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SURVEY OF CITRUS ORCHARDS FOR MICRONUTRIENTS DEFICIENCY IN SWAT VALLEY OF NORTH WESTERN PAKISTAN

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Abstract

Citrus (*Citrus sinenesis* L.) orchards in Swat were assessed for micronutrients (Zn, Cu, Fe, Mn, B) deficiency during 2006. Representative soil and leaf samples from 51 citrus orchards were collected and analyzed for micronutrients. The results on leaf analysis showed that Zn was deficient in 100%, Mn in 96%, B in 24% and Cu in 16% orchards. The soil analysis showed that Zn was deficient in 10-44%, Fe in 12-18%, and Mn in 4-14% orchards, whereas Cu and B were adequate in all 51 orchards. The soil pH of citrus orchards was between 7.5 and 8.5, and EC was below 4.0 dS m^{-1}. These results suggested that the deficiency of Zn and Mn in citrus orchards of Swat were wide-spread but that of B and Cu were sparse. The soil and plant tests for diagnosing micronutrient deficiencies in citrus orchards were poorly correlated. However, the surface soil (0-15 cm) and cumulative micronutrients contents of the profile (0-45 cm) were strongly positively correlated. Thus, the surface soil analysis can be used to measure pattern in micronutrients fertility of the profile using the regression equations developed in this study. Further studies are needed to determine suitable dose of micronutrients application to citrus orchards in Swat in field experiments.

Introduction

Citrus is one of the major fruit crops of Pakistan. Among citrus, kinnow mandarin is primarily adaptable and grown in Punjab (Altaf *et al*., 2009) while Sweet orange (*Citrus sinenesis* L.) in NWFP (Anon., 2006). Sweet orange of Khyber Pakhtunkhwa (formerly known NWFP) is popular for its special taste. Unfortunately, the citrus orchards in NWFP (now Khyber Pakhtunkhwa) in general and of Malakand division in particular are deteriorating gradually. In addition to citrus diseases (Iftikhar *et al*., 2009; Razi *et al*., 2011) and other factors, little attention is paid to the nutritional requirements of citrus orchards. For maintaining healthy and productive citrus orchard, a balanced nutrient supply is necessary. The farmers, however, have now realized the importance of nutrition of citrus plants and have started the use of major nutrients (N, P, K) on their farms. However, the soils are not only deficient in major nutrients (Shah *et al*., 2003) but also in micronutrients (Haq, 2002). The extent of micronutrient deficiency in citrus orchards of Malakand division is however unknown. Micronutrients are as essential as major nutrients and their deficiency greatly affect the production and quality of citrus fruit.

Evaluation of the mineral nutritional requirements of fruit trees is different from that of annual crops. Tree crops are perennial, large and deep rooted and therefore, require more exact evaluation of their nutritional needs. Nutrient deficiencies can be assessed through visual symptoms, soil test or plant analysis. Identification and quantification of nutrient deficiencies from visual symptoms is not easy and therefore either soil test or plant analysis is widely used for the same. Among the later two tests, soil analysis has been reported to be of lesser value because of the tree roots penetration to a greater depth and encounters greater variation (Shah & Shahzad, 2008). Plant tissue analysis has appealed as a more direct method and has been, and is being considered as a more reliable diagnostic tool for assessing the nutrient status of fruit trees (Ibrahim *et al*., 2004; Shah & Shahzad, 2008).

Keeping in view the importance of nutritional requirements particularly of micronutrients for sweet orange orchards, this study was conducted to assess the micronutrients status of citrus orchards in Swat valley.

Materials and Methods

Experimental site: The citrus orchards in Swat valley of Khyber Pakhtunkhwa were assessed for micronutrients (Zn, Cu, Fe, Mn, B) deficiency during 2006. For this, 51 orchards were surveyed. In each survey, representative soil and leaf samples were collected from each orchard as described below:

Collection and processing of soil and leaf samples: Soil samples from each citrus orchard were collected from three depths viz. 0-15, 15-30, and 30-45 cm during the second week of September, 2006. At the time of soil sampling, leaf samples were also collected from same orchard. For this, 120 to 150 of 5-7 month old terminal spring cycle leaves were collected randomly from about 20 trees per orchard. Leaf samples were taken from around the tree at about 5-6 ft height. The soil and leaf samples were processed following the procedure as described in Shah & Shahzad (2008).

