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INFLUENCE OF TREATED SEWAGE SLUDGE APPLICATIONS ON CORN AND SUCCEEDING WHEAT YIELD AND ON SOME PROPERTIES OF SANDY CLAY SOIL

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ABSTRACT

The objective of this study was to determine influence of treated sewage sludge (TSS) rates on corn and wheat yield and on some properties of sandy clay soil. The field study was conducted in the Randomized Block Design with four replications and five different applications including control, mineral fertilizer and TSS (12.5; 25.0; 37.5 Mg.ha^{-1} as dry matter). Corn (*Zea mays* L. var. ZP 737) was the first crop, wheat (*Triticum durum* L. var. Ege 88) was the succeeding crop. Soil samples were taken five times in two years. Increasing TSS applications resulted in significantly increased total biomass and grain yield of corn. However, grain yield of succeeding wheat did not change significantly. Increasing TSS aplications were significiantly increased total N, available P and K, pH, total salt and organic matter content of sandy clay soil. However, $CaCO_3$ and cation exchange capacity values of soil did not change significantly. Due to decomposition of TSS in the soil, effect of TSS levels on soil properties decreased in the last sampling periods. Thus, it can be recommended that 37.5 Mg.ha^{-1} TSS as dry matter can be added once in 2 years for improving plant nutrients and soil properties of sandy clay soil.

Keywords: corn, sandy clay, sewage sludge, soil properties, wheat

INTRODUCTION

Wastes and by-products, which are organic residual from different processes, have beneficial properties when added to soil. When correctly applied, organic residues can restore soil quality, by balancing pH, increasing soil organic matter (OM), enlarging carbon reservoirs, increasing porosity, soil aggregation and water retention capacity, improving fertility and stimulating microbial communities. Thus, amelioration of soil conditions enables vegetation development, increasing productivity. Treated sewage sludge (TSS) is an ultimate product of municipal wastewater treatment plant and highly enriched in OM. Sewage sludge gives us the opportunity of beneficial use by closing the cycle of nutrients (Sequi et al., 2000). At present the major ways of disposing of sewage sludges are deposition, landfill and incineration, only part of the sludges are used in agriculture. Where sludge is to be used on land, it is usually stabilised by mesophilic anaerobic digestion, or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting. As municipalities upgrade waste water treatment systems and public opinion and legislation discourages disposal of organic materials in landfills, biosolids are projected to become increasingly available for agricultural use. Organic materials can differ considerably in terms of the extent to which they increase soil organic matter contents and alter soil physical and chemical properties (Barker et al., 2000). Sewage sludge may contain significant amounts of N, P and trace elements. The use of sewage sludge has been recommended to improve the chemical and physical properties of soil (Wong and Su 1997; Debosz et al., 2002). The beneficial effects of using sludge on agricultural soils have been proven by numerous researchers (Wong and Su 1997; Aggelides and Londra 2000; Benitez et al. 2001; Selivanovskaya et al. 2001; Debosz et al. 2002). The use of biosolids as agricultural soil amendments and fertiliser replacements is also relatively well researched (Cogger et al. 2004; Correˆa 2004; Tarrasoˊn et al. 2008; Delibacak et al. 2009a), and fertiliser advice is available for these materials (Defra 2010). TSS contains macronutrients, trace elements and heavy metals. These attributes potentially make TSS an excellent fertilizer at very low cost for agricultural land in Turkey which is generally rich in lime, low in OM. However, special care should be taken with respect to micronutrients and heavy metals so as not to introduce excessive amounts of these elements, which could have an adverse effect on the environment, especially when soil is acidic (Delibacak et al. 2009a; Mercik et al. 2003, Pascual et al. 2004).

The purpose of this work was to evaluate the influence of municipal TSS doses on the corn and succeeding wheat yield and on some properties of sandy clay soil during the five different periods in two years.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the research field of Aegean Agricultural Research Institute in Menemen plain, Izmir, Turkey (38°56′29.02″-38°56′37.59″N; 27°05′23.08″-27°05′30.74″E). The experimental site is in the Western Anatolia region of Turkey (Figure 1), where the Mediterranean climate prevails with a long-term mean annual temperature of 16.8 °C. Long-term mean annual precipitation is 542 mm, representing about 75% of rainfalls during the winter and spring, and the mean relative humidity is 57%. Long-term mean annual potential evapotranspiration is 1,570 mm (IARTC 2012). The investigated soil is characterized by sandy clay texture with slightly alkaline reaction and classified as a Typic Xerortent (Soil Survey Staff 2006). Some selected properties of experimental soil is given in Table 1 and some selected properties and total heavy metal concentrations in TSS used in the experiment is given in Table 2.

