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Macronutrient assessment in apple growing region of Punjab

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Abstract

This study was undertaken with the aim of examining soil and plant macronutrient status (N, P, K, Ca, Mg and S) and their interaction to understand causes of low apple yield. Murree region was studied being major apple cultivated area in Punjab. Surveyed apple orchards were selected from all union councils of Murree. Out of thirteen orchard sites, soils of seven sites have been classified as clay loam, three sandy clay loam, two clayey and one loam. Electrical conductivity varied from 0.12 to 2.00 dS m^{-1} at surface and 0.12 to 1.60 dS m^{-1} at subsurface soil. Surface soil pH ranged from 7.2 to 8.4. Orchard soils were low in nitrogen, phosphorus, sulphur and potassium. Calcium was deficient in all the orchards sites while a general deficiency of magnesium was observed in the area. Apple orchards were deficient in foliage nitrogen, potassium and magnesium but sufficient in phosphorus and calcium contents. Both in soil and foliage, there was a general deficiency of nitrogen, potassium and sulphur. A variable trend of correlation between plant and surface, subsurface N, P, K, Ca, Mg and S was established. Insufficient nutrient status of apple orchards could be the major concern for low yield in the area.

Key words: Apple, macronutrients, soil, plant

Introduction

Plant growth, productivity and eminence are closely related to nutrients concentration of plants. For optimum fruit production, nutrients concentration should be at sufficient level in plants. Factors relevant to nutrient availability to plants are mainly governed by evaluating soil fertility status (Marschner, 1995). Nitrogen (N) and phosphorus (P) affect fruit size, color and seed development. P deficiency causes fruit coarseness in texture and rough in appearance, increase in acid contents and delayed maturity. Potassium (K) deficiency in fruits can check rate of photosynthesis and it can reduce carbohydrates production and increase fruit creasing and drop. Resistance of the plants against the drought and cold is also weakened due to K deficiency. Premature fall of fruits, reduced fruit size, low concentration of acid in the fruit are all the consequences of low K level in the soil (Zekri *et al*., 2003). Presence of calcium (Ca) in optimum concentration in plant tissues helps in reduction of ethylene production, overdue ripening and senescence, improve fruit quality and increase fruit resistance to diseases (Carl and William, 1984).

The availability of nutrients at different growth stages in leaves and fruits of apple trees indicated that concentration of N, P and K in leaf decreased; Ca increased and magnesium (Mg) did vary significantly along the plant vegetative cycle. In fruits, initially nutrient concentration decreases quickly and then remains almost constant until the end of fruit maturation. K was the nutrient present in the highest quantity in apple tree fruits and thus, a large amount is removed from the soil (Nachtigall and Dechen, 2006).

Yield and quality of major fruit crops grown in the country is low, mainly due to N and P deficiency (Obreza *et al.*, 1993; Aziz *et al.*, 2004). Nutrient status of soils of Galliyat area, district Abbottabad, Pakistan had 50 and 54 percent deficiency of N and P, respectively (Khattak and Hussain, 2007). Evaluation of P and K in leaves revealed their deficiency in apple orchards of Swat district. Out of fifty foliage samples, 62 percent were marginal to deficient in P and 48 percent samples were deficient in K content (Haq *et al.*, 1996).

AB-DTPA extractable P was medium in 15 and sufficient to high in 78 percent soil samples, while K contents were deficient in eleven percent samples of citrus orchards in Swat valley (Sharif *et al*., 1998). Foliage P, K, Ca and Mn contents were deficient in 69, 24, 64 and 11 %, respectively, in apple orchards. It was also observed that the soils of these apple orchards were deficient in respective nutrients (Erdal, 2005).

Total cultivated area of apple orchards of Punjab is 400 hectares (ha) and 93 percent is mainly in Murree with average yield of 3.1 Mg ha^{-1} which is too low as compared to world average yield of 12 Mg ha^{-1} (Economic Survey of

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Pakistan, 2008). Evaluation of macronutrients (N, P, K, Ca, Mg and S) status and the relationship between soil and foliage contents was the primary aim of this research work to diagnose causes of low apple yield in the Murree area.

