Int. J. of Environmental Pollution & Environmental Modelling, Vol. 2(2): 68-79 (2019)
(Original Paper)

The Effect of Irrigation by Textile Wastewater on the Growth of MM106 Apple Sapling and Soil

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Abstract: Nowadays, in many regions of the world face to drought problems that directly affect the agricultural production due to water deficiency or some conditions that cause the depletion of the existing water resources. In these water deficit areas, the use of wastewater for agricultural irrigation could contribute to decrease water shortage, protect surface and groundwater resources and supports the agricultural industries. In this study, in order to assess wastewater from textile industry could be used safely to irrigate '*Golden Delicious*' apple seedlings grafted onto an MM 106 parent, a pot experiment in glass house was conducted in a sand clay loam soil (pH=7.22) from Bolu province. Municipal water (T_0) prepared as a control sample, 1/3 diluted (T_1) and raw textile wastewaters (T_2) were applied to investigate the effects of irrigation treatments by measuring soil and leaves chemical properties. Although the Electrical Conductivity (EC) (4 dS/m) and pH values (8.5) at the end of the experiment were lower than the critical value in all the irrigated samples, the sodium adsorption ratio (SAR) values were higher than 13 in T_1 and T_2. The cubic model was determined to be suitable for the shoot lengths of the apple saplings irrigated with T_0, T_1 and T_2 and R^2 values could be obtained as 0.987, 0.987 and 0.992, respectively. This study clearly demonstrated that textile wastewater at appropriate dilutions could be used for irrigation in agricultural fields.
Keywords: Heavy metals, Irrigation, *Malus domestica*, Soil properties, Wastewater

INTRODUCTION

Freshwater resources of countries which have arid and semi-arid climates are particularly inadequate to meet the increasing population's drinking and utility water requirements [1]. Sustainability of human livelihoods as well as environment and economic development are threatened by increasing water scarcity especially in developing countries [2]. It is estimated that in 2030 the population in Turkey will reach 100 million and consequently the water potential will drop down to 1000 m^3/capita-year. It means Turkey is among the countries that may expect water stress in the nearest future based on population increment and water resources' quality deteriorations [3]. Currently, about 70% of water consumption is committed to agricultural irrigation, and the growing use of bioenergy tends to aggravate water scarcity [4]. Reuse of wastewater has increasingly become the predominant low cost and reliable alternative to conventional irrigation water in many countries that reduces both the consumption of limited fresh water resources and the environmental pollution and disposal problems [5, 6]. In general, wastewater resources contain substantial amounts of beneficial carbon nutrients (NPK) and micronutrients (Ca, Mg, B, Cu, Zn and S), which are important to increase the productivity of the nutrient content on one hand and the efficiency of the soil's physical properties on the other [7]. However, wastewater resources also contain toxic pollutants such as heavy metals, which are creating problems for agricultural production [8]. Beneficial use of water for domestic or industrial application can be severely limited by priority toxic pollutants such as heavy metals [9]. Consequently, special management precautions should be taken to provide satisfactory benefits from wastewater irrigation and prevent the environmental and sanitary dangers of its presence in the soil, in plants, and in surface and ground water [10].

The textile industry produces wastewaters of different compositions during manufacturing processes that contain a mixture of chemicals, auxiliaries and various dyestuffs of different classes and chemical compositions with organic characteristics such as chemical oxygen demand (COD), and

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This study was extended from the paper presented at the ISEM2018 symposium as a study titled "Use of Raw Textile Wastewater on the growth of MM106 Apple Sapling: Effects on Leaf and Soil".

inorganic characteristics such as metals, chlorides and nitrogen [11]. In this context, limited studies have been published to evaluate using textile industry effluents for agricultural practices, such as seedling yields, growth rates and monitoring of the physico-chemical properties of soil [12-15]. Turkey, which produces 3.128.450 tons of apples, is in third place in the world in apple production [16].

The effects of wastewater on soil-plant environment may ultimately be both positive, due to the nutrient loading, and negative, due to presence of toxic compounds, pH or electrical conductivity (EC). With this mind, the aims of this study are: 1) to evaluate the impacts of textile wastewaters on the N,C, nutrient (P, K, Na, Mg, Al, B) and metal contents (Cd, Mn, Fe, Cu, Ni, Pb, Hg, Cr, As) of apple seedlings; 2) to recognize the impact of textile wastewater at municipal wastewater (T_0), 1/3 diluted (T_1) and raw textile wastewaters (T_2) on the properties of soil, with particular regards to pH, EC, SAR, (Exchangeable Sodium Percentage (ESP) and heavy metals (Fe, Cu, Zn, Mn, Pb, Cd, Ni, Hg, Cr, As); 3) to apply the most commonly used growth models in the literature for this study to determine the correct shoot lengths of "*Golden Delicious*" apple saplings, and to calculate model characteristics.

EXPERIMENTAL METHOD

Study Site and Plant Materials

This study was conducted at the Bolu Abant Izzet Baysal University, Vocational Community Collage of Bolu research greenhouse located in Bolu, Turkey (N: 40º43´, E: 31º33´, Altitude: 768 m) during 2015 and 2016. The physicochemical analysis of the soil and leaf were carried out in the Environmental Engineering Department, BAIBU in Bolu, Turkey. Two-year old apple '*Golden Delicious'* sapling having uniform diameters (between 4.80 and 5.20 mm) and shoot length (between 35 and 50 cm) were used as plant materials. The saplings were grafted by chip budding method on two-year-old MM 106 rootstocks under the nursery conditions. MM 106 is a semi-dwarf rootstock, producing a tree about 60% the size of seedling. The graftings were done on May 15, 2014.