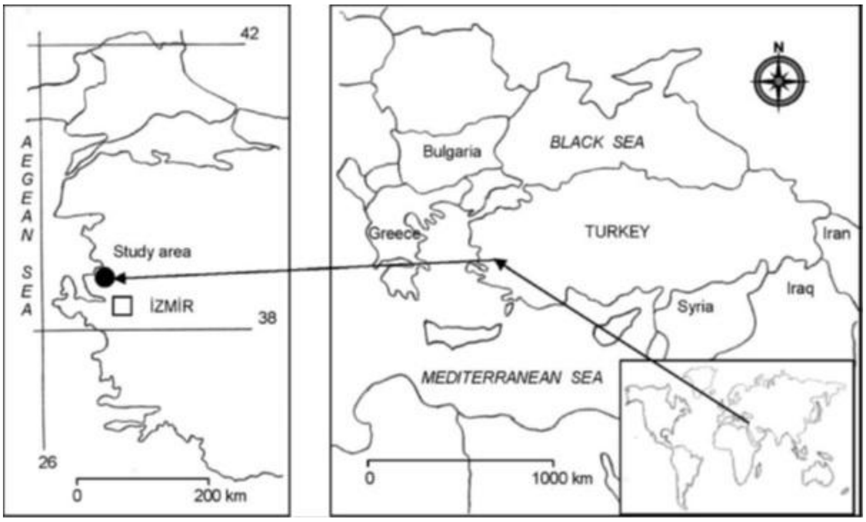

Figure 1. Location of study area

Table 1. Some selected properties of the experimental soil

Sand	(%)	44.84	**pH**	(Saturation paste)	7.53
Silt	(%)	16.44	**Salt**	(%)	0.167
Clay	(%)	38.72	**$CaCO_3$**	(%)	0.51
Texture		Sandy clay	**OM***	(%)	0.94

*OM:organic matter

Table 2. Some selected properties and total heavy metal concentrations of treated sewage sludge used in the experiment

EC	dS/m	16,35	**Fe**	%	1,14
$CaCO_3$	(%)	10,24	**Cu**	mg/kg	268,8
Org. matter	(%)	70,32	**Zn**	mg/kg	1335
Org. C	(%)	40,79	**Mn**	mg/kg	298,6
N[1]	(%)	5,33	**B**	mg/kg	035,2
P[1]	(%)	1,33	**Co**	mg/kg	014,2
K[1]	(%)	0,68	**Cd**	mg/kg	004,1
Ca[1]	(%)	3,74	**Cr**	mg/kg	250,6
Mg[1]	(%)	0,68	**Ni**	mg/kg	115,4
Na[1]	(%)	0,59	**Pb**	mg/kg	199,4

[1]Total

Field experiment

Five different applications including the control, mineral fertilizer, treated sewage sludge 12.5 $Mg.ha^{-1}$; 25.0 $Mg.ha^{-1}$; 37.5 $Mg.ha^{-1}$ as dry matter were compared in a field trial arranged in the Randomized Block Design with four replications in 2011 and 2012. The plot dimensions were 3 m width and 3 m length. The TSS used in the experiment was obtained from the wastewater treatment plant of Metropolitan Region, Izmir city. It may produce around 600 Mg (moist basis) sewage sludge per day. Calcium oxide was added to raise the efficiency of the dewatering process of sewage sludge. In addition, the SS produced presented a pH varying between 10 and 13, what increased the pathogen control and decreased the heavy metal availability by added calcium oxide. TSS was added to the soil under investigation at the rates of 12.5 $Mg.ha^{-1}$; 25.0 $Mg.\ ha^{-1}$; 37.5 $Mg.ha^{-1}$ as dry matter on July 14, 2011. Also 150 kg N, 150 kg P_2O_5, 150 kg K_2O ha^{-1} (1000 kg ha^{-1} 15.15.15. composed fertilizer) were applied to the only mineral fertilizer parcels at the same time and mixed with soil to 15 cm depth. Corn (*Zea mays* L. var. ZP 737) was sown with seeding machine on rows 18 cm and in rows 70 cm apart. Drop irrigation was provided when required. Harvest of corn was done by hands on November 17, 2011. Wheat (*Triticum durum* L. var. Ege 88) was sown with seeding machine on November 22, 2011 to 5 cm of soil depth as succeeding crop. Also 80 kg N and 80 kg P_2O_5 ha^{-1} (400 kg ha^{-1}20.20.0. composed fertilizer) were applied to the only mineral fertilizer parcels at the same time and mixed with soil to 15 cm depth before wheat seeding. Wheat was harvested with machine on July 10, 2012. Second year, without applying any TSS (for determination of its second year effect), corn seeds were sown with seeding machine on July 18, 2012. Also 150 kg N, 150 kg P_2O_5, 150 kg K_2O ha^{-1} were applied to the only mineral fertilizer parcels at the same time and mixed with soil to 15 cm depth before corn seeding. Harvest of second year's corn was done by hands on November 1, 2012.

