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MICRONUTRIENT CATIONS DISTRIBUTION IN THE SOIL PROFILE OF ORANGE (*Citrus reticulata)* ORCHARD OF TAMENGLONG DISTRICT, MANIPUR (INDIA)

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ABSTRACT

Vertical distribution of DTPA-extractable micronutrient cations (Zn, Cu, Fe and Mn) and their relationship with various soil properties were studied in sixteen profiles of orange orchard of Tamenglong district of Manipur. The DTPA-extractable Zn, Cu, Fe and Mn content were greater in the surface soils than the sub-surface horizons. In most of the profiles the value of Zn, Cu, Fe and Mn ranged from 0.20 to 1.75, trace to 0.80, 5.80 to 42.10 and 0.35 to 39.55 mg kg^{-1}, respectively. The content of DTPA-extractable Zn, Cu, Fe and Mn were higher surface and gradually decreased with the depth. DTPA-extractable Zn was found deficient in 73 per cent, marginal in 16 per cent and sufficient in 1.50 per cent in the soil samples while Cu, Fe and Mn were sufficient in all soils except one profile in Cu and Mn. Multiple regression co-efficient analysis showed that the extractable Zn, Cu, Fe and Mn content were influenced by silt, EC, Al$_2$O$_3$ and Mg to the level of 0.77, 0.80, 0.73 and 0.66, respectively. However, these micronutrient cations were significantly contributed only by silt and EC.

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1 Introduction

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). Application of Mg + Cu + Zn gave the highest fruit yield of orange but did not affect fruit quality (Ram & Bose, 2000). Sweet orange fruit yield was increased with foliar application of 0.4 kg Zn ha^{-1} and 0.2 kg Mn ha^{-1} in the presence of 1.56 kg N ha^{-1} (Tariq et al., 2007). Foliar spray of $CuSO_4$ (0.4 %) at pea stage and gravel stage increased the fruit retention of Nagpur mandarin was reported by Soni et al. (2017). Flourishes in the growth and yield attributes of Mandarin orange was noticed with foliar spray of micronutrients (Kumar et al., 2017). Foliar application of micronutrients gave the higher Kinnow mandarin fruit yield than the soil treatment under semi-arid zone (Vijaya et al., 2017). 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 & Choudhary, 2007). Continuous negligence of micronutrient application and avoidance of organic manures are the major causes of deficiency of these micronutrients (Srivastava et al., 2017). Moreover, citrus is deep rooted plant, micronutrients application at the soil surface may be of a little value. Therefore, a major constraint for productivity and sustainability of the Indian soils were due to the deficiency of micronutrients in the surface soil as well as sub-surface soil. The availability of micronutrients to plants is also influenced by the distribution within the soil profile (Singh & Dhankar, 1989). The knowledge of pedogenic distribution of micronutrients is important as many plant roots penetrate to the sub-surface layers and thus, draw a part of the nutrient requirement from the sub-surface horizon of the soils. The distribution of micronutrient cations of orange orchards of Tamenglong district of Manipur was not yet studied. Therefore, the present work has been undertaken to assess the distribution of micronutrient cations of the orange orchards and to find out the relationship between the soil properties and micronutrients.

2 Materials and Methods

The studied area lies between $24^0 45'$N to $24^0 59'$N latitudes and $93^0 26'$ longitudes and located in South-western part of Manipur, India with an elevation of 900-1200 m MSL. Sixteen typical soil profiles from different orchards of Tamenglong District, Manipur were exposed and soil samples were collected depth-wise i.e. 0-20, 20-40, 40-60 and 60-80 cm. in the clean polythene bags. All the composite soil samples were air-dried in the shade, ground and passed through 2 mm sieve for chemical analysis. Typical soil profiles were exposed by collecting depth wise i.e. 0-20, 20-40, 40-60 and 60-80 cm soil samples. These were processed and analyzed for various physicochemical properties like sand, silt, clay content, pH, EC (1:2.5 soil: water), organic carbon, CEC, available N, P and K, Al_2O_3 and Fe_2O_3 using standard laboratory procedures outline by Jackson (1973), Borah et al. (1987) and Chopra & Kanwar (1976).