Plant Growth Conditions and Soil Substrate

Apple saplings were potted in 8-L plastic pots and placed in the greenhouse on April 15, 2015. Especially prepared growing medium (mix of 1:1: ½: ½ sieved garden soil, stream sand, peat and burned manure) were used. The greenhouse has unheated, side ventilation with manual, UV anti fog-coated cover. Pest control, weeding and removal of suckers below graft union were performed regular at one-week intervals. There was no chemical spraying in the apple sapling. Soil samples irrigated with three different types of irrigation water, were taken from each pot before planting (April 15, 2015) and after irrigation, i.e. at the end of the experiment (September 15, 2015).

Irrigation Waters

Three types of irrigation water were tested of apple sapling in the study. Municipal water (control - T_0), 1/3 diluted textile wastewater (T_1) and raw textile wastewater (T_2) using sterilized sampling bottles. The sapling was irrigated from the top of the pot during growing period (between April 15 and 15 September, 2015). Prior to begin of the study, pots were initially saturated with tap water and pot surface covered with plastic in order to prevent evaporation. After drainage ceased, the weight of each pot was considered as to be field capacity of that pot. In each irrigation event, the amount of irrigation water was given to each pot to the field capacity. Textile wastewater effluents were collected prior to any treatment from a denim dying textile facility in Düzce, Bolu (Turkey). The color of raw textile wastewater was dark bluish and had pungent smell. The detailed information about water quality parameters investigation and irrigation effect on plant growth was given in [17].

Chemical and Statistical Analysis

In order to determine the physicochemical properties of the soil, soil samples irrigated with three different types of irrigation water, were taken from each pot before planting (April 25, 2015) and after irrigation, i.e. at the end of the experiment (September 15, 2015). The samples were analyzed for their physicochemical properties, their nutrient content and heavy metal concentrations. The soil samples were prepared by air drying at a temperature between 25 ºC and 30 ºC and sifted through a 2 mm mesh sieve.

The pH value was measured with a Thermo Scientific Orion 5 Star Multi analyzer. EC was measured in soil sludge at 25°C using a Thermo Scientific Orion 5 Star Multi analyzer conductivity probe. The percentage humidity was determined by gravimetric analyses. The total nitrogen was determined by the Kjeldahl method, whereas organic matter content was calculated using the Walkley-Black method. Soil texture was determined by using a Bouyoucos hydrometer. Lime percentage was calculated with a Scheiblercalcimeter. Chloride (Cl^-) content was determined by titration using $AgNO_3$. Sulphate content was determined by a colorimetric method by precipitation with $BaCl_2$. Carbonate and bicarbonate content were measured by titration using H_2SO_4 [18].

The study was carried out on randomly selected samples with three replications and 3 plants per replication. Soil analyses were evaluated using a one-way ANOVA test for the three irrigation samples by statistically evaluating the parameters between themselves. The data was analyzed using an SPSS statistical software package [19].

Growth Modeling

In this study, statistical modeling was used to examine apple sapling shoot growth. When these models were determined, R-R v 3.3.2 was used. The mean squared error (MSE), Akaike information criterion (AIC), and Bayesian information criterion (BIC) were considered in the modeling. R^2 was used to determine the most suitable model because this value is a measure of how the model can explain the dependent variable based on the independent variables. Equations of applied models in apple saplings' shoot heights are shown in Table 1.

Table 1. Equations of applied models in plant growth

Growth Model	**Equation**
Proportional	$y = at$
Linear	$y = at + b$
Quadratic	$y = at^2 + bt + c$
Quadratic/zero	$y = at^2 + bt$
Parabola	$y = at^2 + c$
Cubic	$y = at^3 + bt^2 + ct + d$
Exponential	$y = ae^{bt}$
Restricted exponential	$y = a - be^{-ct}$
Logistic	$y=\frac{abe^{ct}}{ae^{ct}+b-a}$
Von Bertalanffy	$y=\left(\frac{a}{b}-\frac{1}{b}e^{\frac{bt}{s}-\frac{cb}{s}}\right)^3$
Richards	$y=\frac{a}{(1+be^{-cdt})^{\frac{1}{d}}}$
Gompertz	$y= a * \exp\left(-e^{-(t-c)/b}\right)$

The equations and parameters of proportional, linear, quadratic, quadratic zero, parabola, cubic, exponential, restricted exponential, logistic, Von Bertalanffy, Gompertz, Richards, and hyper-Gompertz that were used to compare apple sapling shoot height growth values that were irrigated by T_0, T_1 and T_2 wastewater, are provided in Table 2-4 In the models used, a, b, c, and d show the model coefficients.

Table 2. Performance metrics for saplings' shoot height irrigated with T_0

Model	**MSE**	**R^2**	**R^2_{adj}**	**AIC**	**BIC**
Proportional	1510.64	0.579	0.544	146.21	147.49
Linear	283.06	0.921	0.907	124.77	126.69
Quadratic	152.51	0.957	0.945	118.11	120.67
Quadratic zero	180.38	0.950	0.935	118.46	120.38
Parabola	203.059	0.943	0.933	120.12	122.04
Cubic	45.65	0.987	0.982	103.23	106.42
Exponentional	113.44	0.968	0.963	111.97	113.89
Restricted Exponentional	113.41	0.968	0.963	115.96	119.16

Logistic	3588.27	0.000	-0.300	164.33	167.52
VonBertalanffy	3588.27	0.000	-0.300	164.33	167.52
Gompertz	3567.35	0.006	-0.292	164.24	167.44
Richards	3586.23	0.001	-0.444	166.32	170.15
Hyper-Gompertz	13220.21	-2.684	-3.354	180.58	183.14

