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The Effects of Sewage Sludge and Nitrogen Fertilizer Application on Nutrient and Heavy Metal Concentration of Soil and Smooth Bromegrass (*Bromus inermis* Leyss.)

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Abstract: In order to evaluate the growth of smooth bromegrass, nutrient and heavy metal accumulation of plant tissue and heavy metal accumulation in soil, this research was conducted. The study included seven treatment: a zero-N (control), three inorganic nitrogen fertilizer rates (50, 100 and 150 kg ha^{-1}) and three sewage sludge rates (7.0, 14.0 and 21.0 Mg ha^{-1}). Sewage sludge and N fertilizer increased dry matter yield and N, K, Cu, Zn, Pb, Cr, Cd contents of smooth bromegrass. The highest dry matter yield obtained at the highest sewage sludge (21.0 Mg ha^{-1}) and the highest N fertilizer (150 kg N ha^{-1}). Applications did not effect P, Cu, Mg, Cr (only 2005 year), Fe and Mn contents of plant tissue. At the end of research (2006 year), soil samples for Fe, Mn, Zn, Cu, Pb and Cd analysis were collected in three soil depth (0-20, 20-40 and 40-60 cm) for all application. N fertilizer and sewage sludge application had no effect in 20-40 and 40-60 cm soil depth for all analysed elements. Applications had very effect in only 0-20 cm soil depth (on surface soil). Compared to control plots, sewage sludge increased DTPA-extractable Fe, Mn, Zn, Cu, Pb and Cd contents of soil.

Key words: Sewage sludge, biosolid, heavy metal, nitrogen fertilizer, smooth bromegrass, *Bromus inermis*

INTRODUCTION

Nitrogen (N) is one of the most important nutrients for grasses. It usually increases plant growth and crop yield. Because most soils are often deficient in the type of N that plants can readily use, therefore organic residuals such as manure or biosolids are added annually to agricultural soils.

Sewage sludge (biosolids), which is enriched in nitrogen, phosphorus, organic matter and other trace elements, represents a good source of nutrients for plant growth and a good soil conditioner to improve soil physical properties. Organic matter can increase water infiltration and reduce soil erosion, increase water-holding capacity, reduce soil compaction, increase soil granulation, increase the ability of soil or surface material to retain nutrients, provide nutrients for plant growth and provide food and energy for beneficial soil micro-organisms. All these beneficial properties make biosolids a good choice for homeowners, farmers and foresters. In addition, farmers can benefit from biosolids application by reducing their fertilizer cost (Matthews and Davis, 1984; Su and Wong, 2003). Bulk density, water retention and nutrient contents of soil were also improved with the amendment of sewage sludge (Roudsari and Pishdar, 2007). 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. 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).

The rate at which municipal sewage sludge may be applied to land is based on a number of factors including concentrations of heavy metals, pathogens, toxic organic compounds and nutrients. Where metals, pathogens, toxic organic compounds and nutrients such as P do not limit application rates, matching crop N needs with the plant available N in the sewage sludge is often used to determine application rates (Gilmour and Skinner, 1999).

Thirty to forty percent of sludge organic nitrogen could be assumed to mineralize during the first year of application (Reed *et al*., 1991; Cogger *et al*., 2001). Therefore, the differences in the soil, climate, sludge composition and management factors require more specific estimates for different climatic regions or different cropping systems (Binder *et al*., 2002).

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Perennial grass forage can be a good choice for repeated application of biosolids. It can utilize 300 kg/ha/year or more of available N with little residual remaining in the soil (Steenvoorden *et al*., 1986; White, 1985). Under intensive management, grass forages make efficient use of high rates of biosolids N (Sullivan *et al*., 1997; Muchovej and Rechcigl, 1998).

The goals of the research were to assess herbage yield of Smooth Bromegrass (*Bromus inermis* Leyss.), to determine nutrients and heavy metals in crop plant and different soil depth (0-20, 20-40 and 40-60 cm) and to determine the potential of using sewage sludge as a alternative to nitrogen fertilizer.

MATERIALS AND METHODS

The study was conducted in 2004-2006 years, in the experimental area of Agricultural Faculty of Yüzüncü Yıl University, in East Anatolia Region of Turkey, 1725 m above sea level. Total precipitation was 426, 337 and 427 mm for 2004, 2005 and 2006 year, respectively. According to same years, mean temperature were 9.5, 9.9 and 10.0°C, respectively (Anonymous, 2004-2006).

