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GIS Based Mapping of Copper, Manganese and Boron Availability in Apple Orchards of Murree, Pakistan

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Abstract: Average yield of fruit orchards (9 tonnes ha^{-1}) in Pakistan is far low when compared with the average international yield (25 tonnes ha^{-1}). Micronutrient deficiencies of soil are causing wide spread nutritional disorder in horticultural crops, grown in the calcareous soils. Micronutrient deficiencies also result in to a poor quality fruit production so a field survey was conducted to examine the site specific micronutrients (Cu, Mn and B) availability of major apple producing region Murree in the Punjab province. Five different sites were selected from each of 13 apple orchards situated at various locations. One hundred and thirty soil samples and 65 foliage samples were collected. Dry ashing, AB-DTPA and dilute HCl acid extraction techniques were employed to estimate availability of nutrients in plants and soil. Of the sixty one samples surveyed, 38% and 15% of apple orchards were found deficient in Cu, Mn and B content the foliage. Bio-available Mn was deficient in 8% of surveyed apple orchards. Keeping in view, the importance of advanced techniques, like, GPS (Global Positioning System) and GIS (Geographical Information System), in the site specific and balanced nutrient management, location coordinates, were recorded and the data was incorporated to maps in order to facilitate the site specific policy making and nutrient management. Positive relationship, among the availability of micronutrients and organic matter, clay and silt, was a common phenomenon, whereas a negative relationship was observed in the case of pH, $CaCO_3$ and available micronutrients.

Key words: Apple, Copper, Manganese, Boron, Availability, GIS.

INTRODUCTION

Agriculture is the mainstay for the economy of Pakistan and nearly 80% of the population is concerned with agriculture, however, the average yield of crops, grown in the country, is very low. The low yield and area under the cultivation of horticultural crops and lower yield hamper the production of fruits and vegetables. This lower average yield might be due to various factors, like, lack of knowledge about the modern production technology, but the low or no use of fertilizers and lack of awareness in the soil fertility by farmers seem to be the major reasons for the decline in the yield (Yousaf *et al*., 2001; Ahmad *et al*., 2010). Apple is one of the nutritious fruits that not only provide elements, essential for human health but also contains carbohydrates, protein, fat and water. Unfortunately, the average yield of apple orchards in Pakistan is very low, i.e., 6.1 tonnes ha^{-1} (Mukhtar *et al*., 2010; Ahmed *et al*., 2014).

Soils, once fertile, have now become deficient in the plant available nutrients, due to regular mining by the crops. Micronutrients, though required in small quantities, are essential and their deficiencies cause losses in terms of yield and quality of the fruit orchards. Calcareous soils, having high pH, influence the availability of Cu to plants negatively, as the complexation and adsorption of Cu are higher under alkaline conditions. Deficiency of Cu is more pronounced in alkaline soils compared to acidic. Optimum pH for the availability of Mn ranges from 6 to 6.8 and the deficiency is more likely to occur at alkaline pH (Lucas and Knezek, 1972).

Boron is being considered essential for transporting sugars through membranes as it tends to make complexes with 6-phosphogluconate de-hydrogenase, thereby avoiding vitamin accumulation of compounds, which occur in case of B deficiency. Vitamin B also plays an important role in the root growth. Cu containing proteins, like cytochrome oxidase, has essential metabolic role in plants. Manganese activates a number of enzymes, like, pyruvate carboxylase, and plays a role in the production of lignin, flavonoids, fatty acids, indole acetic acid and other pathways. It is also a component of enzymes arginase and phosphotransferase and

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helps in nucleic acid synthesis, cell wall formation and tissue development (Price *et al*., 1972; Peryea and Drakes, 1991). Copper deficiency results in the development of gum pockets under the bark and fruit split open and drop before maturity. Mn deficiency leads to yellowing and necrosis (Chaudhry, 1994). Similarly, toxicities of micronutrients also hamper plant growth by producing leaf symptoms, like interveinal chlorosis, which leads to necrosis when toxicity is increased. Mn toxicity causes chlorosis of older leaves and crinkled young leaves. So, the knowhow of micronutrient status is not only necessary for managing the yield losses, due to deficiency but also due to toxicity (Reichman, 2002). Usually, deficiencies of nutrient occur in the soil without a specific pattern, because of various physical, chemical and biological properties acting simultaneously in the soil, thereby making it dynamic. Such variation in the soil of a particular area or locality is termed as spatial variability. Though, prediction can be made through various soil characteristics but the recommendations, on the basis of the climatic and soil data of a whole area, are not a perfect solution of the problems or the benefits cannot be obtained through such recommendations (Moral *et al*., 2011). GIS (Geographical Information System) involving GPS (Global Positioning System) computer data base is the only way to combat or manage the spatial variability. Maps prepared through GIS are digital and encumbered with information: which make them suitable for the efficient nutrient management in the soils of particular area. These maps also help the future scientists to conduct research in the identified sites (Memon *et al*., 2011). Present research work was carried out in the apple growing region of Rawalpindi district (Fig. 1). This study aimed to identify the status of micronutrients Cu, Mn and B and to determine their relationship with selected physico-chemical characteristics at various locations in apple growing area. Digital maps using GIS and GPS technology were prepared to consolidate the information in maps, so that the site specific nutrient status will be available to the future scientists.

