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Effects of Sewage Biosolid Application on Seed Protein Ratios, Seed NP Contents, Some Morphological and Yield Characters in Lentil (*Lens culinaris* Medic.)

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Abstract: This field experiment was conducted during October 2002-July 2003 winter growing seasons in Van, Turkey. Mineral fertilizer (20 kg N ha^{-1} +50 kg P_20_5 ha^{-1}) and six levels of sewage biosolid (T_1=10–T_6=60 T ha^{-1}) were applied to lentil variety Sazak-91 (*Lens culinaris* Medic.) to supply organic matter and macronutrients. The experimental design was a randomized complete block with four replications. Some important plant characters such as plant height, first pod height, number of pod per plant, number of seed per plant, seed weight per plant (g), and 1000 seed weight and one of the yield characters number of plant per m^2 were investigated in this experiment. Application of sewage biosolid to lentil increased plant seed yield significantly. Compared with the treatment of mineral NP fertilizers and sewage biosolid treatments of 10, 20, 30, 40, 50 and 60 T ha^{-1} with the Control plots increased the seed weight per plant 34.7 %, 14.4 %, 34.6 %, 42.7 %, 53,6 %, 51.4 %, 56.6% respectively. Seed nitrogen concentrations were generally higher in all amended treatments than in the Control. Seed P contents were normally higher in biosolid and mineral fertilizer plots compared to the Control plots, but always higher in the sewage biosolid amended plots.

Key words: Lentil, sewage biosolid, N-P fertilizer, macronutrient, plant yield

INTRODUCTION

Sewage sludge can substitute for commercial fertilizers and organic matter if applied in the right amounts to soil. Sewage biosolid consists of multi-element organic wastes that are used commonly as manures[1]. Moreover sewage biosolid build soils, restore barren lands, and help keep landscapes open and growing. In addition sewage biosolid decreased soil acidification if applied to soil in the right amounts[2], and increased beneficial soil organisms, improving soil physical and biological properties. All these effects are advantageous for plant health[3]. Pagliai *et al* [4] reported that sewage sludge increases soil aeration and the water holding capacity of the soil. Naggar and Ghamry[5] reported that sewage sludge and town refuse might be used as soil conditioners to improve the soil health and hence the crop yield.

Sludge greatly increases trace element contents on agricultural land above their natural levels (6). In general, concentrations of essential elements in plants grown on sludge were similar to concentrations of essential elements in plants grown with inorganic fertilizer. Sewage sludge is justified by its fertilizer value in terms of N and P and as a source of organic matter and micronutrients. Sewage biosolid application produced an immediate increase of the inorganic N, mainly in ammonium form. The N mineralization in the amended soil was higher than in the control soil. Composts were considered low analysis fertilizers because their N was from 1 to 2 % and the N mineralization rate is near 10 %[7]. Bozkurt *et al*[8,9] reported that they obtained no heavy metal toxicity on plant except in soil Zn with application of sewage biosolid doses. Nitrogen content and uptake of plant were increased by applications of sewage sludge.

Main problems of an excessive application of sewage sludge are plant toxicity due to accumulation of heavy metals in soils[10]. In addition, sewage sludge heavy metal content and parasitical organisms are the negative characteristics[11-13]. Due to its hygienic instability and immaturity of organic matter, sewage sludge should not be introduced into the soil environment directly[14]. The treatments of gamma radiation and lime minimized the population densities of certain microbial groups of hygienic significance[15]. Composts of sewage sludge might prefer to introduce it to soil. However, the heavy metal content of sewage sludge might be very variable depending on its origin and processing applications[16,17].

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There might be an increase in the heavy metal content of sewage sludge with a heavy industry nearby the urban areas. Arvas[18] reported that green herbage and hay yield of meadow were greater with sewage biosolid compared to chemical fertilizers.

Wollan[19] reported that germination of barley and ryegrass seeds appeared to be inhibited by the presence of sewage sludge. This effect and showed that germination was not permanently inhibited but merely delayed.

