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Altitudinal and depth-wise micro nutrient indexing of high density apple orchards in North Kashmir, India

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Abstract
A total of forty five soil samples collected from twelve representative profiles of high density apple orchards were analyzed for fertility parameters (Zn, Cu, Mn, Fe and B) using the standard procedures. Interestingly, significant differences are found in different micro nutrients. Micronutrients shows irregular trend with altitude but almost all micronutrient were found in adequate amounts in different altitudes (High, Mid and Low). Depth also shows an irregular trend in micronutrient concentration and usually higher amount of micronutrients were found in surface soils than sub surface soils in all three altitudes, over all mean surface micro nutrients of all three altitudes were higher in surface soils (1.91, 2.32, 56.66, 59.54 and 1.35) than sub surface soils (1.35, 1.68, 49.51, 51.16 and 0.97). All micronutrient shows positive correlation between soil available micronutrients with that of leaf micronutrients both in surface and sub surface soil. Present study though first of its kind on high density apple orchards is expected to quite useful for horticulturists for formulation of future research programme.

Keywords: profile, depth, apple, Kashmir, correlation and micronutrient

Introduction
The horticulture occupies a very significant position in the agricultural sector of Indian economy. Kashmir has a rich heritage of fruit cultivation. Walter. R. Lawerence, (1895) [31] revealed that “Kashmir is the country of fruits” and perhaps no country has greater facilities for horticulture, as the indigenous apples, pear, vine, mulberry, walnut, hazel, cherry, peach, apricot, strawberry, raspberry and can be obtained without any difficulty in most parts of the valley of Kashmir. Due to its geographical location, climate and soil type J&K is the producer of rich variety of fruits and vegetables and is the highest temperate fruit producing state of India (Farm-to-Fork, 2010) [7]. However, the geographical terrain and climate also create disadvantages for the state in terms of connectivity and other factors (Zahoor, 2013) [36]. Apple cultivation in J&K is fast expanding because apple has a comparative advantage over the other crops that can be grown in hilly regions. High density apple orchards developed on dwarfing rootstocks like M 9, M 26 have become common in many apple growing regions of the Kashmir.

Soils are considered as vital natural resources and integral part of the landscape. The basic needs of life can be fulfilled by maintaining soil in a state of high productivity and having the rational use of soil as per its potentiality in order to maintain sustainability. The production of quality fruit is also influenced by the nutritional status of the soil, fruit mineral composition, harvesting at maturity stage and leaf fruit ratio. Physiographic features like slope aspect, relief and the altitude have pronounced effect on physical and chemical properties and the nutrient supplying capacity of the soils, thereby influencing growth, yield and quality of fruit. The detailed information with regard to the impact of these features on the difference in morphology, physico-chemical properties of apple growing soils are scanty in our state especially in case of high density.

The nutrient supplying power of a soil depends on dissociation of the nutrients from the exchange site, which is in turn depend on the degree of saturation of the nutrients on the exchange site, type of clay and complementary ion-effect (Foth and Ellis, 1997) [9]. Continued removal of nutrients, with little or no replacement has aggravated the potential for future nutrient related plant stress and yield loss. Therefore, evaluating the fertility status of a soil is important to know the productivity of a soil as soil fertility is one of the parameters of soil productivity.

The soil and plant analysis are complimentary to each other because at times one will supply the information that the other may not therefore, it is advisable to consider analysis of both the components in assessing the nutritional status of fruit crops especially those fruit crops where the plants have deep and ramified root system, thus provides a valuable tool for understanding the nutrient supplying capacity of soil for ascertaining the relationship between available soil nutrient content and leaf nutrient status and therefore predicting the yield levels. Besides, knowledge of nutrient distribution down the profile is important to evaluate the contribution of different sub-surface soil horizons. Therefore, the studies nutrient content in both soil and leaf is essential to generate information regarding soil characteristics and nutrient indexing of apple growing orchards and standardize site-specific technologies to improve the yield. Besides, the information can be utilized for framing the fertilizer recommendations. The information would be useful for the subsequent research and developmental activities and shall guide in assessing the possible cause of low yield and quality fruit production.

