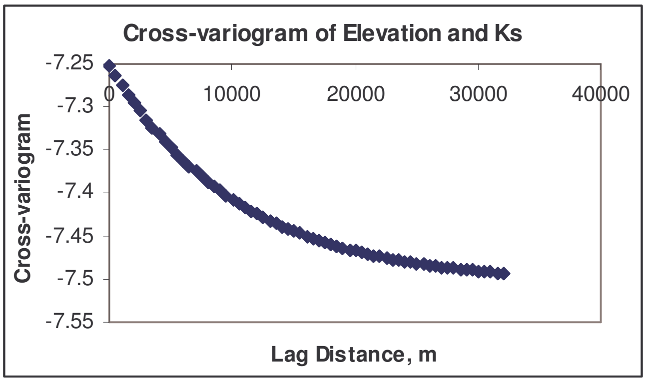

Figure 5. Cross-variogram of elevation and saturated hydrauclic conductivity of the soil ($\gamma_{12(h)}$=-7.25 -0.26 (1-exp(-h/10458)).

Figure 5 shows that cross-variogram decreases with distance for the elevation and Ks variables. The reason for this is because of the fact that both of the variables are negatively correlated (Table 2). Therefore, cross-variogram is not expected to increase. The cross-variograms for the rest of the combination of the variables were not developed for testing the hypothesis that cross-variogram always an increasing function if the random variables are positively correlated. Among the cross-variogram of the variables, the cross-variogram of elevation-Ks was unique to develop because of the fact that Ks and elevation was negatively correlated with the lowest correlation coefficient. Elevation and Ks predict each other via this model given above.

Kriging prediction maps for the variables

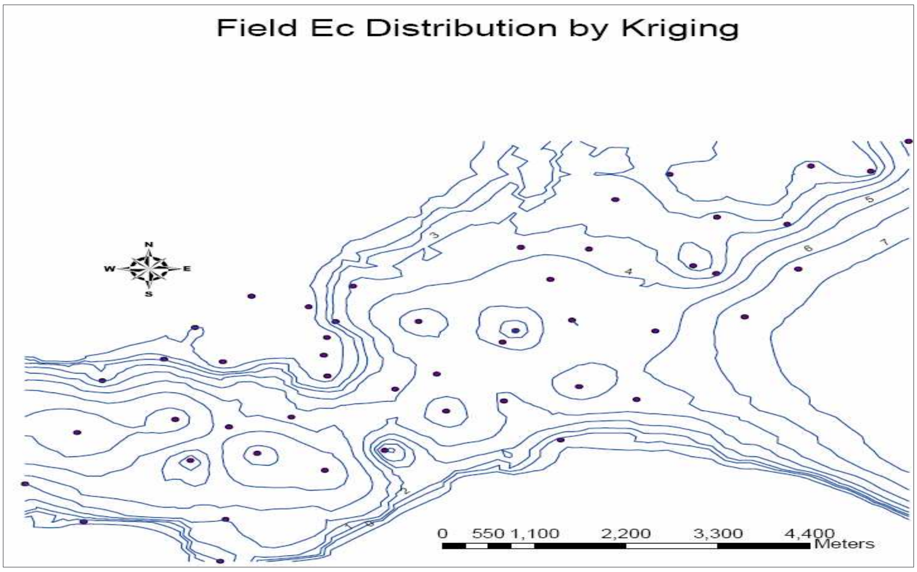

Figure 6. Kriging prediction map of soil EC.

Figure 6 illustrates the kriging distribution of field EC. The EC distribution is very much like homogeneous in the field. The contour lines of EC do not change in their slopes and contour intervals are quite similar with each other. However, level of EC varies for each contour line in the field. According to the contour labels, in the north-east direction, the highest EC values are encountered in the center of the field. This high level of EC decreases when the contour lines come closer on the boundaries of the water well field. This may mean that the factors that influence field EC are spatially different in the areas of center of the field and edges of the field. Therefore, the adverse effects of soil EC can be improved in the center line of the field. Kriging method weighted higher for the pairs of points in the center of the field than the points of samples on the edge of the field. Beside, the north-east border of the central field wasn't given enough weight so that the prediction would be more consistent for allover the field. The lower weighted north-east corner of the field reveals more variability to the kriging method. The reasons for the variability may be various such that the data had a mathematically defined trend and anisotropy was not completely eliminated. In fact, the EC distribution of the field corresponds very well to the field elevation kriging map. Where elevation increases are the places where the soil EC decreases. In the end, it is likely to impact water quality of the well field. For example, withdrawal of water from the basin-fill aquifers via water wells could cause changes in vertical head gradient and that may increase the potential for water quality degradation. Also, the wells themselves, if not properly constructed, could provide pathways for salts, pesticides, and fertilizers to reach the basin-fill aquifer.

