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Effect of sewage sludge and fertilizers on accumulation of micronutrients and yield of cauliflower (*Brassica oleracea* var *botrytis*) in an alluvial soil

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ABSTRACT

A field experiment was conducted at Bichpuri (Agra) during rabi seasons of 2007-08 and 2008-09 by using treated sludge along with fertilizer levels to study the effect on yield and accumulation of heavy metals in cauliflower [(*Brassica oleracea* var *botrytis* (L.)] and soil. The eight manurial treatments consisted of inorganic and organic sources (treated sludge and FYM) of nutrients. Application of 10 tonnes sludge/ha significantly enhanced the yield and dry matter of cauliflower curd by 36.0 and 36.8% over control, respectively. Increasing levels of NPK fertilizers up to 150% increased the mean curd yield, dry matter yield, content and uptake of elements significantly over control. The maximum curd (33.08 and 28.71 tonnes/ha) and dry matter yields (11.39 and 9.86 tonnes/ha) were recorded under 100% NPK + 10 tonnes treated sludge/ha and minimum (10.83 and 10.45 tonnnes/ha and 3.68 and 3.54 tonnes/ha) under control in first and second year, respectively. Therefore, for the higher productivity of cauliflower about 50% NPK fertilizers could be replaced with addition of treated sludge. Application of 100% NPK + 10 tonnes sludge/ha resulted in the maximum contents of heavy metals in cauliflower curd over control and sludge treated soil. The content of Pb only in curd exceeded the threshold values but no reduction in yield was noted. The highest uptake of Fe (1364 g/ha), Mn (428 g/ha), Cu (121 g/ha), Zn (396 g/ha), Cd (6.1 g/ha) Ni (6.9 g/ha), Pb (52.2 g/ha) and cobalt (7.2 g/ha) by cauliflower curd was recorded under 100% NPK + 10 tonnes sludge/ha. Soil amended with sewage sludge alone resulted in significant build-up of DTPA-extractable micronutrients and heavy metals over control. Combined use of 100% NPK + 10 tonnes sludge/ha resulted in further build–up of micronutrients and heavy metals over sludge treated soil. Thus, it can be concluded that use of sewage sludge can be followed as a good supplement of nutrients for crop production, but care should be taken for the presence of heavy metals and pollutants.

Key words: Cauliflower, Fertilizers, Heavy metals, Sludge, Yield

Sewage sludge is a residue consisting of mixtures of organic and inorganic solids derived from municipal waste water treatment. The solid portion of the sewage is rich in organic matters as well as in nutrients. Although, FYM is commonly used manure, but it is not adequately available. Sewage sludge has proved to be an organic source of nutrients to increase the crop yield. It has been found that application of sewage sludge improves physical, chemical and biological properties of the soil. Use of sewage sludge helped in improving the soil structure which increased the water infiltration rate, aggregate stability and water holding capacity of soil (Sort and Alcaniz 1999). Sludge amendment increased the yield of cabbage (Singh *et al*. 2011) and Palak (Roy *et al*. 2013). Since sludge contains higher concentrations of potentially toxic elements, the accumulation of heavy metals in soils and their subsequent uptake by plants is of major concern. Application of sewage sludge in soils affects the metal content of edible crops directly by serving as a source of trace metals. The uptake and accumulation of metals in the edible parts of crops represent a direct pathway of incorporation of heavy metals in to the human food chain. The occurrence and distribution of heavy metals in soil, plants and animals have been adequately reported by many workers (Datta *et al.* 2007 and Kumar *et al*. 2010). When fertilizers are used along with treated sewage sludge, improvement in soil properties towards sustaining soil productivity has been noted (Roy *et al.* 2013). The importance of vegetables in the balanced diet of human beings as protective food and suppliers of adequate quantities of carbohydrate, fiber, minerals and vitamins is well known. Cauliflower [*Brassica oleracea* var. *Botrytis* (L.)] is a rich source of vitamin A and C. Therefore, it is very pertinent to assess the impact of sewage sludge application on yield, accumulation of micronutrients and heavy metals in plant tissues and their availability and build up in soil. Hence, the present study was undertaken to study the effect of soil application of treated sludge alone and in combination with chemical fertilizers on yield and nutrient uptake by curd of cauliflower.