Materials and Methods

A survey for soil and foliar sample collection of apple orchard was conducted in Murree area. Representative samples were collected from union councils using global positioning system (GPS) for precise site identification or position on the Earth's surface (Table 1). Laboratory analysis of the collected samples was performed at PMAS Arid Agriculture University, Rawalpindi. Five apple trees were selected from each orchard for soil and plant samples collection.

Table 1. Global positioning and textural class of sites of apple orchards in Murree area

Union Council	Latitude	Longitude	Texture
Murree	33°55' 13.47"	73°23' 59.20"	Clay Loam
Ghora Gali	33°53' 09.41"	73°23' 02.05"	Clay Loam
Sunny Bank[a]	33°55' 02.29"	73°23' 32.44"	Clay Loam
PFR[b]	33°53' 19.69"	73°25' 55.52"	Sandy Clay Loam
Phugwari	33°53' 53.65"	73°26' 02.53"	Clay Loam
Charehan	33°51' 58.36"	73°27' 44.79"	Clay Loam
Tret	33°52' 53.58"	73°21' 13.32"	Loam
Alyot	33°56' 41.84"	73 °28' 11.02"	Clayey
Darya Gali	33°57' 07.67"	73°21' 52.07"	Sandy Clay Loam
Devil	33°57' 39.75"	73°20' 17.65"	Clay Loam
Sher Bugla	33°55' 12.31"	73°27' 38.56"	Sandy Clay Loam
Ghail	33°50' 14.19"	73°29' 13.31"	Clay Loam
Rawat	33°55' 53.39"	73°19' 15.73"	Clayey

[a]Punjab Fruit Research Hill Station, Sunny Bank
[b]Punjab Fruit Research Hill Station, Lower Topa

Sampling and processing of soil and foliage

Soil samples were taken from area under the canopy of five selected apple trees of each orchard in every union council at two depths i.e., surface (0-15 cm) and sub surface (15-30 cm). During this survey, 130 soil samples were collected, dried, sieved through 2 mm sieve and accurately amassed for analysis. Plant samples comprised of 70-75 recently mature leaves collected in the month of July and August from 5 selected trees in each orchard. During this survey 65 foliar samples were collected from 13 apple orchards. Leaves were washed with distilled water, oven dried at 65 ^{0}C for 24 h, ground in Wiley-Mill and stored for the analysis.

Soils analyzed for their physical and chemical properties such as soil texture (Gee and Bauder, 1982), pH (Mclean, 1982), $CaCO_3$ percentage (Loeppert *et al*., 1984), electrical conductivity (Mclean, 1982), and organic matter (Nelson and Sommers, 1982). NO_3-N was determined using salicylic acid (Vendrell and Zupanic, 1990) and sodium bicarbonate method was adopted to determine the available P (Kuo, 1996). Exchangeable K was determined using ammonium acetate (Helmke and Sparks, 1996) and SO_4-S by calcium chloride dihydrate (Verma *et al.*, 1977). Soluble Ca and Ca + Mg were determined by versinate method (Richards, 1954). Plant samples were ashed for five hours at 550 ^{0}C and prepared aliquot was used for P determination by colorimetry (Ammonium Vanadate-Ammonium Molybdate Yellow color method) and K by flame photometer while Ca and Mg by atomic absorption spectrophotometer (Chapman and Pratt, 1961). SO_4-S (Verma *et al*., 1977) and total N (Anderson and Ingram, 1993) was determined using spectrophotometer. The data was analyzed statistically (Steel *et al*., 1997).

Results

Soil Analysis

Soil pH, ECe, OM and $CaCO_3$ had standard deviations i.e., 0.35, 0.56, 1.07 and 7.70, respectively, at surface and 0.28, 0.48, 0.70 and 7.90, respectively, at subsurface soil depth that reflects the variation of values from the mean value which is a good statistical indicator (Table 2). The soil pH of the orchards was normal to alkaline, ranged from 7.2 to 8.4 at surface and 7.5 to 8.4 at subsurface depth. Maximum soil pH at surface depth was found at the site Alyot and Chahrehan (Table 2). Higher trend of soil pH at surface and subsurface depth might be due to the presence of high $CaCO_3$ content at the respective depths. The soils of

apple orchards were normal from salinity point of view, varied from 0.12 to 2.00 dS m^{-1} at surface and 0.12 to 1.60 dS m^{-1} at subsurface depth. Surface soils had the maximum mean value of ECe (2.0 dS m^{-1}) at the sites of Alyot and Phugwari union councils (Table 2). Most of the union councils had more than 1 percent organic matter, possibly due to high rate of precipitation and low temperature in the region. Organic matter had a definite effect on the availability of different macronutrients. Similar information was disseminated by Khattak and Hussain (2007).