Due to soils in our region are fairly low in organic matter content (generally about 1%) and the soil has medium phosphorus, low nitrogen and low alkaline; this study was planned and executed to examine different application rates of sewage biosolid and the effects on lentil yield.

MATERIALS AND METHODS

Study design and plant material: Sewage biosolids were applied to lentil to supply organic matter, macronutrients. There is concern that this practice can increase the concentration of macronutrients in the soil. Lentil variety Sazak-91 (*Lens culinaris* Medic.) was used as a plant material. Lentil seeds of Sazak 91 variety were obtained from the TAE of Anadolu in Eskiºehir. Sazak 91 was selected as the test plant because of the current concern for high yielding in Van Region.

Field experiments were conducted in 2002-2003 in winter growing seasons in Van, Turkey. The experimental design was a randomized complete block with four replications with a total number of 32 plots. Area of each plot was 6 m^2 (1. 20 m X 5 m each one).

The plots were ploughed one year ago in spring. Second ploughing was done in opposite directions before planting on October. Sewage biosolid and fertilizers were applied with a hand and mixed into the top 1-5 cm of soil at planting time.

Treatments were as fallows: Control, Mineral fertilizer (20 kg ha^{-1} N+50 kg ha^{-1} $P_2 0_5$), which was the common practice in the study area for the application of mineral fertilizers; T_1=10 T ha^{-1}, T_2 =20 T ha^{-1}, T_2 =30 T ha^{-1}, T_4 =40 T ha^{-1}, T_5 =50 T ha^{-1} and T_6 =60 T ha^{-1}. Each plot was sown 2 meters away each other due to limit the mixing of treatments. Lentil was sowed on 25 October 2002 with 250 seed per m^2. During this experiment, all plots were weeded there times by hand and plots was not irrigated any time. Lentil was harvested in the third week of June.

Plant Measurements: The sample unit consisted of 15 plants harvested from three randomly selected samples from the two middle rows of each plot, at grain maturity. Plant yields were obtained by removing 15 plants in each plot at harvest. All plant samples were collected from the central part of each plot to avoid edge effects. Some important plant characters such as plant height, first pod height, number of pod per plant, number of seed per plant, seed weight per plant (g), and 1000 seed weight and one of the yield characters number of plant per m^2 were investigated in this experiment.

Soil and Sewage Biosolid Description: The soil samples were taken from the surface horizon of experiment area. The physical and chemical characteristics of the biosolid and soil are shown in Table 1. The soil has sandy-clay loam texture and low organic matter and nitrogen, rich potassium and lime content medium phosphorus and is low alkaline.

The sewage biosolid has high organic matter, low pH and rich all macro and micronutrients (Table 1). Dried sewage biosolid was obtained from the Campus of Yüzüncü Y?l University Waste Water Unit. Biosolid samples were air dried.

The sewage biosolid, soil and plant material analysis has been described in detail by Kacar,[20]. Soil structure analysed as Bouyoucous[21]; soil pH was described as Jackson[22], total organic matter as Walkley[23], phosphorus was determined as Olsen *et al*[24]; The N content of seed samples digested in concentrate sulfuric acid was determined by the Kjeldahl method[20], total P, K, Fe, Mn, Zn and Cu as Khan and Frankland[25].

Climatic Description: The climatic data of the region are represented in Table 2. Temperate climatic condition is ruled in the region. During the course of experiment, from October to July in 2002-2003 years, Rainfall was high during the autumn and winter months, which is important for recharging soil water. Amount of the rainfall was quite different over long term period. For instance, the 2002-2003 Winter growing season had higher rainfall as long term period. Temperatures were obtained as same as long term periods[26].

Statistical Analysis: The data were statistically analyzed by Costat and comparative analyses of the means were performed by Duncan Test using the Mstatc Programme[27].

