Soil & Environ. 27(1): 123-130, 2008

Micronutrients status of apple orchards in Swat valley of North West Frontier Province of Pakistan

Z. Shah* and K. Shahzad
Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar

Abstract

A survey was conducted to assess the micronutrients (Zn, Cu, Fe, Mn, B) status of apple orchards in Swat valley of North West Frontier Province during summer 2006. For this 52 orchards were surveyed. Soil and leaf samples were collected from each orchard and analyzed for micronutrients. The analysis of apple leaves showed that Zn was low in 37%, adequate in 50% and high in 13% high orchards. Copper was low in 2%, adequate in 88% and high in 10% orchards. Manganese was low in 58% and adequate in 42% orchards. Boron was low in 44% and adequate in 48% orchards. None of the 52 orchards was deficient in Fe. The leaf analysis showed that apple orchards were deficient in Zn, Mn and B in almost all areas in Swat valley. The soil analysis revealed that almost all of the 52 apple orchards were adequate in Cu, Fe and Mn at all soil depths. However, Zn was deficient in both surface and sub-surface soils of large number of orchards. The soils at lower depths (15-30 and 30-45 cm) were more deficient in Zn than the surface (0-15 cm) soil. The soil pH of most apple orchards was between 6.5 and 7.5, and EC below 4.0 dS m^{-1}. Based on leaf analysis, our results suggested that apple orchards in Swat were found deficient in Zn, Mn and B but pH and EC were not likely responsible for unavailability of such nutrients to apple trees. No or poor correlation was found between the soil and plant tests for diagnosing micronutrient deficiencies in apple orchards. 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 pattern in micronutrients fertility of the profile using the regression equations developed in this study. To overcome micronutrients deficiencies in apple, experiments are needed to determine suitable dose of micronutrients application to apple orchards in Swat valley.

Key words: Apple, zinc, copper, iron, manganese, boron, Swat

Introduction

Apple (*Malus domestica*) is a deciduous fruit and belongs to the family Rosaceae. Because of its exceptionally high storage and shipping qualities, it is available for human consumption in most parts of the world round the year. Although not rich in calories, vitamins or other basic food elements, apple is beneficial in digestion, reduces respiratory illness and strengthens teeth. Apple is consumed mostly as fresh but is also used in the production of a variety of other food products such as juice, jams and marmalade, and others.

In Pakistan, the area under apple cultivation was 112 thousand ha producing 351.3 thousand tones of apple during the year 2006 (MINFAL, 2006). In Pakistan, apple is grown in NWFP and Balochistan. The area under apple cultivation in NWFP was 9.3 thousand ha producing 126.7 thousand tonnes of apple during the year 2006. The major apple growing areas in NWFP are Swat, Dir and Chitral. In NWFP, apple comprises about 26% of all deciduous and nut production. The average production of apple in the province is very low. One of the obvious causes of low yield is the limited use of fertilizers for fruit plants. The major share of the fertilizer use in NWFP goes to cereal, sugar and tobacco crops with limited share goes to fruit plants.

In addition to macronutrients, the incidence of micronutrients deficiencies in fruit crops has increased markedly in recent years due to intensive cropping, loss of top soil by erosion, losses of micronutrients through leaching, and limited use of organic fertilizers (FYM). Micronutrients deficiency problems are also aggravated by the high demand of new fruit cultivars. Soil and plant analysis showed that more than 50% of the cultivated soils of the country are unable to supply sufficient zinc and boron to meet the needs of many crops (Khattak, 1995). The soils of apple growing areas in NWFP (Swat, Dir) have been found low in almost all major nutrients as well as in some micronutrients (Bhatti *et al*., 2002; Haq, 2002). The results of one study (Haq *et al*., 1996) showed that apple orchards in Swat were deficient both in macro (P, K) and micronutrients (Zn, Cu, Fe, Mn, B). The extent of nutrients deficiency was P in 10-70%, K in 30-48%, Zn in 46%, Mn in 32%, B in 10%, Fe in 6% and Cu in 1% apple orchards. Bhatti (2004) reported that apple orchards in NWFP were low in B while marginal in Zn and Mn.

