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Utilization of Sewage Sludge as Organic Fertiliser in Sustainable Agriculture

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Abstract: A field experiment was conducted to study the effect of addition of different levels of domestic sewage sludge on the soil properties and yield of wheat crop. Addition of sewage sludge raised soil pH, increased organic matter, EC_e, NPK, Ca+Mg and trace metals (Fe, Cu, Mn and Zn) with its increasing levels. Different treatments of sludge also increased the yield and yield attributing components as compared to untreated (control) treatments. Significantly maximum plant height (107 cm), number of tillers (433 m^{-2}) and straw yield (9.82 t ha^{-1}) were obtained where 80 t ha^{-1} sewage sludge was applied while spike length, number of productive tillers m^{-2}, number of grains $spike^{-1}$, 1000-grain weight and grain yield were maximum in the treatments amended with 40 t ha^{-1} of sewage sludge. The study indicates that sludge application at the rate of 40 t ha^{-1} can enhance economic yield of wheat and also improve soil productivity.

Key words: Organic wastes, sewage sludge, calcareous soil, wheat

INTRODUCTION

Regular additions of organic materials such as animal manures, crop residues and municipal wastes are of utmost importance in maintaining the tilth, fertility[1] and productivity of agricultural soil[2]. Sewage sludge is one of the most important organic wastes, which can be used as organic fertiliser[3]. It is a product of sewage treatment plants and results from removal of solids and organic matter from the sewage (municipal as well as industrial waste water). Sewage sludge is further processed through digestion, thickening, denaturing and drying for disposal. Disposal of sewage sludge has traditionally been through incineration, dumping in rivers /oceans or depositing in landfills. However, these methods are costly and cause environmental pollution. Since, sewage sludge is a good source of organic matter and plant nutrients[4,5], therefore, the best way to utilize this waste is to use it as organic fertiliser in agriculture, because it consists of many essential plant nutrients like N, P, K and Zn, Cu, Fe, Mn and other trace elements. Thus land application of sludge for crop production provides a feasible and cost effective disposal alternative[6,7]. As the soils of Dera Ismail Khan are calcareous in nature, deficient in N, P and Zn[8], the present study was therefore, planned with the following objectives:

- To examine the effects of sewage sludge on soil properties and growth of wheat crop.
- To study the effects of sewage sludge on yield and yield components of wheat.
- To find out an appropriate and economical dose of the sludge for higher yield of wheat.

MATERIALS AND METHODS

A field experiment was carried out in the research area of Faculty of Agriculture, Gomal University, D.I. Khan, Pakistan, during 2002-2003. The soil was sandy clay loam having pH 8.2, EC_e 0.38 dS m^{-1}, total organic matter 8200 mg kg^{-1}, total N 300 mg kg^{-1}, available K 172 mg kg^{-1}, Ca+Mg 94 mg kg^{-1} and Zn, Cu, Fe and Mn 6.2, 6.5, 5.4 and 11.0 mg kg^{-1}, respectively (Table 1). Sewage sludge was collected from the sewerage channels of Dera Ismail Khan City Phyco-chemical characteristics of swage slugse are given in Table 2. It was air dried, ground and passed through a 4 mm sieve and was applied at the rate of 10, 20, 40, 60, 80 and 100 t ha^{-1} before sowing to respective plots. Wheat variety Fakhr-e-Sarhad was sown with 30 cm line-to-line spacing. The experiment was laid out by following Randomized Complete Block Design having four replications using plot size of 3x5 m^2. The growth and yield data on the parameters like, plant height (cm), spike length (cm), number of tillers m^{-2}, number of productive tillers m^{-2}, number of grains $spike^{-1}$, 1000-grain weight (g), grain yield t ha^{-1} and straw yield t ha^{-1} were recorded. Soil samples were taken from each plot at the depth of 0-30 cm after harvest to determine the fertility status[9].