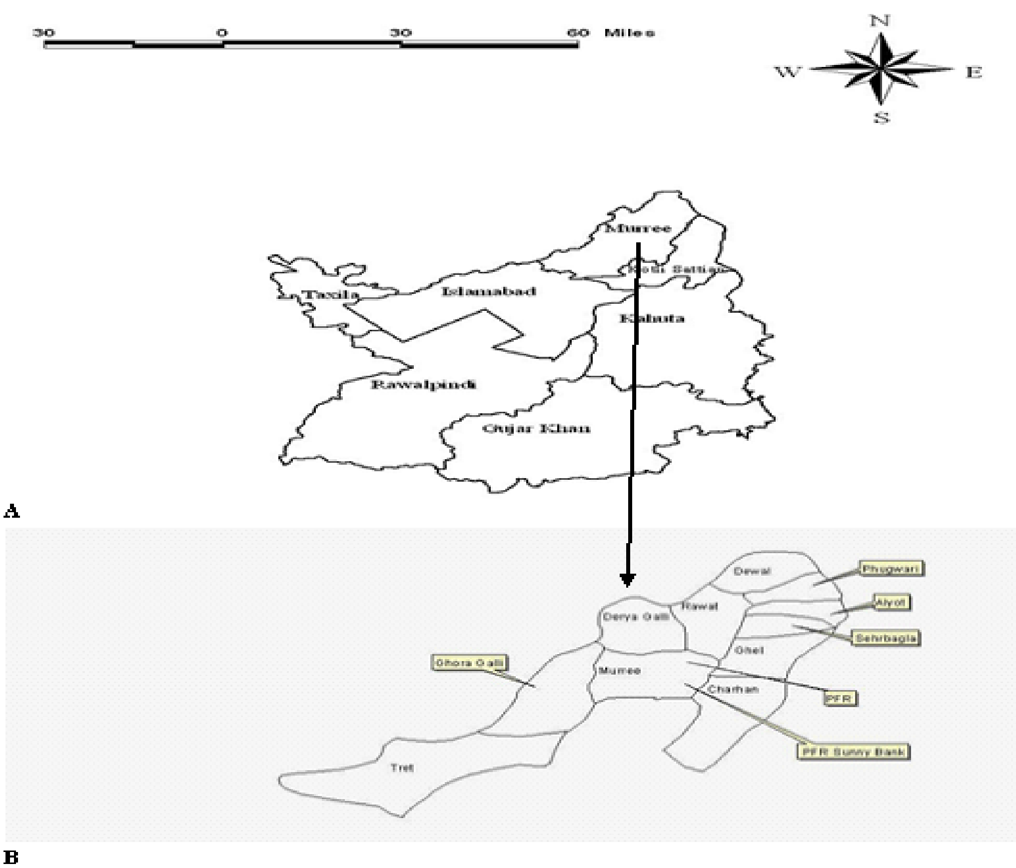

Fig. 1. Maps indicating the Geo- graphical location Rawalpindi District (A) and Surveyed Area (B).

MATERIALS AND METHODS

Sampling, processing and mapping: One hundred and thirty soil samples were collected from thirteen apple orchards, selecting one apple orchard from each apple producing Union Council and one orchard each from the Hill Fruit Research Sub Station, Lower Topa and Hill Fruit Research Station, Sunny Bank. Diagnostic plant samples, i.e., recently matured leaves in the months of July and August, were collected from five trees in an orchard. Samples were collected around the canopy and dried, using hot air oven, and processed for analysis. Soil samples were collected from the surface (0-15 cm) and sub-surface (15-30 cm) under the canopy of each apple tree. Samples were air dried, ground with wooden mortar and pestle, and passed through 2 mm sieve. Coordinates were noted, using GPS, for site identification and were downloaded to GIS software. Maps were prepared, using Arc View GIS software that can be used by scientific community, interested to conduct the research in the identified area (Fig. 1). The data regarding the micronutrient status was incorporated in the digital maps (Figs. 2-4).

Soil and plant analyses: The soils were analyzed for texture (Gee and Bauder, 1986), pH (McLean, 1982), $CaCO_3$ contents (Loeppert *et al*., 1984), electrical conductivity (McLean, 1982), organic matter (Nelson and Sommers, 1984), AB-DTPA extractable Cu and Mn (Soltanpour and Workman, 1979) and dilute HCl extractable B (Ponnamperuma *et al*., 1981). Foliage samples were analyzed for micronutrients (Cu, Mn and B), following dry ashing procedure (Chapman and Pratt, 1961). Subsequent determination of B was done by colorometry technique, using azomethine (Bingham, 1982). Critical values described by Soltanpour (1985); Johnson and Fixen (1990) were used to classify the soil into low, medium and high in plant available micronutrient contents. Foliage samples were classified, according to criteria suggested by Neubert *et al*. (1970).

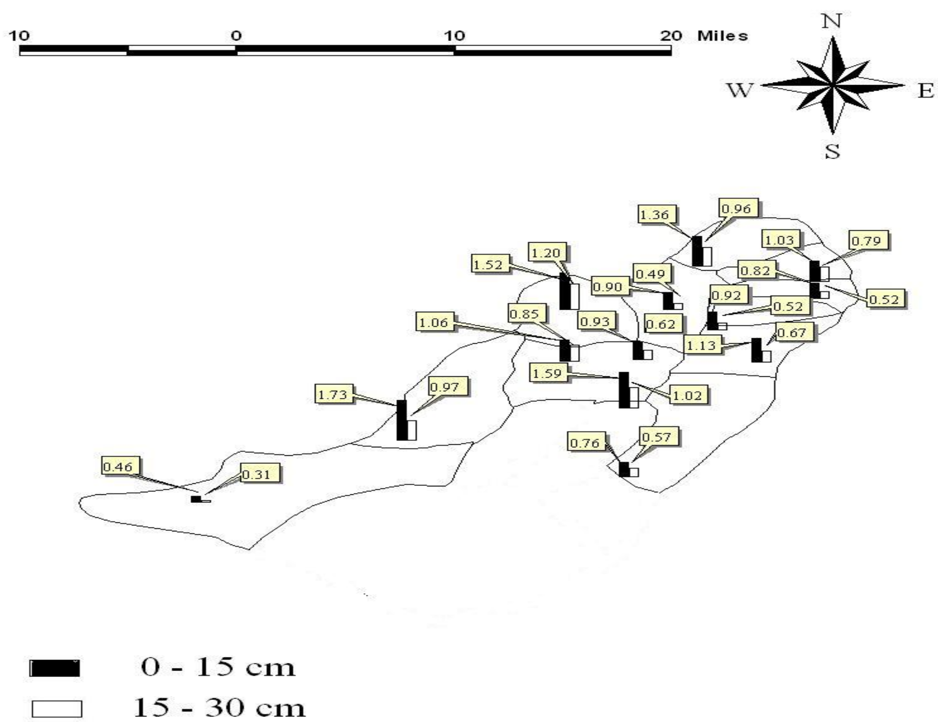

Fig. 2: Site specific distribution of Cu (µg g^{-1}) in the surface and sub-surface soils of the surveyed apple orchards.

