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Effect of sewage sludge application on yield, nutrients uptake and nutrient use efficiency of spinach (*Spinacia oleracea* L.)

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ABSTRACT

Soil application of sewage sludge in crop production offers an alternative technique for its disposal andmanagement and it is a good source of organic matter along with essential macro and micronutrients for plant growth and development. Thus, agreenhouse experiment was conducted in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, B.H.U., Varanasi, during kharif season of 2018 to investigate the influence of sewage sludge application on growth, yield, nutrients uptake and nutrient use efficiency of spinach(Spinacia oleracea L.). The ten treatments were evaluated in completely randomized design with three replications. The results showed that significant increase in plant height, greenness index and fresh weight of leaves was recorded with application of RDF+20 t sewage sludge ha^{-1}. Application of 20 t sewage sludge ha^{-1} significantly enhanced the micro and micronutrients uptake in leaves over RDF except phosphorus and manganese. The lowest values of uptake of nutrients by spinach were recorded under control. The apparent nutrient use efficiency for N, P, K and Zn ranged between 5.33 and 50.0, 6.06 and 14.7, 5.51 and 37.4 and 2.26 and 5.64%, respectively. In post-harvest soil significantly highest amounts of organic matter (19.6 g kg^{-1}), N (237 kg ha^{-1}), P(7.52 kg ha^{-1}) and K (207 kg ha^{-1}) were recorded due to application of 40 t sewage sludge ha^{-1} and lowest in control.

Key words: Nutrient use efficiency, nutrients uptake, sewage sludge, spinach, yield

INTRODUCTION

Spinach (*Spinacia oleracea* L.) is one of the most valuable green vegetables and rich in essential nutrients particularly iron, zinc, calcium, magnesium etc. Several vitamins such as vitamin A and vitamin C and antioxidants like lutein, zeaxanthin and β-carotene are present in spinach leaves.It is widely cultivated throughout the world and is recommended by modern nutritionists because of its numerous health benefits due to presence of minerals, vitamins, and antioxidants.Like most of the leafy vegetables, spinach is a short duration crop and accumulates the higher amount of biomass within small life periods.Sewage sludge is an unavoidable and organic carbon rich byproduct that is generated in huge quantities by wastewater treatment plants. It contains micro and macronutrients that are important for plant growth, and it is potentially an important source of organic matterfor the majority of agricultural soils (Latare *et al.* 2014).The application of sewage sludge could decrease the dependence on chemical fertilizers, provide significant economic advantages, and be important for carbon sequestration in soils, which is critical for mitigating climate change. Preserving carbon in soils has an additional value for soil improvement in terms of soil biological activity, soil structure and water-holding ability (Kumar *et al.* 2020). It was well evident that application of sewage sludge significantly increased the yield of rice, wheat, maize, barley, lentil, cucumber, spinach, sunflower etc. (Singh and Agrawal 2007, 2010; Jatav*et al.* 2018). Large scale urbanization is leading to increased production of sewage sludge in India. Its management and disposal in a cost effective and environment friendly manner is one of the most pressing problems of the country. Information regarding effect of sewage sludge application on nutrients uptake and nutrients use efficiency by spinach is relatively scarce and such data are needed for the environmentally sustainable use of sewage sludge as a soil amendment. Hence, the present study was conducted to understand the impact of sewage sludgeapplication on growth, yield, nutrients uptake and nutrient use efficiency of spinach in Inceptisol of middle Gangetic plain of India.

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MATERIALS AND METHODS

The pot experiment was conducted in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University,Varanasi during *kharif* season of 2018 by taking spinach as a test crop (variety All Green).The experiment was carried out in completely randomized design (CRD) with ten treatments *viz.,* T_1: control (no fertilizer), T_2: recommended dose of fertilizer (RDF), T_3:RDF + 5.0 t SS ha^{-1}, T_4:RDF + 10 t SS ha^{-1}, T_5:RDF + 15 t SS ha^{-1}, T_6:RDF + 20 t SS ha^{-1}, T_7:RDF + 25 t SS ha^{-1}, T_8:RDF + 30 t SS ha^{-11}, T_9:RDF + 35 t SS ha^{-1} and T_{10}:RDF + 40 t SS ha^{-1} and each treatment was replicated thrice.Bulk soil sample (0–15cm) was collected from the field and sewage sludge was collected from Ganga water sewage treatment plant Bhagwanpur, Varanasi. Both the soil and sewage sludge sampleswere air dried, grounded and passed through 2.0 mm sieve and 10 kg of this soil was filled in each pot sowing of spinach. Sewage sludge was applied 15 days before sowing of crop and recommended dose of N, P and K @ 80, 50 and 50 kg ha^{-1}, respectively was applied in liquid from using urea, di-ammonium phosphate and muriate of potash as a source of N, P and K, respectively. Ten spinach plants were maintained in each pot up to maturity and irrigated with tap water to maintained field capacity moisture up to harvest. The initial soil had pH 8.50, EC 0.07dS m^{-1}, organic carbon 4.2 g kg^{-1}, available nitrogen 78.9 kg ha^{-1}, available phosphorus 4.60 kg ha^{-1} and available potassium 168 kg ha^{-1}. DTPA extractable iron, manganese, copper, and zinc were 12.7, 6.40, 1.22 and 1.00 mg kg^{-1}, respectively. The sewage sludge had pH 6.90, EC 1.17 dS $m^{-1}$and organic carbon 46.3 g kg^{-1}. The DTPA extractable Zn, Cu, Fe and Mn contents were 26.2, 27.6, 95.2 and 39.6 mg kg^{-1}, respectively. Growth characters mainly plant height and greenness index (SPAD value) was recorded at 30 days after sowing (DAS).After harvesting, leaf samples were washed properly and recorded fresh weight of leaves. For recording total dry weight, plant samples (leaves and roots) were dried in hot air oven at 60^oC till the constant weight was achieved. Nitrogen content in plant samples was determined by micro-Kjeldahl method (Jackson 1973). For estimation of P content, grounded plant samples were digested with di-acid mixture (HNO_3:$HClO_4$ in 3:1 ratio) and P content in the acid digest was estimated by vanadomolybdo yellow color method and K content by flamephotometer. Zinc, Cu, Fe and Mn were estimated by atomic absorption spectrophotometer (Agilent FS-240).Nutrient uptake was calculated by multiplying yield data with nutrient contents.In post-harvest soil, organic carbon and available N, P and K were determined by using standard procedures. Statistical analyses were done under completely randomized design with three replications using SPSS version 16.0 software.