*Email: zahirshah59@yahoo.com

Apple is one of the cash crops of the farmers of Swat Valley in NWFP but the current yield and quality of its fruits is low probably because of imbalanced nutrition. Considerable research work has been conducted to determine the nutritional requirements of cereal crops in Swat valley but little attention is paid to research on apple plants. Although deficiency of certain micronutrients have appeared in apple orchards in Swat, no formal micronutrients recommendations is available to correct such deficiencies. It is therefore, necessary to identify deficiency, if any, of micronutrients in apple orchards of Swat Valley and develop micronutrient management strategies for enhanced production of quality apple fruit in the area. An FAO report on micronutrients (published by National Fertilizer Development Centre, Islamabad) has also emphasized the need for more comprehensive research for arriving at micronutrients management strategies for fruits (and major cropping systems) of the country. This paper reports the micronutrients status of apple orchards in Swat valley.

Materials and Methods

A survey was conducted to assess the micronutrients (Zn, Cu, Fe, Mn and B) status of apple orchards in Swat valley of North West Frontier Province during summer 2006. For this, 52 orchards were surveyed. During the survey, general observations on orchards were recorded. Each orchard was particularly observed for micronutrients deficiency symptoms. Soil and leaf samples were collected from each orchard and analyzed for micronutrients.

Collection and processing of soil and leaf samples

Soil samples from each apple orchard were collected from three depths viz. 0-15, 15-30, and 30-45 cm in August 2006. After air-drying, soil samples were ground and passed through 2 mm sieve. At the time of soil sampling, leaf samples were also collected from each orchard. For this, 120 to 150 recently matured leaves of current season growth were collected randomly from about 20 trees per orchard. Leaf samples were taken from around the tree at about 5-6 ft height. Leaf samples were washed with tap water containing detergent followed by rinsing in distilled water within 24 h of sampling. After air-drying, leaf samples were dried in oven at 70 ^{o}C till reaching to constant weight followed by grinding in a stainless steel Mill.

Soil and leaf analysis

Soil samples were analyzed for extractable micronutrients (Zn, Cu, Fe, Mn and B), pH and EC. The leaf samples were also analyzed for total micronutrients (Zn, Cu, Fe, Mn and B). The concentration of extractable micronutrients (Zn, Cu, Fe, Mn) in soil was determined by the AB-DTPA extraction procedure (Soltanpour and Schwab, 1977). In this method, 10 g soil sample was shaken with 20 ml AB-DTPA extractant in an open Erlenmeyer flask for 15 min. After filtering, the extract was read for Zn, Cu, Fe and Mn on an 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 by 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) suspension/extract. The extract was read for pH on pH meter (InoLab pH Level 1) and for EC on EC meter (DDC-308A Conductivity Meter).

The concentration of micronutrients (Zn, Cu, Fe and Mn) in leaf samples was determined using the wet digestion procedure (Rashid, 1986) as described by Ryan *et al.* (2001) with minor modification. In brief, 1.0 g dry leaf sample was treated overnight with 10 ml concentrated HNO_3 followed by treatment with 4.0 ml perchloric acid, and then digested on block-digester by gradually increasing the temperature to 235^{o}C until dense white fumes of perchloric acid appeared in the tube. After cooling, the digest was filtered and read for micronutrients (Zn, Cu, Fe and Mn) on Atomic Absorption Spectrophotometer (Perkin Elmer Analyst-200, USA) after the required dilutions. Boron concentration in leaf sample was measured by dry ashing (Jones and Case, 1990) 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 and Torrie, 1980). Nutrient status was compared with standard criteria for nutrient indexation (Neubert *et al.*, 1970; Soltanpour, 1985).

Results

Micronutrient concentrations in apple leaves

The results showed that the concentration of micronutrients in leaves varied greatly among orchards. The

Zn concentration in leaves ranged from as low as 13.29 µg to as high as 84.61 µg g^{-1} with a mean value of 34.25±16.8 (Table 1). The Cu concentration in leaves ranged from 4.40 µg to 54.3 µg g^{-1} with a mean value of 10.01±6.6. The Fe concentration in leaves ranged from as low as 182 µg to as high as 440 µg g^{-1} with a mean value of 323±50. The Mn concentration in leaves ranged from as low as 11.4 µg to as high as 99.31 µg g^{-1} with a mean value of 34.9±17.4. The B concentration ranged from as low as 0.56 µg to as high as 73.5 µg g^{-1} with a mean value of 38.14.