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 tri-ethanolamine adjusted to pH 7.3 as outlined by Lindsay & Norvell (1978). This micronutrient cations concentration in the soils was analyzed by using AAS. Multiple regression equations were computed between DTPA-extractable micronutrients and soil properties by adopting statistical procedures (Panse & Sukhatme, 1961).

3 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 i.e. 11.8 to 45.2, 5.0 to 32.9 and 37.3 to 62.3 per cent, respectively. The EC of the soils varied from 0.011 to 0.256 dSm^{-1} and soil organic carbon ranged from 4.2 to 18.6 g kg^{-1}. Organic carbon in surface soil layers was more than the sub-surface layers. CEC ranged from 9.6 to 24.0 $[cmol(p^+)]kg^{-1}$ soil. Free oxides of iron and aluminum varied from 0.2 to 0.6 and 5.7 to 13.5 per cent, respectively. The exchangeable Ca and Mg content in the soils were 0.39 to 7.85 and 0.13 to 5.00 $[cmol(p^+)]kg^{-1}$ soil, respectively, both bases decreased with increased in depth in all the soil profiles. The available N, P and K content in the soils were 125.0 to 313.0, 2.2 to 22.4 and 39.2 to 269.0 kg ha^{-1}, respectively. These nutrients content decreased with increased the depth in the profile.

3.1 Zinc (Zn)

DTPA-extractable Zn in the studied soil profiles varied from trace to 1.75 mg kg^{-1} in the orange growing soils of Tamenglong district of Manipur. Sen et al. (1997) reported the available Zn content varies from 0.2 to 1.4 mg kg^{-1} and decreased down the profile (Khanday et al., 2017). Similar report was also reported by Athokpam et al. (2016) in the citrus orchard of Ukhrul district, Manipur. Considering 0.6 mg kg^{-1} as the critical limit of available Zn as suggested by Takkar & Mann (1975), 73.4, 25.0 and 1.6 percent of the studied soil samples fell in deficient, marginal and sufficient categories, respectively. DTPA-extractable Zn showed significant regression (Table 3) with EC (0.868*) and Fe (0.024*).