Plant, sewage sludge and soil analyses methods: The N content of plant samples was determined by the Kjeldahl metod. Phosphorus was measured by spectrophometer. K, Ca, Mg, Fe Mn, Cd, Cr, Cu, Pb and Zn contents were determined using flame atomic absorbtion spectrophotometry (Kacar and Inal, 2008).

Organic matter in sewage sludge was measured by the dry combustion method (Nelson and Sommers, 1982). Total P in sludge was measured spectrophotometrially. Total metals in sludge were determined using flame atomic absorbtion spectrophotometry following extraction by nitric-hydrochloric acid digestion (Khan and Frankland, 1983).

Soil samples were dried and sieved (2 mm) for analytical purposes. Textural analysis was performed using the hydrometer method (Bouyoucos, 1965). Soil pH was determined in a 1:2.5 soil water suspension (Jackson, 1958). Electrical Conductivity (EC) was determined acording to Richards (1954). Total N was measured by the Kjeldahl method. Available P was determined by the Olsen procedure for calcareous soil (Olsen *et al*., 1954). Calcium carbonate was measured with a calcimeter. Organic matter was analysed colorimetrically using the modified Walkley-Black method (Houba *et al*., 1989).

Exchangeable K, Ca and Mg were measured by atomic absorbtion spectroscopy after an ammonium acetate extraction (Thomas, 1982). The concentrations of soil Fe, Mn, Cd, Cu, Pb and Zn were determined in DTPA extract using AAS (Lindsay and Norvell, 1978).

Soil and sewage sludge properties: Properties of experimental site soil and sewage sludge used in the experiment are given in Table 1.

The soils at the experimental site are sandy loam, pH was 8.50, organic matter content was 1.41% and DTPA extractable of Fe, Mn, Zn, Cu, Cd, Ni and Pb in the upper 30 cm of soil were 6.5, 11.2, 1.33, 1.12, 0.043, 0.65 and 0.62 mg kg^{-1}, respectively.

Chemical characteristics of sewage sludge are given in Table 1. pH was 6.97, organic matter content was 47.2%, total N, total P and total K was 2.35, 0.45 and 0.49%, respectively.

Total metal concentrations of Fe, Mn, Zn, Cr, Cd and Pb was 9578, 427, 795, 84, 129, 1.37 and 47 mg kg^{-1},

Table 1: Characteristics of soil and sewage sludge (dry weight basis)

Properties	Soil	Properties	Sewage sludge
Sand	65	pH	6.97
Silt	18	EC (mS cm^{-1})	4.31
Clay	16	Organic matter (%)	47.2
Texture	Sandy-loam	Total N (%)	2.35
$CaCO_3$ (%)	16.3	Total P (%)	0.45
EC (mS cm^{-1})	0.31	Total K (%)	0.49
pH (1:2.5)	8.50	**Total metal concentrations (mg kg^{-1})**	
Organic matter (%)	1.41	Fe	9578
N-Kjeldahl (g kg^{-1})	0.10	Mn	427
P-Olsen (mg kg^{-1})	6.8	Zn	795
Extractable cations (mg kg^{-1})		Cu	84
K	220	Cr	129
Fe	6.5	Cd	1.37
Mn	11.2	Pb	47
Zn	1.33	**DTPA extractable metals (mg kg^{-1})**	
Cu	1.12	Fe	160
Cd	0.043	Mn	20
Ni	0.65	Zn	150
Pb	0.62	Cu	15
		Cr	0.67
		Cd	0.35
		Pb	10.7

respectively. DTPA extractable metals of Fe, Mn, Zn, Cu, Cr, Cd and Pb was 160, 20, 150, 15, 0.67, 0.35 and 10.7 mg kg^{-1}, respectively.

Field applications: The experimental design was completely randomized blok design with 4 replication. Plot size was 2.4×5 m = 12 m^2. Row spacing was 40 cm. Smooth bromegrass was planted 6 May 2004. Sowing density was 20 kg ha^{-1} seed.

Sewage sludge application rates were chosen to supply an estimated 50, 100 and 150 kg ha^{-1} N per year. The experiment included seven treatment: a Zero-N (control), three inorganic nitrogen fertilization rates (50, 100 and 150 kg N ha^{-1}) and three sewage sludge rates (7, 14 and 21 Mg ha^{-1}). Cumulative sludge doses were 21.0, 42.0 and 63.0 Mg ha^{-1}. Also, 80 kg ha^{-1} triple P_2O_5 were applied in control plots and plots of inorganic nitrogen applications.