The data illustrated that all the selected apple orchards of Murree area were 100 percent deficient in exchangeable K contents. Soil K contents ranged from 44 to 73 mg K kg^{-1} at surface and 41 to 71 mg K kg^{-1} at subsurface depth. Soils of Alyot union council had lowest mean K values at surface

Table 2. Soil Chemical analysis of apple orchards in Murree area

Chemical characteristic	Depth(cm)	Standard Deviation	Mean	Minimum	Maximum
pH (1:1 suspension)	0-15	± 0.35	7.80	7.20	8.40
	15-30	± 0.28	7.90	7.50	8.40
ECe (dS m^{-1})	0-15	± 0.56	0.40	0.12	2.00
	15-30	± 0.48	0.30	0.12	1.60
O M (%)	0-15	± 1.07	2.50	1.20	4.10
	15-30	± 0.70	1.90	0.93	3.13
$CaCO_3$ (%)	0-15	± 7.70	10.5	0.35	23.3
	15-30	± 7.90	11.0	0.50	24.1

No. of samples per mean= 130

High percent value of calcium carbonate ($CaCO_3$) was perceived and ranged from 0.24 to 24.1 % in selected apple orchards. Soils of Chahrehan orchards had the maximum mean value of 23.3 % at surface (0-15 cm) and 24.1 % at subsurface (15-30 cm) soil while the Gorah Gali site had minimum mean value of 0.35 % in its surface (0-15 cm) and 0.50 at sub surface (15-30 cm) soils depth (Table 2). During our survey, seven sites were classified as clay loam, 3 sandy clay loam, 2 clayey and one loam in texture among 13 orchards. The soils with sandy clay loam texture suggested a slight removal of clay contents from upper soils due to erosion.

Primary and secondary nutrient contents in (figure 1) are arranged in descending order with respect to the relevant union council to exhibit trend of nutritional status in the region. The N content of apple orchards soils varied from 0.88 to 4.16 mg NO_3-N kg^{-1} at surface soil and 0.68 to 3.76 mg NO_3-N kg^{-1} at sub surface soil in different union councils in Murree (Table 3a and 3b). All the soil samples of the selected orchards were categorized deficient in N contents. The soil available P contents varied from 4.8 to 32.6 mg P kg^{-1} at surface and 3.80 to 28.00 mg P kg^{-1} at subsurface depth. Lowest P contents were diagnosed at the site of Alyot union council (Table 3a and 3b). Sixty two percent sites were categorized as marginal to deficient and 38 percent high in P contents (Table 6). Low concentration of N and P might be associated with losses through leaching or runoff due to high rate of precipitation in the area and light texture of the soils. Presence of high P (38 %) in orchards in spite of high $CaCO_3$ contents seems to be the result of occurrence of high organic matter in these soils. and sub surface depth while soils of Devil union council had the maximum K values at its surface soil (Table 3a and 3b). Nachtigall and Dechen (2006) reported that apple plant required more potassium and thus a large amount is removed from the soil.

All the soil samples of the selected orchards were categorized deficient in Ca (Table 6).The Ca content of apple orchards varied from 0.045 to 0.16 mg Ca kg^{-1} at surface soil and 0.03 to 0.13 mg Ca kg^{-1} at sub surface soil. Soils of Murree union council had the maximum Ca contents and soils of Chahrehan union council had the minimum one, at both the surface and sub surface soil depths (Table 3a and 3b). In spite of the prevalence of high percentage of $CaCO_3$ (> 15 %) in seventy percent surveyed apple orchards, Ca deficiency seems to be surprising. This finding indicates that there are some factors preventing Ca uptake by the plants and its availability in soil i.e., imbalance irrigation, and low transpiration rate due to high percentage of humidity in Murree area. The trend of high (64%) Ca deficiency in apple orchard was also supported by the research work conducted by Edral (2005).

