Research Article

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Micronutrients status of mango (*Mangifera indica*) orchards in Multan region, Punjab, Pakistan, and relationship with soil properties

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Abstract: Mango orchards in Pakistan are deficient in soil micronutrients. Multan is one of the prime regions for mango production in Pakistan; therefore, this study was conducted to evaluate the micronutrient status of mango orchards in the Multan region. Soil samples from four different depths (0–30, 30–60, 60–90, and 90–120 cm) and leaf samples were collected from thirteen different locations of Multan. Depth-wise variations in the micronutrient status and the levels of pH, EC, CEC, SOM, and CaCO_3 were determined. All data collected from the field and laboratory work of mango orchards under study were analyzed statistically by applying the RCBD design. It was observed that pH and EC_e of soil under study were significantly higher in upper depths when compared with lower depths whereas CaCO_3 content was contrary to pH and EC as it was observed to be higher from the lower depth of the soil. Moreover, mango leaves from the majority of locations were deficient in total micronutrients due to poorly available micronutrients status of the soil.

Thus, there is a serious need to improve the chemical properties of the soil, and the proper dose of micronutrients should be applied every season for sufficient supply throughout the growing cycle of mango in and around the Multan region.

Keywords: chemical properties, mango, micronutrients, Multan region, orchards

1 Introduction

Pakistan is one of the best mango growing countries, which exports high-quality mango fruits globally. Pakistan is ranked at fourth position in the mango production (The Daily Records 2017). The contribution of Punjab to total mango production is about 67% and Sindh about 32% (Khan et al. 2008). In Punjab, mango orchards mostly cover the soils of Multan and Bahawalpur districts, which contribute 52.4% of the mango production (Khan 2005). Multan district (Pakistan) is facing a severe deficiency of some mineral nutrients, which results in the low yield of mango fruit (Ahmad and Rashid 2003). Mainly, most of the farmers are practising intercropping in mango orchards with fodder crops, further exacerbating the nutrient supply to mango trees (Masroor et al. 2016). For improved quality and better mango growth, application of macronutrients is not sufficient (Guzman-Estrada et al. 1996). In plants, micronutrients are required for different physiological and metabolic processes, and their deficiency affects a number of processes including hindered plant growth, productivity, and quality (Berdanier and Berdanier 2015; Gurjar et al. 2015; Souri and Aslani 2018a; Souri and Bakhtiarzade 2019). In enzymatic activities, micronutrients act as a cofactor and take part in a number of oxidation–reduction reactions (Memon et al. 2012). The key role of micronutrients is in respiration and photosynthesis (Ahmed et al. 2009). Zinc plays a role in enzymatic activities and confers high sugar contents to fruits (Singh and Rajput 1977;

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Phillips 2004). Manganese (Mn) application is crucial for plant yield and relative growth, photosynthesis, and the net assimilation rate of plants (Dutta and Dhua 2002). Boron deficiency is a serious common problem (Ahmed *et al.* 2011); however, foliar application of boron fertilizers increased the quality and production of mango (Ahmad *et al.* 2018). Iron deficiency affected the yield, chlorophyll contents, fruit quality, and mineral nutrients in a number of fruit trees (Tagliavini *et al.* 2000; Souri *et al.* 2018). Chelates are the best sources for the correction of iron chlorosis (Pestana *et al.* 2003; Souri and Hatamian 2019). Copper is also an important nutrient for the proper metabolism and healthy growth of plants (Ilyas *et al.* 2015). Furthermore, deficiency of micronutrients frequently results in delay in mango maturation (Iqbal *et al.* 2012). About 60% of soils of Pakistan are deficient in zinc (Imtiaz *et al.* 2010). Soils of Punjab are deficient in micronutrients with these values: 57% Zn, 50% B, and 21% Fe (PHDEB 2005). Soil chemical properties such as pH and calcium carbonates are antagonistically correlated, and organic matter and clay contents are synergistically correlated to micronutrient availability (Niaz *et al.* 2007). These problems are being solved by adding artificial fertilizers and biofertilizers and also by employing contemporary field practices. Therefore, the current study was carried out with the aim to explore the current status of micronutrients and their correlation with soil properties in the Multan region. This study will be helpful for formulating micronutrients application for better quality and production of Mango.