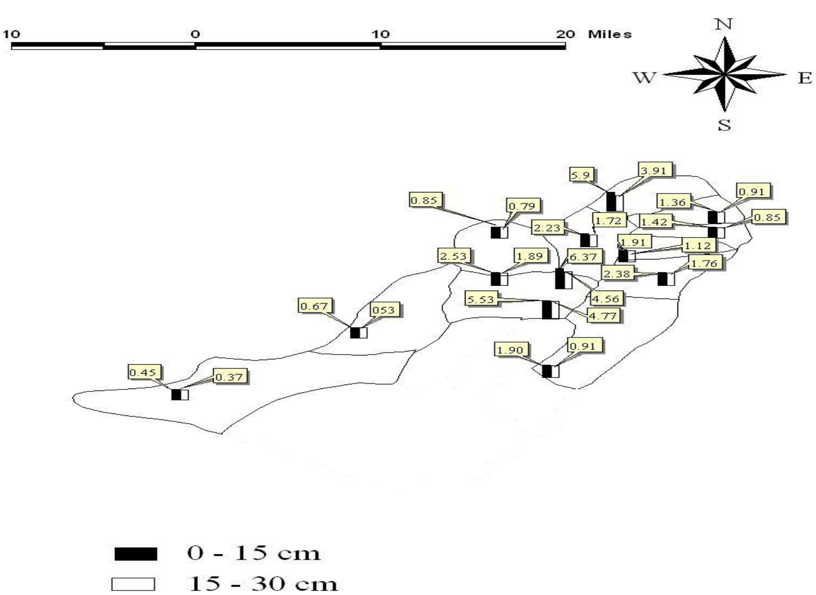

Fig 3: Site specific distribution of Mn (µg g^{-1}) in surface and sub-surface soil of surveyed apple orchards.

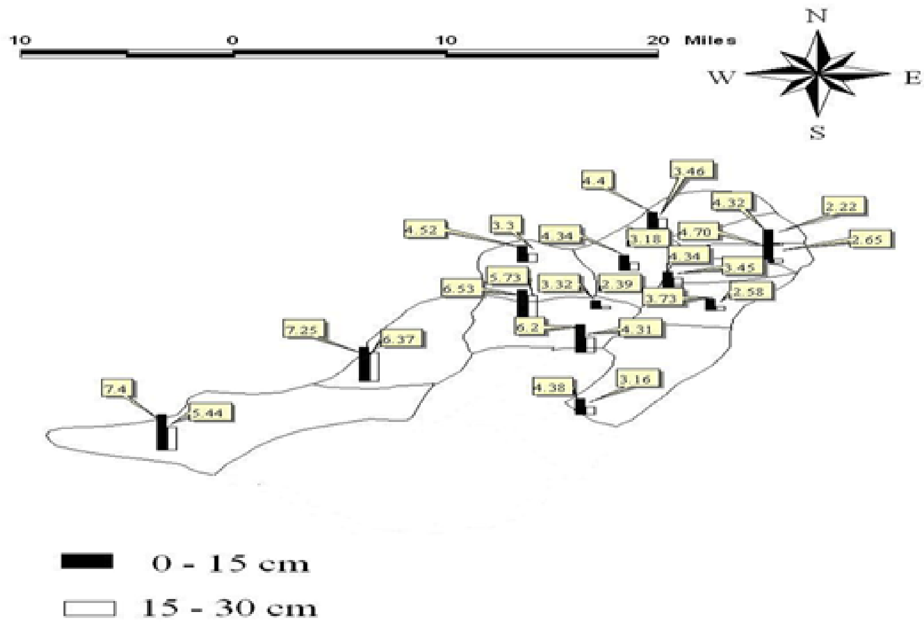

Fig. 4: Site specific distribution of B (µg g^{-1}) in the surface and sub-surface soil of surveyed apple orchards.

RESULTS AND DISCUSSION

Information related to physico-chemical properties (ECe, $CaCO_3$, pH and texture) is presented in Table 1. The soil texture of surveyed area ranged from sandy clay loam to clay loam. Clay loam was dominant texture distributed over 47% of surveyed area, followed by sandy clay loam that was distributed over 23% of the surveyed area. Clay and loam soil texture constituted 30 and 15%, respectively. Soils located in the union councils, i.e., Charhan, Murree, Ghel, Ghora Galli and Hill Fruit Research Station Sunny Bank, had clay loam texture. Soils of Dewal and Sehrbagla were loamy in texture, whereas, soil texture of union councils, Derya Galli and Phugwari, was sandy clay loam. Soils were free from salinity hazard and electrical conductivity, ranging from 0.15 to 1.8 dSm^{-1}. Soil pH ranging from 7.61 to 8.42, indicated that the soils of apple orchards were slightly alkaline to strongly alkaline. This increasing trend of high pH is the indicator for micronutrient deficiency, due to their low solubility at alkaline pH. Organic matter contents ranged from 0.93 to 2.5%. Soils of orchards ranged from non calcareous to strongly calcareous. Orchards, located in the Union Council Murree, Dewal, Hill Fruit Research Station, Sunny Bank, Hill Fruit Research Station, Lower Topa, Sehrbagla, Rawat and Phugwari, were found moderately calcareous.

Table 1: Physico- Chemical characteristics in the soils of surveyed apple orchards.

Sites	Textural class	Soil pH	Lime contents (%)	Degree of calcareousness	Organic matter (%)
Derya Galli	Sandy clay loam	7.61	18.0	Strongly calcareous	1.41
Murree	Clay loam	7.28	13.0	Moderately calcareous	3.0
Ghel	Clay loam	7.49	15.94	Strongly calcareous	3.33
Alyot	Clay	8.2	18.7	Strongly calcareous	1.24
Ghora Galli	Clay loam	7.93	0.43	Non calcareous	2.6
*Sunny Bank	Clay loam	7.68	3.93	Moderately calcareous	2.8
**PFR	Sandy clay loam	7.93	6.0	Moderately calcareous	3.74
Charhan	Clay loam	7.79	23.74	Strongly calcareous	1.08
Dewal	Loam	7.80	1.4	Slightly calcareous	1.79
Sehrbagla	Sandy clay loam	7.89	1.0	Slightly calcareous	2.0
Rawat	Clay	8.29	7.0	Moderately calcareous	1.71
Tret	Loam	8.42	17.0	Strongly calcareous	3.38
Phugwari	Clay loam	8.35	14.0	Moderately calcareous	1.64

Sample Size: 130
*Hill Fruit Research Station, Sunny Bank
**Hill Fruit Research Station, Lower Topa

Copper, manganese and boron contents in the soils of surveyed apple orchards: The concentration of Cu in the surface soils ranged from 0.40 to 1.84 µg g^{-1} of soil with a mean value of 1.10 ± 0.36. In the sub surface soil, it ranged from 0.27 to 1.29 µg g^{-1} of soil with the mean value of 0.73 ± 0.25 (Fig. 6). In the upper soils, Mn ranged from 0.41 to 6.78 µg g^{-1} of soil with a mean value of 2.56 ± 1.97. In lower soil, it ranged from 0.34 to 5.39 µg g^{-1} of soil with mean value of 1.91 ± 1.51 (Fig. 8). The concentration of B in the surface soil ranged from 3.24 to 8.16 µg g^{-1} of soil with a mean value of 4.99 ± 1.33. In the sub surface soils, it ranged from 2.1 to 6.49 µg g^{-1} soil with a mean value of 3.69 ± 1.32 (Fig. 10).

