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Micronutrient distribution in soils developed on different physiographic units of Fatehgarh Sahib district of Punjab

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Abstract : The distribution of DTPA-extractable micronutrient cations (Zn, Cu , Fe and Mn) and their association with soil properties was studied in five representative soil profiles developed on different physiographic units *viz.*, alluvial plain (Ap1, Ap2 and Ap3), alluvial plain salt affected (Ap4) and sand dunes (SD) in Fatehgarh Sahib district of Punjab. In general, DTPA-extractable micronutrients were higher in surface horizons and decreased in sub-surface horizons. The content of DTPA-extractable micronutrients was highest in intensively cultivated and fine-textured soils (Ap3) and least in that of sand dunes. Based upon the linear coefficient of correlation between DTPA-extractable micronutrients and soil properties, highly significant relationship between DTPA-Zn and OC (r = 0.979*) was found in fine-textured soils of Ap3 but it had a significant positive effect on Cu availability in soils of all the physiographic units. Most of soil properties (except silt and clay) had significant effect only on DTPA-Mn in salt affected soils(Ap4). A significant negative relationship between sand content and DTPA-Zn and Cu was found in soils of alluvial plain with sand cover(Ap1). The additive effect of organic carbon was found to be more pronounced on Fe among all the micronutrient cations, irrespective of physiography. Multiple regression analysis indicates that available Zn, Cu, Fe and Mn were significantly influenced by soil properties at the level of 92, 70, 91 and 59 per cent respectively.

Additional key words: *DTPA-extractable micronutrients, physiography, distribution pattern, soil properties*

Introduction

Micronutrient deficiencies have become one of the major constraints in sustaining crop production in the present day exploitive agriculture. The rice-wheat cropping system, being exhaustive in terms of nutrient removal, resulted in increased pressure on native nutrient reserve of soil. The deficiency of Fe and Mn has been found to occur in this cropping system (Takkar and Nayyar 1981). The availability of micronutrients is influenced by their distribution within the soil profile and other soil characteristics (Singh *et al.* 1989). The distribution of micronutrients may also differ among the profiles developed on different parent materials and landforms (Verma *et al* 2005). Keeping this in view, the present study was undertaken to study the pedospheric variations and correlation of DTPA-extractable micronutrients (Fe, Cu, Zn and Mn) *vis-à-vis* soil characteristics for the soils developed on different land forms in Fatehgarh Sahib district of Punjab.

Materials and Methods

The study area is a part of Indo-Gangetic alluvial plain covering an extent of 1177 sq km. The climate of the area is characterized by a large seasonal variation as well as fluctuations both in monthly rainfall and temperature. The district falls in the semi arid region of Punjab having annual

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average rainfall of 523 mm. Sirhind *Choe* and Patiali *Rao* are only two natural drainage channels which pass through the district. However, the Bhakhra canal along with its distributaries and minors form the irrigation network in the area.

The Indian remote sensing satellite IRS 1C/1D LISS III data (print form) for the year 2002 on 1:50,000 scale was visually interpreted based upon the combination of relevant elements of photo-interpretation. Physiographically, the area has been divided into two major units *viz.* alluvial plain and sand dunes.

The alluvial plain with sand cover (white or light tone, Ap1) has sand cover of varying thickness. These include some of the areas of reclaimed sand dune complexes. The alluvial plain with mixed tone (Ap2) and dark tone (Ap3) on satellite imagery are intensively cultivated and irrigated areas with medium to heavy textured soils, respectively. The alluvial plain-salt affected (Ap4) is comparatively at a lower topographic position than the surrounding areas and has high water table at places. The sand dunes occupy a small portion of the area because most of them have been reclaimed (cleared) by the farmers and brought under cultivation. They stand out as low and high ridges in the alluvial plain and have coarse textured soils.

Typical soil profiles representing different physiographic units were exposed based on reconnaissance soil survey of the area and horizon-wise sampling was done. The processed soil samples were analyzed for pH, electrical conductivity (EC), organic carbon (OC), calcium carbonate ($CaCO_3$) and particle -size distribution. The available Fe, Mn, Zn and Cu were determined in DTPA-TEA buffer (0.005 *M* DTPA+ 0.01 *M* $CaCl_2$ + 0.1*M* TEA, pH 7.3) as per the method of Lindsay and Norvell (1978). Simple correlations between available micronutrient cations and soil properties were worked out. The combined influence of soil properties was also determined by regression analysis.