Table 3. Performance metrics for saplings' shoot height irrigated with T_1

Model	**MSE**	**R^2**	**R^2_{adj}**	**AIC**	**BIC**
Proportional	1270.04	0.646	0.617	143.79	145.06
Linear	240.65	0.933	0.921	122.50	124.41
Quadratic	142.53	0.960	0.948	117.16	119.72
Quadratic zero	153.29	0.957	0.944	116.18	118.10
Parabola	166.70	0.954	0.945	117.36	119.27
Cubic	46.47	0.987	0.981	103.47	106.67
Exponentional	121.09	0.966	0.960	114.88	117.44
Restricted Exponentional	3588.27	0.000	-0.182	164.33	167.52
Logistic	3588.27	0.000	-0.300	164.33	167.52
VonBertalanffy	3588.27	0.000	-0.300	164.33	167.52
Gompertz	3588.27	0.000	-0.300	164.33	167.52
Richards	3333.19	0.071	-0.342	165.29	169.13
Hyper-Gompertz	13220.21	-2.684	-3.354	180.58	183.14

Table 4. Performance metrics for saplings' shoot height irrigated with T_2

Model	**MSE**	**R^2**	**R^2_{adj}**	**AIC**	**BIC**
Proportional	1241.72	0.654	0.625	143.47	144.75
Linear	206.67	0.942	0.932	120.37	122.28
Quadratic	144.42	0.960	0.948	117.35	119.91
Quadratic zero	147.47	0.959	0.947	115.64	117.56
Parabola	154.45	0.957	0.949	116.29	118.21
Cubic	28.88	0.992	0.988	96.81	100.01
Exponentional	4130.90	-0.151	-0.361	164.30	166.85
Restricted Exponentional	3588.27	0.000	-0.182	164.33	167.52
Logistic	3588.27	0.000	-0.300	164.33	167.52
VonBertalanffy	3588.27	0.000	-0.300	164.33	167.52
Gompertz	3588.27	0.000	-0.300	164.33	167.52
Richards	3588.24	0.000	-0.444	166.33	170.16
Hyper-Gompertz	13220.21	-2.684	-3.354	180.58	183.14

RESULTS AND DISCUSSION

The Effects of Wastewater on Soil Properties

The results of the physicochemical parameters of the wastewater used in the irrigation of apple seedlings that are T_0 (control), T_1 (1/3 dilution textile wastewater) and T_2 (raw textile wastewater, without dilution) reported in Table 5. In general, the critical water quality problems in relation to the chemical risks and hazards from wastewater reuse for irrigation are excessive concentrations of salt, heavy metals, toxic organics and organic matters [5].

Table 5. Physicochemical characteristics of the irrigation waters used in the experiment

Characterization	T_0 control	T_1	T_2	One-way ANOVA
Electrical conductivity, EC (25 °C) (dS/m)	$0.46^c±0.01$	$0.84^b±0.01$	$1.51^a±0$	*
pH	$7.8^a±0.14$	$7.34^b±0.01$	$7.18^b±0.01$	*
Color (Pt/Co)	$41^c±1.41$	$69.5^a±0.71$	109^b ±1.41	*
Chemical oxygen demand (COD) (mg/l)	$24^c±1.41$	$96^b±1.41$	$283.5^a±0.71$	*
Cations				
Sodium (Na) (me/l)	$3.61^c±0.01$	$7.35^b±0.01$	$15.29^a±0.01$	*
Potassium (K) (me/l)	$0.07^b±0$	$0.11^a±0.01$	$0.15^a±0.01$	*
Calcium (Ca) (me/l)	$5.47^a±0.01$	$5.46^a±0$	$3.81^b±0$	*
Magnesium (Mg) (me/l)	$2.78^a±0.01$	$2.81^a±0.02$	$2.42^b±0.01$	*
Anions				
Carbonate (CO_3) (me/l)	-	-	-	
Bicarbonate (HCO_3) (me/l)	$8.18^c±0.01$	$8.76^b±0.01$	$10.36^a±0.02$	*
Chloride (me/l)	$1.06^c±0.01$	$4.05^b±007$	$7.38^a±0.01$	*
Sulphate (SO_4) (me/l)	$2.65^b±0.07$	$2.84^b±0.01$	$3.9^a±0.07$	*
Nitrate (NO_3) (mg/l)	$2.15^b±0.07$	$2.3^b±0.14$	$3.45^a±0.07$	*
Total nitrogen (mg/l)	$0.35^c±0.07$	$3.8^b±0.14$	$26.8^a±1.06$	*
Orthophosphate (PO_4-P) (mg/l)	$0.14^b±0.01$	$0.22^b±0.01$	$2.0^a±0.14$	*
Residual Sodium Carbonate (RSC) (me/l)	-0.08±(-0.075)	0.45±0.07	4.13±0.01	
Boron (B) (mg/l)	0^b	$0^b±0.01$	$0.22^a±0.01$	*
SAR	$1.77^c±0.01$	$3.61^b±0.01$	$8.65^a±0.01$	*
Irrigation water class	C_2 - S_1	C_3 - S_1	C_3 - S_1	
Heavy metals				
Lead (Pb) (mg/l)	< 0.10	<0.10	<0.10	
Copper (Cu) (mg/l)	$0.01^c±0$	$0.04^b±0.01$	$0.18^a±0.01$	*
Manganese (Mn) (mg/l)	$0.38^c±0.01$	$1.02^b±0$	$1.96^a±0.01$	*
Chromium (Cr) (mg/l)	$0.48^c±0.01$	$0.56^b±0.01$	$1.18^a±0.01$	*
Iron (Fe) (mg/l)	$0.17^c±0.01$	$0.78^a±0.02$	$0.48^b±0$	*
Zinc (Zn) (mg/l)	$1.22^c±0.01$	$1.83^b±0.02$	$2.2^a±0$	*

Abedi-Koupai et al.[20] found that the soil infiltration rate and saturated hydraulic conductivity increased after the application of wastewater irrigation to the land by sprinkler, but decreased after surface irrigation. The use of wastewater for irrigation can increase the soil conductivity due to its nutrient content and organic matter. The nutrients increase the soil's productivity and provide necessary fertilizer to it; the organic matter improves the soil's texture. Soil texture is an important characteristic that drives MM106 seedling growth. In this study, soil texture can be classified as sandy clay loam, according to USDA classification. The changes – which result from applying different irrigation waters to MM 106 apple seedlings – in the physical and chemical properties of the soil are shown in Table 6.