Eighty five percent soils of orchards found sufficient and 15 percent were classified as deficient in Mg (Table 6). This information is also supported by Stevenson (1986) who advocated sufficiency of nutrients due to high values of soil organic matter of orchards (> 1 %) when compared to common agriculture soil. Soils of Punjab Fruit Research Hill Station, Lower Topa had maximum mean Mg contents (0.4 mg Mg kg^{-1}) at surface followed by 0.3 mg Mg kg^{-1} at subsurface soil, while soils of Tret union council had the

minimum mean value of 0.09 mg Mg kg^{-1} at both the surface and subsurface soils, respectively (Table 3a and 3b). Soils of all the apple orchards were classified as deficient in SO_4-S contents (Table 6) and varied between 2 and 10 mg SO_4-S kg^{-1} (Table 3a and 3b).

(Table 7). Potassium contents in foliage of apple orchard varied from 0.46 to 0.84 % (Table 4). The maximum mean values of K were found in the apple orchards of Alyot union council and minimum one in the orchards of Rawat union council. Prevailing K deficiency might be due to high

Table 3a. Macronutrient status of apple orchards in Murree area at surface[a] soil

		mg kg^{-1}		
Nutrient	**Standard Deviation**	**Mean**	**Minimum**	**Maximum**
NO_3-N	± 1.050	2.400	0.880	4.16
P	± 9.300	16.50	4.800	32.6
K	± 9.100	58.30	44.00	73.0
SO_4-S	± 1.800	7.600	4.000	10.0
Ca	± 0.035	0.925	0.045	0.16
Mg	± 0.790	0.200	0.090	0.40

No. of samples per mean=130
[a]0-15 cm depth

Table 3b. Macronutrient status of apple orchards in Murree area at subsurface[a] soil

		mg kg^{-1}		
Nutrient	**Standard Deviation**	**Mean**	**Minimum**	**Maximum**
NO_3-N	± 1.02	2.10	0.68	3.76
P	± 8.30	14.3	3.80	28.0
K	± 8.50	53.9	41.0	71.0
SO_4-S	± 2.30	4.40	2.00	9.00
Ca	± 0.02	0.06	0.03	0.13
Mg	± 0.05	0.17	0.09	0.30

No. Of samples per mean =130
[a]15-30 cm depth

Foliage Analysis

Macronutrients content pictured in figure 2 are arranged in descending order with respect to the relevant union council to exhibit trend of nutritional status in the region. All apple orchards were classified deficient in foliage N (Table 7). Among all sites, Rawat union council had maximum (1 %) N contents and Punjab Fruit Research Hill Station, Sunny Bank had the minimum (0.52 %) N contents (Table 4). Plant N contents in other sites ranged from 0.68 to 0.92 %. This information is also supported by the work of Asif *et al*. (1998). Foliage P contents were high in all apple orchards sites (Table 7). Foliage P contents in apple orchards of Deryia Galli Union council had the maximum mean value of 1.12 % while orchards of Charhan union council had minimum content with mean value of 0.54 % (Table 4). Apple orchards have low P requirements which are also confirmed by the sufficiency of plant P in contrary to marginal deficiency in soil P (Haynes and Goh, 1980).

A general deficiency of foliage K was observed through out the apple growing region which is also confirmed by the prevailing soil K deficiency in the area

requirement of K by the apple plants.