RESULTS AND DISCUSSIONS

In this experiment, biosolid toxicity was not occurred in all stage of growth and symptoms of chlorosis or necrosis were not found on the above ground parts of the Sazak 91 cv. of lentil plants. Lentil leaves were obviously greener than those of the Control plants.

Table 1: Selected physical and chemical properties of the soil and sewage biosolid.

	pH	O. M. %	P mg/kg	N %	Fe mg/kg	Cu mg/kg	Zn mg/kg	Mn mg/kg	K mg/kg
Biosolid*	6.20	25.00	2320.00	1.30	12.71	11.16	270.00	74.20	2679.60
Soil	8.05	1.05	15.48	0.13	4.75	2.15	0.35	8.18	505.5

*Arvas (2005)

Table 2: Climatic data of Van province in 2002-2003 years and long term*.

	Rainfall (mm)		Temperature (EC)		Relative humidity	
	2002-03	Long Term Period**	2002-03	Long Term Period	2002-03	Long Term Period
October	58.8	43.8	12.8	10.5	63.4	59.0
November	40.6	47.0	4.3	4.2	66.0	67.0
December	30.3	31.5	-1.4	-1.0	68.1	69.0
January	26.1	39.3	-1.4	-3.8	68.3	70.0
February	54.5	34.9	-1.4	-3.2	66.3	70.0
March	83.4	45.1	0.1	0.6	71.9	69.0
April	78.8	56.9	8.4	6.9	73.0	63.0
May	6.4	42.8	14.5	12.8	64.2	67.0
June	50.2	18.4	18.2	17.8	61.5	50.0
July	-	6.5	23.1	22.0	53.4	44.0
Total	429.1	366.2				
Average			7.7	6.7	65.6	62.8

*Taken from the recording of Meteorogical Department in Van province
**Average of climatic data of last 54 years (1948-2002 years)

Table 3: Effects of different doses of sewage biosolid and chemical fertilizer on number of plant per m^2, plant height (cm) and first pod height (cm) of lentil.

Treatments	Plant/m^2	Plant height (cm)	First pod height (cm)	Pod/Plant (number)	Seed/Plant (number)	Seed w./plant (g)	1000 seed weight (g)
Control	176.25 a 1*	26.50 c 2	16.00 c 2	12.55 d 3*	11.87 d 2	0.651 c 2	54.33
Fertilizer (NP)	183.50 a 1	28.76 b 1-2	17.25 bc 1-2	13.82 c 2-3	14.60 bc 1-2	0.877 ab 1-2	57.32
T_1 (10 T/ha^{-1})	185.00 a 1	28.50 bc 1-2	17.50 bc 1-2	13.87 c 2-3	14.32 abc 1-2	0.745 b 2-3	55.02
T_2 (20 T/ha^{-1})	178.75 a 1	28.25 b 2	17.50 bc 1-2	13.62 c 2-3	15.50 abc 1	0.876 ab 1-2	57.55
T_3 (30 T/ha^{-1})	188.50 a 1	28.50 bc 2	17.75 ab 1-2	15.00 b 2	15.92 abc 1	0.929 ab 1-2	57.47
T_4 (40 T/ha^{-1})	177.50 a 1	29.00 b 1-2	17.75 ab 1-2	16.45 a 1	16.92 abc 1	1.000 a 1	57.15
T_5 (50 T/ha^{-1})	188.75 a 1	29.25 b 1-2	18.50 ab 1	16.35 a 1	16.87 ab 1	0.986 a 1	57.75
T_6 (60 T/ha^{-1})	183.00 a 1	31.00 a 1	19.25 a 1	16.50 a 1	17.37 a 1	1.020 a 1	57.93

*Difference indicated with same letter(s) are non-significant (<0.05); Numeral (0.01) (Duncan's Multiple Range Test)

Number of per plant meter square of means and means grouped in Duncan Multiple Comparison Test that were given Table 3. There were no differences in number of plant per meter square of lentil between different applications. Numbers of per plant meter square were unaffected by different applications and it were changed between 176.25 and 188.75. Seedling growth was uniform and any negative affects on seedling was not occurred with application of sewage biosolid. Rapid and uniform crop stand is an important for better quality produce. Wollan[19] reported that germination was not permanently inhibited but merely delayed by application of sewage biosolid in barley production. In this experiment, similar results were obtained with Wollan[19].