Soil pH is an important parameter because it can interfere with nutrient charge, increasing or decreasing their availability to the crops. During the study period, the average pH changes of T_0, T_1 and T_2 irrigation waters were found to be 7.95, 7.82 and 7.93. No significant difference was found between the irrigation waters' pH values ($p > 0.05$). Çay[21] reported that wastewater causes small changes in soil pH values, because of the high capacity buffering process which arose due to coverage of the soil with clay and limescale. Based on the soil analyses before and after the experiment, the pH value can change according to the content of the soil used. In this study, the irrigation water's EC and salinity values were found to be statistically significant ($p < 0.05$). The control of used water resources increased the EC value of the soil (Table 6).

One of the most important factors that restrict the use of wastewater as irrigation water is the increase in soil salinity. Increasing the salinity value of wastewater and the accumulation of toxic compounds are the most important factors to consider in agricultural applications. Bratby[22] reported that, based on the type of soil, wastewater irrigation might cause salinity problem, so they should be classified in the middle salinity class. In addition, Mañas et al. [23] determined that under humid conditions, wastewater irrigation for a one-year period does not statistically change the soil's pH and EC values.

The sodium adsorption ratio (SAR) is employed to supply information on the comparative concentrations of Na^+, Ca^{2+} and Mg^{2+} in soil solutions. The SAR of the soil extract paste reflects the combined effects of sodium, calcium and magnesium ions on the soil dispersion. It is stated that the SAR tends to increase with the application of wastewater to the soil [5]. Soil irrigated with municipal water (T_0) gave the lowest SAR value of 14.45. Soil irrigated with textile wastewater (T_1 and T_2) gave a higher SAR value of 44.57 and 60.82, respectively. When the SAR is greater than 13, the soil is called a sodic soil. Excess sodium in sodic soils causes soil particles to repel each other, preventing the formation of soil aggregates.

This results in a very tight soil structure with poor water infiltration, poor aeration and surface crusting; this makes cultivating land difficult and restricts the emergence of seedlings and root growth [24].

Although the EC value (4 dS/m) [25] and pH value (8.5) at the end of the experiment were lower than the critical values in all the irrigated samples, the SAR values were higher than the critical value when using the textile wastewater as irrigation water (SAR> 13).
Bedbabis et al. [26] attributed the sudden increase in SAR value to sodium (Na) accumulation in the plant when using the textile wastewater as irrigation water. According to Table 6, while the T_0 irrigated soil exhibited a decrease in the amount of Na and Cl, T_1 and T_2 irrigated soils exhibited a statistically important increase in their amount. ($p < 0.05$).

If excessive salt is not removed, it may result in accumulation in the soil, particularly in the top soil as a result of high rates of evaporation. It may also lead to elevated levels of exchangeable sodium concentrations and the exchangeable sodium cation (Na^+) percentage (ESP) [27]. With regard to the ions, textile wastewater irrigation (T_1, T_2) induced a significant accumulation of Na and Cl in the content of all soils, which led to a significant increase in the SAR (Table 6). This situation is thought to cause a significant reduction of the water infiltration rate [26]. According to Table 6, there was no statistically significant difference in the amount of micro and macronutrients between the different irrigation waters. But, it was found that the Na value in the raw wastewaters was different ($p < 0.05$).

Table 6. Macro-micronutrients level in '*Golden Delicious*' apple seedlings cultivated in soil samples using different irrigation water

Analyses	**Unit**	**$T_{INF.}$**	**After**			**One-way ANOVA**
			T_0	**T_1**	**T_2**	
Total Nitrogen (N)	%	0.33±0.01	0.28±0.04	0.3±0.03	0.31±0.03	ns
Phosphorus (P)	ppm	26.5^{ab}±2.12	22.43^{b}±0.07	24.25^{ab}±0.03	27.61^{a}±0.27	*
Potassium (K)	ppm	402.3±0.01	297.88±13.38	349.03±57.52	356.74±8.99	ns
Organic Matter	%	4.87±0.02	3.71±0.86	3.63±0.11	4.27±0.54	ns
Organic Carbon	%	2.84±0.01	2.15±0.51	2.11±0.06	2.48±0.32	ns
Volume Weight	gr/cm^3	1.45±0	1.43±0	1.43±0.01	1.43±0.02	ns
pH		7.22^{b}±0.02	7.95^{a}±0.03	7.82^{a}±0.07	7.93^{a}±0.01	*
EC	dS/m	0.61^{c}±0.01	0.56^{c}± 0.07	0.80^{b}±0.03	0.99^{a}±0.03	*
Salt	%	0.026^{bc}±0.001	0.025^{c}± 0.002	0.038^{ab} ± 0.001	0.046^{a}± 0.01	*
Lime ($CaCO_3$)	%	5.08^{c}±0.01	4.99^{c}±0.098	4.99±0.509	5.43±0.106	ns
Chlorine (Cl)	ppm	90.94^{c}±0	57.48^{c}±40.63	186.78^{b}±20.32	330.46^{a}±20.31	*
Calcium (Ca)	ppm	2903^{b}±0	3434^{a}±130.10	3218^{ab}±144.25	3620^{a}±145.66	*