Comparing with the critical values of micronutrients in apple leaves established by Neubert *et al.* (1970), our data revealed that Zn was low in 37%, adequate in 50% and high in 13% orchards (Table 2). Copper was low in 2%, adequate in 88% and high in 10% apple orchards. The Fe concentrations in apple leaves were rather on higher side in all 52 orchards. Manganese was low in 58% and adequate in 42% orchards. Boron was also deficient in considerable number of orchards. The data revealed that 44% orchards were low and 48% adequate in B. None of the 52 orchards included in the survey was deficient in Fe. These results suggested that 37 to 58% of apple orchards in Swat valley were found deficient in Zn, Mn and B.

The area-wise data revealed that apple orchards of Jura-Shangwati area were deficient in Mn and B (Table 3). The apple orchards of Baikan, Arkot-Ronial/Dagai, Aghal-Gwaleri, Null-Dureshkhela and Shin were deficient in Zn, Mn and B. The Choprial and Ashari-Baghdheri apples were deficient in Zn and Mn whereas the Sambat apples were deficient in Mn and B.

Micronutrients concentration in soils of apple orchards

The data obtained on concentration of AB-DTPA extractable micronutrients in soils of apple orchards are presented in Tables 4-5. The concentration of micronutrients in soils varied with depth and with orchards. The concentration of Zn was generally high in the surface 0-15 cm soil but decreases gradually with increasing soil depth. The concentration of Zn in the 0-15 cm soil ranged from as low as 0.42 to as high as 9.37 µg g^{-1} soil with a mean value of 3.76±1.96 (Table 4). In 15-30 cm soil, it ranged from 0.49 to 6.35 µg g^{-1} soil with a mean value of 1.76±1.31. Similarly, in 30-45 cm, it ranged from 0.29 to 7.06 µg g^{-1} soil with a mean value of 1.25±1.09. Like Zn, the concentration of Cu in soil also decreases gradually with increasing soil depth. The concentration of Cu in the 0-15 cm soil ranged from as low as 1.95 µg to as high as 17.32 µg g^{-1} soil with a mean value of 8.43±3.41. In 15-30 cm soil, it ranged from 2.78 to 11.05 µg g^{-1} soil with a mean value of 6.17±2.11. Similarly, in 30-45 cm, it ranged from 2.11 to 12.66 µg g^{-1} soil with a mean value of 5.87±2.21. The concentration of Fe in soil also generally decreases gradually with increasing soil depth. The concentration of Fe in the 0-15 cm soil ranged from as low as 24 µg to as high as 194 µg g^{-1} soil with a mean value of 86±50. In 15-30 cm soil, it ranged from 20 to 178 µg g^{-1} soil with a mean value of 71±41. Similarly, in 30-45 cm, it ranged from 20 to 154 µg g^{-1} soil with a mean value of 60±35. Like other micronutrients, the concentration of Mn in soil was generally high in the surface soil but decreases gradually with increasing soil depth. In 0-15 cm soil, it ranged from as low as 0.59 µg to as high as 15.09 µg g^{-1} soil with a mean value of 8.75±3.45. In 15-30 cm soil, it ranged from 2.44 to 14.80 µg g^{-1} soil with a mean value of 7.87±2.95. Similarly, in 30-45 cm, it ranged from 2.04 to 15.13 µg g^{-1} soil with a mean value of 6.81±3.18. The concentration of B in the 0-15 cm soil ranged from as low as 5.99 µg to as high as 27.0 µg g^{-1} soil with a mean value of 10.3±3.18. In 15-30 cm soil, it ranged from 3.27 to 19.4 µg g^{-1} soil with a mean value of 8.57±2.34. Similarly, in 30-45 cm, it ranged from 4.06 to 22.7 µg g^{-1} soil with a mean value of 7.82±2.81.

Comparing with the critical values of micronutrient concentration in soil established by Soltanpour (1985), our data revealed that the surface 0-15 cm soil was low (<9 µg g^{-1} soil) in Zn in 3, marginal (0.9 and 1.5 µg g^{-1} soil) in 5 and adequate (>1.5 µg g^{-1} soil) in 44 out of 52 orchards (Table 5). The 15-30 cm soil was low in 14, marginal in 17 and adequate in 21 orchards. The 30-45 cm soil was low in 29, marginal in 14 and adequate in 9 orchards. Our results showed that the soils (0-45 cm) of all 52 orchards included in the survey had adequate concentration of Cu (>0.5 µg g^{-1} soil), Fe (>5.0 µg g^{-1} soil), Mn (>1.0 µg g^{-1} soil) and B (>0.45 µg g^{-1} soil).

