Micronutrient Status of Soil and Response to Long-term Application of Farmyard Manure (FYM)

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Summary

In a long-term experiment carried out between 1967 and 2001 at Hisar, India, pearl millet (Pennisetum typhoides) and wheat (Triticum aestivum) were grown during summer and winter in sequence. The treatments consisted of application of farmyard manure (FYM) at rates of 15, 30, or 45 mg ha^{-1} during both seasons or either of the seasons. In addition to these treatments, an absolute control was maintained without any FYM in any of the seasons to give a total of 10 treatments. In addition two levels of nitrogen (N), 0 and 120 kg ha^{-1}, were added through urea (46% N) to both crops in 2000. Soil samples were collected from depths of 0-15, 15-30, and 30-45 cm and analysed for diethylene triamine pentaacetic acid (DTPA) extractable and total content of zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) as per standard procedures. Application of farmyard manure (FYM) significantly increased the DTPA extractable and total content of all the micronutrients studied at all soil depths. However, the rate of increase was greater in the surface layer than at lower depths. The time of application of FYM also influenced the content of micronutrients in the soil. The rate of increase of DTPA extractable and total content of all micronutrients was higher when FYM was applied in the winter season compared to the summer. Application of nitrogen (N) did not show any significant effect either on DTPA extractable or on total content of the micronutrients.

Introduction

The unabated use of high analysis chemical fertilisers together with high-yielding varieties of crops and intensive agricultural practices have led to a decline in the capacity of soils to supply micronutrients, resulting in sporadic appearances of deficiency. Furthermore, overdependence on chemical fertilisers and extensive tillage practices have led to deterioration of the soil's physico-chemical properties (Haynes et al. 1991). Thus there is an emerging need to revive the age-old practice of application of farmyard manure to retain the productive nature of soil and also to supplement many essential plant nutrients, especially micronutrients. The periodic application of farmyard manure (FYM) has been reported to improve many physico-chemical properties of the soil, viz., improvement in soil structure, increased water-holding capacity, and enhanced biological activity (Schjønning et al. 1994; Maheswarappa et al. 1999). Farmyard manure is also a good reservoir of nutrients, adding to fertility build up in the soil. It is known to improve soil productivity on a sustainable basis over a long period (Flaig 1975). The application of FYM to enhance micronutrient availability is of special significance for intensive agriculture with high analysis fertilisers, as it is closely associated with the dynamics of nutrient availability in soil (Stevenson 1982; Bhadoria et al. 2003). However, with all these known benefits of FYM, information on its long-term effects on soil micronutrient content is rather limited. The objective of this experiment was to study the impact of dose and time of FYM application in combination with N levels on extractable and total content of micronutrients in the soil after long-term FYM application to a pearl millet-wheat cropping sequence grown on a coarse loamy (Typic Ustochrepts) soil at the experimental farm of the Haryana Agricultural University, Hisar, India.

Materials and Methods

Field experiment

A long-term field experiment on the application of FYM and N to a pearl millet-wheat cropping sequence was established in 1967 at the research farm of the Department of Soil Science, Haryana Agricultural University, Hisar, India. The experiment is still continuing. The experimental site is located at 29°16' N latitude and 75°7' E longitude in northwest India. The climate of the area is semi-arid with a mean annual rainfall of 443 mm and mean annual temperature of 23.9°C. All agronomic practices were followed and weeding carried out manually. Treatments for this study consisted of three doses of FYM – 15, 30 and 45 mg ha^{-1} (Table 1); and three modes of application – in every summer season (June), in every winter season (October), or in both seasons. In addition to these treatments, an absolute control was maintained without any FYM in any of the seasons. This made the total number of treatments 10. These ten treatments (3 FYM levels each with 3 modes of application + 1 FYM control) were assigned in main plots and each main plot was divided into two sub-plots (10 x 6m) receiving 0 or 120 kg N ha^{-1} applied through urea to both crops.

Table 1: **Average micronutrient composition of FYM applied during the experiment**

Element	Range (mg g^{-1})	Mean
Zn	50 - 66	57
Fe	2128 - 2385	2214
Mn	25 - 32	28
Cu	200 - 267	239

Soil sampling

The experiment was carried out in a split-plot design with four replications. Soil samples were collected from depths of 0-15, 15-30, and 30-45 cm after harvesting the wheat crop in May 2001. Five cores collected from each treatment plot were mixed thoroughly and a composite sample was taken. Soil samples were air dried and passed through a two mm sieve for further analysis.

Analysis of soil samples

Total micronutrients in soil

For total concentration of micronutrient cations, 2g of soil was digested in aqua regia (HNO_3 and $HClO_4$ in 3:1 ratio), diluted with double deionised water, and then filtered through a Whatman No.40 filter paper. The total concentrations of zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) were measured using an atomic absorption spectrophotometer (Model-Varian Spectra AA 20 Plus).