Since various high density apple orchards with different varieties have been planted on different dwarf and semi-dwarf rootstocks to boost the apple production in Kashmir valley which is the major apple growing area and scanty information is available with respect to high density apple cultivation. Despite the importance of the area for producing quality apples no systematic study was undertaken with respect micro nutritional indexing of apple orchard soils under high density plantation.

Material and Methods

Forty two high density apple orchards selected from twelve representative high density apple production sites located in three different physiographic altitudes viz. Low Altitude (<1600mts.amsl), Mid Altitude (1600- 1800mts.amsl) and High Altitude (>1800mts.amsl) of north Kashmir consisting of three districts namely Kupwara, Baramulla and Bandipora were sampled for soils for the variation of available micro nutrients with altitude and depth variables. The surveyed area has sub-humid temperate climate and temperate variation between -6º to 32ºC. The topography of the location is highly uneven characterized by moderately steep to very steep slopes in upper reaches, moderately undulating in the middle and flat to moderately sloping land under cultivation and near habitation. Sampling sites were recorded by GPS coordinated in the center covered by high density orchards of uniform age group (5-15 years). Stratified random soil sampling was preferred due to large number of Apple orchards present in this region. Composite soil samples collected at an interval of 30 cm were taken up to 90 cm at more than 8 random points in each selected high density apple orchard. Analytical determination of Fe, Mn, Zn and Cu was performed by atomic absorption spectroscopy, B by hot water by using Azomethane-H reagent. Determination of plant micro-nutrient, the leaf samples were digested separately in diacid mixture of nitric acid and perchloric acid in the ratio of 10:3. The digested material was diluted in double distilled water and filtered in 100 ml volumetric flask. In order to ensure complete transfer of digested material, about six washings were given with double distilled water and final volume was made to 100 ml. The leaf micronutrient cations like zinc, copper, manganese and iron were determined on atomic absorption spectrophotometer. Micronutrient anion i.e., B was extracted by wet digestion method and determined on spectrophotometer. Data generated were analyzed for average, confidence interval at 95% level of significance (95% CI) using the computer program SPSS statistical software 17.0 versions for Windows.

Results and Discussion

A. Soil micronutrients

1. Available zinc (Zn)

The available zinc or DTPA-extractable zinc content The available zinc content in surface soils of high, mid and low altitude ranged statistically (95% CI) from 1.74 to 5.23, 1.43 to 2.10 and 1.66 to 2.26 ppm with mean value of 1.74, 1.76 and 1.96 ppm respectively, whereas, in sub-surface soils it ranged statistically (95% CI) from 0.16 to 2.58, 1.20 to 1.68 and 0.96 to 1.69 ppm with mean value of 1.37, 1.44 and 1.33 ppm respectively (Table-1). The available zinc status was medium to high. The available zinc content showed a irregular trend with an increase in soil depth and significantly higher amounts of available zinc were recorded in surface soils (p = 0.001). The available zinc in high density apple orchards of high altitude varied significantly with that of low altitude, which can be attributed to the accumulation of high organic matter, the major source of available zinc, in surface soils. To some extent, organic matter reduces the pH of the soil locally which helps in increasing solubility of zinc besides its effect on weathering of minerals containing zinc. Products of organic matter decay may also have chelating effect on zinc and chelated zinc may become available to plant. Further, it is less subjected to fixation reaction. Similar results were reported by Singh and Ahuja (1990) [27], Sharma (1995) [24], Najar (2002) [18], Dar (2009) [6] and Bhat (2010) [4].