Table 1 Physico-chemical properties of the soil profiles

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (dS m^{-1})	OC (gkg^{-1})	CEC [cmol (p^{+}) kg^{-1}]	Fe_2O_3 (%)	Al_2O_3 (%)	Ca [cmol(p^{+}) kg^{-1}]	Mg [cmol (p^{+}) kg^{-1}]	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Profile 1(Longmai Noney II)															
0 – 20	39.3	22.5	38.2	CL	4.70	0.084	1.41	15.2	0.56	6.7	0.93	2.70	250.88	15.68	95.2
20 – 40	36.8	25.0	38.2	CL	4.80	0.032	0.66	14.0	0.48	6.2	0.73	1.92	313.60	13.44	50.4
40 – 60	36.8	22.5	40.7	C4.9	4.90	0.015	0.51	13.6	0.32	6.0	1.00	1.93	188.16	13.44	39.2
60 – 80	39.3	17.5	43.2	C	5.00	0.015	0.42	14.8	0.32	6.1	0.80	2.13	188.16	11.20	44.8
Profile 2 (Longmai Noney II)															
0 – 20	26.7	24.7	48.6	C	4.84	0.098	1.86	16.0	0.56	5.8	1.60	1.26	313.60	11.20	123.2
20 – 40	23.5	32.9	43.6	C	4.85	0.033	1.26	14.0	0.48	7.2	1.00	0.46	188.16	6.72	78.4
40 – 60	36.0	20.4	43.6	C	4.82	0.022	1.20	15.8	0.44	7.1	0.86	0.86	188.16	4.48	72.8
60 – 80	33.5	22.5	44.0	C	4.84	0.019	1.20	13.8	0.52	6.3	0.93	0.80	125.44	2.24	72.8
Profile 3 (Longmai Noney I)															
0 – 20	24.3	25.0	50.7	C	4.71	0.103	1.86	17.0	0.36	11.9	1.73	1.70	313.60	13.44	224.0
20 – 40	26.4	15.9	57.7	C	4.82	0.043	1.32	17.2	0.32	13.5	0.66	1.33	313.60	8.96	128.0
40 – 60	23.5	25.6	50.9	C	4.85	0.023	1.02	16.8	0.36	13.3	0.73	0.73	125.44	4.48	95.2
60 – 80	23.5	25.6	50.9	C	4.90	0.020	0.78	15.0	0.40	8.6	0.66	0.72	188.16	6.72	106.4
Profile 4 (Longmai Noney I)															
0 – 20	19.3	27.5	53.2	C	4.60	0.068	1.71	23.6	0.52	6.6	1.33	3.33	313.60	8.96	184.8
20 – 40	11.8	30.0	58.2	C	4.63	0.033	1.26	19.2	0.44	8.6	0.86	1.00	250.88	4.48	140.0
40 – 60	15.2	27.5	57.3	C	4.64	0.020	0.90	18.6	0.32	8.4	0.80	0.26	188.16	4.48	112.0
60 – 80	12.7	25.0	62.3	C	4.61	0.050	0.66	17.6	0.36	9.0	0.66	0.76	125.44	6.72	117.6
Profile 5 (Tupul I)															
0 – 20	35.2	22.5	42.3	C	5.20	0.210	2.16	24.0	0.56	6.7	7.85	3.30	250.88	22.40	240.8
20 – 40	42.7	17.5	39.8	SC	5.30	0.216	1.50	20.4	0.44	9.2	6.33	3.93	250.88	13.40	184.8
40 – 60	37.7	20.0	42.3	C	5.20	0.214	1.41	19.2	0.48	9.1	6.10	3.30	188.16	13.40	173.6
60 – 80	45.2	17.5	37.3	SCL	4.82	0.050	0.96	13.6	0.24	9.4	4.20	3.30	188.16	8.96	128.0
Profile 6(Tupul II)															
0 – 20	21.4	30.0	48.6	C	4.80	0.130	2.01	20.0	0.44	7.9	3.50	3.40	250.88	17.92	102.4
20 – 40	23.5	27.9	48.6	C	4.84	0.079	1.53	19.4	0.48	9.0	1.60	2.90	313.60	13.44	112.0
40 – 60	30.5	25.9	43.6	C	4.85	0.049	1.02	14.0	0.48	9.1	1.90	1.50	250.88	13.44	78.4
60 – 80	27.3	26.2	46.5	C	4.82	0.050	0.96	13.6	0.40	7.7	1.00	1.60	250.88	8.96	89.6
Profile 7 (Nungtek)															
0 – 20	29.4	22.0	48.6	C	4.60	0.256	1.56	16.4	0.48	5.7	5.80	2.50	313.60	15.68	257.6
20 – 40	32.0	22.0	46.0	C	4.90	0.088	0.87	14.4	0.36	8.4	3.00	1.95	250.88	13.44	140.0
40 – 60	32.1	26.8	41.1	C	4.80	0.045	0.63	12.4	0.28	7.6	1.90	0.99	250.88	8.96	67.2
60 – 80	40.5	19.3	40.2	C	4.70	0.040	0.57	12.0	0.20	6.7	1.50	1.26	188.16	11.20	78.4