Soil pH and EC

The results obtained on pH and EC of soils of apple orchards are presented in Table 6. The results showed that the soil pH of majority of apple orchards was between 6.5 and 7.5 with the exception of only 4 orchards where the pH was above 7.5 but below 8.5. These results suggested that the soils of apple orchards were generally neutral in reaction. The EC of all soils at all depths of apple orchards included in this study was below 4.0 dS m^{-1} and were non-saline.

Table 1. Micronutrients concentration (µg g^{-1} dry matter) in leaves of apple orchards

Nutrient	Mean	S.D	Minimum	Maximum
Zn	34.25	16.83	13.29	84.61
Cu	10.01	6.60	4.40	54.30
Fe	323	50	182	440
Mn	34.9	17.4	11.4	99.3
B	38.14	14.92	0.56	73.50

Table 2. Number out of 52 apple 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	19	37	26	50	7	13
Cu	1	2	46	88	5	9
Fe	0	0	0	0	52	100
Mn	30	58	22	42	0	0
B	23	44	25	48	4	8

Table 3. Number of apple orchards deficient in micronutrients in designated areas of Swat valley based on leaf concentration

Village/area	No. of orchards	Zn (<25 µg g^{-1} DM)	Cu (<5 µg g^{-1} DM)	Fe (<50 µg g^{-1} DM)	Mn (<35 µg g^{-1} DM)	B (<25 µg g^{-1} DM)
Jura-Shangwatai	3	0	0	0	3 (100)*	3 (100)
Biakan	10	2 (20)	0	0	4 (40)	5 (50)
Arkot-Ronial/Dagai	7	2 (29)	0	0	4 (57)	1 (14)
Chamanlalai	8	4 (50)	0	0	4 (50)	5 (63)
Aghal-Gwalerai	7	2 (29)	0	0	7 (100)	4 (57)
Choprial	3	1 (33)	0	0	2 (66)	0
Sambat	2	0	0	0	1 (50)	1 (50)
Null-Dureshkhela	7	4 (50)	1 (14)	0	3 (43)	3 (43)
Ashari-Baghdheri	3	3 (100)	0	0	1 (33)	0
Shin	2	1 (50)	0	0	1 (50)	1 (50)
Total	**52**	**19 (37)**	**1 (2)**	**0**	**30 (58)**	**23 (44)**

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

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 micronutrients fertility pattern in the profile (0-45 cm).

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 61% for Mn to 91% for Fe. This trend can

Table 4. Micronutrients concentration (µg g^{-1} soil) in soils of apple orchards

Micronutrient	Soil depth (cm)	Mean	S.D	Minimum	Maximum
Zn	0-15	3.76	1.96	0.42	9.37
	15-30	1.76	1.31	0.49	6.35
	30-45	1.25	1.09	0.29	7.06
Cu	0-15	8.43	3.41	1.95	17.32
	15-30	6.17	2.11	2.78	11.05
	30-45	5.87	2.21	2.11	12.66
Fe	0-15	86	50	24	194
	15-30	71	41	20	178
	30-45	60	35	20	154
Mn	0-15	8.75	3.45	0.59	15.09
	15-30	7.87	2.95	2.44	14.80
	30-45	6.81	3.18	2.04	15.13
B	0-15	10.3	3.18	5.99	27.0
	15-30	8.57	2.34	3.27	19.4
	30-45	7.82	2.81	4.06	22.7

Table 5. Number out of 52 apple orchards classified as low, adequate or high in AB-DTPA extractable Zn, Cu, Fe, Mn or dilute HCl extractable B based soil analysis

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	3	6	5	10	44	84
	15-30	14	27	17	33	21	40
	30-45	29	56	14	27	9	17
Cu	0-15	0	0	0	0	52	100
	15-30	0	0	0	0	52	100
	30-45	0	0	0	0	52	100
Fe	0-15	0	0	0	0	52	100
	15-30	0	0	0	0	52	100
	30-45	0	0	0	0	52	100
Mn	0-15	2	4	0	0	50	96
	15-30	0	0	0	0	52	100
	30-45	0	0	0	0	52	100
B	0-15	0	0	0	0	52	96
	15-30	0	0	0	0	52	100
	30-45	0	0	0	0	52	100