2 Materials and methods

2.1 Survey

A detailed survey was conducted to collect the soil and plant samples from mango orchards in the Multan district (Table 1) for the determination of micronutrient status and concomitant effect of soil properties on the availability of these micronutrients.

2.2 Soil sampling and analysis

The soil samples were collected from the selected areas for laboratory analysis. The samples were collected from the upper surface to the lower surface at different depths such

as 0–30, 30–60, 60–90, and 90–120 cm from the selected positions of orchards. After removing impurities, the samples were ground by mortar and passed through 2 mm sieve. Finally, the samples were used for the chemical analysis of soils. Soil pH was determined using pH meter, and electrical conductivity was determined by using electrical conductivity meter (EC meter) from saturated soil paste extract. The cation exchange capacity (CEC) measurements were done by taking 5 g of the soil sample in a centrifuge tube. The soil sample was saturated with sodium acetate (1 N). Later, it was washed with ethanol thrice and subsequently extracted with ammonium acetate (1 N). After that, reading of replaced sodium in the extracted solution was determined on the Flame photometer by using the calibration curve. Then, the value of CEC was calculated by following Richards (1954) and Rhoades (1982). Organic matter of the soil was determined by the titration method (Ryan *et al.* 2001). Potassium was extracted with ammonium acetate and then determined by a flame photometer (Shi 1976). Calcium carbonates were determined by following the lime method proposed by Allison and Moodie (1965). Soil available micronutrients B, Fe, Zn, and Cu were determined by the method of Ponnampuruma *et al.* (1981) and Lindsay and Norvell (1978). The soil samples (10 g) were taken and thoroughly mixed with 20 mL of 0.005 M DTPA + 0.01 M CaCl_2 + 0.1 M triethanolamine (TEA; pH 7.0). After mixing, it was shaken for 2 h at 180 rpm. Finally, the slurry was filtered, and the concentration of micronutrients was examined by the atomic absorption spectrophotometer.

2.2.1 Leaf sampling and analysis

Leaf samples were collected from the selected mango trees. During processing, leaves were washed out with distilled water, blotted with tissue paper, and then placed under shade in the room. Impurities such as dried leaves, roots, and other plant leaves were removed. After air drying, samples were ground and sieved through a 2-mm sieve. Then, these samples were sealed in polythene bags and used for further determinations. Boron determination from plant samples was done by Gaines and Mitchell (1979). Plant leaf samples were collected and oven-dried at 60°C for 48 h. The samples were ground for micronutrient analysis. Briefly, 0.2 g of leaf sample was digested with HNO_3 and HClO_4 mixture of acids. When the mixture became clear, supernatant was collected and transferred to 50 mL volumetric flasks. The concentrations of Fe, Mn, Zn, and Cu were measured by the atomic absorption spectrophotometer.

Table 1: GPS location regarding sampling date and data of mango orchards selected for study from Multan region

Locations	GPS location	Address of mango orchard	Sampling date
Location 1	30.34115° N, 071.48867° E & 438 ± 115 ft	Lutfabad Mango Farm	26-12-2017
Location 2	30.21270° N, 071.66542° E & 352 ± 85	Tate Pur	26-12-2017
Location 3	30.09707° N, 071.34132° E & 359 ± 43	Mouza Sheer Shah Multan	26-12-2017
Location 4	30.37938° N, 071.58598° E & 390 ± 59	Hamid Per Murkha	27-12-2017
Location 5	Waqas Wains		27-12-2017
Location 6	30.17882° N, 071.69709° E & 365 ± 66	(LahliPur)	29-12-2017
Location 7	30.28762° N, 071.47364° E & 395 ± 56	Mouza Buch Khusru Abad	29-12-2017
Location 8	30.25950° N, 071.70826° E & 347 ± 82	Qadir Pur Ran	29-12-2017
Location 9	30.031653° N, 071.38169° E & 356 ± 52	Mouza Balail	31-12-2017
Location 10	30.36449° N, 071.55367° E & 385 ± 46	Basti ChahAnayat Wala	31-12-2017
Location 11	30.31212° N, 071.68275° E & 377 ± 26	Chah Fareed Wala	31-12-2017
Location 12	Farhat		02-01-2018
Location 13	30.31620° N, 071.70884° E & 385 ± 52	Rawan Police Chowki	02-01-2018

2.3 Statistical analysis

All data were analyzed statistically by applying the RCBD design. Data were analyzed statistically using the software statistics 8.1 (2005).