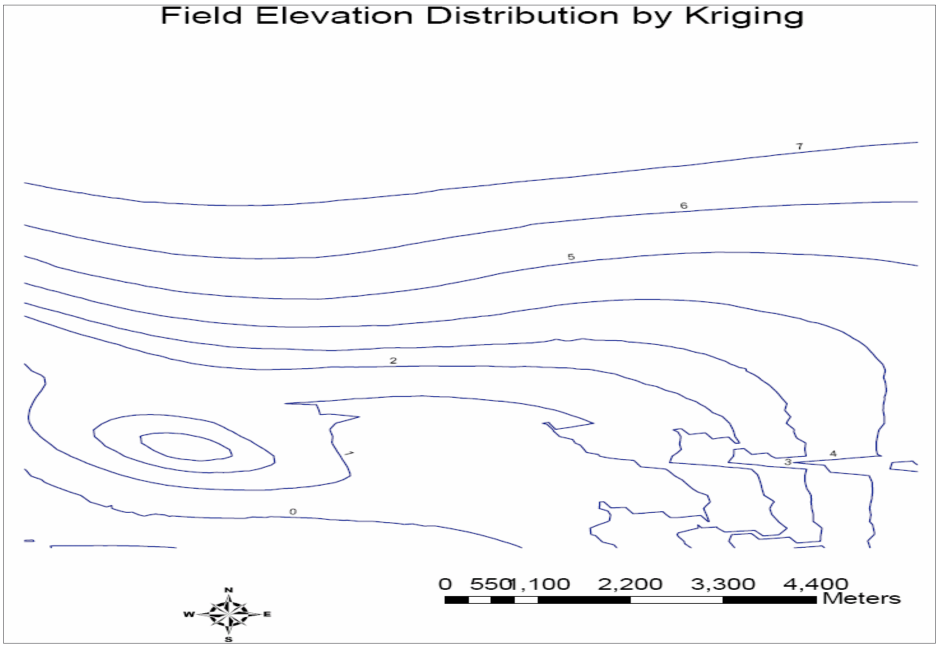

Figure 7. Kriging prediction contour map of sampling point elevations in the field.

Figure 7 shows the elevational changes over the water-well field. In northward increases elevation steadily and a small alluvial channel or valley rift exists on the east direction, while south and southeast corner is gentle slopping. This spatial pattern of the field influences the distribution of the soil and water-well properties. Accordingly, field management options must take the surface topography into consideration for the particular soil unit in the studied area. As a result, any yearly precipitation is highly likely to end up with the accumulation in the lower elevation of the field, which is responsible of the salt content levels of the water-well field. Kriging method predicted anisotropic elevation field. The variogram was not omnidirectional, but changing.

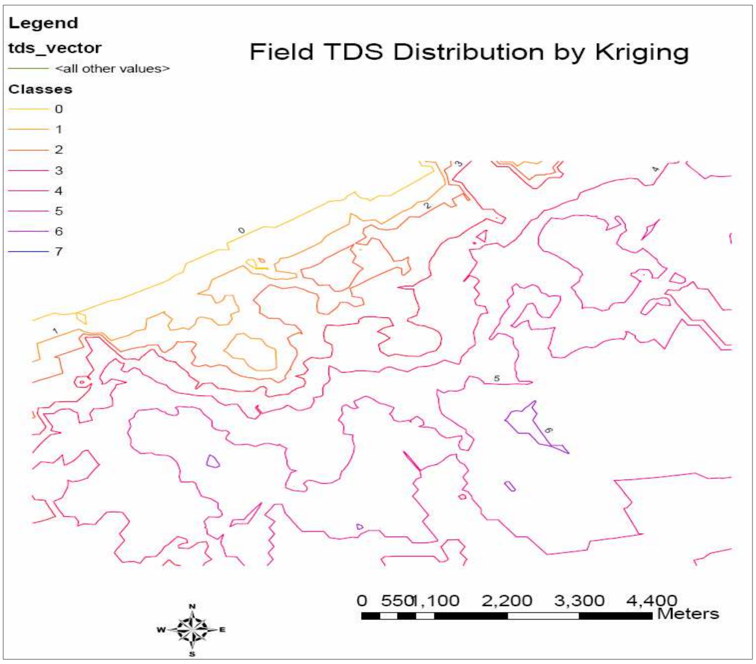

Figure 8. Kriging prediction map of TDS.

Figure 8 depicts TDS distribution contours by kriging method. Although TDS and EC significantly correlate with each other, their distributions prove completely different in the space. The TDS of the well field is not homogeneous as was the case with the field EC. The highest TDS concentrations occur in the center of the field as did field EC, while the TDS concentrations decreases outward of the central field. Similarly, Figure 8 proves that high elevations correspond to low TDS values and low elevations have the highest TDS values, a similar spatial pattern to the field EC. In contrast to soil EC, TDS values did not show strong anisotropy. The search direction had 2.7 degree of tolerance, whereas EC had more than 290 degree of search direction. If the field is a recharge area, return irrigation water may increase TDS in the shallow unconfined aquifers of the basin. High TDS values generally correspond very well with the high soil EC and SAR due to excessive clay dispersion and freed Na+. Therefore, chemical amendment that includes Ca and Mg is always among the reclamation options. Further, they increase aggregation and soil drainage which eventually contributes to favorable crop growth conditions in soil. Various crops can improve soil permeability by removing more Na^+ from soil that would increase aggregate stability and drainage in the soil. According to the data set analyzed, soil pH is fairly high and Na^+ may be problematic issue in the soil. Kriging prediction map of TDS shows that the basin can be improved for TDS and drainage if the hydrologic settings provide excess high quality water that can remove Na^+ and penetrate the soil downward. Furthermore, if Na^+ is replaced with Ca and Mg, the leaching will be facilitated to remove excess Na+ from the soil. As a result, pH will decline to a favorable condition for plant growth and TDS will be lowered. The kriging map provides another option to improve soil management. If the preceding reclamation options do not provide mitigation of the problem, deep tillage may apply to the well field to decline salinity impact to dilute soil salts. The kriging contours of TDS may be the tracking lines to apply point specific land management strategies.

