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Yield and Metal Concentration in Garden burnet (*Sanguisorba minor* Scop. Bunyan 80) from Application of Sewage Sludge and Chemical Fertilizer

[1]Hakki Akdeniz, [1]Bilal Keskin and [2]Mehmet Ali Bozkurt
[1]Yuzuncu Yil Universitesi Ercis MYO, Ercis, Van, Turkey
[2]Yuzuncu Yil Universitesi, Ziraat Fakultesi Toprak Bolumu, Van, Turkey

Abstract: The objective of this study, was to evaluate the effects of sewage sludge applications on herbage yield, grain yield, nutrients and heavy metal accumulations on Garden burnet (*Sangiusorba minor* Scop. Bunyan 80). The study was conducted in 2004 and 2007 years at the fields of Agricultural Faculty in Yuzuncu Yil University. The experiment was a randomized complete block design, with 4 replications for 4 years. Three levels of sewage sludge were applied at rates 0.7, 1.4 and 2.1 ton day^{-1}; 3 levels of nitrogen were also applied at rates of 5, 10 and 15 kg day^{-1} with control. The research demonstrated that sewage sludge produced higher herbage yield than the chemical fertilizer, however equivalent to the chemical fertilizer in grain yields of the garden burnet. Plant tissue N, P, K, Mg, Fe, Cu, Zn and Pb contents varied with treatments. The highest plant-N was obtained from chemical fertilized plots. Results showed that sewage sludge applications increased extractable metal concentrations of Fe, Zn and Cr of the soil. None of the amendments produced excessive levels of the nutrients and heavy metals; rather the amendments improved the feed quality of the forage.

Key words: Sewage sludge, garden burnet, yield, nutrient, heavy metal

INTRODUCTION

Sewage sludge (biosolids) is a product derived from the treatment of municipal wastewater. Land application of sewage sludge has been extensively used as an effective dispersive method throughout Canada, the United State and Europe for >40 years (Warman and Termeer, 2005).

Sludge land application has proven an excellent substitute for commercial fertilizers and is cost effective for both the municipality applying the sludge and farmer who accept it. Many studies have demonstrated the positive effect of land application of sewage sludge or sludge compost on corn and forage yields and soils (Reed *et al.*, 1991). The addition of sewage sludge to agricultural soil improves physical characteristic and acts as valuable source of nutrients to growing crops (Obbard, 2001; Byron and Bradshaw, 1991). The primary plant nutrient associated with sewage sludge is N; however, sludge also, contribute significant amounts of other macro and micronutrients. However, biosolids may also contain heavy metal and organic pollutants that can affect living organism in the soil. Moreover, the toxic elements enter the food chain due to uptake and accumulation by crops, posing a potential threat to human health. The accumulation elements, like heavy metals in soil, the risk of their uptake by corps by their movements in the food chain is now a topic of great concern (Chander and Brooks, 1991; Lavado *et al.*, 2001). However, there is less information available on the effects of biosolids in arid and semi arid rangelands (Mark and Wester, 1998). In general, biosolids increase plant production and improve forage quality when application rates are not excessive relative to N requirements of treated plants and metal concentrations are not toxic.

Metal accumulation in crops is a function of complex inter-action among soil, plant and environmental factors. It has been documented that the contents of elements in crops are closely associated with their levels in soil. Moreover, the uptake and accumulation of elements by plants are largely dependent on the available rather than total level of elements in soil (Smith, 1996).

Agricultural land of Turkey, especially the East Anatolia region soils are generally rich in lime and low organic matter and available P, Fe and Zn concentrations and soil pH is alkaline because of generally rich in lime. The mobility of heavy metals depends on soil pH and line content; the physical and chemical properties of soils of the region can be improved by using sewage sludge, which has remarkable contents of organic matter and available P and micronutrient (Bozkurt and Cimrin, 2003).

Corresponding Author: Hakki Akdeniz, Yuzuncu Yil Universitesi Ercis MYO, Ercis, Van, Turkey

Ranges and pastures of Eastern Anatolia are worn-out and they can not produce enough feed for animals. Also, cultivated forages such as alfalfa, sainfoin and wetches insufficient to he feed animals. Animals in the region are mostly feed with cereal straw. This improvement may solve part of the actual roughage problem of livestock sector in Turkey (Keskin *et al*., 2005). Garden burnet (*Sanguisorba minor* Scop. Bunyan 80) is widely distributed in Turkey; its ratio in the vegetation in grazing lands has been decreasing due to continuous excessive grazing (Kendir, 1999). Garden burnet is hardy, relatively long-lived, evergreen, introduced, perennial forbs. Plant is noted to have good to excellent forage value for livestock and wildlife during all seasons. It says green throughout the growing season and into winter until heavy snow covers occurs, providing forage and seed to livestock and wildlife.