Table 1: Micro-nutrient status (ppm) of High density Apple orchard soils of North Kashmir

Location (Altitude)	Depth (cm)	Zn	Cu	Mn	Fe	B
High Altitude (H)						
P_3 Sambler Bandipora (H-1)	0-15	2.02	3.34	46.02	74.2	1.84
	15-25	1.47	2.45	29.80	63.66	1.80
	25-58	1.28	2.32	36.48	52.00	1.24
	58-100	1.47	2.91	23.04	53.66	0.88
Surface	Mean	1.74	2.89	37.91	68.93	1.82
	95% CI	1.74-5.23	2.75-8.54	15.13-140.95	15.96-75.89	1.56-2.07
Sub-surface	Mean	1.37	2.61	29.76	52.83	1.06
	95% CI	0.16-2.58	1.13-6.36	25.62-55.14	42.28-63.37	1.22-3.34
Mid Altitude (M)						
P_5 Kunzer Baramulla (M-1)	0-15	1.75	3.06	64.38	60.38	1.14
	15-25	1.49	2.16	63.94	56.4	0.76
	25-53	1.52	2.04	57.28	54.44	0.92
	53-100	1.36	1.24	53.57	45.02	0.60
P_{12} Parihaspora	0-24	1.99	1.92	65.64	59.04	1.65

Baramulla (M-2)	24-56	1.84	1.87	63.09	60.22	1.44
	56-80	1.29	1.90	51.70	48.76	1.48
	80-106	1.62	1.07	49.12	45.00	1.35
Surface	Mean	1.76	2.25	64.26	59.01	1.24
	95% CI	1.43-2.10	1.37-3.13	62.57-65.95	56.08-61.93	0.63-1.86
Sub-surface	Mean	1.44	1.56	52.91	48.30	0.44
	95% CI	1.20-1.68	0.80-2.32	47.45-58.38	41.21-55.39	0.44-1.72
Low Altitude (L)						
P_1 Unagam Bandipora (L-1)	0-25	1.20	2.71	68.56	59.12	2.00
	25-48	1.09	2.08	58.26	47.12	1.65
	48-76	0.65	1.38	42.50	55.29	1.52
	76-98	0.78	1.12	51.28	43.21	0.58
P_2 Upper kunan Bandipora (L-2)	0-26	1.89	2.07	66.84	54.96	0.98
	26-45	1.04	1.27	55.44	48.98	0.55
	45-80	0.25	1.01	62.04	37.68	0.95
	80-104	0.76	0.94	55.14	30.01	0.24
P_4 Lodder Baramulla (L-3)	0-25	2.38	2.33	57.52	68.12	0.89
	25-51	2.02	2.84	56.24	63.04	0.85
	51-76	1.69	1.64	50.66	58.64	0.79
	76-100	1.5	1.34	47.76	45.00	0.79
P_6 Chooru Baramulla (L-4)	0-12	1.79	2.68	63.72	67.45	1.05
	12-25	1.23	2.64	63.98	62.87	1.02
	25-56	1.00	2.33	62.68	59.23	0.98
	56-92	1.04	2.48	61.00	62.48	0.98
P_7 Mazibug Baramulla (L-5)	0-15	2.43	1.92	66.75	63.19	2.04
	15-26	2.22	1.90	63.21	61.97	1.95
	26-58	1.65	1.02	61.96	60.02	1.24
	58-106	1.60	1.00	59.54	58.00	0.98
P_8 Sopore Baramulla (L-6)	0-14	2.63	2.65	54.64	63.65	1.05
	14-25	2.52	2.15	54.49	54.52	0.85
	25-52	2.53	1.52	46.56	55.15	0.96
	52-101	2.66	1.60	53.70	46.00	0.80
P_9 Pandithpora Kupwara (L-7)	0-25	2.78	2.10	59.28	53.1	1.00
	25-54	1.96	2.01	52.70	46.01	0.85
	54-92	1.15	2.02	47.84	52.80	0.80
P_{10} Chougul Kupwara (L-8)	0-24	1.79	2.68	38.18	64.04	2.75
	24-54	1.17	2.06	21.72	55.16	2.55
	54-90	1.19	2.16	13.75	59.86	2.50
P_{11} Jalalabad Baramulla (L-9)	0-25	2.87	2.56	62.82	63.56	0.98
	25-54	2.30	2.36	62.71	58.32	0.90
	54-90	1.53	2.27	52.12	52.27	0.82
Surface	Mean	1.96	2.27	57.05	58.62	1.32
	95% CI	1.66-2.26	2.07-2.47	51.44-62.66	55.26-61.97	1.00-1.65
Sub-surface	Mean	1.33	1.58	51.23	51.70	0.93
	95% CI	0.96-1.69	1.28-1.88	44.49-57.97	46.49-56.91	0.61-1.24
Surface	Mean	1.91	2.32	56.66	59.54	1.35
	95% CI	1.68-2.13	2.13-2.51	51.65-61.67	56.71-62.37	1.10-1.60
Sub-surface	Mean	1.35	1.68	49.51	51.16	0.97
	95% CI	1.10-1.61	1.41-1.94	43.86-55.15	47.43-54.89	0.74-1.20
Surface	p-value	0.001	0.001	0.0003	0.001	0.003
Sub-surface						

