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Effect of integrated nutrient management on zinc fractions and rice yield

Navdeep Singh, RS Gill* and GS Dheri

Punjab Agricultural University, Ludhiana, Punjab, India

****Corresponding author e-mail: rsgill79@pau.edu***

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ABSTRACT

Integrated nutrient management (INM) effects chemical transformation of nutrients in soil and plant uptake. This study present the long-term (30 years) effects of integrated nutrient management on zinc (Zn) fractions and rice yield. The treatments include ten combinations of nitrogen, phosphorous and potassium applied through mineral fertilizers and substituted through farmyard manure (FYM), green manure (GM) and wheat cut straw (WCS).The distribution of Zn into exchangeable (EXCH), carbonate bound (CARB), organic matter bound (OM), manganese oxides bound (MnOX), amorphous iron oxide bound (AFeOX) and crystalline iron oxide bound (CFeOX) was determined. The effect of long-term use of mineral fertilizers on EXCH-Zn was not significant as compared to control, however, EXCH-Zn increased significantly in INM treatments compared to both control and mineral fertilizer in surface soil (0-15 cm). Similarly, CARB-Zn and OM-Zn was significantly higher in INM as compared to control and mineral fertilizer treatments. The distribution of Zn in MnOX, AFeOX and CFeOX fractions was not distinctly affected with long-term fertilizations. In general, concentration of Zn fractions was lower in subsurface soils (15-30 cm) as compared to surface soils. The grain yield of rice increased in order control< mineral fertilizers <INM treatments. The highest grain yield (71.8 q ha^{-1}) was recorded in INM treatment where 25% of the recommended NPK were supplied through GM. The positive and significant correlation of EXCH-Zn (r = 0.714), CARB-Zn (r = 0.601) and OM-Zn(r = 0.648) fractions and Zn uptake in grain showed that the plant availability of Zn depends upon these fractions in soils.

Key words: *Rice-wheat cropping system, integrated nutrient management, zinc fractions, organic manures, micronutrients uptake*

INTRODUCTION

Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture, coupled with use of high analysis fertilizer and low amount of organic manures. With the introduction of rice cultivation on highly permeable coarse textured alkaline soils of Punjab, the deficiencies of Zinc (Zn) and Iron (Fe) have been reported (Nayyar et al., 1990). In Punjab, currently 22 percent soils are deficient in Zn (Sadana et al., 2010). In soils, Zn occurs in five distinct pools *viz*., water soluble, exchangeable, adsorbed, chelated or complexed, Zn occluded in oxides and hydroxides of aluminium (Al), iron (Fe) and manganese (Mn) and entrapped in primary and secondary minerals. These pools differ in strength (or reversibility) and therefore in their susceptibility to plant uptake, leaching and extractability. The readily available forms *viz*., water soluble, exchangeable and chelated zinc are in reversible equilibrium with each other (Viets, 1962). Water soluble plus exchangeable and organically complexed forms are considered to be available, amorphous sesquioxide bound form is potentially available and crystalline sesquioxide bound and residual forms are unavailable to plants (Mandal et al.,1992). Estimation of total content of micronutrient cations in soil provides little information regarding the mobility, plant availability, chemical reactivity and biological effects. Therefore, it is essential to identify, the forms of these nutrients actually present in the soil as the mobility and bioavailability are governed by dynamic processes. Understanding the distribution of these nutrients in different fractions helps to know their retention in soils and release to plants. Different nutrient management practices play a major role in influencing the distribution of Zn among various chemical pools through adsorption, chemisorption and chelation. In view of the above, the present investigation was taken up to study the effect of long term integrated nutrient management on the distribution of zinc fractions and rice productivity in rice-wheat cropping system.

MATERIALS AND METHODS

Soil and plant samples were collected from an on going long-term integrated nutrient management experiment under rice-wheat cropping sequence which is in progress at Research Farm, Department of Agronomy, PAU, Ludhiana, since 1983. The soil of experimental site has been classified as inceptisol, particularly Samana coarse loamy typic ustochrept and hyperthermic.

