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Full Length Research Paper

Effects of municipal sewage sludge doses on the yield, some yield components and heavy metal concentration of dry bean (*Phaseolus vulgaris* L.)

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Significant grain yield increase to applied municipal sewage sludge was obtained. This study was carried out in order to investigate the effects of the different doses municipal sewage sludge application on the heavy metal concentrations, yield and quality of dry bean in the 2006 and 2007 years. The trial was conducted in randomized complete block design with three replications. Four municipal sewage sludge doses (0, 20 000, 40 000 and 60 000 kg ha^{-1}) were applied. Significantly higher pod and seed number per plant in municipal sewage sludge treatments had increasing effects on grain yield. Whereas grain yield, which was the highest component was obtained from 60 000 kg ha^{-1} municipal sewage sludge with 1766.3 kg ha^{-1} in the first year and with 1881.6 kg ha^{-1} in the second year. The lowest grain yield were obtained from 0 kg ha^{-1} municipal sewage sludge in both years. 60 000 kg ha^{-1} municipal sewage sludge application was optimal with respect to increasing yield and yield characteristics. Concentrations of heavy metals in grain and shoot were similar to those in the fertilizer treatments. Cu, Zn, Cr, Pb and Ni in grain and shoot were well below their toxic thresholds.

Key words: Sewage sludge, heavy metal, yield, dry bean.

INTRODUCTION

Dry bean (*Phaseolus vulgaris* L.) is one of the three food legumes, produced in the largest quantity in Turkey. Of the grain legumes grown for food, dry bean comes foremost on the global scale with 26.54 million ha of sowing area and 19.55 million tones of produce, whereas in Turkey, it ranks third with its 141 200 ha of sowing area and 195 970 tones of produce; the mean global yield is 736 kg ha $^{-1}$, whereas this parameter is 1387.9 kg ha $^{-1}$ for Turkey (Anonymous, 2006). Dry bean is a major crop grown on fine texture alkaline soils in Turkey.

Sewage sludge's high content of nutrients and organic matter, sludge has been applied worldwide in increasing amounts for this purpose during the few decades. Organic wastes such as municipal sewage sludge that is usually inexpensive and available locally could be used as fertilizer to increase yield and to improve soil properties together with legume crop of marginal lands. The applications of biosolids improve the physical and chemical properties of soil and fertility. The most beneficial effects of sewage sludge treated soils are increased organic matter content, improvement of structure and water holding capacity (Mc Connel et al., 1993). Sewage sludge also increased biological activity and enrichment with nitrogen, phosphorus and micronutrients (Brofas et al., 2000). East Anatolia Region soils are generally rich in lime, low in organic matter and available phosphorus, iron and zinc. Therefore, the physical and chemical properties of soil of region can be improved by using sewage sludge which has remarkable contents of organic matter, available macronutrients and micronutrients. The pollutants such as heavy metals are transferable and are not biodegradable, and at some levels, they become toxic and tend to accumulate along the food chain, where man is the last link (Dudka and Miller, 1999). In order to minimize the prospective health risks of sludge during land application, many studies have been performed using various methods to study the chemical fraction and emendation of heavy metal in sewage.

This study was conducted in order to analyze the effects

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Table 1. Selected chemical properties of the municipal sewage sludge and soil used in this study.

Properties	Sewage sludge	Soil
pH	6.2	8.7
Electrical Conductivity dS m $^{-1}$	10.51	0.71
Organic Matter %	46.8	1.87
Total concentrations		
N (%)	2.68	0.078
P (%)	0.64	4.7
K (mg kg $^{-1}$)	0.5	2.96
Fe (mg kg $^{-1}$)	11.88	10.5
Mn (mg kg $^{-1}$)	776	3.86
Cd (mg kg $^{-1}$)	1.17	-
Cr (mg kg $^{-1}$)	2.3	0.03
Cu (mg kg $^{-1}$)	99	0.42
Ni (mg kg $^{-1}$)	116.6	24
Pb (mg kg $^{-1}$)	54.8	-
Zn (mg kg $^{-1}$)	552.4	0.98

of different doses of municipal sewage sludge on heavy metal concentrations, yield and some yield components in dry bean plant which is grown in alkaline soils.

