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Effect of sewage sludge on soil properties, productivity and accumulation of nutrients and heavy metal *in* fenugreek *(Trigonella foenum-graceum)* and their availability in soil

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ABSTRACT

A field experiment was conducted during rabi season of 2009-11 at crop research farm, SHIATS, Allahabad (U.P.) to evaluate the effect of treated slude application on crop productivity and accumulation of micronutrients and heavy metals in plant and soil using fenugreek (Trigonella foenum-graceum) as a test crop. The experiment was laid out in randomized block design with four levels of sewage sludge (0, 10, 15 and 20 t ha^{-1}) and five replications.The results revealed that the green foliage and dry matter yield of fenugreek increased significantly by application of sewage sludge. Highest green foliage (10.61 t ha^{-1}) and dry matter (2.14 t ha^{-1}) yields were recorded in the treatment where 20t ha^{-1}sludge was applied. Similarly, the micronutrient and heavy metal accumulation by fenugreek plants were greater in the treatment receiving higher levels of sewage sludge application. But the accumulation of Zn and heavy metal in plants was within the permissible limits. Application of sewage sludge tended to reduce the bulk density, particle density and soil pH over control. EC of post harvest soil was not affected but CEC increased significantly with increasing levels of sludge addition. Soil amended with sewage sludge resulted in significant increase in status of organic carbon, available N, P and K in post harvest soil. There was a buildup of DTPA- extractable micronutrients (Fe and Zn) and heavy metals in soil over control with the application of sewage sludge. And maximum values of Fe (6.66 mg kg^{-1}), Zn (1.20mg kg^{-1}), Cd (0.79 mg kg^{-1}), Pb (0.86 mg kg^{-1}) and Cr (1.16 mg kg^{-1}) were recorded with 20 t sludge ha^{-1}.

Keywords: Sewage sludge, micronutrients, heavy metals, fenugreek yield accumulation

INTRODUCTION

The sewage and sludge constitute the liquid and solid wastes, respectively generated from the waste water treatment plants. Application of municipal sewage sludge to agricultural land has many beneficial effects including improved soil physical properties, supply of essential nutrients and build up of organic matter in soils. Use of sewage sludge helped in improving the soil structure, increased the water infiltration rate, aggregate stability and water holding capacity of the soil. Utilization of sewage sludge is source of organic manure provides nutrients to crops on one hand and paves the means and ways for safe disposal of sewage through treatment and avoids potential environmental hazands. Yields of palak (Roy *et al.* 2013) and rice (Latare and Singh 2013) also improved as a result of sewage sludge application. But there are also some concerns that need to be addressed to ensure a safe, economical and environmentally sound approach for land application of sludge. One of the major concerns that limits its use in agriculture is the contamination of soils with heavy metals like Cd, Cr, Ni, Pb etc., which may accumulate in considerable amounts in plant tissues beyond the levels that become toxic to animal or human beings before they produce visible phytotoxic effects. The behavior of heavy metals present in sewage sludge and industrial wastes that are used in agriculture has been the centre of much attention during the last decade. Fenugreek (Trigonella foenum-graceum) is an important condiment crop. The crop has immense medicinal value and is a good source of vitamin, protein and essential oils. It is very pertinent to assess the impact of sewage sludge application on yield, accumulation of micronutrients and heavy metals in plant tissue and their availability and build up in soil. Limited studies have been conducted to work out effect of sewage sludge on yield and accumulation of heavy metals in vegetable crops.The present study was undertaken to examine the effect of digested sludge application to soil on availability of nutrients and heavy metals in fenugreek and soil property.

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MATERIALS AND METHODS

Sewage sludge sample was collected from waste water treatment plant located in Naini, Allahabad (U.P.) during September, 2009. The sludge sample are dried in shade, ground to pass through 2mm sieve and used in field experiment. The characteristics of sewage sludge are presented in Table 1. Field experiment was conducted during rabi season of 2009-11 at crop research farm SHIATS, Allahabad (25^0 18^1 N latitude and 81^0 50^1 E longitude at an altitude of 98 meter above the mean sea selevel). The experimental soil was sandy loam in texture, pH 7.7, EC 0.37 dSm^{-1} organic carbon 5.2 g kg^{-1}, available N 182 kg ha^{-1} available P 16.3 kg ha^{-1} K 239 kg ha^{-1}, DTPA extractable Fe, Zn, Cr, Cd, Pb, 3.3, 0.82, 0.96, 0.61 and 0.55 mg kg^{-1}, respectively. The treatment consisted of four levels of sewage sludge i.e. 0, 10, 15 and 20 t ha^{-1}. The experiment was laid out in randomized block design with five replications. The recommended dose of N, P and K (50 kg N + 130 kg P_2O_5 + 80 kg K_2O ha^{-1}) was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Fenugreek (Var Pusa early bunching) was sown in the first week of December during both the years. Irrigation was given as and when required the crop was harvested after 40 days of sowing.The harvested plants were washed with double distilled water, dried at 70° C, weighed, crushed in a stainless steel grinder and stored in glass vials for chemical analysis. Soil samples were also collected after harvest of the crop. These soil samples and sludge were analysed for nutrients and heavy metals by adopting standard procedures . Soil, sludge and plant samples were digested in a di-acid mixture of HNO_3 : $HClO_4$ (2:1). Soil samples were extracted with DTPA (Lindsay and Norvell 1978) and the contents of Cd, Cr, Zn, Fe in digest/filtrate of soil, di-acid extract of soil, sludge and plant samples were determined by using atomic absorption spectrophotometer. The EC, pH, organic carbon, available, N, P and K in post harvest soil were determined by adopting standard procedures (Jackson 1973). The trend of result was similar during both the years; hence, data were subjected to pooled analysis for results and discussion.