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

Soil depth (cm)	pH (6.5-7.5)		pH (7.5-8.5)		EC (<4.0 dS m^{-1})		EC (>4.0 dS m^{-1})	
	Number out of 52 orchards	% of total orchards	Number out of 52 orchards	% of total orchards	Number out of 52 orchards	% of total orchards	Number out of 52 orchards	% of total orchards
0-15	48	92	4	8	52	100	0	0
15-30	44	85	8	15	52	100	0	0
30-45	42	81	10	19	52	100	0	0

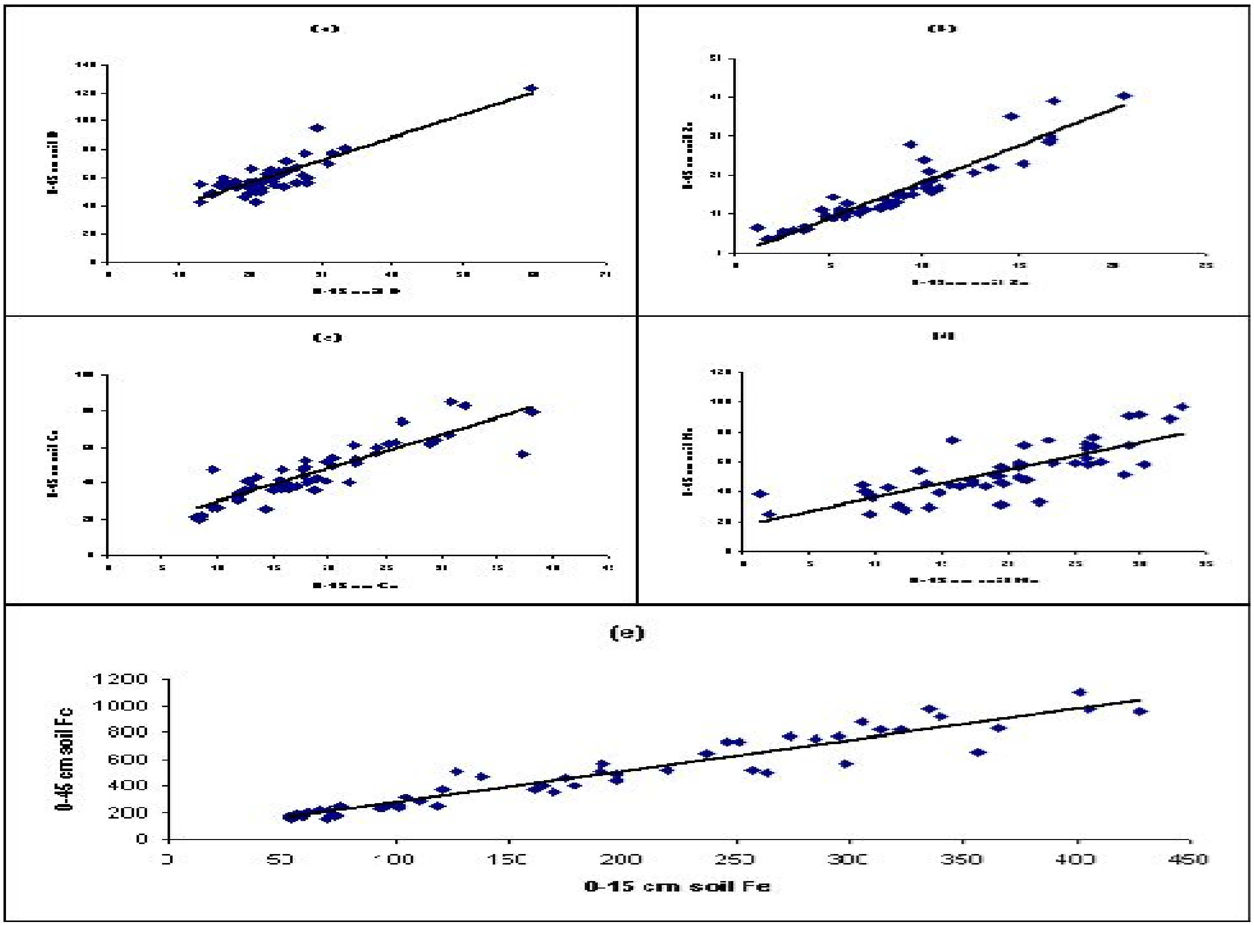

Figure 1a-e. Relationship of surface (0-15 cm) and profile (0-45 cm) a) B, b) Zn, c) Cu, d) Mn, and e) Fe contents in soil

be used to estimate micronutrient levels in the profile (0-45 cm) using regression equations parameters developed in this study (Table 8). The rediction of micronutrients contents in the profile (0-45 cm) from the surface soil (0-15 cm) analysis using the regression equations developed in this study will certainly save time, labour and chemicals in future.