Morphological Characters: Significant differences were obtained in plant height. The highest plant height was determined from 60 T ha^{-1} of sewage biosolid applications. The minimum plant height was found from the Control plots. Plant height tended to increase in biosolid and mineral fertilizer amended plots as compared to the Control plots. Especially, biosolid effects on plant height were increased linearly and maximum plant height was found from T_6 (60 T ha^{-1}) treatments. T_6 treatment effects on plant height 17 % were higher than the Control effects (no amended plots) was obtained. Plant height was obtained from mineral fertilizer amended plots was similar to sewage biosolid amended (10 T ha^{-1}-50 T ha^{-1}) plots. But T_6 treatment effects on plant height 7.8 % were higher than mineral fertilizer amended plots effects were obtained (Table 3). This increase in plant height was concerned with the increasing of nitrogen levels in soil. In generally nitrogen in soil affect on plant vegetative growth.

Table 3 shows first pod height (cm) of lentil plant mean average and Duncan Multiple Comparison Test results. There were significant differences in first pod height and sewage biosolid and mineral fertilizer affected on this character. The highest first pod height was determined from 60 T ha^{-1} of sewage biosolid applications. The shortest first pod height of this research was found from the Control plot. First pod height was obtained from mineral fertilizer amended plots was similar to sewage biosolid amended (10 T ha^{-1}-40 T ha^{-1}) plots. But T_5 (50 T ha^{-1}) and T_6 (60 T ha^{-1}) treatments effects on first pod height were higher than mineral fertilizer amended plots effects was obtained. Similar results were obtained as plant height. Biosolids were used as a soil amendment that was beneficial treatments for vegetative growth of lentil. Naggar and Ghamry[5] reported that using of sewage biosolid to soil improved the soil health and hence the crop yield and Pagliai *et al*[4] reported that sewage biosolid increases soil aeration and the water holding capacity of the soil. Bozkurt *et al*[8,9] declared that nitrogen content and uptake of plant were increased by applications of sewage biosolid. All of these beneficial attributes might be affected on plant vegetative growth

Yield Characters: According to Table 3, numbers of pod per plant were affected by both mineral fertilizer and sewage biosolid treatments significantly that was obtained. In this experiment, number of pod per plant was changed between 12.55 and 16.50. Sewage biosolid effects on number of pod per plant were increased linearly and maximum number of pod per plant was found from T_4, (40 T ha^{-1}), T_5 (50 T/ha^{-1}) and T_6 (60 T/ha^{-1}) treatments. Mineral fertilizer and T_1 (10 T ha^{-1}) and T_2 (20 T ha^{-1}) effects on number of pod per plant were similar. T_3 treatment (30 T ha^{-1}) effects on number of pod per plant was higher than mineral fertilizer and T_1 (10 T ha^{-1}) and T_2 (20 T ha^{-1}) effects, but lower than T_4, (40 T ha^{-1}) T_5 (50 T ha^{-1}) and T_6 (60 T ha^{-1}) treatment were determined in this study. High level of sewage biosolid increased number of pod per plant. This effect may be concerned with increasing of nitrogen and phosphorus levels in soil. Limited data have been collected about numbers of pod per plant increases derived from the application of sewage biosolid to lentil.

Numbers of seed per plant were affected by both mineral fertilizer and sewage biosolid treatments significantly that was obtained. In this experiment, number of seed per plant was changed between 11.87 and 17.37. Sewage biosolid effects on number of seed per plant were increased linearly and maximum number of seed per plant was found from 60 T ha^{-1}. Mineral fertilizer and 10-50 T ha^{-1} effects on number of seed per plant were similar. The lowest number of seed per plant was obtained from the Control plants (Table 3).