3 Results

3.1 Soil chemical parameters of locations

Soil samples from all the opted 13 locations were collected for chemical analysis. We observed that some of the locations depicted similar responses in case of pH. Locations L2, L4, L5, L6, L7, L9, and L11 exhibited that their pH was almost similar to each other but significantly ($p \leq 0.05$) different from L1, L3, L8, L10, L12, and L13 in the Multan district for the first 30-cm depth. Data regarding locations of L1, L8, and L12 were found ideal with soil pH more suitable for better growth of mango. Soil electrical conductivity was measured significantly as highest ($p \leq 0.05$) from L13 when compared with all other locations. There was a negative correlation between pH and sampling depth, i.e., pH decreased with an increase in the depth of sampling. The lowest pH was measured from the soil samples collected at 91–120 cm. Moreover, it was observed that EC_e at all soil depths was in the normal range ($<4 \text{ dS m}^{-1}$) (Table 2). The soil cation exchange capacity is indispensable parameters for nutrient availability in mango orchards and is an inherent quality of every soil that is difficult to alter. It was observed from our study that L6 and L11 were statistically similar to each other but

differed significantly ($p \leq 0.05$) to all other locations while L2, L3, L4, L7, L8, L10, and L12 also remained statistically similar to each other but differed from other locations at the depth of 30 cm. Lime content (CaCO_3) of all the locations was almost within the same range except for L6 and L11 (Table 2). Organic matter content of L6 and L11 was found significantly ($p \leq 0.05$) higher relative to other locations of the Multan region. However, there were also similar organic matter contents measured from L2, L3, L5, L7, L8, L10, and L12 locations. Soil organic matter at all soil depths was observed to be deficient than the normal range ($<1\%$) except L6 and L11 soil (Figure 1). Soil correlation matrix confirmed significantly ($p \leq 0.05$) negative correlation (-0.7397) for all the soil chemical parameters of soil under investigation in this study.

3.2 Mineral nutrients of the soil

Soil potassium concentration from all the locations was measured. It was observed that all locations were statistically ($p \leq 0.05$) similar regarding potassium concentration available for mango trees but the location (L4) differed significantly from the rest of the locations (Figure 2) at the depth of 30 cm. However, in the case of zinc concentration, all locations were different from each other for soil extractable zinc concentration of mango orchards. Boron concentration of locations L6, L10, L11, L12, and L13 was similar to each other and performed significantly best when compared with L5, L2, L8, L4, L3, and L1 for soil extractable boron concentration of mango orchards. The manganese content was found higher from L2 and L6 locations while copper concentration was

Table 2: Soil chemical properties of different locations of mango orchards in Multan