Soil sampling and analyses

During the experiment, soil samples were taken from the center of each plot in five different periods (1st, August 11, 2011-3 weeks after sowing of corn; 2nd, November 17, 2011-after corn harvest; 3rd, July 11, 2012-after wheat harvest; 4th, August 7, 2012-3 weeks after sowing of second year corn; 5th, November 1, 2012- after corn harvest of second year). The samples were air-dried and sieved using 2-mm sieve. All analysis were done in these sieved soils. Particle size distribution of experimental soil was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). Total salt, OM concentration, $CaCO_3$, pH, total P, K, Ca, Mg, Na, Fe, Cu, Mn, Zn, Cd, Cr, Co, Ni, Pb and B concentrations of TSS were all determined according to Page et al. (1982). Some properties (total salt, OM concentration, $CaCO_3$, pH) of the soil were also determined according to Page et al. (1982). Cation exchange capacity (CEC) of experimental soil was determined according to Chapman (1965). Total N content of soil and TSS were determined using a modified Kjeldahl method (Bremner 1965). Available P in soil was determined by the Mo blue method in $NaHCO_3$ extract (Olsen et al., 1954). Available K was analyzed with 1N NH_4OAc extract method (Kacar 1994).

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS 17.0 2008). Tukey test was used to find if differences in the treatments were significant at $P \leq 0.01$ or $P \leq 0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Influence of TSS applications on yield of corn and succeeding wheat crop grown in sandy clay soil

Influence of TSS applications on total biomass and grain yield of corn grown in sandy clay soil are given in Table 3 and Table 4, respectively. The increasing TSS rates significantly increased average of 1st and 2nd year total biomass and grain yield of corn in the experiment. Antolı´n et al. (2005) stated that the yield of barley increased in sludge and mineral amended plots in comparison to unamended plots. The higher yields in sludge-treated crops are usually attributed to the improvement in the soil conditions, by the supply of additional C from the sludge (Navas et al. 1998; Christie et al. 2001). Daur et al. (2015) showed that increasing levels of organic manure and humic acid enhance nutrient uptake and increase crop yield of organic berseem.

Table 3. Influence of treated sewage sludge (TSS) applications on total biomass yield of corn grown in sandy clay soil, Tukey: P≤ 0,01

Applications	**Average of 1st and 2nd. year yield ($Mg.ha^{-1}$)**	**1st year yield ($Mg.ha^{-1}$)**		**2nd year yield ($Mg.ha^{-1}$)**		
Control	33.51 b[1]	34.75 c	A[2]	32.28 a	A	
Fertilizer	37.55 ab	43.09 bc	A	32.02 a	A	
12.5 $Mg.ha^{-1}$TSS	40.06 ab	49.37 abc	A	30.75 a	B	**
25.0 $Mg.ha^{-1}$TSS	44.21 ab	52.67 ab	A	35.76 a	B	**
37.5 $Mg.ha^{-1}$TSS	47.62 a	59.78 a	A	35.47 a	B	**
	**	**				

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for years.