Compared with the treatment of mineral N–P fertilizers and sewage biosolid treatments of 10, 20, 30, 40, 50 and 60 T ha^{-1} with the Control plots increased the seed weight per plant 34.7 %, 14.4 %, 34.6 %, 42.7 %, 53,6 %, 51.4 %, and 56.6 %, respectively. The highest seed weight was determined from 60 T ha^{-1} sewage biosolid applications. The lowest one was obtained from the Control plants. Therefore, the lentil seed weight, were increased much more by the treatment of T_6 than the other treatments. According to results of this experiment mineral N–P fertilizers effects were higher than 10 T ha^{-1} and similar to 20 T ha^{-1} but lower than other treatment of sewage biosolid (Table 3). The soil was fertile by application of sewage biosolid to soil, due to these conditions lentil plant seed yield was tended to increase in this study.

Many researchers have been reported about sewage biosolid that beneficial for crop growth. The mineral N–P fertilizers were active fertilizer whose nutrients were readily available for crops. Sewage biosolid was slow released fertilizer which provided a whole array of nutrients to soil. Limited data have been collected about yield increases derived from the application of compost to lentil. We had to correlate our result with other crops. In the most spectacular of these, Logsdon[28] reported when a form of sewage biosolid was ploughed into the field at a rate of 4.5 dry t/ha/year prior to planting. Yield increases of 35% for both barley and wheat. Beaton, *et al*[29] reported that development of durum wheat fertilized with 2 T ha^{-1} biosolids was slower. Maqsood *et al*[30] reported that mineral phosphorus increased lentil yield. Karem *et al*[15] reported that significant effects on dry weight of roots and shoots as well as grain yield production of cowpea plants treated bio-fertilizers. Naggar and Ghamry[5]

Table 4: Effects of different doses of sewage biosolid and chemical fertilizer on protein ratio, nitrogen content and phosphorus content of lentil seeds.

Treatments	Seed Protein (%)	Seed N (%)	Seed P (%)
Control	19.82 b 2 *	3.17 b 2	0.0285 d 3
Fertilizer (NP)	23.62 a 1	3.73 a 1	0.0645 c 2
T_1 (10 T/ha^{-1})	22.30 a 1	3.60 a 1	0.0635 c 2
T_2 (20 T/ha^{-1})	22.55 a 1	3.61 a 1	0.0600 c 12
T_3 (30 T/ha^{-1})	22.62 a 1	3.71 a 1	0.0650 c 2
T_4 (40 T/ha^{-1})	23.26 a 1	3.72 a 1	0.0707 bc 1-2
T_5 (50 T/ha^{-1})	23.27 a 1	3.83 a 1	0.0787 ab 1-2
T_6 (60 T/ha^{-1})	23.92 a 1	3.73 a 1	0.0855 a 1

*Difference indicated with same letter(s) are non-significant (<0.05); Numeral (0.01) (Duncan's Multiple Range Test).

reported that a significant increase in grain and straw yield of wheat was found in biosolid treated soils as compared with the control. Azam and Lodhi[31] found that in their study with wheat the above ground plant components responded positively to the application of both fertilizer N and Sewage biosolid. Menelik *et al*[32] reported that a significant increase in grain yield of winter wheat was found in biosolid treated soils as compared with the Control.

Seed Quality Characters: The thousand seed weight for the treatment means are summarized in Table 4. There were no significant differences in 1000 seed weight and means for all treatment were changed between 54.33 g and 57.93 g (Table 3). Maqsood *et al*[30] reported that maximum 1000-seed weight (19.38 g) was recorded with the application of 75 kg P_2O_5 ha^{-1} in lentil (*Lens culinaris* medic) CV. Masoor-85.