Magnesium (Mg)	ppm	1357^a±0	518.2^b±26.8	468.5^b±61.51	446^b±22.62	*
Sodium (Na)	ppm	16470^b±0	642.0^c±47.30	2941.5^{ab}±446.89	3741.5^a±48.08	*
ESP	%	2.42^c±0.01	0.91^d±0.02	4.14^b±0.01	4.93^a±0.01	*
Sulphur (S)	%	0.26^b±0.01	0.21^d±0.03	1.15^a±0.01	0.21^c±0.01	*
Iron (Fe)	ppm	6.06±0.01	8.82±2.11	8.41±2.33	7.41±0.20	ns
Copper (Cu)	ppm	0.45^c±0	0.43^c±0.01	0.53^b±0.01	0.57^a±0.04	*
Zinc	ppm	2.38±0.002	1.83±0.32	2.26±0.08	2.38±0.01	ns
Manganese (Mn)	ppm	2.29±0.001	2.76±1.13	2.52±0.05	2.05±2.05	ns
Boron (B)	ppm	< 0.005	< 0.005	< 0.005	< 0.005	ns
Cadmium (Cd)	ppm	< 0.005	< 0.005	< 0.005	< 0.005	ns
Aluminum (Al)	ppm	1.61±0.01	1.89±0.24	2.07±0.21	2.23±0.12	ns
Nickel (Ni)	ppm	0.23±0.01	0.2±0.01	0.22±0.01	0.22±0	ns
Lead (Pb)	ppm	0.01±0	< 0.005	< 0.005	0.01	ns
Chromium (Cr)	ppm	0.25±0	0.27±0.06	0.3±0.01	0.31±0.02	ns

Moreover, ESP ratio is statistically significant before and after the irrigation with T_0, T_1 and T_2 (Table 6). Likewise, in arid and semi-arid western USA was indicated that irrigation with recycled wastewater has exhibited 187% higher EC and 481% higher SAR compared with sites irrigated with fresh water. Soil properties and plant growth are significantly affected by increased soil EC, exchangeable Na and ESP that is concluded with a decrease soil productivity and crop yields [5].

It is possible to ensure the movement of water in the soil and have a good water-air balance by adsorption of divalent or trivalent cations such as calcium, which affects the amount of organic matter, processes it, and facilitates freezing and thawing of the soil. As a result of adsorption of sodium by the soil, there is a possibility of deterioration in the aggregate structure of the soil by dispersing the existing aggregates. The deterioration decreases the soil's permeability due to the clogged pores caused by clay and silt particles, which come from the deteriorating soil surface. Soil permeability decreases due to excess sodium [28]. Thus, the physical properties of the soil will deteriorate and become impermeable, and the water-air balance will be degraded.

Ions that are found in irrigation waters, such as boron, sodium, chlorine and bicarbonate, cause physiological drought through increased osmotic pressure. They are also toxic to plants. It has been found that extreme levels of sodium, chlorine and boron are responsible for the most significant toxicity problems [29]. Belaid et al. [30] stated that wastewater applications increased the Na, K and Mg content in the soil. The differences between the applications of wastewaters are due to the different chemical properties of the water resources. Based on the control applications, Angin et al. [31] reported that using wastewater in irrigation increased the Na, K, Ca, and Mg content of the soil.

Heavy metal concentrations in the soil won't be increased by a statistically significant amount by treatment with T_0, T_1 and T_2 effluents. Metals are fixed to soils with a pH of 6.5 to 8.5 and/or with high organic matter content. Fortunately, sewage pH is always slightly alkaline (7.2 to 7.6) [32]. Angin et al. [31] stated that wastewater irrigation, and the soil's Fe, Cu, Mn and Zn content depends on the soil's depth. Based on the control, it was found to increase from 2 to 14 times.

Modeling Apple Sapling Growth

During the 191-d operation period using "*Golden Delicious*" apple saplings irrigated by T_0, T_1 and T_2 wastewater 13 growth models were examined, and their model coefficients were determined. Tables 3 to 5 show the regression analysis from the data obtained from apple saplings irrigated with T_0, T_1 and T_2. According to these criteria, in models with low MSE, AIC, and BIC values and those with high R^2, corrected R^2 values are preferred. Models in which their R^2 and corrected R^2 values are equal to zero or negative are excessively incompatible. According to these criteria, the cubic model is the most suitable for the all apple saplings irrigated with T_0, T_1 and T_2.

Tables 7 to 9 show the estimated coefficients of the regression models obtained using the data set obtained from the apple saplings irrigated with T_0, T_1 and T_2, respectively.

Table 7. Coefficients of the model for the apple saplings irrigated with T_0

Model	a	b	c	d
Proportional	1.615			
Linear	-162.901	3.990		
Quadratic	0.086	-6.623	143.835	
Quadratic zero	0.047	-1.730		
Parabola	0.033	-48.915		
Cubic	0.008	-1.403	82.549	-1579.972
Exponentional	1.818	0.057		
Restricted Exponentional	1.25E+38	-2.96E+38	-0.057	
Logistic	0.980	2.684	1.781	
Von Bertalanffy	-1.040	0.191	432.471	
Gompertz	0.670	0.181	0.082	
Richards	0.600	0.748	0.255	0.698
Hyper-Gompertz	0.771	0.081		

Table 8. Coefficients of the model for the apple saplings irrigated with T_1

Model	a	b	c	d
Proportional	1.423			
Linear	-131.117	3.078		
Quadratic	0.044	-3.055	66.940	
Quadraticzero	0.030	-1.031		
Parabola	0.022	-32.661		
Cubic	0.003	-0.686	46.178	-994.104
Exponentional	3.62E+28	0.039		
RestrictedExponentional	0.609	0.811	0.839	
Logistic	4.832	0.224	2.445	
VonBertalanffy	-29.295	0.262	167298.800	
Gompertz	0.298	0.972	0.960	
Richards	0.234	0.144	0.075	0.423
Hyper-Gompertz	0.465	0.097		

Figures 1 to 3 provide graphical representations of the predicted values of the regression models generated using data sets obtained from the apple saplings irrigated with T_0, T_1 and T_2, respectively. From the graphs, we observed that there is a harmonious relationship between the actual and predicted values for the linear, quadratic, quadratic-zero, parabolic, cubic, exponential and restricted-exponential models according to the data set obtained from the apple saplings irrigated with T_0; whereas, according to the data obtained from the apple saplings irrigated with T_1, we determined that there is a harmonious relationship between the real and estimated values of linear, quadratic, quadratic-zero, cubic and exponential models.