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MATERIALS AND METHODS

A field experiment was carried on a sandy loam soil at RBS College research farm, Bichpuri (Agra), during *rabi* seasons of 2007-08 and 2008-09. Bichpuri (Agra) is situated at a latitude of 27°22' N, longitude of 77° 9' E and altitude of 168 meters above the mean sea level. The mean annual rainfall of Agra is about 650 mm and more than 80% of it generally occurs during south-west monsoon season (July-September). Important physical and chemical properties of soil were: pH 8.0, organic carbon 4.3 g/kg, and available N, P and K 160, 9.0 and 100 kg/ha, respectively. The soil had DTPA extractable Fe 7.4 mg/kg, Mn 4.6 mg/kg, Cu 0.5 mg/kg, Zn 0.70 mg/kg, Cd 0.14 mg/kg, Ni 0.90 mg/kg, Pb1.21 mg/kg and Co 0.44 mg/kg. The eight treatments consisted of, T_1, control; T_2, 10 tonnes FYM/ha; T_3, 10 tonnes treated sludge/ha; T_4, 50% RD NPK; T_5, 50% NPK + 10 tonnes sludge/ha; T_6, 100% RD NPK; T_7, 100% NPK + 10 tonnes sludge/ha and T_8, 150% RD NPK were replicated three times in a randomized block design. The recommended dose of N, P_20_5 and K_20 for cauliflower was 120+80+160 kg/ha. The sources of N,P and K were urea, diammonium phosphate and muriate of potash, respectively. The sewage sludge was collected from the sewage treatment plant, Dhandupura, Agra. The important characteristics of treated sludge were: total N 1.39, total P 0.42 and total K 0.72%, available Zn 24.7, Cu 2.5, Fe 125.0, Mn 27.0, Ni 9.5, Pb 18.0 and Cd 1.8 mg/kg. Well decomposed FYM had total N 1.0%, total P 0.70%, total K 0.55%, available Zn 7.5, Cu 1.2, Fe 47.5, Mn 11.5, Ni 0.32 and Cd 0.25 mg/kg. The seedlings of cauliflower (Snowball-16) were transplanted on 30 November during both the years. The crop was allowed to grow up to maturity by adopting standard package of practices. At harvest, the curd yield was recorded. The curds were analyzed for heavy metals in di-acid (HNO_3 and $HClO_4$) digest on atomic absorption spectrophotometer. DTPA extractable micronutrient cations and heavy metals in post harvest soils were determined as per procedure of Lindsay and Norvell (1978). Nitrogen content in sludge and FYM was determined following the micro Kjeldahl method. For analysis of other nutrients including micronutrients and heavy metals, the samples of sludge and FYM were digested using di-acid mixture (HNO_3, : $HClO_4$: 10.4) and the digest was used for the analysis of P,K, micronutrients and heavy metals. Phosphorus content in the digest was determined by vanadomolybado – phosphoric yellow color method. Potassium in the digest was determined by a flame photometer, while Zn, Cu, Fe, Mn and heavy metals in the digest were determined by an atomic absorption spectrophotometer. The uptake of nutrients was calculated from the data on concentration of the given nutrient multiplied by the corresponding dry matter yield.

RESULTS AND DISCUSSION

Yield

Perusal of the data (Table 1) indicates that the effect of 10 tonnes sludge/ha application was significant on crud and dry matter yields of cauliflower, which induced 38.1% and 34.2% increment in crud yield and 39.0% and 35.0% in dry matter yield of cauliflower over control during 2007-08 and 2008-09, respectively. Incorporation of sludge in to the soil influencing the physical condition, improves soil productivity and crop production. In addition, the nutrient availability in the presence of sludge coupled with higher nutrient content and uptake might have resulted in the increased yield of test crop (Paulraj and Sree Ramula 1994, Khankhane and Yadav 2003). On an average, higher yield was recorded with sewage sludge (14.49 tonnes/ha) as compared to FYM (12.44 tonnes/ha) application indicating its superiority over FYM. Application of NPK fertilizers also improved the yield of curd in both crop seasons. Increasing levels of 50, 100 and 150 NPK increased the mean yield of curd over control by 8.44, 13.39 and 16.9 tonnes/ha, respectively. The corresponding increases in dry matter yield were 2.92, 4.63 and 6.83 tonnes/ha. This was probably due to higher availability of N, P and K in the initial stage, which helped to acquire a definite advantage over control in respect of growth. Better partitioning of photosynthates from source to sink might have resulted in higher yield of cauliflower, Application of 100% NPK +10 tonnes sludge/ha produced the curd yield of 33.08 and 28.71 tonnes/ha in first and second year, respectively, which were significantly superior to all the other treatments including 150% NPK. The curd yield in this treatment was 3.35 tonnes/ha higher over 150% recommended dose of NPK through fertilizers. Therefore,

