INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2005/07–2–243–246
http://www.ijab.org

Pedospheric Variations in Distribution of DTPA- extractable Micronutrients in Soils Developed on Different Physiographic Units in Central Parts of Punjab, India

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ABSTRACT

Six soil profiles developed on different physiographic units (alluvial plain, alluvial plain with sand cover, alluvial plain salt affected, sand dunes, old and recent flood plain) in central parts of Punjab (India) were studied for the distribution of DTPA-extractable micronutrients. The changes in physiography had a strong influence on micronutrient distribution. It was higher in fine textured soils of old flood plain. The soils of sand dunes had least content of DTPA extractable micronutrients. The DTPA Zn, Cu and Fe decreased with increasing soil depth but DTPA Mn did not follow a definite trend. Based upon the linear coefficient of correlation between DTPA-extractable micronutrients and soil properties according to physiography (i) the highest and significant relationship between DTPA Zn and OC (r = 0.992*) was found in soils of old flood plains (ii) calcium carbonate had a pronounced effect on increasing the Cu availability in soils of old flood plain (iii) organic carbon had least effect on availability of Fe in soils of alluvial plain (iv) maximum soil properties had significant effect on DTPA Mn in soils of old flood plains. DTPA Mn decreased with rise in pH and sand whereas, it increased with organic matter and clay content. The additive effect of organic carbon was found to be more pronounced in Fe among all the micronutrient cations, irrespective of physiography.

Key Words: Pedospheric; Micronutrients; Physiographic units; India

INTRODUCTION

The micronutrient availability in soils is a function of rate of replenishment from soil solids to soil solution. In all soils, replenishment of micronutrients takes place from earth minerals present in the pedosphere or lithosphere. The pedospheric variations due to parent material, topography, climate etc. lead to spatial variation of micronutrients in soils (Katyal & Sharma, 1991). The distribution of micronutrients may differ among the profiles developed on different parent materials and landforms. With the introduction of high yielding varieties, the removal of nutrients including micronutrients from the soils is very large. Continuous use of nitrogenous and phosphatic fertilizers in the intensive cropping system with less use of organic manures resulted in quick depletion of micronutrients from soils (Dhane & Shukla, 1995).

In central parts of Punjab, the agriculture scenario has been completely changed due to the ushering of green revolution as the consumption of fertilizers (in Ludhiana district representing the central parts) has increased from 137,000 tonnes (1987-88) to 147,000 tonnes (1999-2000) and cropping intensity from 172 (1987-88) to 185 (1999-2000). This suggests the probable depletion of nutrients particularly micronutrient cations from the soil reserves (Katyal & Rattan, 2003). Over the past couple of decades, the farmers have started cultivation of rice even in some highly permeable soils, which is otherwise not recommended for rice cultivation. The rice-wheat cropping system being exhaustive in terms of nutrient removal, results in increased pressure on native nutrient reserve of soil. Under such situation, Fe and Mn deficiency has been found to occur in rice-wheat cropping system (Takkar & Nayyar, 1981). Now, the soil ill health due to micronutrient deficiency is becoming a major challenging issue in the soils of central parts of Punjab. Therefore, for an effective correction of a nutrient deficiency in the field, it is necessary to get information about the inherent capacity of soil to supply nutrient from the lower soil layers (Setia & Sharma, 2004). As the distribution of nutrients in soils is closely related to pedogenic development, the present study was, therefore, undertaken to study the pedospheric variations of DTPA- extractable micronutrients (Fe, Cu, Zn & Mn) and their relationship with soil properties in the soils developed on different land forms and parent materials in central parts of Punjab, India.

MATERIALS AND METHODS

The study area (Ludhiana district) covering an area of 3700 Sq Km, is a part of Indus plain formed by Pleistocene and recent deposits of the rivers of the Indus system. The major physiographic units identified in the area are: flood plain, alluvial plain, sand bars / dunes. The district enjoys a sub-tropical monsoonal climate, subject to south-easterly summer rains. The average rainfall of the area is 660 mm, about 70% of which is received during June and September and coincides with the growth period of the kharif crops.

The soils of the area qualify for 'Ustic' soil moisture regime and 'hyperthermic' soil temperature regime.