DTPA extractable fractions of micronutrients

Soil samples were also analysed for extractable contents of micronutrients in soil according to the DTPA extractable procedure (Lindsay and Norvell 1978). The DTPA extractable fractions of Zn, Fe, Mn, and Cu were measured using an atomic absorption spectrophotometer (Model-Varian Spectra AA 20 Plus).

Statistical Analysis

Analysis of variance (ANOVA) was carried out using the split plot design method and critical difference (CD) was calculated on soil data for treatment means at 0.05 probability.

Results and Discussion

Effect of rate of farmyard manure application

There was a significant increase in DTPA extractable Zn in the soil with increasing dose of FYM application (Table 2). The increase in DTPA extractable Zn may be attributed to slow release of Zn from FYM after mineralisation and its chelating effect in maintaining a regular supply of Zn (Gupta et al. 2000). Compared to the control treatment, the increase in DTPA extractable Zn was also noticed in the sub-surface layers, i.e., 15-30cm and 30-45cm, indicating that some Zn released from FYM may have leached down to the lower layers along with dissolved carbon. At every successive dose of FYM, the total Zn content of the soil increased significantly. Kher (1983) also reported that the total Zn content of soil increased with the addition of FYM as a result of the mineralisation of organic forms of Zn present in the FYM. The total Zn content exhibited the same general trend as DTPA extractable Zn at all soil depths (Table 3).

Application of increasing doses of FYM also increased the DTPA extractable Fe in the soil significantly (Table 2). As with Zn, the highest content of DTPA extractable Fe was recorded with 45 mg FYM ha^{-1} and it was significantly higher than with the application rates of 15 and 30 mg ha^{-1}. The increase in Fe content at the highest rate of FYM application was more than twice that of the control treatment. A similar effect was observed on the total Fe content in the soil (Table 3). Although the DTPA extractable Fe and total Fe exhibited similar trends at all soil depths, both forms of Fe showed a greater increase in the surface layer than at lower soil depths. Hegde (1996) also reported a significant increase in availability of extractable Fe content in soil apparently due to the supply of additional Fe through organic matter sources (Nambiar and Abrol 1989).

Total and DTPA extractable Mn and Cu (Tables 2 and 3) in soil showed the same trend as Zn and Fe. The highest DTPA extractable Mn and Cu were observed at the highest rate of FYM application. Sub-surface layers (15-30cm and 30-45cm) of soil also showed an increase in total and DTPA extractable Mn and Cu, but the rate of increase was less pronounced than in the surface layer. Build up of organic matter under continuous manuring may result in higher DTPA extractable and total micronutrient content in soil. Swarup (1984) reported that incorporation of manures brought about a marked improvement in the availability of native and applied micronutrient cations (Zn, Fe, and Mn) in soil. These elements are known to form stable complexes with organic ligands that decrease their susceptibility to adsorption, fixation, and/or precipitation in soil; addition of FYM may have resulted in the formation of such metal-organic complexes of higher availability.

Time of application of farmyard manure (FYM)

The time of application of FYM also influenced the extractable content of micronutrients in the soil. The rate of increase in total and DTPA extractable Zn, Fe, Mn, and Cu contents (Tables 2 and 3) was higher when FYM was applied in winter than when it was applied in summer. This could be because when FYM was applied only in summer two crops were grown

Table 2: **Effect of different doses and time of FYM application with and without nitrogen fertiliser on DTPA extractable fractions (mg kg^{-1}) of micronutrients at different soil depths**

	Soil depth (cm)											
	Zn			Fe			Mn			Cu		
Treatments	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Time of application												
Summer	2.05	0.85	0.52	8.70	6.18	5.79	6.25	5.26	4.57	0.76	0.66	0.55
Winter	2.04	0.92	0.71	9.90	6.31	5.85	6.97	5.58	4.45	0.76	0.56	0.59
Both	2.60	0.97	0.73	11.67	8.52	7.88	10.0	6.45	5.20	0.85	0.75	0.65
CD (P=0.05)	0.04	0.02	0.03	0.03	0.04	0.03	0.04	0.09	0.05	0.02	0.01	0.02
Rate of FYM (mg ha^{-1})												
0 (Absolute	0.63	0.51	0.49	5.31	4.60	3.95	3.31	3.25	3.19	0.42	0.39	0.38
15	2.05	0.83	0.59	8.19	5.79	5.63	5.50	4.69	4.24	0.74	0.60	0.54
30	2.20	0.93	0.63	9.83	7.25	6.51	7.87	5.91	4.61	0.79	0.63	0.59
45	2.46	0.98	0.74	12.25	8.10	7.38	9.85	6.69	5.38	0.85	0.74	0.67
CD (P=0.05)	0.04	0.02	0.03	0.03	0.04	0.03	0.04	0.09	0.05	0.02	0.01	0.02
N Dose (kg ha^{-1})												
0	2.43	0.81	0.62	8.81	6.38	5.82	6.59	5.12	4.29	0.70	0.59	0.54
120	2.44	0.81	0.61	8.97	6.42	5.91	6.67	5.16	4.42	0.70	0.59	0.55
CD (P=0.05)	ns	ns	ns	0.03	0.02	0.02	0.04	ns	0.03	ns	ns	ns