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (dS m $^{-1}$)	OC (gkg^{-1})	CEC [cmol (p^{+}) kg^{-1}]	Fe$_2$O$_3$ (%)	Al$_2$O$_3$ (%)	Ca [cmol (p^{+}) kg^{-1}]	Mg [cmol (p^{+}) kg^{-1}]	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Profile 8 (Thangal)															
0 – 20	25.5	18.4	56.1	C	4.80	0.252	2.16	22.4	0.60	6.6	5.80	4.80	313.60	22.4	268.8
20 – 40	28.0	25.9	46.1	C	4.60	0.155	1.32	20.0	0.48	5.9	4.32	4.20	313.60	17.92	257.6
40 – 60	40.5	15.9	43.6	C	4.60	0.072	0.81	16.4	0.44	6.6	2.93	3.40	250.88	13.44	190.4
60 – 80	38.9	15.9	45.2	C	4.70	0.040	0.60	14.8	0.32	7.8	2.33	3.26	188.16	15.68	117.6
Profile 9 (Awang Khul)															
0 – 20	33.9	17.5	48.6	C	4.20	0.104	2.16	14.8	0.32	7.2	0.93	0.79	250.88	20.16	145.6
20 – 40	32.5	16.0	51.5	C	4.40	0.070	1.20	13.0	0.48	10.5	0.73	0.79	250.88	17.92	84.0
40 – 60	33.5	5.0	61.5	C	4.60	0.021	0.66	12.8	0.36	9.3	0.53	0.26	188.16	11.20	72.8
60 – 80	29.0	20.0	51.0	C	4.60	0.043	0.45	9.6	0.36	9.6	0.39	0.39	188.16	8.96	84.0
Profile 10 (Rengpang)															
0 – 20	16.0	28.8	55.2	C	4.30	0.065	1.71	16.4	0.44	8.2	1.19	0.66	250.88	20.16	246.4
20 – 40	25.3	15.2	59.5	C	4.40	0.052	0.96	14.4	0.56	9.4	1.19	0.46	250.88	17.92	123.2
40 – 60	25.3	16.8	57.9	C	4.50	0.012	0.54	13.8	0.48	8.7	0.79	0.26	188.16	17.92	100.8
60 – 80	18.4	26.3	55.3	C	4.60	0.011	0.51	13.2	0.40	9.0	0.73	0.26	125.44	15.68	95.2
Profile 11 (Longmai I)															
0 – 20	32.7	22.5	44.8	C	4.60	0.084	1.08	14.4	0.48	8.7	2.30	2.90	313.60	17.92	95.2
20 – 40	27.7	22.5	49.8	C	4.70	0.042	0.78	14.0	0.36	11.1	2.10	2.90	250.88	17.92	67.2
40 – 60	25.2	25.0	49.8	C	4.80	0.045	0.75	12.8	0.32	10.2	1.70	3.19	188.16	15.68	67.2
60 – 80	30.2	27.5	42.3	C	4.80	0.023	0.81	12.0	0.32	9.9	1.30	2.53	188.16	13.44	72.8
Profile 12 (Longmai II)															
0 – 20	29.1	30.9	40.0	C	4.70	0.060	1.38	16.0	0.52	6.4	2.70	5.00	188.16	8.96	162.4
20 – 40	37.5	20.0	42.5	C	4.80	0.052	1.11	14.0	0.52	7.8	190	2.93	188.16	6.72	78.4
40 – 60	37.5	20.0	42.5	C	4.60	0.040	0.81	11.6	0.44	8.6	1.50	1.79	188.16	4.48	56.0
60 – 80	34.3	25.7	40.0	C	4.60	0.023	0.42	10.0	0.32	9.0	1.30	1.86	125.44	2.24	50.4
Profile 13 (Khumti I)															
0 – 20	38.5	20.0	41.5	C	4.70	0.082	1.47	16.4	0.48	6.1	4.20	4.40	313.60	17.92	218.4
20 – 40	36.0	22.5	41.5	C	4.80	0.075	1.17	15.8	0.56	6.5	3.50	4.20	250.88	6.72	162.4
40 – 60	33.5	22.5	44.0	C	5.00	0.076	0.78	15.0	0.32	8.4	2.60	4.80	188.16	4.48	154.6
60 – 80	30.0	20.2	49.8	C	5.00	0.032	0.75	14.6	0.32	9.9	1.90	2.90	188.16	8.96	112.0
Profile 14 (Khumti II)															
0 – 20	28.8	28.4	42.8	C	4.70	0.154	1.56	17.8	0.44	6.6	4.00	3.80	313.60	15.69	196.0
20 – 40	34.8	22.5	42.7	C	4.50	0.064	1.02	16.8	0.48	7.9	1.90	2.30	250.88	13.44	151.2
40 – 60	38.0	18.4	43.6	C	4.60	0.038	0.57	13.0	0.56	12.0	1.30	2.20	188.16	13.44	168.0
60 – 80	26.2	26.8	47.0	C	4.40	0.021	0.42	14.0	0.32	10.0	1.20	2.30	125.44	8.96	140.0