2. Available copper (Cu)

The data presented in Table-1 revealed that available copper content ranged statistically (95% CI) from 2.75 to 8.54, 1.37 to 3.13 and 1.28 to 1.88 ppm with mean value of 2.89, 2.25 and 2.27 ppm in surface soils of high, mid and low altitude, respectively, whereas, it varied statistically (95% CI) from 1.13 to 6.36, 0.80 to 2.32 and 2.13 to 2.51 ppm with mean value of 2.61, 1.56 and 1.58 ppm in sub-surface high density apple orchard soils of high, mid and low altitude, respectively. The available copper status was medium to high. This is supported by the findings of Mushki (1994) [16], Najar (2002) [17], Dar (2009) [6] and Bhat (2010) [4]. The content of available copper in high density apple orchard soils showed irregular trend (p = 0.001) with an increase in soil depth, but more copper is found in surface soils than sub surface soils, which may be due to regular addition of plant residues, farm yard manure and agricultural chemicals. Similar results were reported by Tiwary and Mishra (1990) [30], Najar (2002) [18] and Dar (2009) [6], Khanday *et al*., (2017) [14].

3. Available manganese (Mn)

The available manganese content in surface soils of high, mid and low altitude ranged statistically (95% CI) from 15.13 to140.95, 62.57 to 65.95and 51.44 to 62.66 ppm with mean value of 37.91, 64.26 and 57.05 ppm respectively, whereas, in sub-surface soils it ranged statistically (95% CI) from25.62 to 55.14, 47.45to 58.38 and 44.49 to57.97 ppm with mean value of 29.76, 52.91and 51.23 ppm respectively as shown Table 1. These results are in accordance with the findings of Najar (2002) [18], Dar (2009) [6] and Wani *et al*, (2016). The surface soils showed higher content of available manganese in all the three altitudes than sub surface soils. The decrease in mangnese content in sub surface may be attributed to increase in pH, which makes it less soluble or insoluble after oxidation hence precipitating it thereby reducing its availability. These finding corroborates with those of Sharma *et al.* (2005), Yadav and Meena (2009), Sidhu and Sharma (2010) and Behera and Shukla (2013).

4. Available iron (Fe)

Examination of the data in Table-1 indicated that available iron content in surface soils of high density apple orchards in high, mid and low altitude varied with the statistical range (95% CI) from 15.96 to 75.89, 56.08 to 61.93and 55.26 to 61.97 ppm with mean value of 68.93, 59.01 and 58.62 ppm respectively, while as, it varied with the statistical range (95% CI) of 42.28 to63.37, 41.21 to 55.39 and 46.49 to 56.91 ppm with mean value of 52.83,48.30 and 51.70 ppm in sub-surface soils of three altitudes, respectively. These results are in agreement with the findings of Mushki (1994) [16] and Dar (2009) [6] while working on apple and pear orchard soils of Kashmir. The available iron content showed irregular trend with an increase in soil depth with higher amounts on the surface soils than sub-surface soils. The higher amount of available iron recorded in surface soils of high altitude can be attributed to the maximum amount of organic matter and favourable pH in these soils, because availability of iron decreased with an increase in soil pH as iron is converted to highly insoluble oxides at higher pH. Further, organic matter forms soluble complexes with iron, which subsequently becomes available to the plants. These results are supported by the findings of Lahiri and Chakravati (1989), Sharma *et al.* (2005), Dar (2009) [6] and Wani *et al.*, 2017 [33] who observed that available iron in soils is largely influenced by the organic carbon content.