Soil and leaf analysis: Soil samples were analyzed for extractable micronutrients (Zn, Cu, Fe, Mn, B), organic matter, pH and EC. The concentration of extractable micronutrients (Zn, Cu, Fe, Mn) in soil was determined by the AB-DTPA extraction procedure (Soltanpour & Schwab, 1977). In this method, 10 g soil sample was shaken with 20 ml AB-DTPA extract in an open Erlenmeyer flask for 15 min. After filtering, the extract was read for Zn, Cu, Fe and Mn on Atomic Absorption Spectrophotometer (Perkin Elmer Analyst-200, USA). The concentration of extractable B in soil was determined by the dilute hydrochloric acid method as described in Ryan *et al*. (2001). For this, 10.0 g air-dry soil was shaken with 20 ml of 0.05 N HCl for 5 min. After filtering, B concentration in the extract was measured by the

Azomethine-H method at 420 nm on Spectrophotometer (Lambda-35). Soil pH and EC were determined in soil-water (1:5) extract. The extract was read for pH on pH meter (InoLab pH Level 1) and EC on EC meter (DDC-308A Conductivity Meter).

The leaf samples were analyzed for total micronutrients (Zn, Cu, Fe, Mn, B). The concentration of micronutrients (Zn, Cu, Fe, Mn) in leaf samples was determined using the wet digestion procedure (Rashid, 1986) as described in Ryan *et al*., (2001) with minor modification. In brief, 1.0 g of finely ground leaf sample was treated with 10 ml of concentrated HNO_3 for overnight followed by treatment with 4.0 ml of perchloric acid. The samples were digested on block-digester until dense white fumes of perchloric acid appeared in the tube. After cooling, the digest was filtered and read for micronutrients (Zn, Cu, Fe, Mn) on Atomic Absorption Spectrophotometer (Perkin Elmer Analyst-200, USA) after the required dilutions. Boron concentration in leaf sample was measured by dry ashing (Chapman & Pratt, 1961) with subsequent measurement of B on Spectrophotometer using Azomethine-H method (Bingham, 1982). For this, 0.5 g dry, ground leaf sample in porcelain crucible was ignited in a muffle furnace (Vucan Box Furnace) by slowly raising the temperature to 550^{o}C. After 4 h of muffling at 550^{o}C, the crucibles were removed and cooled. After wetting with 5 drops of DI water, dissolved the ash in 10 ml mixture of dilute HCl and HNO_3 acids. After filtering, B concentration in the digest was measured by the Azomethine-H method at 420 nm on Spectrophotometer (Lambda-35) after the required dilutions.

Descriptive statistics was applied for calculation of means and standard deviations (Steel & Torrie, 1980). Nutrient status was compared with standard criteria for nutrient indexation (Neubert *et al*., 1970; Soltanpour, 1985).

Results

Micronutrient concentrations in citrus leaves: The micronutrients concentration in leaf samples of citrus varied greatly among orchards (Table 1). Zinc varied from 10.85 to 18.84 ug g^{-1} (mean 13.47 ug g^{-1}), Cu 4.60 to 12.95 ug g^{-1} (mean 7.18 ug g^{-1}), Fe 127 to 446 ug g^{-1} (mean 210 ug g^{-1}), Mn 7.95 to 27.85 ug g^{-1} (mean 14.68 ug g^{-1}) and B 1.2 to 83.8 ug g^{-1} (mean 42.4 ug g^{-1}). Comparing with the critical levels of micronutrients in citrus leaves established by Jones *et al*. (1991) and reported by Zia *et al*., (2004), our data revealed that Zn was low (<25 ug g^{-1}) in 100% citrus orchards (Table 2). Copper was low (<6.0 ug g^{-1}) in 16% and adequate (6.0-100 ug g^{-1}) in 84 % citrus orchards. The Fe concentration in leaf samples of all 50 orchards was greater than 150 ug g^{-1} and hence none of them was deficient in Fe. Iron was rather on higher side in 2 out of 50 orchards. Manganese was low (<25 ug g^{-1}) in 96% and adequate (25-200 ug g^{-1}) in 4% orchards. Boron was deficient (<25 ug g^{-1}) in 24% and adequate (25-100 ug g^{-1}) in 76% citrus orchards.