Sewage sludge were applied to mixed in the depth of soil 20 cm by hand using a shovel in early spring in the 1st year of experiment and in following years was applied in autumn for each year (spring-2004, autumn-2004 and autumn-2005).

We harvested a times in 2005 and 2006 because of without irrigation. Grasses were harvested at full flowering with a reaping hook at 25 June 2005 and 15 June 2006. The harvested grass from each plot was weighed wet and a 3000 g subsample was collected and dried at 70°C for determination of dry matter.

The SPSS for Windows program was used for the statistical analysis. Treatment means were compared with Duncan test at ($p<0.05$).

RESULTS AND DISCUSSION

Dry matter yield: Dry matter yields were given in Table 2. Both sewage sludge and commercial N fertilizer application increased the dry matter yield of smooth bromegrass in 2005 and 2006 years. The highest dry matter yields was found at the highest sewage sludge (21.0 Mg ha^{-1}) and the highest N fertilizer (150 kg ha^{-1}) in 2005 and 2006. The lowest dry matter yields were obtained from Zero-N in 2006 and 2007. In 2005 year, medium (14.0 Mg ha^{-1}) and high (21.0 Mg ha^{-1}) sewage sludge rates were not significant in dry matter yield increasing.

Sewage sludge improves the physical and chemical properties of infertility soil and increases the fertility (Akdeniz *et al*., 2006; Penn and Sims, 2002). Organic matter (47.2%), total N (2.35%) and other nutrients (P, K, Fe, Mn, Zn, Cu) in sewage sludge used this research (Table 1). Improving soil and providing nutrient at plant of sewage sludge can be increased dry matter yield.

There are many other studies indicating that dry matter yield increased with increasing nitrogen fertilizer (Akdeniz *et al*., 2006, 2009; Keskin *et al*., 2009; Bozkurt *et al*., 2006; Cogger *et al*., 2001; Shober *et al*., 2003) and sewage sludge (Akdeniz *et al*., 2009, 2006; Pietz *et al*., 1989; Bozkurt *et al*., 2006, 2009; Cogger *et al*., 2001; Keskin *et al*., 2009; Kresse and Naylor, 1983; Binder *et al*., 2002; Shober *et al*., 2003).

Nutrient and heavy metal contents in plant tissue: Nitrogen, P, K, Ca, Mg, Fe, Mn, Cu, Zn, Pb, Cr and Cd contents of bromegrass was given Table 2 and 3.

Sewage sludge and commercial N fertilizer did not significantly affect Phosphorous (P), Calcium (Ca), Magnesium (Mg), iron (Fe) and Manganez (Mn) contents of bromegrass (Table 2 and 3). On the other hand, sewage sludge and N fertilizer applications affected Nitrogen (N), potassium (K), copper (Cu), zinc (Zn), lead (Pb), chromium (Cr, only 2006 year) and cadmium (Cd) contents of bromegrass.

Compared to control, N content of bromegrass increased 20.7-7.8% with commercial N fertilizer in 2005 and 2006 years, respectively. On the other hand, N

Table 2: Effect of sewage sludge and N fertilizer on dry matter yield and N, P, K, Ca, Mg Fe content of smooth bromegrass

Years	Treatments	Rate kg ha^{-1}	Dry matter yield kg ha^{-1}	N	P	K	Ca	Mg
				-----------	-----------	%	-----------	-----------
2005	Control	Zero-N	2612.5^{d}	1.45^{d}	0.127	1.04^{bc}	0.85	0.26
	N-fertilizer	50	2825.0^{c}	1.64^{bc}	0.130	1.24^{ab}	0.94	0.33
		100	3020.0^{b}	1.75^{ab}	0.128	1.20^{ab}	0.84	0.26
		150	3237.5^{a}	1.66^{bc}	0.129	1.35^{a}	0.85	0.31
	Sewage sludge	7000	2907.5^{bc}	1.58^{cd}	0.129	0.97^{c}	0.96	0.30
		14000	3200.0^{a}	1.86^{a}	0.132	1.18^{ab}	0.89	0.24
		21000	3275.0^{a}	1.76^{ab}	0.136	1.19^{ab}	0.88	0.27
2006	Control	Zero-N	2850.0^{c}	1.52^{bc}	0.115	1.09^{b}	0.36	0.23
	N-fertilizer	50	3312.5^{a}	1.49c	0.117	1.11^{ab}	0.39	0.22
		100	3225.0^{ab}	1.61^{bc}	0.109	1.07^{b}	0.42	0.25
		150	3400.0^{a}	1.64^{b}	0.117	1.16^{ab}	0.40	0.23
	Sewage sludge	7000	3000.0^{c}	1.55^{bc}	0.114	1.07^{b}	0.44	0.24
		14000	3050.0^{bc}	1.81^{a}	0.110	1.14^{ab}	0.38	0.25
		21000	3350.0^{a}	1.80^{a}	0.112	1.24^{a}	0.41	0.26

