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Distribution of micronutrient cations in different physiographic units of semi-arid region of Punjab

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Abstract: The distribution of DTPA-extractable micronutrients was studied in six major physiographic units namely alluvial plain with sand cover, upper alluvial plain, lower alluvial plain, alluvial plain with salt encrustation, micro-basins and sand dunes in semi-arid parts of Punjab. DTPA-extractable micronutrients (except DTPA-Fe) were highest in sandy loam to loam soils of lower alluvial plains and lowest in sandy soils of dunes. DTPA-Fe was highest in soils of micro-basins. In general, DTPA-extractable micronutrients were higher at surface and decreased with soil depth and their distribution followed the similar trend as of organic carbon and clay content. The step down multiple regression analysis indicated that pH, EC, OC and clay content influenced 57, 97, 26 and 60 per cent variation in DTPA- Zn, Cu, Fe and Mn, respectively.

Additional keywords: *Indo-Gangetic alluvial plain, salt-affected soils, sand-dune soils*

Introduction

It is known that micronutrients are held within the mineral matter (Miller *et al* 1986) and finer fractions of soils (Follet and Lindsay 1978; Sharma *et al.* 1999, 2004). The availability of micronutrients is sensitive to changes in soil environment as well as physiography, however, landscape position and land use may be the dominant factors of soil properties.

Traditionally status of micronutrients was studied in only surface horizons (Takkar *et al.* 1989). The sub-soil micronutrient status, which varies in the soil profile depending upon parent materials, landforms, climatic conditions, natural vegetation and land use pattern (Deka *et al.* 1996) is an important characteristic to know the soil resources, especially for agronomic practices. The distribution of micronutrients in Alfisols under different land-forms of Punjab was studied by Sharma *et al.* (2005) but not in areas with a semi-arid climate such as Faridkot district of Punjab. Thus the present work has been undertaken to assess the effect of physiography on distribution of micronutrients in alluvial soils of Faridkot district and to find out the relationship between soil properties and micronutrients.

Material and Methods

Geographical Setting

The study area lies between $30^0 20'$ to $30^0 47'$ N latitudes and $74^0 18'$ to $75^0 02'$ longitudes covering 1776 km^2, constituting a part of Indo-Gangetic alluvial plain in the southwestern zone of Punjab state. The soils have been developed from alluvial deposits of Pleistocene to late Holocene period on nearly level land (Wadia 1976). The alluviam was later modified and new deposits laid by the occasional shifting of the Satluj river course. The annual rainfall varies from 368 mm in south-west to 480 mm in north-east. Based on visual interpretation of IRS 1C LISS-III satellite data for the year 2002, the area has been divided

