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Vertical Distribution of Micronutrient Cations in the Orange (*Citrus reticulata*) Orchard, Tamenglong District, Manipur (India)

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Vertical distribution of DTPA-extractable micronutrient cations (Fe, Cu, Mn and Zn) and its correlation with several physico-chemical properties of soils in fifteen orange orchards of Tamenglong district, Manipur was studied. Most of the upper soil layer had higher DTPA-extractable micronutrient cations (Fe, Cu, Mn and Zn) content than the lower horizons. In the profiles, the value of DTPA- extractable micronutrients (Fe, Cu, Mn and Zn) ranged from 18.62 to 45.12 mg kg^{-1}, 0.12 to 1.26 mg kg^{-1}, 3.42 to 44.33 mg kg^{-1} and 0.16 to 1.36 mg kg^{-1}, respectively. The DTPA-extractable Fe and Mn were found to be sufficiently available in all the profiles whereas, Cu was found adequate in most of the surface horizon (0 - 20cm) in most of the soil samples. However, Zn deficiency occurred in 55.56 % of the soil sample. Multiple regression analysis showed that the DTPA-extractable micronutrient cations (Fe, Cu, Mn and Zn) content in the soils were influenced by pH, OC, EC, Mg, silt, K and clay to the degree of 50.1, 25.7 and 60.5 % in the surface horizon but their influenced were significant only by soil OC and silt.

Introduction

The word "micronutrients" represents some essential nutrients (Fe, Mn, Zn, Cu, B, Mo, Ni and Cl) that are required in very small quantities for the growth and development of plants. Micronutrients are very important for maintaining soil health and also in increasing productivity of crops (Rattan *et al.,* 2009). Through their involvement in various enzymes and other physiologically active molecules, these micronutrients are important for gene expression, biosynthesis of proteins, nucleic acids, growth substances, chlorophyll and secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance, etc. (Singh, 2004, Rengel, 2007 and Gao *et al.*, 2008).

Less nutrient management practices contribute towards exhaustion of micronutrients from the soil and micronutrients are bound to become a limiting factor. The deficiency of micronutrients has become major constraint to productivity, stability and sustainability of soils (Bell and Dell, 2008). Deficiency of micronutrients may either be primary, due to their low total contents or secondary, caused by soil factors reducing their availability to plants. Improper nutrient management has led to the emergence of multi-nutrient deficiencies in Indian soils (Sharma, 2008). Moreover, continuous negligence of micronutrient application and avoidance of organic manures are the major causes of deficiency of micronutrients (Srivastava *et al.*, 2017).

Citrus is claimed to have originated in south China and Cathaysian ancient continent including Sichuan, Kangdian, South of Yangtze river and Indo-China peninsula, then dispersed into India, Africa and Australia according to the theories of continental drift, the ecological and geological vicissitude. Agro-meteorologically, citrus is observed more comfortable under tropical and sub-tropical and climate representing 24 – 38^0 at either side of equator with hot days/cool nights and less exposed to prolonged freezing temperature. The highest quantum of production harvested globally is represented by soil orders viz. Alfisol, Oxisol, Ultisol, Entisol and Inceptisol (Srivastava and Singh, 2002b). The current average productivity of citrus orchards in India is 8.9 tons ha^{-1} compared to 4.52 tons ha^{-1} obtained in North-East India (Srivastava and Singh, 2002a), the region historically believed to have witnessed the dissemination of citrus to other parts of the world. Cultivation of Khasi mandarin (*Citrus reticulata* Blanco.) in North-East India is mainly confined to mid-hills up to an elevation of 1200 m above mean sea level under humid tropical climate. Manipur has a geographical area of 22,327 sq. km. which constitutes 0.7 % of the total land surface of India. Ninety per cent of the total geographical area of the state *i.e.* 20,097 sq. km. is covered by hills. Around 3,838 hectares of land are under orange cultivation in Manipur. Khasi Mandarin is a variety of orange produced in Tamenglong, a district located 140 kms from Imphal and lies at coordinates bearing 24°59′ N 93°29′ E Tamenglong district is known as the "Orange Bowl" of the state. The district contributes over 50 % of the state's annual total orange production of nearly 10,000 to 11,000 metric tons. The total geographical area of Tamenglong is 4391 km^2. The climate here is humid and sub-tropical type. The climate and soil here are well suited for the production of orange. The knowledge of pedogenic distribution of micronutrients is, therefore, important as many plant roots penetrate to the sub-surface layers and draw a part of the nutrient requirement from the sub-surface layers. However, there is little or no information regarding status and distribution of micronutrients in soils under orange cultivation in the district. Keeping in view of the close relationship between soil properties and micronutrient availability, the present study was undertaken to analyze the depth-wise distribution of micronutrients (Fe, Cu, Mn and Zn) in the soil and to study the relationship of the micronutrients (Fe, Cu, Mn and Zn) with the physico-chemical properties of soil.

