EFFECTS OF SEWAGE SLUDGE ON THE YIELD OF PLANTS IN THE ROTATION SYSTEM OF WHEAT-WHITE HEAD CABBAGE-TOMATO

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Abstract

This research was carried to determine the effects of sewage sludge applications on the yield and yield components of plants under crop rotation system. The field experiments were conducted in the Bafra Plain, located in the north region of Turkey. In this research, the "wheat-white head cabbage-tomato" crop rotation system have been examined and the same crop rotation has been repeated in two separate years and field trials have been established. Seven treatments were compared: a control without application of sludge nor nitrogen fertilization, a treatment without sludge, but nitrogen and phosphorus fertilization, applied at before sowing of wheat and five treatments where, respectively 10, 20, 30, 40 and 50 tons sludge ha^{-1}. The experimental design was a randomized complete block with three replications. The results showed that all the yield components of wheat and yield of white head cabbage and tomato increased significantly with increasing rates of sewage sludge as compared to control. As a results, 20 t ha^{-1} of sewage sludge application could be recommended the suitable dose for the rotation of wheat-white head cabbage-tomato in soil and climatic conditions of Bafra Plain.

Key words: sewage sludge, tomato, wheat, white head cabbage

The generation of sewage is increasing due to rapid urbanization. The municipalities all over the world are concerned with safe and feasible methods of its disposal. The current methods for disposal include land filling, incineration, dumping in sea and field application for agricultural use. Incineration and land filling are not popular because of the high cost and environmental hazards involved. Therefore, the only viable option left for sludge management is its utilization in agriculture as a source of organic matter and plant nutrients, which is perhaps the most convenient and feasible practice of its disposal.

The motivation for recycling of sewage sludge to agricultural soil is the low cost of this disposal method, the soil organic matter preservation effect and the fertilization effect. 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.

Due to its high organic matter content, sewage sludge can improve physical, chemical, and biological properties of soil (Stamatiadis et al. 1999; Aggelides and Londra 2000; Benitez et al. 2001; Selivanovskaya et al. 2001; McBride 2003; Sanchéz-Monedero et al. 2004; Gonzáles-Pérez Martha et al. 2006; Zhang et al. 2007; Alcantara et al. 2009; Angın and Yağanoğlu 2009). Thus, sludge application helps to reduce soil erosion and improves the soil quality as a plant growth medium. The fertilizer effect enables a reduction in cost for nitrogen and phosphorus mineral fertilizers and may improve crops yield on sludge treated fields (Wild and Jones 1991; Petersen et al. 2003).

Considerable research has been accomplished worldwide on the use of sewage sludge on soil and crop. In many investigations with different climatic and soils conditions have reported a substantial increase in plant growth, crop yield and biomass production upon sewage sludge application (Azam and Lodhi 2001; Chatha et al. 2002; Bozkurt and Yarılgaç 2003; Mohammad and Athamneh 2004; Dursan et al. 2005; Casado-Vela et al. 2006 and 2007; Jamil et al. 2006; Samaras et al. 2008; Togay et al. 2008; Angın and Yaganoğlu 2011).

However, the main problems of an excessive application of sewage sludge are plant toxicity due to accumulation of heavy metals in soils (Jarausch-Wehrheim et al. 1999; McGrath et al. 2000) but also the increase in its salt content (Hao and Chang 2003). Sewage sludge can substitute for commercial fertilizers and organic matter if applied in the right amounts to soil. By using sludge, it is a

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possibility for farmers to supply their lands with organic fertilizer at low costs. Therefore, recycling of sludge for agricultural purpose seems to be an appealing solution for sustainable management of sludge.

This study was conducted in order to determine the effects of different doses of municipal sewage sludge on yield and some yield components in the rotation of wheat-white head cabbage-tomato.

MATERIAL AND METHODS

Location of the research areas

The investigation was carried out in the Bafra Plain, located in the north region of Turkey (longitude 35^o 30'-36^o 11' E, latitude 41^o 26'-41^o 45'N, and altitude 7 m). Investigations conducted during 2002-2005 at the Samsun Black Sea Agricultural Research Institute have followed the influence of different sewage sludge rates on yield agricultural characteristics. In this research, the "wheat-white head cabbage-tomato" crop rotation system was examined and the same crop rotation was repeated in two separate years and field trials were established.

