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Zinc status of apple orchards and its relationship with selected physico-chemical properties in Murree tehsil

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Abstract

A field survey was conducted to assess the zinc (Zn) status of apple orchards and associated soils in Murree tehsil. Each union council was considered as a grid for selection of apple orchard and Global Positioning System (GPS) was used for site identification. Thirteen apple orchards, i.e., one from each apple producing union council and one from each Punjab Fruit Research Hill Station, Lower Topa and Punjab Fruit Research Hill Station, Sunny Bank were selected. Five apple trees were selected from each orchard to collect plant and soil samples. Zinc deficiency was more prevalent in plant samples in comparison to the soils; all the surveyed apple orchards were deficient in Zn supply while soil testing indicated that 38 % apple orchards were deficient in Zn contents. A positive correlation existed between the plant available Zn and organic matter, clay contents, and silt contents where as negative correlation was observed between soil Zn contents and pH, sand and $CaCO_3$. No correlation was established between the soil and foliage Zn contents.

Keywords: Apple, Zinc, Orchards, Soil testing, Plant analysis, Relationship

Introduction

Zinc deficiency in the orchard soils of Pakistan is attributed to high soil pH conducive to formation of insoluble compounds of Zn like insoluble calcium zincate, calcareousness, low organic matter contents and coarse texture (Rashid *et al*., 1997). Situation becomes very alarming in case of apple orchards where average yield is 3.9 tonnes per hectare (GOP, 2008). According to an estimation, 30 to 49 % of world's total area is Zn deficient (Sillanpaa, 1990; Wojcik, 2007). The bioavailability of Zn decreases hundred folds for each unit increase in soil pH in the range 4 to 9 (Lindsay, 1972). Most of the fruit trees are considered sensitive to Zn deficiency but apple is more prone to Zn deficiency than other deciduous fruits (Chapman, 1966; Rashid and Ryan, 2004).

Zinc plays an important role as a structural ingredient and regulatory co-factor for a wide range of enzymes in many imperative biochemical pathways including carbohydrate, protein and auxin metabolisms (Cakmak and Marschner, 1988). Zinc deficiency in apple tree results in rosetting of the leaves at the end of shoot. The leaves become small, mottled, weird and narrow. Consequently shoot dieback and defoliation occurs in severe Zn shortage. Deficiency of Zn causes browning in fruit orchards. Fruit set and apple yield are reduced, and fruit are small, deformed, and poorly colored. Apple fruits ripe early and lack flavor (Woodbridge, 1954; Wojcik, 2007). Under Zn deficiency, plasma membrane becomes porous and releases organic compounds, which attract pathogens to the rhizosphere. Zinc application has been shown to suppress root rotting pathogens, root nematode infestation and all infections (Siddiqui *et al*., 2002). Therefore, adequate soil Zn supply is necessary for good apple production. Micronutrient deficiencies including Zn have long been reported to potentially cause major growth problems for apple orchards. Zinc application is fundamental for improving apple yield and quality.

Zinc is an essential element for all life and soil is the primary source of Zn for plants, animals and human beings. Soil tests provide information about the plant available nutrient level in the soil and foliar analysis is also very important tool for diagnosing nutrient needs of the plants. Plant nutrient contents indicate their bioavailability in the soils. Nutrient concentration in the plant is also related to the quantity of the available nutrient in the soil (Celik and Katkat, 2007). In Pakistan, although widespread deficiencies of micronutrient have been well documented (Rashid *et al*., 1997) but little work in apple orchards has been reported so far in the Punjab. Main apple growing region in Punjab is Murree which represent the 93 percent apple producing area in the Punjab (Siddique *et al*., 2009). So, this research work was conducted to evaluate the Zn status of apple orchards by soil testing and plant analysis in the Murree tehsil.