MATERIAL AND METHODS

The experimental field was in the city of Van located in the east region of Turkey (longitude 43° 17´E´, latitude 38° 33´N´, and altitude 1655 m). Two field experiments were conducted to measure the effects of different municipal sewage sludge on dry bean in the spring cropping seasons on an alkaline soil, classified as entisols (Soil Survey, 1999). Average growing season rainfall at the site of the experiment is 85.1 mm, with 60.3 mm falling in 2006 and 72.2 mm in 2007. Average growing season temperature near the experiment is 18.7°C, and was 18.3°C in 2006 and 20.0°C in 2007. Selected chemical properties of the municipal sewage sludge and soil used in this study are listed in Table 1. Municipal sewage sludge was collected from the Van Municipal Sewage Sludge Treatment Plant in Turkey.

For the analysis of plant samples, shoot samples (250 mg) were digested in a mixture of concentrated HNO_3 and $HClO_4$ (4:1, by volume) and the trace elements in the solutions were determined by ICP-OES (Shen et al., 2002). Reagent blank and analytical duplicates were used where appropriate to test the accuracy and precision of the analysis. The data reported in this paper were the mean values based on the three replicates. pH of sludge and soil was mesured by 1:2.5 soil-water suspension methods (Jackson, 1958), Soil texture was determined using the hydrometer method (Bouyoucus, 1951). Organic matter was analyzed colorometrically using the modified Walkley Black method (Walkey, 1947). Electric conductivity was determined by the methods described by Page et al. (1982). Available phosphorus was measured by the methods of Olsen et al. (1954), potassium in an extraction of neuter ammonium acetate (Thomas, 1982), available iron, copper, zinc, and manganese by mixing with DTPA (Lindsay and Norvell, 1978). Plant grains and shoot were dried for 48 h at 70°C and were ground.

This study was conducted completely randomized block design with three replications. Dry bean seed (cv. Aras-98) was sown 6 cm deep by hand in 10 cm rows down each plot, with a row spacing of 50 cm. Plots were 2.5 m wide and 5 m long. Sowing was done on lines on 02 May in 2006 and 05 May in 2007 by hand. Four municipal sewage sludge doses (0, 20 000, 40 000 and 60 000 kg ha $^{-1}$) were applied. Data on grain and biological yields were recorded from the whole plot, but the yield components data were recorded from 10 randomly selected plants in each plot. The trial was carried out under irrigated conditions, irrigation was conducted for 10 times and weed control was made by hoeing three times after taking into consideration the state of precipitation, temperature and humidity in the soil.

Methods and procedures used to measure grain yields and yield components were undertaken as outlined by Ciftci and Sehirali (1984). The following observations were recorded: plant height, first pod height, number of pods per plant, number of seeds per plant, number of seeds per pod, biological yield, harvest index, grain yield and 1000 seed weight. From each treatment, grain and shoot at harvest were sampled for chemical analysis of Zn, Cu, Ni, Cr and Pb plant grain. Analysis of variance was used to compare treatment means using SAS (1998).

RESULTS AND DISCUSSION

Yield and yield components

The means related with yield, yield components and LSD showing the differences between average values is given in Table 2. Whereas the lowest values related with plant height and first pod height based on different doses of municipal sewage sludge was obtained from control plots which were not applied to municipal sewage sludge, in the both years the highest value was obtained from the highest doses of the application of it (60000 kg ha^{-1}). Values related with plant height obtained in the trial changed between 24.9 and 31.1 cm. The highest first pod height was obtained from 60000 kg ha^{-1} (12.2 and 16.0 cm) application. Plant height in dry bean changes between 17.0 - 164.0 cm depending on the environmental conditions and the cultivars (Ciftci and Sehirali, 1984).