The objectives of this study, were to assess herbage yield and grain yield of Garden burned (*Sanguisorba minor* Scop. Bunyan 80), to determine nutrients and heavy metals in crop plant and different soil depths (0-20, 20-40 and 40-60 cm) and to assess the potential of using sewage sludge as an alternative to commercial fertilizer in dry conditions.

MATERIALS AND METHODS

The experiment started in April 2004, in the experimental area of Agricultural Faculty of Yuzuncu Yil University, located in Eastern Anatolia Region of Turkey, 1725 m above sea level. Mean temperatures and rainfall during the year studied are presented in Fig. 1. Total rainfall was 426, 337, 427 and 349 mm for 2004-2007 years, respectively. According to same years, mean temperatures were 9.5, 9.9, 10.0 and 9.6°C, respectively (Anonymous, 2004-2007).

Selected some characteristics of sewage sludge used in the experiment and soils are given in Table 1. The soils at the experimental site are sandy loam, pH was 8.49, organic matter content was 1.77% and DTPA-extractable of Fe, Mn, Zn, Cu, Cr, Cd, Ni and Pb in the upper 30 cm of soil were 4.02, 8.49, 0.45, 1.25, 0.12, 0.019, 0.43 and 0.46 (mg kg^{-1}), respectively.

The experimental design was completely randomized block design, with 4 replications. Plots consisted of 5 rows 5 m long and 70 cm row spacing (5×3.5 = 17.5 m^2). Plots were established by hand and sowing were planted in each plot at a density of 3 kg day^{-1} (Ipek and Sevimay, 2002) with distance of 2 m between plots and blocks and

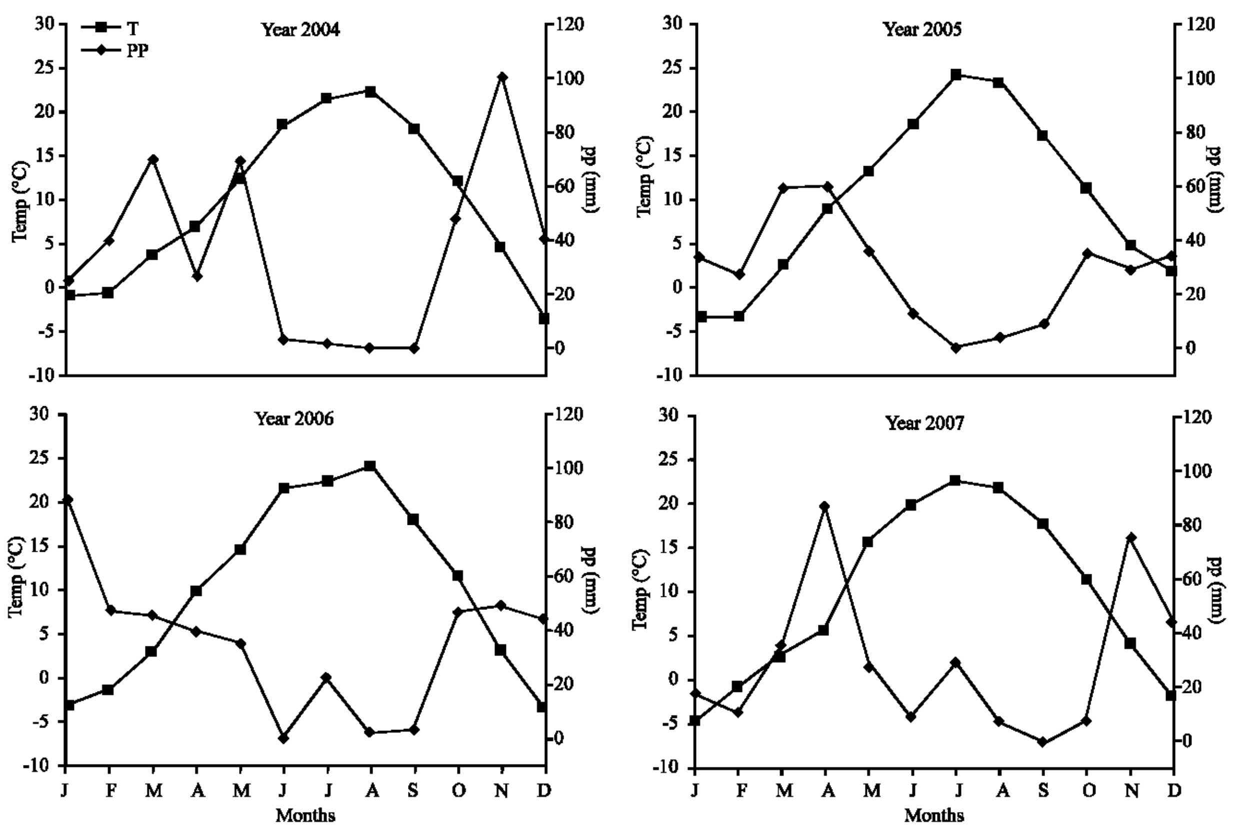

Fig. 1: Monthly rainfall (Pp, mm) and mean monthly temperatures (°C) in 2004-007 at Van Province in Turkey

