International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 9(4): 691-697 August 2016
DOI Number: 10.5958/2230-732X.2016.00090.5

AGRICULTURE ENGINEERING

Profile distribution of micronutrient cations in citrus orchard of Ukhrul district, Manipur (India)

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Paper No. 493 Received: 29-2-2016 Accepted: 28-8-2016

Abstract

Profile distribution of DTPA-extractable micronutrient cations (Zn, Cu, Fe and Mn) and their relationship with various soil properties were studied in eighteen profiles of citrus orchard of Ukhrul district of Manipur. The content of DTPA-extractable Zn, Cu, Fe and Mn were higher in surface horizons and decreased with depth in most of the profiles and ranged from 0.08 to 0.76, 0.01 to 0.34, 8.0 to 54.0 and 1.6 to 20.4 mg Kg^{-1}, respectively. Surface horizons contain sufficient amount of DTPA-extractable micronutrient cations except Zn. Distribution of Mn was influenced positively with EC in the first (0-20 cm) and second layer (20-40 cm), Cu was influenced inversely by organic carbon and positively by EC, Zn was influenced positively with CEC and Fe was influenced by clay content of the soils. Multiple regression analysis indicated that DTPA-extractable Zn, Cu, Fe and Mn were influenced by CEC, EC, clay and EC to the level of 0.25, 0.63, 0.25 and 0.41, respectively. However, only clay and EC contributed significantly towards these nutrient cations.

Highlights

- Deficiency of micronutrients has become a major constraint to productivity and sustainability in many Indian soils.
- The knowledge of profile distribution of micronutrient cations is important as roots of many plants go beyond the surface layer and thus draw a part of the nutrient requirement from the subsurface layers of the soils.
- Same per cent of the studied soil samples fell in deficient categories.
- Out of the eighteen profiles, DTPA-extractable Cu content in the three surface profiles were found in adequate range.
- All the soils had sufficient amounts of available Fe considering 4.5 mg kg^{-1} as critical limit.
- Considering the critical limit of 1.0 mg kg^{-1}, b the soils were well above the critical limits.

Keywords: DTPA, micronutrient cations, citrus orchard, profile, multiple regression analysis

Role of micronutrients in balanced plant nutrition is well established. Micronutrients are very important for maintaining soil health and also in increasing productivity of crops (Rattan *et al.* 2009). However, exploitive nature of modern agriculture involving use of high analysis NPK fertilizers coupled with limited use of organic manure and less recycling of crop residues are important factors contributing towards accelerated exhaustion of micronutrients from the soil (Sharma and Choudhary 2007). Thus, the deficiency of micronutrients has become a major constraint to productivity and sustainability in many

Indian soils. The availability of micronutrients to plants is also influenced by the distribution within the soil profile (Singh and Dhankar 1989). The knowledge of profile distribution of micronutrient cations is important as roots of many plants go beyond the surface layer and thus draw a part of the nutrient requirement from the subsurface layers of the soils. The distribution of micronutrient cations of citrus orchards of Ukhrul district of Manipur was not yet studied. Therefore, the present work has been undertaken to study the distribution of micronutrient cations of the citrus orchards and to find out the relationship between the soil properties and micronutrient cations.

Materials and Methods

The studied area lies between 24^{o} N to 25.41^{0}N latitudes and 94^{o}E to 94.47^{0}E longitudes and located in north-eastern part of Manipur with an elevation of 913-3114 m MSL. Typical soil profiles were exposed and depth wise i.e. 0-20, 20-40, 40-60 and 60-80 cm soil samples were collected. These were processed and analyzed for various physico-chemical properties like sand, silt, clay content, pH, EC, (1:2.5 soil : water), organic carbon, CEC, available N, P and K using standard laboratory procedures.

The DTPA-extractable Zn, Cu, Fe and Mn in the soil samples were extracted with a solution of 0.005M DTPA, 0.01M $CaCl_2$ and 0.1M triethanolamine adjusted to pH 7.3 as outlined by Lindsay and Norvell (1978). The concentration of micronutrient cations in the extract was determined using atomic absorption spectrophotometer. Multiple regression equations were computed between DTPA-extractable micronutrients and soil properties was done by adopting statistical procedures (Panse and Sukhatme 1961).