Table 1. Micronutrient concentrations in leaves (ug g^{-1} DM) of citrus orchards in Swat valley.

Micronutrient	Mean	S.D	Minimum	Maximum
Zn	13.47	1.64	10.85	18.84
Cu	7.18	1.54	4.60	12.95
Fe	210	54	127	446
Mn	14.68	3.69	7.95	27.85
B	42.4	23.0	1.2	83.8

The deficiency of micronutrients in citrus orchards, however, varied with the area. The deficiency of Zn and Mn were wide-spread as they were deficient in all citrus orchards included in the survey (Table 3). The deficiency of Cu was 8% in Nawagai, 20% in Palai, 25% in Nutmerra and 57% in Merra. The orchards in Sherkhana, Zoormandi, Koozabanda and Warther were adequate in Cu. The deficiency of B was 14% in Merra, 20 % each in Koozabanda and Sherkhana, 38% in Nutmerra and 50% in Nawagai. The orchards in Palai, Zoormandi and Warther were adequate in B. All 51 orchards were adequate in Fe.

These results thus suggested that citrus orchards in Swat were severely deficient in Zn (100%) and Mn (96%), and to some extent in Cu (16%) and B (24%).

Table 2. Number out of 51 citrus orchards classified as low, adequate or high in micronutrients based on leaf concentration.

Micronutrient	Low		Adequate		High	
	No. of orchards	% of total orchards	No. of orchards	% of total orchards	No. of orchards	% of total orchards
Zn	51	100	0	0	0	0
Cu	8	16	43	84	0	0
Fe	0	0	49	96	2	4
Mn	49	96	2	4	0	0
B	12	24	39	76	0	0

Table 3. Number of citrus orchards deficient in micronutrients in designated areas of Swat and Malakand based on leaf concentration.

Village/area	No of orchards	Zn (<25 ug g^{-1} DM)	Cu (<6 ug g^{-1} DM)	Fe (<60 ug g^{-1} DM)	Mn (<25 ug g^{-1} DM)	B (<25 ug g^{-1} DM)
Nawagai	12	12 (100)*	1 (8)	0	12 (100)	6 (50)
Nutmerra/Najigar	8	8 (100)	2 (25)	0	7 (88)	3 (38)
Sherkhana	5	5 (100)	0	0	5 (100)	1 (20)
Palai	5	5 (100)	1 (20)	0	5 (100)	0
Zoormandi	8	8 (100)	0	0	8 (100)	0
Kooza Banda	5	5 (100)	0	0	5 (100)	1 (20)
Merra	7	7 (100)	4 (57)	0	6 (86)	1 (14)
Warther	1	1 (100)	0	0	1 (100)	0
Total	51	51 (100)	8 (16)	0	49 (96)	12 (24)