A comparison of the deficiency, adequacy and toxic values of micronutrient concentration in soil, shows that (established by Soltanpour, 1985) all apple orchards had adequate concentration of Cu (> 0.5 µg g^{-1} of soil), except one orchard, having marginal Cu contents in the surface soils and three orchard had marginal Cu contents in the sub surface soils (Table 2). Ten apple orchards were classified adequate (>1.0 µg g^{-1} of soil), two orchards were marginal (0.6-1.0 µg g^{-1} of soil) and one orchard was deficient (<0.6 µg g^{-1} of soil), in case on Mn in the surface soils. In the lower depth, 8 apple orchards were adequate (>1.0 µg g^{-1} of soil), 4 orchards were marginal (0.6-1.0 µg g^{-1} of soil) and one orchard was found deficient (< 0.6 µg g^{-1} of soil), at lower depth. Surface and subsurface soils were adequate (>1.0 µg g^{-1} of soil) in plant available B in all orchards.

Table 2: Guideline criteria for the classification of bio-available micronutrients.

Micronutrient	Low	Marginal	Adequate
Cu	< 0.2	0.2 – 0.5	> 0.5
Mn	< 0.5	0.5 – 1.0	>1.0
B[1]	<0.45	0.45 – 1.0	>1.0

(Soltanpour, 1985; [1]Johnson and Fixen, 1990).

Cu, Mn and B contents in the foliage of surveyed apple orchards: Foliage Cu content in the entire apple orchard ranged from 1-20 µg g^{-1} with the mean value of 5.41 ± 4.97. When compared with the critical values, summarized in Table 3, the apple orchards, located in the Union Councils Charhan, Murree, Alyot, Dewal, Sehrbagla, Tret, Phugwari and Hill Fruit Research Station, Sunny Bank, were found low in the Cu content (<5 µg g^{-1}). Orchards, located in the Union Councils Derya Galli, Ghora Galli, Rawat, Ghel and Hill Fruit Research Stations, were sufficient in Cu content (Figs. 5-6). Foliage Mn content (Fig. 7) varied greatly among the orchards with the minimum value of 7.25 and maximum value of 42.9 µg g^{-1} and with the mean value of 25.7 ± 10.6. Apple orchards, located in the Union Councils, Derya Galli, Ghel, Alyot, Ghora Galli and Tret, were low (<20 µg g^{-1}).

Table 3: Guideline criteria for the classification of plant micronutrients.

Micronutrient	Deficient	Sufficient	Toxic
Cu	< 4	5 – 20	> 20
Mn	< 20	20 – 500	>500
B	<15	15 – 100	>200

(Neubert *et al*., 1970)

Apple orchards, located in the Union Councils Ghora Galli and Ghel, were low in the foliage B content, whereas, orchards, located in the Union Councils, Dewal, Murree, Charhan, Rawat, Phugwari, Sehrbagla, Hill Fruit Research Station, Sunny Bank, and Hill Fruit Research Station, Lower Topa, contained sufficient (20-500 µg g^{-1}) in B content (Fig.9).

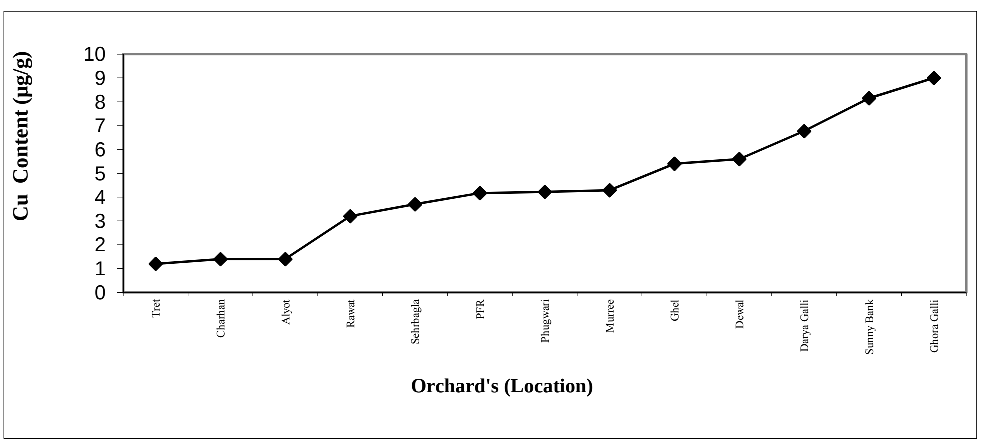

Fig. 5: Foliage Cu content (µg g^{-1}) in the surveyed apple orchards.

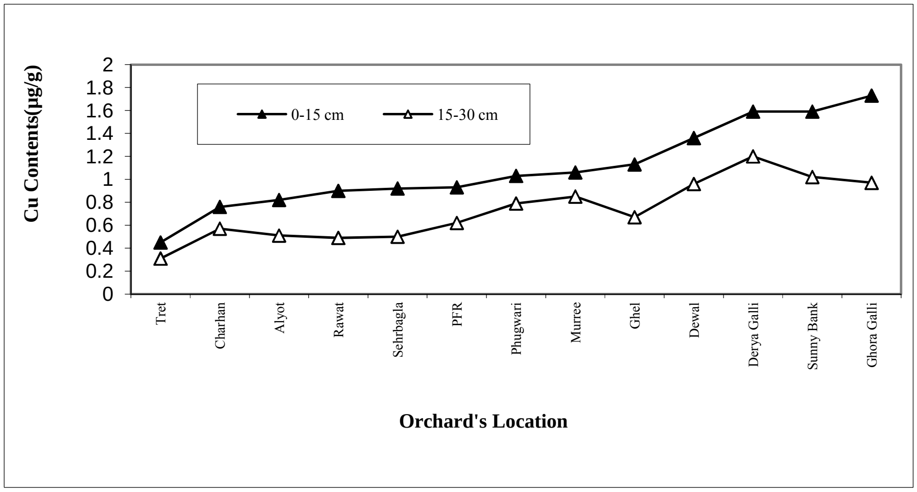

Fig. 6: Cu content (µg g^{-1}) in the soil of surveyed apple orchards.