Table 4. Influence of treated sewage sludge (TSS) applications on grain yield of corn grown in sandy clay soil Tukey: P≤ 0,01: P≤ 0,05

Applications	**Average of 1st and 2nd. year yield ($Mg.ha^{-1}$)**	**1st year yield ($Mg.ha^{-1}$)**		**2nd year yield ($Mg.ha^{-1}$)**		
Control	3.11 c[1]	3.31 c	A[2]	2.91 b	A	
Fertilizer	4.81 bc	6.47 b	A	3.14 ab	B	**
12.5 $Mg.ha^{-1}$TSS	5.19 bc	7.72 ab	A	2.66 b	B	**
25.0 $Mg.ha^{-1}$TSS	6.16 ab	8.59 ab	A	3.73 ab	B	**
37.5 $Mg.ha^{-1}$TSS	7.69 a	10.19 a	A	5.20 a	B	**
	**	**		*		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for years.

Influence of TSS applications on grain yield of succeeding wheat grown in sandy clay soil are given in Table 5.

The highest grain yield of succeeding wheat was found with the highest TSS application dose. Hernandez et al. (1991), Jamil et al. (2004), Jamil et al. (2006) and Tamrabet et al. (2009) reported that sewage sludge increased the grain yield and straw production of wheat. They mentioned that the maximum yields in both grain and straw were obtained at 40 Mg ha^{-1} of sewage sludge application. Al-Mustafa et al. (1995), Singh and Singh (1999), Al Zoubi et al. (2008) and Ailincăi et al. (2010) also mentioned highest increase in the grain and straw yield of wheat treated with sewage sludge.

Table 5. Influence of treated sewage sludge (TSS) applications on grain yield of succeeding wheat grown in sandy clay soil Tukey: P≤ 0,01

Applications	Control	Fertilizer	12.5 $Mg.ha^{-1}$TSS	25.0 $Mg.ha^{-1}$TSS	37.5 $Mg.ha^{-1}$TSS
Grain yield of succeeding wheat ($Mg.ha^{-1}$)	1.486 b[1]	2.270 ab	1.883 ab	2.259 ab	2.609 a

[1]Significant differences between treatments at P≤ 0,01 level indicated by different letters.

Influence of TSS applications on some properties of sandy clay soil

Influence of TSS applications on total N content of sandy clay soil is given in Table 6.

The increasing TSS rates significantly increased total N concentration of the average of 5 sampling periods of soil compared with the control. Total N concentration in the soil decreased particularly in the last periods because of the plant uptake of N in soil. Brofas et al. (2000) stated that N concentration increased with sludge applications. Bozkurt and Cimrin (2003) determined that sewage sludge applications increased the total N concentration about five-fold at the highest sludge rate. White et al. (1997) found that N mineralization potentials were significantly higher at high sludge rates. Magdoff and Amadon (1980) estimated that 55% of organic N in sludge incorporated in soil was mineralized during the first year. Under optimum laboratory conditions at a temperature of 35 °C, 55 to 95% of the organic N was mineralized in a 24-week period. The rate of mineralization is a function of the amount of the sludge added to soil. A good N balance is a critical factor in any land application program. Over application of N can result in groundwater contamination. Under application can lead to less than optimum crop yields and consequently to farmer dissatisfaction. It is important that sufficient sludge is applied to obtain optimum crop response without excessive NO_3-leaching. Further investigation is needed to develop more precise methods for balancing N from different sludge types and for varying soil conditions.

Table 6. Influence of treated sewage sludge (TSS) applications on total N content of sandy clay soil Total N (%) Tukey:P≤ 0,01

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.083 b[1]	0.099 c	A[2]	0.101 b	A	0.086 a	A	0.085 a	A	0.045 a	B	**
Fertilizer	0.088 b	0.110 bc	A	0.108 b	A	0.081 a	A	0.098 a	A	0.041 a	B	**
12.5 $Mg.ha^{-1}$TSS	0.090 ab	0.118 bc	A	0.109 b	A	0.095 a	A	0.084 a	A	0.043 a	B	**
25.0 $Mg.ha^{-1}$TSS	0.098 ab	0.134 ab	A	0.131 ab	A	0.082 a	B	0.101 a	AB	0.044 a	C	**
37.5 $Mg.ha^{-1}$TSS	0.109 a	0.157 a	A	0.153 a	A	0.085 a	B	0.107 a	B	0.043 a	C	**
	**	**		**								

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on plant available P content of sandy clay soil is given in Table 7.

