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Changes in DTPA-extractable micronutrients under long term differential fertilization at various growth stages of wheat

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Abstract: The effect of continuous application of N, P and K fertilizer for 22 years to a maize-wheat annual sequence was studied on the changes in DTPA-extractable micronutrient cations at tillering, ear initiation and harvest of wheat. Continuous application of increasing level of N depleted the DTPA-extractable micronutrients in the soil, irrespective of growth stages, but phosphate fertilization resulted in significant increase in DTPA-Zn, Fe and Mn, whereas, application of K had positive effect on DTPA-Cu. These micronutrients significantly decreased in soil with plant age. The mean decrease from tillering to harvesting stage was 0.26 mg kg^{-1} for DTPA-Zn, 0.07 mg kg^{-1} for DTPA-Cu, 0.71 mg kg^{-1} for DTPA-Fe and 1.3 mg kg^{-1} for DTPA-Mn. DTPA- Zn and Fe showed a negative correlation with pH whereas, DTPA Cu and Mn showed a positive correlation with pH. The additive effect of organic carbon was more pronounced on Cu. A negative correlation was obtained between available N and DTPA- extractable micronutrients. A significant positive relationship existed between DTPA extractable micronutrients and soil P barring DTPA-Cu. Multiple regression analysis indicated that available P and pH were the major controlling factors for DTPA-Zn, pH and organic carbon (OC) for DTPA-Cu, available P and K for DTPA-Fe and available P and OC for DTPA-Mn in these soils.

Additional key words: *PAU Ludhiana soils, sandy loam soils, influence of NPK on micronutrients.*

Introduction

In the context of changing scenario in agriculture, it is necessary to critical examine the availability of micronutrients as affected by high analysis fertilizers which have resulted in quick depletion of micronutrients (Dhane and Shukla 1995; Katyal and Rattan 2003). The long-term studies provide unique opportunities to study the influence of NPK fertilizers on physical and chemical properties of the soils. This necessitates the monitoring of micronutrients under long-term experiments from time to time.

The uptake of micronutrients by wheat plants varies with different growth stages (Ali *et al.* 1990). Considerable research has been conducted on the influence of long term fertilization on DTPA-extractable micronutrients for a wider range of crops (Sharma and Meelu 1975; Kapur *et al.* 1986; Singh *et al.* 1995) but a little attention has been paid on the availability of micronutrients at various stages of wheat growth in a soil fertilized differentially over a number of years. The appraisal of micronutrients at various growth stages may be helpful in ameliorating the micronutrient deficiency at these stages so as to obtain higher crop production and with these objectives the present investigation was carried out.

Materials and Methods

Surface (0 - 15 cm) soil samples were collected at tillering, ear initiation and harvesting of wheat (44th crop in the sequence) during winter season of 2000-01 from a long-term fertilizer experiment with maize-wheat cropping system (initiated in summer of 1979 at the Punjab Agricultural

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University Farm, Ludhiana) on a sandy loam soil (Typic Ustochrept). At the start of experiment, the experimental soil had pH 8.2, EC 0.132 dS m^{-1} and organic carbon 3.45 g kg^{-1}, DTPA-extractable Zn, Cu, Fe and Mn were 1.04, 0.72, 7.2 and 9.4 mg kg^{-1}, respectively. Application of fertilizers at different rates over the years caused a decline in soil pH and organic carbon but EC increased after 22 cycles of maize-wheat sequence. The available N and P content in control plot ($N_0P_0K_0$) declined but available K was not much affected. N, P and K were supplied through urea, single superphosphate and muriate of potash, respectively. There were four nitrogen levels (0, 60, 120 and 180 kg N ha^{-1}), three P levels (0, 17.5 and 35 kg P ha^{-1}) and two K levels (0 and 33.2 kg K ha^{-1}) in 3^2 x 2 factorial partially confounded design with one control plot in each block with four replications. The N, P and K were applied to both the crops in sequence whereas Zn @ 40 kg $ZnSO_4$ ha^{-1} was given to maize only since 1990. The soil samples were air dried and processed for analysis. Available micronutrients were extracted with DTPA-TEA buffer as per the method proposed by Lindsay and Norvell (1978) and the concentrations of Fe, Mn, Zn and Cu were determined using an atomic absorption spectrophotometer. The relationship between soil properties and DTPA-extractable micronutrients was established through simple correlation and multiple regression analysis.

