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Influence of Sewage Sludge and Organic Manures Application on Wheat Yield and Heavy Metal Availability

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Abstract: A field experiment was carried out to see the effects of sewage sludge and organic manures on heavy metals availability and wheat yield. The treatments included, control, NP fertilizers @ 100-75 kg ha^{-1}, farmyard manure @ 25 t ha^{-1}, poultry manure @ 25 t ha^{-1} sewage sludge @ 25 t ha^{-1}, ½ FYM + ½ NP, ½ PM + ½ NP and ½ SS + ½ NP fertilizers. Highest increase in tiller length, number of grain spilke^{-1} and number of tiller plant^{-1} 106.3 cm, 55.3 and 305 respectively were observed in the plots treated with ½ PM + ½ FERT. Highest yield (3424 kg ha^{-1}) was obtained by the combined use of PM and NP-fertilizers (half the rate of each) followed by PM and NP-fertilizers applied singly. The results revealed that use of SS, PM, FYM or NP-fertilizers did not affect soil pH, EC_e, but application of SS and PM to soil increased soil organic matter considerably. The organic matter went up from 0.48 (control) to 1.08 % in case of sewage treated soil and to 1.28 % in case of PM amended soils. Sewage sludge and PM amended soils were found to have significantly higher Cd contents (two-fold) than those of control. Plant contents of Cd did not change significantly with the application of SS, PM, FYM or NP-fertilizers to the soil. AB-DTPA extractable Pb was significantly increased (two-fold) by the soil application of SS and PM. But these treatments did not affect Pb contents in plants. No significant differences among the treatments could be detected for extractable Ni and Cr in soil and leaves of wheat crop.

Key words: Sewage sludge, poultry manures, FYM, heavy metals, soil, wheat

Introduction

To sustain high yield, soil must contain adequate supply of nutrients. Due to continuous and intensive cultivation and the use of high yielding crop varieties with high nutrients demand, the nutrient supplying capacity of the soil is becoming a limiting factor. Traditional use of chemical fertilizers in agricultural production cannot be over emphasized, but with fertilizer costs going up, these need to be supplemented or substituted with available organic waste or manures.

One of the organic wastes which can be used as manure is sewage sludge. Sewage sludge 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 (Tisdale *et al.*, 1993), land application of sludge for crop production provides a feasible and cost effective disposal alternative. In USA, approximately one fourth of it is applied to land and in UK, in 1983, 43% of the sludge produced was applied to land and 30% dumped at sea (Alloway and Ayers, 1997). However, in sewage sludge, certain heavy metals may be present in excess and prove either phytotoxic (e.g. zinc, copper, nickle) or hazardous for human health (e.g. cadmium, lead, mercury) of special concern is cadmium which enters the food chain more readily than lead or mercury (Higgins, 1984). With large application of sludge, salts may also accumulate. In view of the above problems, use of sewage sludge for crop production needs precautions to avoid deterioration of soil quality, and its harmful effects on plants and human health. Sewage sludge is being generated at CDA sewage treatment plant; and being sold to nursery- men and farmers as organic manure. However, not much research studies have been conducted in the past with regard to its effects on heavy metals. It is therefore essential to know the effects of heavy metals additions in the soil and plants before its use on agriculture lands.

Poultry manure (poultry litter) is another source of nutrients, which is being produced by the poultry farms in large quantity in main towns of Pakistan. However, very limited research work on its use on field crops has been conducted and its comparative evaluation with the traditionally used farmyard manure and chemical fertilizers is required. Therefore, it was considered important to include this manure in this study. The objectives of these experiments were to study the comparative effects of farmyard manure, poultry manure, sewage sludge and chemical fertilizers on soil fertility and heavy metals contents in soil and wheat crop.

Materials and Methods

A field experiment was conducted on wheat at the University of Arid Agriculture Rawalpindi Research farm during 1999-2000. The experiment consisted of the following treatments:

Control, NP fertilizers @ 100-75 kg ha^{-1}, FYM @ 25 t ha^{-1}, poultry manure @ 25 t ha^{-1}, sewage sludge @25 t ha^{-1}, ½ FYM + ½ of above, given rates for NP fertilizers ½ PM + ½ of above given rates for NP fertilizers, ½ SS + ½ of above given rates for NP fertilizers.