5. Available boron (B)

Perusal of data in Table-1 indicated that available boron varied with the statistical range (95% CI) from 1.56 to 2.07, 0.63 to 1.86 and 1.00 to 1.65 ppm with mean value of 1.82,1.24 and 1.32 ppm, in surface soils of high, mid and low altitude, respectively, while as, in sub-surface soils it varied with the statistical range (95% CI) from 1.22 to 3.34, 0.44 to 1.72 and 0.61 to 1.24 ppm with mean value of 1.06, 0.44 and 0.93 ppm in high, mid and low altitude, respectively. The available boron showed medium to high status. The available boron revealed decreasing trend downwards and varied significantly with soil depth ($p = 0.003$)**.** This may attributed to increase in soil pH with depth which renders low available B content comparatively due to its adsorption or sorption unto soil colloid in sub-surface soils. These results are in line with the findings of Keren and Bingham (1985) [13], Horng-yuh *et al*. (2009) [6] and Ibrahim *et al.*, (2016) [11].

B. Leaf micronutrients

1. Zinc (Zn)

The zinc content in leaves of high density apple ranged from 14.72 to 59. 90, 11.31 to 73.58 and 36.56 to 38.79 per cent with mean value of 46.80, 42.45 and 37.67 per cent in high, mid and low altitude, respectively, as shown in Table-2. These values are in conformity with those of Chaplin and Westwood (1980) [5], Shear and Faust (1980) [25], Shen (1990) [26] and Dar (2009) [6]. The significantly high mean value of leaf zinc (46.80 %) was recorded in high density apple orchards located in high altitude than high density apple orchards in mid and low altitude. Similarly maximum and minimum leaf zinc content (60.25, 28.0%) were found at Rohomu and Pahu located in high and low altitudes, respectively. However adwquate zinc is found in high density apple leaves which may be due to adequate amount of organic matter and available zinc in soils and favourable pH for its uptake. This is supported by the findings of Najar (2002) [19], Dar (2009) [6] and Samiullah *et al.* (2013) [21] while working on apple, pear and peach respectively in Kashmir conditions.

Table 2: Micro-nutrient content (ppm) of High density apple leaves on dry weight basis in North Kashmir

Location (Altitude)	Zn	Cu	Mn	Fe	B
High Altitude (H)					
P_3 Sambler Bandipora (H-1)	46.8	13.20	108.505	119.6	53.62
Mean	46.8	13.20	108.50	119.6	53.62
CI (95%)	14.72 - 59. 90	2.25 - 20.57	92.3 - 131.02	102.44-141.25	42.51-60.84
Mid Altitude(M)					
P_5 Kunzer Baramulla (M-1)	44.90	11.40	83.10	145.30	41.25
P_{12} Parihaspora Baramulla (M-2)	40.00	9.40	80.60	133.10	51.25
Mean	42.45	10.40	81.85	139.20	46.25
95% CI	11.31-73.58	2.30-23.10	65.96-97.0	61.69-216.70	17.28-109.78
Low Altitude(L)					
P_1 Unagam Bandipora (L-1)	39.20	10.40	99.20	140.00	32.37
P_2 Upper kuna Bandipora (L-2)	38.00	17.70	77.70	135.80	33.62
P_4 Lodder Baramulla (L-3)	37.00	12.60	91.20	133.00	40.50
P_6 Chooru Baramulla (L-4)	39.00	10.40	87.70	138.50	40.50
P_7 Mazibug Baramulla (L-5)	39.10	18.50	60.00	105.60	38.50
P_8 Sopore Baramulla (L-6)	38.00	11.00	105.00	141.30	40.12
P_9 Pandithpora Kupwara (L-7)	36.00	13.50	73.50	86.50	36.00
P_{10} Chougul Kupwara (L-8)	35.0	11.00	116.90	125.70	40.15
P_{11} Jalalabad Baramulla (L-9)	37.80	17.70	90.00	90.60	39.50
Mean	37.67	13.64	89.02	121.88	35.50
95% CI	36.56-38.79	11.02-16.25	75.83-102.21	105.11-138.66	35.50-40.33
Mean	39.23	13.06	89.45	124.58	40.61
95% CI	37.06-41.40	11.04-15.09	79.24-99.65	111.87-137.29	36.65-44.57