Results and Discussion

The relevant soil characteristics of the representative soil profiles are describe in Table 1. No definite pattern was found in the distribution of sand, silt, and clay content in the profile. Sand content varied from 13.06 to 51.84 per cent, silt ranged from 9.28 to 31.44 per cent and clay contents were varied from 33.06 to 64.04 percent. The soils were acidic (pH 3.04– 5.85). The EC ranges from 0.005 to 0.058 dSm^{-1} and organic carbon content from 1.0 to 24.0 g kg^{-1}. Organic carbon in surface soil layers was more than the sub-surface layers. CEC ranged from 3.6 to 21.8 $cmol(p^{+})kg^{-1}$ soil. The available N, P and K content in the soils were 188.16 to 439.04, 1.56 to 20.38 and 3.20 to 262.08 kg ha^{-1}, respectively. These nutrients content decreased with increased the depth in the profile.

DTPA-Extractable Micronutrients Status and Influence of Soil Characteristic

Zinc: DTPA-extractable Zn in the studied soil profiles varied from 0.08 to 0.76 mg kg^{-1} in the citrus growing soils of Ukhrul district of Manipur. Sen *et al.* (1997) reported the available Zn content vary from 0.2 to 1.4 mg kg^{-1} and decreased down the profile. Considering 0.6 mg kg^{-1} as the critical limit of available Zn as suggested by Takkar and Mann (1975), same per cent of the studied soil samples fell in deficient categories. DTPA-extractable Zn showed significant regression with CEC (0.013*). The multiple regression equations presented in the Table 3 indicate a predictability value of 25.0 per cent by all factors taken together in the 1st layer. The surface horizon contents higher amount of DTPA extractable Zn, which progressively declined with depth. The relative high value of Zn in the surface horizon might be due to variable intensity of pedogenic processes and more complexions with organic matter that provided chelating agents for complexion and coincided with the distribution pattern of organic carbon, as suggested by Gupta *et al.* (2003).

Copper: DTPA-extractable Cu content in the profiles ranged from 0.01 to 0.34 mg kg^{-1}. Out of the eighteen profiles, DTPA-extractable Cu content in the three surface profiles were found in adequate range, being 0.2 mg kg^{-1} as critical value (Lindsay and Norvell 1978). DTPA-extractable Cu content was higher in the surface soils and decreased gradually in all the profiles. Similar results were also reported by various scientists (Gupta *et al.* 2003 and Verma *et al.* 2007).

Iron: DTPA-extractable Fe content in the profiles ranged from 8.00 to 54.00 mg kg^{-1} and are comparable with those reported by Gupta *et al.* (2003) and Sharma and Choudhary (2007) in the soils of Madhya Pradesh and north-west Himalaya (H.P.), respectively. All the soils had sufficient amounts of available Fe considering 4.5 mg kg^{-1} as critical limit