The treatment plot size measured 5 x 3 m^2. The field was well prepared by cultivation and the experiment laid out according to the RCBD. Urea and di-ammonium phosphate were used for N and P, respectively. Poultry manure was procured from Poultry Research Institute, Rawalpindi. Aerobic digested SS was purchased from CDA Sewage Treatment Plant, Islamabad. The three manures were analyzed for macro and micro nutrients and heavy metals (Table 1). The manures were applied to the soil about 15 days before sowing of the crop so that they could undergo the process of decomposition and could release plant nutrients in time for crop requirement. Chemical fertilizers were applied just before sowing. After application of manures and NP fertilizers, these were thoroughly mixed in the soil with the spade. Wheat variety Kohistan-97 was sown and recommended cultural practices were observed during the growth of the crop.

Soil samples were collected with an agar from a depth of 0-15 cm before sowing and at earing stage from each treatment. Each soil sample was composite of three sub samples collected randomly. The samples were air dried in the laboratory, ground in mortar and pestle, sieved through 2 mm stainless steel sieve and stored in plastic containers for pH, EC, O.M, B.D and heavy metals (Cd, Pb, Ni, Cr) analyses. Plant samples were collected at earing stage. Each plant sample consisted of four upper most leaf from ten plant selected randomly in a treatment. The samples were washed with distilled water, dried in a forced draft oven at 65^{0}C for 48 hours and ground in a Wiley machine. The samples were stored in polyethylene container for heavy metals (Cd, Pb, Ni, Cr) analysis. Grain and straw yield data were collected from entire treatment plot and then converted in to kg ha^{-1}. The data collected for various variables was subjected to statistical analysis using analysis of variance techniques (Steel and Torrie, 1980). Significant treatment differences were determined by applying least significant difference (LSD) test.

Results and Discussion

Effect on soil pH, Electrical conductivity (EC_e), Organic matter and Bulk density (BD): The results revealed that use of SS, PM, FYM or NP-fertilizers did affect soil pH, EC_e, or the BD. The soil pH ranged from 7.5-7.6 and EC_e from 0.27- 0.35 dS m^{-1}(Table 2). Values for BD ranged from 1.32 to 1.50 Mg m^{-3}. This is evident from the data that application of SS and PM to soil increased soil organic matter considerably. The organic matter went up from 0.48 (control) to 1.08 % in case of sewage treated soil and to 1.28 % in case of PM amended soils (Fig. 1). Increases in OM were also reflected in treatments where FYM or NP-fertilizers were applied but to lesser extent. Comparatively higher increase in soil OM due to PM and SS could be the result of higher organic C in these manures (Moore *et al.*, 1995; Clapp *et al.*, 1986). Krause (1988) stated that high rates of sewage sludge improved the aggregate size and stability with the increases in soil organic matter. The above stated report support well the finding of this study.

Effect on heavy metals contents in soil and plants: The effect of sewage sludge on heavy metals will be discussed in comparison with the farm yard manure and poultry manure; considering them as safe organic sources as far as heavy metals contents are concerned. According to the data, it can be observed that sewage sludge had higher contents of all the four heavy metals to be discussed (Table 1).

Cadmium: The result having effect of various treatments on cadmium contents of soil (Table 3) and leaves of wheat (Table 4). The data ranged from 0.05-0.12. Sewage sludge and PM amended soils were found to have significantly higher Cd contents (two-fold) than those of control. Sewage sludge did not affect Cd in soil differently from poultry manure and farm yard manure. The results are in accordance with those of Lerch *et al.* (1990), who reported increase soil Cd-level over control in surface eight inches of soil. It is evident from the data that none of the treatment affected Cd-contents significantly in plant. However, these values i.e., 0.11-0.12 mg kg^{-1} were quite low when compared to the toxicity critical level of 1-3 mg kg^{-1} for Cd pollution in soil as recommenced for European Economic Communities (Couillard, 1994).