RESULTS AND DISCUSSION

Quality of sewage sludge

Data (Table 1) reveal that the sewage sludge was slightly acidic in nature. Soluble salts concentration was1.87 dSm^{-1}. Sewage sludge contained 26.8 g kg^{-1} organic carbon, 3.08% total nitrogen 1.47% total P, 0.84% total K, 3.12% total Ca and 0.64% total magnesium. The concentrations of total Fe (842.2 mg kg^{-1}), total lead (548.3 mg kg^{-1}), total cadmium (512.1 mg kg^{-1}), total chromium (521.5 mg kg^{-1}) and total Zn (775.4 mg kg^{-1}) were above the standard limits permissible for land use.

Table1: Characteristics of sewage sludge

Parameters	Value
pH (Sludge water 1 : 5)	6.58
EC (dSm^{-1})	1.87
Organic Carbon (g kg^{-1})	26.8
Total Nitrogen (%)	3.08
Total Phosphorus (%)	1.47
Total Potassium (%)	0.84
Total Calcium (%)	3.12
Total Magnesium (%)	0.64
Total Iron (mg kg^{-1})	842.2
Total Lead (mg kg^{-1})	548.3
Total Cadmium (mg kg^{-1})	512.1
Total Chromium (mg kg^{-1})	521.5
Total Zinc (mg kg^{-1})	775.4

Yield

The green foliage and dry matter yields of fenugreek increased significantly with levels of sludge over control (Table 2). The increase in green foliage yield with levels of sewage sludge ranged from 24.1 to 83.9 % over control and that of dry matter yield from 27.3 to 82.9 percent. The maximum yields of green foliage (10.61t ha^{-1}) and dry matter (2.14t ha^{-1}) were recorded with 20t sludge ha^{-1} The increase in yields could be explained on the basis of better nutritional environment of soil with the application of sludge. The results are in conformity with the findings of Bhat *et al.* (2011) and Roy *et al.* (2013).

Heavy metal content in plants

Soil application of sludge increased the concentration of one or more of the metals in plants over control (Table 2). Cadmium was absorbed in highest amount (0.16 mg kg^{-1}) by plants with 20t sludge ha^{-1} addition. Chromium content in plants increased from 0.19 mg kg^{-1} at control to 0.32 mg kg^{-1} with 20t sludge ha^{-1}. The corresponding increase in lead content was from 0.14 to 0.24 mg kg^{-1}. Increase in heavy metal concentration in plants has been reported in several experiments where sludge was applied to the soil (Bhat *et al.* 2011, Roy *et al.* 2013). Overall, highest plant metal levels (0.16 mg kg^{-1} Cd, 0.32 mg kg-1Cr and 0.24 mg kg^{-1} Pb) observed with sludge application were below the tolerance levels of the crop quoted by Melsted (1973) and Chang *et al.* (1992). Zinc content in fenugreek plants ranged from 28.5 to 47.1 mg $^{kg-}$ 1, the lowest and maximum contents being in control and 20t sludge ha^{-1}, respectively. Roy *et al.* (2013) reported significant enhancement in the Zn concentration in the foliage due to application of sludge which is tune with our results.The sewage sludge conained high concentration of Zn which resulted in higher concentration of Zn in fenugreek leaves. The fenugreek crop is consumed as leafy vegetable and after use as an Zn supplement by the people of suburban and urbans (Sharma *et al.* 2007). Therefore higher content of Zn in fenugreek leaves as obtained in the present study is good for human consumption.

Table 2: Effect of sewage sludge on yield and micro nutrients and heavy metal content in fenugreek (mean of two years)

Sludge (t ha^{-1})	Green foliage yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Chromium (mg kg^{-1})	Lead (mg kg^{-1})	Cadmium (mg kg^{-1})	Zinc (mg kg^{-1})
0	5.77	1.17	0.19	0.14	0.10	28.5
10	7.16	1.49	0.22	0.16	0.11	32.2
15	7.90	1.70	0.25	0.20	0.13	37.1
20	10.61	2.14	0.32	0.24	0.16	47.1
SEm $\pm$	0.30	0.11	0.004	0.005	0.005	0.37
CD (P=0.05)	0.64	0.23	0.010	0.011	0.011	0.80