Table 9. Coefficients of the model for apple saplings irrigated with T_2

Model	a	b	c	d
Proportional	1.486			
Linear	-130.551	3.205		
Quadratic	0.040	-2.160	37.994	

Quadraticzero	0.031	-0.976		
Parabola	0.024	-30.434		
Cubic	0.004	-0.817	54.046	-1143.532
Exponentional	0.687	0.351		
RestrictedExponentional	0.549	0.606	0.948	
Logistic	3.317	0.665	4.470	
VonBertalanffy	-27.976	0.190	54661.150	
Gompertz	0.741	0.526	0.874	
Richards	0.364	0.609	0.413	0.649
Hyper-Gompertz	0.367	0.103		

Figure 3 shows that we find a harmonious relationship between the actual and the predicted values for the linear, quadratic, quadratic-zero, cubic and parabolic models according to the data set obtained from the apple saplings irrigated with T_2.

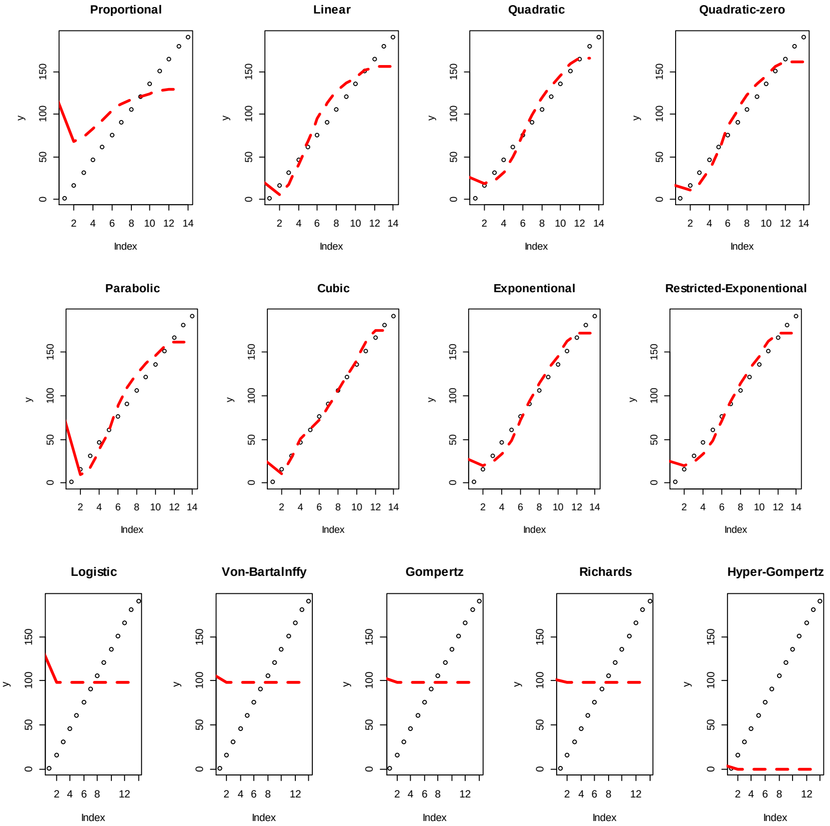
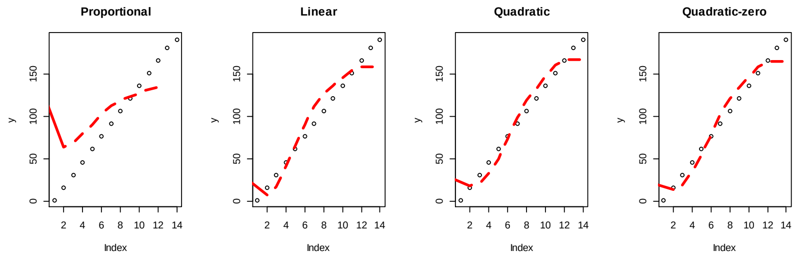