Applications of increasing TSS rates significantly increased the plant available P concentrations of soil in 5 different soil sampling periods according to the control. In the course of time, depending on decomposition of OM and using of plant available P in soil by produced plants, the effect of TSS rates on plant available P concentrations in soil decreased especially in the last periods. White et al. (1997) and Brofas et al. (2000) also reported a remarkable increase in plant available P in soil after the application of sewage sludge. Another study showed that P concentrations increased more than six-fold from control to the highest application rate plots (Sullivan et al. 2006). Rathod et al. (2013) reported that the beneficial effect of organics on P availability was possibly due to the solubilization of native phosphate by organic acids released during microbial decomposition of organic materials.

Table 7. Influence of treated sewage sludge (TSS) applications on plant available ($NaHCO_3$-extractable) P content of sandy clay soil Available P ($mg.kg^{-1}$), Tukey:P≤ 0,01

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	41.19 d[1]	63.68 c	A[2]	27.25 c	B	46.14 c	AB	37.21 c	B	31.65 c	B	**
Fertilizer	61.42 bc	73.85 c	A	43.20 c	B	78.02 b	A	63.05 ab	AB	49.00 bc	B	**
12.5 $Mg.ha^{-1}$TSS	53.70 cd	67.94 c	A	39.90 c	B	63.10 bc	A	51.05 bc	AB	46.50 bc	AB	**
25.0 $Mg.ha^{-1}$TSS	73.18 b	96.89 b	A	79.30 b	A	82.72 b	A	53.07 bc	B	53.94 b	B	**
37.5 $Mg.ha^{-1}$TSS	103.29a	121.02 a	A	111.90 a	A	121.58 a	A	81.49 a	B	80.45 a	B	**
	**	**		**		**		**		**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on plant available K content of sandy clay soil is given in Table 8.

Increasing TSS rates and mineral fertilizer applications significantly increased available K concentration of the average of 5 sampling periods of soil compared with the control. Delibacak et al. (2009a) found that, plant available K increased with TSS rates from 340 mg kg^{-1} in the control plots to 419 mg kg^{-1} with the 90 Mg ha^{-1} application rate. On the other hand, Martı´nez et al. (2003) noted that, plant available K concentrations in soil were low and did not increase significantly with biosolid treatments compared with the control.

Table 8. Influence of treated sewage sludge (TSS) applications on plant available (1N NH_4OAc- extractable) K content of sandy clay soil, Available K ($mg.kg^{-1}$), Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	168.81 c[1]	188.83 b	A[2]	175.23 ab	AB	168.50 a	AB	161.73 b	AB	149.79 b	B	**
Fertilizer	211.35 a	213.29 ab	B	207.10 a	B	190.34 a	B	259.25 a	A	186.75 a	B	**
12.5 $Mg.ha^{-1}$TSS	171.95 bc	191.16 b	A	165.93 b	AB	181.77 a	AB	164.58 b	AB	156.33 ab	B	*
25.0 $Mg.ha^{-1}$TSS	179.34 bc	205.15 ab	A	180.49 ab	AB	176.87 a	AB	168.28 b	B	165.92 ab	B	**
37.5 $Mg.ha^{-1}$TSS	190.71 b	226.13 a	A	184.85 ab	B	180.34 a	B	179.65 b	B	182.60 ab	B	**
	**	**		**				**		**		

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on pH of sandy clay soil is given in Table 9.

The increasing TSS rates significantly increased pH values of the average of 5 sampling periods of soil according to the control and mineral fertizer applications. It can be said that the reason of increasing pH value of soil is high pH values of sewage sludge treated with lime to eliminate the pathogens. It is recommended that soil pH should be maintained above 6.5 for sludge amended soils (Henning et al. 2001). Smith (1994) noted that optimal pH value for growth of the majority of plants was between 6.5 and 7.0. The soil pH is also one of the major factors controlling the availability of heavy metals.