Materials and Methods

The experimental location is in Tamenglong district of Manipur which has an area of 4391 km^2 which constitutes 19.66 % of the total geographical area of the state. It is located in the north-western part of Manipur and lies at coordinates bearing 24°59′ N 93°29′E. The altitude is 1260 m above MSL. It has humidity range of 76 to 96 % and temperature of 4°C at minimum and 31°C at maximum. The climate here is humid and sub-tropical type. The climate and soil here are well suited for the production of orange. In Tamenglong, the average annual temperature is 18.5°C and about 3336 mm of precipitation falls annually. Generally, the main soils found in the district are red loamy soil, red sandy soil and red gravelly soil. The experimental sites under study were mainly dominated by orange orchards. Soil samples were collected from fifteen different orange orchards of Tamenglong district. From each site, three samples were collected depth wise up to 60 cm at an interval of 20 cm from the surface i.e. 0-20, 20-40 and 40-60, respectively. Totally, 45 soil samples were collected for study. The collected soil samples were thoroughly air dried in shade and ground with a wooden mortar and pestle and passed through 2 mm sieve for analysis. The collected samples were processed and analyzed following standard procedures for mechanical analysis using Bouyoucos hydrometer method (Bouyoucos, 1951); soil pH and EC using (1: 2.5) soil: water suspension (Jackson 1973); organic carbon by the Walkley and Black rapid titration method (Walkley and Black 1934); CEC by leaching with 1N ammonium acetate (Borah *et al.*, 1987). The soil sample were determined for available N (Subbiah and Asija, 1956); available P (Bray and Kurtz 1945); available K, Ca and Mg of soil were extracted with neutral normal ammonium acetate as outlined by Chopra and Kanwar (1976) and DTPA-extractable Zn, Cu, Mn and Fe following standard procedures as outlined by (Lindsay and Norvell, 1978). The relationship between various soil physico-chemical properties and micronutrients distribution were established by using simple correlation coefficient. Multiple regression equations were computed between DTPA- extractable micronutrients and soil properties by adopting statistical procedures (Panse and Sukhatme, 1985).

Results and Discussion

The physico-chemical properties as well as DTPA-extractable Fe, Cu, Mn and Zn are presented in table 1 and 2. There was no exact pattern in the distribution of clay, silt and sand with the depth of soil profiles. Clay, silt and sand fractions in the soils ranged from 37.6 to 53.1, 13.4 to 26.0 and 26.3 to 44.6 per cent, respectively. The samples were very strongly acidic (pH 4.68) to slightly acidic (pH 6.10) in reaction. EC values ranging from 0.02 to 0.27 dSm^{-1}. Organic carbon content ranged from 0.46 to 1.58 per cent. Cation exchange capacity (CEC) varied from 10.60 to 20.00 [cmol (p^+) kg^{-1}] soil.

The available nitrogen, phosphorus and potassium content in the soil profiles varied from 138.9 to 536.5 kg ha^{-1}, 10.2 to 25.4 kg P_2O_5 ha^{-1} and 81.4 to 242.5 kg K_2O ha^{-1}, respectively. Exchangeable Ca^{++} content ranged from 0.3 to 0.9 and Mg^{++} from 0.3 to 1.4 [cmol(p+)kg^{-1}]. The region is high rainfall area which might be due to intense the leaching action of the bases from the surface layers. The content of these nutrients decreased with increase in depth in most of the studied profiles. Similar results were also reported by Athokpam *et al.*, (2016) and Athokpam *et al.*, (2018) in the soils of Ukhrul and Tamenglong districts of Manipur, respectively.