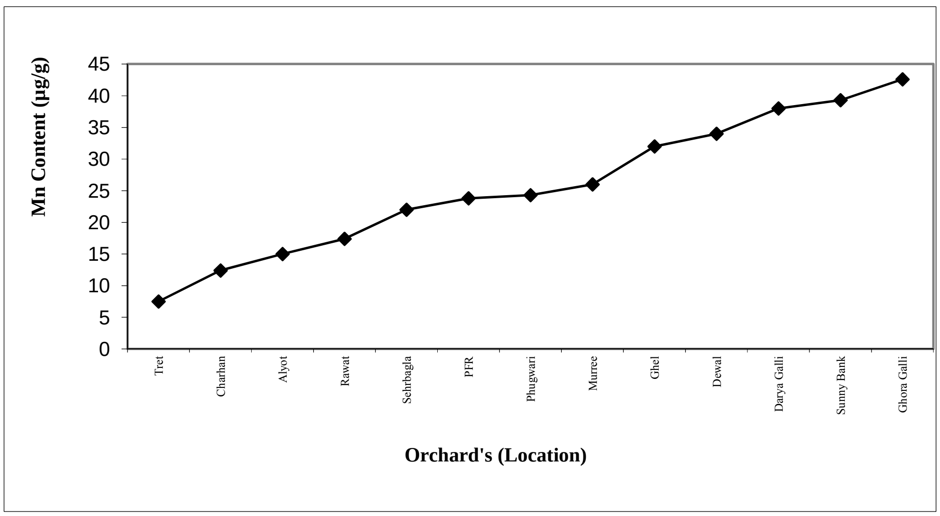

Fig. 7: Foliage Mn content (µg g^{-1}) in the surveyed apple orchards.

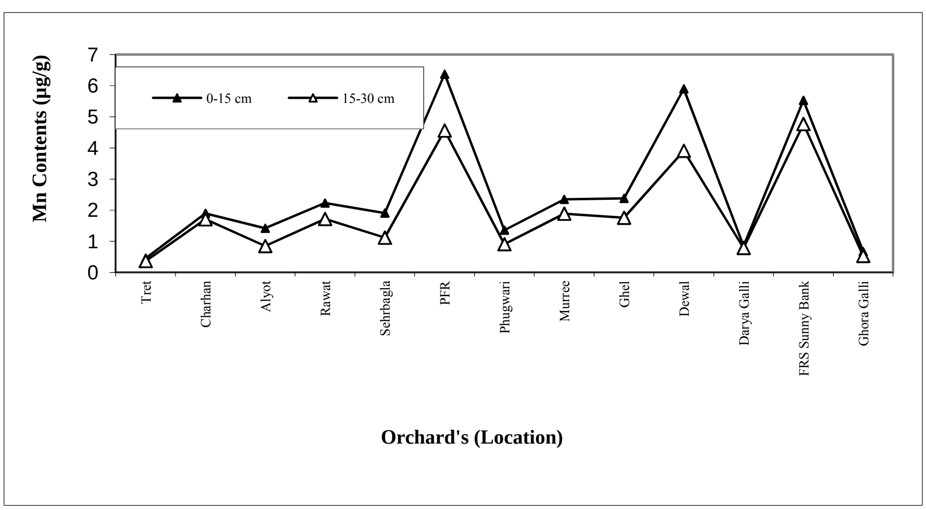

Fig. 8: Mn content (µg g^{-1}) in the soil of surveyed apple orchards.

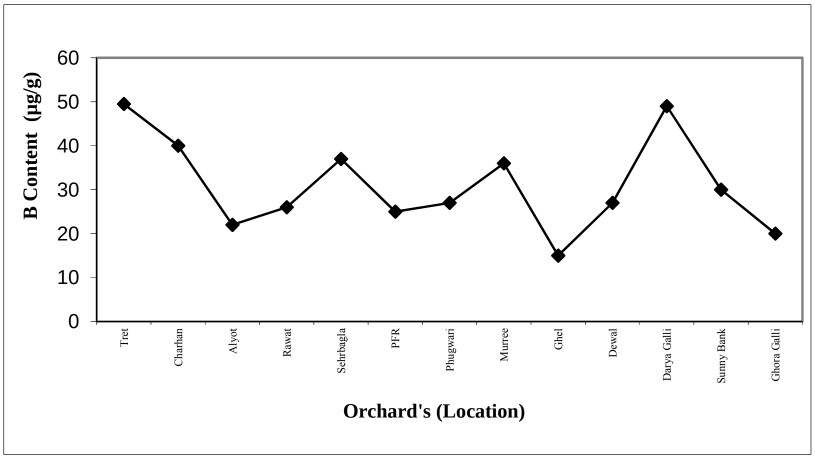

Fig. 9: Foliage B content ($\mu g\ g^{-1}$) in the surveyed apple orchards.

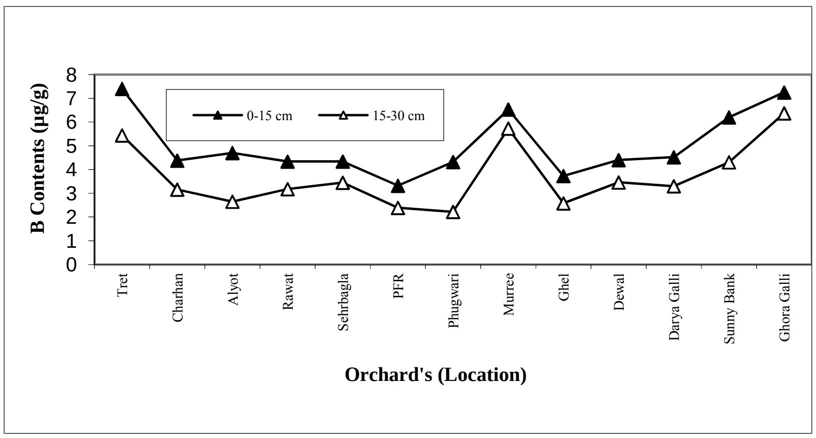

Fig. 10. B content ($\mu g\ g^{-1}$) in the soil of surveyed apple orchards.