Table 1: Selected some chemical properties of the soil and sewage sludge as a means (dry weight basis)

Properties	Soil	Properties	Sewage sludge
Sand (%)	68	pH	6.97
Silt (%)	14	EC (mS cm^{-1})	4.31
Clay (%)	18	Organic matter (%)	47.2
Texture	Sandy loam	Total N (%)	2.35
$CaCO_3$ (%)	16.1	Total P (%)	0.45
EC (mS cm^{-1})	1.69	Total K (%)	0.49
pH (1:2.5)	8.49	Total metal concentrations (mg kg^{-1})	
Organic matter (%)	1.77	Fe	9578
N-Kjeldahl (%)	0.083	Mn	427
P-Olsen (mg kg^{-1})	11.1	Zn	795
Exctractable cations (mg kg^{-1})		Cu	84
K	220	Cr	129
F e	4.02	Cd	1.37
Mn	8.49	Pb	47
Zn	0.45	DTPA extractable metals (mg kg^{-1})	
Cu	1.25	Fe	160
Cr	0.12	Mn	20
Cd	0.019	Zn	150
Ni	0.43	Cu	15
Pb	0.46	Cd	0.35
		Cr	0.67
		Pb	10.7

sowing date was on 6 May 2004 and experiment was longed for 4 year. Sludge and nitrogen application dozes were determined on the nitrogen requirement of Garnet burnet.

Fertilization was applied as follows: inorganic fertilization at 3 rates (5, 10 and 15 kg N day^{-1}) as ammonium sulphate sewage sludge at 3 rates (S_1 = 0.7, S_2 = 1.4 and S_3 = 2.1 ton day^{-1}; a zero N-control were applied. Treatments were applied for along 4 years. So, cumulative sewage sludge dozes were S_1: 2.80 t day^{-1}, S_2: 5.60 t day^{-1} and S_3: 8.40 t day^{-1}. Also, 8 kg P_2O_5 day^{-1} was applied as triple phosphate the plots that did not take sewage sludge. Half of the N and P were applied to the Garden burnet at the time of sowing. Sewage sludge were applied to mixed in the dept 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.

Forage herbage inner three rows of each plot were harvested at full flowering with a reaping hook at 9 June 2005, 13 June 2006 and 4 June 2007, respectively. Fresh plants samples were weighed and hay yield was determined by using dry sampling weight. Herbage yield was calculated after oven-drying at 70°C until constant. Then, grains of plant were harvested at physiological stage and grain yield was determined for each year.

Fresh plant samples from each plot were washed tap water and after that washed with dionized water, dried at 70°C and finely they were ground. Samples were dissolved in 3 N HCl after the plant samples had been ashed in a furnace at 500°C. N content of samples were determined by the Kjeldahl method. Phosphorus content of samples were measured by spectrophotometer. The other nutrients and heavy metal contents of samples (K, Ca, Mg, Fe, Mn, Zn, Cu, Cr, Cd and Pb) were determined using flame atomic absorption spectrophotometer (Kacar and Inal, 2008). Besides, organic matter in sewage sludge was measured by dry combustion method (Nelson and Sommers, 1982). Total, P in sludge was measured by spectrophotometrically. Total metals in sludge were determined using flame atomic absorption spectrophotometer following extraction by nitric-hydrochloric digestion (Khan and Frankland, 1983). At the end of every growth period, for each plot, soil was sampled over dept intervals of 0-20, 20-40 and 40-60 cm and were dried and sieved (2 mm) for analytical purposes. Textural analysis was performed using hydrometer method (Bouyoucos, 1965). Soil pH was determined in a 1:2.5 soil water suspension (Jackson, 1958). Electrical Conductivity (EC) was determined by Richard (1954). Total N was measured by the Kjeldahl method. Available P was determined by the Kacar (1998) procedure for calcareous soil, Calcium carbonate was measured with a calcimeter. Organic matter was analyzed colorimetrically using the modified Walkley-Black method (Houba *et al*., 1989). Exchangeable K, Ca and Mg were measured by atomic absorption spectroscopy after an ammonium acetate extraction (Thomas, 1982).