Ludhiana is situated at 30°56' N latitude and 75°52' E longitude with a mean height of 247 meter above the mean sea level. The mean maximum and minimum temperatures show considerable variations during different months of year. The maximum air temperature often exceeds 38°C during summer and sometimes touches 45°C with dry spells during May and June. Minimum temperature falls below 0.5°C with frosty spells during winter months of December and January. The average annual rainfall of Ludhiana is 650 mm. There were 10 treatments, T_1 was control, in T_2, T_3 & T_4 treatments 50, 75 & 100 percent of the recommended Nitrogen (N), Phosphorus (P) and Potassium (K) was applied through Urea, Diammonium Phosphate and Muirate of Potash respectively. In the treatments T_5 & T_6 respectively, 50 & 25 percent of recommended N, P & K was supplied through Farmyard manure (FYM). Similarly in T_7 & T_8 treatments 50 & 25 per cent N, P & K were applied through wheat-cut straw (WCS) and in the treatments T_9 &T_{10} 50 & 25 percent of recommended N, P & K was supplied through green manure *i.e.*, Sesbania aculeate (GM) (Table 1).

Table 1. Details of treatments of the experimental soils

Treatment No.	Treatments
T_1	Control
T_2	50%NPK
T_3	75%NPK
T_4	100%NPK
T_5	50%NPK+50%NPK (FYM*)
T_6	75%NPK+25%NPK (FYM)
T_7	50%NPK +50%NPK (WCS**)
T_8	75% NPK + 25% NPK (WCS)
T_9	50%NPK+50%NPK (GM***)
T_{10}	75%NPK+25%NPK (GM)

* Farm yard manure **Wheat cut straw *** Green manure

The soil samples (0-15 & 15-30 cm soil depths) from each treatment were taken using a 5 cm diameter auger after harvest of paddy. The grain and straw samples of rice crop were collected from each plot after harvesting and dried in hot air oven at 65ºC for 3 days. The dried samples were grinded in a stainless steel willeys mill and stored in paper bags for further chemical analysis

Different fractions of Zn were determined by sequential fractionation procedure given by Singh et al. (1988), the detail of the method as given in Table 2. The Zn and Fe contents in the extracts were estimated on atomic absorption spectrophotometer.

Table 2. Sequential fractionation procedure for Zinc.

Fraction	Solution	g soil/ml soln	Procedure
Exchangeable (EXCH)	1 M Mg(NO3)2	10:40	Shake 2 h
Carbonate bound (CARB)	1 M NaOAc (pH 5.0,CH3COOH)	10:40	Shake 5 h
Organic matter bound (OM)	0.7 M NaOCl	10:20	30 min in boiling water bath. Stir occasionally
Mn oxides bound (MnOX)	0.1 M NH2OH.HCl(pH-2, HNO3)	5:50	Shake for 30 minutes
Amorphous Fe oxide bound (AFeOX)	0.25 M NH2OH.HCl+0.25M HCl	5:50	Shaken for 30 minutes in water bath at 50 ºC
Crystalline Fe oxide bound (CFeOX)	0.2 M (NH4)2 C2O4+0.2 M H2C2O4(pH3) + 0.1 M ascorbic acid	5:50	Boiling for 30 minutes

Singh et al. (1988)

RESULTS AND DISCUSSION

Distribution of Zn fractions in soils under long-term Integrated Nutrient Management

The effect of long-term use of mineral fertilizers on exchangeable zinc (EXCH-Zn) was not significant as compared to control, however, EXCH-Zn increased significantly in integrated nutrient management (INM) treatments compared to both control and mineral fertilizer in surface soil (0-15 cm) (Fig. 1). Similarly, carbonate bound zinc (CARB-Zn) and organic matter bound zinc (OM-Zn) was significantly higher in INM as compared to control and mineral fertilizer treatments. The distribution of Zn in manganese oxide (MnOX), amorphous iron oxide (AFeOX) and crystalline iron oxide (CFeOX) fractions was not distinctly affected with long-term fertilizations. The highest amount of EXCH, CARB and OM bound zinc was found in the treatments where 50 and 25% of the recommended NPK were applied through farmyard manure (FYM), wheat cut straw (WCS) and green manure (GM) respectively in the surface layer, 0-15 cm (Fig. 2). The EXCH-Zn in the control treatment was 0.60 mg kg^{-1} and it was 0.55 mg kg^{-1} in the treatment where 100% NPK was supplied through inorganic fertilizers only.