*Values in brackets are percent of the orchards surveyed in that specific area

Micronutrient concentration in soils of citrus orchards: The data obtained on AB-DTPA extractable micronutrients showed that the concentration of micronutrients in soils of citrus orchards varied with depth and with orchards (Table 4). The concentrations of micronutrients were generally high in the surface 0-15 cm soil compared with that in lower depths. The concentration of Zn ranged from 0.56 to 10.10 ug g^{-1} soil (mean 2.70 ug g^{-1}) in 0-15 cm, 0.35 to 8.22 ug g^{-1} soil (mean 2.07 ug g^{-1}) in 30-45 cm, and 0.24 to 7.10 ug g^{-1} soil (mean 1.63 ug g^{-1}) in 30-45 cm soil depth. The concentration of Cu ranged from 0.56 to 4.68 ug g^{-1} soil (mean 2.03 ug g^{-1}) in 0-15 cm, 0.37 to 4.82 ug g^{-1} soil (mean 1.93) in 15-30 cm, and 0.38 to 5.63 ug g^{-1} soil (mean 1.86 ug g^{-1}) in the 30-45 cm soil depth. The concentration of Fe ranged from 1.57 to 16.36 ug g^{-1} soil (mean 6.66 ug g^{-1}) in 0-15 cm, 1.87 to 17.10 ug g^{-1} soil (mean 6.45 ug g^{-1}) in 15-30 cm, and 1.55 to 17.33 ug g^{-1} soil (mean 5.95 ug g^{-1}) in the 30-45 cm soil depth. The concentration of Mn ranged from 0.36 to 40.72 ug g^{-1} soil (mean 5.15 ug g^{-1}) in 0-15 cm, 0.19 to 32.07 ug g^{-1} soil (mean 4.09 ug g^{-1}) in 15-30 cm, and 0.14 to 12.28 ug g^{-1} soil (mean 2.56 ug g^{-1}) in the 30-45 cm soil depth. The concentration of B ranged from 0.73 to 15.24 ug g^{-1} soil (mean 4.56 ug g^{-1}) in 0-15 cm, 0.46 to 6.34 ug g^{-1} soil (mean 3.51 ug g^{-1}) in 15-30 cm, and 0.87 to 9.05 ug g^{-1} soil (mean 3.59 ug g^{-1}) in the 30-45 cm soil depth.

Table 4. Micronutrient concentrations in soil (ug g^{-1} soil) of citrus orchards in Swat valley.

Micronutrient	Soil depth (cm)	Mean	S.D	Minimum	Maximum
Zn	0-15	2.70	2.13	0.56	10.10
	15-30	2.07	1.82	0.35	8.22
	30-45	1.63	1.48	0.24	7.10
Cu	0-15	2.03	1.12	0.56	4.68
	15-30	1.93	1.11	0.37	4.82
	30-45	1.86	1.14	0.38	5.63
Fe	0-15	6.66	3.58	1.57	16.36
	15-30	6.45	3.90	1.87	17.10
	30-45	5.95	3.37	1.55	17.33
Mn	0-15	5.15	7.04	0.36	40.72
	15-30	4.09	5.90	0.19	32.07
	30-45	2.56	2.36	0.14	12.28
B	0-15	4.56	2.88	0.73	15.24
	15-30	3.51	1.49	0.46	6.34
	30-45	3.59	2.27	0.87	9.05

Comparing with the critical levels of micronutrient concentration in soil established by Soltanpour (1985), our data showed that the soils of citrus orchards were deficient in Zn, Cu, Fe and Mn at varying levels. In 0-15 cm soil, Zn was low (<9 ug g^{-1} soil) in 10%, marginal (0.9-1.5 ug g^{-1} soil) in 30% and adequate (>1.5 ug g^{-1} soil) in 60% orchards (Table 5). In 15-30 cm soil, Zn was low in 34%, marginal in 18% and adequate in 48 % orchards. Similarly in 30-45 cm soil, Zn was low in 44%, marginal in 20% and adequate in 36% orchards. It was evident that Zn was deficient in both surface and sub-surface soils of many orchards. The soils at lower depths (15-30 and 30-45 cm) were more deficient in Zn than the surface 0-15 cm soils.

Table 5. Micronutrient status of citrus orchards in Swat valley based on soil concentration (ug g^{-1} soil) in AB-DTPA extract (Zn, Cu, Fe, Mn) or dilute HCl (B).

Micronutrient	Soil depth (cm)	Low		Marginal		Adequate	
		No. of orchards	% of total orchards	No. of orchards	% of total orchards	No. of orchards	% of total orchards
Zn	0-15	5	10	16	31	30	59
	15-30	17	33	10	20	24	47
	30-45	22	43	11	22	18	35
Cu	0-15	0	0	2	4	49	96
	15-30	0	0	4	8	47	92
	30-45	0	0	4	8	47	92
Fe	0-15	6	12	18	35	27	53
	15-30	8	16	18	35	15	27
	30-45	9	18	16	31	26	51
Mn	0-15	2	4	6	12	43	84
	15-30	7	14	2	4	42	82
	30-45	7	14	7	14	37	72
B	0-15	0	0	4	8	47	92
	15-30	0	0	2	4	49	96
	30-45	0	0	1	2	50	98