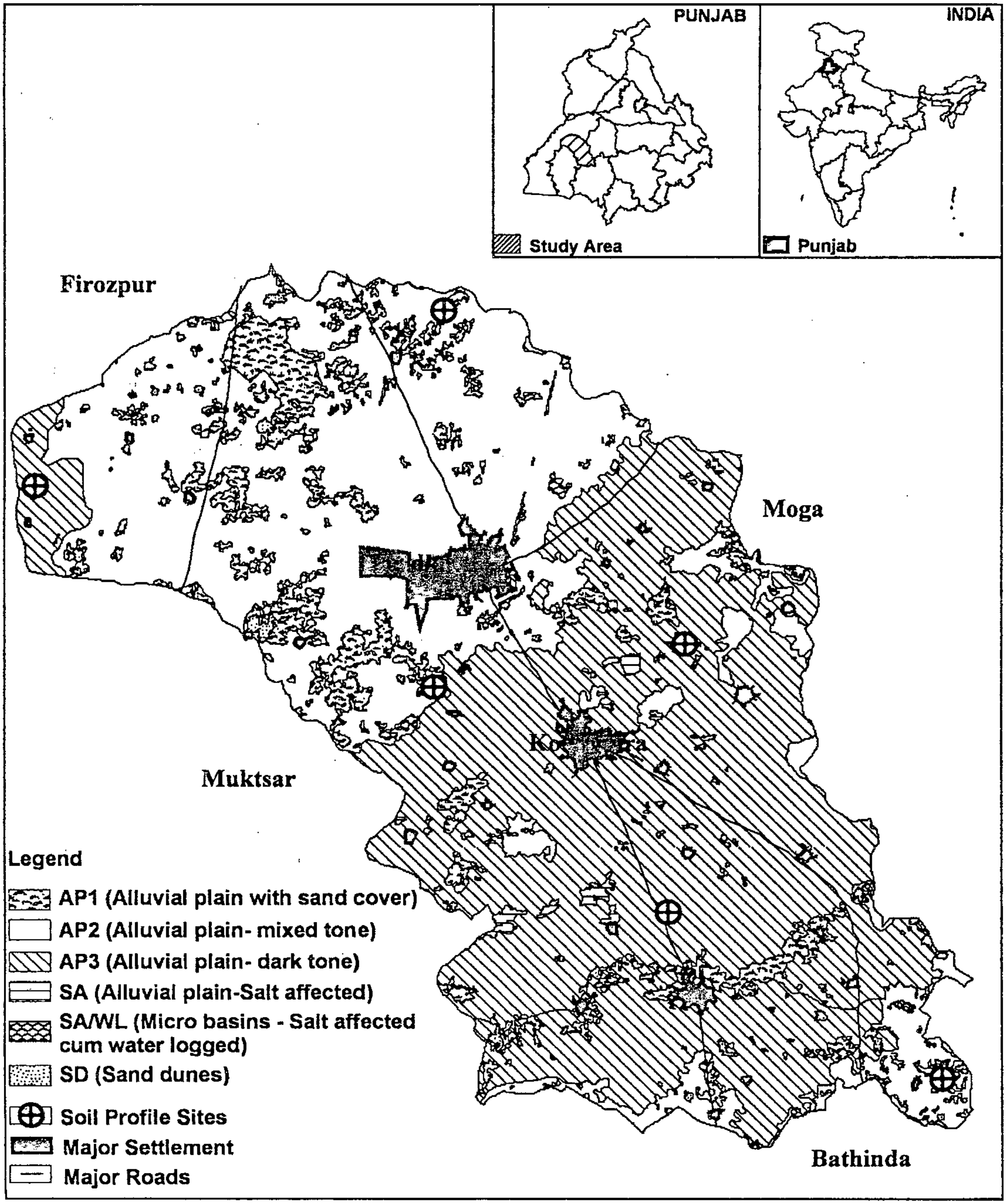

Fig. 1. Physiography Map and Location of Soil Profile Sites in the Study Area

into two major physiographic units *viz.* alluvial plain (Ap) and sand dunes (SD). The alluvial plain constitute a major portion of the district and has been further categorized into alluvial plain with sand cover (Ap1), upper alluvial plain (Ap2), lower alluvial plain (Ap3), alluvial plain with salt encrustation (Ap4) and micro-basins (B). The alluvial plain with sand cover (Ap1) with varying thickness of sand includes some of the areas of reclaimed sand-dune complexes. The soils of upper (Ap2) and lower (Ap3) alluvial plain are intensively cultivated. The soils of micro-basins and alluvial plain with salt encrustations (Ap4) occupied lower topographic position and have high water table at places. The dunes (SD) occupying a small part of the study area, occur as low ridges in the alluvial plain.

Typical soil profiles (Fig. 1), three from each Physiography unit were exposed and horizon-wise soil samples were collected. These were processed and passed through a 2 mm sieve and analyzed for pH, electrical conductivity (EC) in 1:2 soil:water suspension, particle-size distribution, calcium carbonate ($CaCO_3$) and organic carbon following standard procedures as described by Page *et al.* (1991). The available Fe, Mn, Zn and Cu were extracted with DTPA-TEA buffer (0.005 *M* DTPA+ 0.01*M* $CaCl_2$ + 0.1*M* TEA pH 7.3) as described by Lindsay and Norvell (1978). The relationship between micronutrients and physico-chemical properties was computed by simple correlation and stepwise regression analysis (Panse and Sukhatme 1967).