The experimental region has a semiarid climate with long-term mean annual minimum and maximum temperatures of 10.3ºC and 18.3ºC, relative humidity of 74.8%, and annual precipitation of 737.4 mm.

Soil and sewage sludge properties

Some characteristics of sewage sludge used in the experiment and soils are given in Table 1. In general, the experimental soils were clayed in texture, slightly alkaline in reaction (pH), moderate level calcareous and organic matter. The soils showed no signs of salinity problem, available phosphorus (P) content was at poor level, available potassium (K) content was high (Ülgen and Yurtsever, 1995) (Table 1).

Sewage sludge material used in the research was provided from Bafra Municipality Wastewater Treatment Facility (Samsun-Turkey). Treatment facility was designed according to the long aerobic active sludge system process. When Table 2 is examined, it can be seen that the sewage sludge material contains, 4.50-5.25% N, 1.95-2.23% P and 0.36-0.64% K. pH was 6.49-7.55, EC content was 7.11-8.00 dS m^{-1} and total Fe was 0.91-1.42%.

According to the Regulation on Control of Soil Pollution which was promulgated in Turkey tolerated maximum heavy metal rates that can be included in the sewage sludge that will be used in the soil are determined as follows: 750 ppm for lead, 10 ppm for cadmium, 1000 ppm for chrome, 1000 ppm for copper, 300 ppm for nickel and 2500 ppm for zinc (in oven in dry soil) (Anonymous, 2010). According to that; when the heavy metal contents in the sewage sludge to be used in soil are examined, it has been determined that it contained less heavy metal content values included in "Regulation on Control of Soil Pollution". In addition, Fecal Coli content that limits the usage has not been determined in the results of microbiological analysis of sewage sludge.

Plant and inorganic fertilizer materials

In the research Panda has been used as the variety of wheat. Local variety is used for white headed cabbage seed and it is very widespread in the region. Tomato variety 5656 F1 was used as a plant material. The form of inorganic fertilizer was used as ammonium sulfate (21% N) and triple super phosphate (43-44% P_2O_5).

Experimental design

The experiment was conducted using a complete randomized block design with three replications in 21 plots, each measuring 56.40 m^2 (5.64 m x 10 m), with a separation strip of 1 m between them. Each plot was randomly assigned to receive one of seven treatments as follows:

Control: (a control without application of sludge nor nitrogen fertilization)

S1: 10 t ha^{-1} sewage sludge

S2: 20 t ha^{-1} sewage sludge

S3: 30 t ha^{-1} sewage sludge

S4: 40 t ha^{-1} sewage sludge

S5: 50 t ha^{-1} sewage sludge

Fertilizer (NP): (a treatment without sludge, nitrogen and phosphorus fertilization: for wheat 200 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1}, for white headed cabbage 130 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}, for tomato 130 kg N ha^{-1}. Since the soils were rich in potassium (Table 1), K was not applied).

Mineral nitrogen application rates were based on the agronomic nitrogen requirement of wheat, white headed cabbage and tomato (Deniz and Özdemir 1980; Özdemir and Güner 1983a, 1983b).

In NP treatment, since beneficial phosphorus enough for tomato has been found in the sample soil examined after cabbage cropping period phosphorus fertilizer was not applied to the tomato.

Field applications

The dates of important cultural practices applied in the experiment are given in Table 2. Sewage sludge were applied to mixed in the depth of soil 20 cm by hand using a shovel before sowing of wheat which is the first plant of crop rotation.

Wheat sowing was made with aerobic combined grain seeder 180 kg of seed were sowed per hectare. Plot size was 5.64m x 10m=56.40 m^2. The seedlings of white head cabbage and tomato were spaced 5.00m x 9.75m and 5.60m x 9.60 m in the field, respectively. Row spacing was 100 cm (white head cabbage) and 140 cm (tomato).

In NP treatment, half of the nitrogenous fertilizer was applied before wheat sowing and before planting of white headed cabbage and tomato the other was applied when at middle tillering stage of wheat, at 2nd hoe of white head cabbage and at the fruits are seen of tomato. All phosphorus fertilizer was used during sowing/planting time.

All recommended cultural practices such as irrigation, eradication of weeds and plant protection were adopted uniformly according to standard crop requirements.