The results on Cu concentration in soils of citrus orchards showed that 96% orchards were adequate (>0.5 ug g^{-1} soil), 4-8% marginal (0.2-0.5 ug g^{-1}) and none was low in Cu. The results on Fe concentration in soils of citrus orchards showed that 12% of the surface 0-15 cm soil was low (<3.0 ug g^{-1} soil), 34% marginal (3.0-5.0 ug g^{-1} soil), and 54% adequate (>5.0 ug g^{-1} soil) in Fe. The 15-30 cm soil was low in 16%, marginal in 36% and adequate in 28% orchards. The 30-45 cm soil was low in 18 %, marginal in 32% and adequate in 50% orchards. With respect to Mn, the surface 0-15 cm soil was low (<0.5 ug g^{-1} soil) in 4%, marginal (0.5-1.0 ug g^{-1} soil) in 12 % and adequate (>1.0 ug g^{-1} soil) in 84 % orchards. The 15-30 cm soil was low in 14 %, marginal in 4 % and adequate in 82 % orchards. The 30-45 cm soil was low in 14 %, marginal in 14 % and adequate in 72 % orchards.

The results on B status of soils showed that both the surface and subsurface soils were generally adequate (>1.0 ug B g^{-1} soil) in B. The soils of only few orchards were marginal (0.45-1.0 ug g^{-1} soil) in B. For example, 8 % orchards were marginal in B in the 0-15 cm, 4 % in the 15-30 cm and 2 % in the 30-45 cm soil depth.

These results thus suggested that the soils of citrus orchards were low to marginal in Zn, Cu, Fe, Mn and B to varying levels. The frequency of Zn deficiency was highest followed by Mn, Fe and Cu respectively but the B deficiency in soils was not widespread.

Soil pH and EC: The results obtained on pH and EC of soils of citrus orchards are presented in Table 6. The results showed that the soil pH of majority of citrus orchards was between 7.5 and 8.5. These results suggested that the soils of citrus orchards were generally alkaline in reaction. The EC of all soils at all depths of citrus orchards included in this study was below 4.0 dS m^{-1}. These results suggested that the soils of citrus orchards were non-saline.

Table 6. Soil pH and EC of citrus orchards in Swat valley.

Soil depth (cm)	pH (6.5-7.5)		pH (7.5-8.5)		EC (<4.0 dS/m)		EC (>4.0 dS/m)	
	No. of orchards	% of total orchards	No. of orchards	% of total orchards	No. of orchards	% of total orchards	No. of orchards	% of total orchards
0-15	0	0	51	100	51	100	0	0
15-30	0	0	51	100	51	100	0	0
30-45	0	0	51	100	51	100	0	0

Soil sampling strategy: Simple correlation coefficients between total profile (0-45 cm) and surface soil (0-15 cm) micronutrients contents showed that there was a strong correlation between surface soil and cumulative micronutrients contents of profile (Table 7). Surface soil micronutrients contents seem to be an acceptable indicator of pattern in micronutrients fertility in the profile (0-45 cm).

Table 7. Simple correlation coefficient (r) between total profile (0-45 cm) and surface (0-15 cm) soil micronutrients contents (kg ha^{-1} soil).

Micronutrient	r-value
Zn	0.87^{**}
Cu	0.95^{**}
Fe	0.95^{**}
Mn	0.92^{**}
B	0.90^{**}