Results and Discussion

DTPA-extractable micronutrients

A decline in DTPA-extractable micronutrients was observed with increasing N levels which was significant at N_{180} over N_{120} or N_{60} (Fig. 1). The application of P either at 17.5 or 35 kg P ha^{-1} significantly enhanced the availabilities of Zn, Fe and Mn in soils over applied N alone but DTPA- Cu significantly decreased with application of P (Fig. 1, b). In P_{35} plots, there was a significantly higher content of DTPA-Zn, Fe and Mn than $P_{17.5}$ or P_0 plots.On an average, application of P at 17.5 kg P ha^{-1} resulted in an increase of 63.8 per cent for DTPA-Zn, 23.2 per cent for DTPA-Fe and 27.2 per cent for DTPA-Mn over applied N alone (Fig. 1). K application caused a significant increase in DTPA- Zn and Cu, but decrease in DTPA-Mn. Application of K with increasing levels of N at 17.5 kg P ha^{-1} had a significant increase in Fe content whereas reversed the trend with P addition at 35 kg P ha^{-1} (Fig. 1,c). The higher DTPA-Zn, Fe and Mn in P and K treated plots can be attributed to the possible addition of these nutrients through superphosphate and muriate of potash, respectively (Arora *et al.* 1975). The decline in DTPA- micronutrients content in N and NK treated plots resulted in more stress on the soil reserve because of higher yields (Anonymous 2001) and subsequently higher removal of micronutrients. The stress on native micronutrients increased further with the increasing level of NP additions. The addition of DTPA-Zn, Fe and Mn through fertilizer P as a contaminant was substantial during the period of experimentation. As such, the stress on the native source was comparatively less in plots fertilized with P.

The higher DTPA- extractable micronutrients was observed at tillering stage which got decreased with age of crop. The mean decrease from tillering to harvesting stage was 0.26 mg kg^{-1} for DTPA-Zn, 0.07 mg kg^{-1} for DTPA-Cu, 0.71 mg kg^{-1} for DTPA-Fe and 1.3 mg kg^{-1} for DTPA-Mn. With an increase in age of the wheat plant, an increase in biomass production between tillering and ear-initiation resulted in depletion of native micronutrients for meeting the crop demand. Moreover, translocation of micronutrients within the plant and its accumulation in the grain part resulted in higher withdrawal of micronutrients from the native source. An increased Al^{3+} activity in soil solution as a result of continuous use of acid forming fertilizer also resulted a decrease in DTPA-extractable micronutrients. Maji and Mandal (2004) reported that continuous use of urea in soil increases Al^{3+} activity in soil solution which caused a decline in available micronutrients in soil.

As per the critical limit of Zn (0.6 mg kg^{-1}) suggested by Lindsay and Norvell (1978), the Zn content came down to deficient level in N_{180} and NK treatment plots (Fig. 1,a). It is clear (Fig. 1,c) that Fe content in the plots receiving varying rates of N alone or in combination with 33.2 kg K ha^{-1} declined to deficient level (less than 4.5 mg kg^{-1}). However, no visual symptoms of Fe deficiency were observed during various stages of wheat growth. At the same time, declining trend in Fe with continuous cropping points towards the stage when we may have to go for Fe application as foliar spray.