2. Copper (Cu)

Perusal of data in Table-2 indicated that leaf copper content in high, mid, and low altitude varied from 2.25 to 20.57, 2.30 to 23.10 and 11.02 to 16.25 per cent with mean value of 13.20, 10.40 and 13.64 per cent, respectively. These values are nearly in similar magnitude as reported by Chaplin and

Westwood (1980) [5], Rathore (1991) [20], Arora *et al.* (1992) [1], Seth (1997) [22] and Dar (2009) [6]. The highest mean value of leaf copper (16.64%) was recorded in low altitude which is statically at par with high altitude and lowest mean value (10.40%) was found in mid altitude. which could be attributed to higher amount of organic matter and available copper in soils and favourable soil pH. This has been supported by the findings of Mamgain *et al.* (1998) [15], Najar (2002) [17], Dar (2009) [6] and Xu *et al*. (2015) [35].

3. Manganese (Mn)

The leaf manganese content of high density apple in high, mid and low altitude orchards varied from 92.3 to 131.02, 65.96 to 97.00 and 75.83 to 102.21 per cent with mean value of 108.50, 81.85 and 89.02 per cent, respectively as shown in Table 2.Similar results have been observed by Mushki (1994) [16], Najar (2002) [18] and Dar (2009) [6] they also reported adequate amount of manganese in the orchards of Kashmir. The highest mean value of leaf manganese (108.50) was found in high altitude and lowest mean value (89.02%) was recorded in low altitude. The leaf manganese content exhibited significant variation among the orchards located in three altitudes, which could be ascribed to the amount of available manganese and organic matter content and favourable pH. This is supported by the findings of Bhandari and Randhawa (1978) [3], Mamgain *et al.* (1998) [15] and Dar (2009) [6], Xu *et al*., (2015) [35].

4. Iron (Fe)

Examination of the data in Table-2 revealed that iron content in the leaves of high density apple in high, mid and low altitude ranged from 102.44 to141.25, 61.69 to 216.70 and 105.11 to 138.66 per cent with mean vale of 119.6, 139.20 and 121.88 per cent, respectively. These values are in conformity with the findings of Singh *et al.* (2005) [29] and Dar (2009) [6]. The leaves showed adequate iron status in all the high density apple orchards. These results corroborates with the findings of Najar (2002) [19] and Dar (2009) [6]. The leaf iron content varied significantly among the orchards of three altitudes, which could be due to the amount of available iron and organic matter content of the soil as well as factors affecting its uptake. This is supported by the findings of Mamgain *et al.* (1998) [15], Najar (2002) [19] and Dar (2009) [6], Wani *et al.*, (2017) [34].

5. Boron (B)

The leaf boron content of high density apple in high, mid and low altitude orchards varied from 42.51 to 60.84, 17.28 to 109.78 and 35.50 to 40.33 per cent with mean value of 53.62, 46.25 and 35.50 per cent respectively. The highest mean value of leaf boron (53.62 %) was found in high altitude and lowest mean value (35.50 %) was recorded in low altitude.These results are in agreement with the findings of Singh (1987) [28], Sharma and Bhandari (1992) [23], Najar (2002) [17] and Fida *et al*. (2011) [8]. 100 per cent samples were adequate in leaf boron content (Table-2). Similar results were earlier reported by Sharma and Bhandari (1992) [23], Najar (2002), [18] Wani *et al.*, (2017) [33].