Results and Discussion

Physical and chemical characteristics of soils

The sand content ranged from 95 to 96% in soils of dunes and 50 to 81% in other soils of alluvial plains, however, reverse trend was observed for silt and clay content (Table 1). The soils were alkaline with pH ranging from 8.7 to 10.2. High pH in alluvial plain with salt encrustations and micro-basins may be due to higher concentration of Na and Mg ions. The electrical conductivity was higher in soils of micro-basins than other soils. Organic carbon content was relatively higher in extensively cultivated soils of upper and lower alluvial plains (Table 1). The soils of alluvial plains were calcareous, whereas soils of dunes were non-calcareous.

Distribution of DTPA-extractable micronutrients

The DTPA-Zn varied from 0.02 to 0.10 mg kg^{-1} in the soils of dunes and 0.06 to 1.52 in soils of alluvial plain. There was significant differences in different physiographic units for DTPA-Zn. The DTPA-Zn content (mean 0.82 mg kg^{-1}) was the highest in fine-textured soils of lower alluvial plain (Ap3) followed by salt affected and waterlogged soils (mean 0.67 mg kg^{-1}) of micro-basins. Sharma *et al* (1999) also reported higher Zn content in fine textured soils than coarse textured soils. The higher content of available Zn in the soils of Ap3 may be due to higher organic carbon addition through crop residues and decreased with soil depth (Dhane and Shukla 1995; Setia and Sharma 2004). The available Cu in surface soils ranged from 0.14 to 1.00 mg kg^{-1}. The soils of lower alluvial plain (mean 0.51 mg kg^{-1}) and micro-basins (mean 0.50 mg kg^{-1}) had higher Cu content as compared to other soils developed on sand-dunes and other parts of alluvial plain (Verma *et al.* 2005).

The available Fe ranged from 1.02 to 1.38 mg kg^{-1} in the soils of dunes, 1.12 to 2.34 mg kg^{-1} in alluvial plain with sand cover, 0.85 to 3.04 mg kg^{-1} in upper alluvial plain, 1.26 to 7.98 mg kg^{-1} in lower alluvial plain, 0.71 to 7.68 in the soils developed on alluvial plain with salt encrustations and 0.98 to 15.26 mg kg^{-1} in micro-basins (Table 2). The available Fe increased from sand-dunes (mean 1.19 mg kg^{-1}) to micro-basins (mean 6.38 mg kg^{-1}). The highest available Fe in waterlogged soils may be attributed to its greater sensitivity to fluctuations in soil moisture (Han and Banin 1996). In general, available Fe decreased with soil depth.

The data (Table 2) indicated that available Mn varied from 0.62 to 3.60 mg kg^{-1} in soils of dunes and alluvial plain with sand cover, 1.52 to 5.92 mg kg^{-1} in upper and lower alluvial plain and from 0.92 to 7.46 mg kg^{-1} in alluvial plain with salt encrustations and micro-basins. The available Mn was highest in salt affected soils and soils of lower alluvial plain. The lowest amount of DTPA-Mn was in sandy soils (mean 1.54 mg k^{-1}). The higher content of available Mn was observed in surface soils which could be attributed to the chelation effect of organic compounds.