Table 3. Effect of integrated nutrient management on yield (q ha^{-1}) of paddy.

Treatment No.	Treatments	Grain	Straw
T_1	Control	15.6	36.2
T_2	50%NPK	36.4	47.0
T_3	75%NPK	48.1	65.3
T_4	100%NPK	64.7	92.8
T_5	50%NPK+50%NPK (FYM)	66.8	98.3
T_6	75%NPK+25%NPK (FYM)	68.2	102.9
T_7	50%NPK+50%NPK(WCS)	56.3	82.4
T_8	75%NPK+25%NPK(WCS)	58.2	80.5
T_9	50%NPK+50%NPK(GM)	69.8	109.2
T_{10}	75%NPK+25%NPK (GM)	71.8	112.0
	CD(p=0.05)	4.7	2.2

However, the values of EXCH Zn were 0.84, 0.66 and 0.74 mg kg^{-1} in the treatments where 50% of the recommended NPK were supplied by FYM, WCS and GM respectively. Similarly, the values were 0.79, 0.62 and 0.69 mg kg^{-1} where 25% of the recommended NPK were supplied by FYM, WCS and GM respectively. The EXCH-Zn in the treatment where 50% of the recommended NPK was supplied through FYM, WCS and GM was 52.7, 20.0 and 34.5 % higher than the treatment where 100% of the recommended NPK were

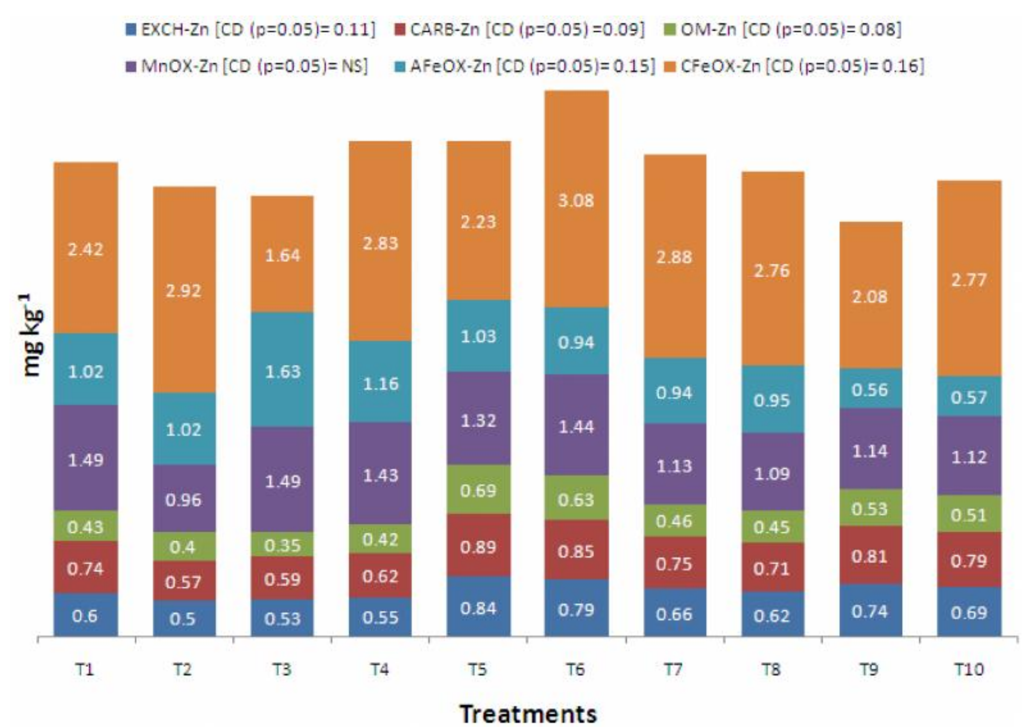

Fig. 1. Effect of long-term fertilization on zinc fractions (mg kg^{-1}) in surface soils (0-15 cm) under rice-wheat cropping system.