Table1 Effect of various treatments on fresh curd and dry matter yield of cauliflower

Treatment	Curd yield (tonne/ha)			Dry matter yield (tonne/ha)		
	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
T_1 Control	10.83	10.45	10.64	3.68	3.54	3.61
T_2 FYM 10 tonnes/ha	12.67	12.22	12.44	4.31	4.15	4.23
T_3 Treated sludge10 tonnes/ha	14.96	14.02	14.49	5.11	4.78	4.94
T_4 50% RD NPK	20.25	17.92	19.08	6.94	6.12	6.53
T_5 50% NPK + 10 tonnes sludge/ha	23.25	19.84	21.54	7.98	6.79	7.38
T_6 100 % RD NPK	25.09	22.97	24.03	8.62	7.87	8.24
$T_7$100% NPK +10 tonnes sludge/ha	33.08	28.71	30.89	11.39	9.86	10.62
T_8 150% RD NPK	29.25	25.84	27.54	10.04	8.85	9.44
SEm ±	1.10	0.87	0.98	0.41	0.39	0.43
CD (P=0.05)	2.30	1.87	2.08	0.85	0.81	0.89

for the higher productivity of cauliflower, about 50% NPK fertilizer could be replaced with 10 tonnes treated sludge/ha. The yield increase in *palak* (*Beta vulgaris*) and cabbage with treated sludge or the recommended dose of fertilizer has been reported by Roy *et al.* (2013) and Singh *et al.* (2011) respectively. Such increased yield might be due to the additional plant nutrients supplied through the sludge and the subsequent improvement in soil physical properties. Its use resulted in significant improvement in soil organic carbon content and increased amount of available soil nutrients. The significant increase in curd yield due to integrated use of sewage sludge and inorganic fertilizers over only sludge application was mainly because the total nutrient requirement of cauliflower could not be met through the sludge alone (Maiti and Singh 2003). It is very likely that when organic waste like sewage sludge is applied along with inorganic fertilizers, it not only releases nutrients slowly from it but also prevents the losses of inorganic fertilizers through volatilization, leaching and denitrification by binding the nutrients and releasing them with the passage of time. Hence, the increase in the growth and yield of cauliflower could be attributed to enhanced nutrients use efficiency in the presence of organics like sludge which is also an excellent source of macro and micronutrients.

Nutrients content

The content of Fe, Mn, Cu and Zn in cauliflower curd ranged from 57 to 127, 15 to 39, 7.7 to 11.3 and 24.5 to 37.1 mg/kg, respectively due to various treatments (Table 2). Highest content of these micronutrients was recorded in 100% NPK + 10 tonnes sludge/ha treatment and the lowest in the control. Micronutrient contents due to 10 tonnes sludge/ha alone were higher than those of fertilizer levels (50 to 150%). Application of 10 tonnes sludge/ha along with 50 and 100% NPK doses increased the micronutrient contents significantly as compared to their application alone. Increasing levels of NPK from 50 to 150% had a synergistic effect on micronutrient content in cauliflower curd and higher amounts of these elements were noted at 150% NPK dose. But the effect of fertilizers in improving the amounts of micronutrient cations was less pronounced than those of FYM and sludge application. Application of 10 tonnes sludge/ha increased the Pb content in curd significantly over control. FYM recorded relatively lower value (3.8 mg/kg) of Pb than that of sludge (4.3 mg/kg). Application of sludge increased the Ni, Co and Cd contents in curd over control, because of their contribution and it agrees with the findings of Chitdeshwari *et al*. (2002). Increasing levels of fertilizers also increased the content of heavy metals in curd. The maximum contents of heavy metals in curd (Cd 0.57, Ni 0.65, Pb 4.9 and Co.67 mg/kg) were recorded under 100% NPK+10 tonnes sludge/ha and minimum in control. This increase in contents of heavy metals in curd may be due to heavy metals in soils which might have been contributed from sewage sludge. Similar results were reported by Singh *et al*. (2006) in spinach and cauliflower. The contents of Pb in cauliflower curd exceeded the threshold values, but no reduction in yield and symptoms of phytotoxicity in plants was noticed in present study.