Iron (Fe)

The DTPA-extractable Fe content of the soil samples was fairly high with a value ranging from 18.62 to 45.12 mg kg^{-1} soil in the orange orchard soils of Tamenglong district of Manipur. The iron content of these soils is high because, the solubility of ferric and ferrous iron is much lower at high pH than at low pH and leaching of exchangeable bases. In view of critical limit of 4.5 mg Fe kg^{-1} soil (Lindsay and Norvell, 1978), all the samples were highly sufficient in available Fe. DTPA-Fe content in the profile showed significant positive coefficient with OC (r=0.531*) and (r=0.523*) in the 1st and 2nd layer, respectively and negatively significantly correlated with pH (r= -0.626**) and EC (r= -0.527**) in the 1st layer as well as with pH (r= -0.513*) in the 2nd layer. It showed significant regression coefficient with OC (20.028*) at 2nd (20-40 cm) layer. Multiple correlation and regression analyses indicated that 50.1, 37.1 and 29.3 per cent variability in the profile was due to the simultaneous effect of pH, EC, OC and Mg in the soil. The surface layer soil contained more available Fe than those in lower depth and showed a decreasing pattern along with depth except for few samples. These findings are in agreement with the works of Sen *et al.*, (1997), Gupta *et al.*, (2003), Sharma *et al.*, (2003), Pati and Mukhopadhyay (2011), Athokpam *et al.*, (2013), Athokpam *et al.*, (2016), Athokpam *et al.*, (2018) and Singh *et al.*, (2018).

Copper (Cu)

The DTPA-Cu content varied from 0.12 to 1.26 mg kg^{-1} soils. Considering 0.20 mg Cu kg^{-1} soil as critical limit (Lindsay and Norvell, 1978), most of the samples, except a few in the sub-surface horizons, were well supplied with available Cu. Similar findings were also reported by Sen *et al.*, (1997). Higher DTPA-extractable Cu content was observed in surface soil than those of lower layers. This might be due to higher biological activity and organic carbon content in the surface layers (Murthy *et al.*, 1997). Available Cu content decreased with increase in depth in most profiles. These results were also conveyed by Gupta *et al.*, (2003), Verma *et al.*, (2007b), Athokpam, *et al.*, *(*2016), Singh and Athokpam (2018) and Athokpam *et al.*, (2018). Nevertheless, the study observed that there was an irregular distribution of DTPA-extractable Cu with depth in a few soil samples. This finding is in accordance with the work of Kumar *et al.*, (1996) and Satyavathi and Reddy (2004). The present study revealed that there was no significant multiple correlation and regression analyses which indicated no per cent variability of available soil Cu content in each layer could be attributed to the effect of soil properties.

Manganese (Mn)

The range of Mn availability varied from 3.42 to 44.33 mg kg^{-1} soil. Considering critical value of 1.0 mg Mn kg^{-1} soil (Lindsay and Norvell, 1978), all the samples were well distributed with DTPA-extractable Mn. Sen *et al.*, (1997), Sarkar *et al.*, (2002), Athokpam *et al.*, (2013), Athokpam *et al.*, (2016), Athokpam *et al.*, (2018) reported the abundance of DTPA – Mn in soils of Manipur. The high amount of Mn in the soil might be due to the solubility of this cation is higher at low pH. The distribution did not trail any regular trend in the entire sample. Irregular distribution of DTPA-extractable Mn with depth was observed. There is a similar finding as compared to Rajkumar *et al.*, (1990), Athokpam *et al.*, (2013), Athokpam *et al.*, (2016), Athokpam *et al.*, (2018) and Singh and Athokpam (2018). DTPA-extractable Mn content in the soil profile showed positive and significant correlated with soil OC (r=0.507*) and (r=0.569*) in the 1st layer and 2nd layer, respectively. Only OC (19.400* and 18.707*) content in the soils significantly correlated with Mn content in the 2ndand 3rd layers. Multiple correlation and regression analyses indicated that 25.7, 32.4 and 24.9 per cent variability in available Mn content were due to the effect of OC content in the soils (Table 3).