Table 9. Influence of treated sewage sludge (TSS) applications on pH of sandy clay soil, pH Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	7.33 ab[1]	7.42 ab	AB[2]	7.47 ab	A	7.22 ab	B	7.22 ab	AB	7.49 ab	A	*
Fertilizer	7.09 b	7.13 b	ABC	7.37 b	A	6.79 b	BC	6.79 b	C	7.24 b	AB	**
12.5 $Mg.ha^{-1}$TSS	7.54 a	7.47 ab	AB	7.77 a	A	7.53 a	B	7.53 a	AB	7.66 a	AB	**
25.0 $Mg.ha^{-1}$TSS	7.56 a	7.60 a	AB	7.69 ab	A	7.56 a	B	7.56 a	AB	7.67 a	A	*
37.5 $Mg.ha^{-1}$TSS	7.55 a	7.51 ab	AB	7.71 ab	A	7.57 a	B	7.57 a	AB	7.64 a	AB	*
	**	**		*		*		**		*		

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on total salt content of sandy clay soil is given in Table 10.

It was found that, total salt content of soil was significantly increased by increasing TSS levels in average of 5 sampling periods of soil compared with the control.

The highest total salt was 0.202% with 37.5 Mg.ha^{-1}TSS level. On the other hand, control had the lowest total salt as 0.136% (Table 10). In the last three periods, all salt contents of soil samples were statistically in the same grup. It can be said that irrigation and precipitation caused this situation.

Table 10. Influence of treated sewage sludge (TSS) applications on total salt content of sandy clay soil, Total salt (%) Tukey:P≤ 0,01

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.136 c[1]	0.165 c	AB[2]	0.103 c	BC	0.070 a	C	0.186 a	A	0.156 a	AB	**
Fertilizer	0.160 bc	0.190 bc	AB	0.131 bc	BC	0.080 a	C	0.241 a	A	0.157 a	B	**
12.5 Mg.ha^{-1}TSS	0.159 bc	0.228 bc	A	0.131 bc	BC	0.076 a	C	0.196 a	AB	0.165 a	AB	**
25.0 Mg.ha^{-1}TSS	0.178 ab	0.248 ab	A	0.174 ab	B	0.089 a	C	0.205 a	AB	0.174 a	B	**
37.5 Mg.ha^{-1}TSS	0.202 a	0.288 a	A	0.230 a	AB	0.078 a	C	0.225 a	AB	0.191 a	B	**
	**	**		**								

Significant differences between treatments at ** P≤ 0,01 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on $CaCO_3$ content of sandy clay soil is given in Table 11.

The increasing TSS rates were significantly increased $CaCO_3$ content of the average of 5 sampling periods of soil compared with the control. It can be said that high $CaCO_3$ content of TSS (10.24%) caused this situation.

Influence of TSS applications on cation exchange capacity (CEC) of sandy clay soil is given in Table 12.

It was found that, there is no statistical relationship between TSS levels and CEC of soil in all periods. Ahmed et al. (2010) determined that use of sewage sludge in soil showed higher nitrogen and phosphorus contents than the control soil, but a similar content of cation exchange capacity (CEC). On the other hand, Alcantara et al. (2009) observed that the concentrations of phosphorus, nitrogen, sulfate, and CEC, organic carbon were positively correlated with sewage sludge dose applied to the soil.

Table 11. Influence of treated sewage sludge (TSS) applications on $CaCO_3$ content of sandy clay soil, $CaCO_3$ (%) Tukey:P≤ 0,01; P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	0.617 c[1]	0.445 b	B[2]	0.592 a	AB	0.779 a	A	0.684 a	AB	0.584 b	AB	**
Fertilizer	0.630 bc	0.461 b	B	0.570 a	AB	0.794 a	A	0.677 a	AB	0.651 ab	AB	**
12.5 Mg.ha^{-1}TSS	0.673 abc	0.539 ab	B	0.547 a	B	0.824 a	A	0.818 a	A	0.636 ab	AB	**
25.0 Mg.ha^{-1}TSS	0.769 ab	0.635 ab	B	0.713 a	AB	0.855 a	A	0.825 a	AB	0.815 ab	AB	*
37.5 Mg.ha^{-1}TSS	0.795 a	0.684 a	A	0.714 a	A	0.855 a	A	0.848 a	A	0.847 a	A	
		*								**		

Significant differences between treatments at ** P≤ 0,01 or * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Table 12. Influence of treated sewage sludge (TSS) applications on cation exchange capacity (CEC) of sandy clay soil, CEC (meq/100g), Tukey:P≤ 0,05