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (dS m $^{-1}$)	OC (gkg^{-1})	CEC [cmol (p^{+}) kg^{-1}]	Fe_2O_3 (%)	Al_2O_3 (%)	Ca [cmol (p^{+}) kg^{-1}]	Mg [cmol (p^{+}) kg^{-1}]	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Profile 15 (Khomjaron)															
0 – 20	24.3	19.2	56.5	C	4.90	0.122	3.06	16.0	0.40	10.2	2.90	2.10	313.60	17.92	224.0
20 – 40	19.3	22.5	58.2	C	4.60	0.054	1.11	13.0	0.30	13.8	0.93	0.53	250.88	13.44	145.6
40 – 60	16.8	27.5	55.7	C	4.80	0.045	0.96	12.8	0.52	12.5	0.66	0.47	250.88	11.20	123.6
60 – 80	16.8	26.7	56.5	C	4.80	0.021	0.96	9.6	0.52	13.6	0.60	0.46	188.16	8.96	134.4
Profile 16 (Khebuching)															
0 – 20	34.3	25.0	40.7	C	4.30	0.063	2.13	15.0	0.20	8.8	1.00	0.33	250.88	17.92	168.0
20 – 40	41.8	15.0	43.2	C	4.50	0.051	1.17	13.0	0.36	9.6	0.73	0.19	250.88	15.68	84.0
40 – 60	41.8	12.5	45.7	C	4.50	0.022	0.75	12.0	0.24	11.0	0.53	0.13	188.16	13.44	78.4
60 – 80	29.3	25.0	45.7	C	4.60	0.014	0.63	11.0	0.28	10.2	0.53	0.13	125.44	8.96	67.2

The multiple regression equations presented in the Table 3 indicate a predictability value of 77.4 per cent by all factors taken together in the 1st layer. Significant regression with EC (3.566*) and Fe (0.022**) in the 2nd layer, Fe (0.012*) in the 3rd layer and silt (0.029**) and Cu (0.451*) in the 4th layer and their predictability were 71.1, 75.0 and 73.7 percent, respectively (Table 3).

3.2 Copper (Cu)

DTPA-extractable Cu content in the profiles ranged from trace to 0.8 mg kg^{-1}. In all the sixteen profiles, DTPA-extractable Cu content in the soil was found in adequate range, being 0.2 mg kg^{-1} as critical value (Lindsay & 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 researchers (Gupta et al., 2003, Verma et al., 2007a, Verma et al., 2007b, Athokpam, et al., 2016). The multiple correlation and regression analyses indicated that 46.7, 69.1 and 80.4 per cent variability may be the combine effect of Fe, Mn, Mg and Zn content in the profile.

3.3 Iron (Fe)

DTPA-extractable Fe content in the profiles ranged from 5.8 to 42.1 mg kg^{-1} and is comparable with those reported by Gupta et al. (2003) and Sharma & Choudhary (2007) in the soils of Madhya Pradesh and north-west Himalaya (H.P.), respectively. The critical limit of the soils is 4.5 mg kg^{-1} as given by Lindsay & Norvell (1978), all the profiles have sufficient amounts of Fe in the soils. It showed significant regression coefficient with Zn (15.322*, 29.673* and 8.288*) in the 2nd, 3rd and 4th layers, respectively indicating dynamic equilibrium in the profiles. Multiple correlation and regression analyses indicated that 73.0, 70.1 and 55.0 percent variability in the DTPA-extractable Fe in the profiles was due to the combine effect of Al_2O_3, Cu, Zn, Mn, Mg and silt in the soils.