Relationship between soil and leaf nutrients

Among the micronutrients zinc, copper, iron and boron in both surface and sub-surface soils showed non significantly positive correlation except manganese which showed significant correlation in surface and sub surface soils only. The manganese content in leaves of high density apple revealed significant and positive relationship with available manganese content in surface and sub-surface soils (table 3). Similar results were reported by Singh (1987) [28], Mushki (1994) [16], Najar (2002) [19] and Jeyabaskaran and Pandey (2008) [12], Wani *et al.*, (2017) [34]. This indicates that maximum absorption of most of the soil available nutrients takes place from the surface soils (0-30cm), whereas zinc, manganese, iron and boron were also absorbed from sub-surface soils (30-100 cm) as well. The variation in degree of relationship of the surface and sub-surface available nutrient supply with the plant content may be due to differences in tree root ramification or the competition between tree roots and roots of cover crops and nutrient-ion interactions (Beattie and Ellenwood, 1950) [2]. The variable correlations may be also due to the influence of weather, size of the crop and orchard management practices (Walter, 1961) [32]. This could be the reason for differential degree of association between soil nutrient supply and contents in plants.

Table 3: Correlation coefficients (r) of available surface (A) and Sub Surface (B) micro nutrients in high density apple orchard soils with apple leaf micro nutrient content of north Kashmir

A. Surface micro nutrients						**B. Sub surface micro nutrients**					
Nutrient	Zn Soil	Cu	Mn	Fe	B	Nutrient	Zn Soil	Cu	Mn	Fe	B
Zn plant	0.357	0.321	-0.107	0.268	-0.025	Zn Plant	0.247	0.208	-0.021	-0.032	-0.232
Cu		0.370	0.170	-0.046	-0.155	Cu		0.222	0.357	-0.137	-0.402
Mn			0.756**	0.354	0.367	Mn			0.573*	0.171	0.496
Fe				0.463	-0.060	Fe				0.248	-0.021
B					0.401	B					0.270

*Significant at 5 per cent level
**Significant at 1 per cent level

Conclusion

All the available micronutrients-zinc, copper, manganese, iron and boron showed a irregular trend with increase in soil depth. The higher values of all the micronutrients were recorded in high altitude followed by mid and low altitude soils of the studied high density apple orchards except Zinc with irregular trend and manganese which showed higher status in mid altitude. Among the micronutrients, zinc, copper, and iron were found in the medium to high status while as manganese was found to be present in high status and boron in low to medium status. The leaf zinc, copper, manganese, iron, boron were found in the range of 37.06 to 41.40, 11.04 to 15.09, 79.24 to 99.65, 111.87 to 137.29 and 36.65 to 44.57 ppm, respectively. The leaf zinc, manganese and iron were adequate to high, copper low to adequate in all samples analyzed. The leaf analysis indicated that all the high density apple orchards have adequate amount of nutrient elements. Micronutrients like zinc, copper, iron and boron in both surface and sub-surface soils showed non significantly positive correlation except manganese which showed significant correlation in surface and sub surface soils only. The manganese content in leaves of high density apple revealed significant and positive relationship with available manganese content in surface and sub-surface soils. The variation observed between soil and leaf analysis indicates a need either to standardize the available nutrient extraction methods or change in critical limits suiting our conditions. A study of relationship of nutrient extracting capability of plant roots from different depths need to be studied in a detailed manner. Since most soil properties are dynamic in nature, detailed field and laboratory investigations be carried out on site specific to establish nutrient status and further strengthen the validity of the soil test-plant response relationship more accurately. The present study though first of its kind on high density apple orchards is expected to quite useful for horticulturists for formulation of future research programme.

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