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	25.95 a[1]	27.35 a	A[2]	26.26 a	A	25.10 a	A	25.66 a	A	25.37 a	A	
Fertilizer	25.83 a	27.26 a	A	25.27 a	AB	25.23 a	AB	26.85 a	AB	24.52 a	B	*
12.5 Mg.ha^{-1}TSS	26.73 a	28.08 a	A	26.99 a	A	25.85 a	A	27.10 a	A	25.62 a	A	
25.0 Mg.ha^{-1}TSS	26.71 a	27.08 a	A	26.90 a	A	25.96 a	A	27.50 a	A	26.12 a	A	
37.5 Mg.ha^{-1}TSS	27.01 a	26.63 a	A	26.99 a	A	26.59 a	A	27.90 a	A	26.92 a	A	

Significant differences between treatments at * P≤ 0,05 level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

Influence of TSS applications on organic matter content of sandy clay soil is given in Table 13.

Treatments of increasing TSS levels significantly increased OM content of soil samples in the average of 5 periods. Analogously to our study, Delibacak et al. (2009b) found out an increase in the concentrations of OM in soil caused by increasing doses of sewage sludge introduced to soil.

Table 13. Influence of treated sewage sludge (TSS) applications on organic matter (OM) content of sandy clay soil, OM (%) Tukey: $P \leq 0,01$; $P \leq 0,05$

Applications	Average of 5 periods	Soil sampling periods										
		1		2		3		4		5		
Control	1.40 b[1]	1.21 b	B[2]	1.19 b	B	1.72 a	A	1.49 a	AB	1.36 a	AB	**
Fertilizer	1.43 ab	1.29 ab	B	1.27 ab	B	1.79 a	A	1.48 a	AB	1.33 a	B	**
12.5 $Mg.ha^{-1}$TSS	1.48 ab	1.32 ab	B	1.36 ab	B	1.78 a	A	1.53 a	AB	1.42 a	AB	**
25.0 $Mg.ha^{-1}$TSS	1.54 ab	1.47 ab	A	1.47 ab	A	1.77 a	A	1.52 a	A	1.45 a	A	
37.5 $Mg.ha^{-1}$TSS	1.61 a	1.65 a	A	1.64 a	A	1.68 a	A	1.57 a	A	1.53 a	A	
	*	**		**								

Significant differences between treatments at ** $P \leq 0,01$ level indicated by different letters. [1]Small letter in column for applications, [2]capital letter in row for periods.

CONCLUSION

Increasing TSS applications to sandy clay soil resulted in significantly increased total biomass and grain yield of corn and grain yield of succeeding wheat according to the control. Also, increasing treated sewage sludge aplications were significiantly increased total N, plant available P and K, pH, total salt, $CaCO_3$ and organic matter content of sandy clay soil as average of 5 sampling periods . However, CEC values of soil did not change significantly as average of 5 sampling periods when compared with the control. In the course of time, effect of TSS levels on soil properties decreased particularly in the last periods due to decomposition of TSS in soil. For this reason, it is recommended that 37.5 $Mg.ha^{-1}$ TSS as dry matter can be added once in 2 years for having more yield and improving soil properties of sandy clay soil under Mediterranean climate, which are characterized by low OM content and high pH. Sewage sludge application to agricultural land has been a widely accepted practice during recent years. Its use in agricultural land is promoted because it is considered that it will solve not only the problem of disposal but also will increase productivity in agriculture. Further investigations are necessary to quantify the fertiliser replacement value of plant nutrients. In particular, accurately characterising the P fertiliser replacement value of sewage sludge will become an increasingly important issue for effective P recycling in agricultural production and food security in future as geological P reserves are depleted and P fertiliser costs increase. At levels above the agronomic recommended rate, however, the potential for negative externalities may be quite substantial. Monitoring the soil periodically for nutrient levels would be prudent to avoid any excess levels on N or other plant nutrient. More continuous long-term experiments are needed to improve the understanding of the effects of sewage sludge on soil fertility and crop yield to contribute to the development of sustainable agricultural practices. However, negative effects of sewage sludge such as elevated heavy metal levels resulting from the usage of sewage sludge must also be taken into consideration (Smith 1996). Sewage sludge containing pathogenic organisms should be handled and applied in a proper manner to reduce the risks to human and animal health. Finally, the application of TSS to soil must obey the limited regulations. After the analysis of sewage sludge and soil, a governmental permission is needed to apply them to agricultural lands in Turkey.

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