Table 1. Chemical characteristics of soils of Faridkot District of Punjab

Horizon	Depth (cm)	pH	ECe ($dS\ m^{-1}$)	Organic carbon	CaCO3	Sand	Silt	Clay	Texture
		(1:2 soil: water)		(%)					
Pedon 1: Sand-dunes (SD)									
A	0-16	8.7	0.08	0.09	Nil	95.3	0.9	3.8	s
C1	16-52	8.9	0.09	0.05	Nil	96.5	0.7	2.8	s
C2	52-109	9.0	0.08	0.03	Nil	95.6	0.2	4.2	s
C3	109-150	8.9	0.09	0.05	Nil	95.9	1.3	2.8	s
Pedon 2: Alluvial plain with sand cover (Ap1)									
Ap	0–10	8.7	0.10	0.22	Nil	78.5	10.5	11.0	sl
C1	10-19	8.9	0.11	0.09	Nil	80.4	13.6	6.0	ls
C2	19-42	8.8	0.13	0.08	0.7	78.5	14.9	6.6	ls
C3	42-65	8.9	0.14	0.08	0.8	79.5	14.3	6.2	ls
C4	65-97	8.8	0.14	0.11	4.6	78.3	15.7	6.0	ls
C5	97-150	8.7	0.17	0.05	7.0	79.4	14.6	6.0	ls
Pedon 3: Upper alluvial plain (Ap2)									
Ap	0-18	8.8	0.11	0.35	2.7	75.3	17.3	7.4	sl
Bw1	18-39	9.0	0.19	0.12	4.8	68.6	19.0	12.4	sl
Bw2	39-81	9.1	0.38	0.11	8.2	69.4	18.6	12.0	sl
Bw3	81-124	9.2	0.37	0.09	8.8	75.7	12.5	11.8	sl
C	124-150	9.2	0.34	0.05	4.4	79.1	11.7	9.2	sl
Pedon 4: Lower alluvial plain (Ap3)									
A	0-26	9.0	0.21	0.30	0.4	59.1	24.5	16.4	sl
AB	26-46	9.2	0.18	0.09	2.7	53.5	28.3	18.2	sl
Bw1	46-82	9.0	0.17	0.11	Nil	50.4	27.8	21.8	l
Bw2	82-120	9.1	0.17	0.08	Nil	50.7	27.3	22.0	l
C	120-150	9.2	0.19	0.09	2.7	52.4	29.0	18.6	sl
Pedon 5: Alluvial plain with salt encrustation (Ap4)									
Ap	0-8	9.9	11.23	0.18	4.8	58.6	27.3	14.1	sl
AB	8-23	9.9	4.75	0.09	3.8	62.4	23.6	14.0	sl
Bw1	23-38	10.1	4.17	0.15	9.1	64.9	18.9	16.2	sl
Bw2	38-59	10.0	2.81	0.17	11.5	63.3	19.3	17.4	sl
Bw3	59-78	10.0	1.97	0.12	12.4	59.5	22.8	17.7	sl
Bw4	78-97	10.1	1.86	0.14	18.1	48.3	36.4	15.3	l
BC	97-116	10.1	1.87	0.06	15.2	31.8	48.3	19.9	l
C	116-160	10.1	1.84	0.12	16.6	25.0	45.3	29.7	sil
Pedon 6: Micro-basins (B)									
A	0.16	9.9	4.04	0.08	4.7	55.5	30.3	14.3	sl
Bw1	16-38	9.9	0.86	0.08	5.1	52.2	32.8	15.0	sl
Bw2	38-51	10.0	1.00	0.08	5.6	54.3	30.7	15.0	sl
Bw3	51-91	10.0	1.12	0.12	8.2	53.2	30.0	16.8	sl
C	91-127+	9.50	0.82	0.12	13.0	40.0	41.0	19.0	l

Table 2. Distribution of DTPA extractable micronutrients in the soils of Faridkot District of Punjab

Depth (cm)	DTPA-extractable micronutrients (mg kg^{-1})			
	Zn	Cu	Fe	Mn
Pedon 1: Sand-dunes (SD)				
0-16	0.10	0.14	1.38	3.18
16-52	0.10	0.12	1.24	1.60
52-109	0.07	0.06	1.12	0.62
109-150	0.02	0.04	1.02	0.74
Pedon 2: Alluvial plain with sand cover (Ap1)				
0-10	0.18	0.28	2.34	3.60
10-19	0.12	0.24	1.85	2.28
19-42	0.10	0.20	1.60	1.12
42-65	0.10	0.18	1.60	1.02
65-97	0.07	0.09	1.28	1.28
97-150	0.08	0.06	1.12	1.12
Pedon 3: Upper alluvial plain (Ap2)				
0-18	0.48	0.38	3.04	5.92
18-39	0.10	0.38	2.52	1.68
39-81	0.16	0.30	1.86	1.56
81-124	0.10	0.24	1.04	1.56
124-150	0.06	0.22	0.83	1.52
Pedon 4: Lower alluvial plain (Ap3)				
0-26	1.52	0.60	7.98	5.12
26-46	0.95	0.70	2.55	4.88
46-82	0.78	0.20	1.32	4.06
82-120	0.58	0.48	1.26	4.78
120-136+	0.28	0.58	1.36	4.46
Pedon 5: Alluvial plain-salt encrustation (Ap4)				
0-8	1.30	1.00	7.68	7.46
8-23	1.15	0.48	3.54	6.72
23-38	0.98	0.58	3.40	4.76
38-59	0.75	0.42	2.34	3.12
59-78	0.52	0.31	1.12	2.02
78-97	0.28	0.21	1.25	1.98
97-116	0.24	0.12	1.08	1.56
116-160	0.12	0.12	0.71	0.92
Pedon 6: Micro-basins (B)				
0-16	0.20	0.60	15.26	3.46
16-38	0.10	0.46	7.12	2.24
38-51	0.08	0.44	6.92	1.56
51-91	0.14	0.50	1.52	3.34
91-127+	0.14	0.52	0.98	1.28