Statistical analysis was carried out using the analysis of variance procedure for each depth and each harvest year (ANOVA). The means were compared using Fisher's protected least significant difference.

RESULTS AND DISCUSSION

Garden burnet has an important role in protecting soils from water and soil wind erosion since new shoots from the crown form at a tough rosette on soil surface. Plant has been known to persist on rangelands since for a long time. It provides livestock with fresh feed in much of the year on rangelands on dry and hot summer months.

Some chemical properties of experimental soil and sewage sludge used in the experiment are shown in Table 1. The average DTPA Extractable metals Fe, Mn, Zn, Cu, Cd, Cr and Pb concentrations in sewage sludge samples were 160, 20, 150, 15, 0.35, 0.67 and 10.7 mg kg^{-1}, respectively.

Effects of different sewage sludge dozes on the herbage and grain yield and plant tissue N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, Cd, Pb and in 2005, 2006 and 2007 years, are presented in Table 2. Sewage sludge application significantly increased herbage yield than the chemical fertilizer. Plant tissue N, P, K, Mg, Cu, Zn and Pb contents varied with treatments. In general, all the treatments, especially sewage sludge applications improved the feed quality of the forage compared with the unfertilized plots (Table 2).

Table 2: Effects of different sewage sludge dozes on the herbage and grain yield and plant tissue N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, Cd, Pb and in 2005, 2006 and 2007

Years	Treatment	Herbage	Grain	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Cd	Cr	Pb
		----Yield (kg day)----		-----(%)-----					-----(ppm)-----						
2005	N_o	323.2	62.0	1.09	0.15	1.25	1.34	0.75	90.3	60.6	9.37	3.71	0.030	0.96	0.24
	N_1	360.9	81.1	1.16	0.18	1.47	1.46	0.72	96.5	57.4	9.08	4.05	0.013	1.07	0.25
	N_2	372.1	83.8	1.32	0.17	1.42	1.56	0.80	88.5	60.5	11.25	4.19	0.023	1.12	0.27
	N_3	443.1	96.0	1.46	0.15	1.89	1.34	0.75	92.8	68.5	11.83	4.20	0.028	0.96	0.38
	S_1	379.8	65.0	1.19	0.17	1.60	1.42	0.85	94.6	58.3	10.45	4.04	0.037	1.07	0.42
	S_2	445.5	77.8	1.16	0.16	1.28	1.47	0.83	88.8	67.3	12.26	4.39	0.037	1.01	0.40
	S_3	443.7	75.1	1.28	0.19	1.70	1.46	0.85	97.7	58.9	12.94	4.52	0.038	1.00	0.52
	Prob. level	0.0001	0.0001	0.0001	0.19	0.012	0.21	0.022	0.77	0.31	0.14	0.006	0.46	0.86	0.0002
	$LSD_{0.05}$	34.6	11.8	0.13	ns	0.35	ns	0.0085	ns	ns	ns	0.75	ns	ns	0.112
2006	N_o	165.2	33.7	1.25	0.12	0.88	1.44	0.47	95.0	63.0	11.55	5.25	0.028	0.60	0.30
	N_1	218.1	32.2	1.43	0.13	0.97	1.49	0.47	104.5	74.6	11.40	5.40	0.022	0.62	0.29
	N_2	223.7	35.5	1.53	0.12	0.96	1.50	0.49	105.8	63.9	10.15	5.40	0.017	0.62	0.39
	N_3	229.2	34.3	1.61	0.11	0.96	1.77	0.46	89.5	75.6	10.20	5.64	0.019	0.68	0.20
	S_1	288.5	36.0	1.32	0.13	0.96	1.81	0.48	115.1	68.2	10.13	5.34	0.019	0.78	0.27
	S_2	285.7	38.8	1.41	0.13	0.95	1.79	0.48	115.0	64.8	13.60	6.02	0.023	1.06	0.28
	S_3	358.6	47.8	1.58	0.14	1.04	1.43	0.49	116.5	73.9	12.45	6.10	0.036	0.96	0.42
	Prob. level	0.0001	0.0049	0.011	0.49	0.94	0.16	0.36	0.09	0.70	0.069	0.36	0.077	0.089	0.24
	$LSD_{0.05}$	34.7	9.6	0.20	ns	ns	ns	ns	20.92	ns	ns	ns	ns	ns	ns
2007	N_o	155.4	49.8	1.22	0.16	0.96	1.38	0.88	94.5	58.6	9.40	5.56	0.036	1.51	0.38
	N_1	299.8	47.3	1.11	0.16	1.09	1.18	0.86	111.3	61.5	12.55	5.27	0.024	0.77	0.37
	N_2	380.9	59.5	1.74	0.14	1.35	1.26	0.91	102.9	57.1	12.14	5.28	0.036	0.87	0.33
	N_3	426.4	55.1	1.68	0.13	1.37	1.15	0.82	94.5	56.4	10.89	5.59	0.035	1.25	0.37
	S_1	338.2	62.3	1.36	0.17	1.29	1.22	0.86	105.8	50.8	13.29	5.61	0.041	1.12	0.26
	S_2	390.9	61.8	1.57	0.18	1.37	1.19	0.84	99.8	61.1	15.96	5.64	0.028	1.49	0.32
	S_3	533.4	58.0	1.59	0.18	1.56	1.22	0.84	128.3	53.3	16.23	5.60	0.037	2.18	0.51
	Prob. level	0.0002	0.35	0.0001	0.017	0.004	0.77	0.326	0.027	0.67	0.0003	0.97	0.78	0.072	0.53
	$LSD_{0.05}$	76.2	ns	0.18	0.03	0.21	ns	ns	18.60	ns	2.73	ns	ns	ns	ns