Table 1: Some physic-chemical properties of the soil profiles

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (d m-1)	OC (gkg-1)	CEC [cmol(p+)kg-1]	N (kgha-1)	P (kgha-1)	K (kgha-1)
Profile 1											
0 – 20	22.96	23.44	54.47	C	5.28	0.015	12.1	16.8	379.23	20.38	188.00
20 – 40	14.96	21.44	63.06	C	5.14	0.014	08.0	14.9	213.06	17.84	120.96
40 – 60	20.96	31.44	47.06	C	5.14	0.013	06.0	13.0	226.32	07.84	109.76
60 – 80	40.96	25.44	33.06	CL	5.13	0.012	05.0	09.0	226.32	03.13	89.01
Profile 2											
0 – 20	29.44	27.28	45.28	C	4.88	0.012	11.5	13.6	276.32	14.11	147.84
20 – 40	35.44	19.28	45.28	C	4.69	0.011	04.0	10.6	231.76	07.84	123.02
40 – 60	37.44	17.28	45.28	C	4.00	0.009	04.0	06.6	221.76	07.84	116.48
60 – 80	31.44	19.28	49.28	C	4.00	0.005	03.0	05.4	213.06	03.13	98.06
Profile 3											
0 – 20	41.06	14.00	45.38	C	5.37	0.047	11.4	13.4	301.76	15.68	91.08
20 – 40	35.06	18.00	46.04	C	5.06	0.043	01.0	12.5	306.32	07.84	89.01
40 – 60	13.06	24.00	62.04	C	5.04	0.038	09.0	12.8	313.06	03.13	87.04
60 – 80	25.06	10.00	64.04	C	5.03	0.031	05.0	08.8	297.02	03.13	85.01
Profile 4											
0 – 20	36.24	19.44	46.52	C	5.62	0.045	11.7	13.8	286.32	15.68	129.92
20 – 40	20.04	20.00	59.06	C	5.38	0.043	04.0	12.2	213.06	12.54	120.96
40 – 60	51.84	10.00	38.16	SC	4.69	0.037	01.0	10.4	213.06	14.11	98.06
60 – 80	37.84	10.00	52.16	C	4.45	0.033	02.0	06.8	250.88	10.97	78.00
Profile 5											
0 – 20	27.44	21.28	54.48	C	4.94	`0.034	21.2	21.8	389.04	15.68	176.96
20 – 40	29.44	11.28	59.28	SC	4.07	0.027	06.0	19.6	326.32	10.97	172.48
40 – 60	29.44	11.28	59.28	C	4.07	0.023	06.0	11.0	326.32	10.97	172.48
60 – 80	29.44	14.56	56.00	C	4.86	0.024	02.0	04.5	250.88	03.13	116.48
Profile 6											
0 – 20	18.96	27.44	53.39	C	5.85	0.048	11.5	15.8	279.43	12.54	107.52
20 – 40	14.96	21.44	63.06	C	5.13	0.045	07.0	12.8	250.88	10.97	94.01
40 – 60	20.96	31.44	47.06	C	5.12	0.035	06.0	09.8	250.88	07.84	85.01
60 – 80	40.96	25.44	33.06	CL	5.02	0.025	06.0	13.6	188.16	03.13	80.06
Profile 7											
0 – 20	29.28	25.28	48.44	C	4.07	0.058	11.5	16.7	359.04	12.54	107.52
20 – 40	37.28	13.28	49.44	C	4.04	0.052	09.0	08.2	313.06	10.97	94.01
40 – 60	43.28	23.28	33.44	CL	5.02	0.053	09.0	07.6	250.88	07.84	85.01
60 – 80	41.28	17.28	41.44	C	4.82	0.046	05.0	09.4	250.88	01.56	71.07
Profile 8											
0 – 20	30.56	16.00	53.44	C	4.87	0.052	13.4	14.6	339.04	15.68	35.09
20 – 40	34.59	14.00	51.44	C	4.19	0.045	08.0	12.5	313.06	12.13	26.09
40 – 60	34.56	20.44	45.44	C	3.04	0.033	07.0	11.4	250.88	10.97	22.00
60 – 80	22.56	22.00	55.44	C	3.07	0.022	03.0	06.3	250.88	03.13	65.04