Discussion

The soil and plant analysis showed deficiencies of varying levels of micronutrients in apple orchards in Swat valley. The correlations between soil and plant tests for micronutrients in apple orchards were however poor or nil. Based on leaf analysis, 37% of apple orchards were low in Zn, 4% low in Cu, 58% low in Mn and 44% low in B. Whereas the soil test showed deficiency of only Zn (6% orchards in 0-15 cm, 27% in 15-30 cm and 56% in

30-45 cm soil) while other micronutrients (Cu, Fe and Mn) were found in adequate amount. 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 (Aziz *et al*., 2004; Ibrahim *et al*., 2004; Zia *et al*., 2004). These differences were attributed mainly due to diverse soil characteristics such 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 the profile (0-45 cm) using regression equations parameters developed in this study. The prediction of micronutrients contents in the profile (0-45 cm) from the surface soil (0-15 cm) analysis using the regression equations developed in this study will certainly save time, labour and chemicals in future. Shah (2008) has reported similar findings for prediction of micronutrients in the profile from the surface soil analysis through regression equations in citrus orchards. Looking into other soil properties of orchards included in this study, the soil pHs of apple orchards were close to neutral and electrical conductivity were below <4.dS m^{-1} exhibiting no salt problem in soils. The soil pH and EC of apple orchards did not seem to have unfavorable affect on the availability of micronutrients. However, 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 apple orchards of Swat valley were deficient in varying levels of micronutrients. Apple orchards were deficient in Zn, Cu, Mn and B. However, micronutrients deficiency varied with locality. The results of earlier survey of apple orchards in Swat carried out 10 years ago by Haq *et al.* (1996) showed that Zn was marginal in 46%, Cu in 2%, Fe in 6%, Mn in 32% and B in 10% orchards based on leaf analysis. These results indicated that the deficiency of Zn decreased from 46% in 1996 to 39% in 2006. The reason is the farmers have started using Zn to some extent on apple orchards in Swat. The deficiency of Mn increased from 32% in 1996 to 58% in 2006. Similarly, the deficiency of B increased from 10% in 1996 to 24% in 2006. These results suggested that serious deficiency of certain micronutrients have appeared in apple orchards in Swat and hence require special attention to overcome such deficiencies. Therefore, experiments are required to determine suitable dose of micronutrients application to apple orchards in Swat.

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

Micronutrient	r-value
Zn	0.93^{**}
Cu	0.88^{**}
Fe	0.95^{**}
Mn	0.78^{**}
B	0.86^{**}

**Highly significant at P <0.01

Table 8. Coefficients of regression equations to estimate micronutrient concentrations in soil (0-45 cm) from the surface (0-15 cm) soil analysis for apple orchards in Swat

Micronutrients kg ha^{-1} soil	a (intercept)	b (slope)	R^2
Zn	-0.16	1.84	0.86
Cu	12.06	1.83	0.78
Fe	40.48	2.35	0.91
Mn	17.54	1.84	0.61
B	23.43	1.61	0.74

Conclusions

It could be concluded from this study that apple orchards in Swat were found deficient in varying levels of micronutrients. Based on leaf analysis, Zn was deficient in 37%, Cu in 2%, Mn in 58%, and B in 44% orchards and the deficiency of such nutrients were distributed throughout in Swat valley. The soil analysis exhibited deficiency of only Zn both in the surface and sub-surface soils of apple orchards. However, no or poor correlation was found between the soil and plant tests for diagnosing micronutrient deficiencies in apple orchards. The soils of apple orchards in Swat were generally neutral and non-saline. 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 pattern in micronutrients fertility of the profile using regression equations developed in this study.

Acknowledgements

This study was part of an ALP-funded project on management of micronutrients for apple and citrus production in Swat valley. The authors wish to thank PARC, Islamabad for providing funds for this study through ALP project.

