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Long-term effect of sewage sludge and farmyard manure on grain yields and availability of zinc and iron under pearlmillet (*Pennisetum glaucum*)–Indian mustard (*Bassica juncea*) cropping sequence

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ABSTRACT

A study was conducted during 2005–07 to study the effect of sewage sludge with or without farmyard manure on yield of pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend] and Indian mustard [*Bassica juncea* (L.) Czernj & Cosson] and micronutrient availability using the field that received the farmyard manure and sewage sludge treatments for preceding 5 years (2000–05). The treatments tried were sewage sludge @ 2.5, 5.0, 10 and 20 tonnes/ha, farmyard manure @ 5.0 and 10 tonnes/ha and farmyard manure+sewage sludge @ 10+2.5, 10+5.0 and 10+10 tonnes/ha in pearlmillet (*kharif*) in randomized block design with 3 replications. The residual effect was investigated on succeeding mustard crop. Both farmyard manure and sewage sludge were found beneficial in increasing grain yield and oil content of pearlmillet and it had a similar (residual) effect on succeeding mustard. Application of 10 tonnes farmyard manure + 10 tonnes sewage sludge/ha gave maximum yields of pearlmillet grain (1.16 tonnes/ha) and mustard seed (1.73 tonnes/ha). Use of sewage sludge increased the Zn and Fe contents in surface soil as well as in plant. The overall effect of farmyard manure + sewage sludge increased Zn and Fe uptake in both the crops, and organic carbon in soil. The DTPA-extractable Zn and Fe were higher in sewage sludge than in farmyard manure + sewage sludge or farmyard manure-treated soil.

Key words: Farmyard manure, Iron, Mustard, Pearlmillet, Sewage sludge, Zinc

Sewage sludge is considered to be a good source of organic matter, N, P, K and micronutrients. An estimate indicated that the waste could supply about 21 thousand tonnes of micronutrients annually (Prasad 1999). The disposal of sludge on arable lands has been increasingly favoured by the farmers as a source of plant nutrients and as a soil conditioner. Sludge provides a short-term input of plant available nutrients and stimulation of microbial activity and it contributes to long-term maintenance of nutrient and organic matter pools. The fertilizer value of sewage sludge can be significant, but varies considerably depending on origin and processing prior to application. Farmyard manure which is the traditional organic manure is most readily available to the farmers. These organic resources are also useful as amendments as well as a source of nutrients due to their beneficial effect on bio-chemical reactions in soil (Fernandes *et al.* 2005). Hence, an investigation was carried out on effect of farmyard manure and sewage sludge on crops yield, Zn and Fe uptake and availability of Zn and Fe in soil under pearlmillet–mustard cropping sequence.

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MATERIALS AND METHODS

A field experiment was conducted on sandy loam soil which was treated with farmyard manure and sewage sludge for preceding 5 years (2000–05) at Anand Agricultural University (AAU), under a long-term study, which was continued during 2005–07 under 'GHB 526' pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend] –'GM 2' Indian mustard [*Brassica juncea* (L.) Czernj & Cosson] cropping sequence. A sandy loam soil classified as a Typic Haplustept, was used for the study. It was alkaline in reaction with *p*H 8.6, non-saline with electrical conductivity of 0.17 dS/m and organic carbon content was 3.10 g/kg. There were 10 treatments consisting 4 rates of sewage sludge @ 2.5, 5.0, 10 and 20 tonnes/ha, 2 rates of farmyard manure @ 5.0 and 10 tonnes/ha and 3 rates of both combined farmyard manure+sewage sludge @ 10+2.5, 10+5.0 and 10+10 tonnes/ha, besides control. The treatments were applied to pearlmillet in *kharif* for direct effect and their residual effect was studied on mustard during *rabi* in randomized block design with 3

replications. The treatments are:

T_1, NP recommended dose; T_2, NP+5.0 tonnes farmyard manure/ha; T_3, NP+10 tonnes farmyard manure/ha; T_4, NP+10 tonnes farmyard manure+2.5 tonnes sewage sludge/ha; T_5, NP+10 tonnes farmyard manure+5.0 tonnes sewage sludge/ha; T_6, NP+10 tonnes farmyard manure+10 tonnes sewage sludge/ha; T_7, NP+2.5 tonnes sewage sludge/ha; T_8, NP+5.0 tonnes sewage sludge/ha; T_9, NP+10 tonnes sewage sludge/ha and T_{10}, NP+20 tonnes sewage sludge/ha