	pH				EC (dS m^{-1})				CEC ($\text{meq}/100 \text{ g}$)				CaCO_3 (%)			
	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm
L1	8.10 ^{c*}	8.07 ^c	8.00 ^{bc}	7.98 ^b	2.59 ^b	2.29 ^b	2.09 ^b	2.07 ^b	11.29 ^{cd}	6.84 ^d	4.58 ^{cd}	4.71 ^b	8.87 ^c	9.33 ^{bc}	9.80 ^{cd}	10.83 ^d
L2	8.63 ^a	8.50 ^a	8.40 ^a	7.87 ^{bc}	2.55 ^b	2.10 ^b	1.98 ^{bc}	1.99 ^{bc}	14.33 ^{bc}	4.45 ^e	4.00 ^d	4.65 ^b	9.33 ^b	9.57 ^b	11.40 ^a	12.50 ^{ab}
L3	8.31 ^{bc}	8.18 ^{bc}	8.08 ^b	8.01 ^{ab}	1.12 ^d	0.77 ^d	0.71 ^d	0.61 ^d	11.82 ^{cd}	8.26 ^c	5.16 ^{bc}	4.39 ^{bc}	6.67 ^f	6.97 ^f	8.53 ^d	11.63 ^c
L4	8.40 ^{ab}	8.34 ^{ab}	8.17 ^{ab}	7.95 ^b	1.92 ^c	1.55 ^c	1.40 ^c	1.40 ^c	15.17 ^b	9.87 ^{bc}	6.84 ^b	3.36 ^{de}	8.60 ^c	8.28 ^{de}	9.93 ^c	10.53 ^d
L5	8.45 ^{ab}	8.32 ^{ab}	8.22 ^{ab}	8.02 ^{ab}	1.09 ^d	0.86 ^d	0.87 ^d	0.60 ^d	9.87 ^e	3.81 ^f	4.97 ^c	4.13 ^{bcd}	7.80 ^d	9.51 ^b	9.73 ^c	11.27 ^{cd}
L6	8.56 ^a	8.43 ^{ab}	8.33 ^a	8.12 ^a	1.95 ^c	1.60 ^c	1.29 ^{cd}	1.38 ^c	24.01 ^a	10.97 ^b	8.52 ^a	4.71 ^b	8.67 ^{cd}	9.54 ^b	11.13 ^{ab}	12.33 ^b
L7	8.63 ^a	8.50 ^a	7.99 ^{bc}	7.97 ^b	2.01 ^c	1.56 ^c	1.39 ^c	1.35 ^c	13.04 ^c	3.81 ^f	5.03 ^{bc}	4.00 ^c	7.63 ^d	7.75 ^e	8.03 ^e	8.40 ^e
L8	8.11 ^c	8.00 ^a	8.00 ^{bc}	7.66 ^d	2.08 ^c	1.54 ^c	1.45 ^c	1.45 ^c	15.68 ^b	8.58 ^c	3.74 ^{de}	3.36 ^{de}	6.63 ^f	8.27 ^{de}	10.30 ^{bc}	12.60 ^{ab}
L9	8.61 ^a	8.47 ^a	8.08 ^b	7.90 ^b	1.13 ^d	0.68 ^d	0.56 ^e	0.51 ^e	9.81 ^e	7.74 ^{cd}	7.36 ^{ab}	3.61 ^d	10.27 ^a	10.33 ^a	10.77 ^b	12.23 ^{bc}
L10	8.31 ^{bc}	8.18 ^{bc}	8.15 ^{ab}	8.11 ^a	2.30 ^b	2.15 ^b	1.92 ^{bc}	1.86 ^{bc}	15.49 ^b	10.26 ^b	4.90 ^c	4.52 ^b	7.00 ^e	8.57 ^d	10.87 ^b	12.43 ^{ab}
L11	8.66 ^a	8.53 ^a	7.95 ^d	7.97 ^b	1.26 ^d	0.86 ^d	0.68 ^d	0.70 ^d	24.97 ^a	13.10 ^a	8.65 ^a	6.26 ^a	10.4 ^{ab}	10.33 ^a	11.00 ^{ab}	12.67 ^{ab}
L12	8.14 ^c	8.02 ^d	8.01 ^{bc}	7.70 ^{bc}	2.70 ^b	2.30 ^b	2.10 ^b	2.08 ^b	13.62 ^c	5.87 ^{def}	5.10 ^{bc}	2.90 ^f	7.33 ^{de}	9.03 ^c	10.93 ^b	12.40 ^{ab}
L13	8.24 ^{bc}	8.08 ^c	7.76 ^d	7.77 ^{bc}	3.17 ^a	2.72 ^a	2.53 ^a	2.56 ^a	10.33 ^d	3.36 ^f	3.94 ^d	3.16 ^e	8.43 ^{cd}	9.33 ^{bc}	10.23 ^{bc}	13.33 ^a

*Mean values of varying depths followed by different letters are significantly ($P \leq 0.05$) different in column.

much higher from L4, L10, and L11 locations. Soil iron content of the locations under observation was significantly different though L13 had the lowest concentration. Soil correlation matrix confirmed a significant negative correlation (-0.6294) of soil extractable mineral content of mango orchards at all the 13 locations at variable depths (Table 3).

3.3 Micronutrients contents in the leaf of mango

Leaf samples were collected for measuring micronutrient concentration from all the 13 locations in Multan. We observed that the zinc content in leaves L6 and L11 were statistically similar to each other but remained significantly best for vigorous fruiting of mango when compared with other locations. Keeping in mind the critical limit ($<25 \mu\text{g g}^{-1}$) of Zn in leaves, no mango plants were deficient in Zn. Similarly, manganese and copper concentrations in leaves were also significantly higher from the locations L6 and L11 when compared with the other locations. The boron critical limit is $<25 \mu\text{g g}^{-1}$; so, the L1 area of Multan mango plants was deficient in boron while for other micronutrients, iron was higher in an amount from the leaves collected from L5 and L9, and they were statistically similar to each other. Plant correlation matrix confirmed a nonsignificant positive correlation (0.2172) for leaves regarding all micronutrients concentration with spatial variability of mango orchards at all locations (Figure 3).