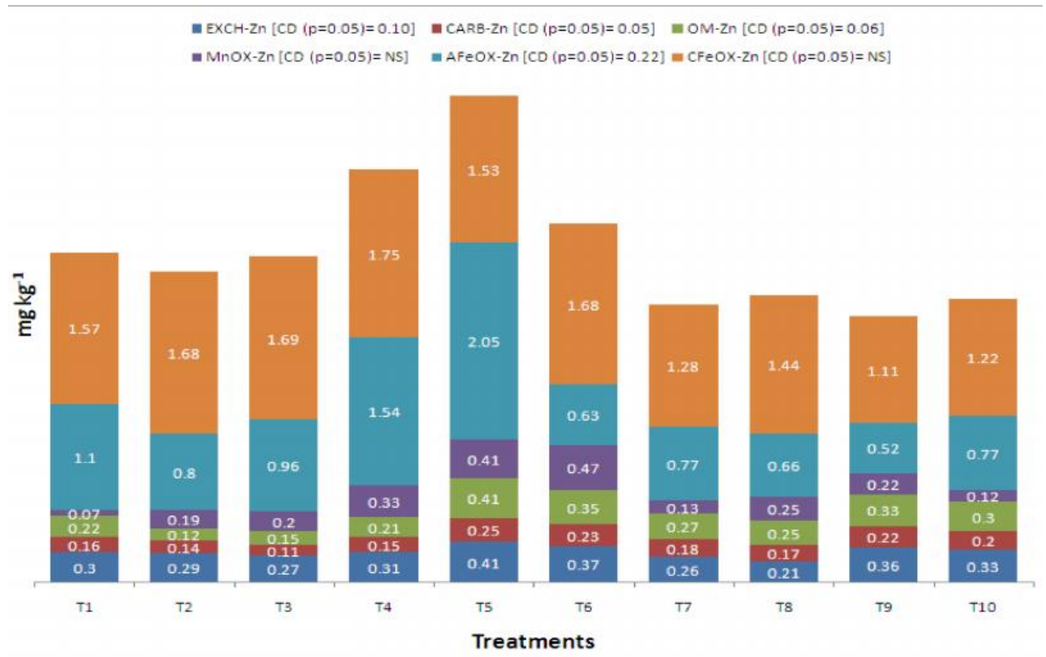

Fig. 2. Effect of long-term fertilization on zinc fractions (mg kg^{-1}) in sub surface soils (15-30 cm) under rice-wheat cropping system.

supplied through inorganic fertilizers alone. Similarly the CARB-Zn in the treatments where 50% of the recommended NPK were applied through FYM, WCS and GM was 43.5, 20.1 and 30.6% higher than the treatment where 100% of the recommended NPK was applied through inorganic fertilizers only. If we compare the different organic sources of nutrition the highest amount of EXCH, CARB and OM-Zn was found in FYM treatments followed by GM and WCS respectively (Table 3).

Table 4. Effect of integrated nutrient management on Zn uptake by grain and straw (g ha^{-1}) of paddy.

Treatment No.	Treatments	Grain Zn	Straw Zn
T_1	Control	87.1	97.7
T_2	50%NPK	176.9.	103.8
T_3	75%NPK	246.7	143.0
T_4	100%NPK	347.4	215.2
T_5	50%NPK+50%NPK (FYM)	454.9	345.0
T_6	75%NPK+25%NPK (FYM)	452.1	340.5
T_7	50%NPK+50%NPK(WCS)	336.1	248.0
T_8	75%NPK+25%NPK(WCS)	342.7	240.6
T_9	50%NPK+50%NPK(GM)	442.5	378.9
T_{10}	75%NPK+25%NPK (GM)	450.1	367.3
	CD (p=0.05)	31.9	26.9