Figure 1. Graphs of estimates for the apple saplings irrigated with T_0



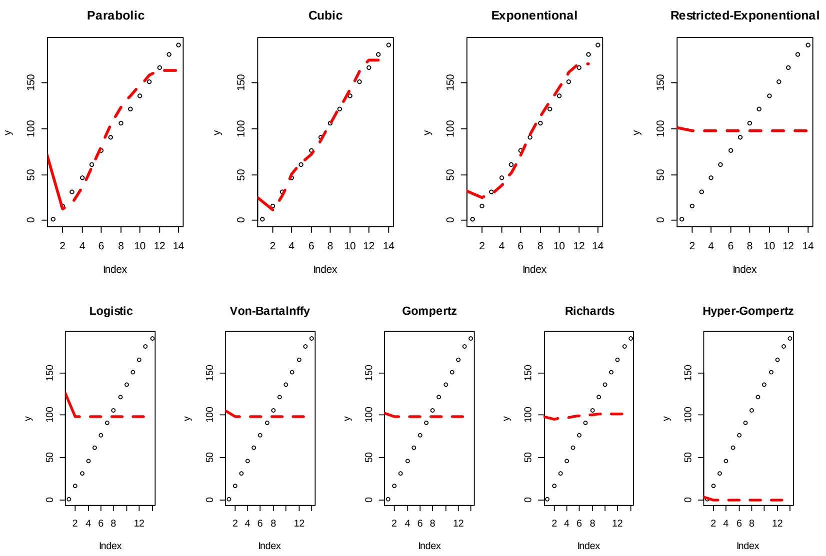


Figure 2. Graphs of estimates for the apple saplings irrigated with T_1

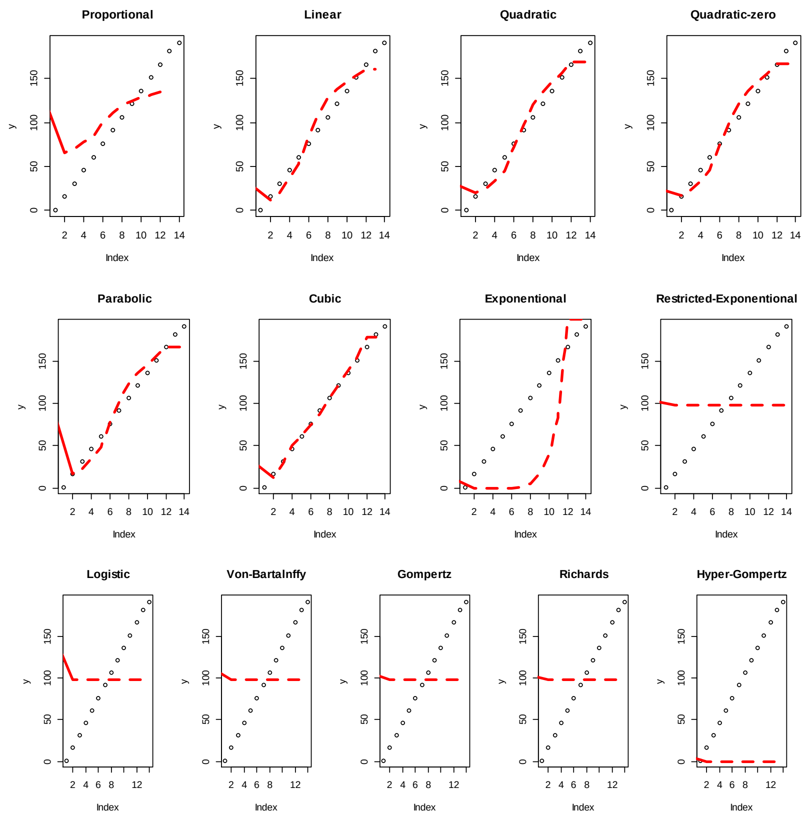


Figure 3. Graphs of estimates for the apple saplings irrigated with T_2

Growth modeling was applied in various other studies. For example; Yildizbakan [33] studied the growth model of the eucalyptus tree and found that the Gompertz model was the most suitable. Yılmaz et al. [34] studied the growth model of the Eucalyptus grandis W. Hill ex Maiden and found that the Von Bertalanffy model was the most suitable.

CONCLUSIONS

The results of this study have shown the effects of irrigation with municipal water (control), 1/3 diluted textile wastewater and raw textile wastewater on the growth of 'Golden Delicious' apples, on soil properties and on the accumulation of micronutrients and heavy metals in 'Golden Delicious' apple leaves. It was observed, according to obtained results, that it is possible to use T_1 as irrigation water. There was no statistically significant difference in the values of nutrient elements obtained from leaves that had been irrigated using T_1, T_2 and T_0 ($p > 0.05$). Although the EC values (4 dS/m) and pH values (8.5) at the end of the experiment were lower than the critical value in all the irrigated samples, the SAR values were higher than the critical value when using textile wastewater as irrigation water (SAR> 13). When SAR is greater than 13, the soil is called a sodic soil. Wastewater should be diluted by more than one-third for it to be used as agricultural irrigation water. Heavy metal concentrations won't be increased by a statistically significant amount when soil is treated with T_0, T_1 and T_2 effluents. Apple saplings' shoot height growth using with T_0, T1 and T_2 wastewater were found to be most consistent with the cubic model, respectively.

As a result, to eliminate water limitations without harming the environment, raw textile wastewater and raw textile wastewater diluted by 1/3 can be used for irrigation by taking precautions such as the necessary drainage and the appropriate irrigation methods.

ACKNOWLEDGMENTS

This study is supported by Bolu Abant Izzet Baysal University Scientific Research Projects Coordination Unit. Project Number: 2014-18-10-772.

REFERENCES

[1] Darvishi, H., Manshouri, M. and Farahani, H.A., 2010, The effect of irrigation by domestic wastewater on soil properties, J Soil Sci Environ Manage, Vol. 1(2), 30-33.

[2] Scott C.A., Faruqui, N.I. and Raschid-Sally, L., 2004, Wastewater Use in Irrigated Agriculture. In: Scott CA, Faruqui NI, Raschid-Sally L, editors. Confronting the Livelihood and Environmental Realities, UK: CABU.

[3] Arslan-Alaton, I., Türkman, A.and Orhon, D., 2011, Future of Water Resources and Wastewater Reuse in Turkey. In: Baba A, Tayfur G, Gündüz O, Howard K, Friedel M, Chambel A, editors. Climate Change and its Effects on Water Resources. NATO Science for Peace and Security Series C: Environmental Security, Dordrecht: Springer, Vol. 3, 285-292.

[4] Tsoutsos, G., Chatzakis, M., Sarantopoulos, I., Nikologiannis, A. and Pasadakis, N., 2013, Effect of wastewater irrigation on biodiesel quality and productivity from castor and sunflower oil seeds, Renew Energ, Vol. 75, 211-215.

[5] Elgallal, E., Fletcher, L. and Evans, B., 2016, Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: A review, Agric Water Manag, Vol. 177, 419-431.

[6] Pandey, R., and Singh, I., 2015, Effect of textile factory effluent irrigation on productivity of weight growth, J Sol Energ Research, Vol. 3(1), 65-72.

[7] Singh, P.K., Deshbhratar, P.B., and Ramteke, D.S., 2011, Effects of sewage wastewater irrigation on soil properties, crop yield and environment, Agric Water Manag, Vol. 103, 100-104.