Zinc (Zn)

DTPA-extractable Zn in the soil profile varied from 0.24 to 1.36 mg kg^{-1} soil. DTPA-extractable Zn, like other soil nutrients, accumulates more in surface layers than sub-surface layers and goes on decreasing with the increase in depth. This might be due to the Zn interacts with organic matter in the soils, thus formed both soluble and insoluble Zn-organic complexes, as studied soils are high organic matter content in the surface soils. Pati and

Mukhopadhyay, (2011), Athokpam *et al.*, (2013), Athokpam *et al.*, (2016), Athokpam *et al.*, (2018) and Singh and Athokpam (2018) reported similar findings. In view of the critical limit of 0.6 mg Zn kg^{-1}soil (Lindsay and Norvell, 1978), Zn which deficiency occurred in 55.56 % soils and required Zn fertilization for better yield of orange. Sen *et al.*, (1997) and Sarkar *et al.*, (2002) also observed inadequate or marginal adequate in available Zn in soils of Manipur. DTPA-Zn content in the soil showed positive and significantly related with clay (r=0.494*) and K (r=0.501*) in the 1st and 3rd layer, respectively and negatively significantly related with silt content (r= -0.709**). Multiple correlation and regression analyses revealed that 60.5 and 24.8 per cent variability in available Zn content may be due to the simultaneous effect of the various soil properties such as silt and clay and K included in the1st and 3rd profiles, respectively. Only silt content in the soils significantly correlated with Mn content in the surface layer (0.076*) (Table 4–6).

Table.1 Physico-chemical properties of soil profiles

Sample	Depth (cm)	Clay %	Silt %	Sand %	Texture	pH (1:2.5)	E.C (dSm $^{-1}$)	CEC [Cmol (p+) kg^{-1}]	OC (%)	N Kg/ha	P_2O_5 Kg/ha	K_2O Kg/ha	Ca^{++} [Cmol (p+) kg^{-1}]	Mg^{++} [Cmol (p+) kg^{-1}]
1.Taningjam														
	0-20	47.1	22.2	30.7	Clay	4.90	0.08	14.60	1.36	512.7	21.3	198.3	0.9	0.5
	20-40	51.0	21.9	27.1	Clay	5.04	0.04	14.90	0.98	430.5	18.1	118.1	0.7	0.5
	40-60	46.8	19.0	34.2	Clay	5.13	0.06	12.50	0.72	352.5	15.5	106.0	0.5	0.5
2.Dailong-1														
	0-20	44.8	19.0	36.2	Clay	4.95	0.22	12.40	1.38	338.9	16.2	196.3	0.8	0.6
	20-40	43.1	13.4	43.5	Clay	5.16	0.15	11.00	1.10	286.6	14.0	142.2	0.6	0.8
	40-60	40.8	17.5	41.7	Clay	5.27	0.11	10.80	0.86	225.9	12.8	106.1	0.4	0.6
3.Dailong-2														
	0-20	39.1	24.2	36.7	Clay loam	4.92	0.12	16.40	1.08	348.2	17.3	206.3	0.6	1.1
	20-40	49.9	16.7	33.4	Clay	5.08	0.05	17.20	1.02	262.4	15.1	136.1	0.4	1.2
	40-60	47.5	22.3	30.2	Clay	5.22	0.08	16.80	0.78	236.6	13.6	116.9	0.4	1.0
4.Bhalok														
	0-20	41.2	22.2	36.6	Clay	4.68	0.10	19.34	1.58	536.5	23.8	186.3	0.6	0.9
	20-40	38.9	21.6	39.5	Clay loam	4.90	0.11	18.30	1.02	404.6	19.6	108.1	0.5	0.8
	40-60	38.7	24.8	36.5	Clay loam	5.39	0.08	16.70	0.94	346.7	16.1	96.0	0.4	0.9
5.Tamei Road														
	0-20	42.6	22.5	34.9	Clay	4.92	0.11	16.80	1.29	452.8	19.0	144.8	0.4	0.6
	20-40	48.0	22.7	29.3	Clay	5.16	0.10	17.40	1.04	344.9	16.8	133.2	0.4	0.5
	40-60	51.8	19.3	28.9	Clay	5.28	0.06	16.20	0.78	264.4	15.2	92.1	0.4	0.3
6.Kahulong-1														
	0-20	49.4	24.3	26.3	Clay	4.90	0.17	17.30	0.94	415.1	20.5	194.9	0.6	0.8