Shuman (1999) found an increase in Zn in the exchangeable, organic and manganese fractions due to addition of organic amendments. The increase in more soluble forms of Zn due to addition of organic manures may be due to their release from Zn bound by oxide forms. Zinc, occluded by carbonates and crystalline oxides, could have been released by the dissolution action of organic compounds present in FYM and GM (Sharad and Verma, 2001). Sekhon et al. (2006) observed that the addition of organic manures in the absence of inorganically applied Zn increased the water-soluble plus exchangeable, organic fraction, the manganese oxide and amorphous iron oxide fractions of Zn over their initial levels. Mandal et al. (1988) observed that addition of 0.5 % FYM caused a substantial increase in the contents of AFeOX bound fraction of native soil Zn with simultaneous decrease in that of CFeOX bound and Al oxides Zn fractions. Narwal et al., (2010) also reported that with the addition of FYM, there is a increase in all the Zn fractions, thus exhibiting the importance of OM addition. Herencia et al. (2008) showed that addition of OM caused Zn to

Table 5. Coefficient of correlation between Zinc content and uptake with different fractions.

Fractions of Zn	Zn Conc.		Zn Uptake	
	Grain	Straw	Grain	Straw
Exch	0.983**	0.942**	0.714**	0.815**
Carb	0.977**	0.959**	0.601	0.752*
OM	0.921**	0.853**	0.648*	0.716*
MnOX	0.04	-0.161	-0.253	-0.232
AfeOx	-0.559	-0.714*	-0.362	-0.549
CfeoX	0.054	0.052	-0.115	-0.124

*. Correlation is significant at 0.05 level of significance
**. Correlation is significant at 0.01 level of significance

move from less soluble forms to more plant available fraction which was always favoured by organic amendment.

The effect of long-term use of mineral fertilizers on EXCH-Zn was not significant as compared to control, however, EXCH-Zn increased significantly in INM treatments compared to both control and mineral fertilizer in surface soil (0-15 cm). Similarly, CARB-Zn and OM-Zn was significantly higher in INM as compared to control and mineral fertilizer treatments. The distribution of Zn in MnOX, AFeOX and CFeOX fractions was not distinctly affected with long-term fertilizations. In general, concentration of Zn fractions was lower in subsurface soils (15-30 cm) compared to surface soils (Fig. 2).

The highest amount of EXCH, CARB and OM bound Zn was found in the treatments where 50 and 25% of the recommended NPK were supplied by FYM, WCS and GM respectively. The EXCH Zn in the control treatment was 0.30 mg kg^{-1} while it was 0.31 mg kg^{-1} in the treatment where 100% of the recommended NPK was supplied through inorganic fertilizers. However, the values of EXCH Zn were 0.41, 0.26 and 0.36 mg kg^{-1} soil in the treatments when 50% of the recommended NPK were supplied by FYM, WCS and GM respectively. Similarly, these values were 0.37, 0.21 and 0.33 mg kg^{-1} where 25% of the recommended NPK were supplied through FYM, WCS and GM respectively. The EXCH, CARB and OM-Zn content decreased with increase in depth of soil profile, because organic matter is incorporated in the surface soil layer (0-15 cm), therefore with increase in depth of soil profile, organic matter content decreases and there is a decrease in extractability of Zn with increase in depth even with the addition of organic matter. Setia and Sharma (2004) reported that Zn content in 45-60 cm depth was 22 percent less than that in surface layer (0-15 cm). Kumar et al. (1996) reported highest amount of DTPA-extractable Zn, Copper (Cu), Iron (Fe) and manganese (Mn) in the surface layers, which might have been due to their regular addition through plant residue.

There is a significant increase in paddy yield with the addition of organic amendments. The highest grain yield 71.8 q ha^{-1} was recorded in the treatment where 25% of the recommended NPK were supplied through GM followed by the treatment where 50% of the recommended NPK were supplied through GM (69.8 q ha^{-1}).In the treatment where 100% recommended dose of nutrients (NPK) were applied through chemical fertilizers only the grain yield was 64.7 q ha^{-1}. The grain yield where 50% of NPK was supplied through FYM and GM was 3.2 and 7.8% higher than the treatment where 100% of the recommended NPK was supplied through chemical fertilizers only. Similarly, the grain yield where 25% of the recommended NPK was supplied through FYM and GM was 5.4, and 10.8 % higher than the treatment where 100% of the recommended NPK was applied through chemical fertilizer. The highest straw yield (112.0 q ha^{-1}) was recorded where 25% of the recommended NPK were applied through GM followed by the treatment where 50% of the recommended NPK were applied through GM. The straw yield where 50% of NPK was applied through FYM & GM was respectively 5.8 and 17.5 % higher than the treatment where 100% NPK was applied through chemical fertilizers.