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Materials and Methods

Sampling and processing

A field survey was conducted to determine Zn contents and diagnosing the Zn deficiency in the apple orchards of Murree region. Thirteen apple orchards were selected, one 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 month of July and August were collected from five trees in an orchard. Samples were collected all around the canopy and dried using hot air oven, and processed for analysis. Soil samples were collected from the surface (0-15 cm) and subsurface (15-30 cm) under the canopy of each apple tree. Samples were dried, ground with wooden mottle and pestle, and passed through 2 mm sieve. Global positioning system (GPS) was used for precise site identification as a reference for future studies (Table 1).

Table 1: Site descriptions of surveyed apple orchards using Global Positioning System

Union Council	Latitude	Longitude	Height
Murree	33º 55' 13.47"	73º 23' 59.20"	2170 m
Ghora Gali	33º 53' 09.41"	73º 23' 02.05"	1854 m
Sunny Bank*	33º 55' 02.29"	73º 23' 32.44"	1955 m
PFR**	33º 53' 19.69"	73º 25' 55.52"	1889 m
Phugwari	33º 53' 53.65"	73º 26' 02.53"	1510 m
Charehan	33º 51' 58.36"	73º 27' 44.79"	1785 m
Tret	33º 52' 53.58"	73º 21' 13.32"	1604 m
Alyot	33º 56' 41.84"	73º 28' 11.02"	1637 m
Derya Gali	33º 57' 07.67"	73º 21' 52.07"	1873 m
Dewal	33º 57' 39.75"	73º 20' 17.65"	1426 m
Sher Bugla	33º 55' 12.31"	73º 27' 38.56"	1822 m
Ghael	33º 50' 14.19"	73º 29' 13.31"	1990 m
Rawat	33º 55' 53.39"	73º 19' 15.73"	1249 m

*Punjab Fruit Research Hill Station, Lower Topa
**Punjab Fruit Research Hill Station, Sunny Bank

Soil and plant analysis

The soils were analyzed for soil texture (Gee and Bauder, 1982), pH (Mclean, 1982), $CaCO_3$ contents (Leoppert *et al*., 1984), electrical conductivity (Mclean, 1982), organic matter (Nelson and Sommers, 1982) and AB-DTPA extractable Zn (Soltanpour and Workman, 1979). Plant leaf samples were dry ashed and the digest was analysed for Zn by atomic absorption spectroscopy (Chapman and Pratt 1961).

Results and Discussion

Physico-chemical characteristics of soils

The soil texture of the surveyed area ranged from sandy clay loam to clay loam. Clay loam was dominant in the area. union councils, i.e., Charehan, Murree, Ghel, Ghora Galli, and Hill Fruit Research Station Sunny Bank had clay loam texture. Soil located in the Dewal and Sehr Bagla was loamy in texture, whereas soil texture of union councils Derya Galli and Phugwari was sandy clay loam in (Table 2).

Textural classes of soils of all apple orchards suggested that soils are suitable to grow apple and other stone fruits and have good ability to supply nutrients to plants. Electrical conductivity ranged from 0.15 to 1.8 dS m^{-1}. Soil pH ranged from 7.2 to 8.4 indicating that soils of apple orchard were slightly alkaline to strongly alkaline. Soil pH is the indicator of deficiency of plant available Zn due to low solubility at alkaline pH. Organic matter contents (Figure 1) ranged from 0.93 to 2.5% indicating that enough amount of organic matter was present for the maintenance of soil aggregation and preventing nutrients from leaching (Milne and Haynes, 2003). Lime contents ($CaCO_3$) ranged from 0.24 to 24 % and union council Charhan had maximum mean value, i.e., 23.3 % , at surface (0-15 cm) and 24.1 % at subsurface soil while the Gorah Gali site had minimum mean value, i.e., 0.35 % in its surface (0-15 cm) and 0.5% at sub surface (15-30 cm) soils depth. Calcium carbonate contents increased with the depth and were found as a major factor for lowering the Zn availability. Zinc availability decreases by increasing the $CaCO_3$ contents due to co precipitation with Zn as calcium zincate, high $CaCO_3$ contents also thwart Zn availability by increasing pH and thus lowering Zn solubility (Lindsay, 1972).