Results and Discussion

Soil Characteristics

The soils were alkaline in reaction (pH 7.42 to 9.47) and pH usually increased with soil depth (Table 1). There was a significant variation in salt content of different horizons. The electrical conductivity of A horizons of pedons ranged from 0.13 to 0.48 dSm^{-1} and decreased with soil depth. The surface soils are generally medium in organic carbon in all the profiles. It might be due to low biological activity and rapid decomposition of organic matter due to prevalence of high temperature in the area. There was a regular decrease in organic carbon with soil depth. The calcium carbonate content varied from nil to 1.40 per cent in all the pedons, irrespective of physiography. The soils of the area have developed on the alluvial parent material and there is a wide variation in the texture of these soils depending upon topographic position. The soils of sand dunes are coarser in texture whereas, that of alluvial plain are finer in nature with clay content increasing from Ap1 to Ap2 and Ap3. The soils from less stable surfaces like sand dunes are young, lack subsurface diagnostic horizons, having A-C profiles with texture coarser than loamy fine sand are classified as Typic Ustipsamments whereas, that of stable surfaces of alluvial plain (Ap1, Ap2 and Ap3) having A-Bw-C profiles qualified for coarse to fine- loamy Typic Ustochrepts.

DTPA extractable Zn

The DTPA-Zn in surface soil ranged from 0.36 to 0.78 mg kg^{-1}, irrespective of physiography and depth (Table 1). The surface horizons contain higher amount of Zn which progressively declined with depth in all the pedons. Similar distribution pattern of zinc was also reported by Sharma *et al.* (1999). The physiography had a strong influence on Zn distribution in the soils. It was higher in intensively cultivated and fine textured soils of Ap3 (mean 0.37 mg kg^{-1}) followed by Ap2 (mean 0.34 mg kg^{-1}). The soils of sand dunes had least content of DTPA-Zn (mean 0.13 mg kg^{-1}). The relatively high value of available Zn in Ap3 may be attributed to variable intensity of pedogenic processes and more complexing with organic matter which resulted in chelating of Zn. Thus, the coarse textured soils of sand dunes and alluvial plain with sand cover (Ap1) having comparatively high pH and low organic matter, are more prone to Zn deficiency (Takkar and Randhawa 1978). Considering 0.6 $mgkg^{-1}$ as critical limit, the soils of physiography Ap1, Ap4 and sand dunes showed Zn deficiency. However, it requires detailed investigation of spatial distribution of Zn in these soils for proper management practices.

Table 1. Some important characteristics and DTPA-extractable micronutrients of soils

Depth (cm)	(1:2 soil : water) pH	EC (dS m⁻¹)	OC	$CaCO_3$	sand	Silt	Clay	Zn	Cu	Fe	Mn
			←		%		→	←	($mg\ kg^{-1}$)		→
Pedon 1 : Alluvial plain with sand cover (Ap1)											
0-18	7.70	0.16	0.43	0.00	64.2	22.0	13.8	0.58	0.90	7.7	5.00
18-39	7.76	0.14	0.19	0.00	68.8	16.6	14.6	0.14	0.58	4.10	2.22
39-71	7.68	0.13	0.21	0.00	68.4	13.8	17.8	0.10	0.48	3.10	1.88
71-99	7.80	0.14	0.18	0.00	68.0	13.6	18.4	0.12	0.54	3.38	3.64
Pedon 2 : Alluvial plain (Ap2)											
0-19	8.32	0.46	0.54	1.10	60.5	27.1	13.4	0.74	0.88	10.5	6.04
19-40	8.10	0.37	0.22	0.00	35.9	40.1	24.0	0.34	0.56	3.54	8.84
40-67	8.11	0.27	0.15	0.00	35.1	40.1	24.8	0.14	0.58	3.96	8.0
67-108	7.42	0.77	0.13	0.00	29.0	45.6	25.8	0.32	0.68	3.72	5.48
108-132	8.16	0.15	0.10	0.00	28.0	46.0	26.0	0.18	0.54	2.02	4.82
Pedon 3 : Alluvial plain (Ap3)											
0-18	8.59	0.18	0.61	0.70	19.4	51.0	29.6	0.78	1.90	11.9	10.2
18-46	8.92	0.15	0.27	0.00	10.8	50.2	39.0	0.36	0.70	4.08	9.72
46-64	9.21	0.48	0.21	0.00	11.4	47.4	41.0	0.34	0.56	2.92	8.0
64-92	9.32	0.47	0.19	0.60	9.90	38.1	52.0	0.18	0.64	3.10	9.26
92-110	9.35	0.32	0.16	1.10	11.9	34.3	53.8	0.17	0.39	2.92	2.68
Pedon 4 : Alluvial plain salt affected (Ap4)											
0-18	8.62	0.29	0.54	1.40	33.70	45.5	20.8	0.48	1.18	8.92	6.52
18-37	9.19	0.43	0.24	0.80	29.60	45.0	25.4	0.08	0.66	3.68	2.96
37-53	9.34	0.48	0.21	0.70	22.00	48.4	29.6	0.14	0.92	3.36	2.42
53-84	9.22	0.38	0.15	0.60	20.20	49.8	30.0	0.14	0.90	3.26	4.40
84-107	9.45	0.62	0.15	0.65	24.80	42.2	33.0	0.14	0.92	3.38	1.23
107-156	9.47	0.58	0.12	0.00	24.40	42.8	32.8	0.20	0.94	3.70	1.02
Pedon 5 : Sand dunes (SD)											
0-18	8.68	0.42	0.46	0.85	69.3	20.1	10.6	0.36	0.54	6.40	4.42
18-48	8.60	0.16	0.07	0.00	95.3	2.30	2.40	0.08	0.26	1.44	3.74
48-80	8.62	0.14	0.07	0.00	93.8	3.00	3.20	0.06	0.28	2.08	1.44
80-150	8.33	0.35	0.04	0.00	93.0	4.00	3.00	0.02	0.34	3.26	0.92