Relationship between AB-DTPA extractable Cu and physico-chemical properties: Correlation coefficient values indicating relationship between the bioavailable micronutrients and physico-chemical characteristics are given in Table 4. A significant positive correlation was found between the organic matter and Cu content in all apple orchards. Correlation coefficient values obtained were Derya Galli ($r = 0.63$ $P \leq 0.05$), Murree ($r = 0.92$ $P \leq 0.01$), Ghel ($r = 0.90$ $P \leq 0.01$), Alyot ($r = 0.95$ $P \leq 0.01$), Ghora Galli ($r = 0.77$ $P \leq 0.01$), Hill Fruit Research Station, Sunny Bank ($r = 0.78$ $P \leq 0.01$), Hill Fruit Research Station, Lower Topa ($r = 0.92$ $P \leq 0.01$), Sehrbagla ($r = 0.94$ $P \leq 0.01$), Rawat ($r = 0.92$ $P \leq 0.01$), Tret ($r = 0.82$ $P \leq 0.01$), Phugwari ($r = 0.89$ $P \leq 0.01$), Charhan ($r = 0.80$ $P \leq 0.01$) and Dewal ($r = 0.55$ $P \leq 0.05$). This might be due to the reason that organic matter has high cation exchange capacity and chelating agents that hold nutrient and inhibits the Cu leaching. The results were supported by Khalifa *et al.* (1996) and Rajakumar *et al.* (1996), who also reported a positive correlation between Cu and organic matter. A non-significant negative correlation was established between the soil pH and plant available Cu in the soils of apple orchards, located at Derya Galli ($r = -0.08$), Murree ($r = -0.13$), Alyot ($r = -0.25$), Hill Fruit Research Station, Sunny Bank ($r = -0.18$), Hill Fruit Research Station, Lower Topa ($r = -0.13$), Sehrbagla ($r = -0.17$), Rawat ($r = -0.34$), Tret ($r = -0.46$), Phugwari ($r = -0.16$) and Charhan ($r = -0.082$); whereas, a significant negative correlation was established in the soils of Ghel ($r = -0.74$ $P \leq 0.01$), Ghora Galli ($r = -0.61$ $P \leq 0.05$) and Dewal ($r = -0.65$ $P \leq 0.05$). Significant negative correlation between $CaCO_3$ and Cu was a common phenomenon in the soils of Murree ($r = -0.93$ $P \leq 0.01$), Ghel ($r = -0.92$ $P \leq 0.01$), Alyot ($r = -0.53$ $P \leq 0.05$), Ghora Galli ($r = -0.78$ $P \leq 0.01$), Sehrbagla ($r = -0.90$ $P \leq 0.01$), Rawat ($r = -0.67$ $P \leq 0.05$), Tret ($r = -0.68$ $P \leq 0.05$), Phugwari ($r = -0.63$ $P \leq 0.05$) and Dewal ($r = -0.83$ $P \leq 0.01$). Non- significant correlation was established between available Cu and $CaCO_3$ in the soils of Derya Galli ($r = -0.023$), Hill Fruit Research Station, Sunny Bank ($r = -0.40$), Hill Fruit Research Station, Lower Topa ($r = -0.23$) and Charhan ($r = -0.46$).

Table 4: Correlation coefficient values of extractable micronutrients with various physico-chemical properties.

Orchard's Sites	Nutrients	Sand	Silt	Clay	pH	$CaCO_3$	Organic Matter
	---------- r-values ----------						
Derya Galli	Cu	-0.290	0.190	0.320	-0.080	-0.023	0.630
	Mn	-0.270	0.460	-0.940	-0.460	-0.360	0.200
	B	-0.367	0.380	0.157	-	-0.127	0.690
Murree	Cu	-0.070	0.030	0.058	-0.130	-0.930	0.920
	Mn	-0.180	0.260	-0.159	-0.095	-0.890	0.890
	B	-0.147	0.037	0.259	-	-0.930	0.880
Ghel	Cu	-0.036	0.250	0.790	-0.740	-0.920	0.900
	Mn	-0.091	0.800	0.594	-0.570	-0.920	0.950
	B	-0.042	0.480	0.530	-	-0.850	0.910
Alyot	Cu	-0.570	0.037	0.150	-0.250	0.530	0.950
	Mn	0.345	0.098	-0.193	-0.280	-0.440	0.860
	B	-0.514	0.062	0.124	-	-0.480	0.950
Ghora Galli	Cu	-0.840	0.460	0.760	-0.610	-0.780	0.770
	Mn	-0.600	0.840	-0.013	-0.720	-0.510	0.730
	B	-0.880	0.560	0.540	-	-0.790	0.730
Sunny Bank[1]	Cu	-0.700	0.500	0.210	-0.180	-0.400	0.780
	Mn	-0.421	0.630	-0.200	-0.150	-0.023	0.370
	B	-0.820	0.680	-0.073	-0.310	-0.500	0.830
PFR [2]	Cu	-0.850	0.110	0.750	-0.640	-0.230	0.920
	Mn	-0.800	0.550	0.106	-	-0.310	0.800
	B	-0.800	0.280	0.076	-	-0.440	0.930
Charhan	Cu	-0.580	0.580	0.750	-0.082	0	0.800
	Mn	-0.320	0.430	0.158	-0.095	-0.840	0.550
	B	-0.352	0.630	0.860	-	-0.580	0.890
Dewal	Cu	-0.830	0.570	0.300	-0.650	-0.830	0.550
	Mn	-0.360	0.286	0.017	-0.520	-0.650	0.530
	B	-0.760	0.470	0.265	-	-0.820	0.580
Sehrbagla	Cu	-0.023	0.013	0.039	-0.170	-0.900	0.940
	Mn	-0.023	0.098	-0.067	-0.182	-0.910	0.960
	B	-0.096	0.020	0.037	-	-0.790	0.840
Rawat	Cu	-0.920	0.030	0.490	-0.340	-0.670	0.920
	Mn	-0.510	0.240	0.082	-0.176	-0.044	0.470
	B	-0.800	0.010	0.296	-	-0.460	0.910
Tret	Cu	-0.770	0	0.270	-0.460	-0.680	0.820
	Mn	-0.650	0.027	0.023	-0.030	-0.660	0.850
	B	-0.900	0.370	0.076	-	-0.800	0.920
Phugwari	Cu	-0.750	0.78	0.150	0.160	-0.630	0.890
	Mn	-0.360	0.79	-0.099	-0.480	-0.027	0.440
	B	-0.840	0.747	0.228	-	-0.640	0.850

