Long-term effect of farmyard manure and N on the distribution of zinc and copper in soil fractions under pearl millet – wheat cropping system

R.P. Narwal[B], Rohtas Kumar[A] and R.S. Antil[A]

[A]Department of Soil Science, CCS Haryana Agricultural University, Hisar, India, Email rsantil@hau.ernet.in
[B]Directorate of Research, CCS Haryana Agricultural University, Hisar, India, Email rpnarwal@yahoo.com

Abstract
A long-term field experiment was initiated in November, 1967 to study the response of N on pearl millet (*Pennisetum typhoides*)-wheat (*Triticum aestivum*) cropping sequence for various doses and modes of farmyard manure (FYM) application. Increasing levels of FYM from 0 to 45 Mg /ha increased the exchangeable, carbonate bound, oxide bound, organic bound and residual fraction of both Zn and Cu in surface (0-15 cm) and sub-surface (15-30 cm) soil. FYM applied during the winter (rabi) season caused a greater increase in all Zn and Cu fractions as compared to summer (kharif) application. The percent contribution of different Zn and Cu fractions towards total Zn and Cu in surface and sub-surface soil revealed the following order: exchangeable < carbonated bound < oxide bound < organic bound < residual.

Key Words
Long-term, FYM, pearl millet, wheat, zinc, copper, fractions

Introduction
Organic amendments, such as FYM are known to improve soil physical properties (Marinori *et al*. 2000). Organic matter is an important soil constituent influencing a number of constraints linked with crop productivity. The loss of soil fertility, in many developing countries, due to continuous nutrient depletion by crops without adequate replenishment poses an immediate threat to food and environmental security. Intensive cropping and tillage system have led to substantial decreases in soil organic matter levels of much prime land in the world. This decrease in soil organic matter levels seems to be associated with the decline in soil productivity.

The importance of micronutrients has been realized during the past three decades when widespread micronutrient deficiencies were observed in most of the soils of India, where intensive agriculture is practised. The micronutrient deficiency in soil is either due to continuous removal of micronutrients from the soil by recently introduced fertilizer responsive and high yielding varieties of crops, or use of micronutrient free high analysis fertilizers.

Estimation of only total content of micronutrient cations in soil does not provide any information regarding the mobility, plant availability, chemical reactivity and biological effects. Elements such as Zn and Cu present in soils are found in a variety of physicochemical forms/fractions (Berti and Jacobs, 1996, Sekhon *et al*. 2006)). To assess their impact in agriculture it is essential to identify which forms are actually present in soil, as the mobility and bioavailability of these elements are governed by dynamic processes, and not the total element contents (Kuo *et al*. 1983). Organic matter redistributes applied Zn in less soluble fraction under a field-capacity moisture regime (Sekhon *et al*. 2006). FYM application increased Cu more in the organic fraction as compared to the oxide-bound fraction (Rupa *et al*. 2001). The objective of this investigation was to determine the effect of long-term application of FYM and N on the dynamics of Zn and Cu fractions in soil.

Methods
A long-term field experiment was established in November, 1967 to study the response of fertilizer N at various doses of FYM and their modes of application in pearl millet (*Pennnisetum typhoides*) - wheat (*Triticum aestivum*) cropping sequence. The experimental field soil was classified as a mixed Typic HaplusteptThe experimental site is located in north-west India between 29.16^{o}N latitude and 75.75^{o}E longitude with a mean annual precipitation of 443 mm. Farmyard manure was applied at 15, 30 and 45 Mg /ha under three modes i.e. applying to each summer (kharif) crop (June), applying to every winter (rabi) crop (November) and to both the crops. One FYM control plot (where no FYM was applied) was also maintained. These 10 treatments were allocated in the main plots and each main plot was divided into three sub-plots

receiving fertilizer N at 0, 60 and 120 kg N /ha in each season through urea. Urea was applied in each crop in two split applications. The sub-plot size was 10x6 m and each treatment was replicated four times. Surface (0-15 cm) and sub-surface (15-30 cm) soil samples from each plot were collected after the harvest of wheat crop in April-2004. Soil samples were air dried, grounded to pass through a 2 mm sieve and stored for further analysis. Different fractions of Zn and Cu in soil were estimated by following the method of Tessier *et al*. (1979) and modified by Jeng and Singh (1993).

Results

Increasing levels of FYM from 0 to 45 Mg /ha increased the exchangeable-Zn (0.55 to 0.98 mg/kg), carbonate bound-Zn (0.81 to 1.21 mg/kg), oxide bound-Zn (7.12 to 11.12 mg/kg), organic bound-Zn (1.22 to 3.15 mg/kg) and residual-Zn (67.07 to 91.69 mg/kg) contents surface soil (Table 1). Similarly in sub surface soil also increasing levels of FYM increased all the fractions i.e. exchangeable-Zn (0.39 to 0.85 mg/kg), carbonate bound-Zn (0.94 to 1.33 mg/kg), oxide bound-Zn (4.05 to 9.03 mg/kg), organic bound-Zn (0.69 to 2.54 mg /kg) and residual-Zn (50.27 to 74.62 mg /kg) . Farmyard manure applied in winter showed a greater increase in all the Zn fraction as compared to its application in summer. Higher values of all the fractions were observed especially when FYM was applied in both the seasons. Surface soil has higher content of all Zn fraction except carbonate bound-Zn (Table 1). Application of N from 0 to 120 kg /ha also increased all the fraction of Zn both in the surface and sub-surface soil layers. The amount of Zn in different fractions as a percent of total Zn at both depths followed the order: Exchangeable < carbonate bound < organically bound < oxide bound < residual. The exchangeable Zn fraction contributed least towards total Zn i.e. 0.72 to 1.03 % and 0.69 to 1.11 % in surface and sub-surface soil, respectively. Residual fraction contributed highest i.e. 84.01 to 87.36 % and 82.34 to 89.23 % in surface and sub-surface soil, respectively.