RESULTS AND DISCUSSION

Growth attributes and yield

Both the growth attributes (plant height and greenness index) and yield showed a highly significantresponse to sewage sludge application (Table 1). These attributes increased up to RDF+20 t SS ha^{-1}beyond which a significant decline was observed at RDF + 40 t SS ha^{-1}. The maximum plant height and greenness index were recorded with application of 20 t SS ha^{-1} at 30 DAS and respective increases were 26.7 and 13.6% over RDF. For leaf fresh weight (97.0 g pot^{-1}) and total dry weight (26.5 g pot^{-1}) highest values were recorded with RDF + 20 t SS ha^{-1} and the increases were21.1and 7.8%, respectively over RDF. Increase in growth and yield with sewage sludge application might be due to the increased bio-availability of macro and micronutrient in soil but excessive sewage sludge application causes negative impact on growth parameters due to heavy metal toxicity. Similar result was also reported by Kumar *et al.* (2016) and Khan and Kaleem (2017) in spinach.

Table 1: Effect of sewage sludge application on growth attributes and yield (g pot^{-1}) of spinach

Treatments	Plant height(cm)	Greenness index	Leaves fresh weight(g pot^{-1})	Total dry weight(g pot^{-1})
T_1	20.9	28.1	61.0	16.2
T_2	23.9	30.1	80.1	21.8
T_3	25.4	32.8	79.9	21.6
T_4	27.9	33.5	84.0	22.6
T_5	29.9	34.1	96.1	25.9
T_6	30.3	34.2	97.0	26.5
T_7	29.5	33.0	89.0	22.4
T_8	29.1	33.0	88.1	21.6
T_9	28.6	32.3	86.0	20.8
T_{10}	28.6	31.9	85.1	20.4
SEm±	0.59	0.08	3.53	0.95
CD (P <0.05)	1.75	0.23	10.4	0.32

T_1: control (no fertilizer), T_2: recommended dose of fertilizer (RDF), T_3:RDF + 5.0 t SS ha^{-1}, T_4:RDF + 10 t SS ha^{-1}, T_5:RDF + 15 t SS ha^{-1}, T_6:RDF + 20 t SS ha^{-1}, T_7:RDF + 25 t SS ha^{-1}, T_8:RDF + 30 t SS ha^{-11}, T_9:RDF + 35 t SS ha^{-1} and T_{10}:RDF + 40 t SS ha^{-1}

Nutrients uptake

The uptake of primary macronutrients (N, P and K) in spinach significantly varied due to sewage sludge application (Table 2). The maximum uptake of N was documentedat RDF+20 t SS ha^{-1} (1230mg pot^{-1}) in leaves. All the sewage sludge proved superior to control (T_1) and RDF (T_2) in respect of N uptake by crop application of 20 t SS ha^{-1} increased the N uptake in leaves by 58.7% over RDF. The maximum P and K uptake was recorded with RDF+40 t SS ha^{-1}.The P uptake by leaves was increased by 1.84 folds over RDF due to application of RDF + 20 t SS ha^{-1}. For K uptake, application of 20 t SS ha^{-1} recorded an increase of 32.9% in leaves over RDF. This increase in uptake of nutrients by crop may be attributes to increased yield and their concentrations in leaves. The results of Singh *et al.* (2015) corroborate our findings. Application of RDF also improved the uptake of these nutrients over control. The highest uptake of Zn, Cu, Fe, and Mn in leaves was observed with RDF+40 t SS ha^{-1} (1675, 133, 11868 and 798 µg pot^{-1}, respectively)(Table 2). Micronutrients uptake in plants increased with increasing sewage sludge application rates, indicating that sewage sludge increases the availability of micronutrientsin soil (Singh and Agrawal 2007). A similar result was reported by Kumar *et al.* (2016) and Jatav *et al.* (2018). On the other hand, minimum values of these micronutrient cations were recorded in control. However, RDF alone (T_2) proved superior to control in respect of uptake of these micronutrients.