Profile 9											
0 – 20	27.12	23.28	52.48	C	5.04	0.056	21.2	19.4	351.76	10.97	56.00
20 – 40	43.12	09.28	47.06	C	4.96	0.048	17.0	12.0	313.06	07.84	42.06
40 – 60	35.12	21.28	43.06	C	4.98	0.042	06.0	07.8	313.06	04.07	35.08
60 – 80	35.12	17.28	47.06	C	4.09	0.042	04.0	07.2	250.88	03.13	22.00
Profile 10											
0 – 20	31.58	16.00	52.42	C	6.93	0.039	12.4	14.8	286.32	12.54	262.08
20 – 40	33.28	16.00	50.72	C	5.22	0.036	04.0	06.8	276.32	10.98	145.12
40 – 60	37.28	14.00	48.72	C	5.17	0.033	04.0	05.8	250.88	06.27	112.00
60 – 80	37.28	20.00	42.72	C	5.09	0.034	05.0	05.5	213.06	03.14	107.52
Profile 11											
0 – 20	14.56	`34.00	51.44	C	5.38	0.054	12.6	16.6	378.34	17.25	145.06
20 – 40	20.56	26.00	53.44	C	5.26	0.039	14.0	09.4	213.06	14.11	120.96
40 – 60	21.84	20.00	58.16	C	5.16	0.033	03.0	08.8	213.06	10.98	109.76
60 – 80	21.84	22.00	56.16	C	5.16	0.022	03.0	06.8	250.88	03.14	76.02
Profile 12											
0 – 20	25.44	21.28	53.48	C	4.66	0.038	21.7	21.6	386.32	06.27	76.02
20 – 40	29.44	19.28	51.28	C	4.68	0.035	12.0	08.1	376.32	04.07	53.08
40 – 60	31.44	21.28	47.28	C	4.12	0.035	08.0	07.4	313.06	03.14	53.08
60 – 80	27.44	21.28	51.28	C	3.56	0.032	07.0	04.4	250.88	03.14	47.00
Profile 13											
0 – 20	14.56	34.00	52.44	C	5.08	0.048	12.06	13.3	296.32	1098	76.02
20 – 40	20.56	26.00	53.44	C	4.94	0.038	05.0	11.0	250.88	06.27	67.00
40 – 60	21.84	20.00	58.16	C	4.94	0.034	08.0	07.0	213.06	03.14	62.07
60 – 80	21.84	22.00	56.16	C	4.92	0.034	05.0	03.7	188.16	03.14	58.02
Profile 14											
0 – 20	30.56	16.00	51.44	C	5.23	0.052	12.8	16.0	359.04	20.30	08.01
20 – 40	34.59	14.00	51.44	C	5.17	0.044	09.0	11.5	313.06	13.14	08.01
40 – 60	34.56	20.44	45.44	C	5.17	0.041	04.0	08.3	313.06	15.68	07.00
60 – 80	22.56	22.00	55.44	C	4.77	0.037	06.0	06.0	250.88	03.14	03.00
Profile 15											
0 – 20	30.58	16.00	53.42	C	4.98	0.054	21.5	16.4	439.04	17.25	230.72
20 – 40	33.28	16.00	50.72	C	4.66	0.046	24.0	17.4	376.32	18.16	159.04
40 – 60	37.28	14.00	48.72	C	4.21	0.042	25.0	09.8	313.06	10.98	179.02
60 – 80	37.28	`20.00	42.72	C	4.05	0.034	21.0	08.6	313.06	06.27	203.84
Profile 16											
0 – 20	24.04	26.00	51.38	C	5.23	0.053	13.6	14.0	339.04	17.25	240.08
20 – 40	36.04	10.00	53.06	C	4.77	0.047	13.0	11.1	336.32	14.11	296.08
40 – 60	32.04	24.00	43.06	C	4.19	0.044	18.0	06.3	339.04	10.98	235.02
60 – 80	30.04	24.00	45.06	C	4.08	0.033	13.0	05.2	376.32	03.14	179.02

Profile 17											
0 – 20	27.12	23.28	52.58	C	4.04	0.029	12.8	13.7	377.02	17.25	132.16
20 – 40	43.12	09.28	47.06	C	4.05	0.024	09.0	12.2	313.06	10.98	118.72
40 – 60	35.12	21.28	43.06	C	4.03	0.024	07.0	11.8	250.88	06.27	91.08
60 – 80	35.12	17.28	47.06	C	4.02	0.024	06.0	10.4	188.16	03.14	134.04
Profile 18											
0 – 20	29.28	25.28	52.44	C	5.05	0.048	21.3	14.3	386.32	17.25	129.92
20 – 40	37.28	13.28	49.44	C	4.03	0.033	14.0	17.3	376.32	12.54	120.96
40 – 60	43.28	23.28	33.44	CL	3.08	0.031	07.0	14.6	313.06	12.54	98.06
60 – 80	41.28	17.28	41.44	C	3.06	0.022	08.0	13.2	250.88	12.54	76.02