Statistical analysis: The data were analyzed statistically according to standard statistical procedures[10] and the

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Table 1: Physico-chemical characteristics of the soil

Characteristics	Value
pH	8.20
EC_e (d Sm^{-1})	0.38
Ca^{++}+Mg^{++}(mg kg^{-1})	94.00
Cl^- (mg kg^{-1})	93.00
CO_3^{-2} (mg kg^{-1})	26.00
HCO_3^- (mg kg^{-1})	100.00
SO_4^{-2} (mg kg^{-1})	27.00
Textural class	Sandy clay loam
$CaCO_3$ (mg kg^{-1})	63000.00
Available K (mg kg^{-1})	172.00
OM (mg kg^{-1})	8200.00
Total N (mg kg^{-1})	300.00
Available P (mg kg^{-1})	7.50
Fe (mg kg^{-1})	5.40
Mn (mg kg^{-1})	11.00
Cu (mg kg^{-1})	6.50
Zn (mg kg^{-1})	6.20

Table 2: Physico-chemical characteristics of sewage sludge

Characteristics	Value
PH	8.00
EC_e (dS m^{-1})	2.39
Ca^{++}+Mg^{+}+(mg kg^{-1})	860.00
Cl^- (mg kg^{-1})	1681.00
CO_3^{-2} (mg kg^{-1})	Nil
HCO_3^- (mg kg^{-1})	787.00
SO_4^{-2} (mg kg^{-1})	158.00
Soluble Na (mg kg^{-1})	420.00
Available K(mg kg^{-1})	288.00
OM (mg kg^{-1})	194000.00
Total N (mg kg^{-1})	16000.00
Available P (mg kg^{-1})	70.00
Fe (mg kg^{-1})	250.00
Mn (mg kg^{-1})	210.00
Cu (mg kg^{-1})	260.00
Zn (mg kg^{-1})	640.00

treatment means were compared by Duncan's Multiple Range Test at 5% level of probability[11].

RESULTS AND DISCUSSION

Impact of sewage sludge on physico-chemical characteristics of the soil: Result of Table 3 revealed that sewage sludge slightly decreased the soil pH, which was a positive effect of sludge on the environment of the calcareous soil[12]. Electrical conductivity of the treated soil increased from 0.38 up to 1.50 dS m^{-1}[13]. Appreciably, high contents of macro and micronutrients like, NPK, Zn, Cu, Fe and Mn were also found in the soil treated with sewage sludge. The highest amount of Zinc (16 mg kg^{-1}), Copper (15 mg kg^{-1}), Iron (15.5 mg kg^{-1}) and Manganese (21 mg kg^{-1}) were recorded in the soil receiving 100 t ha^{-1} of sewage sludge. Maximum contents of Nitrogen (1600 mg kg^{-1}), Phosphorus (40 mg kg^{-1}) and Potassium (213 mg kg^{-1}) were also recorded in the treatments having sewage sludge @100 t ha^{-1}. Organic matter content of the soil also increased sufficiently from 8200 up to 10580 mg kg^{-1} with sewage sludge application. Improvement in soil aggregation, increase in soil aeration and favorable effects on different physico-chemical characteristics of the soil due to sewage sludge applications have been reported by dBridiand Zerrouk[2]. Accumulation of some heavy metal contents in plants and soil treated with high doses of sewage sludge were also reported by Aguilar *et al.*[14]. As the availability, mobility and chemical activity of heavy metals in soil depends on the nature of soil and its pH level, it was observed in the present investigation that due to calcareous nature of the soil the availability of heavy metals was sufficiently low. Huma[15] also reported that the increase in organic matter content, available P, exchangeable K, Fe, Mn, Zn and Cu were also reported in soil when treated with different rates of sewage sludge. Various scientists have recorded similar results during their experiments[16,17].

Plant height and spike length (cm): Application of different doses of sewage sludge along with NPK fertilisers brought significant changes in the plant height (Table 4). The maximum plant height (107 cm) was recorded in the treatment getting 80 t ha^{-1} sewage sludge followed by (106 cm) from the treatment receiving 100 t ha^{-1} of sewage sludge. Both of which were statistically at par with each other and with the treatments getting sewage sludge at the rate of 40 and 60 t ha^{-1}. The increase in plant height could be due to the abundant supply of organic matter, N, P and other nutrients by the sludge and also improvement in soil texture and structure due to sludge application. Al-Nahidh[18] have revealed similar results during their experiments.

Spike length is a genetic factor but it may be affected by the organic amendments. The Table 4 showed that all the treatments increased spike length significantly over control. Maximum spike length (11.50 cm) was reported in the treatment having 40 t ha^{-1} sewage sludge followed by the 11.40 cm from the treatments where sewage sludge was applied at the rate of 20 t ha^{-1}. However, both of them were statistically at par with each other and with the treatments receiving 60, 80 and 100 t ha^{-1} of sewage sludge. Minimum spike length (9.75 cm) was obtained from control. The increase in spike length could also be attributed to the higher amount of nutrients supplied by the sludge application. The results support the findings of Hernandaz *et al.*[19] and Mashhady[20] who reported increase in soil micronutrients and adequate supply of NPK due to the application of sewage sludge.