Table 2: Effect of sewage sludge application on nutrients uptake by spinach leaves

Treatments	N (mg pot^{-1})	P (mg pot^{-1})	K (mg pot^{-1})	Zn (µg pot^{-1})	Cu (µg pot^{-1})	Fe (µg pot^{-1})	Mn (µg pot^{-1})
T_1	670	60.8	623	705	41.3	6766	304
T_2	775	74.9	674	835	48.7	7979	340
T_3	995	82.4	729	1009	58.9	8697	386
T_4	1064	101	770	1251	63.8	9530	455
T_5	1144	116	822	1382	82.2	9823	531
T_6	1230	138	869	1582	102	10853	577
T_7	1220	143	857	1654	107	11809	601
T_8	1181	152	865	1620	114	11539	619
T_9	1142	155	883	1680	110	11663	665
T_{10}	1121	160	908	1675	133	11868	798
SEm±	19.1	1.33	12.7	67.5	12.1	147	13.7
CD (P <0.05)	56.3	5.22	37.7	199	35.3	434	40.6

Nutrient use efficiency

The apparent recovery efficiency (AUE) depends on the congruence between plant demand and nutrient release from organic and inorganic fertilizers. The AUE of N, P, K, and Zn was significantly affected due to application of different doses of sewage sludge along with NPK (Table 3). The AUE for N, P, K, and Zn ranged between 5.33 and 50.0, 6.06 and 14.7, 5.51 and 37.4, and 2.26 and 5.64%, respectively. Compared to sewage sludge,the higher value of AUE was recorded with RDF. It might be due to organic sources usually released nutrient slowly than mineral fertilizer. The maximum AUE of N was recorded with RDF + 5 t SS ha^{-1}. On the other hand, AUE of P and K were observed with RDF + 10 t SS ha^{-1}. Thereafter the AUE tended to decrease with increasing levels of sewage sludge.

Table 3: Effect of sewage sludge application on apparent nutrient use efficiency (%) of spinach and status of nutrients in post-harvest soil

Treatments	Apparent nutrient use efficiency (%)				Organic matter (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
	N	P	K	Zn				
T_1	-	-	-	-	7.00	75.7	4.40	166
T_2	50.0	14.7	37.4	-	7.70	88.0	5.44	173
T_3	25.9	6.06	13.7	5.64	8.30	111	5.54	175
T_4	17.2	6.47	10.6	5.06	9.80	149	5.67	180
T_5	14.2	6.33	9.95	4.22	11.6	162	6.15	185
T_6	12.8	6.82	9.30	4.04	13.3	174	6.43	187
T_7	10.1	5.87	7.14	3.48	14.4	187	6.53	192
T_8	7.90	5.52	6.24	2.83	16.1	198	7.23	198
T_9	6.30	4.93	5.74	2.58	17.4	210	7.40	203
T_{10}	5.33	4.58	5.51	2.26	19.6	237	7.52	207
SEm±	0.90	0.40	0.32	0.28	0.20	0.42	0.07	2.08
CD (P <0.05)	2.60	1.22	9.61	0.89	0.40	1.29	0.21	6.13

Post-harvest soil properties

Post-harvest soil nutrients content were significantly increased as amount of sewage sludge application increases gradually (Table 3). The organic matter content in the soil ranged between 7.00to 19.6 g $kg^{-1}$and maximum content (19.6 g kg^{-1}) was recorded with RDF + 40 t SS ha^{-1}.The highest values of N, P and K (237, 7.52, and 207 kg ha^{-1}, respectively) were recorded with 40 t SS ha^{-1}. The respective increase in organic matter, N, P and K content were 2.54, 2.69, 1.38, and 1.20 folds over RDF. However, soil application of 20 t SS ha^{-1} also recorded a significant increase in organic matter, N, P and K content in post-harvest soil and the percent increase over RDF was 72.7, 97.7, 18.2, and 8.09, respectively.This increase may be attributed to improvement in nutrients content in soilwith sewage sludge application as it is a source of all essential nutrients of plants. Findings of the present investigation lined with the results of Saraswat *et al.* (2015), Singh and Singh (2017) and Latare *et al.* (2018). There was a marked decline in organic matter and available nutrients (N, P and K) in post-harvest soil in control which may be attributed to higher production of crop which must have exhausted these nutrients from soil.

The findings of this study clearly demonstrated that the use of sewage sludge is an efficient way for boosting the growth, yield and nutrients uptake by spinach. Among the different doses of sewage sludge,20 t SS ha^{-1} along with inorganic fertilizers was most effective for enhancing growth attributes, yield and nutrients uptake by spinach. The slow nutrient release nature of sewage sludge has recorded lower AUE but it provides nutrients over the cultivation period of spinach.Application of sewage sludge not only boosting the crop production but also enhanced the soil organic matter and available status of nutrients.

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