3.4 Manganese (Mn)

DTPA-extractable Mn in the studied profiles varied from 0.35 to 29.55 mg kg^{-1} with a mean value of 15.58 mg kg^{-1}. The surface soils contained higher Mn and decreased with increase in the depth (Gupta et al., 2003; Thangasawy et al., 2005; Verma et al., 2007a; Verma et al., 2007b). The studied soil profiles were above the critical limit as suggested by Lindsay & Norvell (1978), as the critical limit of the soils is 1.0 mg kg^{-1}. Only 4.67 percent of the studied samples were below critical limits. Multiple correlation and regression analyses indicated that 41.1, 65.6 and 64.5 per cent variability of the available Mn content and could be attributed to the combine effect of Mg, Cu, Fe, Zn and silt content in the profiles (Table 3).

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 (Table 2). Similar distribution pattern of micronutrient cations within the profiles was also reported by Sharma et al. (1999) and Sharma & 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

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

Depth (cm)	Zn	Cu	Fe	Mn	Depth (cm)	Zn	Cu	Fe	Mn
Profile 1 (Longmai Noney II)					**Profile 2 (Longmai Noney II)**				
0 – 20	0.65	0.55	31.5	10.0	0 – 20	0.45	0.45	38.2	26.6
20 – 40	0.20	0.25	22.3	7.0	20 – 40	0.00	0.35	24.3	12.0
40 – 60	0.20	0.30	15.0	8.7	40 – 60	0.00	0.20	22.5	10.0
60 – 80	0.40	0.25	13.8	9.3	60 – 80	0.10	0.20	21.5	10.1
Profile 3 (Longmai Noney I)					**Profile 4 (Longmai Noney I)**				
0 – 20	0.40	0.30	24.6	17.0	0 – 20	0.20	0.30	27.6	18.8
20 – 40	0.00	0.25	22.4	11.9	20 – 40	0.40	0.20	18.7	6.9
40 – 60	0.10	0.15	19.6	7.1	40 – 60	0.25	0.05	14.8	4.1
60 – 80	0.00	0.15	18.4	8.3	60 – 80	0.15	0.05	14.0	5.8
Profile 5 (Tupul I)					**Profile 6 (Tupul II)**				
0 – 20	0.70	0.20	24.4	26.1	0 – 20	0.95	0.40	36.0	37.0
20 – 40	0.40	0.25	18.3	16.7	20 – 40	0.35	0.40	32.2	33.1
40 – 60	0.25	0.25	16.7	12.2	40 – 60	0.40	0.40	24.2	20.7
60 – 80	0.45	0.20	11.5	8.3	60 – 80	0.35	0.30	20.6	17.0
Profile 7 (Nungtek)					**Profile 8 (Thangal)**				
0 – 20	1.10	0.40	31.2	25.3	0 – 20	1.75	0.50	45.2	21.7
20 – 40	0.60	0.60	33.7	22.3	20 – 40	1.20	0.40	48.5	16.5
40 – 60	0.50	0.55	36.7	28.8	40 – 60	0.85	0.45	48.2	13.7
60 – 80	0.45	0.45	32.2	24.5	60 – 80	0.65	0.55	40.8	7.5
Profile 9 (Awang Khul)					**Profile 10 (Rengpang)**				
0 – 20	0.80	0.35	37.0	25.7	0.25	0.25	27.8	23.5	0.25
20 – 40	0.65	0.20	22.3	13.1	0.10	0.15	17.2	10.8	0.10
40 – 60	0.10	0.20	20.7	8.4	0.00	0.05	13.7	4.5	0.00
60 – 80	0.30	0.15	14.2	7.8	0.10	0.00	14.0	3.8	0.10
Profile 11 (Longmai I)					**Profile 12 (Longmai II)**				
0 – 20	0.70	0.55	22.0	40.0	0 – 20	0.70	0.30	42.1	24.0
20 – 40	0.30	0.65	21.2	33.3	20 – 40	0.50	0.40	36.6	15.6
40 – 60	0.25	0.65	13.6	20.9	40 – 60	0.10	0.45	23.0	8.8
60 – 80	0.35	0.80	12.4	27.9	60 – 80	0.25	0.25	18.2	6.8
Profile 13 (Khumti I)					**Profile 14 (Khumti II)**				
0 – 20	0.65	0.25	31.8	34.7	0 – 20	0.65	0.20	25.6	30.9
20 – 40	0.30	0.25	28.7	28.8	20 – 40	0.25	0.20	20.6	25.4
40 – 60	0.20	0.25	21.0	18.4	40 – 60	0.20	0.25	16.4	20.1
60 – 80	0.00	0.15	13.8	9.35	60 – 80	0.15	0.20	11.5	19.0
Profile 15 (Khomjaron					**Profile 16 (Khebuching)**				
0 – 20	0.60	0.40	21.7	24.4	0 – 20	0.60	0.10	36.3	2.1
20 – 40	0.10	0.25	10.2	2.1	20 – 40	0.10	0.00	18.1	0.8
40 – 60	0.15	0.00	7.4	1.1	40 – 60	0.10	0.00	10.0	0.5
60 – 80	0.20	0.05	7.5	1.4	60 – 80	0.15	0.00	5.8	0.4