4 Discussion

Soil nutrients status of orchards under study were higher in upper depth (0–30 cm) when compared with lower depths (31–60, 61–90, and 91–120 cm) with a negative correlation. Moreover, Multan has an arid climate with severe summers and cold winters, somehow climatic condition favors such changes in soil solum to favor mango growth in the area under study.

Pakistani soils are generally alkaline in nature having basic soil pH more than 7 (Muhammad *et al.* 2008). The calcareousness and alkalinity of Pakistani soils are due to the parent material (Ahmad *et al.* 1977). A similar result was reported regarding the basic soil pH of mango orchards from Multan (Ahmad *et al.* 2018). The pH of the Pakistani soils is basic (Ahmed *et al.* 2009;

Figure 1: Soil organic matter status of different locations of mango orchards in the vicinity of Multan. Vertical bars represent standard error.

Figure 2: Soil potassium contents of different locations of mango orchards in the vicinity of Multan. Vertical bars represent standard error.

Ahmed et al. 2011; Chaudhry et al. 2016). Higher electrical conductivity on the upper layer might be due to the hot climate of Multan (arid and semiarid) and less rainfall. Due to low rainfall, salts remain intact and some of it infiltrates when irrigation is applied (Rhoades and Corwin 1990; Da Silva et al. 2009). Irrigation sample analysis is not a common practice that must be adopted by the farmers before irrigating their orchards. Saline-sodic water is responsible for adding salts to the upper surface of the soil than to lower depths (Murtaza et al. 2006). EC also increases with the application of chemical fertilizers and sometimes heavy dose causes more salt accumulation to the upper soil (Sarwar et al. 2008; Dehnavard et al. 2017; Ahmadi and Souri 2018). These phenomena might be the reasons for higher EC of soils of mango orchards around Multan. Furthermore, Khattak

and Hussain (2007) illustrated that a low amount of SOM in the upper layers of soils is one of the major reasons for an increase in EC_e and pH. Soil organic matter (SOM) was found less in lower depths than the critical value in our study areas, and the mean value of all mango orchards came out as 0.40 g kg^{-1} . As there is no practice of farmyard manure (FYM) application by the local farming community into mango orchards, different sources of its addition are available in Pakistan, i.e., crop residues, animal manure, rice husk, and sugar cane trash (Khan et al. 2010). It was elucidated that organic matter decomposed rapidly due to high temperature (Sierra et al. 2015). Similar findings were reported by Sarwar (2005) as a reduction in soil organic matter in soils of Pakistan is due to high temperature that causes oxidation of organic fractions in soils. The results of the

Table 3: Soil mineral contents of different locations of mango orchards in Multan