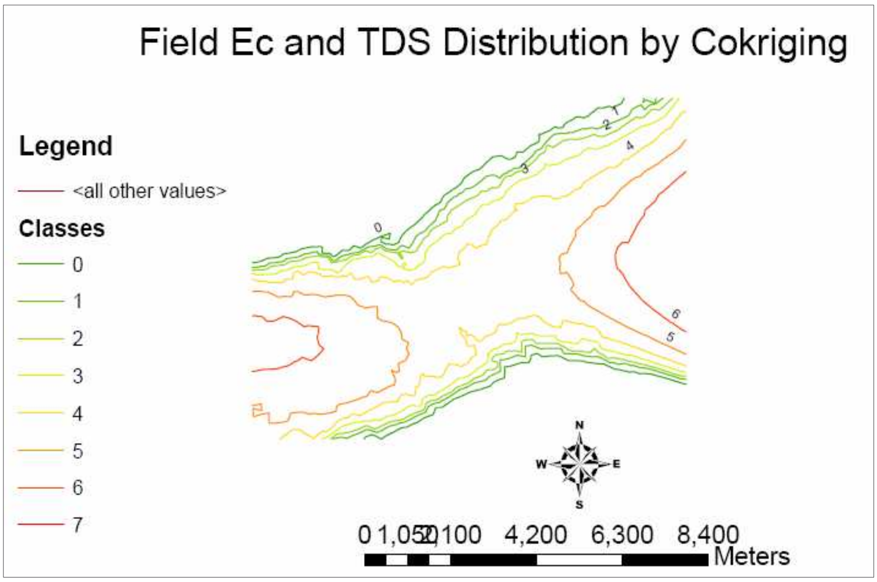

Figure 9. Cokriging prediction map of the EC and TDS.

Figure 9 shows cokriging prediction map of soil EC and TDS. The TDS and EC have predicted each other according to the cross-variogram model that produced the TDS-EC contour map (figure 9). The only obstacles for agriculture are the areas of red contour lined parts, while the rest of the contour lines of concentrations don't pose a stringent threat for the crop species in the basin. The reasons for better prediction of TDS and EC in the basin may be attributed to the closer groundwater to the soil surface, accumulation of the salts and total solids due to storm events and snow melts in the basin, high summer temperature and evaporation and transpiration. In addition, cokriging is an extended kriging that uses more than one variable to predict the other. From the agricultural standpoint, soil quality and land management may be the major goals in the basin. The cokriging map can be utilized to strategize how much and what kind of agrochemicals to be applied when-and- where in the soil. The cokriging map reveals that EC and TDS, collectively and homogeneously, distribute in the field. Therefore, soil may be managed for EC more efficiently if the drainage and irrigation practices suffice.

CONCLUSIONS

The geospatial analyses of the salinity parameters (soil EC, pH, TDS and Ks) used in this study gave detailed prediction maps of the salinity parameters so that they could be used on purpose of land management practices in the study area. The data showed very large trend and anisotropy. However, ArcGIS removed the trend and predicted the maps of random variables by adding the trend to the predictions at the end. This yielded into a better spatial prediction of the variables in the soil. Almost all the variables negatively correlated with each other, except field EC and TDS. The data for the all analyzed variables distributed spherically in the study area. All variables negatively correlated with field elevation. Spatial variability maps showed that the soil spatial variability of all the variables tested was the largest along the central line of the basin. Most of the agricultural constraints occurred in the central area of the basin, also. This was because the basin was an accumulation ditch for the any precipitation event year around and all transportable solids and chemicals accumulated in the basin. The soil EC was the biggest constraint to agriculture in the basin because of its high variability and relatedness to the field TDS. Some of the wells were dry in midsummer in the field. This showed that the basin water pumping rates and evaporation were very high and vertical gradient of the groundwater drops largely in summer. At some points water table was close to soil surface. This increased the vulnerability of the groundwater quality due to salt accumulation, which eventually turned to be a constraint in agricultural use. The results showed that the basin needed improved drainage and irrigation methods. Beyond these practices, chemical amendment of Ca and Mg was required to reduce the adverse effect of soil Na^+ so that soil structural stability and drainage could improve better. For better management purposes, soil water quality and soil properties need dynamic modeling using stochastic approach.

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