*Means with a column followed by a different letter are significantly different at $p<0.05$

Table 3: Effect of sewage sludge and N fertilizer on Mn, Cu, Zn, Pb, Cr and Cd content of smooth bromegrass.(mg kg^{-1})

Years	Treatments	Rate kg ha^{-1}	Fe	Mn	Cu	Zn	Pb	Cr	Cd
			--------	--------	--------	mg kg^{-1}	--------	--------	--------
2005	Control	Zero-N	85.80	63.64	3.97^{b}	11.02^{b}	0.137^{b}	0.875	0.022^{c}
	N-fertilizer	50	86.54	69.43	5.45^{a}	11.54^{ab}	0.262^{b}	0.865	0.032^{bc}
		100	83.39	70.85	5.39^{a}	13.95^{a}	0.240^{b}	0.735	0.027^{bc}
		150	77.72	69.98	5.44^{a}	13.43^{a}	0.247^{b}	0.792	0.047^{ab}
	Sewage sludge	7000	79.65	69.59	3.78^{b}	11.99^{ab}	0.190^{b}	0.892	0.050^{ab}
		14000	84.06	65.21	4.19^{b}	12.09^{ab}	0.212^{b}	0.945	0.042^{bc}
		21000	87.40	68.17	4.23^{b}	13.48^{a}	0.390^{a}	0.857	0.070^{a}
2006	Control	Zero-N	67.50	74.75	4.77^{c}	11.22^{b}	0.590^{b}	1.070^{b}	0.069^{c}
	N-fertilizer	50	62.12	77.25	5.20^{bc}	11.12^{b}	0.930^{ab}	1.142^{b}	0.074^{bc}
		100	67.00	74.81	$6.07a^{bc}$	10.50^{b}	0.810^{ab}	1.320^{b}	0.079^{abc}
		150	68.00	79.25	6.52^{ab}	11.62^{b}	0.932^{ab}	1.570^{ab}	0.072^{bc}
	Sewage sludge	7000	70.50	70.50	5.37^{abc}	10.77^{b}	1.160^{a}	1.410^{ab}	0.083^{abc}
		14000	63.75	76.75	6.30^{ab}	11.75^{ab}	1.150^{a}	1.445^{ab}	0.090^{a}
		21000	65.25	68.50	6.72^{a}	13.97^{a}	1.050^{a}	1.795^{a}	0.086^{ab}

*Means with a column followed by a different letter are significantly different at $p<0.05$

content of bromegrass increased 28.3-19.1% with sewage sludge application in 2005 and 2006 years, respectively. Nitrogen is the key element for grasses and influences the grasses clor and growth rate (Roudsari and Pishdar, 2007). N fertilizer addition in soil with commercial N fertilizer and sewage sludge increased both dry matter yield and N content of bromegrass.

In general, researchers reported that N content of plant tissue increased with sewage sludge application (Akdeniz *et al*., 2006, 2009; Bozkurt *et al*., 2006, 2009; Keskin *et al*., 2009; Cogger *et al*., 2001; Roudsari and Pishdar, 2007) and N fertilizer (Akdeniz *et al*., 2009; Keskin *et al*., 2009; Bozkurt *et al*., 2006; Roudsari and Pishdar, 2007).

Potassium content of bromegrass increased both N fertilizer and sludge applications. Compared to control, potassium content of plant tissue increased more N fertilizer than sewage sludge in 2005 and 2006 years (Table 2). Some studies showed that potassium content of plant tissue increased with N fertilizer (Akdeniz *et al*., 2009) and sewage sludge application (Akdeniz *et al*., 2009; Keskin *et al*., 2009; Roudsari and Pishdar, 2007). In contrast, most researchers reported that K content of plant tissue did not affected with N fertilizer (Akdeniz *et al*., 2006; Keskin *et al*., 2009) and Sewage sludge application (Shober *et al*., 2003; Bozkurt *et al*., 2009; Akdeniz *et al*., 2006; Keskin *et al*., 2009; Dowdy *et al*., 1994).