N_o= control, N_1=5 kg, N_2=10, N_3=15 N day^{-1}; S_1=0.7, S_2=1.4, S_3=2.1 t day^{-1}, ns = non-significant

Sewage sludge applications significantly affected levels and distribution of DTPA-extractable metal concentrations in the soil profile (Table 3, 4 and Fig. 2).

Garden burnet (*Sanguisorba minor* Scop. Bunyan 80) yield data, an important forage and erosion control plant, varied widely among replications each year (Table 2). In the 1st year of the experiment, the highest herbage yields were obtained from N_3 and S_2-S_3 dozes from plots in both chemical and amended sewage sludge. However, herbage yield was significantly higher in sewage sludge treated soils than the chemical fertilizers in both 2006 and 2007. As seen in herbage yields, the grain yield of Garden burnet increased significantly under both chemical N and sewage sludge fertilization. In 2005 and 2006 year, the highest grain yields (96 and 47.8 kg day^{-1}) were obtained from chemical fertilizer (N_3) and sewage sludge fertilized treatment (S_3), respectively.

The use of both nitrogen fertilizer and sewage sludge did not lead to a significant increase in grain yields in 2007. In other words, the use of sludge produced the same benefits on grain yields as mineral fertilization in comparison with non-fertilization at the end of the experiment.

However, biosolid to soil increased the content of the organic matter, which would be attributed to the incorporation of organic compounds from sewage sludge. This increase can be encouraging the vegetative growth of the plants and decrease the grain yields. Acar *et al*. (1999) conducted to determine the appropriate of row spacing and nitrogen dozes on some characteristics of lesser burnet. These authors found that the highest yields were obtained from plots with 30 cm row spacing and 8-12 kg day^{-1} nitrogen fertilization program. Our herbage yields were similar to data conducted by Ipek and Sevimay (2001) that the highest green and hay and crude protein were obtained from Ganden burnet (*Sanguisorba minor* Scop. Bunyan 80) cultivar with 4-8 kg day^{-1} nitrogen application.

Plant tissue-N content for the treatments are summarized in Table 2. Sewage sludge and inorganic nitrogen fertilization increased plant-N content compared to control plots. The highest plant-N was obtained from chemical fertilized plots (N_3) in all years. Sewage sludge application (S_3) had less effect on the plant-N than N-fertilized plots compared to control plots. Typical, N mineralization rates for the 1st year can be from 0-60% of the organic nitrogen. Decomposition is not complete in the 1st year. It continues during the next few years at progressively slower rates. This increase in the plant-N was observed in 2006 and 2007 years in this experiment.

Table 3: Effects of different sewage sludge dozes on the DTPA Fe, Mn, Zn, Cu, Cd, Pb and Cr concentrations (mg.kg-^{1}) for 0-60 cm soil depts in 2005, 2006 and 2007