The highest and significant relationship between DTPA-Zn and OC (r = 0.979*) was found in soils of Ap3 which also validates the results that these soils had highest amount of Zn. The available Zn in soils from Ap1 and Ap2 also had significant and positive correlation with OC. A negative and significant coefficient of correlation between DTPA-Zn and sand (r =0.973) in soils of sand dunes indicates that Zn availability decreased with increase in sand content. Similarly, DTPA-Zn was negatively and significantly correlated with sand content in soils of Ap1 (r = 0.980*). There was a significant negative correlation (r = 0.561*) of DTPA-Zn with EC in salt affected soils (Ap4). Among all the physiographic units, available Zn showed a negative correlation with pH in soils of Ap3 (r = 0.952*) and Ap4 (r = 0.823*). These results are in conformity with the findings of Bhogal *et al.* (1993).

DTPA extractable Cu

The available Cu content in different profiles ranged from 0.26 to 1.90 mg kg^{-1}, irrespective of depth and physiography. In general, DTPA-Cu decreased with soil depth but inconsistent pattern occurred in soils of physiographic units. The probable reason for decreasing Cu content with soil depth is due to the accumulation of biomass in the surface layer of soils leading to higher organic carbon content in the surface than subsurface soils. Setia and Sharma (2004) also found a decrease in DTPA-Cu with soil depth in a Typic Ustochrepts. The DTPA-extractable Cu was highest in the surface soils of Ap3, followed by salt affected soils (Ap4). These changes appear to have resulted from corresponding variation either through organic carbon or $CaCO_3$. All the soils are well supplied with Cu as none of the soil was found to be deficient in Cu according to the critical limit of Cu suggested by Lindsay and Norvell (1978).

Like Zn, the highest degree of correlation (r = 0.992*) was found in soils of physiography Ap3. The available Cu was significantly correlated with OC in all the physiographic units of alluvial plain. The calcium carbonate had a pronounced effect on the Cu availability in soils of sand dunes and Ap2. The relationship between DTPA-Cu and particle-size fractions was significant in soils of Ap1 and sand dunes. A negative correlation between available Cu and sand (r = 0.980* for sand dunes and r = 0.951* for Ap1) indicates that Cu availability significantly decreased with increasing sand content.

DTPA extractable Fe

The DTPA-Fe content ranged from 6.4 to 11.9 mg kg^{-1} in the surface horizon of all the pedons (Table 2). The distribution of Fe in all the pedons did not show a definite pattern but this was abruptly decreased after A horizo n. Singh *et al* (1990) also observed similar distribution pattern of DTPA-Fe in alluvial soils of semi-arid region. Similar to Zn, soils of the sand dunes were lower in DTPA-Fe but higher in alluvial plain. Among three physiographic units of alluvial plain, DTPA-Fe was highest in intensively cultivated soils (Ap3). These results find support from the findings of Katyal and Sharma (1991). Like Zn, the highest degree of positive coefficient of correlation of DTPA-Fe with organic carbon (r = 0.998) was observed in fine textured soils of Ap3. A significant negative effect between DTPA-Fe and pH was found in soils of Ap3 (r = 0.903*) and Ap4 (r = 0.924*).