	Boron ($\mu\text{g g}^{-1}$)				Zinc ($\mu\text{g g}^{-1}$)				Manganese ($\mu\text{g g}^{-1}$)				Copper ($\mu\text{g g}^{-1}$)				Iron ($\mu\text{g g}^{-1}$)			
	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm	0–30 cm	30–60 cm	60–90 cm	90–120 cm
L1	0.75 ^c	0.71 ^c	0.62 ^d	0.48 ^f	0.62 ^f	0.58 ^d	0.49 ^f	0.45 ^d	6.19 ^e	5.53 ^b	3.06 ^c	1.18 ^g	6.40 ^h	5.51 ^{bc}	2.69 ^g	1.78 ^d	5.35 ^d	4.58 ^{ef}	4.29 ^c	3.93 ^b
L2	0.86 ^b	0.72 ^{bc}	0.68 ^c	0.59 ^d	0.74 ^{cd}	0.59 ^d	0.55 ^{cd}	0.53 ^c	7.09 ^{ab}	5.11 ^c	2.49 ^f	0.99 ^g	7.26 ^f	5.76 ^b	3.46 ^b	1.03 ⁱ	5.66 ^a	4.84 ^c	4.37 ^b	3.65 ^c
L3	0.85 ^b	0.72 ^{bc}	0.64 ^{cd}	0.57 ^e	0.72 ^d	0.59 ^d	0.51 ^e	0.44 ^d	6.28 ^d	4.51 ^c	2.26 ^g	0.81 ^h	7.63 ^d	5.33 ^c	4.05 ^a	2.10 ^b	5.54 ^b	5.02 ^a	4.47 ^a	3.92 ^b
L4	0.85 ^b	0.71 ^c	0.68 ^c	0.55 ^{ef}	0.86 ^b	0.58 ^d	0.55 ^{cd}	0.49 ^{cd}	6.59 ^{cd}	4.98 ^d	3.54 ^a	1.57 ^{cd}	8.04 ^c	4.00 ^g	3.11 ^e	1.39 ^f	5.35 ^d	4.95 ^b	4.13 ^{de}	3.56 ^d
L5	0.90 ^{ab}	0.74 ^{bc}	0.69 ^c	0.60 ^d	0.84 ^b	0.61 ^{cd}	0.56 ^c	0.51 ^c	6.17 ^e	5.29 ^c	2.82 ^d	1.87 ^{ab}	6.74 ^g	4.96 ^d	2.54 ^h	1.15 ^h	5.49 ^{bc}	4.70 ^d	4.31 ^{bc}	3.87 ^{bc}
L6	0.95 ^{ab}	0.92 ^a	0.88 ^a	0.72 ^b	0.84 ^{bc}	0.82 ^a	0.75 ^a	0.59 ^b	7.26 ^a	5.87 ^a	2.41 ^{fg}	1.72 ^b	7.39 ^{ef}	4.65 ^e	2.16 ⁱ	1.98 ^c	5.28 ^e	4.45 ^g	4.18 ^d	3.64 ^c
L7	0.91 ^{ab}	0.88 ^{ab}	0.86 ^a	0.76 ^{ab}	0.78 ^c	0.75 ^{bc}	0.73 ^a	0.63 ^{ab}	6.18 ^e	5.56 ^b	3.25 ^b	1.21 ^f	7.04 ^{fg}	6.00 ^a	3.35 ^c	1.40 ^f	5.25 ^{ef}	4.55 ^f	4.28 ^c	4.00 ^a
L8	0.80 ^{bc}	0.79 ^b	0.64 ^{cd}	0.62 ^{cd}	0.67 ^e	0.66 ^c	0.64 ^b	0.59 ^b	6.50 ^{cd}	4.77 ^e	2.38 ^{fg}	1.93 ^a	6.46 ^h	4.31 ^f	2.82 ^f	1.20 ^g	5.31 ^{de}	4.92 ^b	4.22 ^{cd}	3.63 ^c
L9	0.88 ^b	0.78 ^b	0.73 ^b	0.65 ^c	0.75 ^{cd}	0.65 ^c	0.60 ^{bc}	0.52 ^c	6.95 ^b	4.37 ^{fg}	2.13 ^h	1.63 ^c	7.44 ^e	5.39 ^c	3.25 ^{cd}	1.73 ^d	5.22 ^f	4.74 ^d	3.87 ^e	3.20 ^g
L10	1.00 ^a	0.91 ^a	0.74 ^b	0.71 ^b	0.87 ^b	0.84 ^a	0.61 ^{bc}	0.58 ^b	6.15 ^{ef}	5.47 ^{bc}	2.39 ^{fg}	0.40 ⁱ	8.45 ^b	5.23 ^{cd}	3.45 ^b	1.05 ⁱ	5.32 ^{de}	4.67 ^{de}	3.45 ^h	3.33 ^{de}
L11	0.97 ^a	0.85 ^{ab}	0.71 ^{bc}	0.63 ^c	0.94 ^a	0.79 ^b	0.58 ^c	0.50 ^c	6.61 ^{cd}	4.22 ^g	2.05 ^j	0.98 ^g	8.71 ^a	4.02 ^g	2.72 ^g	1.62 ^e	5.41 ^c	4.63 ^e	3.70 ^f	3.19 ^{fg}
L12	0.96 ^a	0.90 ^a	0.84 ^a	0.80 ^a	0.83 ^{bc}	0.85 ^a	0.71 ^{ab}	0.67 ^a	6.83 ^c	4.53 ^f	2.62 ^e	1.50 ^d	6.15 ⁱ	4.97 ^d	3.15 ^e	2.21 ^a	5.36 ^d	4.26 ⁱ	3.52 ^g	3.28 ^e
L13	0.98 ^a	0.91 ^a	0.86 ^a	0.77 ^{ab}	0.75 ^{cd}	0.78 ^b	0.73 ^a	0.64 ^{ab}	5.93 ^f	5.14 ^c	2.54 ^{ef}	1.37 ^e	6.68 ^g	6.10 ^a	2.42 ⁱ	1.14 ^h	5.18 ^{fg}	4.30 ^h	3.46 ^h	3.22 ^f