Based on rapid reconnaissance soil survey of the area, typical soil profile representing different physiographic units were exposed 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 (Soil Survey Staff, 1998). The available fractions of Fe, Mn, Zn and Cu were extracted with DTPA-TEA buffer (0.005 M DTPA+ 0.01M $CaCl_2$ + 0.1M TEA, pH 7.3) as per the method of Lindsay and Norvell (1978) and the concentration of Fe, Mn, Zn and Cu in the DTPA-extracts was determined on an Atomic Absorption Spectrophotometer. The relationship between various soil properties and micronutrient distribution was established by using simple correlation and multiple regression analysis.

RESULTS AND DISCUSSION

Physico-Chemical Characteristics. The soils were alkaline in reaction (pH varied from 7.20 to 9.65) and usually increased with increasing soil depth (Table I). There was a great variation in salt content of different horizons. The electrical conductivity of A horizons of all the pedons ranged from 0.09 to 0.42 dSm^{-1} and decreased with increasing soil depth. The surface soils are generally medium in organic carbon in all the profiles except the soils from sand dunes/bars and alluvial plain with sand cover which had a lower content of organic matter content. 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 content with increasing soil depth. The calcium carbonate content varied from nil to 17.60% in all the pedons, irrespective of physiography. The $CaCO_3$ content was the highest in the soils of recent flood plain and nil in that of sand dunes.

The soils of the area have been 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 bars/dunes and alluvial plain with sand cover are coarser in texture whereas, that of recent flood plain are stratified in nature. The finer sediments are found in soils of old flood plain and alluvial plain. The heterogeneity in texture is due to erosion and deposition as a result of flooding in Satluj river. The soils of unstable landforms like sand dunes and alluvial plain with sand cover are young, having A-C profiles and classified as Typic Ustipsamments, whereas, soils of recent flood plain being stratified in nature have been classified as Typic Ustifluvents. The soils from stable land forms like old flood plain and alluvial plain having A-B-C profiles were classified as Typic Ustochrepts.

Pedospheric Distribution of DTPA Extractable Micronutrients

DTPA-Zinc. The DTPA-Zn in surface soil ranged from 0.10 to 1.36 mg kg^{-1}, irrespective of physiography and depth (Table II). All the pedons contain higher amount of Zn in the surface layer but there was a regular decrease in Zn content in the soil profile (Singh *et al.*, 1990). The accumulation of Zn in surface horizon in all the pedons might be due to the addition through plant residues left over by the preceding crop (Jalali *et al.*, 1989) as intensive cropping system is followed in the studied area which resulted in complexing of Zn with organic matter. The physiography had a strong influence on Zn distribution in the soils. It was higher in fine textured soils of old flood plain (Mean = 0.32 mg kg^{-1}) followed by that of recent flood plain (Mean=0.30 mg kg^{-1}). The soils of sand dunes had least content of DTPA Zn (Mean = 0.07 mg kg^{-1}, respectively). It indicates that the distribution of DTPA Zn coincided with the distribution of organic carbon in the soils. Thus, the coarse textured soils of sand dunes and alluvial plain with sand cover which are low in organic

Table I. Physico-Chemical Characteristics of Soils of Central Parts of Punjab, India