Zn status of soils

The concentration of Zn in the surface arable soils ranged from 0.31 to 12.15 µg g^{-1} of soil with a mean value

of 4.21 ± 3.40. Thirty eight percent of surveyed soils were low (< 0.90 µg g^{-1}) and 62 % were adequate (>1.5 µg g^{-1}) in Zn supply. In arable sub soil, Zn ranged from 0.27 to 9.7 µg g^{-1} with a mean value of 3.16 ± 2.78 (Figure 2). The surface soils were low (<0.9 µg $g^{-1}$of soil) when compared with the critical values (Table 3) described by Soltanpour (1985). Soils of orchards located in the Union Councils Derya Galli, Charhan, Alyot and Tret were deficient in Zn contents at

Soil fertility is actually the presence or absence of certain amounts of nutrients which include macro and micronutrients. The availability of micronutrients like other nutrients is affected by various soil and climatic conditions. So, the correlation of Zn with various physic-ochemical properties was established to monitor the effect of various physico-chemical properties on the availability of Zn in the orchard's soils.

Table 2: Physico-chemical characteristics in soils of surveyed apple orchards

Union Council	Sand	Silt	Clay	Organic Matter	$CaCO_3$	pH	Textural Class
	Percent						
Derya Galli	49.3	24.4	26.0	1.41	18.0	7.61	Sandy Clay Loam
Charhan	33.0	34.0	32.5	1.08	23.74	7.79	Clay Loam
Ghora Galli	29.5	35.0	35.0	2.6	0.43	7.93	Clay Loam
Dewal	39.5	29.0	31.0	1.79	1.4	7.80	Loam
Murree	21.5	40.0	39.0	3.0	13.0	7.28	Clay Loam
Sehrbagla	48.1	19.0	32.2	2.0	1.0	7.89	Sandy Clay Loam
Rawat	29.0	29.5	41.0	1.71	7. 0	8.29	Clay
Phagwari	42 .0	28.5	29.0	1.64	14.0	8.35	Clay Loam
Ghel	29.0	35.5	35.0	3.33	15.94	7.49	Clay Loam
Tret	29 .0	42.1	29.5	3.38	17.0	8.42	Loam
Alyot	27.3	15.2	57.0	1.24	18.7	8.2	Clay
***Sunny Bank**	29.8	34.7	35.0	2.8	3.93	7.68	Clay Loam
****PFR**	50.25	27.4	22.0	3.74	6 .0	7.93	Sandy Clay Loam

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

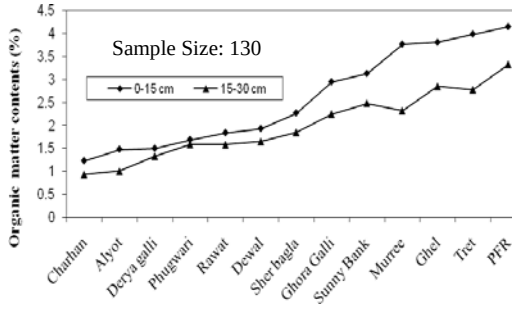

Figure 1: Organic matter contents in the soils of surveyed apple orchards

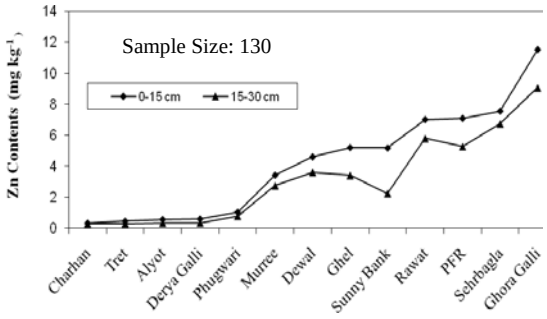

Figure 2: Distribution of AB-DTPA Zn in surface and sub- surface soils of surveyed apple orchards

both depths and apple orchard located in the union council Phagwarri was deficient at the lower depth only. While rest of orchards located in other union councils i.e. Murree, Dewal, Ghel, Rawat, Sehrbagla and Ghora Galli and Fruit Research Stations were adequate in Zn contents.