Table 3: **Effect of different doses and time of FYM application with and without nitrogen fertiliser on total micronutrient status (mg kg $^{-1}$) at different soil depths**

	Soil depth (cm)											
	Zn			Fe			Mn			Cu		
Treatments	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Time of application												
Summer	36.07	32.23	27.35	859.0	760.6	469.9	188.7	178.3	161.2	14.54	13.94	11.79
Winter	36.73	32.26	27.58	860.3	764.6	667.5	190.6	177.8	162.1	15.79	14.04	11.83
Both	46.25	37.94	33.17	915.9	817.0	709.6	215.3	189.0	168.6	17.56	16.18	13.27
CD (P=0.05)	0.86	1.06	0.96	0.75	1.27	1.14	0.60	1.19	0.79	0.80	0.77	0.65
Rate of FYM (mg ha $^{-1}$)												
0 (Absolute	26.92	24.06	20.98	754.7	669.9	496.9	170.3	170.3	149.5	11.82	10.35	10.12
15	33.76	29.75	25.45	843.2	751.7	626.1	185.7	171.5	159.9	14.63	13.52	11.38
30	39.76	34.44	32.22	879.3	776.1	671.8	189.8	179.9	163.5	15.92	15.03	12.16
45	45.54	37.91	33.41	912.7	814.4	742.7	210.7	193.1	168.5	17.34	15.62	13.36
CD (P=0.05)	0.86	1.06	0.96	0.75	1.27	1.14	0.60	1.19	0.79	0.80	0.77	0.65
N Dose (kg ha $^{-1}$)												
0	35.16	30.62	26.27	840.5	746.3	614.6	190.0	178.4	159.9	14.77	13.62	11.56
120	37.83	32.63	28.27	854.4	759.8	654.2	192.4	179.1	160.8	15.08	13.33	11.94
CD (P=0.05)	0.65	0.92	0.77	0.93	0.81	0.77	0.76	ns	0.84	ns	ns	ns

before soil sampling was done; FYM was added for the first crop, pearl millet, and the following wheat crop used the residual nutrients. In plots where FYM was only applied in winter, soil sampling was done after taking a single crop, wheat. The micronutrient content value was significantly lower following single application of FYM compared to application of FYM during both winter and summer seasons. Application of FYM during both seasons increased total and DTPA extractable fractions of Zn, Fe, Mn, and Cu in different soil layers compared to application of FYM in one season alone or not at all.

Nitrogen dose

There was no significant difference in DTPA extractable or total content of Zn, Fe, Mn, and Cu at any of the soil depths in response to application of N fertilisers (Tables 2 and 3). However, the N fertiliser application increased the production of crops, thereby leaving more root biomass in soil for mineralisation. It is possible that the higher root mass in the soil and its subsequent decomposition might have influenced the organic carbon status of the soil along with the DTPA extractable and total availability status of Zn, Fe, Mn, and Cu to some extent, as revealed by the organic carbon status and available micronutrient status relationship curves.

Relationship between organic carbon and micronutrients

There was a general relationship between organic carbon (OC) and DTPA extractable Zn, Fe, Mn, and Cu content (Figure 1) with different R^2 values. The same trend was apparent for OC and total Zn, Fe, Mn, and Cu (Figure 2). In other words, DTPA extractable and total micronutrient content of soil increased with increasing organic carbon content of soil, which was governed by the application of FYM.