		Year (2005)							Year (2006)					
Dept (cm)	Treatment	Fe	Mn	Zn	Cu	Cd	Pb	Cr	Fe	Mn	Zn	Cu	Cd	Pb
0-20	N_o	3.73	6.19	0.245	0.910	0.025	0.450	0.073	3.54	8.10	0.178	0.885	0.029	0.330
	N_1	4.06	5.78	0.235	0.913	0.017	0.363	0.068	2.90	8.32	0.232	0.960	0.038	0.300
	N_2	3.83	6.57	0.190	0.968	0.018	0.415	0.175	3.26	8.42	0.170	0.845	0.021	0.350
	N_3	3.69	8.32	0.235	1.048	0.020	0.320	0.123	2.98	8.23	0.162	0.875	0.027	0.360
	S_1	4.72	7.66	0.227	1.073	0.020	0.378	0.165	4.28	9.31	0.786	1.105	0.029	0.563
	S_2	4.49	6.79	0.360	1.128	0.028	0.397	0.233	4.57	9.17	2.263	1.575	0.033	0.560
	S_3	5.23	7.50	1.517	1.162	0.025	0.420	0.238	5.65	11.60	3.393	1.007	0.043	0.630
	Prob. level	0.013	0.11	0.0001	0.63	0.394	0.82	0.0001	0.0003	0.065	0.0001	0.044	0.059	0.0001
	LSD $_{0.05}$	0.91	ns	0.66	ns	ns	ns	0.053	1.12	ns	0.739	0.30	0.014	0.14
20-40	N_o	3.55	5.73	0.152	0.888	0.010	0.418	0.088	2.88	6.12	0.120	0.895	0.034	0.355
	N_1	3.42	7.07	0.165	0.963	0.017	0.350	0.142	3.58	7.77	0.172	0.980	0.031	0.385
	N_2	3.72	6.48	0.192	0.983	0.017	0.320	0.320	3.19	6.72	0.125	0.825	0.028	0.325
	N_3	3.73	6.30	0.152	1.000	0.015	0.270	0.210	2.89	6.54	0.150	0.935	0.033	0.365
	S_1	3.77	5.21	0.285	0.938	0.021	0.355	0.245	3.12	6.64	0.244	0.888	0.037	0.360
	S_2	4.17	8.38	0.475	0.998	0.032	0.445	0.370	3.38	6.03	0.602	0.973	0.032	0.340
	S_3	3.80	6.25	0.585	0.987	0.020	0.357	0.300	3.18	6.51	0.796	0.885	0.028	0.418
	Prob. level	0.80	0.74	0.013	0.999	0.008	0.479	0.120	0.92	0.98	0.059	0.97	0.99	0.80
	LSD $_{0.05}$	ns	ns	0.260	ns	0.010	ns	ns	ns	ns	0.520	ns	ns	ns
40-60	N_o	3.69	4.59	0.168	0.797	0.020	0.383	0.095	2.65	5.28	0.096	0.780	0.340	2.89
	N_1	4.06	5.75	0.138	1.125	0.018	0.360	0.182	3.08	5.32	0.101	0.885	0.303	3.59
	N_2	3.96	5.74	0.116	1.055	0.023	0.325	0.132	3.48	4.68	0.091	0.720	0.290	3.21
	N_3	4.02	6.51	0.152	1.110	0.020	0.360	0.222	3.30	5.78	0.109	0.660	0.373	3.22
	S_1	3.82	5.21	0.285	0.718	0.025	0.400	0.160	3.00	5.00	0.151	0.600	0.375	3.64
	S_2	3.75	6.53	0.313	0.908	0.018	0.383	0.282	3.09	4.74	0.192	0.650	0.245	3.10
	S_3	4.05	5.80	0.310	1.070	0.020	0.290	0.318	3.70	5.12	0.247	0.855	0.327	3.24
	Prob. level	0.97	0.92	0.006	0.44	0.98	0.910	0.0001	0.28	0.89	0.016	0.420	0.63	0.49
	LSD $_{0.05}$	ns	ns	0.103	ns	ns	ns	0.075	ns	ns	0.094	ns	ns	ns

		Year 2007						
Dept (cm)	Treatment	Fe	Mn	Zn	Cu	Cd-	Pb	Cr
0-20	N_o	3.02	8.55	0.344	0.979	0.014	0.307	0.141
	N_1	3.30	9.50	0.269	1.085	0.021	0.482	0.172
	N_2	3.21	10.39	0.255	1.028	0.016	0.371	0.140
	N_3	3.15	10.40	0.268	1.107	0.018	0.420	0.123
	S_1	3.93	9.43	1.051	1.231	0.020	0.351	0.192
	S_2	4.17	11.01	2.899	1.347	0.031	0.508	0.290
	S_3	6.15	12.99	3.040	1.544	0.026	0.622	0.287
	Prob.level	0.0001	0.173	0.0001	0.198	0.086	0.087	0.0004
	LSD $_{0.05}$	0.73	ns	0.535	ns	ns	ns	0.087
20-40	N_o	3.06	7.19	0.269	1.012	0.019	0.361	0.245
	N_1	3.41	7.45	0.250	1.116	0.027	0.325	0.183
	N_2	3.25	8.14	0.217	0.960	0.016	0.405	0.277
	N_3	3.12	7.98	0.191	1.192	0.020	0.576	0.295
	S_1	3.49	7.54	0.277	1.066	0.019	0.306	0.135
	S_2	3.20	7.16	0.345	0.954	0.025	0.396	0.141
	S_3	3.69	8.89	0.309	1.102	0.018	0.536	0.243
	Prob. level	0.29	0.89	0.06	0.42	0.60	0.62	0.686
	LSD $_{0.05}$	ns	ns	0.118	ns	ns	0.229	ns
40-60	N_o	2.89	5.18	0.161	0.959	0.018	0.313	0.170
	N_1	3.59	6.69	0.164	1.027	0.023	0.316	0.174
	N_2	3.21	5.40	0.203	0.957	0.021	0.375	0.257
	N_3	3.22	7.31	0.185	1.175	0.014	0.606	0.184
	S_1	3.64	6.91	0.307	0.830	0.019	0.348	0.185
	S_2	3.10	5.45	0.210	0.856	0.020	0.319	0.116
	S_3	3.24	6.96	0.423	1.026	0.019	0.573	0.264
	Prob. levle	0.49	0.66	0.028	0.86	0.323	0.022	0.66
	LSD $_{0.05}$	ns	ns	0.163	ns	ns	0.21	ns