The wheat harvesting was done by cutting with a sickle. Crop of each plot was harvested separately. Threshing was done by a small plot thresher and cleaned using experimental winnowing machine. After threshing the grains were dried and weight to record the grain yield. The weights of grain and straw per plot were converted to hectare basis. The cabbages were harvested on the 80th day of cultivation (seedling plantation), and they were weighed for total commercial biomass. Outer dirty or broken leaves were removed to obtain the commercial biomass, and the head circle of the commercial products was measured. The tomato harvesting was done by hand. Total marketable yield in kg and harvested number of fruits per plot was recorded. Based on the surface of the plot and the yield in kg, yield in kg per hectare was calculated.

Table 1

Characteristics of soil and sewage sludge used in the study

Soil			Sewage sludge		
Parameters	1st period trial material	2nd period trial material	Parameters	1st period trial material	2nd period trial material
Clay, %	56.3	57.1	Solid Substance,%	40	87
Silt, %	36.2	35.6	Combustion Loss, %	61	73
Sand, %	7.6	8.2	pH	7.55	6.49
Textural Class	clayed	clayed	EC 25 ^oC, dSm^{-1}	7.11	8.00
pH	7.80	7.93	Total N, %	4.50	5.25
Electrical Conductivity (EC), dSm^{-1}	2.638	1.953	Total P, %	2.23	1.95
Calcareous ($CaCO_3$), %	5.5	5.8	Total K, %	0.64	0.36
Organic Matter, %	2.77	2.76	C/N	8	8
Available P, kg P_2O_5 ha^{-1}	30	30	Total Fe, %	1.42	0.91
Available K, kg K_2O ha^{-1}	990	900	Total metal concentrations (ppm)		
Total metal concentrations (ppm)			Mn	812	986
Cu	55.14	35.60	Cu	136	120
Zn	83.38	58.81	Zn	718	926
Cd	0.12	1.37	Cd	1.5	1.1
Cr	54.40	54.92	Cr	45	39
Ni	175.00	150.00	Ni	57	42
Pb	1.47	16.72	Pb	35±9	37

Table 2

Dates of cultural practices in field experiments

Agricultural operations	1st period field experimental			2nd period field experimental		
	Wheat	White head cabbage	Tomato	Wheat	White head cabbage	Tomato
Sewage sludge application	23.10.2002	---	---	13.10.2003	---	---
Sowing/ planting	18.11.2002	30.07.2003	15.05.2004	10.11.2003	19.08.2004	12.05.2005
The second half of the application time of nitrogen fertilizer	13.03.2003	09.09.2003	23.06.2004	15.03.2004	01.10.2004	15.06.2005
Hoe	---	1st:12.08.2003 2nd:09.09.2003	1st:31.05.2004 2nd:22.06.2004 3rd:09.07.2004	---	1st:15.09.2004 2nd:01.10.2004	1st:30.05.2005 2nd:15.06.2005 3rd:12.07.2005
Harvest	03.07.2003	22.10.2003 06.11.2003 20.11.2003	26.07.2004 02.08.2004 06.08.2004 11.08.2004 16.08.2004 20.08.2004 24.08.2004 31.08.2004	08.07.2004	07.12.2004 31.12.2004	21.07.2005 26.07.2005 01.08.2005 09.08.2005 16.08.2005 23.08.2005 01.09.2005 07.09.2005

Plant measurements and analysis

Data of wheat were recorded for grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}), 1000-grain weight (1000 GW) (g), grain protein percentage (%). For 1000-grain weight, two samples of thousand grains were counted from threshed clean lot of each treatment, their weight was taken and average calculated (Kün, 1983). Total nitrogen content of wheat grains was determined by micro-Kjeldahl method. The protein content was determined from per cent total nitrogen multiplied by 5.85 (Kacar and İnal, 2008).

Data of cabbage and tomato were recorded for total head and fruit yield (kg ha^{-1}), respectively.

Statistical analysis

Statistical analysis was conducted using the MSTAT-C statistical package. The F test was then applied to examine the statistical significance of differences among treatments. Statistical analysis of the two years data was done at 1% or 5% level of probability using Duncan's Multiple Range Test (DMRT) to test the difference between the individual means (Yurtsever, 1984).