[8] Shilpi, S., Seshadri, B., Sarkar, B., Bolan, N., Lamb, D. and Naidu, R., 2018, Comparative values of various wastewater streams as a soil nutrient source, Chemosphere, Vol. 192, 272-281.

[9] Chaoua, S., Boussaa, S.Z., Gharmali, A.E. Boumezzough, A., 2018, Impact of irrigation with wastewater on accumulation of heavy metals in soil and crops in the region of Marrakech in Morocco, J Saudi Soc Agric Sci, (in press).

[10] Asgari, K., Najafi, P., Soleymani, A. and Larabi, R., 2007, Effects of treated municipal wastewater on growth parameters of corn in different irrigation conditions, J Bio Sci, Vol. 7, 1430-1435.

[11] Bulc, T.G. and Ojstrsék, A., 2008, The use of constructed wetland for dye-rich textile wastewater treatment, J Hazard Mater, Vol. 155(1&2), 76–82.

[12] Wins, J.A. and Murugan, M., 2010, Effect of textile mill effluent on growth and germination of black gram Vigna mungo (L.) Hepper, IJPBS, Vol. 1(1), 1-7.

[13] Panaskar, D.B. and Pawar, R.S., 2011, Effect of textile mill effluent on growth of *Sorghum vulgare* and *Vigna aconitifolia* seedlings, Indian J Science & Technology, Vol. 4(3), 273-278.

[14] Carr, G., Potter, R.B. and Nortcliff, S., 2011, Water reuse for irrigation in Jordan: perceptions of water quality among farmers, Agric Water Manag, Vol. 98(5), 847–854.

[15] Castro, B.C., Lopez, A.R., Moreira, I.V., Silva, E., Manaia, C.M. and Nunes, O., 2015, Wastewater reuse in irrigation: a microbiological perspective on implications in soil fertility and human and environmental health, Environ Int, Vol. 75, 117–135.

[16] FAO, 2015, Food and agriculture organization of the United Nations, (web page: http://faostat3.fao.org/download/Q/QC/E).

[17] Zenginbal, H., Dogdu Okcu G. and Yalcuk A. 2018, The impact of textile wastewater irrigation on the growth and development of apple plant. Int J Phytoremediation, 20(2):153-160.

[18] American Public Health Association (APHA), 2005, In: 21st ed. Standard methods for the examination of waste and wastewater. Washington, DC.

[19] SPSS, IBM Corporation. 2011, IBM SPSS Statistics for Windows, Version 23.0. IBM Corporation, Armonk, NY.

[20] Abedi-Koupai, J., Mostafazadeh-Fard, B., Afyuni M. and Bagheri, M.R., 2006, Effect of treated wastewater on soil chemical and physical properties in an arid region, Plant Soil and Environ, Vol. 52(8), 335-344.

[21] Çay, Ş., 2013, The Using of the urban waste water on agricultural irrigation on Konya and Effects on Maize Farming," PhD Thesis, Çukurova University, Institute of Natural and Applied Sciences, Department of Agricultural Structure and Irrigation, Adana.

[22] Bratby, J., 2006, Coagulants, in Coagulation and Flocculation in Water and Wastewater Treatment. IWA Publishing, London.

[23] Mañas, P., Castro, E. and Heras, J.D.L., 2009, Irrigation with treated wastewater: Effects on soil, lettuce (*Lactucasativa L.*) crop and dynamics of microorganisms, J Environ Sci Health A, Vol. 44, 1261–1273.

[24] Munshower, F.F., 1994, Practical Handbook of Disturbed Land Revegetation. Boca Raton.

[25] Christiansen, J.E., Olsen, E.C. and Willardson, L.S., 1977, Irrigation water quality evaluation, J Irrig Drain, Vol. 103, 155–169.

[26] Bedbabais, S., Rouina, B.B., Boukhris, M. and Ferrara, G., 2014, Effect of irrigation with treated wastewater on soil chemical properties and infiltration rate, J Environ Manag, Vol. 133, 45-50.

[27] Qadir, M. and Scott, C.A., 2010, Non-pathogenic trade-offs of wastewater irrigation. In: Dreschel P, Scott CA, Raschid-sally L, Redwood M, Bahri A, editors. Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low Income Countries. London: Earthscan.

[28] Kaya, N. and Ozturk, M., 2003, Agricultural Investigation of Irrigation Waters and Soil Sources of Elazığ Region. Researches of Eastern Anatolia Region, Vol. 1(3), 87-92.

[29] Kanber, R., Önder, S., Ünlü, M., Köksal, H., Özekici, B., Sezen, S., et al., 1996, The Optimization of Surface Irrigation Methods Which Are Used for Cotton Production and Their Comparison with Sprinkler Irrigation. Final Report for Prime Ministry of Turkey, GAP-RDA, No: 18, GAP Pub., No: 96, General No: 155, Adana.

[30] Belaid, N., Neel, C., Kallel, M., Ayoub, T., Ayadi, A. and Baudu, M., 2012, Long term effects of treated wastewater irrigation on calcisol fertility: A case study of Sfax-Tunisia, Agric Sci, Vol. 3, 702-713.

[31] Angin, A., Yaganoglu, A.V. and Turan, M., 2008, Effects of Long-Term Wastewater Irrigation on Soil Properties, J Sustain Agr, Vol. 26(3), 31-42.

[32] Jiménez, B., 2006, Irrigation in Developing Countries Using Wastewater, International Renewable Energy Storage Conference, Vol. 6(2), 229-250.

[33] Yıldızbakan, A., 2005, Growing Mathematical Models in Trees and Comparative Analysis of These Models, Çukurova Üniversitesi Fen Bilimleri Enstitüsü, Adana.

[34] Yılmaz, E., Akgün, C. and, Yıldızbakan, A., 2005, (Eucalyptus grandis W. Hill ex Maiden) have examined the growth pattern of tree species and found that they fit the von bertalanffy model of the most suitable breeder, Journal of DOA, Vol. 11, 35-52.