The recommended dose of fertilizers (pearlmillet: 80:40:0 and mustard: 50:50:0 kg N: P_2O_5: K_2O/ha respectively) were applied in all treatments including control. Both test crops were grown up to maturity. The soil and plant samples collected during the course of investigation were analyzed for Zn and Fe uptake and availability of micronutrients in soil. Oven-dried plant samples were finely ground in a stainless steel Wiley mill and were digested with HNO_3: $HClO_4$ (4:1) di-acid mixture as per the procedure outlined by Jackson (1973). The soil samples were air-dried, ground and passed through 2 mm sieve and were analyzed for soil organic carbon by wet oxidation method (Walkley and Black 1934) and DTPA-extractable Zn and Fe (Lindsay and Norvell 1978) using atomic absorption spectrophotometer (AAS).

RESULTS AND DISCUSSION

Grain yield of crops

There was an in increase in pearlmillet and Indian mustard seed yield by 0.41 tonnes/ha (59%) and 0.25 tonnes/ha (17%) respectively, due to overall effect of farmyard manure+sewage sludge, while similar improvement due to application of sewage sludge alone was by 29 and 9% respectively over the control (Table 1). Among the farmyard manure+sewage sludge treatments, 10 tonnes farmyard manure+10 tonnes sewage sludge/ha was the superior and gave maximum yield of pearlmillet (1.16 tonnes/ha) and Indian mustard (1.73 tonnes/ha), which was comparable with 10 tonnes farmyard manure+5 tonnes sewage sludge/ha also. The direct and residual effect of farmyard manure+sewage sludge application was found beneficial on yield which could be attributed to balanced nutrition and favourable condition for root growth and activities of microorganisms. Comparatively less improvement in yield was noticed due to alone sewage sludge application, average increase by 29% in pearlmillet and 9% in mustard. This might be due to harmful effect arisen from heavy metals added in large quantity to inhibit root growth and translocation of essential nutrients (Brendecke *et al.* 1993). The straw also followed similar trend as grain yield of prearlmillet and mustard. The increase in yield and yield attributes in different crops due to farmyard manure and sewage sludge application has been reported by Antolin *et al.* (2005). The favourable influence of the organics on soil properties could increase the availability of native nutrients in the soil, besides addition of appreciable quantities of major and micronutrients which might have helped in increasing mustard yield (Maiti and Singh 2003).

Seed quality

The application of farmyard manure and sewage sludge to pearlmillet had significantly increased oil content of pearlmillet grain and mustard seed over control due to its residual effect (Table 1). The application of farmyard manure+sewage sludge to pearlmillet significantly increased oil content by 23% in pearlmillet grain over control. The highest value of oil (5.97%) was recorded with 10 tonnes farmyard manure+10 tonnes sewage sludge/ha, while minimum was under NPK (4.69%). The residual effect also improved oil content of mustard seed over control. The lowest

Table 1. Effect of farmyard manure and sewage sludge on yields (tonnes/ha) and oil content of grain in pearlmillet and mustard

Treatment	Pearlmillet grain				Mustard seed			
	2005	2006	Pooled	Oil (%)	2006	2007	Pooled	Oil (%)
Control (NPK)	0.76	0.63	0.70	4.69	1.65	1.28	1.47	37.00
5 tonnes farmyard manure	0.94	0.89	0.92	5.35	1.80	1.38	1.59	37.05
10 tonnes farmyard manure	0.94	0.96	0.95	5.50	1.84	1.39	1.62	36.95
10 tonnes farmyard manure + 2.5 tonnes sewage sludge	1.08	0.99	1.04	5.59	1.97	1.40	1.69	37.05
10 tonnes farmyard manure + 5.0 tonnes sewage sludge	1.25	1.00	1.13	5.71	1.97	1.46	1.71	37.06
10 tonnes farmyard manure + 10 tonnes sewage sludge	1.23	1.09	1.16	5.97	1.98	1.49	1.73	37.01
2.5 tonnes sewage sludge	0.89	0.78	0.84	5.46	1.81	1.32	1.56	36.83
5.0 tonnes sewage sludge	0.89	0.94	0.92	5.52	1.88	1.32	1.60	36.74
10.0 tonnes sewage sludge	0.89	0.95	0.92	5.50	1.82	1.44	1.63	36.84
20.0 tonnes sewage sludge	0.88	0.98	0.93	5.08	1.78	1.41	1.59	36.82
LSD (P=0.05)	0.14	0.09	0.08	4.20	0.13	0.09	0.07	NS
Y × T	0.11		NS					

oil (36.74%) content of seed was observed under sewage sludge @ 5 tonnes/ha application. The highest oil content (37.06%) of Indian mustard seed was noticed with 10 tonnes farmyard manure+5 tonnes sewage sludge/ha; however, the difference was non-significant. The oil content in pearlmillet and mustard seed was decreased with the increasing levels of sewage sludge alone. Similar observations were made by Tsakou *et al.* (2001) in cotton (*Gossypium hirsutum* L.).