	20-40	52.5	16.5	31.0	Clay	5.17	0.13	19.50	0.84	322.1	18.3	118.8	0.5	0.5
	40-60	44.5	15.3	40.2	Clay	5.17	0.12	16.17	0.50	241.3	16.2	98.7	0.5	0.4
7.Kahulong-2														
	0-20	45.5	18.6	35.9	Clay	4.87	0.06	13.60	1.30	400.1	18.6	208.0	0.8	0.6
	20-40	46.4	17.9	35.7	Clay	5.13	0.09	13.90	1.07	312.1	15.4	124.9	0.6	0.4
	40-60	45.9	16.5	37.6	Clay	5.22	0.09	11.90	0.64	251.3	11.9	118.7	0.3	0.6
8.Kahulong-3														
	0-20	48.8	17.8	33.4	Clay	4.84	0.11	15.20	1.33	458.8	25.4	212.7	0.5	0.8
	20-40	41.0	17.3	41.7	Clay	5.06	0.14	20.00	1.16	370.8	18.3	142.6	0.5	0.8
	40-60	49.4	17.2	33.4	Clay	5.18	0.07	16.40	0.72	284.7	11.2	94.2	0.7	0.7
9.Farmland-1														
	0-20	41.5	25.9	32.6	Clay	4.98	0.02	13.20	0.94	334.4	16.4	130.9	0.5	0.7
	20-40	46.6	21.7	31.7	Clay	5.09	0.06	13.60	0.75	244.4	15.3	107.8	0.4	0.3
	40-60	41.5	19.0	39.8	Clay	5.27	0.06	13.40	0.63	158.6	12.7	98.7	0.4	0.4
10.Farmland-2														
	0-20	37.8	22.1	40.1	Clay loam	4.97	0.17	15.80	1.02	436.8	19.9	170.3	0.4	0.6
	20-40	37.6	23.5	38.9	Clay loam	5.13	0.06	14.30	0.52	355.9	15.9	117.1	0.3	0.4
	40-60	41.2	19.0	39.8	Clay	5.39	0.09	13.70	0.48	284.2	11.1	94.2	0.4	0.3
11.Keikao-1														
	0-20	45.2	26.0	28.8	Clay	4.91	0.16	13.80	1.26	501.7	18.8	230.5	0.7	0.8
	20-40	53.1	15.4	31.5	Clay	5.12	0.08	14.30	0.68	390.6	16.7	168.3	0.5	0.5
	40-60	52.6	17.8	29.6	Clay	5.44	0.10	13.10	0.46	282.7	13.1	116.2	0.5	0.6
12.Keikao-2														
	0-20	46.3	20.0	33.7	Clay	4.91	0.14	14.80	0.96	285.6	17.9	224.4	0.8	0.9
	20-40	47.7	14.4	37.9	Clay	4.99	0.27	13.00	0.74	182.7	13.7	119.2	0.7	0.6
	40-60	50.2	18.1	31.7	Clay	5.05	0.12	10.60	0.52	138.9	10.2	114.1	0.5	0.5
13.Tamenglong Headquarter														
	0-20	43.0	21.6	35.4	Clay	4.72	0.20	16.00	1.34	378.4	17.0	140.7	0.7	1.4
	20-40	39.5	18.6	41.9	Clay loam	5.10	0.14	15.60	1.32	312.3	14.8	90.5	0.5	0.7
	40-60	40.1	15.3	44.6	Clay	6.10	0.11	14.80	0.80	252.6	12.3	81.4	0.7	0.8
14.C-Center														
	0-20	40.2	20.8	39.0	Clay	4.77	0.06	18.00	1.46	340.0	14.1	242.5	0.5	1.0
	20-40	46.8	16.2	37.0	Clay	5.13	0.10	18.80	1.14	336.0	13.9	130.3	0.4	0.7
	40-60	45.5	22.9	31.6	Clay	5.17	0.06	15.00	0.84	251.2	11.3	118.2	0.4	0.6
15.Azuram														
	0-20	38.8	22.3	38.9	Clay loam	4.98	0.08	13.80	1.02	398.7	15.9	194.9	0.6	0.7
	20-40	45.5	20.1	35.4	Clay	5.04	0.07	13.00	0.82	262.8	12.8	102.7	0.5	0.4
	40-60	44.6	20.3	35.1	Clay	5.12	0.12	12.80	0.76	239.9	12.2	84.6	0.5	0.5

Table.2 Distribution of available DTPA-extractable micronutrients of soil profile