**Highly significant at p<0.01

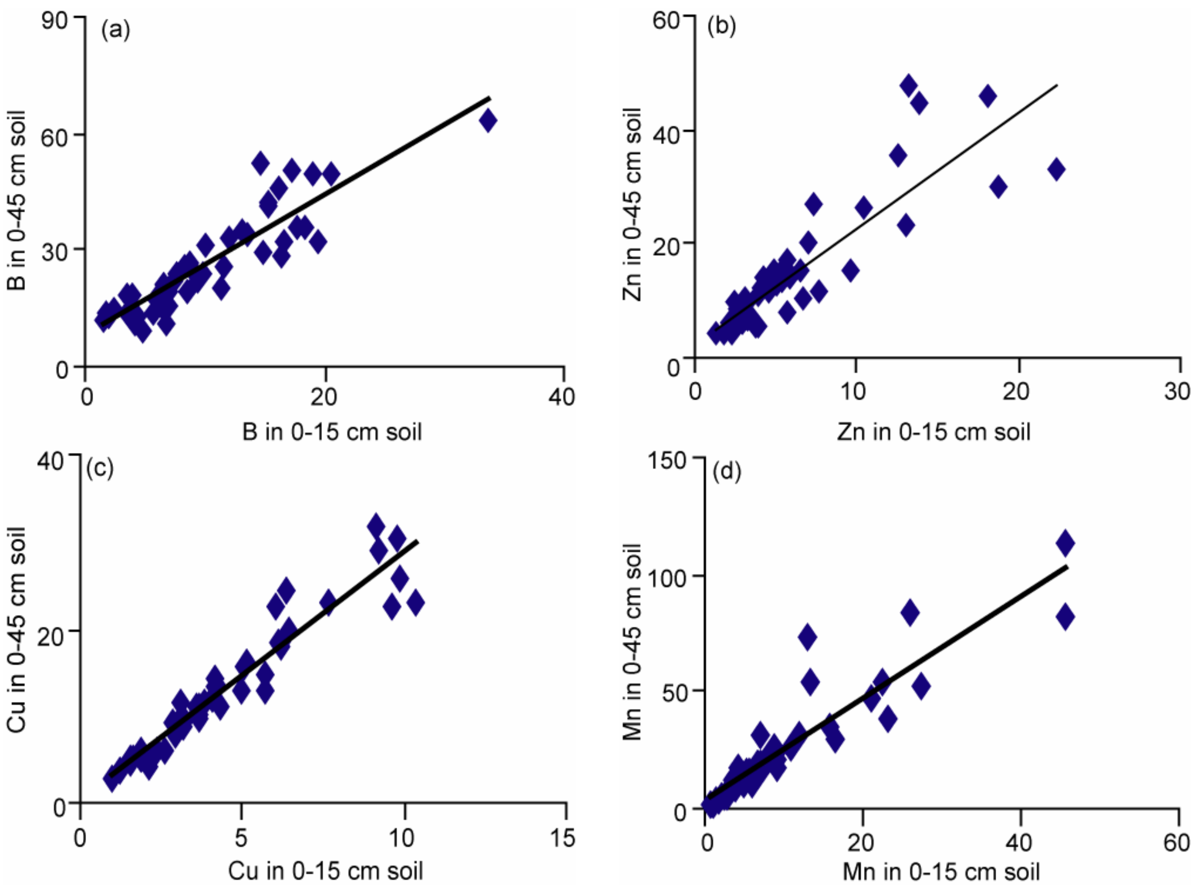
Regression analysis of cumulative profile micronutrients contents with surface soil contents showed that R^2 approached unity with a slope of greater than one (Fig 1a-e). Variation in total profile concentration of micronutrients was accounted for Zn (76 %) to Cu (91 %). This trend can be used to estimate micronutrient levels in profile (0-45 cm) using regression equations parameters given in Table 8. This estimation in future will save time, labour and chemicals by using surface soil (0-15 cm) micronutrients in the above equations.

Table 8. Coefficients of regression equation.

Micronutrients kg ha^{-1} soil	a (intercept)	b (slope)	R^2
Zn	2.13	2.06	0.76
Cu	0.35	2.84	0.91
Fe	2.70	2.73	0.89
Mn	3.24	2.19	0.85
B	7.82	1.81	0.81