References

Aziz, T., M.A. Gill, Rahmatullah and M. Sabir. Mineral nutrition of fruit trees. 2004. p. 28-33. In: Proceedings of Symposium on Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions. M. Ibrahim (ed.), organized by Soil Science Society of Pakistan, Agriculture Research Institute (ARI), Sariab, Quetta, and PSF on October 5-6, 2004 at ARI Sariab, Quetta, Balochistan.

Bhatti, A.U. 2004. Micronutrients in fruits production in NWFP. p. 44-56. In: Proceedings of Symposium on Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions. M. Ibrahim (ed.), organized by Soil Science Society of Pakistan, Agriculture Research Institute (ARI), Sariab, Quetta, and PSF on October 5-6, 2004 at ARI Sariab, Quetta, Balochistan.

Bhatti, A.U., A. Ghani and Z. Shah. 2002. Statistical procedures for formulations of fertilizer recommendations. Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar. 68p.

Bingham, F.T. 1982. Boron. p. 431-448. In: Methods of Soil Analysis Part-2 Chemical and Microbiological Properties. A.L. Page (ed.), American Society of Agronomy, Madison, WI, USA.

Haq, H. 2002. Nutrient status of citrus orchards of district Dir Upper. M.Sc (Hons) thesis, submitted to Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar.

Haq, I., A. Ghani and H. Rehman. 1996. Nutritional status of apple orchards in NWFP and effect of fertilizer application on fruit production. Soil and Fertilizer Research Technical Bulletin 1/95. Directorate of Soil and Plant Nutrition, ARI Tarnab, Peshawar, NWFP, Pakistan.

Ibrahim, M., N. Ahmad, A. Niaz and M.Y. Nadeem. Micronutrient status of soils and citrus orchards of citrus growing area. 2004. p. 88-94. In: Proceeding of Symposium on Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions. M. Ibrahim (ed.), organized by Soil Science Society of Pakistan, Agriculture Research Institute (ARI), Sariab, Quetta, and PSF on October 5-6, 2004 at ARI Sariab, Quetta, Balochistan.

Jones, J.B. Jr. and V.W. Case. Sampling, Handling, and Analyzing Plant Tissue Samples. 1990. p. 389-428. In: Soil Testing and Plant Analysis. R.L. Westerman (ed.), Soil Science Society of America (SSSA) Book Series: 3. SSSA, Inc., Madison, Wisconsin, USA.

Khattak, J.K. 1995. Micronutrients in Pakistan agriculture. Joint Report by Pakistan Agriculture Research Council and Department of Soil Science, NWFP Agricultural University, Peshawar.

MINFAL. 2006. Agricultural Statistics of Pakistan. Ministry of Food, Agriculture and Livestock, Islamabad.

Neubert, P., W. Wrazidlo, H.P. Vielemeyer, I. Hundt, F. Gollmick and W. Bergmann. 1970. Tables of plant analysis. Institute of Plant Nutrition, Jena.

Rashid, A. 1986. Mapping zinc fertility of soils using indicator plants and soils-analyses. Ph.D. Dissertation, University of Hawaii, HI, USA.

Ryan, J., G. Estefan and A. Rashid. 2001. Soils and Plant Analysis Laboratory Manual. Second Edition, Jointly published by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Center (NARC), available from ICRADA, Aleppo, Syria, 172 p.

Shah, M.Z. 2008. Micronutrients status of citrus orchards in Swat valley. M.Sc. (Hons) thesis submitted to Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar.

Soltanpour, P.N. 1985. Use of ammonium bicarbonate DTPA soil test to evaluate elemental availability and toxicity. *Communications in Soil Science and Plant Analysis* 16: 323-338.

Soltanpour, P.N. and A.P. Schwab. 1977. A new soil test for simultaneous extraction of macro- and micro-nutrients in alkaline soils. *Communications in Soil Science and Plant Analysis* 8: 195-207.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A biometrical approach. 2nd Edition, McGraw-Hill, New York. 633p.

Zia, M.S., M. Aslam, N.M. Cheema, A. Shah and H. Laghari. 2004. Diagnosis of plant nutrient disorder in fruit plants. p. 16-27. In: Proceedings of Symposium on Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions. M. Ibrahim (ed.), organized by Soil Science Society of Pakistan, Agriculture Research Institute (ARI), Sariab, Quetta, and PSF on October 5-6, 2004 at ARI Sariab, Quetta, Balochistan.