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Effect of sewage sludge application on spinach *(Spinacia oleracea L)* yield, soil properties and heavy metal availability in soil

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ABSTRACT

A field experiment was conducted during rabi seasons of 2009-10 and 2010-11 at SHIATS, Allahabad (U.P.) to study the effect of sewage sludge on yield and heavy metal accumulation in spinach (Spinacia oleracia L) and soil. Four doses of sewage sludge (0, 10, 15 and 20t ha^{-1}) with five replications were evaluated in randomized block design. Results of this study showed a significant increase in plant height, green foliage and dry matter yield of spinach over control. About 9.84 t ha^{-1}more green foliage yield was observed over control in the treatment where 20t sewage sludge ha^{-1} was applied. Application of sewage sludge significantly increased the concentrations of Cr, Cd and Pb content in spinach plants over control. But the accumulation of Zn and heavy metals in plants was within the permissible limits. Zinc content in spinach plants also significantly improved with sewage sludge application. Soil organic carbon increased in post harvest soil with application of sewage sludge. Soil amended with sewage sludge resulted in marked decrease in bulk density, particle density and soil pH over control. EC of post harvest soil was not affected but CEC improved significantly with increasing doses of sludge application. Available N was highest in treatment receiving 20t sewage sludge ha^{-1}. Available P and K increased by 43.0 and 7.0% over control with 20t sewage sludge ha^{-1}, respectively. Application of sewage sludge resulted in significant build up in DTPA-extractable micro nutrients and heavy metals in post harvest soil and maximum values of Fe (6.7 mg kg^{-1}), Zn (1.32 mg kg^{-1}), Cd (0.87 mg kg^{-1}), Pb (0.90 mg kg^{-1}) and Cr (1.20 mg kg^{-1}) were recorded with 20 t sewage ha^{-1}.

Keywords: Sewage sludge, spinach, heavy metal accumulation, plant, soil.

INTRODUCTION

One of the organic wastes which can be used as manures is sewage sludge. Large scale urbanization is leading to production of huge quantities of effluents in our country and posing serious environmental problems for their disposal. Sewage sludge is a product of sewage treatment plant and results from removal of solids and organic matter from the sewage. Sewage sludge, being organic waste, is a good source of plant nutrients as well as other organic constituents. Land application of sludge for crop production provides a feasible and cost effective alternative disposal means. However, sewage sludge and effluents may contain high amount of toxic heavy metals such as Pb, Cd, Ni, Cr and Hg due to the mixing of industrial waste water with sewage (Singh and Agarwal 2007and Roy *et al.* 2013). Spinach (*Spinacia oleracia*) is an important leafy vegetable crop which is consumed most of the people of our country. 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 the effect of sewage sludge on yield and accumulation of heavy metals in vegetable crops. Hence the present study was undertaken to investigate the effect of sewage sludge on yield of spinach and to study the accumulation of heavy metals in leaves and soil properties.

MATERIALS AND METHODS

Sewage sludge sample was collected from waste water treatment plant located in Naini, Allahabad (U.P.) during September, 2009. The sludge samples were air dried in shade, ground to pass through 2 mm sieve and used in field experiment. The characteristics of sewage sludge are presented in Table 1. The 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 level). 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 (90 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. Spinach (Var. All green) 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 analyzed 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, 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 results 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 green in 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: Plant height of spinach crop ranged from 11.1 cm at control to 15.9 cm with 20t sludge ha^{-1}. The tallest plants of spinach crop were recorded with 20t sewage sludge ha^{-1}. This increase in plant height may be attributed to improved environment of rhizosphere in respect to physico- chemical properties and nutrition status. The green foliage yield of spinach increased significantly by supplying sewage sludge at 20t ha^{-1} over control. Maximum green foliage yield (19.93 t ha^{-1}) imparted by 20t sewage sludge ha^{-1} which has yielded 110.6 % higher than control. Lowest green foliage yield (9.16 t ha^{-1}) was recorded in control (Table 2). This increase in yield with the application of sewage sludge might be attributed to increased number of leaves. Higher yield in sewage sludge treated crops are usually attributed to an improvement in the soil conditions by the supply of additional organic carbon from the sludge. Roy *et al.* (2013) also reported an increase in green foliage yield of palak. Dry matter yield of spinach ranged from 1.51 to 3.19 t ha^{-1} (Table 1). The lowest yield (1.51t ha^{-1}) was recorded with control and maximum (3.19 t ha^{-1}) with 20t sludge ha^{-1}. The increase in yield might be due to improvement in the soil fertility with application of sewage sludge (Latare and Singh, 2013).

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

Sludge ($t\ ha^{-1}$)	Plant height (cm)	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	11.1	9.16	1.51	0.17	0.11	0.12	26.2
10	12.8	12.39	2.13	0.20	0.12	0.13	30.3
15	14.1	14.07	2.47	0.23	0.16	0.17	35.2
20	15.9	19.93	3.19	0.29	0.21	0.20	44.9
SEm $\pm$	0.25	2.74	0.07	0.003	0.004	0.007	0.39
CD (P=0.05)	0.49	5.85	0.15	0.007	0.009	0.014	0.84