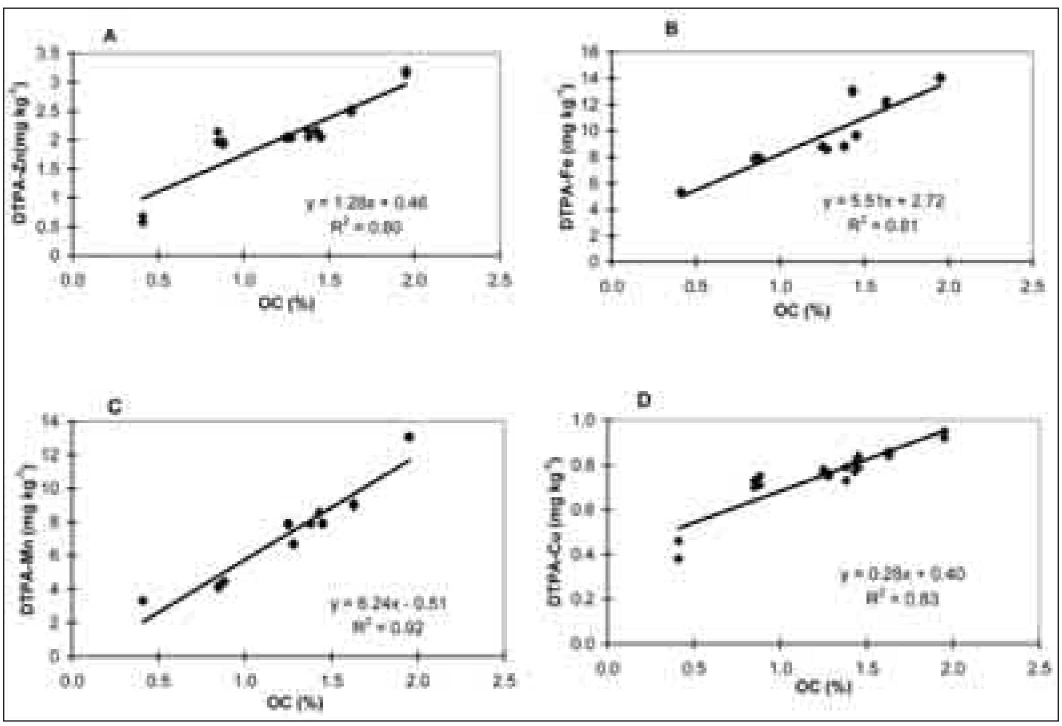

Figure 1: **Relationship between organic carbon (OC) in soils and DTPA extractable Zn, Fe, Mn, and Cu**

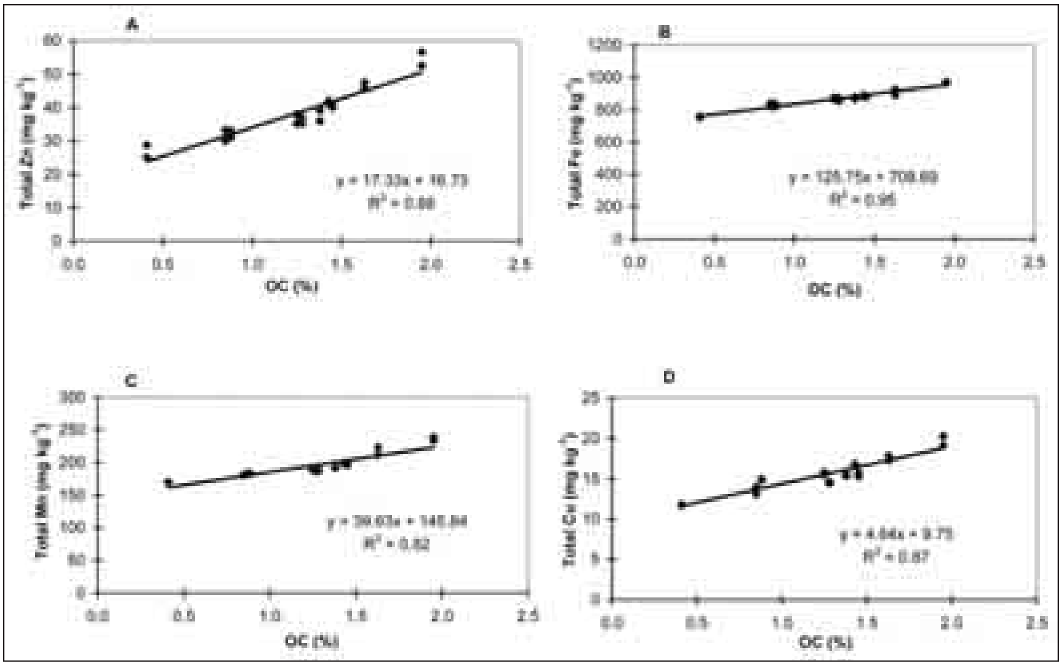

Figure 2: **Relationship between organic carbon (OC) in soils and content of total Zn, Fe, Mn, and Cu**

Conclusions

The results show that both dose and mode of application of FYM in the pearl millet-wheat cropping sequence significantly affect the DTPA extractable fraction and total availability of Zn, Fe, Mn, and Cu in soil. Application of 45 mg ha^{-1} FYM led to the highest values of micronutrients. Winter application of FYM was relatively better than summer application. Application during both seasons was much better than application only once in either of the seasons. But whether this should be recommended depends on economic considerations and availability of FYM.

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