Table 2: DTPA-extractable micronutrient cations (mg kg^{-1}) in the soils

Depth (cm)	Zn	Cu	Fe	Mn	Depth (cm)	Zn	Cu	Fe	Mn	Depth (cm)	Zn	Cu	Fe	Mn
Profile 1					**Profile 2**					**Profile 3**				
0 – 20	0.48	0.34	45.2	11.6	0 – 20	0.36	0.24	21.2	11.4	0 – 20	0.36	0.08	35.2	15.6
20 – 40	0.43	0.32	33.2	10.8	20 – 40	0.32	0.22	10.0	09.8	20 – 40	0.34	0.06	42.8	13.6
40 – 60	0.43	0.23	08.4	10.8	40 – 60	0.34	0.16	08.0	09.6	40 – 60	0.28	0.05	24.4	12.6
60 – 80	0.34	0.17	09.2	06.0	60 – 80	0.24	0.13	10.4	06.0	60 – 80	0.28	0.03	19.2	10.6
Profile 4					**Profile 5**					**Profile 6**				
0 – 20	0.33	0.04	32.8	14.8	0 – 20	0.46	0.04	48.8	14.6	0 – 20	0.34	0.08	53.2	15.6
20 – 40	0.32	0.04	27.6	12.2	20 – 40	0.32	0.03	20.0	12.8	20 – 40	0.32	0.07	46.0	14.4
40 – 60	0.34	0.03	17.2	08.8	40 – 60	0.23	0.03	`20.0	06.8	40 – 60	0.29	0.05	36.8	12.8
60 – 80	0.24	0.02	12.0	02.0	60 – 80	0.12	0.02	16.0	04.4	60 – 80	0.24	0.06	34.0	11.6
Profile 7					**Profile 8**					**Profile 9**				
0 – 20	0.36	0.06	49.6	18.8	0 – 20	0.28	0.04	48.0	12.2	0 – 20	0.39	0.03	46.0	20.0
20 – 40	0.32	0.04	45.0	18.8	20 – 40	0.14	0.03	36.0	10.2	20 – 40	0.28	0.03	42.0	17.0
40 – 60	0.40	1.06	44.4	24.8	40 – 60	0.14	0.02	21.6	09.8	40 – 60	0.23	0.02	26.8	13.6
60 – 80	0.38	0.02	16.8	14.8	60 – 80	0.18	0.02	19.8	08.8	60 – 80	0.14	0.01	18.8	11.6
Profile 10					**Profile 11**					**Profile 12**				
0 – 20	0.34	0.04	38.8	14.6	0 – 20	0.32	0.04	42.8	15.6	0 – 20	0.34	0.04	54.0	12.6
20 – 40	0.28	0.04	24.2	12.8	20 – 40	0.28	0.05	32.8	12.4	20 – 40	0.28	0.03	52.8	14.6
40 – 60	0.28	0.04	21.6	10.4	40 – 60	0.24	0.06	24.0	06.8	40 – 60	0.12	0.02	39.2	12.0
60 – 80	0.18	0.02	18.0	04.8	60 – 80	0.14	0.04	20.0	04.8	60 – 80	0.28	0.01	27.6	11.6
Profile 13					**Profile 14**					**Profile 15**				
0 – 20	0.34	0.04	36.0	18.8	0 – 20	0.31	0.02	38.8	20.4	0 – 20	0.42	0.02	21.2	12.8
20 – 40	0.28	0.04	32.0	12.8	20 – 40	0.28	0.02	19.2	12.0	20 – 40	0.76	0.01	10.0	12.2
40 – 60	0.24	0.06	26.8	18.8	40 – 60	0.23	0.05	21.6	09.2	40 – 60	0.58	0.01	08.0	08.8
60 – 80	0.08	0.04	18.8	18.0	60 – 80	0.08	0.04	18.0	08.2	60 – 80	0.46	0.01	10.4	02.0
Profile 16					**Profile 17**					**Profile 18**				
0 – 20	0.24	0.02	52.8	13.6	0 – 20	0.22	0.04	54.0	15.6	0 – 20	0.24	0.23	49.6	12.6
20 – 40	0.16	0.02	43.8	12.6	20 – 40	0.24	0.04	52.8	14.4	20 – 40	0.28	0.18	42.0	11.7
40 – 60	0.12	0.02	17.2	11.0	40 – 60	0.24	0.02	39.2	11.9	40 – 60	0.24	0.12	24.4	11.4
60 – 80	0.09	0.02	12.0	13.2	60 – 80	0.18	`0.01	27.6	01.6	60 – 80	0.12	0.08	16.8	09.7

Table 3: Effect of soil characteristics on predictability of micronutrient cations

	Equations	$R^2 \times 100$
DTPA-extractable Zn		
1st layer Zn	= 0.126 + 0.013*CEC	25.0**
Available Cu		
1st layer Cu	= 0.660 – 0.117 OC + 0.000N	37.7**
3rd layer Cu	= - 0.587 + 3.573 EC + 1.013 TN + 0.003Fe + 0.041**Mn	63.4**
Available Fe		
1st layer Fe	= – 46.403 + 1.733**Clay	24.6**
2nd layer Fe	= – 9.230 + 3.311** Mn	30.8**
3rd layer Fe	= 8.281 + 1.132Mn + 6.223 Cu	38.0**
Available Mn		
1st layer Mn	= 13.132 + 90.283 EC - 0.150 K	41.4**
2nd layer Mn	= 7.656 + 74.620 EC + 0.77**Fe	64.5**
3rd layer Mn	= 9.513 – 0.450 P + 8.516 TN + 0.035 Fe + 6.701**Cu	41.1*

(Lindsay and Norvell 1978). It showed significant regression coefficient with clay (1.733*) in the first layers. Multiple correlation and regression analyses indicated that 24.6, 30.8 and 38.0 per cent variability in the DTPA-extractable Fe in the profiles was due to the combine effect of clay, Mn and Cu in the soils.