Relationship between AB-DTPA extractable Zn and physico-chemical properties of soils

Soil fertility is the ability of a soil to provide nutrients and is an important attribute of soil to produce certain crop.

Correlation coefficient values among the extractable Zn and soil properties are given in the Table 5. A positive significant correlation existed between AB-DTPA extractable Zn and organic matter in the soils of all apple orchards for the sites located in the union council of Derya Galli ($r = 0.68$, $P \leq 0.05$); Murree ($r = 0.94$, $P \leq 0.1$); Ghel ($r = 0.86$, $P \leq 0.01$); Alyot ($r = 0.87$, $P \leq 0.01$); Ghora galli ($r = 0.64$, $P \leq .05$); Hill Fruit Research Station Sunny Bank ($r = 0.89$, $P \leq 0 .01$); Punjab Fruit Research Station Lower Topa ($r = 0.89$, $P \leq 0.01$); Sherbagla ($r =$

0.64, , P ≤ 0.05); Rawat (r = 0.73, , P ≤ 0 .05); Tret (r = 0.92, P ≤ 0.01); Phugwari (0.80, P ≤ 0.01). In contrary, a non- significant correlation was observed between the soil Zn and organic matter at the Charhan (r = 0.53) and Dewal (r = 0.27) sites. The positive relation may be due to the formation of complexes between organic matter and Zn that protect it from leaching. Other important factor responsible for this relationship may be the chelating agents produced by the microorganisms present in the organic matter which enhance the micronutrient availability. Similar results have been advocated by Perveen *et al*. (1993).

Table 3: AB-DTPA Soil Zn critical values used for surveyed apple orchards

Micronutrient	Low	Marginal	Adequate
		µg g^{-1}	
Zn	< 0.9	0.9 - 1.5	> 1.5

Soltanpour (1985)

Table 4: Foliage Zn critical values used for surveyed apple orchards

Micronutrient	Low	Marginal	Adequate
		µg g^{-1}	
Zn	< 25	25 - 150	> 150

Neubert *et al*. (1970)

Negative non- significant correlation was observed between the soil Zn and $CaCO_3$ contents. Relationships for the soils of Derya Galli (r = -0.41); Charhan (r = -0.64); Murree (-0.95); Ghel (-0.82); Alyot (r = -0.43); Dewal (r = -0.78); Sunny bank (r = -0.48); Punjab Fruit Research Station Lower Topa (r = -0.58); Sherbagla (r = -0.58); Rawat (r = -0.60) , Tret (r = -0.75) and Phugwari (r = -0.64). This revealed that the $CaCO_3$contents are one of major factors limiting the Zn availability in the surveyed area. Zinc availability is mostly diminished in calcareous soils due to sorption to clays and carbonates, co-precipitation with carbonates or formation of insoluble compounds. Similar results were reported by Gupta *et al*. (2000).

Soil Zn availability correlated negatively or poor positively with pH at most of sites. Poor positive correlation was observed at Derya Galli (r = 0.25); Murree (r = 0.03); Alyot (r = 0.24); Sherbagla (r = 0.31); Phugwari (0.025); Charhan (r = 0.036). Non significant negative correlation was observed at Ghel (r = -0.65); Tret (r = -0.26); Ghora Galli (r = -0.45); Hill Fruit Research Station, Sunny Bank (r = 0.-0.29); Punjab Fruit Research Station, Lower Topa (r = -0.46); Rawaat (r = -0.46) and Dewal (r = -0.45). Similar correlations were reported by Nazif *et al.*, (2006) who studied the correlation of AB-DTPA extractable micronutrients with various physicochemical properties. Availability of Zn is affected by soil pH which decreases with increasing pH. Activity and consequently the bioavailability of Zn decrease hundred folds for each unit increase in soil pH in the range 4 to 9 (Lindsay, 1972).