Depth (cm)	(1:2 soil : water)			Percent				
	pH	EC	OC	$CaCO_3$	Sand	Silt	Clay	Texture
Pedon 1 (Physiography - Alluvial plain)								
0-13	8.49	0.30	0.45	2.4	54.60	25.60	19.80	sl
13-32	8.64	0.22	0.29	0.9	36.60	43.80	20.40	l
32-60	8.67	0.19	0.30	0.9	26.00	51.60	22.40	sil
60-87	8.59	0.18	0.28	0.9	26.40	50.40	23.20	sil
87-109	8.46	0.20	0.21	0.8	24.20	55.00	24.80	sil
109-130	8.45	0.19	0.13	0.7	40.20	29.40	30.40	cl
130-160	8.45	0.19	0.12	0	40.10	29.10	30.80	cl
Pedon 2 (Physiography - Alluvial plain with sand cover)								
0-12	8.2	0.16	0.21	0	86.00	5.20	8.80	ls
12-38	8.25	0.16	0.19	0	86.50	5.10	8.40	ls
38-60	8.24	0.14	0.09	0	80.30	7.90	11.80	ls
60-105	8.28	0.13	0.09	0	78.00	10.80	11.20	ls
105-152	8.3	0.15	0.07	0	71.60	14.40	15.00	sl
Pedon 3 (Physiography-salt affected)								
0-15	8.80	0.34	0.48	1.4	53.00	29.80	17.20	sl
15-27	9.27	0.43	0.25	1.1	46.00	32.40	21.60	l
27-42	9.35	0.41	0.09	1.2	32.70	41.70	25.60	l
42-89	9.19	0.39	0.06	1.2	33.50	40.50	26.00	l
89-118	9.50	0.42	0.06	1.5	32.00	45.20	22.80	l
118-150	9.65	0.48	0.07	6.4	31.10	49.10	19.80	l
Pedon 4 (Physiography -sand dunes)								
0-33	8.19	0.09	0.06	0	95.60	1.40	2.80	s
33-63	7.25	0.08	0.04	0	95.10	1.50	3.40	s
63-115	7.2	0.08	0.04	0	95.90	1.50	2.60	s
115-144	7.39	0.07	0.04	0	96.20	1.50	2.40	s
144-165	7.29	0.08	0.06	0	96.20	1.40	3.00	s
Pedon 5 (Physiography -old flood plain)								
0-26	8.27	0.42	0.76	8.4	25.00	56.80	18.20	sil
26-44	8.53	0.34	0.19	8.2	16.60	64.40	19.00	sil
44-63	8.62	0.23	0.09	2	73.50	20.10	6.40	sl
63-77	8.54	0.26	0.09	6.1	28.50	62.50	9.00	sil
77-87	8.63	0.20	0.06	0.03	82.00	11.20	6.80	ls
87-150	8.65	0.17	0.03	1.3	94.80	0.80	4.40	s
Pedon 6 (Physiography - recent flood plain)								
0-17	8.46	0.19	0.62	1.54	95.80	2.80	2.40	s
17-25/35	8.55	0.27	0.33	4.76	79.80	12.40	7.80	ls
25/35-50	8.60	0.25	0.34	7.04	59.10	26.70	14.20	sl
50-81	8.57	0.33	0.40	8.58	49.20	35.40	15.40	l
81-116	8.75	0.31	0.30	11.00	35.90	41.90	22.20	l
116-138	8.83	0.28	0.25	17.60	22.50	45.30	32.20	l
138-160	8.82	0.20	0.04	2.86	93.50	2.70	3.80	cl

Table II. Distribution of DTPA extractable micronutrients in the soils of Central Parts of Punjab, India

Depth (cm)	(mg kg^{-1})			
	Zn	Cu	Fe	Mn
Pedon 1 (Physiography : Alluvial plain)				
0-13	0.52	0.46	4.30	5.88
13-32	0.12	0.40	2.46	4.86
32-60	0.16	0.32	2.46	4.82
60-87	0.12	0.34	2.50	4.60
87-109	0.14	0.38	2.76	3.78
109-130	0.16	0.30	2.82	4.04
130-160	0.16	0.25	2.92	3.12
Pedon 2 (Physiography- Alluvial plain with sand cover)				
0-12	0.26	0.08	1.12	3.22
12-38	0.24	0.08	1.20	3.50
38-60	0.08	0.08	0.80	3.82
60-105	0.08	0.10	0.96	3.02
105-152	0.10	0.08	1.04	3.12
Pedon 3 (Physiography- Alluvial plain with salt affected)				
0-15	0.44	0.56	5.68	3.86
15-27	0.24	0.62	7.34	6.72
27-42	0.14	0.44	3.06	3.32
42-89	0.10	0.24	2.70	2.34
89-118	0.10	0.16	1.70	2.66
118-150	0.08	0.14	4.66	1.56
Pedon 4 (Physiography - Sand dunes)				
0-33	0.10	0.06	1.06	2.66
33-63	0.08	0.06	0.92	2.98
63-115	0.07	0.06	0.86	3.08
115-144	0.06	0.04	0.42	1.64
144-165	0.03	0.04	0.46	1.86
Pedon 5 (Physiography -Old flood plain)				
0-26	1.36	0.60	9.84	6.26
26-44	0.16	0.60	5.12	4.72
44-63	0.14	0.14	2.60	1.64
63-77	0.12	0.28	3.40	2.28
77-87	0.08	0.08	2.10	1.04
87-150	0.04	0.04	1.86	1.10
Pedon 6 (Physiography- Recent flood plain)				
0-17	1.01	0.56	6.68	3.30
17-25/35	0.08	0.14	1.48	3.74
25/35-50	0.35	0.86	12.82	3.16
50-81	0.38	1.44	21.14	6.72
81-116	0.16	1.36	8.28	8.92
116-138	0.08	0.80	4.16	6.26
138-160	0.06	0.18	2.32	4.02