RESULTS AND DISCUSSIONS

Effects of sewage sludge on the yield and yield components of wheat

The data recorded on grain yield, straw yield, grain protein percentage and 1000-grain weight are presented in Table 3. It revealed that all the different doses of sewage sludge increased the grain yield over control significantly ($p<0.01$). In the both periods, significantly ($p<0.01$) highest grain yield (5895 and 4962 kg ha^{-1} in 2003 and 2004, respectively) was observed in the S2 treatments followed by application of chemical fertilizer (5382 and 4107 kg ha^{-1}, respectively of years). The grain yield increases obtained in the first period in wheat, by applying rates of 20 t/ha sewage sludge, were of 2445 kg ha^{-1} (70%), compared to untreated control. However, nitrogen and phosphorus fertilizers resulted in yield increases of 1932 kg ha^{-1} (56%). Similar results was obtained in the second period field experiment. In research, minimum grain yield was recorded in the control (3450 and 1828 kg ha^{-1} in 2003 and 2004, respectively) (Table 3).

Table 3

Effects of different doses of sewage sludge and chemical fertilizer on grain yield, straw yield, grain protein percentage and 1000-grain weight of wheat

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Grain protein percentage (%)		1000-grain weight (g)	
	Crop rotation periods		Crop rotation periods		Crop rotation periods		Crop rotation periods	
	2002-2004 periods	2003-2005 periods	2002-2004 periods	2003-2005 periods	2002-2004 periods	2003-2005 periods	2002-2004 periods	2003-2005 periods
Control	3450 f	1828 d	5596 c	1971 d	11.64 c	11.46 c	39.67 c	33.67 d
S1	5074 c	3727 bc	7740 b	6292 bc	13.75 b	11.91 bc	41.40 abc	36.80 bcd
S2	5895 a	4962 a	8388 ab	6671 bc	14.23 ab	13.87 ab	43.13 a	43.90 a
S3	4471 d	4060 bc	8421 ab	7882 ab	15.31 ab	12.30 bc	41.13 bc	37.80 bc
S4	4471 d	3751 bc	8903 a	9117 a	15.55 a	14.60 a	41.30 bc	36.03 bcd
S5	3887 e	3538 c	8018 ab	8523 a	15.86 a	14.61 a	41.70 ab	34.87 cd
Fertilizer (NP)	5382 b	4107 b	7574 b	5461 c	14.43 ab	13.90 ab	42.63 ab	40.03 ab
F Values								
	3.79**	64.15**	21.34**	45.13**	17.44**	7.92**	4.60*	16.68**
Means followed by the same letter in a column are not statistically different (Duncan tetst, P≤0.05), *: Significant with P≤0.05; **: Significant with P≤ 0.01								

Sewage sludge addition significantly ($P<0.01$) increased straw yield in comparison to control and chemical fertilizer treated wheat in both periods. In the first period, maximum straw yield (8903 kg ha^{-1}) was obtained from the treatment receiving 40 t ha^{-1} of sewage sludge followed by 8421 kg ha^{-1} from the treatment receiving 30 t ha^{-1} sewage sludge, which were statistically at par with the treatment receiving 20 and 50 t ha^{-1} of sewage sludge. The highest straw yield (9117 kg ha^{-1}) was recorded in the S4 treatment, and there was no significant difference between the straw yields for the S5 and the S3 treatments during 2004. The minimum straw yield (5596 and 1971 kg ha^{-1} in 2003 and 2004, respectively) was obtained from the control treatment (Table 3).

Sewage sludge and nitrogen applications had a favorable effect on the crop N uptake. Sewage sludge, due to its high nitrogen content, statistically significantly ($P<0.01$) increased in the grain protein percentages with the increasing rates of it. The highest grain protein percentage (15.86 and 14.61% in 2003 and 2004, respectively) was obtained in the S5 treatments. However, the difference between this application and that based on S2, S3, S4, S5 and NP were found to be statistically insignificant during both years. The lowest grain protein percentages (11.64 and 11.46% in 2003 and 2004, respectively) was recorded in the control plots (Table 3).