Differences in seed protein were obtained significantly. Seed protein concentration was increased by applications of mineral fertilizer and sewage biosolid during growth season. Sewage biosolid and mineral fertilizers treated plants had higher seed proteins than did the Control seeds. All treatment of sewage biosolid and mineral fertilizer amended plot given similar seed protein. Seed protein was changed between 19.82 % and 23.92 %. The lowest seed protein was in the Control plots. All the sewage biosolid treatment and mineral fertilizer amended effects on seed protein were higher than the Control effects (no amended plots) was obtained (Table 4). An increase in seed protein was related to nitrogen contents of sewage biosolid.

Seed nitrogen concentrations were generally higher in all amended treatments than in the Control. N content in seed for the treatment means are summarized in Table 4. Initially, the N concentration was similar in the lentil seed both the fertilizer and sewage biosolid amended plots. The N content increased in the seed amended with sewage biosolid compared with the Control plots. The lowest seed N concentrations was determined from the Control plots with 3.17 % and the similarity in yield (Table 4). Bozkurt *et al*[8] reported that sewage biosolid increased seed N content in corn plants. Naggar and Ghamry[5] reported that a significant increase in plant N content of wheat was found in biosolid treated soils as compared with the Control. Kirkham[33] reported that soil if applied sewage sludge in soil had more N, P, K, Mg, Fe, Cu, Mn, Zn, Cd, Cr and Ni than did soil from the control fields.

Phosphorus content for the treatment means were summarized in Table 4. There were significant differences in seed phosphorus. Seed P concentrations were normally higher either biosolid or mineral fertilizer compared to the Control, but always higher in the sewage biosolid amended plots (Table 4). The sewage biosolid and mineral fertilizer produced the greatest effect on seed P because of the high total P application which was used to provide in the sewage biosolid and mineral fertilizer amended plots. Seed phosphorus contents tended to increase in biosolid and mineral fertilizer amended plots as the Control plots. Biosolid effects on seed phosphorus contents were increased linearly and maximum seed phosphorus contents was found from T_6 (60 T ha^{-1}) treatments with 0.0855 %. The minimum seed P content determined from the Control plots with 0.0285 %. According to results of this experiment mineral N–P fertilizers and T_1, T_2, T_3 sewage biosolid effects on seed P content were similar amount. T_4 and T_5 effects on seed P content were higher than mineral N–P fertilizers and T_1, T_2, T_3 effects, but lower than T6 treatment of sewage biosolid (Table 4). Sewage sludge applications affected phosphorus content and uptake of plant more than inorganic phosphorus fertilizer.

A statistical evaluation variance analysis was performed to determine the probability that the mean P concentration in seed receiving the high application dosage single biosolid application was greater than that in the fertilizer applied plants. Beaton *et al*[29] reported that durum wheat fertilized with 4 T biosolids showed similar P uptake values as plants fertilized with the mineral fertilizer. Bozkurt *et al*[9] reported that sewage biosolid applications increased seed P content in barley. However, heavy metal contents of soil were found to be very below toxicity level. Biosolid treated soils as compared with the control significant increase was found in plant P content of wheat by Naggar and Ghamry[5]. El-Dawwey[34] reported that found an increase in wheat seed N and P contents. Menelik *et al*[32] obtained an increase in seed N and P.

Nitrogen and phosphorus requirement of plant may be covered by sewage biosolid without using fertilizers. Phosphorus content in sewage sludge and sludge compost and P availability to crops varies even more widely than N[35,36]. The sewage sludge can be used supplying some part of phosphorus for any plant[37].

According to the results given above, sewage biosolid would be given to soil to improve lentil yield in amount of 20-30 T ha^{-1}. This amount of biosolid affected on lentil yield and gave similar impact with NP (20-50 kg ha^{-1}) fertilizer. The amount of 20-30 T ha^{-1} would be amended instead of NP fertilizer to get optimum lentil yield.

This work pointed out the effect of sewage biosolid on lentil yield excepted sewage biosolid toxic effects. Detailed work should make with sewage biosolid about heavy metals detrimental effects.

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