Plant contents of Cd did not change significantly with the application of SS, PM, FYM or NP-fertilizers to the soil, however, it concentrations tended to increase in the SS treatment soils. It could be related to the higher levels of Cd in SS treated soils. Cadmium concentrations in wheat leaves were found in the range of 0.56 to 0.93 mg kg^{-1}, the levels normally found in plants. These concentrations were quite below the toxicity levels (5-30 mg kg^{-1}) according to Alloway and Ayers (1997).

Lead: The result showing effect of sewage sludge application on Pb-contents of soil (Table 3) and leaves of wheat plant are given in Table 4. AB-DTPA extractable Pb was significantly increased (two-fold) by the soil application of SS, and PM. It may be due to the higher contents of Pb in the manures (Table 1). Where the values are 94.25 and 39.07 mg kg^{-1} in SS and PM respectively. In general, the Pb concentrations ranged from 0.99-2.54 mg kg^{-1}, which were far below the critical level for toxicity. Concentrations of

Table 1: Total concentration of heavy metals in poultry manure (PM) farm yard manure (FYM) and sewage sludge (SS)

Manures	Cd	Pb	Ni	Cr
	mg kg^{-1}			
PM	1.04	39.07	84.02	24.93
SS	1.06	94.25	102.10	82.34
FYM	0.86	46.60	103.28	50.66

Table 2: Effect of sewage sludge (SS), poultry manure (PM), farm yard manure (FYM) and NP fertilizers on soil pH, ECe, organic matter (OM) and bulk density (BD)

Treatment	pH	ECe (dS m^{-1})	OM(%)	B.D (Mg m^{-3})
Control	7.5	0.33	*0.48e	1.46
NP@100-75kg ha^{-1}	7.5	0.27	0.80d	1.32
SS@25t ha^{-1}	7.5	0.27	1.08b	1.46
FYM@25t ha^{-1}	7.5	0.32	0.90cd	1.45
PM@ 25 t ha^{-1}	7.6	0.28	0.28a	1.49
½SS + ½Fertilizer	7.7	0.30	0.86cd	1.48
½FYM + ½Fertilizer	7.6	0.35	0.57e	1.37
½PM + ½Fertilizer	7.6	0.33	0.96c	1.50
LSD $_{0.05}$	NS	NS	0.11	NS

NS= Non significant * The means followed by common letters in each column are not significantly different from each other at 5% level of probability.

Table 3: Effect of sewage sludge (SS), poultry manure (PM), farm yard manure (FYM) and NP fertilizers on cadmium, lead, nickel, chromium contents (mg kg^{-1}) in soil.

Treatments	Cadmium	Lead	Nickel	Chromium
Control	*0.05bc	*0.99b	0.97	2.29
NP @ 100-75 kg ha^{-1}	0.07b	1.89ab	0.92	1.78
SS @ 25 t ha^{-1}	0.12a	2.22a	0.91	3.64
FYM @ 25 t ha^{-1}	0.05bc	1.05b	0.89	2.99
PM @ 25 t ha^{-1}	0.11ab	2.54a	0.91	4.13
½ SS + ½Fertilizer	0.10ab	1.59ab	0.91	2.94
½ FYM + ½Fertilizer	0.04c	0.88b	1.02	3.04
½ PM + ½Fertilizer	0.09b	1.03b	0.91	1.07
LSD $_{0.05}$	0.02	0.43	NS	NS

NS= Non significant * The means followed by common letters in each column are not significantly different from each other at 5% level of probability.

Table 4: Effect of sewage sludge (SS), poultry manure (PM), farm yard manure (FYM) and NP fertilizers on cadmium, lead, nickel, chromium contents (mg kg^{-1}) in wheat plants.