The data pertaining to the 1000-grain weight as affected by different levels of sewage sludge revealed significant effect in comparison with the control treatment. The highest 1000-grain weight (43.13 and 43.90 g in 2003 and 2004, respectively) was recorded in the S2 treatments, and in 2003 it was statistically similar to the S5, S1 and NP treatments. There was no significant difference between the 1000-grain weights for the S2 and the NP treatments during 2004. In the both periods, the lowest (39.67 and 33.67 g, respectively) 1000-grain weight were obtained from the application of control treatments (Table 3).

Effects of sewage sludge on the yield of white head cabbage

The different levels of sewage sludge application had a significant ($p<0.01$) effect on the head yield of white head cabbage. In first period, the highest head yield (67879 kg ha^{-1}) was obtained in the S4 treatment, and there was no significant difference between the head yields for the S3 and the S2 treatments. In second periods, the highest head yield (56700 kg ha^{-1}) was determined in the S4 treatments, and it was statistically similar to the S2, S3, S5 and NP treatments. The minimum head yield was found from the control plots during both periods (Table 4).

Effects of sewage sludge on the fruit yield of tomato

There were significant ($p<0.01$) difference in fruit yield of tomato with the application of the different rates of sewage sludge in the both periods. The fruit yield of tomato increased with increasing rates of sewage sludge. The highest fruit yield was recorded in the S3 (61990 kg ha^{-1}) treatment, and there was no significant difference between the fruit yields for the S2, S4, S5 and NP treatments in first period. In second periods, the highest fruit yield was obtained in the S5 (76828 kg ha^{-1}) treatments, and it was statistically similar to the S2, S3 and S4 treatments. The treatment of control resulted the lowest fruit yield (34269 and 27650 kg ha^{-1}) during 2002–04 and 2003–05, respectively (Table 5).

Table 4

Effects of different doses of sewage sludge and chemical fertilizer on head yield of white head cabbage (kg ha^{-1})

Treatments	Crop rotation periods	
	2002-2004 periods	2003-2005 periods
Control	40687 c	28822 c
S1	58061 b	46465 b
S2	60727 ab	55219 a
S3	60727 ab	56027 a
S4	67879 a	56700 a
S5	55758 b	51448 a
Fertilizer (NP)	52647 b	47811 a
F Values		
	23.06**	23.61**
Means followed by the same letter in a column are not statistically different (Duncan tetst, P≤0.05), *: Significant with P≤0.05; **: Significant with P≤ 0.01		

Table 5

Effects of different doses of sewage sludge and chemical fertilizer on fruit yield of tomato (kg ha^{-1})

Treatments	Crop rotation periods	
	2002-2004 periods	2003-2005 periods
Control	34269 c	27650 c
S1	47066 b	53146 b
S2	61352 a	68863 a
S3	61990 a	69643 a
S4	57866 ab	72378 a
S5	52551 ab	76828 a
Fertilizer (NP)	55230 ab	48427 bc
F Values		
	11.04**	82.07**
Means followed by the same letter in a column are not statistically different (Duncan tetst, P≤0.05), *: Significant with P≤0.05; **: Significant with P≤ 0.01		

Grain yield, straw yield, grain protein percentage and 1000-grain weight of wheat significantly increased with sludge addition in this study. Grain yield increases, obtained during 2002-2005, by applying the rate of 20 t ha^{-1} sewage sludge, were of 2445-3134 (71-171%) (respectively of periods) in wheat. The increases noted in grain yield and in the yield associated variables are due to the high concentrations of nitrogen, phosphorus and micronutrients of the sewage sludge applied (Naggar and El-Ghamry, 2001). Aılıncăı et al. (2010) reported that the mean wheat yield increase after applying 20 t/ha sewage sludge was of 1448 kg/ha (72 %), compared to the untreated control. Our results were in agreement with the findings of these researchers. Azam and

Lodhi (2001) found that in their study with wheat the above ground plant components responded positively to the application of both fertilizer N and Sewage biosolid. In this experiment, similar results were obtained with Naggar and El-Ghamry (2001) and Bilgin et al. (2004).

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 t ha^{-1} of sewage sludge application. Al- Mustafa et al. (1995), Singh and Singh (1999), Al Zoubi et al. (2008) and Aılıncăı et al. (2010) also reported highest increase in the grain and straw yield of wheat treated with sewage sludge.