* Mean values of varying depths followed by different letters are significantly ($P \leq 0.05$) different in column.

current study also showed a positive correlation of SOM with CEC of soil. The CEC of soils was in the range of $7.8 \text{ cmol (p}^+) \text{ kg}^{-1}$. It showed an extensive variation with topography and types of soil in all 13 different mango orchards. There was also a positive correlation between CEC and clay contents of soils. The presence of higher amounts of organic matter in the soil makes strong contact with the mineral surface of the soil (Kaiser and Guggenberger 2000; Jien and Wang, 2013). Owing to this strong contact with minerals, microaggregation is facilitated that plays an imperative role in adsorption and exchange of nutrients between the solution and mineral phases of soil (Vogel et al. 2014). Lime content was observed higher in the lower depths of soil when compared with the upper layer of soils which might be due to the calcareous nature of Pakistani soils and higher application of P fertilizers in soils (Mukhtar et al. 2011). According to Shahid et al. (2009), the deposition of alluvium materials and aeolian movement are the major causes of a higher amount of CaCO_3 in soils of Pakistan. A significant enhancement in CaCO_3 was also noted by Jamal and Jamal (2018). Calcareous and alkaline nature of soils is more likely to be deficient in zinc and iron (Souri and Hatamian 2019). Therefore, soil Zn and plant Zn were recorded in small amounts in our study areas. Most soils are deficient in Zn; therefore, uptake by mango tree was also lowered. Zinc solubility is soil pH-dependent, and it declined by 100 folds for each unit pH increase (Yang et al. 2010). Low uptake of Zn by mango trees was correlated to high concentrations of HCO_3^- , which inhibit Zn translocation (Lu et al. 2012). High pH calcareous soils impede Zn availability because of its adsorption on clay (Zhao et al. 2014). The current study exhibited boron deficiency in soils of all mango orchards as well as in mango leaves. It is obvious that the low availability of B in soil ultimately caused the lower uptake of B to trees. Our findings agree with B availability decreases as the soil pH increases because B adsorption occurs onto clay and Al and Fe hydroxyl surfaces (Majidi et al. 2010). Data of the current study also showed that extractable Fe showed an antagonistic effect regarding extractable Zn. A higher concentration of extractable Zn and the lower concentration of extractable Fe were due to their antagonistic effects. Our results concurred with Rietra et al. (2017) who concluded that the antagonistic effect between Zn and Fe caused ferric-chelate reductase activity that produced such types of interactions. Similar results were also observed in the plant's samples where the better intake of Zn in plant leaves showed a significant reduction in the intake of Fe. Higher Zn concentration in maize due to deficiency of iron was also documented by Kanai et al. (2009). In our study, Cu was

Figure 3: Micronutrients concentration in leaves of mango trees from different locations of Multan District.

found in low concentration together with other micronutrients; it was observed that the availability of copper was reduced significantly with an increase in CaCO_3 and pH. The availability of copper decreasing at high CaCO_3 and high pH content is due to the development of less soluble compounds such as $\text{Cu}(\text{OH})_2$ and CuCO_3 (Singh et al. 2013). Manganese deficiency was also related to the chemical behavior of soil under investigation. It decreased due to high pH and calcareousness nature of soil as high pH favors the development of less soluble organic compounds of Mn, which reduces the availability of Mn, and high CaCO_3 causes the reduction of Mn availability by the formation of less soluble compounds such as MnCO_3 or $\text{Mn}(\text{OH})_2$; therefore, uptake would be less by plants (Peverill et al. 1999; Brennan et al. 2001).

5 Conclusion

It is concluded that micronutrient deficiency in the mango orchards of Multan can be overcome by the application of farmyard manure and practicing green manuring. The problem of micronutrient deficiency is amplified due to the less use of organic manure, high pH, and arid climate. These problems could be managed by applying farmyard manure, burying crop residues, and adopting green manuring in orchards. There is a dire need to launch a project regarding mango nutrition especially the management of micronutrients with respect to fertilizer use efficiency (FUE) in the areas of the Multan district. Such management of nutrients would enhance the production and fruit quality of mango.

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