Number of tillers and productive tillers m^{-2}: Table 5 showed that maximum number of tillers m^{-2} (433) were recorded in the treatment getting 80 t ha^{-1} sewage sludge, which was statistically at par with treatments receiving 60 and 100 t ha^{-1} sewage sludge and was statistically

Table 3: Impact of sewage sludge on physico-chemical properties of the soil

Characteristics	Soil treated with sewage sludge (t ha^{-1})						
	0	10	20	40	60	80	100
pH	8.20	8.20	8.10	8.10	8.10	8.00	8.00
Ec_e (dS m^{-1})	0.38	0.85	0.98	1.12	1.28	1.36	1.50
Ca^{++}+Mg^{+}+(mg kg^{-1})	94.00	130.00	148.00	156.00	164.00	172.00	180.00
Cl^- (mg kg^{-1})	93.00	290.00	322.00	348.00	366.00	390.00	420.00
CO_3^{-2} (mg kg^{-1})	26.00	27.00	29.00	32.00	34.00	35.00	37.00
HCO_3^{-1} (mg kg^{-1})	100.00	205.00	230.00	262.00	296.00	310.00	330.00
SO_4^{-2} (mg kg^{-1})	27.00	38.00	50.00	53.00	54.00	54.00	55.00
Soluble Na (mg kg^{-1})	69.00	85.00	94.00	102.00	110.00	116.00	120.00
Available K (mg kg^{-1})	172.00	184.00	192.00	198.00	207.00	211.00	213.00
OM (mg kg^{-1})	8200.00	8910.00	9370.00	9540.00	9892.00	10300.00	10580.00
Total N (mg kg^{-1})	300.00	920.001	1080.00	1190.00	1310.00	1445.00	1600.00
Available P (mg kg^{-1})	7.50	16.00	22.00	29.00	34.00	38.00	40.00
Fe (mg kg^{-1})	5.40	9.00	11.00	12.00	14.00	14.50	15.50
Mn (mg kg^{-1})	11.00	13.00	14.00	16.00	18.00	19.50	21.00
Cu (mg kg^{-1})	6.50	10.00	11.00	12.50	13.00	14.00	15.00
Zn (mg kg^{-1})	6.20	11.00	12.00	13.00	13.50	15.00	16.00

Table 4: Effect of different levels of sewage sludge on the plant height and spike length

Treatments	Sewage sludge (t ha^{-1})	Plant height (cm)*	Spike length (cm)*
T_1	0	83.25d	9.75c
T_2	10	90.00c	10.75b
T_3	20	94.00b	11.40a
T_4	40	104.5a	11.50a
T_5	60	105.5a	11.25ab
T_6	80	107.0a	11.25ab
T_7	100	106.0a	11.00ab

*=Values followed by the same letters are not significantly different at ∝=0.05

Table 5: Effect of different levels of sewage sludge on the number of tillers and productive tillers (m^{-2})

Treatments	Sewage sludge (t ha^{-1})	No. of Tillers (m^{-2})*	No of Productive tillers (m^{-2})*
T_1	0	301.0e	245.0e
T_2	10	348.5d	297.0d
T_3	20	374.0c	345.0bc
T_4	40	416.5b	371.0a
T_5	60	422.0ab	352.5b
T_6	80	433.0a	347.0bc
T_7	100	423.0a	339.0c

* = Values followed by the same letters are not significantly different at ∝=0.05

different from the treatment getting 10, 20 and 40 t ha^{-1} of sewage sludge. Minimum value of 301 tillers m^{-2} was recorded in control. There was also non-significant difference between treatments receiving 40 and 60 t ha^{-1} of sewage sludge. It is revealed from the results that combination of sewage sludge and mineral fertilizer helped to increase the number of tillers m^{-2} because it affectively increased the availability of exchangeable Ca and Mg, lime potential in soils and phosphorous and Ca uptake by the wheat crop. These results were also in line with the findings of Tamura and Yaman[21], Rahman and Rashid[22].

Number of productive tillers m^{-2} is a factor directly contributing towards yield. The Table 5 showed that all treatments increased number of productive tillers m^{-2} significantly over control. Number of productive tillers m^{-2} (371) were maximum in the treatment receiving 40 t ha^{-1} of sewage sludge, followed by 352 from the treatment getting 60 t ha^{-1}. However the number of productive tillers m^{-2} recorded in treatments having sewage sludge at the rate of 20, 60 and 80 t ha^{-1} were statistically at par with each other but significantly different from the treatments receiving sewage sludge as 10 and 100 t ha^{-1}. Minimum number of productive tillers m^{-2} (245) was obtained from control. The increase in the number of productive tillers m^{-2} may also be due the improvement in soil texture, pH and availability of important crop nutrients. Huma[15] and Sugito *et al.*[23] also reported similar results.