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

	pH	EC	OC	$CaCO_3$	Sand	Silt	Clay
Zn	0.026	0.296	0.854*	0.222	-0.088	0.133	-0.028
Cu	0.299	0.478	0.557*	0.693*	-0.480*	0.475*	0.386*
Fe	0.261	0.496	0.557*	0.569*	-0.326*	0.362*	0.171
Mn	0.072	0.209	0.532*	0.406*	-0.344*	0.271	0.425*

* indicates significant at 5 % level

matter are more prone to Zn deficiency (Takkar & Randhawa, 1978). The level of plant available Zn is also low and its deficiency is acute in saline-sodic soils due to low organic matter content.

A negative significant coefficient of correlation between DTPA Zn and sand (r = -0.889*) in soils of sand dunes indicates that Zn availability decreased with increase in sand content and this is also supported by that sand dunes had the least amount of DTPA Zn (Table II). Based on the negative correlation of DTPA Zn with EC in salt affected soils of alluvial plain (r = - 0.827*), it is expected that salt concentration had a negative influence on the availability of Zn. The highest and significant relationship between DTPA Zn and OC (r = 0.992*) was found in soils of old flood plains which also validate the results that old flood plains had highest amount of Zn.

DTPA-Cu. The DTPA Cu varied from 0.04 to 1.44 mg kg^{-1} with a mean value of 0.33 mg kg^{-1}, irrespective of depth and physiography. The available Cu status decreased with increasing soil depth which may be attributed to the accumulation of biomass in the surface layer of soils leading to higher organic carbon content in the surface than subsurface soils (Setia & Sharma, 2004). The distribution of Cu showed a close relationship with physiography. The DTPA extractable Cu was highest in the surface soils of old flood plains and lowest in that of sand dunes. These changes appear to have resulted from corresponding variation either through organic carbon or $CaCO_3$.

The calcium carbonate had a pronounced effect on increasing the Cu availability in soils of old flood plains as DTPA- Cu was only significantly correlated with $CaCO_3$ in these soils (r = 0.954). No significant effect of $CaCO_3$ on Cu availability was found in other soils.

DTPA-Fe. The content of DTPA Fe ranged varied between 1.06 to 9.84 mg kg^{-1} in the surface horizon of all the pedons (Table II). There was a sharp decrease in Fe content with increasing depth and the decrease was very sharp after the Ap horizon. DTPA-Fe increased with change in physiography from sand dunes (Mean = 0.74 mg kg^{-1}) to recent flood plains (Mean = 8.13 mg kg^{-1}). The susceptibility of Fe to change from coarse texture to fine textured soils explained the variability of DTPA-Fe in soils of different physiography, as the fine textured soils of old flood plains contain higher amount of DTPA extractable micronutrients (Katyal & Sharma , 1991). The DTPA- Fe content increased up to C 2 and Bw1 horizon in soils of sand dunes and salt affected areas, respectively. This may be attributed to the movement of finer fractions to lower horizons during the process of illuviation which indicates that a relationship exists between soil processes and Fe movement in the soils.

The highest degree of positive coefficient of correlation of DTPA-Fe with organic carbon (r = 0.998) was observed in soils of old flood plain. The organic carbon had least effect (r = 0.554) on availability of Fe in soils of alluvial plain which confirmed that organic matter is not sufficiently supplying plant available form of Fe in these soils.