Sample	Depth (cm)	DTPA – Extractable micronutrients (mg kg^{-1})			
		Fe	Cu	Mn	Zn
1.Taningjam					
	0-20	37.26	0.43	17.66	0.71
	20-40	34.47	0.37	13.12	0.58
	40-60	29.88	0.22	8.24	0.44
2.Dailong-1					
	0-20	34.10	0.43	44.33	1.22
	20-40	26.31	0.31	32.01	0.68
	40-60	21.72	0.24	21.16	0.54
3.Dailong-2					
	0-20	33.12	0.53	21.16	0.67
	20-40	32.33	0.46	20.17	0.62
	40-60	27.74	0.28	18.00	0.41
4.Bhalok					
	0-20	42.44	0.51	29.80	0.74
	20-40	37.65	0.41	13.14	0.40
	40-60	33.06	0.26	10.24	0.30
5.Tamei Road					
	0-20	25.00	0.39	17.84	0.79
	20-40	23.21	0.29	14.75	0.68
	40-60	18.62	0.12	12.24	0.50
6.Kahulong-1					
	0-20	29.24	0.25	21.35	0.95
	20-40	27.05	0.25	19.19	0.65
	40-60	26.86	0.16	16.50	0.64
7.Kahulong-2					
	0-20	37.32	0.48	13.12	1.32
	20-40	35.53	0.36	12.24	0.68
	40-60	32.94	0.20	9.72	0.54
8.Kahulong-3					
	0-20	40.68	0.41	11.14	1.36
	20-40	39.89	0.35	9.19	1.24
	40-60	31.30	0.18	6.42	0.88
9.Farmland-1					
	0-20	31.28	1.04	6.62	0.54
	20-40	30.49	0.87	5.24	0.48
	40-60	27.90	0.48	3.56	0.26
10.Farmland-2					
	0-20	27.32	0.68	6.13	0.82
	20-40	24.13	0.42	5.97	0.52

	40-60	20.94	0.34	4.68	0.40
11.Keikao-1					
	0-20	38.34	1.26	17.26	0.46
	20-40	29.15	0.87	5.24	0.48
	40-60	24.96	0.52	8.20	0.16
12.Keikao-2					
	0-20	35.76	0.47	6.11	0.83
	20-40	32.97	0.39	4.14	0.50
	40-60	29.38	0.36	3.42	0.42
13.Tamenglong Headquarter					
	0-20	42.24	0.96	25.11	0.38
	20-40	38.55	0.77	23.47	0.36
	40-60	33.86	0.46	18.46	0.26
14.C-Center					
	0-20	45.12	1.07	19.38	0.56
	20-40	41.13	0.82	15.77	0.52
	40-60	32.74	0.50	11.48	0.28
15.Azuram					
	0-20	42.22	0.27	23.14	0.61
	20-40	38.03	0.20	15.46	0.34
	40-60	31.84	0.14	14.66	0.24

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

Depth (cm)	Available Fe	R^2
0-20	173.088 -- 27.812 pH – 45.515 EC + 3.323 OC	0.501*
20-40	132.094 + 20.028* OC– 23.036 pH	0. 371*
40-60	20.840+12.775 Mg	0.293*
	Available Cu	
0-20	NS	
20-40	NS	
40-60	NS	
	Available Mn	
0-20	-11.327+24.647 OC	0. 257*
20-40	-3.894 + 19.400* OC	0. 324*
40-60	-1.875 + 18.707* OC	0.249*
	Available Zn	
0-20	1.287- 0.076 Silt* + 0.041 Clay	0.605*
20-40	NS	
40-60	-0.220 + 0.006 K	0.248*

Table.4 Correlation coefficient (r) between physico-chemical properties and micronutrients of soils in (0-20 cm)

	Fe	**Cu**	**Mn**	**Zn**
pH	-0.626**	-0.202	-0.263	0.131
EC	-0.527*	-0.012	-0.175	0.264
OC	0.531*	0.134	0.507*	0.102
CEC	0.175	-0.004	0.043	0.095
Clay	-0.008	-0.258	-0.018	0.494*
Silt	-0.314	0.405	-0.129	-0.709**
Sand	-0.210	-0.014	0.100	-0.015
N	0.069	-0.080	0.067	0.004
P	-0.033	-0.369	-0.149	0.431
K	0.454	-0.016	0.031	0.237
Ca^{++}	0.314	-0.124	0.291	0.130
Mg^{++}	0.451	0.381	0.130	-0.465

* r significant at 5% level, **r significant at 1% level

Table.5 Correlation coefficient ® between physico-chemical properties and micronutrients of soils (20 – 40 cm)