Treatment	Cadmium	Leaf	Nicked	Chromium
Control	0.57	3.56	7.2	3.8
Np@100-75 kg ha^{-1}	0.56	2.78	6.2	4.5
SS @ 25 t ha^{-1}	0.93	3.06	8.9	3.1
FYM @ 25 t ha^{-1}	0.73	3.00	6.9	3.2
PM @ 25 t ha^{-1}	0.63	2.62	6.2	4.4
½ SS + ½Fertilizer	0.75	2.92	8.9	3.4
½ FYM + ½Fertilizer	0.69	3.23	7.1	3.4
½ PM + ½Fertilizer	0.66	2.30	7.1	4.0
LSD $_{0.05}$	NS	NS	NS	NS

NS= Non significant * The means followed by common letters in each column are not significantly different from each other at 5% level of probability.

Table 5: Effect of sewage sludge (SS), poultry manure (PM), farmyard manure (FYM) and NP fertilizers on wheat yield

Treatments	Yield (kg ha^{-1})
Control	*1556d
NP@100-75kg ha	3086a
SS@25t ha^{-}	2267bc
FYM@25t ha^{-1}	1756cd
PM@ 25 t ha^{-1}	3356a
½SS + ½Fertilizer	2467b
½FYM + ½Fertilizer	2089bc
½PM + ½Fertilizer	3424a
LSD $_{0.05}$	519

NS= Non significant * The means followed by common letters in each column are not significantly different from each other at 5% level of probability.

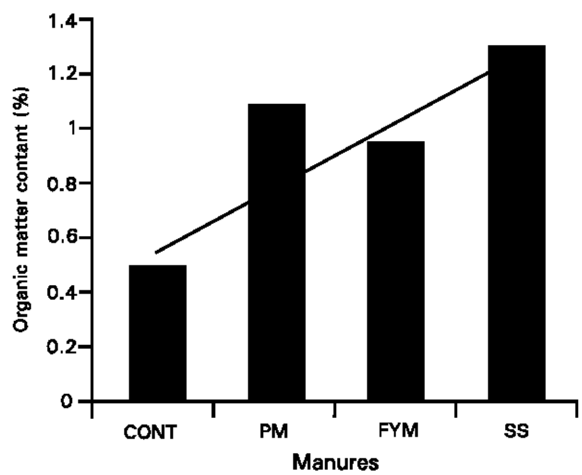

Fig.1: Effect of sewage sludge (SS), poultry manure (PM) and farm yard manure (FYM) on organic matter contents in soil.

more than (100 mg kg^{-1}) of AB-DTPA extractable Pb have been considered harmful for human beings according to Soltanpour (1985). The maximum Pb found in the present study was found far below this level, which illustrated no Pb risk in the land use the SS under evaluation.

Different treatments did not affect Pb contents in plants although these treatments increased Pb concentrations in soil significantly especially in SS and PM treated soils. The Pb concentrations were found in the range of 2.62 to 3.56 mg kg^{-1} which are considered normal for plants; these were however, far below the toxic levels (30-300 mg kg^{-1}) as reported by (Alloway and Ayers, 1997) for plants.

Nickel: The data involving the effects of various treatments on nickel contents in soil (Table 3) and plant show that various treatments did not cause significant increase in the contents of extractable soil Ni (Table 4). Concentrations of Ni were in the range of 0.89 to 1.02 mg kg^{-1} demonstrating very low levels when compared to the maximum permissible limit of 20 mg kg^{-1} for toxicity as suggested by UK Department of Environment (Alloway and Ayers, 1997). The results of this study demonstrate that Ni was quite low in experimental soils from the point of view of its toxicity.

Plant Ni was not affected significantly by any treatment as was the case with the soil Ni, which was also not changed in the treated soils. It is also noted that SS, PM or FYM did not contain significantly different levels of Ni in them (Table 1). The concentrations in plants in general in the various treatments varied from 7.2 to 8.9 mg kg^{-1} which were below the critical levels for its toxicity (10-100 mg kg^{-1}) as reported by Alloway and Ayers (1997). It is seen from the results that many values exceeded the lower limits of toxicity and demands that Ni contents in the plants be monitored off and on.