Heavy metals in plants: The Cd content in spinach crop (Table 2) showed a significant effect with graded application of sewage sludge. Its content varied between 0.12 and 0.20 mg kg^{-1} in plants, maximum was recorded in 20t sewage sludge ha^{-1} treatment and minimum in control. The increase in Cd content in spinach plants may be attributed to the higher concentration of Cd in sewage sludge. The Cd concentration in spinach crop was below the phytotoxicity levels (5-30 mg kg^{-1}) as reported by Alloway and Ayers (1991) and Indian safe limit as suggest by Awashthi (2000).The Cr content in spinach plants ranged from 0.17 to 0.29 mg kg^{-1}. The maximum (0.29 mg kg^{-1}) and minimum (0.17 mg kg^{-1}) values were recorded with 20t sludge ha^{-1} and control, respectively. The normal range of Cr in plants ranged from 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 chromium content in this study was in the normal range. Similar results were reported by Bhat *et al.* (2011).Lead content in spinach plants ranged from 0.11to 0.21 mg kg^{-1}, the maximum (0.21 mg kg^{-1}) was recorded with 20 kg sludge ha^{-1}. The Pb concentration in plants was far below the toxic levels (30-300 mg kg^{-1}) as reported by Alloway and Ayers (1997) for plants. Singh and Agrawal (2010) found that sewage sludge treatment above 45 t ha^{-1} though increased the yield of rice but caused risk of food chain contamination as concentrations of Cd in rice grain were found above the Indian safe limits (1.5mgkg^{-1}) of human consumption above 45 t sludge ha^{-1} and Pb (2.6mgkg^{-1}) above 60t sludge ha^{-1}. The accumulation of heavy metals by plants depends on various factors such as soil physico- chemical properties, sewage sludge composition; application rate of sludge, plant species, climatic factors (Mahdy *et al.* 2007). Zinc content in spinach plants increased significantly with sludge application over control. Zinc content in plants ranged from 26.2 to 44.9 mg kg^{-1} and maximum value was recorded with 20t sewage sludge ha^{-1}. The increase in Zn content in plants may be attributed to the higher concentration of zinc in sewage sludge. Similar results were reported by Roy *et al.* (2013) in palak.

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	1.47	2.63	7.7	0.40	4.8	15.54	177.4	18.8	237.2
10	1.44	2.61	7.7	0.41	5.6	15.64	189.8	21.6	244.4
15	1.41	2.60	7.6	0.40	5.9	15.69	196.1	23.8	249.1
20	1.39	2.60	7.5	0.42	6.3	15.73	204.9	26.9	253.8
sEm $\pm$	0.003	0.003	0.011	0.03	0.009	0.008	4.20	0.79	1.85
CD (P=0.05)	0.006	0.007	0.023	0.NS	0.019	0.017	8.90	1.70	3.42

Soil Properties

Bulk density and particle density of post harvest soil decreased ranged from 1.47 to 1.39 Mg m^3 and 2.63 to 2.60 Mg m^3. 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 7.7 to 7.5 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 4.8 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}.

Available N, P and K in soil: Available N increased in treatments receiving sewage sludge over control (Table 3). 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 increased significantly by application of sewage sludge over control. Increased available N and P by 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 available 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 (Sarswat *et al.* 2015 and Singh *et al.* 2015).

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

Sludge (Ton 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	3.4	0.58	0.52	0.94	0.78
10	4.8	0.70	0.63	1.06	0.84
15	5.2	0.80	0.78	1.13	1.06
20	6.7	0.87	0.90	1.20	1.32
SEm $\pm$	0.022	0.008	0.013	0.015	0.018
CD (P=0.05)	0.046	0.017	0.029	0.031	0.039

Heavy metals in soils: DTPA-extractable Cd content in post harvest soil increased from 0.58 mg kg^{-1} at control to 0.87 mg kg^{-1} with 20t sewage sludge ha^{-1}. The concentration of phytoavailable Cd in this study was within the Indian permissible limit of 3-6 mg kg^{-1} (Awashthi 2000). Singh and Agrawal (2010) reported similar results. DTPA-extractable Cr in post harvest soil ranged between 0.94 and 1.20 mg kg^{-1} where maximum (1.20 mg kg^{-1}) amount was recorded with 20t sewage sludge ha^{-1}. Thus, there was a significant increase in DTPA-Cr in soil with graded levels of sewage sludge. Latare and Singh (2013) reported similar increase in chromium content with sewage sludge application. The concentration obtained in this study was very low as compared to the maximum permissible limit of 25 mg kg^{-1} (Alloway and Ayers, 1994) DTPA-extractable lead content in post harvest soil varied between 0.52 and 0.90 mg kg^{-1} with maximum (0.90 mg kg^{-1}) with 20t sewage sludge ha^{-1}. This increase in lead content in plants may be attributed to higher content of lead sewage sludge (Roy *et al.* 2013).The Pb concentration was far below the toxic levels which indicate no lead risk in the land use of sewage sludge. There was a significant increase in DTPA-extractable Zn content in post harvest soil with graded levels of sewage sludge over control. It ranged from 0.78 to 0.32 mg kg^{-1}. Maximum (1.32 mg kg^{-1}) value of Zn was recorded with 20t sewage sludge ha-1 which showed 69.2 % increase over control. (Roy *et al.* 2013). There was a significant increase in DTPA-extractable Fe in post harvest soil with increasing levels of sewage sludge application. The DTPA-Fe content ranged from 3.4 to 6.7 mg kg^{-1} and maximum value (6.7 mg kg^{-1}) was recorded with 20 t sewage sludge ha^{-1}. Higher DTPA-Fe in soil treated with sludge may be due to higher mineralization and release of organically bound which caused higher availability in soil (Roy *et al.* 2013).

It may be concluded from the results that treated sewage sludge can be used as a source of plant nutrients. Its application brought about an increase in yield and status of available nutrients in soil. However, application of sewage sludge resulted in increased accumulation of heavy metals in plants in soils. But care should be taken for the presence heavy metals and pollutants for long term use.

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