Discussion

The soil and plant analysis of citrus orchards revealed deficiencies of micronutrients to varying levels in Swat valley of Khyber Pakhtunkhwa Province, Pakistan. The correlations between soil and plant tests for micronutrients in citrus orchards were, however, poor or nil. Based on leaf analysis, 100% orchards were deficient in Zn, 96 % in Mn, 16 % in Cu, 24 % in B and none in Fe. Based on soil test, such deficiencies were 10-44 % in Zn, 4-14 % in Mn, 12-18 % in Fe and none in Cu. The poor correlation between soil and plant tests is perhaps not surprising. Poor relationships between soil and plant nutrient levels in perennial crops especially in fruit plants have been widely reported in Pakistan (Zia *et al*., 2004; Aziz *et al*., 2004; Ibrahim *et al*., 2004; Shah & Shahzad, 2008). These differences were attributed mainly to diverse soil characteristics including pH, temperature, moisture, organic matter, mineral contents and interaction of nutrients with each other that influences availability of nutrients in soil (Zia *et al*., 2004). Others suggest that soil tests have limited values for fruit trees and grapes because of difficulty in obtaining representative soil samples over a wide and varying rooting zone (Aziz *et al*., 2004). However, strong correlations were found between surface soil (0-15 cm) and cumulative micronutrients contents of the profile (0-45 cm) and thus, the surface soil analysis can be used to measure pattern in micronutrients fertility of the profile. This trend can be used to estimate micronutrient levels in profile (0-45 cm) using regression equations parameters developed from this study. This estimation in future will save time, labour and chemicals by using surface soil (0-15 cm) micronutrients in the said equations.



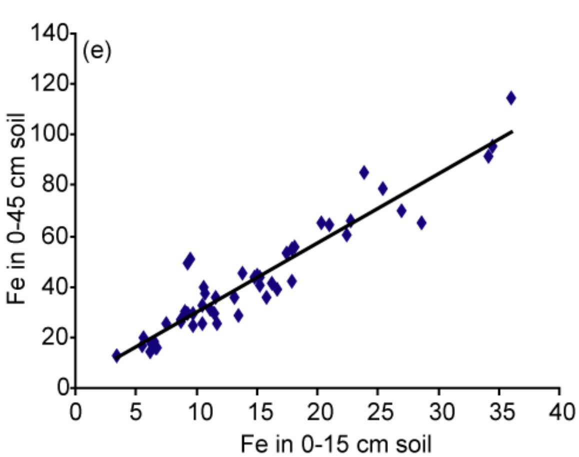


Fig 1 a-e. Relationship of surface (0-15 cm) and profile (0-45 cm) a) B, b) Zn, c) Cu, d) Mn.

Looking into other soil properties of orchards included in this study, the soil pHs of citrus orchards were slightly alkaline and EC were non-saline exhibiting no salt problem in soils. The alkaline soil pH of citrus orchards is an important factor that likely to have adverse affect on the availability of micronutrients to plants. Because of complex nature of soil, soil tests are not widely used to diagnose nutrient deficiencies in perennial fruit trees as no significant correlations are generally found between the soil nutrient status and plant leaf analysis. Soil tests for perennial fruit crops are practiced to indicate other soil problems. Conversely, plant tests are considered to be the best indicators of plant nutrient status.

Relying on plant tests, our data revealed that citrus orchards of Swat were deficient in varying levels of micronutrients. Overall citrus orchards were deficient in Zn (100 %), Mn (96 %), B (24 %) and Cu (16 %). No serious deficiency of micronutrients except Zn in citrus orchards was noticed in NWFP (now Khyber Pakhtunkhwa) before 1990. Comparing our results with the earlier work in NWFP (now Khyber Pakhtunkhwa), we observed that the deficiency of Cu and Mn increased from none in 1990 to 56 % and 96 %, respectively, in 2006. Similarly, the deficiency of Zn increased from about 50 % in 1990 to 100 % in 2006. Zia *et al*., (2006) also observed a wide spread deficiencies of Zn, Cu, B and Fe in various fruit orchards including citrus throughout Pakistan. These results suggested that serious deficiency of certain micronutrients have appeared in citrus orchards in Swat and hence require special attention to overcome such deficiencies. Field experiments are required to determine suitable dose of micronutrients application to citrus orchards in Swat.

Conclusions

This study has shown that citrus orchards in Swat were deficient in micronutrients. Zinc was deficient in 100%, Mn in 96%, B in 24% and Cu in 16% orchards. No or poor correlation was found between the soil and plant tests for diagnosing micronutrient deficiencies in citrus orchards. Soil pH of citrus orchards was alkaline (7.5-8.5) which hinders the availability of Zn, Cu, Fe and Mn. However, strong correlations were found between surface soil (0-15 cm) and cumulative micronutrients contents of the profile (0-45 cm). Thus, the surface soil analysis can be used to measure micronutrients fertility pattern of the profile using regression equations developed in this study.

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