(N_o= control, N_1=5 kg N day^{-1}, N_2=10 N day^{-1}, N_3=15 N da^{-1}, S_1=0.7 t day^{-1}, S_2=1.4 t day^{-1}a, S_3=2.1 t day^{-1}, ns = No Significant)

However, crop N uptake varies widely depending on crop type, growing conditions (moisture and temperature) and management practices. Some researchers reported that plant N uptake increased with sewage sludge application and N fertilization (Kiemnec *et al*., 1990; Cogger *et al*., 2001; Binder *et al*., 2002; Akdeniz *et al*., 2006).

Table 4: Extractable soil Fe (%), Mn, Zn, Cu, Cd and Pb (ppm) profiles according to 3 years and all treatments

Dept (cm)	Fe	Mn	Zn	Cu	Cd	Pb
0-20	3.99a	8.77a	0.978a	1.078a	0.0246	0.419a
20-40	3.39a	6.78b	0.295b	0.978b	0.0234	0.379b
40-60	3.45b	5.68c	0.195c	0.893c	0.0233	0.361b
Prob. level	0.0001	0.0001	0.0001	0.0001	0.50	0.012
$LSD_{0.05}$	0.207	0.54	0.166	0.082	ns	0.0387

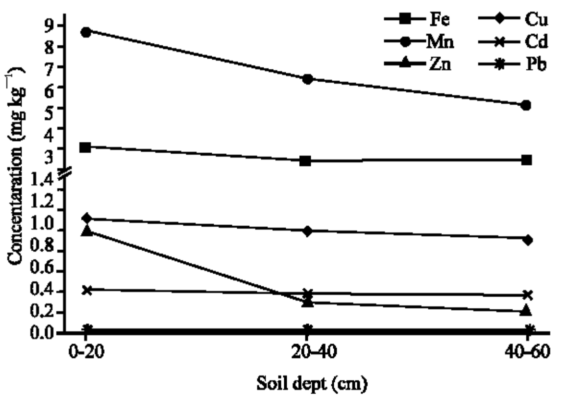

Fig. 2: Effect of long-term sewage sludge application on soil Fe, Mn, Zn, Cu, Cd and Pb in the soil profiles

None of the treatments examined had any significant influence on the plant tissue metals except for K, Mg, Cu and Pb in the 1st year and in the same way P, K and Zn in 2007. The high initial soil Ca levels likely provided sufficient available Ca for the plant and masked the effect of the Ca applied by the sewage sludge. However, Garden burnet as such many other plants had dynamic accumulators of nutrients: Na, S, Mg, Ca and Fe. The NRC (National Research Council, 1980) recommends a Ca: P ratio of 1.5-20: 1 for fed rations and total dietary calcium of <1%. However, since feed rations consists of different components, dietary P could be easily, increased to the recommended level. In general, all the amendments improved the feed quality of the forage compared with the control (Warman and Termeer, 2005).