Negative correlations were observed between Zn and sand at Derya galli (r = -0.41), Murree(r = -0.48); Alyot (r = - 0.50); Sherbagla (r = -0.13); Phugwari (-0. 69); Charhan (r = 0.036); Ghel (r = -0.032); Tret (r = -0.77); Ghora Galli (r = -0.83), Hill Fruit Research Station, Sunny Bank (r = 0.81), Punjab Fruit Research Station, Lower Topa (r = -0.76), Rawat (r = -0.46), and Dewal (r = -0.45) sites. It was observed that as sand percentage increases the available Zn decreases that might be due to low exchangeable capacity of sand. Similar relations were observed by Chinchmalatpure *et al.* (2000).

A positive non significant relationship between AB-DTPA extractable Zn and silt was observed. These relationship were as Derya Galli (r = 0.50), Murree (r = 0.18), Ghel (r = 0.068), Alyot (r = 0.032), Ghora Galli (r = 0.027), Hill Fruit Research Station Sunny Bank (r = 0.58), Punjab Fruit Research Station Lower Topa (r = 0.64), Sher Bagla (r = 0.094), Rawat (r = 0.065), Tret (r = 0.58), Phugwari (0.028) , Charhan (r = 0.18) and Dewal (r = 0.37) Similar information has been reported by Nazif *et al.* (2006). Correlation coefficient values between the clay and AB-DTPA extractable Zn of Darya Galli (r = 0.10), Murree(r = 0..33), Ghel (r = 0.086), Alyot (r = 0.019), Ghora Galli (r = 0.30), Hill Fruit Research Station Sunny Bank (r = 0.85), Punjab Fruit Research Station Lower Topa (r = 0.38,), Sherbagla (r = 0.015), Rawat (r = 0.49), Tret (r = 0.063), Phugwari (0.60) , Charhan (r = 0.33) and Dewal (r = 0.25) sites were positive. The reason for the positive correlation between the Zn and clay is that Zn occurs in silicate clay minerals. Results were in agreement with the findings of Patil and Sonar (1994) and Sharma *et al*. (1996).

Relationship between plant Zn and soil characteristics

Zinc concentration in the diagnostic apple leaves (Figure 3) ranged from 10 to 24 µg g^{-1} with the mean value of 17 ± 4.8. The critical level (Table 4) in recently matured leaves of apple trees is 25 µg g^{-1} (Neubert *et al*., 1970). Using this criterion, all the surveyed apple orchards were deficient in Zn. Deficiency of Zn in plants was widespread irrespective of the Zn deficiency or adequacy in soils. Poor or no relationship existed between the soil and plant Zn contents. Zinc deficiency was most common and general in the plants as compared to the soils in apple orchards. A non-significant positive correlation (r = 0.57) was observed between the soil organic matter and plant Zn contents. Soil rich in organic matter is not only adequate in the

micronutrients but also contains natural chelates that are important for the movement of micronutrients towards roots.

Negative correlation existed between the plant Zn and soil pH (r = 0.28). This may be due to the limited supply of micronutrients to roots as pH increases. Sand and silt did not correlate with foliage zinc contents. It indicated that correlation of other physico-chemical properties with foliage contents do not allow the evaluation of soil fertility in that area.

contents of these orchards, which plays an important role in adsorption of Zn in soils (Olsen, 1972)

Conclusion

Plant analysis indicated that there was an acute Zn deficiency in the apple orchards of tehsil Murree. However, soil revealed less deficiency in the area. Deficiency of Zn in foliage was general and widespread irrespective of its deficiency or adequacy in soils. Calcareousness and alkaline pH of the soil are the main contributing factors for low plant available Zn in the surveyed area. Zinc

Table 5: Correlation Coefficient values of AB-DTPA Zn contents with various soil Physio-chemical properties of surveyed apple orchards