Sample Size: 130

1. Hill Fruit Research Station, Sunny Bank
2. Hill Fruit Research Station, Lower Topa

Sand and Cu contents were also correlated negatively. This relationship was significant at the following sites, Alyot ($r = -0.57$ $P \leq 0.05$), Ghora Galli ($r = -0.84$ $P \leq 0.01$), Hill Fruit Research Station, Sunny Bank ($r = -0.71$ $P \leq 0.01$), Hill Fruit Research Station, Lower Topa ($r = -0.85$ $P \leq 0.01$), Rawat ($r = -0.92$ $P \leq 0.01$), Tret ($r = -0.77$ $P \leq 0.01$), Phugwari ($r = -0.75$ $P \leq 0.01$), Charhan ($r = -0.58$ $P \leq 0.05$) and Dewal ($r = -0.83$ $P \leq 0.01$).

A non-significant relationship was found at the sites of Derya Galli ($r = -0.29$), Murree ($r = -0.07$), Ghel ($r = -0.036$), Sehrbagla ($r = -0.023$). Cu deficiency increases with the increase in pH because of diminished solubility and increased sorption on soil colloids. Cu deficiency is more common in alkaline soils. Most of the soils were alkaline and calcareous in nature so negative correlation of Cu with pH and $CaCO_3$ was inevitable. These results were supported by Khattak (1994) and Nazif *et al*. (2006).

At all sites, positive correlation, between silt and Cu, was found and correlation coefficient values, calculated at various locations, were Derya Galli ($r = 0.19$), Murree ($r = 0.030$), Ghel ($r = 0.037$), Alyot ($r = 0.014$), Ghora Galli ($r = 0.78$ $P \leq 0.01$), Hill Fruit Research Station, Sunny Bank ($r = 0.58$ $P \leq 0.05$), Hill Fruit Research Station, Lower Topa ($r = 0.25$), Sehrbagla ($r = 0$), Rawat ($r = 0.46$), Tret ($r = 0.50$ $P \leq 0.05$), Phugwari ($r = 0.11$), Charhan ($r = 0.03$) and Dewal ($r = 0.57$ $P \leq 0.05$).

Similarly, correlation coefficient, calculated for clay and Cu, was found positive for all sites, which were Derya Galli (r = 0.32), Murree (r = 0.058), Ghel (r = 0.15), Alyot (r = 0.039), Ghora Galli (r = 0.15), Hill Fruit Research Station, Sunny Bank (r = 0.75 P≤ 0.01), Hill Fruit Research Station, Lower Topa (r = 0.79), Sehrbagla (r = 0.27), Rawat (r = 0.76 P ≤ 0.01), Tret (r = 0.21), Phugwari (r = 0.75 P ≤ 0.01), Charhan (r = 0.49) and Dewal (r = 0.38). As clay content have higher CEC and micronutrients occur in silicate clays, So, Cu content had positive correlation with silt and clay. Similar results were reported by Sharma *et al*. (1996), Perveen *et al*. (1993) and Nazif *et al*. (2006).

Relationship between AB-DTPA extractable Mn and physico-chemical properties: The correlation between Mn and organic matter was found positive in all soils with correlation coefficient values for Derya Galli (r = 0.20), Murree (r = 0.89 P ≤ 0.01), Ghel (r = 0.95 P ≤ 0.01), Alyot (r = 0.86 P ≤ 0.01), Ghora Galli (r = 0.73 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = 0.37), Hill Fruit Research Station, Lower Topa (r = 0.80 P≤ 0.01), Sehrbagla (r = 0.96 P≤ 0.01), Rawat (r = 0.47), Tret (r = 0.85 P ≤ 0.01), Phugwari (r = 0.44), Charhan (r = 0.55 P ≤ 0.05) and Dewal (r = 0.53 P ≤ 0.05). Similar results were found by Khattak (1994) and Chinchmalatpure *et al.* (2000).

The correlation value between Mn and soil pH was negative and the correlation coefficient values at the sites, like Derya Galli (r = -0.46), Murree (r = -0.095), Ghel (r = -0.57 P ≤ 0.05), Alyot (r = -0.28), Ghora Galli (r = - 0.72 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = -0.15), Hill Fruit Research Station, Lower Topa (r = -0.64 P ≤ 0.05), Sehrbagla (r = -0.182), Rawat (r = -0.176), Tret (r = -0.03), Phugwari (r = -0.48), Charhan (r = -0.095) and Dewal (r = -0.52 P ≤ 0.05). Correlation values showed that as pH increases the availability of Mn decreases. These results were in agreement with Chattopadhyay *et al.* (1996) and Patiram *et al.* (2000).

The correlation between Mn and $CaCO_3$ content was found negative, in all orchard soils under the study. Correlation coefficient values were as Derya Galli (r = -0.36), Murree (r = -0.89 P ≤ 0.01), Ghel (r = -0.92 P ≤ 0.01), Alyot (r = -0.44), Ghora Galli (r = -0.51 P ≤ 0.05), Hill Fruit Research Station, Sunny Bank (r = -0.023), Hill Fruit Research Station, Lower Topa (r = -0.31), Sehrbagla (r = -0.91 P ≤ 0.01), Rawat (r = -0.044), Tret (r = -0.66 P ≤ 0.05), Phugwari r = -0.027), Charhan (r = -0.84 P ≤ 0.01) and Dewal (r = -0.65 P ≤ 0.05). Correlation values exhibited an inverse relation between plant available Mn and $CaCO_3$ content in soils. The results were supported by the findings of Chattopadhyay *et al.* (1996) and Sudhir *et al.* (1997). The r-value analyzed between Mn and sand was negative in all soils. The correlation coefficient values were as Derya Galli (r = -0.27), Murree (r = -0.18), Ghel (r = -0.091), Alyot (r = -0.345), Ghora Galli (r = -0.60 P ≤ 0.05), Hill Fruit Research Station, Sunny Bank (r = -0.421), Hill Fruit Research Station, Lower Topa (r = -0.80 P ≤ 0.01), Sehrbagla (r = -0.023), Rawat (r = -0.51 P ≤ 0.05), Tret (r = -0.65 P ≤ 0.05), Phugwari (r = -0.36), Charhan (r = -0.032) and Dewal (r = -0.54 P ≤ 0.05). This relationship was supported by Chinchmalatpure *et al.* (2000).