The plant tissue P, K, Mg, Cu and P increased form 0.16-0.18, 1.25-1.70; 0.75-0.85%; 3.71-4.52 and 0.24-0.52 ppm, ppm at increasing sewage sludge fertilization, respectively. Zn is a phytototoxic metal, but it is important as a micro-nutrient at the appropriate levels (Henning *et al*., 2001; Crips *et al*., 1992). The most notable changes in the plant Zn concentration increased from 9.40-16.23 ppm, with sewage sludge addition in 2007. None of the amendments produced tissue Zn levels above the NRC tolerance limit of 300 mg Zn kg^{-1} feed. Since, the minimum recommended Zn content in cattle rations average 35 mg kg^{-1} and the data in Table 2 showed that crop samples were below that amount. The highest plant-Pb concentration was obtained from the highest sewage sludge applications during 3 years periods. Despite low heavy metal contents in the sewage sludge, the lack of heavy metal accumulation in the soil, heavy metal concentrations in plants can increase as a result of long-term sludge application. The significant accumulation of Pb in the crop grown in the soil amendment sewage sludge compared to the control did not show the potential risk. All metal concentrations in the plant tissue were below phytotoxic levels and no significant differences were detected between sewage amended plots and chemical fertilization except for Zn and Pb. Chang *et al*. (1987) pointed out that long-term of sewage sludge applications increased Cd and Zn concentration in the soil. In similarly, Akdeniz *et al*. (2006) also reported that sewage sludge increased concentration of Cd, Pb and especially Zn in the soil with increasing sludge application.

Sewage sludge applications increased DTPA-extractable Fe, Zn and Cr concentration for 0-20 cm soil depth in 2005. However, also Cu concentration increased, difference was not significant between treatments.

The most notable changes both in topsoil and in subsoil extractable elements concentrations were observed for Zn in 2005-2007 (Table 3). Zn concentration, as a means of 3 years, was approximately 10 times higher in sludge-treated soil than in control soil. In agreement with these findings, Barbaric *et al*. (1998) reported that extractable Zn level increased in topsoil an subsoil with sludge application. The increase in extractable Zn concentration observed in the soil also corresponded with the plant tissue Zn content. In 2006, sewage sludge application significantly affected DTPA-extractable concentrations of Fe, Zn, Cu, Cd and Pb except for Mn for 0-20 cm soil depth. Pinamonti *et al*. (1997) carried out on calcareous soil showed that extractable Zn, Cu, Ni, Pb, Cd and Cr concentrations in soil increased with sewage sludge application.

Typical soils profiles (Fe, Mn, Zn, Cu, Cd and Pb) also shown in Fig. 2. Applications of both chemical fertilizer and especially, sewage sludge significantly affected the levels and distribution of DTPA-extractable Fe, Mn, Zn, Cu, Pb and Cr in the soil profile when compared with control (Table 3 and 4).

The only exception was Cd, with slightly decreases in the soil profiles that were not significant at 0-20, 20-40 and 40-60 cm. This means that the metal did not move in a significant way form the upper to the downer layer (Table 4 and Fig. 2). There was a highly significant treatment × soil depth interaction. According to results of the experiments during the 4 years period; Fe, Mn, Cu and Pb decreased from 3.99-3.45%, 8.77-5.68 and 0.978-0.195, 1.078-0.893 and 0.419-0.361 ppm, respectively, in the same horizon (Table 4 and Fig. 2). The accumulation of Zn, Mn, Cu and Pb to the surface soil depth can be attributed the high affinity of the metals to organic matters (Barbarick *et al*., 1998). Madyiwa *et al.* (2002) stated that Cu and Zn showed relatively higher mobility down the soil profile than Ni and Pb. Organic matter and pH are the most important factors that control the availability of heavy metals in the soils. In this research, Zn was relatively more mobile compared to Fe, Mn, Cu, Cd and Pb. The maximum permissible concentrations of heavy metals in the surface soils amended with sewage sludge are normally based on total concentration. Several researches have showed that the Cu and Zn applied in sewage sludge remained in the plow layer of the soil and does not leach downward (Kiemnec *et al*., 1990; Crips *et al*., 1992; Nyamangara and Mzezewa, 1999).

CONCLUSION

This study showed that amendment of soils with sewage sludge in the field greatly increased herbage yield of Garden burnet, but effects of both sewage sludge and chemical fertilizer on grain yield were as nearly as the same. The 3rd sewage sludge dose (S_3) had the highest herbage yield and this followed chemical fertilizer (N_3 = 15 kg day^{-1}). Plant N, K, Mg, Cu, Zn and Pb contents significantly with sewage sludge applications. Exctractable Fe, Zn, Cu, Cd, Pb and Cr concentrations for 0-20 cm soil depth at the experiment significantly increased from 3.02-6.15; 0.34-3.04; 0.98-1.54; 0.014-0.026; 0.31-0.62 and 0.14-0.29 ppm, respectively, at increasing sewage sludge in 2007. The most important changes were observed for extractable Zn concentration concerning with both in the soil depths and years. This increases the likelihood that long-term sludge use may eventually lead to build-up of heavy metals. Thus, land-receiving of sewage sludge should be periodically monitored to ensure that heavy metal levels in the soil and plants remain within acceptable limits and to asses acceptable sludge doses and maximum application.

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