Orchard's Location	Sand	Silt	Clay	pH	Organic Matter	$CaCO_3$
Derya Galli	- 0.41**	0.50**	0.10**	0.25**	0.68*	-0.41**
Murree	- 0.48**	0.18**	0.33**	0.03**	0.94*	-0.95*
Alyot	- 0.50**	0.068**	0.086**	0.24**	0.87*	-0.41**
Sherbagla	- 0.13**	0.032**	0.019**	0.31**	0.64	-0.58*
Phagwaarri	- 0.69**	0.027**	0.30**	0.025**	0.80*	-0.64**
Charhan	- 0.036**	0.58**	0.85**	0.036**	0.53**	-0.64**
Ghel	- 0.032**	0.64**	0.38**	- 0.65**	0.86*	-0.82**
Tret	- 0.77**	0.094**	0.015**	- 0.26**	0.92*	-0.75**
Ghora Galli	- 0.83**	0.65**	0.49**	- 0.45**	0.64*	-
Sunny Bank[1]	- 0.81**	0.58**	0.063**	-0.29**	0.89*	-0.48**
PFR[2]	- 0.76**	0.028**	0.60**	-0.46**	0.89	-0.58**
Rawat	- 0.46**	0.18**	0.33**	- 0.46**	0.73*	-0.60**
Dewal	- 0.45**	0.37**	0.22**	- 0.45**	0.27**	-0.78**

Sample Size= 130

1 Punjab Fruit Research Hill Station, Sunny Bank

2 Punjab Fruit Research Hill Station, Lower Topa

*Significant correlation coefficient

**Non significant correlation coefficient

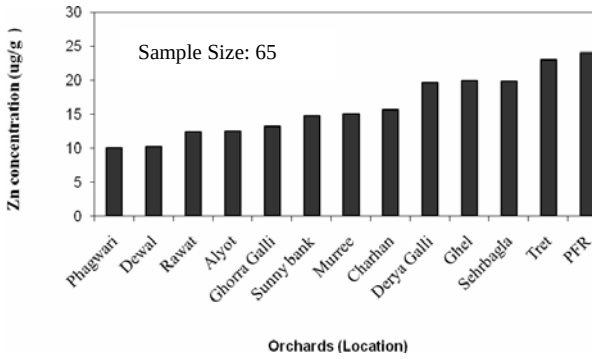

Figure 3: Plant Zn concentration of surveyed apple orchards

Reasons for the deficiency of Zn in the soils of apple orchards located in the union councils, i.e., Derya Galli, Charhan, Alyot and Tret might be due to the higher $CaCO_3$ application may yield improvement in apple production and helps to bridge the gap not only in terms of production but also improvement in quality. There is a need to make up Zn deficiency in apple trees through field experimentation to recommend the appropriate Zn fertilizer rates. Soil Zn critical values should be re-assessed for fruit crops.

References

Cakmak, I. and H. Marschner. 1988. Increase in membrane permeability and exudation in roots of zinc deficient plants. *Journal of Plant Physiology* 132: 356-361.

Chapman, H.D. and P.F. Pratt. 1961. Method of Analysis for Soil, Plants and Water. University of California, Berkeley, CA, USA.

Chapman, H.D. 1966. Zinc. p. 484-499. *In*: Diagnostic Criteria for Plants and Soils. H.D. Chapman (ed.). University of California, Division of Agricultural Science, Riverside, California.

Chinchmalatpure, A.R. Brij-Lal, O. Challa and J. Sehgal. 2000. Available micronutrient status of soils on

different parent materials and landforms in a micro-watershed of Wunna catchment near Nagpur (Maharashtra). *Journal of Agropedology* 10(1) 53-58.

Celik, H. and A.V. Katkat. 2007. Some parameters in relation to iron nutrition status of peach orchards. *Journal of Biological and Environmental Sciences* 1: 111-115.

Gee, G.W. and J.W. Bauder. 1982. Hydrometer method. p. 383-411. *In:* Methods of Soil Analysis Part 1, 1st Ed. A. Klute (ed.). American Society of Agronomy, No. 9. Madison, WI, USA.

GOP. 2008. Agricultural Statistics of Pakistan. Ministry of Food and Agriculture Economic Wing, Govt. of Pakistan, Islamabad.

Gupta, G.P., R.S. Khamparia, B.L. Sharma and Y.M. Sharma. 2000. Extractable micronutrients in relation to properties of some red and yellow soils of Madhya Pradesh. *Annals of Agricultural Research* 21: 522-526.