	Fe	Cu	Mn	Zn
pH	-0.513*	0.097	0.364	0.165
EC	0.075	-0.152	-0.014	0.153
OC	0.523*	0.001	0.569*	0.364
CEC	0.191	-0.017	-0.022	-0.014
Clay	-0.219	0.060	0.024	-0.140
Silt	-0.132	-0.085	-0.413	-0.110
Sand	0.316	-0.022	0.245	0.196
N	0.056	0.025	0.031	0.094
P	-0.084	-0.158	-0.160	0.304
K	-0.289	0.088	0.093	0.267
Ca	0.230	-0.295	0.094	0.049
Mg	0.254	-0.045	0.469	0.268

* r significant at 5% level, **r significant at 1% level

Table.6 Correlation coefficient ® between physico-chemical properties and micronutrients of soils (40 – 60 cm)

	Fe	Cu	Mn	Zn
pH	0.113	0.424	0.300	-0.346
EC	0.038	-0.077	0.354	-0.067
OC	0.297	-0.193	0.499*	-0.039
CEC	0.090	-0.086	0.130	0.106
Clay	-0.221	-0.103	-0.261	0.203
Silt	0.134	0.121	-0.123	-0.413
Sand	0.126	0.025	0.311	0.051
N	0.082	-0.262	0.068	0.064
P	-0.139	-0.460	0.286	0.170
K	0.149	0.046	-0.294	0.501*
Ca^{++}	0.306	0.068	0.053	0.210
Mg^{++}	0.542*	0.131	0.386	-0.076

*r significant at 5% level, ** r significant at 1% level

It can be concluded that there exists variation in soil properties with respect to depth in soil profiles. The surface layer soils were fairly high in organic carbon and adequate in all the micronutrients content. But the content of all the nutrients were low in the sub-surface layers especially from 40 cm to 60 cm depth as compared to the surface layers in all the studied areas. As compared to other micronutrients, the Zn content of the lower layers was found to be more deficient in many samples. The macronutrient content of most the sample varies from low to medium in all the profile. This may be an important reason for decreasing production potential of orange in Tamenglong district of Manipur. Moreover, the lack of fertilization practice results in soil fertility depletion in the long run as well as the demand cannot be supplied. It is of great importance to replenish the nutrient content of the soil and to maintain balanced fertilization for proper crop production. Therefore, it is advisable to apply Cu and Zn along with macronutrients to sustain the fertility of the soils as well as productivity of crop to increase the income of the farming community.

References

Athokpam, H., Wani, S.H., Kamei, D., Athokpam, H.S., Nongmaithem, J., Kumar, D., Singh, Y.K., Naorem, B.S., Devi, T.R. and Devi, L. (2013). Soil macro- and micro-nutrient status of Senapati district, Manipur (India). African Journal of Agricultural Research. 8(39): 4932-4936.

Athokpam, H.S., Singh, K.S., Chongtham, N., Devi, K.N., Singh, N.B., Sanatomba, A. and Sharma, P.T. (2018). Vertical distribution of micronutrient cations in Imphal east and west district, Manipur (India). International Journal of Current Microbiology and Applied Sciences. 7(8): 4222-4227.

Athokpam, H.S., Vikramjit, K., Chongtham, N., Devi, K.N., Singh, N.B., Singh, N.G., Sharma, P.T. and Heisnam, P. (2018). Micronutrient cations distribution in the soil profile of orange (*Citrus reticulata*) orchard of Tamenglong district, Manipur (India). Journal of Experimental Biology and Agricultural Sciences. 6(1): 108-115.

Athokpam, H.S., Zimik, V.S., Chongtham, N., Devi, K.N., Singh, N.B., Watham, L., Sharma, P.T. and Athokpam, H. (2016). Profile distribution of micronutrient cations in citrus orchard of Ukhrul district, Manipur (India). International Journal of Agriculture, Environment and Biotechnology. 9(4): 691-697.

Bell, R.W. and Dell, B. (2008). Micronutrients for sustainable food, feed, fibre and bioenergy production. 1st edn. IFA, Paris, France.

Borah, D.K., Bordoloi, P.K., Karmakar, R.M., Baruah, N.G. and Das, M. (1987). Practical Manual for Fundamental of Soil Science (Part-III), Jorhat, Assam.

Bouyoucos, G.J. (1951). Soil Science. 23: 319-343.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.,* 59: 39-45.

Chopra, S.L. and Kanwar, J. 1976. Analytical Agricultural Chemistry. Kalyani Publishers, Ludhiana, Punjab, India.

Gao, S., Yan, R., Cao, M., Yang, W., Wang, S. and Chen, F. (2008). Effect of on growth, antioxidant enzymes and phenylalanine ammonia-lyase activities in *Jatropha curcas* L. seedling. Plant Soil and Environment. 54(3): 117-122.