Table 1. Long-term effect of FYM and N application on different fractions of Zn in soil after 37 cycles of pearl millet-wheat cropping sequence.

Treatment	Zn fractions (mg/kg)				
	Exchangeable	Carbonate bound	Oxide bound	Organically bound	Residual
FYM levels (Mg /ha)					
0	0.55	0.81	7.12	1.22	67.07
15	0.73	0.95	9.55	2.06	74.74
30	0.87	1.09	10.63	2.54	82.52
45	0.95	1.21	11.12	3.15	91.69
LSD (0.05)	0.05	0.10	0.37	0.17	1.55
Modes of FYM					
Kharif	0.70	0.91	9.27	2.04	77.34
Rabi	0.77	1.00	9.50	2.23	78.27
Both	0.89	1.14	10.04	2.46	81.41
LSD (0.05)	0.05	0.09	0.32	0.15	1.34
N levels (kg /ha)					
0	0.72	0.99	9.61	2.15	78.21
60	0.79	1.00	9.50	2.21	78.99
120	0.82	1.05	9.70	2.36	79.82
LSD (0.05)	0.09	NS	NS	0.30	2.68

Table 2. Long-term effect of FYM and N application on different fractions of Cu in soil after 37cycles of pearl millet-wheat cropping sequence.

Treatment	Cu fractions (mg/kg)				
	Exchangeable	Carbonate bound	Oxide bound	Organically bound	Residual
FYM levels (Mg /ha)					
0	0.17	0.39	5.20	0.55	13.40
15	0.39	0.70	6.34	1.07	18.53
30	0.51	0.89	6.74	1.58	21.24
45	0.67	1.09	7.15	1.96	21.93
LSD (0.05)	0.05	0.08	0.37	0.14	0.82
Modes of FYM					
Kharif	0.37	0.63	6.02	1.02	18.25
Rabi	0.42	0.69	6.43	1.31	18.35
Both	0.52	0.99	6.63	0.56	19.74
LSD (0.05)	0.45	0.08	0.32	0.12	0.71
N levels (kg /ha)					
0	0.43	0.74	6.18	1.28	18.21
60	0.44	0.77	6.35	1.26	19.02
120	0.44	0.80	6.55	1.33	19.10
LSD (0.05)	NS	NS	NS	NS	1.43

Application of FYM increased the Cu content of soil. It increased the exchangeable-Cu (0.17 to 0.67 mg/kg), carbonate bound-Cu (0.39 to 1.09 mg /kg), oxide bound-Cu (5.20 to 7.15 mg /kg), organic bound-Cu (0.55 to 1.96 kg/mg) and residual-Cu (13.40 to 21.93 mg /kg) contents in surface soil. Similarly, in sub-surface soil also Cu increased all fractions exchangeable-Cu (0.12 to 0.48 mg /kg), Carbon bound-Cu (0.74 to 1.87 kg/mg), Oxide bound-Cu (3.83 to 6.16 mg /kg), Organic bound-Cu (0.37 to 1.60 mg /kg) and Residual-Cu (7.47 to 12.43 mg /kg) with increasing levels of FYM from 0 to 45 Mg /ha. Farmyard manure applied in winter showed a greater increase in all the Cu fractions as compared to its application in summer. Nitrogen application also had a positive effect on the build up of all fraction of Cu in soil. The percent contribution of Cu towards total Cu (sum of all 5 fractions) in surface and sub-surface soil followed the order: exchangeable < carbonated bound < oxide bound < organic bound < residual. The exchangeable Cu fraction contributed least towards total Cu i.e. 0.86 to 2.37 % and 0.96 to 2.44 % in surface and sub-surface soil, respectively (Table 2). The residual Cu fraction contributed the most to total Cu i. e. 65.20 % to 71.23 % and 53.60 % to 60.47 % in surface and sub-surface soil, respectively. Generally Exchangeable, carbonate bound and organically bound fractions of Zn and Cu contribution increased and residual fraction of Zn and Cu contribution decreased with increasing level of FYM at both depths.

Conclusion

Increasing levels of FYM from 0 to 45 Mg /ha increased all Zn and Cu fractions (exchangeable, carbonate bound, oxide bound, organic bound and residual) in surface and sub-surface soil. The contribution of both Zn and Cu towards total Zn and Cu followed the order: exchangeable < carbonated bound < oxide bound < organic bound < residual. Hence, the application of FYM is essential for maintaining soil fertility.

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