Number of grains spike^{-1} and 1000-grain weight (g): Table 6 revealed a significant increase in the number of grains spike^{-1} with increasing levels of sewage sludge over control. Maximum number of 56.50 grains spike^{-1} were found in treatment receiving sewage sludge at the rate of 40 t ha^{-1} followed by 55.50 grains spike^{-1} recorded in the treatment receiving 60 t ha^{-1} of sewage sludge, which was statistically at par with the treatments getting sewage sludge at the rate of 20 and 60 t ha^{-1}. The minimum number of grains spike^{-1} (40.75) were recorded in untreated control. The number of grains spike^{-1} increased significantly in the treatments having sewage sludge because it improved the infiltration rate and organic matter along with NPK contents. Barbarick *et al.*[24] also reported similar results.

The maximum 1000-grain weight (45.92 g) was recorded in the treatment getting 40 t ha^{-1} of sewage sludge followed by the treatment (45.03 g) receiving 60 t ha^{-1} of sewage sludge, which were statistically at par with each other (Table 6). The minimum 1000-grain weight (36.17 g) was recorded in control getting no sewage sludge. 1000-grain weight in sludge treatments increased significantly over control due to the improvement in soil

Table 6: Effect of different levels of sewage sludge on the number of grains spike^{-1} and 1000-grain weight

Treatments	Sewage sludge (t ha^{-1})	No. of grains spike^{-1}*	1000-grain weight (g) *
T_1	0	40.75e	36.17e
T_2	10	47.50d	38.25d
T_3	20	55.00abc	41.63c
T_4	40	56.50a	45.92a
T_5	60	55.50ab	45.03ab
T_6	80	54.00bc	44.28b
T_7	100	53.00c	43.60b

* = Values followed by the same letters are not significantly different at ∝=0.05

Table 7: Effect of different levels of sewage sludge on the grain and straw yield

Treatments	Sewage sludge (t ha^{-1})	Grain yield (t ha^{-1}) *	Strawyield (t ha^{-1}) *
T_1	0	3.21e	5.80e
T_2	10	4.22d	7.22d
T_3	20	5.22c	8.00c
T_4	40	6.15a	8.70b
T_5	60	5.65b	9.30ab
T_6	80	5.20c	9.82a
T_7	100	5.10c	9.40a

* = Values followed by the same letters are not significantly different at ∝=0.05

fertility especially phosphorus and micronutrients like Zn and Cu. Lerch *et al.*[25] also recorded similar findings during their studies on sewage sludge.

Grain and straw yield: Result srevealed that all the different doses of sewage sludge increased the grain yield over control significantly (Table 7). Maximum grain yield 6.15 t ha^{-1} was obtained from treatment receiving 40 t ha^{-1} of sewage sludge followed by 5.65 t ha^{-1} from the treatment receiving 60 t ha^{-1} sewage sludge. Minimum grain yield 3.21 t ha^{-1} was recorded in control followed by 4.22 t ha^{-1} from the treatment getting sewage sludge at the rate of 10 t ha^{-1}. The treatments receiving sewage sludge at the rate of 20, 80 and 100 t ha^{-} showed no significant difference to each other. This increase in grain yield was probably in response to the available nutrients supplied by the addition of sewage sludge in combination with the commercial fertilizer. Modaihsh *et al.*[26] also recorded similar observations during their experiments.

The straw yield data also recorded significant increase (Table 7). Maximum straw yield 9.82 t ha^{-1} was obtained from the treatment which was added sewage sludge at the rate of 80 t ha^{-1} followed by 9.40 t ha^{-1} from the treatment getting 100 t ha^{-1} sewage sludge. The treatments receiving 60, 80 and 100 t ha^{-1} sewage sludge were statistically at par with each other. Control gave minimum 5.80 t ha^{-1} straw yield followed by 7.22 t ha^{-1} from the treatment receiving 10 t ha^{-1} sewage sludge. It showed that significant increase in the straw yield could be attributed to N, K and some other nutrients availability to the crop in sufficient amount. Mikhaeel *et al.*[27] and Gupta *et al.*[28] reported similar response from wheat and soil to different doses of sewage sludge.

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