The yield responses to the treatments were mainly due to the effects of the treatments on the number of pods per plant and consequently, number of seeds per plant. While the highest pod number per plant was obtained from 60000 kg ha^{-1} sewage sludge (6.2 and 6.9 number/plant) in 2006 - 07. Similarly the highest seed number per plant was obtained from 60000 kg ha^{-1} (21.5 and 21.5 number/plant) in first and second years. In calcareous soils municipal sewage sludge application improves the structural property of the soil and increases the intake of nutritional elements of the other plants. Thus, significant pod number per plant and seed number per plant were increased to applied municipal sewage sludge (Table 2).

Grain yield was significantly increased by applications of sewage sludge. Our data indicate that the alkaline fine textured soils suitable for dry bean production in Turkey are both nutrients deficient for grain production and applications of sewage sludge increased grain yields and yield components. The effects of different doses of sewage sludge applications on grain yield in dry bean were found to be statistically significant in 2006 - 07 years. In the both years, the highest grain yield was

Table 2. Effects of the different municipal sewage sludge doses application on the yield and yield components of dry bean (*Phaseolus vulgaris* L.)*.

Yield and yield components	Year	Sewage Sludge Doses				LSD (p = 0.05)
		0 (Kg ha^{-1})	20000 (Kg ha^{-1})	40000 (Kg ha^{-1})	60000 (Kg ha^{-1})	
Plant Height (cm)	2006	24.9	26.5	27.5	28.8	1.32
	2007	25.8	26.1	28.4	31.1	0.72
First pod height (cm)	2006	12.2	14.2	15.2	16.5	1.92
	2007	13.5	14.3	16.0	16.6	0.46
Number of pod / plant	2006	5.4	5.7	5.8	6.2	0.37
	2007	5.6	6.1	6.1	6.9	0.35
Number of Seeds/ plant	2006	17.8	18.7	18.8	21.5	2.20
	2007	18.3	19.1	19.5	21.5	0.67
Number of Seeds/pod	2006	3.4	3.3	3.3	3.2	NS
	2007	3.2	3.0	3.2	3.1	NS
Biological yield (kg ha^{-1})	2006	3503.3	3797.0	4281.3	4335.6	185.77
	2007	3454.8	3810.7	4398.6	4502.0	60.72
Grain yield (kg ha^{-1})	2006	1302.0	1461.0	1719.6	1766.3	42.25
	2007	1316.3	1474.8	1725.7	1881.6	22.17
Harvest index (%)	2006	37.1	38.5	40.2	40.7	0.90
	2007	38.1	38.7	39.2	41.8	0.57
1000-seed weight (g)	2006	356.1	358.1	369.3	369.5	1.42
	2007	357.0	360.2	367.0	370.4	2.54

*For each row within each treatment, means follows by the same letter do not differ significantly at 5 % probability level following LSD.

obtained from 60000 kg ha^{-1} sewage sludge application. The lowest values of grain yield were found in control plots. Ozdemir (2005) reported that municipal solid waste compost application improved the growth and yield parameters of chickpea.

The highest biological yield was obtained from 60000 kg ha^{-1} sewage sludge application. The difference between this application and the one based on 60000 kg ha^{-1} sewage sludge and 40000 kg ha^{-1} sewage sludge was found to be statistically insignificant. Theodoratos et al. (2000) reported that sewage sludge addition had a positive effect on plant growth of dwarf bean. Our results were in agreement with the findings of these researchers.

Whereas the highest harvest index were obtained 60000 kg ha^{-1} sewage sludge applications as 40.7 and 41.8% (Table 2), the difference between this application and the based on 40000 kg ha^{-1} and 60000 kg ha^{-1} were found to be statistically insignificant in first year. The effect of different doses of sewage sludge application on 1000 seed weight of the dry bean in both years of the trials was found to be statistically significant.