Gupta, N., Trivedi, S.K., Bansal, K.N. and Kaul, R.K. (2003). Vertical distribution of micronutrient cations in some soil series of northern Madhya Pradesh. Journal of the Indian Society of Soil Science. 51(4): 517-522.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice-Hall of India Pvt. Ltd. New Delhi.

Kumar, T.V., Reddy, M.S., and Krishna, V.G. (1996). Vertical distribution of micronutrient cations in some soil profiles of Northern Telangana of Andhra Pradesh. Journal of the Indian Society of Soil Science. 44(2): 328-330.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. American Journal of Soil Science. 42: 421-428.

Murthy, I.Y.L.N., Sastry, T.G., Dutta, S.C., Narayanasamy, G. and Rattan, R.K. (1997). Distribution of micronutrient cations in vertisols derived from different parent material. *J.* Journal of the Indian Society of Soil Science. 45(3): 577-580.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Methods for Agricultural Workers. ICAR, New Delhi.

Pati, R. and Mukhopadhyay, D. (2011). Distribution of cationic micronutrients in some acid soils of West Bengal. Journal of the Indian Society of Soil Science. 59(2): 125-133.

Rajkumar, Nayyar, V. K., Sidhu, G. S. and Deshmukh, S. N. (1990). Distribution of available micronutrient cations in some dominant soil series in different physiographic units of Bundelkhand region of Madhya Pradesh. Journal of the Indian Society of Soil Science. 38: 410-415.

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(4): 546-558.

Rengel, Z. (2007). Cycling of micronutrients in terrestrial ecosystems. In: Marschner, P. and Rengel, Z. (Eds.) Nutrient Cycling in Terrestrial Ecosystem. Springer-Verlag, Berlin, Heidelberg, pp. 93-121.

Sakar, D., Baruah, U., Gangpadhyay, S.K., Sahoo, A.K. and Velayutham, M (2002). Characteristics and classification of soils of Lotak catchment area of Manipur for sustainable land use planning. Journal of the Indian Society of Soil Science.

50(2): 196-204.

Satyavathi, P.L.A. and Reddy, M.S. (2004). Distribution of DTPA extractable micronutrient in soils of Telengana, Andhra Pradesh, Agropedology. 14(1): 32-37.

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(2): 388-390.

Sharma, P.D. (2008). Nutrient management – challenges and options. Journal of the Indian Society of Soil Science. 55: 395-403.

Sharma, R.P., Singh, M. and Sharma, J.P. (2003). Correlation studies on micronutrients *vis-à-vis* soil properties in some soils of Nagaur district in semi-arid region of Rajasthan. Journal of the Indian Society of Soil Science. 51(4): 522-527

Singh, K.S. and Athokpam, H. (2018). Physico-chemical characterization of farmland soil in some villages of Chandel hill district, Manipur (India). International Journal of Current Microbiology and Applied Sciences. 7(2): 417-425.

Singh, L.P., Athokpam, H.S., Chongtham, N., Devi, K.N., Singh, N.B., Sanatomba, A., Singh, N.G. and Sharma, P.T. (2018). Vertical distribution of micronutrient cations in Thoubal and Bishnupur district, Manipur (India). International Journal of Current Microbiology and Applied Sciences. 7(9): 2178-2183.

Singh, M.V. (2004). Micronutrient deficiencies in Indian soils and field usable practices for their correction. IFA International Conference on Micronutrients, New Delhi.

Srivastava, A. K. and S. Singh, (2002a). World citrus: Climate and soil analysis. In *Citrus: Climate and soil.* Eds.1-2902. International Book Distributing Co., Lucknow, Uttar Pradesh, India.

Srivastava, A. K. and S. Singh, (2002b). Soil analysis based diagnostic norms for Indian citrus cultivar. Communication in Soil Science and Plant Analysis. 33: 1689-1706.

Srivastava, P.P, Pandiaraj, T., Das, S. and Sinha, A.K. (2017). Assessment of micronutrient status of soil under Tasar host plant growing regions in Jashpur district, Chhattisgarh State. Imperial Journal Interdisciplinary Research. 3: 1080-1083.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for estimation of available N in soils. Current Sciences. 25: 259-260

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

Walkley, A. and Black, C.A. (1934). An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 37(16): 29-39.

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