Chromium: The data corresponding to the effects of sewage sludge and the other treatments on Ni-contents of soil (Table 3) and wheat leaves are given in Table 4. No significant differences among the treatments could be detected for extractable Cr in soil, however, Cr concentration tended to increase in case of soil treated with SS or PM. Overall values were found in the range of 1.07 to 4.13 mg kg^{-1}. These concentrations were quite low when compared to the maximum permissible limit of 25 mg kg^{-1} set for extractable Cr in soil by UK Department of Environment (Alloway and Ayers, 1997). Although SS contained comparatively more Cr than PM or FYM (Table 1) yet the addition of these organic materials did not affect soil Cr correspondingly.

The effect of different treatments on plant Cr was non-significant, as was the case with Cr in soils. According to Table 1, the three organic materials, however, differed significantly in their Cr contents; SS having highest contents followed by FYM. The plant concentrations of Cr were found in the range of 3.1 to 4.5 mg kg^{-1} across the treatments. The normal range in plants is considered 0.03-14.0 mg kg^{-1}, while the toxic concentrations fall between 5-30 mg kg^{-1} (Alloway and Ayers, 1997). This suggests that plant Cr in this study was in the normal range.

From the soil and plant analysis, it is illustrated that SS did not differ from other commonly used organic manures (PM and FYM) and fertilizers in effect on Cr in soil as well as in plants.

Effect on grain yield of wheat: Effect of different treatments on yield of wheat grain was found highly significant (Table 5). Highest yield (3424 kg ha^{-1}) was obtained by the combined use of PM and NP-fertilizers (half the rate of each) followed by PM and NP-fertilizers applied singly. These three treatments were, however, statistically non-significant among themselves. The yield increases over control due to these treatments were 120, 116 and 99% for ½ PM + ½ NP, PM alone and NP-fertilizers, respectively.

Sewage sludge either alone or in combination with NP-fertilizer at reduced rates caused significant increase (46-59%) over control. Farmyard manure when applied alone, did not increase the yield but it improved the yield over control significantly (34%) when applied to soil along with NP-fertilizers at half the rates of each. These results indicate that SS was able to improve wheat yield and was next to PM and NP fertilizers in this regard. The results also illustrate that FYM alone may not increase the yield, however, if supplemented with NP-fertilizers at reduced rates can perform better.

Nitrogen and Phosphorus contents of poultry manure (PM), farm yardmanure (FYM) and sewage sludge (SS) are given in Table 1, which shows that poultry manure had higher NP contents (4-5 times) than the farm yard manure and sewage sludge, therefore, it could meet the NP requirements of wheat crop when applied alone. On the other hand FYM and sewage sludge had less NP contents, so they require supplemental NP for giving yield equivalent to poultry manure. Campbel *at al.* (1983) reported that application of sewage sludge increased the dry weights and yield of wheat crop. The results revealed that use of SS, PM, FYM or NP-fertilizers did not affect soil pH, EC_e, but application of SS and PM to soil increased soil organic matter considerably. The organic matter went up from 0.48 % (control) to 1.08 % in case of sewage treated soil and to 1.28 % in case of PM amended soils. Sewage sludge and PM amended soils were found to have significantly higher Cd contents (two-fold) than those of control. Plant contents of Cd did not change significantly with the application of SS, PM, FYM or NP-fertilizers to the soil. AB-DTPA extractable Pb was significantly increased (two-fold) by the soil application of SS and PM. But these treatments did not affect Pb contents in plants. No significant differences among the treatments could be detected for extractable Ni and Cr in soil and leaves of wheat crop. Highest yield (3424 kg ha^{-1}) was obtained by the combined use of PM and NP-fertilizers (half the rate of each) followed by PM, and NP-fertilizers applied singly. From the over all results, it can be concluded that soil application of sewage sludge did not cause toxicity of heavy metals in soil and plants, however, it tended to increase the metals in isolated cases. It did not affect soil pH or salinity. The use of sludge improved organic matter

Farmers are therefore, advised to use sewage sludge and farmyard manure in combination with fertilizers @ half of the recommended doze of each. Since the sewage sludge has shown increasing trend in heavy metals contents in soil, it is recommended that monitoring of soil heavy metals, by soil testing should be carried out in case sewage sludge is used continuously on a farm for many years.

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