Table 3. Correlation Between soil properties and DTPA-extractable micronutrients

	pH	EC	OC	$CaCO_3$	Sand	Silt	Clay
Zn	0.252	0.542*	0.508*	-0.062	-0.276	0.209	0.376*
Cu	0.339*	0.614*	0.379*	-0.002	-0.421*	0.395	0.426*
Fe	0.311*	0.467*	0.219	-0.123	-0.186	0.222	0.100
Mn	0.153	0.541*	0.547*	-0.232	-0.208	0.161	0.277

Relationship between soil properties and DTPA-extractable micronutrients

The DTPA-extractable Zn and Cu had significant and positive correlation with organic carbon. The available Zn had significant postivive correlation with organic carbon in the soils associated with upper alluvial plain (r = 0.987*) and alluvial plain with sand cover. The available Zn in soils of Ap1 and Ap3 units had significant and positive correlation with organic carbon. The available Zn showed a negative correlation with pH, irrespective of physiographic unit but this relationship was significant in soils of upper alluvial plain (r = -0.889*). Bhogal *et al* (1993) also reported a negative relationship between available Zn and pH. The highest degree of correlation (r = 0.968*) between available Cu and organic carbon was found in soils of lower alluvial plain (Pedon 4). Calcium carbonate had a significant negative effect (r = -0.822*) on Cu availability in salt affected soils (Pedon 5). Among all the physiographic units, a significant negative effect between available Fe and pH was found in soils of upper alluvial plain (r = -0.959*). A significant correlation between available Fe and organic carbon was also observed in soils of lower alluvial plain (r = 0.974*) and alluvial plain with sand cover (r = 0.823*). A significant negative correlation (r = -0.830*) of calcium carbonate on Fe was observed in soils of Ap1. DTPA-Mn was negatively correlated with pH in Ap2 (Pedon 3) and Ap4 (Pedon 5). The highest positive value of correlation between available Mn and organic carbon was found in soils of upper alluvial plain (r = 0.979*). Like DTPA Cu, a significant negative influence (r = -0.945*) of $CaCO_3$ on Mn occurred in soils of Ap4 (Pedon 5).

All the micronutrient cations were positively correlated with clay but a significant effect was found for available Zn and Cu only (Table 3). Haque *et al.* (2000) also reported a positive correlation between available micronutrients and clay content. Likewise, negative significant effect of sand occurred on DTPA - Cu (r = -0.421*) and these results corroborate with the findings of Chhabra *et al.* (1996). In general, the salt concentration had positive effect on availability of these micronutrients. There was some irregular relationship between DTPA-extractable micronutrients and soil properties.

The regression equations showed that pH contributed 6 per cent towards vaiation in Zn availability in soils. The coefficient of determination (R^2) increased by 24 per cent with inclusion EC in the regression analysis (Table 4). The inclusion of organic carbon (OC) improved the R^2 value by 18 per cent. The R^2 value suggested that the predictabil-

Table 4. Relationship between soil properties and DTPA- extractable micronutrients using regression analysis

Equation	R^2 value			
	Zn	Cu	Fe	Mn
pH	0.06	0.72*	0.09	0.02
pH+EC	0.30*	0.87*	0.22*	0.33*
pH+EC+OC	0.48*	0.96*	0.24	0.54*
pH+EC+OC+Clay	0.57*	0.97*	0.26	0.60*

ity of relationship between available Zn and soil properties further improved when clay was also taken into consideration. Thus, pH, EC, OC and clay accounted for 57 per cent variation in DTPA-Zn. The pH contributed 72 per cent of the variation towards DTPA-Cu (Table 4). The R^2 value increased by 25 per cent with the inclusion of EC, OC and clay. The stepwise regression equation indicates that all the soil properties accounted for 26 per cent variation in available Fe. The main contributing factor for variation (31 per cent) in available Mn was EC. Inclusion of OC and clay significantly improve the prediction value by 27 per cent.