Effect of INM on Zn uptake by Paddy

The Zn uptake ranged from 87.1 to 454.9 g ha^{-1} and 97.9 to 378.9 g ha^{-1} by grain and straw of paddy, respectively (Table 4). Higher uptake of Zn was recorded in the treatments where 25 & 50% of nutrients were applied by FYM, GM and WCS respectively because of the higher grain yield in these treatments. The Zn uptake by grain in the control treatment was 87.1 g ha^{-1} and it was 347.4 g ha^{-1} in the treatment where 100% of the recommended NPK was applied through inorganic fertilizers. However, the values of Zn uptake in grain were 452.1, 450.1 and 342.7 g ha^{-1}

in the treatments where 25% of the recommended NPK were applied by FYM, WCS and GM, respectively. Similarly, the values were 454.9, 442.1 and 336.1 g ha^{-1} where 50% of the recommended NPK were applied by FYM, GM and WCS respectively. Similarly, the Zn uptake in straw was 97.9 g ha^{-1} in the control treatment and 215.2 g ha^{-1} in the treatment where 100% of the recommended NPK was applied through inorganic fertilizers. The straw Zn uptake was 345.0, 378.9 and 248.0 g ha^{-1} in the treatments where 50% of the recommended NPK were applied by FYM, GM and WCS respectively. The values were 340.5, 240.6 and 367.3 g ha^{-1} where 25% of the recommended NPK were applied by FYM, GM and WCS respectively.

Coefficients of correlation between different fractions of Zn with plant uptake

The coefficients of correlation were determined between different fractions of Zn and their content as well as uptake by paddy. The data pertaining to the coefficients of correlation between different fractions, zinc concentration and uptake is presented in Table 5. The EXCH-Zn fraction gave highest significant coefficient of correlation with grain Zn concentration (r =0.983**) followed by CARB-Zn (r =0.977**) and OM-Zn (r = 0.921**) fraction.

Similarly, CARB-Zn fraction gave highest coefficients of correlation with straw Zn concentration (r = 0.959**) followed by exchangeable fraction (r =0.942**) and organic matter fraction (r = 0.853**).

The EXCH-Zn gave highest coefficient of correlation with grain Zn uptake (r = 0.714*) followed by OM-Zn (r = 0.648*) and CARB-Zn (r = 0.601). Similarly, the EXCH- Zn gave highest coefficient of correlation with straw Zn uptake (r = 0815**) followed by CARB-Zn (r = 0.752*) andOM-Zn (r= 0.716*). Kumar and Quereshi (2012) reported that positive correlations were obtained with water soluble+exchangeable (WSEX) and organic matter zinc fractions, as well as with the DTPA-extractable Zn fraction. Mandal et al. (1992) reported that water soluble plus exchangeable and organically complexed forms are considered to be available, amorphous Fe-oxides bound form is potentially available and crystalline Fe - oxide bound and residual Zn forms are unavailable to plants. Milivojevic et al. (2011) also reported that the available fraction of Zn and Zn bound to metals have a significant correlation with Zn content in oats. Chahal et al. (2005) reported that Grain content of zinc was positively and significantly correlated (r = 0.66) with DTPA-extractable zinc in soils. Soil solution plus exchangeable Zn content of the soils was positively and significantly correlated with straw (r = 0.66) and total Zn uptake (r = 0.81).

CONCLUSION

The positive and significant correlation of EXCH, CARB and OM fractions of Zn with uptake of these nutrients by paddy showed that the availability of Zn to plant depends upon these fractions of Zn in soils. The MnOX, AFeOX and CFeOX fractions are less soluble forms of Zn in soils as indicated by their poor correlation with Zn content and uptake by paddy crop. Higher amount of bio-available pools Zn (EXCH, CARB and OM) were recorded in the INM treatments compared to chemical fertilizers. The EXCH, CARB, OM bound fractions of Zn in soils were significantly correlated with Zn content and uptake in grain and straw of paddy indicating their importance towards plant uptake.

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