Nutrient and heavy metal concentrations

Results of analyses for Zn, Cu, Ni, Pb and Cr in dry bean seed and shoot (at harvesting stage) are summarized in Table 3. The effects of sewage sludge on heavy metal concentration of dry bean were not significant except for Ni of seed in both years, Zn of seed in first year, and Zn and Cu of shoot in second year. Concentrations of Zn, Cu, Ni, Pb and Cr in dry bean seeds were below the limits of detection of the ICP-OES equipment used for the analysis.

The highest Ni in seed was obtained from 40000 kg ha^{-1} (14.60 and 13.86 mg kg^{-1}) sewage sludge application in 2006 and 2007 years. The difference between this application and that based on 60000 kg ha^{-1} were found to be statistically insignificant in both years. The same situation was observed Ni in shoot, too. The higher application rates of municipal sewage sludge caused significant increases Zn concentration in seed and Cu and Zn in shoot. Zn concentration in plant was mostly translocated to seed.

Pinamonti et al. (1997) and Zheljazkov and Warman (2004) reported that compost applications to soil reduced the bioavailability and the transfer of some trace elements to plant tissue. Even though the soil in Turkey and the experimental site are generally calcareous and have a pH value above 7.0, it is an advantage for preventing against the toxic effects of heavy metals (Baldwin and Shelton, 1999). The heavy metal contents of soil and plants to which municipal sewage sludge is applied have to be controlled.

Table 3. Effects of the different municipal sewage sludge doses application on the nutrient and heavy metal concentrations of dry bean seed and shoot*.

Seed	Year	Sewage sludge doses				
		0 (Kg ha^{-1})	20000 (Kg ha^{-1})	40000 (Kg ha^{-1})	60000 (Kg ha^{-1})	LSD (p = 0.05)
Cu (mg kg $^{-1}$)	2006	8.58	12.25	14.37	8.24	NS
	2007	7.52	7.98	8.41	7.24	NS
Ni (mg kg $^{-1}$)	2006	8.85	11.25	14.60	11.21	2.78
	2007	8.87	10.48	13.86	13.33	0.84
Pb (mg kg $^{-1}$)	2006	0.759	0.882	1.071	0.657	NS
	2007	3.59	1.19	2.57	3.64	NS
Zn (mg kg $^{-1}$)	2006	15.85	30.63	27.32	23.1	6.68
	2007	24.42	23.29	20.05	22.68	NS
Cr (mg kg $^{-1}$)	2006	0.22	0.22	0.30	0.19	NS
	2007	0.24	0.20	0.26	0.17	NS
Shoot						
Cu (mg kg $^{-1}$)	2006	8.02	10.23	8.08	7.22	2.02
	2007	8.22	9.76	8.73	10.18	1.08
Ni (mg kg $^{-1}$)	2006	10.30	9.19	9.64	8.27	NS
	2007	9.58	10.26	9.87	10.30	NS
Pb (mg kg $^{-1}$)	2006	0.12	0.26	1.37	0.45	NS
	2007	1.62	1.75	0.71	1.52	NS
Zn (mg kg $^{-1}$)	2006	16.76	14.8	15.42	10.44	NS
	2007	9.71	13.07	15.05	21.36	1.46
Cr (mg kg $^{-1}$)	2006	0.39	0.33	0.49	0.67	NS
	2007	0.34	0.33	0.52	0.52	NS

*For each row within each treatment, means follows by the same letter do not differ significantly at 5 % probability level following LSD.

Conclusion

The results of this study indicate that municipal sewage sludge application was effective on the alkaline and low fertility soil to improve plant growth and yield of dry bean. The analysis of heavy metals both in grain and shoot demonstrated the absence of pollution or toxic levels even with high accumulative doses of municipal sewage sludge. Therefore, 60000 kg ha^{-1} is preferable for achieving the greatest plant biomass production.

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