References

Bhogal, N.S., Sakal, R., Singh, A.P. and Sinha, R.B. (1993). Micronutrient status in aquic Ustifluvents and Udifluvents as related to certain soil properties. *Journal of the Indian Society of Soil Science* **41,** 75-78.

Chhabra, G., P. C. Srivastava, D. Ghosh and A. K. Agnihotri. (1996). Distribution of available mircronutrient cations as related to soil properties in different soil zones of Gola-Kosi interbasin. *Crop Research* (Hisar) **11,** 296-303.

Deka, B., Sawhney, J.S., Sharma, B.D. and Sidhu, P. S. (1996). Soil-landscape relationships in Siwalik hills of semiarid tract of Punjab, India. *Arid Soil Research and Rehabilitation* **10,** 149-159.

Dhane, S. S. and Shukla, L. M. (1995). Distribution of DTPA-extract-able Zn, Cu, Mn and Fe in some soil series of Maharashtra and their relationship with some soil properties. *Journal of the Indian Society of Soil Science* **43,** 597-60.

Follet, R.H. and Lindsay, W. L. (1978). Profile distribution of zinc, copper, iron and manganese in Colorado soils. Colorado state University Experment Station, Fort Collins Co, Technical Bulletin 110.

Haque, I., N.Z. Lupwayi, and T. Tadesse. (2000). Soil micronutrient contents and relation to other soil properties in Ethiopia. *Communications in Soil Science and Plant Analysis* **31,** 2751-2762.

Han, F.X. and Banin, A. (1996). Solid-phase manganese fractionation changes in saturated arid-zone soils:pathways and kinetics. *Soil Science Society of America Journal* **60,** 1072-1080

Lindsay, W. L. and Norvell, W. A. (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu, *Soil Science Society of America Journal* **42,** 421-28.

Miller, W. P., Martens, D.C. and Zelazny, L.W. (1986) Effect of sequence in extraction trace metals from soil. *Soil Science Society of America Journal* **50,** 598-601.

Page, A. L. (1991)'Methods of Soil analysis', 2nd Edition, (American Society of Agronomy and Soil Science America : Madison, Wisconsin, USA).

Panse, V. G. and Sukhatme, P. V (1967) 'Statistical methods for Agricultural Workers'. 2nd Ed. (ICAR, New Delhi).

Setia R.K. and Sharma K.N. (2004) Effect of long-term fertilization on profile stratification of DTPA-extractable micronutrients. *Journal of Food, Agriculture and Environment* **2,** 260-65.

Sharma, Bd. D., Mukhopadhyay, S. S. and Arora, H, (2005). Total and DTPA-extractable micronutrients in relation to pedogenesis in some Alfisols of Punjab. *Soil Science* **170,** 1-14.

Sharma, B. D. Jassal H S, Arora, Harsh, Kumar, Raj, and Nayyar, V. K. (2004). Relationship between soil characteristics and total and DTPA-extractable micronutrients in Inceptisols of Punjab. *Communications in Soil Science and Plant Analysis* **5,** 797-818.

Sharma, B. D. Jassal, H. S. Sawhney, J. S. and Sidhu, P. S. (1999). Micronutrient distributions in different physiographic units of the Shiwalik hills of the Semi-arid tracts of Punjab. *Arid Soil Research and Rehabilitation* **13,** 189-200.

Takkar, P.N., Chhibba, I.M. and Mehta, S.K. (989). Twenty Years of Coordinated Research on micronutrients in soils and plants. Indian Institute of Soil Science, Bhopal (A report)

Verma, V. K., Setia, R.K., Sharm, P.K., Singh, Charanjit and Ashok Kumar (2005). Pedospheric variations in distribution of DTPA- extractable micronutrients in soils developed on different physiographic units in central parts of Punjab, India. *International Journal of Agriculture and Biology* 7, 243-46.

Wadia, D. N. (1976). 'Geology of India', (Tata MeGraw Publishing Co, New Delhi), pp 508.

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