Soil Properties

Bulk density and particle density of post harvest soil decreased from 1.46 to 1.38 Mg m^3 and 2.62 to 2.60 Mg m^3.Thus, use of sewage sludge significantly reduced the densities over control. Lowering of bulk density and particle density is due to increase in organic carbon which results in more pore space and good soil aggregation. The soil pH decreased from the initial levels of 7.74 to 7.59 with the application of 20 t sewage sludge ha^{-1} (Table 3). This could be due to the movement of Na to lower depths owing to its replacement by Ca, particularly as a result of beneficial effect of sewage sludge. EC of the soil was not affected significantly with the levels of sewage sludge application.The soil organic carbon was significantly greater in plots receiving sewage sludge over the control. The mean organic carbon increased to 6.3 g kg^{-1} in 20t sludge ha^{-1} treated plots as compared to that of 5.1 g kg^{-1} in control. Beneficial effect of sewage sludge application was related to the incorporation of organic material in the soil and increase in number and activity of micro organism and better regulation of organic carbon dynamics in soil. Cation exchange capacity of post harvest soil improved significantly with sewage sludge application and maximum value of CEC was recorded with 20t sludge ha^{-1}(Singh *et al.* 2015).

Table 3: Effect of sewage sludge on physico chemical properties of post harvest soil (mean of 2 years)

Sludge (t ha^{-1})	Bulk density (Mg/m^3)	Particle density (Mg/m^3)	pH	EC (dSm^{-1})	Organic Carbon (g kg^{-1})	CEC (c mol kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
0	1.46	2.62	7.74	0.38	5.1	15.52	183.9	19.8	234.1
10	1.44	2.62	7.70	0.40	5.9	15.61	192.9	21.4	240.9
15	1.40	2.62	7.65	0.39	6.1	15.66	199.1	25.2	247.4
20	1.38	2.60	7.59	0.40	6.3	15.70	211.4	29.5	251.8
SEm $\pm$	0.06	0.02	0.007	0.01	0.005	0.006	0.46	0.71	0.94
CD (P=0.05)	0.012	NS	0.014	NS	0.11	0.014	0.99	1.51	2.00

Status of nutrients in soil

Available N increased in treatments receiving sewage sludge over control (Table3). The status of available N in sewage sludge treated soil was significantly higher over control. The results clearly indicate that the sewage sludge helped to increase the status of available N in the soil.Available P content of the post harvest soil by increased significantly by application of sewage sludge over control. Increased available N and P use of sewage sludge may be attributed to increased availability in soil due to sludge application. Available K content in post harvest soil increased in treatments receiving sewage sludge over control. The build-up of soil availble K due to application of sewage sludge may be due to additional K applied through it and also solubilization action of certain organic acids produced during decomposition and greater capacity to hold K in the available form (Serwat *et al.* 2015, Singh *et al.* 2015).

Table 4: Effect of sewage sludge on nutrients and heavy metals in post harvest soil mean of 2 years

Sludge ($t\ ha^{-1}$)	DTPA-Fe ($mg\ kg^{-1}$)	DTPA-Cd ($mg\ kg^{-1}$)	DTPA-Pb ($mg\ kg^{-1}$)	DTPA-Cr ($mg\ kg^{-1}$)	DTPA-Zn ($mg\ kg^{-1}$)
0	3.33	0.53	0.50	0.88	0.66
10	4.45	0.66	0.60	1.01	0.75
15	5.52	0.74	0.73	1.08	0.95
20	6.66	0.79	0.86	1.16	1.20
SEm $\pm$	0.019	0.010	0.012	0.008	0.026
CD (P=0.05)	0.040	0.022	0.025	0.018	0.055

Build up of heavy metals

The data on DTPA extractable micronutrients and heavy metals in soil are presented in Table 4. DTPA-Fe in soil ranged from 3.33 mg kg^{-1} soil in control to 6.66 mg kg^{-1} soil in 20t sludge ha^{-1} treatment. The values of DTPA-Fe in soil increased significantly due to application of sewage sludge over control. Higher DTPA-Fe in soils treated with sewage sludge may be due to higher mineralization and release of organically bound metals which caused higher availability in soil. In case of Zn also higher amount of DTPA-Zn (1.20 mg kg^{-1}) was present in all the treatments where sludge was incorporated compared to those where no addition of sludge had occurred. A perusal of data (Table 4) revealed that only small fractions of total quantities of Cd, Cr and Pb added through digested sludge to soil were extractable with DTPA which increased almost linearly with the increasing sludge rate. A maximum amount of 0.79 mg Cd, 1.16 mg Cr and 0.86 mg Pb kg^{-1} extractable with DTPA was observed with the highest rate of sludge application with out any visible toxicity symptoms in the plants.The increased extractability of metals with increasing rates of sludge application may be due to decrease in soil pH caused by the addition of sludge-borne organic matter (Roy *et al.*2013). In addition, the sewage sludge contained higher amounts of these heavy metals which resulted in higher concentration of these metals in soil.

From the results, it may be concluded that the treated sewage sludge can be used as a source of plant nutrients. Its application to soil brought about an increase in the yields of ferugreek over control. The sewage sludge resulted in increased accumulation of all the major and micronutrients and heavy metals in plants and soils. Thus, sewage sludge can be applied as a good supplement of N, P and K and organic matter for crop production but care should be taken for the presence of heavy metals for long term use.

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