The correlation between Mn and silt was positive and the r-values were for Derya Galli (r = 0.46), Murree (r = 0.26), Ghel (r = 0.098), Alyot (r = 0.098), Ghora Galli (r = 0.79 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = 0.43), Hill Fruit Research Station, Lower Topa (r = 0.80 P ≤ 0.01), Sehrbagla (r = 0. 027), Rawat (r = 0.84 P ≤ 0.01), Tret (r = 0.63 P ≤ 0.05), Phugwari (0.55 P ≤ 0.05), Charhan (r = 0.24) and Dewal (r = 0.286). These results were supported by Sharma *et al.* (1996). The correlation value between Mn and clay content was found positive in the soils of apple orchards located in Ghel (r = 0.193), Dewal (r = 0.017), Hill Fruit Research Station, Sunny Bank (r = 0.158), Hill Fruit Research Station, Lower Topa (r = 0.59 P ≤ 0.05), Phugwari (0.106), whereas negative in the soils of orchards located in Derya Galli (r = -0.94 P ≤ 0.01), Murree (r = -0.159), Charhan (r = - 0.082), Alyot (r = -0.067), Sehrbagla (r = 0. 0233), Rawat (r = -0.0134), Tret (r = -0.20) and Ghora Galli (r = -0.099). These results were supported by Nazif *et al.* (2006), who studied the correlation of available micronutrients and physico-chemical properties of thirty different sites and found negative correlation between Mn and clay, whereas a positive correlation between Mn and clay was supported by Sharma *et al.* (1996) and Chinchmalatpure *et al.* (2000), who found a positive correlation between clay and available Mn. As most of Mn, containing minerals, usually, occurs in the form of coating of other minerals, in the form of nodules and concretions and are very reactive that may be a possible reason for the negative correlation of Mn and clay.

Relationship between AB-DTPA extractable B and physico-chemical properties: A positive correlation between organic matter and available B indicated that a soil, having more organic matter, will have more available B and vice versa. In all soils**,** the correlation between the soil and organic matter was positive. Similar results were found by Perveen *et al*. (1993) and Goldberg *et al*. (2002), who reported a positive significant correlation between Boron and organic matter content. The correlation coefficient values for soils were as Derya Galli (r = 0.69 P ≤ 0.01), Murree (r = 0.88 P ≤ 0.01), Ghel (r = 0.91 P ≤ 0.01), Alyot (r = 0.95 P ≤ 0.01), Ghora Galli (r = 0.73 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = 0.83 P ≤ 0.01), Hill Fruit Research Station, Lower Topa (r = 0.93 P ≤ 0.01), Sehrbagla (r = 0. 84 P ≤ 0.01), Rawat (r = 0.91 P ≤ 0.01), Tret (r = 0.92 P ≤ 0.01), Phugwari (r = 0.85 P ≤ 0.01), Charhan (r = 0.89 P ≤ 0.01) and Dewal (r = 0.58 P ≤ 0.05). Correlation value, calculated between B and $CaCO_3$ content, was found negative. Sudhir *et al*. (1997) also reported negative correlation between B and $CaCo_3$ content. Correlation coefficient values were as Derya Galli (r = -0.127), Murree (r = -0.93 P ≤ 0.01), Ghel (r = -0.85 P ≤ 0.01), Alyot (r = -0.48), Ghora Galli (r = - 0.79 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = -0.50 P ≤ 0.05), Hill Fruit Research Station, Lower Topa (r = -0.44), Sehrbagla (r =-0.79 P≤0.01), Rawat (r =-0.49), Tret (r = -0.80 P≤ 0.01), Phugwari (r = -0.64 P≤ 0.05), Charhan (r = -0.58 P ≤ 0.05) and Dewal (r = -0.82 P ≤ 0.01). The r-value, obtained between B and sand, was also negative, Derya Galli (r = -0.367), Murree (r = -0.147), Ghel (r = -0.0423), Alyot (r = -0.514 P ≤ 0.05), Ghora Galli (r = -0.88 P ≤ 0.01), Hill Fruit Research Station, Sunny Bank (r = -0.82 P ≤ 0.01), Hill Fruit Research Station, Lower Topa (r = -0.80 P≤ 0.01), Sehrbagla (r = -0.096), Rawat (r = -0.80 P≤ 0.01), Tret (r = -0.90 P ≤ 0.01), Phugwari (r = -0.84 P≤ 0.01), Charhan (r= -0.352) and Dewal (r = -0.76 P≤ 0.01).

The correlation coefficient between B and silt was positive, Derya Galli (r = 0.386), Murree (r = 0.0371), Ghel (r = 0.0626), Alyot (r = 0.0203), Ghora Galli (r = 0.747), Hill Fruit Research Station, Sunny Bank (r = 0.63 P ≤ 0.05), Hill Fruit Research Station, Lower Topa (r = 0.482), Sehrbagla (r = 0.0375), Rawat (r = 0.56), Tret (r = 0.68), Phugwari (r = 0.287), Charhan (r = 0.0106) and Dewal (r = 0.472). Similar results were found by Yu and Bell (2002); they found positive correlation between B and silt content. The correlation between B and clay was positive, Derya Galli (r = 0.157), Murree (r = 0.0259), Ghel (r = 0.124), Alyot (r = 0.037), Ghora Galli (r = 0.228), Hill Fruit Research Station, Sunny Bank (r = 0.86 P ≤ 0.01), Hill Fruit Research Station, Lower Topa (r = 0.53 P ≤ 0.05), Sehrbagla (r = 0. 076), Rawat (r = 0.54 P ≤ 0.05), Tret (r = 0.073), Phugwari (r = 0.0762), Charhan (r = 0.296) and Dewal (r = 0.265). Results were in agreement with the findings of Goldberg *et al.* (2002) and Nuttall *et al*. (2003); they reported positive correlation between B and clay contents.

CONCLUSION

Foliage Cu was deficient in 61% orchards while 38% orchards were found deficient in Mn content. Micronutrient deficiency in the soil was a less common phenomenon as only 8% apple orchards were deficient in Mn content, while B and Cu were found adequate in all orchard soils. Relevant nutrients application is mandatory to overcome the deficiencies of Cu and Mn in the apple trees. The prevalence of foliage deficiency of Cu, Mn and B in orchards and the sufficiency in the soils is a researchable issue.

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