Nutrients uptake

The uptake of iron, Mn, Cu and Zn by cauliflower curd varied from 206 to 1364, 69 to 428, 28 to 121 and 87 to 396 g/ha, respectively due to various treatments (Table 3). Differences in magnitude of micronutrients uptake due to sewage sludge and FYM were statistically significant and higher values were recorded with 10 tonnes sludge/ha. Variation in uptake of micronutrients by cauliflower curd might be due to variation in availability of micronutrients and yields with sludge and FYM application. Similar results were recorded by Khankhane and Yadav (2003) in brinjal and tomato. Increasing levels of NPK fertilizers from 50 to

Table 2 Effect of various treatments on contents of micronutrients and heavy metals (mg/ kg) in cauliflower curd (mean of 2007 – 08 and 2008 - 09)

Treatment	Fe	Mn	Cu	Zn	Cd	Ni	Pb	Co
T_1 Control	57	15	7.7	24.5	0.35	0.40	3.4	0.53
T_2 FYM 10 tonnes/ha	72	16	9.1	25.8	0.41	0.46	3.8	0.54
T_3 Treated sludge 10 tonnes/ha	118	34	10.2	35.0	0.54	0.55	4.3	0.62
T_4 50% RD NPK	61	16	8.0	24.9	0.35	0.44	3.4	0.51
T_5 50% NPK + 10 tonnes sludge/ha	120	36	10.7	36.1	0.55	0.59	4.7	0.65
T_6 100 % RD NPK	63	16	9.4	25.5	0.36	0.44	3.5	0.56
T_7 100% NPK +10 tonnes sludge /ha	127	39	11.3	37.1	0.57	0.65	4.9	0.67
T_8 150% RD NPK	67	17	9.7	25.8	0.36	0.47	3.7	0.63
SEm ±	4.0	1.1	0.35	0.81	0.10	0.13	0.08	0.004
CD (P=0.05)	8.6	2.4	0.75	0.38	0.22	0.14	0.18	0.01

Table 3 Effect of various treatments on uptake of elements (g/ ha) in cauliflower (mean of 2007-08 and 2008-09)

Treatment	Fe	Mn	Cu	Zn	Cd	Ni	Pb	Co
T_1 Control	206	54	28	87	1.3	1.4	12.2	1.9
T_2 FYM 10 tonnes/ha	306	69	39	109	1.7	2.0	16.0	2.3
T_3 Treated sludge 10 tonnes/ha	587	169	51	174	2.7	2.8	21.3	3.1
T_4 50% RD NPK	395	101	53	163	2.3	2.9	22.2	3.5
T_5 50% NPK +10 tonnes sludge/ha	890	274	80	298	4.1	4.4	34.8	4.8
T_6 100 % RD NPK	520	208	78	211	3.0	3.6	28.9	4.6
$T_7$100% NPK +10 tonnes sludge/ha	1 364	428	121	396	6.1	6.9	52.2	7.2
T_8 150% RD NPK	630	164	92	244	3.4	4.4	35.0	6.0
SEm ±	40.6	7.6	4.5	4.9	0.04	0.18	1.38	0.11
CD (P=0.05)	86.9	16.2	9.7	10.5	0.10	0.38	2.95	0.24

150% also improved the uptake of these micronutrients and higher values were noted under 150% NPK. This increase in the uptake of nutrients with NPK levels may be attributed to increased dry matter yield. In addition, the increased uptake resulted from labile pool maintained at higher levels of NPK accompanied by root development and greater surface area for absorption of nutrients in curd. The combined use of 100% NPK + 10 tonnes sludge/ha caused significantly higher uptake of these micronutrients over other treatments. Application of sludge caused better plant growth and that finally led to higher uptake of these micronutrients in the crop. Moreover, better nutrient atmosphere of rhizosphere with respect to micronutrients might have increased the root cation exchange capacity which subsequently led to increase in nutrients uptake. Similar results were reported by Singh *et al.* (2011) in cabbage and Singh (2013) in spinach. Among the heavy metals, Pb was removed heavily followed by CO>Ni>Cd. The uptake values ranged from 12.2 to 52.2 for Pb, 1.9 to 7.2 for Co, 1.4 to 6.9 Ni and 1.3 to 6.1 g/ha for Cd (Table 3). The supply of heavy metals from sludge addition might have enhanced the availability, thereby increasing the uptake also (Singh and Agrawal 2007, Singh 2013).