Zinc and iron uptake

The maximum uptake of Zn and Fe by pearlmillet was recorded under farmyard manure+sewage sludge treatments over control (Table 2). Among the treatments, 10 tonnes farmyard manure+10 tonnes sewage sludge/ha recorded maximum Zn uptake (23.13 g/ha) by grain as well as Fe uptake (grain: 46.3, straw: 290.1 and total: 336.4 g/ha) by pearlmillet. However, total Zn uptake (111.31 g/ha) was the highest under alone sewage sludge @ 20 tonnes/ha. The overall results further indicated that the uptake of Zn and Fe was comparatively higher under farmyard manure+sewage sludge than farmyard manure or sewage sludge alone application.

The uptake of micronutrients (Zn and Fe) by seed, straw and their total uptake by mustard was found significantly higher due to farmyard manure and sewage sludge application (Table 3). The Fe (59%) uptake by mustard seed was maximum under 10 tonnes farmyard manure + 10 tonnes sewage sludge/ha treatment, while Zn (58.5 g/ha) uptake in mustard seed was maximum with sewage sludge @ 20 tonnes/ha application over control (Zn: 27.1 and Fe: 79 g/ha). The micronutrient uptake by straw and total uptake was significantly higher under sewage sludge @ 20 tonnes/ha than control. In general, it was observed that Zn and Fe uptake by seed were comparatively less under farmyard manure than sewage sludge treatments.

Contrary to the absorption of major nutrients, the uptake of micronutrients, especially Zn and Fe in pearlmillet and mustard was increased with sewage sludge application due to higher addition of these elements in soil. Tandi *et al.* (2004) reported that the sewage sludge addition significantly increased Zn uptake by lettuce (*Lactuca sativa*) and mustard rape (*Brassica juncea*), while Cu uptake was significant in

Table 2 Effect of farmyard manure and sewage sludge on Zn and Fe uptake (g/ha) by pearlmillet (pooled of 2 years)

Treatment	Zn			Fe		
	Grain	Straw	Total	Grain	Straw	Total
Control (NPK)	8.54	29.54	38.08	16.4	88.4	104.9
5 tonnes farmyard manure	13.45	39.93	53.38	28.5	146.4	174.8
10 tonnes farmyard manure	15.58	47.61	63.19	29.4	172.2	201.6
10 tonnes farmyard manure + 2.5 tonnes sewage sludge	16.55	61.12	77.67	34.3	239.2	273.5
10 tonnes farmyard manure + 5.0 tonnes sewage sludge	19.93	59.92	79.86	41.8	251.6	293.5
10 tonnes farmyard manure + 10 tonnes sewage sludge	23.13	76.01	99.14	46.3	290.1	336.4
2.5 tonnes sewage sludge	13.14	35.86	49.00	27.0	167.7	194.7
5.0 tonnes sewage sludge	15.88	44.44	60.31	31.1	188.2	219.3
10.0 tonnes sewage sludge	19.23	75.86	95.08	35.3	235.6	270.9
20.0 tonnes sewage sludge	22.35	88.96	111.31	40.8	270.2	311.0
LSD (P=0.05)	2.73	11.96	12.12	6.3	44.5	43.9

Table 3 Residual effect of farmyard manure and sewage sludge on Zn and Fe uptake (g/ha) by mustard (pooled of 2 years)

Treatment	Zn			Fe		
	Seed	Straw	Total	Seed	Straw	Total
Control (NPK)	27.1	46.2	73.3	79	271	350
5 tonnes farmyard manure	33.3	48.9	82.2	106	341	448
10 tonnes farmyard manure	37.5	58.1	95.6	109	387	496
10 tonnes farmyard manure + 2.5 tonnes sewage sludge	43.3	62.9	106.2	123	413	536
10 tonnes farmyard manure + 5.0 tonnes sewage sludge	47.6	66.1	113.7	123	461	584
10 tonnes farmyard manure + 10 tonnes sewage sludge	51.9	65.8	117.7	126	547	673
2.5 tonnes sewage sludge	39.2	51.5	90.7	104	381	486
5.0 tonnes sewage sludge	43.4	56.4	99.8	110	410	519
10.0 tonnes sewage sludge	55.7	63.2	118.9	120	453	573
20.0 tonnes sewage sludge	58.5	67.9	126.3	125	554	678
LSD (P=0.05)	5.2	7.38	10.08	106	68	70

lettuce and subsequent mustard. The synergetic effect of farmyard manure and sewage sludge application was noticed at higher level to a greater extent, which caused higher uptake of these micronutrients in both pearlmillet and mustard and thereby total uptake.