Manganese: DTPA-extractable Mn in the studied profiles varied from 1.60 to 20.40 mg kg^{-1}. The surface soils contained higher Mn and decreased with increase in depth (Gupta *et al*. 2003, Verma *et al*. 2007 and Thangasawy *et al*. 2005). Considering the critical limit of 1.0 mg kg^{-1} (Lindsay and Norvell 1978), the soils were well above the critical limits. Multiple correlation and regression analyses indicated that 41.4, 45.0 and 73.5 per cent variability of the available Mn content and could be attributed to the combine effect of K, EC, Fe, and Cu content in the profiles.

The variations observed in available micronutrient cations among and within the profiles might be the result of variable intensity of different pedogenic processes taking place during the soil development. The surface layers contained higher amounts of available Zn, Cu, Fe and Mn which progressively declined with depth in majority of the soil profiles. Similar distribution pattern of micronutrient cations within the profiles was also reported by Sharma and Choudhary (2007). This may be ascribed to low pH values and higher amounts of organic carbon content in the surface soils. Decomposition of organic matter releases micronutrient cations and some organic acids which in turn help in increasing solubility of micronutrient cations from the soil mineral. Significant positive regression coefficients of EC with DTPA-extractable micronutrients have also been reported by Sharma *et al.* (2007).

Conclusion

Zinc and copper nutrients were found deficient in the studied profiles. Therefore zinc and copper micronutrients was needed to be adequately applied to all the orchards for higher production.

References

Gupta, N., Trivedi, S.K., Bansali, K.N. and Kaul, R.K. 2003. Vertical distribution of micronutrient cations in some soil series of north Madhya Pradesh. *Journal of the Indian Society of Soil Science* **51**: 517-522.

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**: 421-428.

Panse, V.G. and Sukhatme, P.V. 1961. Statistical Methods for Agricultural Workers, ICAR, New Delhi.

Rattan, R.K., Patel, K.P., Manjaiah, K.M. and Datta, S.P. 2009. Micronutrients in soil, plant, animal and human health. *Journal of the Indian Society of Soil Science* **57**: 546-558.

Randhawa, H.S. and Singh, P. 1995. Distribution of zinc fractions in alluvium derived soils of Punjab. *Journal of the Indian Society of Soil Science* **43**: 124-126.

Sen, T.K., Dubey, P.N., Maji, A.K. and Chamuah, G.S. 1997. Status of micronutrients in some dominant soils of Manipur. *Journal of the Indian Society of Soil Science* **45**: 388-390.

Sharma, J.C. and Choudhary, S.K. 2007. Vertical distribution of micronutrient cations in relation to soil characteristics in lower Shiwaliks of Solan district in north-west Himalayas. *Journal of the Indian Society of Soil Science* **55**: 40-44.

Singh, K.M.S. and Dhankar, S.S. 1989. Influence of soil characteristics on profile distribution of DTPA-extractable micronutrient cations. *The Indian Journal of Agricultural Sciences* **59**: 331-334.

Takkar, P.N. and Mann, M.S. 1975. Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab. *Agrochemica* **19**: 420-430.

Thangasawy, A. Naidu, M.V.S., Ramavatharam, N. and Reddy, C.L. 2005. Characterization, classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh for sustainable land used planning. *Journal of the Indian Society of Soil Science* **53**: 515-520.

Verma, V.K., Setia, R.K., Sharma, P.K., Khurana, M.P.S. and Kang, G.S. 2007. Pedopheric distribution of micronutrient cations in soil developed on various landforms in north-east Punjab. *Journal of the Indian Society of Soil Science* **55**: 515-520.

Verma, V.K., Setia, R.K. and Sharma, P.K. 2007. Distribution of micronutrient cations in different physiographic units of semi-arid region of Punjab. *Agropedology* **18**: 58-65.