DTPA-Mn. The data presented in Table II indicated available Mn did not show any specific pattern with increasing soil depth in all the pedons, though it had a tendency to decrease up to a certain depth followed by irregular pattern in all the profiles. Sangwan and Singh (1993) also observed irregular pattern in available Mn content of soil with increasing soil depth. This might be due to weak pedological manifestation and alluvial nature of the soils. At the same time, fluctuation in organic carbon also caused the inconsistent pattern of available micronutrient distribution. The distribution of Mn according to physiography revealed that DTPA- Mn was the highest in soils of alluvial plain followed by salt affected soils. Like DTPA-Fe, the lowest amount of DTPA- Mn was found in sandy soils (Mean = 2.44 mg kg^{-1}). There was a little variation in DTPA- Mn up to C horizon in the soils of alluvial plain with sand cover; whereas, in salt affected soils, the B horizons showed a higher content of Mn due to leaching of Mn in these soils (Khattak & Jarrel, 1989).

The physiographical relationship between DTPA-Mn and soil properties revealed that maximum soil properties had significant effect on DTPA Mn in soils of old flood plains. The DTPA-Mn was negatively correlated with pH (r = -0.915*) and sand (r = -0.823*) whereas, a positive correlation existed with EC (r = 0.987*), OC (r = 0.880*), $CaCO_3$ (r = 0.970* and clay (r = 0.823*). From this association, it can be inferred that addition of organic matter encourages the availability of Mn and as the soil become coarser, Mn deficiency become a problem (Nayyar *et al.*, 1985).

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 physiography (Table III).

A significant positive correlation between Zn and organic carbon (r = 0.854*) indicates that complexing agents generated by organic matter promote Zn availability in soils (Hodgson, 1963). An increase in sand content of soils resulted in a decrease in the availability of DTPA- Zn. The availability of copper appears to be mainly influenced by OC as it bore a significant correlation with OC (r = 0.686*). The increasing amount of $CaCO_3$ also had a pronounced effect on increasing the Cu availability. The Cu availability in soils also increased with fineness of soil texture (Katyal & Vlek, 1985) as it is evident from a positive and significant correlation between DTPA-Cu with clay (r = 0.386*).

DTPA-Fe was found to be negatively correlated with sand; whereas, it had a positive and significant correlation with organic carbon and $CaCO_3$ (r = 0.693* and 0.569*, respectively). Soil pH did not have a consistent effect on DTPA-extractable Mn content of soils. However, both clay and organic carbon contents of soils had a marked influence on the DTPA-Mn content of soils as supported by significant and positive value of coefficient of correlation (r = 0.425 and 0.532, respectively).

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:

$$Zn = -0.026 - 0.013\ pH + 0.979^{*}\ EC + 1.21^{*}\ OC - 0.005\ CaCO_3 + 0.009\ S + 0.008\ Si + 0.006\ C$$

$$Cu = -2.41 - 0.013\ pH + 0.221\ EC + 0.659^{*}\ OC + 0.045\ CaCO_3 + 0.024\ S + 0.023\ Si + 0.032\ C$$

$$Fe = -11.7 - 0.822\ pH + 13.91 EC + 7.85^{*}\ OC + 0.371^{*} CaCO_3 + 0.173\ S + 0.160\ Si + 0.142\ C$$

$$Mn = 29.3 - 0.753\ pH - 0.996\ EC + 4.68^{*}\ OC + 0.128\ CaCO_3 - 0.212\ S - 0.234\ Si - 0.090\ C$$

About 78 and 64% variations in DTPA extractable Zn and Cu is 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. Nearly, 53 and 55% variations in DTPA extractable Fe and Mn, respectively are accounted for the combined effect of these soil properties. These equations shows that the additive effect of organic carbon was found to more pronounce in Fe among all the micronutrient cations.

CONCLUSION

The variations in distribution of micronutrients indicated that physiography and physicochemical processes plays a major role in controlling the availability of micronutrients. Among the micronutrients, the deficiency of Zn is of major concern and these soils require application of Zn fertilizers to maximise the crop yield.

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(Received 20 November 2004; Accepted 10 February 2005)