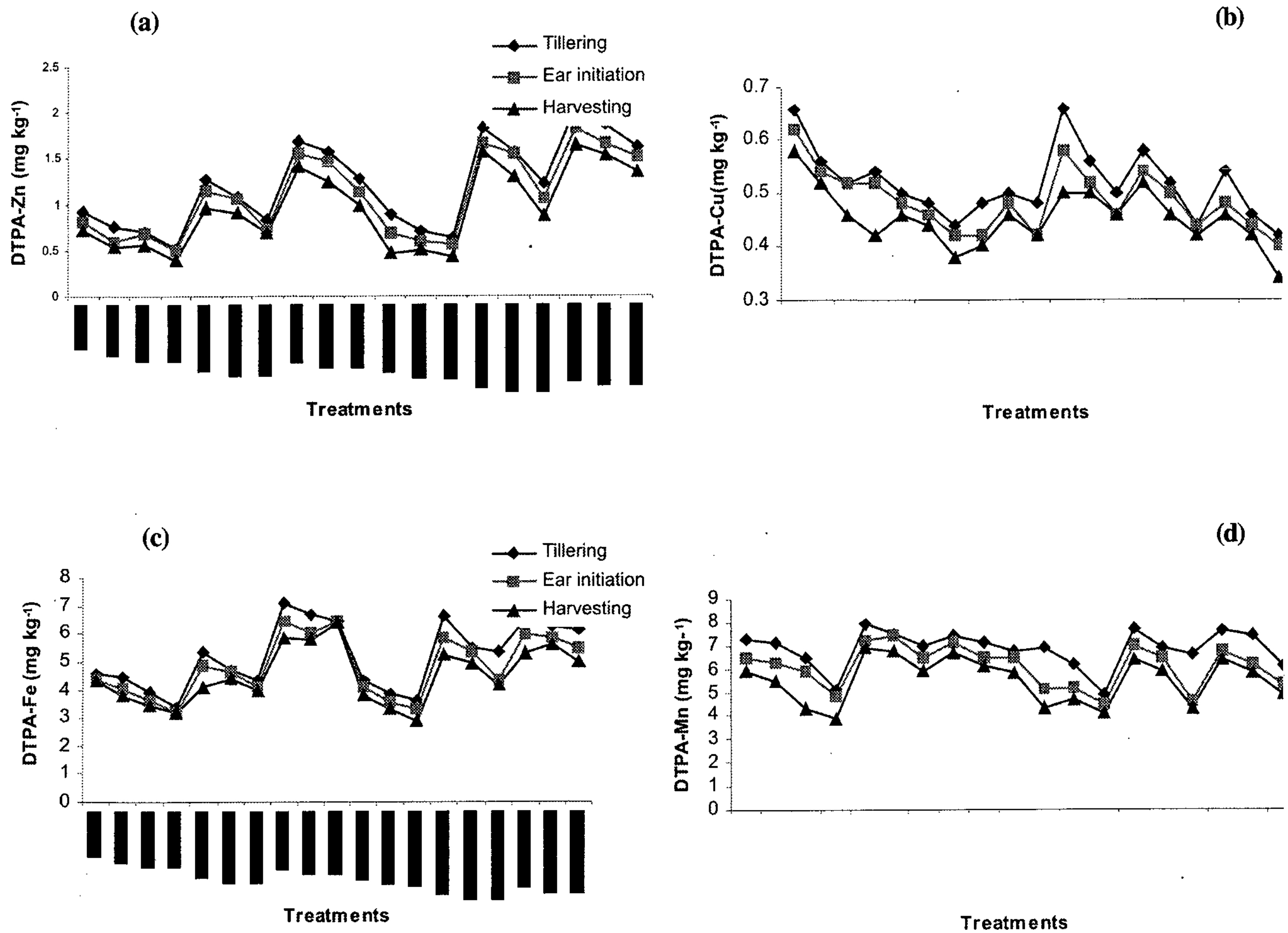

Fig. 1. Changes in DTPA-extractable Zn (a), Cu (b), Fe (c) and Mn (d) at various growth stages of wheat.

Relationship between soil properties and DTPA- extractable micronutrients

The simple correlations and multiple regression equations were worked out to ascertain the degree of relationship between soil properties and DTPA extractable micronutrients, irrespective of growth stage (Table 1 and 2).

Table 1. Correlation between DTPA-extractable micronutrients and soil properties

	pH	EC	OC	N	P	K
Zn	-0.224	0.163	0.377	-0.704*	0.827*	0.101
Cu	0.226	-0.524	0.654*	-0.150	0.520	0.377
Fe	-0.153	0.178	0.267	-0.587*	0.866*	-0.367
Mn	0.143	0.004	0.136	-0.352	0.683*	0.071

* Indicates significance at 5 % level

Table 2. Relationship between DTPA-extractable micronutrients and soil properties using stepwise regression analysis.