Heavy metal (Cu, Zn, Pb, Cr, Cd) contents of bromegrass increased with N fertilizer and sewage sludge application. In general, compared to control, the highest heavy metals obtained in the highest sewage sludge application in 2005 and 2006 years.

Some researchers reported that sewage sludge incresed Cu content (Akdeniz *et al*., 2009; Keskin *et al*., 2009; Bozkurt *et al*., 2006; Cogger *et al*., 2001; Roudsari and Pishdar, 2007), Zn content (Akdeniz *et al*., 2006, 2009; Bozkurt *et al*., 2006, 2009; Keskin *et al*., 2009; Cogger *et al*., 2001; Wen *et al*., 2002; Soon *et al*., 1980; Roudsari and Pishdar, 2007), Pb content (Akdeniz *et al*., 2009; Bozkurt *et al*., 2006, 2009; Roudsari and Pishdar, 2007), Cr content (Akdeniz *et al*., 2006; Bozkurt *et al*., 2006; Logan *et al*. 1997) and Cd content (Bozkurt *et al*., 2006, 2009; Soon *et al*., 1980) of plant tissue. In contrast, other researcher showed that sewage sludge did not affect Cu (Shober *et al*., 2003; Akdeniz *et al*., 2006), Zn (Shober *et al*., 2003), Pb (Akdeniz *et al*., 2006; Roudsari and Pishdar, 2007; Keskin *et al*., 2009) content of plant tissue.

Sewage sludge usually contains high levels of organic matter (47.2% in Table 1) and also it is rich nutrients and heavy metals (Table 1). In general, because of high organic matter decreased soil pH. For this reason, plant tissue uptaked most heavy metal in soil.

Researchers reported that commercial N fertilizer affacted Cu content (Akdeniz *et al*., 2009), Zn content (Akdeniz *et al*., 2009; Keskin *et al*., 2009) and Pb content (Akdeniz *et al*., 2009) of plant tissue.

In contrast, some studies showed that N fertilizer did not affect Cu content (Akdeniz *et al*., 2006), Pb content (Akdeniz *et al*., 2006; Keskin *et al*., 2009), Cr content (Akdeniz *et al*., 2006, 2009; Keskin *et al*., 2009) and Cd content (Akdeniz *et al*., 2006, 2009; Keskin *et al*., 2009) of plant tissue.

DTPA-extractable metals at soil depths: At the end of experiment (2006 year), soil samples for Fe, Mn, Zn, Cu, Pb and Cr analysis were collected in three soil depth (0-20, 20-40 and 40-60 cm) for each plot. Experiment data were showed in Table 4.

N fertilizer and sewage sludge application in soil had no effect in 20-40 and 40-60 cm soil depth for all analysed elements. Applications had very effect in only 0-20 cm soil depth (on surface soil). Nearly all of the increase in DTPA-extractable metals occured in the 0-20 cm soil

Table 4: Effect of sewage sludge and N fertilizer on DTPA-extractable nutrient and heavy metal concentration of experimental soil (mg kg^{-1}) in three soil depth

Dept (cm)	Treatments	Rate kg ha^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}	Pb mg kg^{-1}	Cd mg kg^{-1}
0-20	Control	Zero-N	2.625c	10.85c	0.202d	1.000c	0.307d	0.0037b
		50	3.035c	12.70bc	0.227d	1.247bc	0.532bc	0.0050b
	N-fertilizer	100	3.330bc	13.50b	0.257d	1.217bc	0.482cd	0.0080b
		150	3.775bc	16.30a	0.272d	1.352bc	0.542bc	0.0097b
	Sewage sludge	7000	4.115b	13.20b	2.237c	1.300bc	0.527bc	0.0107b
		14000	3.980bc	13.77b	5.760b	1.540b	0.730b	0.0230a
		21000	5.520a	14.55ab	9.082a	1.902a	0.935a	0.0327a
20-40	Control	Zero-N	2.660	11.22	0.252	1.065	0.392	0.0048
		50	2.997	11.12	0.215	1.242	0.555	0.0050
	N-fertilizer	100	3.255	11.65	0.225	1.160	0.495	0.0063
		150	3.147	12.72	0.205	1.305	0.607	0.0045
	Sewage sludge	7000	3.405	11.10	0.270	1.022	0.352	0.0050
		14000	3.080	11.62	0.287	1.187	0.452	0.0055
		21000	2.815	10.67	0.297	1.082	0.455	0.0061
40-60	Control	Zero-N	2.825	10.05	0.192	1.167	0.340	0.0045
		50	3.152	11.40	0.170	1.157	0.610	0.0043
	N-fertilizer	100	3.157	11.60	0.162	1.130	0.530	0.0048
		150	2.747	11.85	0.167	1.170	0.602	0.0050
	Sewage sludge	7000	2.912	10.30	0.177	1.117	0.362	0.0053
		14000	3.180	9.20	0.212	1.280	0.482	0.0058
		21000	2.752	9.85	0.220	1.167	0.402	0.0050