Build-up of micronutrients and heavy metals in soil

DTPA-extractable micronutrients and heavy metals in soil are presented in Table 4. The DTPA-Fe in soil tended to reduce with increasing levels of NPK fertilizers over control. Soil amended with sewage sludge alone resulted in significant build–up in DTPA-Fe content over control. The maximum amount of DTPA–Fe (18.6 mg/kg) was recorded with 100% NPK + 10 tonnes sludge/ha. The lowest amount of DTPA-Mn (3.7 mg/kg) was observed in 150% NPK but no significant difference in the available Mn in soil was noticed between control and NPK levels. Build-up of DTPA-Mn in soil was observed due to application of sewage sludge alone compared to control as well as NPK levels. DTPA-Mn in the soil was found to be significantly highest in treatment recovering 100% NPK+10 tonnes sludge/ha. There was a reduction in DTPA-Cu with increasing levels of NPK (50% to 150%) over control. Significant build up of DTPA-Cu was observed due to application of sewage sludge compared to control and NPK levels alone. Higher amount of DTPA-Zn was present in all the treatments where sludge was incorporated compared to those where no addition of sludge had occurred. Zinc content in soil was not affected significantly with the application of NPK fertilizers. The highest DTPA-Zn was maintained (1.81 mg/kg) with 100% NPK + 10 tonnes sludge/ha than other treatments. The amounts of DTPA-Cd, Ni, Pb and Co varied from 0.11 to 0.35, 0.82 to 1.3, 1.13 to 2.57 and 0.41 to 0.60 mg/kg, respectively. The highest build-up of these heavy metals was maintained with 100% NPK + 10 tonnes sludge/ha than other treatments. The higher DTPA-extractable metals in soil treated with sewage sludge along with NPK fertilizer may be due to higher mineralization and release of organically bound metals which caused higher availability in soil. The increases in the metal concentration in soil were in tune with the total metal concentration in the sewage sludge used for the present study (Kumar *et al.* 2010 and Roy *et al.* 2013). But the concentration of these heavy metals in soil did not increase to the toxic limit. Latare and Singh (2013) also reported an increase in DTPA extractable heavy metals in post harvest soil but the concentration of these heavy metals were low as compared to maximum permissible limit.

Table 4 Effect of various treatments on available micronutrients (mg/ kg) in post harvest soil (mean of 2007 – 28 and 2008 - 09)

Treatment	Fe	Mn	Cu	Zn	Cd	Ni	Pb	Co
T_1 Control	6.8	4.1	0.44	0.64	0.11	0.82	1.13	0.41
T_2 FYM 10 tonnes/ha	9.4	4.8	0.47	0.88	0.16	0.95	1.38	0.45
T_3 Treated sludge 10 tonnes/ha	16.8	6.2	0.53	1.25	0.31	1.17	2.49	0.55
T_4 50% RD NPK	6.6	4.0	0.42	0.65	0.11	0.83	1.14	0.41
T_5 50% NPK +10 tonnes sludge/ha	18.0	6.4	0.56	1.77	0.32	1.25	2.52	0.57
T_6 100 % RD NPK	6.2	3.8	0.40	0.66	0.12	0.84	1.15	0.42
$T_7$100% NPK +10 tonnes sludge/ha	18.6	6.9	0.60	1.81	0.35	1.30	2.57	0.60
T_8 150% RD NPK	6.5	3.7	0.38	0.67	0.12	0.83	1.14	0.41
SEm ±	0.66	0.17	0.04	0.11	0.04	0.08	0.19	0.04
CD (P=0.05)	1.41	0.36	0.09	0.23	0.09	0.18	0.41	0.08
Initial value	7.4	4.6	0.50	0.70	0.14	0.90	1.21	0.44

It may be concluded from the present study that the treated sewage sludge can be used as source of plant nutrients. Application of sludge alone or in combination with NPK fertilizers brought about an increase in yield of curd in cauliflower over control. The sewage sludge resulted in increased accumulation of micronutrients and heavy metals in curd and post harvest soil. Care should be taken for the presence of heavy metals and pollutants for long term use.

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