DTPA extractable Mn

The results (Table 2) indicate that available Mn decreased with soil depth. Higher content of available Mn was observed in surface soils which could be attributed to the chelating of organic compounds released during the decomposition of organic matter left after harvesting of crop. Singh *et al* (1989) also observed a decreasing pattern of available Mn with soil depth. The distribution of Mn according to physiography indicated that DTPA-Mn was the highest in soils of Ap3 followed by salt affected soils (Ap4). Like DTPA-Fe, the lowest amount of DTPA-Mn was found in sandy soils (mean 2.63 mg kg^{-1}). The physiographic relationship between DTPA-Mn and soil properties indicated that majority of soil properties had significant effect on DTPA-Mn in salt affected soils. The DTPA-Mn was negatively correlated with pH (r = 0.944*), EC (r = 0.965) and sand (r = 0.857*) whereas, a positive correlation existed with OC (r = 0.830*) and $CaCO_3$ (r = 0.871*).

Relationship between Soil Properties and DTPA-Extractable Micronutrients

The simple correlations and multiple regression equations were computed to ascertain the degree of relationship between soil properties and DTPA extractable micronutrients, irrespective of physiography (Table 2).

A significant positive correlation between Zn and organic carbon (r = 0.883*) indicates that complexing agents generated by organic matter promote Zn availability in soils (Hodgson 1963). An increase in clay content of soils resulted in an increase in the availability of DTPA- Zn. The availability of copper appears to be mainly influenced by organic carbon as it had highest degree of correlation with OC (r = 0.696*) among all the soil properties. The Cu availability in soils also increased with fineness of soil texture (Katyal and Vlek 1985) as it is evident from a negative correlation between DTPA-Cu and sand (r = 0.452*).

DTPA-Fe had a positive and significant correlation with organic carbon and $CaCO_3$ (r = 0.942*, 0.518*,). Dolui and Mustafi (1997) also obtained a positive relationship between OC and DTPA- Fe. Soil pH did not have a consistent effect on DTPA extractable Mn of soils. Organic carbon of soils had a remarkable effect on available Mn of soils as supported by significant and positive coefficient of correlation (r = 0.468*). The sand content of soils had a significant negative influence on DTPA- Mn (r = 0.473*).

The relative and combined influence of pH, EC, organic carbon (OC), sand (s), silt (si), clay (c) and calcium carbonate ($CaCO_3$) on the predictability of DTPA- extractable micronutrients are explained from the multiple regression equation as given below :

$$Zn = -27.2 + 0.02\,pH + 0.03\,EC + 1.3\,OC - 0.20\,CaCO_3 + 0.27_s + 0.27_{si} + 0.27\,c$$

$$Cu = 7.86 + 0.07\,pH + 0.02\,EC + 1.4\,OC - 0.10\,CaCO_3 - 0.08_s - 0.07_{si} + 0.08\,c$$

$$Fe = -174 + 0.04\,pH + 0.23\,EC + 15.3\,OC - 0.37\,CaCO_3 + 1.74_s + 1.75_{si} + 1.73\,c$$

$$Mn = -159.1 - 0.20\,pH - 3.03\,EC + 11.4\,OC - 2.98\,CaCO_3 + 1.61_s + 1.67_{si} + 1.09\,c$$

About 92 and 70 per cent variations in DTPA extractable Zn and Cu are explained by the combined effect of above soil properties, respectively. These equations show that the available Zn in these soils is largely controlled by organic carbon, followed by electrical conductivity as it is evident from the value of regression coefficient between Zn and organic carbon (r =1.3). Nearly 91 and 59 per cent variations in DTPA extractable Fe and Mn, respectively are accounted for by the combined effect of these soil properties. These equations showed that the additive effect of organic carbon was found to be more pronounced on Fe among all the micronutrient cations.

Conclusions

The study thus indicaled that the deficiency of Zn is of major concern among all the micronutrients. The contents of DTPA extractable micronutrients were highest in intensively cultivated and fine textured soils of Ap3 due to balanced use of agricultural inputs. There exists a close relationship between availability of micronutrients and soil development. The coarse textured soils of sand dunes were

Table 2. Correlation between soil properties and DTPA- extractable micronutrients

	pH	EC	OC	$CaCO_3$	Sand	Silt	Clay
Zn	-0.156	0.022	0.883*	0.354	-0.203	0.313	0.047
Cu	0.156	0.125	0.696*	0.428*	-0.452*	0.579*	0.232
Fe	-0.149	-0.039	0.942*	0.518*	-0.055	0.189	-0.107
Mn	-0.056	-0.064	0.468*	0.063	-0.473*	0.496*	0.373

* indicates significance at 5 % level

found to be more prone to micronutrient deficiencies. Among all the soil properties, organic carbon had a prominent effect on the availability of micronutrients.

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