Soil nutrient status

Organic carbon: Data on soil organic carbon content as influenced by farmyard manure and sewage sludge application are given in Table 4. The results showed that application of farmyard manure and sewage sludge improved organic carbon status of soil significantly at upper layer (0-15 cm) of soil over NPK application. The highest soil organic carbon (4.62 g/kg) content was noted under 10 tonnes farmyard manure+10 tonnes sewage sludge/ha which was on par with rest of the organic treatments. The improvement in soil organic carbon could be a result of direct addition of organic matter through farmyard manure and sewage sludge and its beneficial effect on crop roots as well as on total microbial biomass of soil. The tropical/sub-tropical climate might have not favoured strong build-up in soil organic carbon in spite of having addition of large quantity of organic matter over years in the soil. These findings are in conformity with the work of Antolin *et al.* (2005).

DTPA-Zn and Fe in soil: The DTPA-Zn content of soil was significantly improved with farmyard manure and sewage sludge application over control (Table 4). The highest Zn content (1.80 mg/kg) was noted under sewage sludge @ 20 tonnes/ha treatment at 0-15 cm depths of the soil. The Zn content of soil was also significantly influenced by farmyard manure application over control. Among the farmyard manure+sewage sludge combinations, 10 tonnes farmyard manure+10 tonnes sewage sludge/ha recorded maximum DTPA-Zn in soil, however, it was at par with other combinations.

Table 4 Effect of farmyard manure and sewage sludge on soil organic carbon (g/ha) and DTPA-extractable Zn and Fe (mg/kg) in soil

Treatment	OC	Fe	Zn
Control (NPK)	2.86	6.39	0.79
5 tonnes farmyard manure	3.98	7.07	1.25
10 tonnes farmyard manure	4.10	7.39	1.50
10 tonnes farmyard manure + 2.5 tonnes sewage sludge	4.35	7.49	1.56
10 tonnes farmyard manure + 5.0 tonnes sewage sludge	4.57	7.44	1.73
10 tonnes farmyard manure + 10 tonnes sewage sludge	4.62	8.10	1.73
2.5 tonnes sewage sludge	4.00	7.15	1.69
5.0 tonnes sewage sludge	4.12	8.15	1.78
10.0 tonnes sewage sludge	4.23	8.99	1.79
20.0 tonnes sewage sludge	4.45	9.62	1.80
LSD (*P*=0.05)	0.60	1.76	0.56

Table 4 revealed that the farmyard manure and sewage sludge to *kharif* pearlmillet significantly affected the DTPA-extractable Fe in soil. The DTPA-Fe was significantly higher than other treatments, maximum being (9.62 mg/kg) under sewage sludge @ 20 tonnes/ha at 0–15 cm depth of soil. The combined application of farmyard manure and sewage sludge also significantly increased DTPA-Fe under 10 tonnes farmyard manure+10 tonnes sewage sludge/ha (8.10 mg/kg) over NPK (6.39 mg/kg). The results in general indicated that the treatments, which received higher dose of sewage sludge showed more accumulation of DTPA-Fe in soil than lower level. The overall availability of Zn and Fe was increased due to farmyard manure and sewage sludge application to the soil. The significant positive correlation between organic carbon and DTPA–extractable micronutrients, viz Fe ($r = 0.717^*$) and Zn ($r = 0.862^{**}$) was noticed. Tandi *et al.* (2004) reported similar observations that the application of the sewage sludge significantly ($P < 0.001$) increased total Zn (13.7–1563.9 mg/kg) and Cu (2.5–133.3 mg/kg) in surface soil (0–20 cm depth) compared to the control. It has indicated that long-term addition of sewage sludge to soil increased concentration of Zn and Cu in surface soil to levels that pose environmental concern. Similar results were also observed by Maiti and Singh (2003).

The findings of the present investigation suggested that the sewage sludge could be a better source of micronutrients, besides organic matter for higher crop yields, quality and nutrient availability in soil. The application rate of sewage sludge @ 2.5 to 5.0 tonnes combined with 10 tonnes farmyard manure/ha was found advantageous in pearlmillet–mustard crop sequence without any harmful effect.

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