Leoppert, R.H., C.T. Hallmark and M.M. Koshy. 1984. Routine procedure for rapid determination of soil carbonates. *Journal of Soil Science Society of America* 48: 1030-1033.

Lindsay, W.L. 1972. Inorganic phase equilibria of micronutrients in soils. p. 41-57. *In:* Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Soil Science Society of America, Inc. Madison, Wisconsin USA.

Mclean, E.O. 1982. Soil pH and lime requirement. p. 199-209. *In:* Methods of Soil Analysis part 2: Chemical and microbiological properties. A.L. Page, R.H. Miller and D.R. Keeney, (2nd eds.). American Society of Agronomy, No. 9. Madison, WI, USA.

Milne, R.M. and R.J. Haynes. 2003. Soil organic matter, microbial properties, and aggregate stability under annual and perennial pastures. *Biology and Fertility of Soils* 39(3): 172-178.

Nazif, W, S. Perveen and I. Saleem. 2006. Status of micronutrients in soils of district Bhimber (Azad Jammu and Kashmir). *Journal of Agricultural and Biological Sciences* 1(2) : 35-40.

Nelson, D.W. and L.E. Sommers. 1982. Carbon, organic carbon and organic matter .p. 539-580. *In:* Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. Page, A.L., R.H. Miller and D.R. Keeney (eds.). American Society of Agronomy. No. 9. Madison, WI, USA.

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

Olsen. 1972. Micronutrient interactions. p. 243-261 *In:* Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Soil Science Society of America, Inc. Madison, Wisconsin USA.

Patil, Y.M. and K.R. Sonar. 1994. Status of major and micronutrients of swell-shrink soils of Maharashtra. *Journal of Maharashtra Agricultural University* 19(2): 169-172.

Perveen, S., M. Tariq, Farmanullah, J.K. Khattak and A. Hamid. 1993. Study of micronutrient status of some important sites of N.W.F.P., Pakistan. *Sarhad Journal of Agriculture* 9(5): 467-473.

Rashid, A., E. Rafique, N. Bughio and M. Yasin. 1997. Micronutrient deficiencies in rainfed calcareous soils of Pakistan. IV. Zinc nutrition of sorghum. *Communications in Soil Science and Plant Analysis* 28: 455-467.

Rashid, A. and J. Ryan. 2004. Micronutrient constraints to crop production in soils with Mediterranean-type characteristics: A review. *Journal of Plant Nutrition* 27: 959–975.

Sharma, B.D., P.S. Sidhu, S. Gurmel, S.S. Mukhopadhyay and G. Singh. 1996. Elemental distribution and mineralogy of arid zone soils of Punjab. *Journal of the Indian Society of Soil Science* 44(4): 746-752.

Siddiqui, I.A., S.S. Shaukat and M. Hamid. 2002. Role of zinc in rhizobacteria mediated suppression of root-infecting fungi and root-knot nematode. *Journal of Phytopathology* 150: 569-575.

Siddique, M., M.T. Siddique., S. Ali and A.S. Javed. 2009. Macronutrient assessment in apple growing region of Punjab. *Soil and Environment* 28(2): 184-192.

Sillanpaa, M. 1990. Micronutrient assessment at the country level: An international study, FAO Soils Bulletin 63. FAO/Finish International Development Agency, Rome, Itlay.

Soltanpour, P.N. and S. Workman. 1979. Modification of $NaHCO_3$ DTPA soil test to omit carbon black. *Communication in Soil Science and Plant Analysis* 10: 1411-1420.

Soltanpour, P.N. 1985. Use of AB-DTPA soil test to evaluate elemental availability and toxicity. *Communication in Soil Science and Plant Analysis* 16(3): 323-338.

Woodbridge, C.G. 1954. Zinc deficiency in fruit trees in the Okanagan Valley in British Columbia. *Canadian Journal of Agricultural Sciences* 34: 545-551.

Wojcik, P. 2007. Vegetative and reproductive responses of apple trees to zinc fertilization under conditions of acid coarse textured Soil. *Journal of Plant Nutrition* 30: 1791 -1802.