*Means with a column followed by a different letter are significantly different at $p<0.05$

depth. This means that the metals did not move in a significant way from the upper to the downer layer (Akdeniz *et al*., 2009).

Compared to control soil, sewage sludge application increased DTPA-extractable Fe, Mn, Zn, Cu, Pb and Cd content. The highest heavy metals obtained 21.0 Mg ha^{-1} sewage sludge applications. And also, N fertilizer application increased DTPA-extractable Mn and Pb concentration.

Compared to control, N fertilizer (150 kg ha^{-1}) increased 1.43, 1.50, 1.34, 1.76 and 2.62 times Fe, Mn, Zn, Cu, Pb and Cd concentration of soil, respectively. On the other hand, sewage sludge (21.0 Mg ha^{-1}) increased 2.10, 1.34, 44.96, 1.90, 3.04 and 8.83 times Fe, Mn, Zn, Pb and Cd concentration of soil, respectively.

In comparision with N fertilizer application, sewage sludge application had very effect heavy metals increases (except Mn concentration). Because of high organik matter (47.2% in Table 2) of sewage sludge and decreasing soil pH of N fertilizer and sewage sludge application, heavy metals could be increased in experiment soil. Akdeniz *et al*. (2009) reported that organic matter and pH are the most important factors that controlled the availability of heavy matals in the soil.

Many studies reported that sewage sludge application increased Fe concentration (Akdeniz *et al*., 2009; Bozkurt *et al*., 2009, 2006; Keskin *et al*., 2009; Datta *et al*., 2000), Mn concentration (Bozkurt *et al*., 2009; Datta *et al*. 2000; Shober *et al*., 2003), Zn concentration (Bozkurt *et al*., 2001, 2006, 2009; Soon *et al*., 1980; Keskin *et al*., 2009; Akdeniz *et al*., 2009, 2006; Cogger *et al*., 2001; Datta *et al*., 2000; Shober *et al*., 2003; Silva *et al*., 2000), Cu concentration (Bozkurt *et al*., 2001, 2006, 2009; Akdeniz *et al*., 2006; Keskin *et al*., 2009; Cogger *et al*., 2001; Datta *et al*., 2000; Shober *et al*., 2003; Silva *et al*., 2000), Pb concentration (Bozkurt *et al*., 2006, 2009; Akdeniz *et al*., 2006; Datta *et al*., 2000; Shober *et al*., 2003) and Cd concentration (Bozkurt *et al*., 2006, 2009; Akdeniz *et al*., 2006; Cogger *et al*., 2001; Soon *et al*., 1980; Silva *et al*., 2000).

In contrast, some researchers reported that sewage sludge did not affect Fe concentration (Akdeniz *et al*., 2006), Mn concentration (Akdeniz *et al*., 2006; Keskin *et al*., 2009; Bozkurt *et al*., 2006), Pb concentration (Keskin *et al*., 2009; Cogger *et al*., 2001) and Cd concentration (Keskin *et al*., 2009) of soil.

CONCLUSION

Sewage sludge and commercial N fertilizer application positively affected dry matter yield of bromegrass. The highest dry matter yields obtained at the hishest sewage sludge (21.0 Mg ha^{-1}) and the highest N fertilizer (150 kg ha^{-1}). This study showed that sewage sludge may be used as nitrogen source for smooth bromegrass production.

Although, both sewage sludge and N fertilizer increased N, K, Cu, Zn, Pb, Cr, Cd concentration of smooth bromegrass, application did not effect P, Ca, Mg, Cr (only 2007 year of this study) Fe and Mn content of bromegrass.

While sewage sludge and N fertilizer had very effect 0-20 cm soil depth, application had no effect in 20-40 and 40-60 cm soil depth for all analysed elements. Based on these observation, we resulted that the metals elements did significantly not move from the upper to the downer layer. Sewage sludge increased DTPA-extractable Fe, Mn, Zn, Cu, Pb and Cd concentration of soil.

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