Table 3 Effect of soil characteristics on predictability of micronutrient cations

Micronutrients	Equations	R^2 x 100
Available Zn		
1st layer (0-20 cm)	-0.523 + 3.868* EC + 0.024** Fe + 0.002 Ca	**77.4****
2nd layer (20-40 cm)	-0.407 + 3.566* EC + 0.022** Fe – 0.068 Ca + 0.001K – 0.003 Mg	**71.1****
3rd layer (40-60 cm)	-0.496 + 0.002 N + 0.137 Cu + 0.012* Fe + 0.00 Mn	**75.0****
4th layer (60-80 cm)	0.832 – 0.005 Mg – 0.029** Silt + 0.451* Cu – 0.001 Fe	**73.7****
Available Cu		
2nd layer (20-40 cm)	0.044 + 0.005 Fe + 0.008* Mn	**46.7***
3rd layer (40-60 cm)	0.070 + 0.002 clay + 0.003 Fe + 0.031 Zn + 0.014* Mn + 0.01Mg	**69.1****
4th layer (60-80 cm)	-0.115 + 0.003 Fe + 0.344 Zn + 0.016** Mn + 0.033 Mg	**80.4****
Available Fe		
2nd layer (20-40 cm)	26.322 – 1.369 Al_2O_3 + 15.518 Cu + 15.322* Zn + 0.240 Mg	**73.0****
3rd layer (40-60 cm)	21.929 – 1.171 Al_2O_3 + 3.552 Cu + 29.673** Zn + 0.119 Mn	**70.7****
4th layer (60-80 cm)	37.159 – 0.335 Silt + 8.288* Zn – 1.929 Al_2O_3 + 11.156 Cu	**55.0***
Available Mn		
2nd layer (20-40 cm)	2.794 + 36.548* Cu + 0.639 Mg	**41.1***
3rd layer (40-60 cm)	1.877 + 27.805* Cu + 0.059 Fe + 0.601 Zn + 0.768 Mg	**65.6****
4th layer (60-80 cm)	7.442 + 0.465 Silt + 30.154** Cu	64.5**

regression coefficients of EC with DTPA-extractable micronutrients have also been reported by Randhawa & Singh (1995) and Sharma et al. (2006).

Conclusion

The surface horizons of the soil profiles were fairly high in organic carbon and adequate in all the macro and micronutrients content. However, in the sub-surface horizons especially 40 cm to 80 cm depth, the content of all the nutrients decreased below critical limits for the proper growth of the fruit trees. Thus, for the deep rooted fruit crops requires a well balanced nutrition of both macro and micronutrients, especially Zn to the root zones for proper growth and development.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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