Equation	R^2 value
DTPA-Zn	
X + Av. P	0.68
X + Av. P + Av N	0.81
X + Av. P + Av N+ OC	0.81
X + Av. P + Av N + OC + pH	0.99
X + Av. P + Av N + OC + pH + EC	0.99
X + Av. P + Av N + OC + pH + EC + Av K	0.99
DTPA-Cu	
X + OC	0.43
X + OC + EC	0.53
X + OC + EC + Av. P	0.56
X + OC + EC + Av. P + Av K	0.66
X + OC + EC *+ Av. P + Av K*+ pH	0.75
X + OC + EC + Av. P + Av K+ pH+ Av N	0.75
DTPA-Fe	
X + Av. P	0.75
X + Av. P + Av N	0.78
X + Av. P + Av N+ OC	0.79
X + Av. P + Av N + OC + EC	0.79
X + Av. P + Av N + OC + Av K	0.82
X + Av. P + Av N + OC + Av K + pH	0.83
DTPA-Mn	
X + Av. P	0.47
X + Av. P + Av N	0.47
X + Av. P + Av N + Av K	0.55
X + Av. P + Av N + Av K + pH	0.64
X + Av. P + Av N + Av K + pH + OC	0.71
X + Av. P + Av N + pH + OC + EC	0.71

Av = Available

The DTPA- Zn and Fe indicated a negative correlation with pH whereas, with DTPA Cu and Mn a positive correlation with pH was obtained. Lal and Mathur (1989) also obtained a positive correlation between DTPA- Cu and pH. A positive correlation between available P and DTPA-extractable micronutrients indicates that the availability of micronutrients increased with availability of P. These contention finds support that depletion of DTPA-Zn, Fe and Mn was lower in P treated plots as addition of micronutrients as a contaminant through super phosphate. No doubt, there is a build up of P in these soils due to continuous application of single super phosphate (Setia 2002) but the solubility product of these micronutrients is higher than ionic product of P and DTPA-Zn, Fe and Mn which resulted a positive significant correlation with P (Table 1). Sakal *et al.*, (1988) and Sharma (1998) also reported a positive interaction between DTPA-extractable micronutrients and available P. An increase in available N of soils resulted in a decrease in the availability of DTPA- extractable micronutrients. Similar relationship were also reported by Sharma (1999). DTPA-Zn and Cu was positively correlated with K whereas it had a negative relationship with DTPA-Fe and Mn.

The relative and combined influence of pH, EC, organic carbon (OC), available N, P and K on the predictability of DTPA extractable micronutrients was computed by stepwise regression analysis as per method suggested by Tandon *et al* (1971). The regression equations indicated that available P contributed 68 per cent towards variation in Zn availability in soil. The prediction value increased by 13 per cent with inclusion of available N in the regression analysis (Table 2). The inclusion of OC did not improve R^2 value due to its smaller variation in soils of different treatments. The R^2 value further suggested that the predictability of relationship between DTPA-Zn and soil properties improved when pH was also taken into consideration. Inclusion of available K did not significantly improve the prediction value. The major controlling factor on DTPA-Cu was found to be OC as that 43 per cent of the variation is explained by OC only (Table 2). The R^2 value increased by 32 per cent with inclusion of EC, available P, K and pH. The step wise regression equation (Table 2) indicates that all the soil properties accounted for 83 per cent variation in available Fe whereas, available P contributed for 75 per cent variation in DTPA extractable Fe content. The main contributing factor for variation (71 per cent) in DTPA- Mn were available P and K, pH and EC. Inclusion of available N and organic carbon did not improve significantly the prediction value.

The study indicated the negative influence of N addition alone on DTPA extractable micronutrients. The positive influence of P addition (in combination with N or K) has been obtained with its addition through superphosphate. The soil chemical characteristics (pH, EC, OC, available N, P and K) can be helpful to diagnose the micronutrient constraints towards productivity of crops. The continuous addition of micronutrients from the fertilizer in the form of impurities and from organic matter left after harvesting of crops could be two possible options to prevent faster depletion of micronutrients in these soils.

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