The results of this study corroborated results from others investigations. Sabey and Hart (1975) reported that addition of sewage sludges at the rate of 0, 25, 50, 100 and 125 t ha-1 to loamy sand affected the germination of sorghum, Sudan grass and pearl millet but sowing of wheat after three months later resulted in increased yield of wheat. Tsadilas et al. (1995) studied the influence of sewage sludge application on soil properties and growth of wheat and maize under pot house conditions. Wheat and maize responded well to sludge application. Bouzerzour et al.(2002) reported that the application of sewage sludge increased leaves dimensions, leaf area index, accumulated above ground dry matter, tillering capacity and plant height of barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.) genotypes, evaluated in pots experiment. Antolın et al. (2005) reported that application of sewage sludge increased barley grain yield because the soil amended had improved microbiological properties, which promoted the recycling of nutrients for the crop. Akdeniz et al. (2006) reported that sewage sludge application positively affected grain yield, leaf nitrogen, harvest index, and total N uptake of sorghum more than chemical fertilizer, except for dry matter yield. Khan et al. (2007) reported that with the increased application of sewage sludge increased wheat grain and total dry matter yield. They mentioned that the maximum yields were obtained at 80 Mg ha^{-1} of sewage sludge application. This application rate was not recommendable because of very high rate and to avoid the possible risk of metals uptake and accumulation in the soil. The recommendable rate is 40 Mg ha^{-1}.

As a results, nitrogen content and uptake of wheat were increased by applications of inorganic nitrogen fertilizer and sewage sludge. Sewage sludge applications affected nitrogen content and uptake of plant more than inorganic nitrogen fertilizer. This results indicated that some of nitrogen requirement of plant can be provided by using sewage sludge. The higher grain protein of the sludge treatments appears to be the result of the greater available soil N levels at the latter part of the growing season (Lerch et al., 1990). These results agree with Lerch et al. (1990), who reported increased grain protein content for sewage sludge application. Mamo et al. (1999) reported that plant N uptake increased with sewage sludge application and N fertilization. Naggar and El-Ghamry (2001) reported that a significant increase in plant N content of wheat was found in biosolid treated soils as compared with the Control. Yağmur et al. (2005) reported that sewage sludge and mineral fertilizers treated plants had higher seed proteins than did the Control seeds.

It has been indicated in various researches that the municipal sewage sludge applied in increasing amounts increase the plant growth and nitrogen content of various plants which have been subjected to testing (Menelik et al. 1991; El-Dawwey 1993; Mohammad and Battikhi 1997; Arcak et al. 2000; Şensoy et al. 2000; Bozkurt et al. 2001).

This increase in 1000-grain weight may also be the result of improvement in the soil fertility due to sewage sludge application. Barbarick et al. (1998), Elsokkary and Salam (1998), Jamil et al. (2004), Khan et al. (2007) and Tamrabet et al. (2009) have also reported similar findings.

Nutrients contained in sludge increase plant biomass and yield (Snyman et al. 1998; Brofas et al. 2000; Cogger et al. 2001). In our results, fruit yield of tomato plant and head yield of white head cabbage were increased by the increasing applications of sewage sludge rates for each years. Önal et al. (2003) reported that plant dry matter and fruit yield, mineral contents including N, P, K, Ca and Mg in fruits of tomato plant were increased by the increasing applications of sewage sludge rates. Many investigators have reported a substantial increase in plant growth and fruit yield of tomato upon sewage sludge application (Kalembasa 1996; Navarro-Pedreno et al. 1996; Pedreno et al. 1996; Perez-Espinosa et al. 1999; Topcuoğlu et al. 2001). Wei and Liu (2005) reported that the yields of Chinese cabbage generated positive response to the sewage sludge compost application. El-Dewiny et al. (2006) showed that dry weight of radish and spinach plants increased with application of sewage sludge.

The experimental results showed that yield and yield components of wheat, yield of white head cabbage and tomato increased significantly with increasing rates of sewage sludge over control, which shows that sewage sludge have a beneficial effect for the rotation of crop. The studies further elucidated that 20 t ha^{-1} sewage sludge was the suitable dose for the rotation of wheat-white head cabbage-tomato in soil and climatic conditions of Bafra Plain.

CONCLUSIONS

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). Sewage sludge containing pathogenic organisms should be handled and applied in a proper manner to reduce the risks to human and animal health.

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.

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