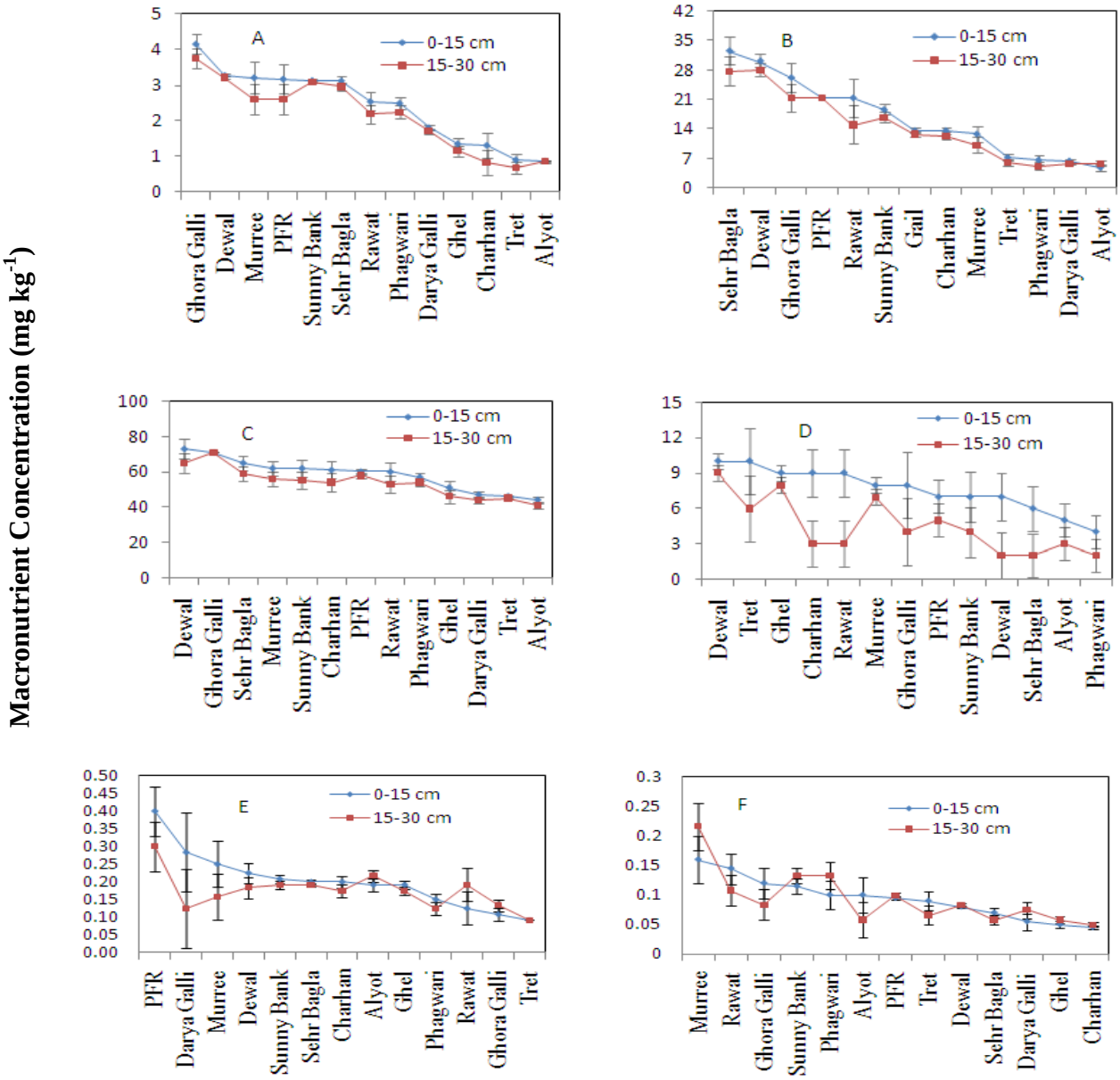
Ca contents in apple orchards varied from 1.87 to 4.82 % and it was found sufficient in all apple orchards of growing area. In contrary to Ca, a general deficiency of foliage Mg contents were observed in all selected apple growing sites and ranged from 0.13 to 0.30 %. SO_4-S contents of foliage were deficient in all the apple orchards (Table 7) and varied from 0.0046 to 0.0158 % (Table 4).These results are in line with the research findings of Erdal (2005). He reported sufficiency of Ca, while a general deficiency of Mg in foliar samples of apple orchards in Isparta province, Egypt.

Relationship of soil and foliage nutrients

A positive correlation of foliage N contents was established with surface and subsurface soil of apple orchards (Table 5 a and b) at the sites of union council Rawat (r = 0.90, 0.76), Daryia Galli (r = 0.46, 0.93), Gail (r = 0.40, 0.86) and Alyot (r = 0.32, 0.82). The P contents of surface soil had a positive correlation with foliar P having r value 0.72, 0.12, and 0.26 at the sites of union council Dewal, Phagwari, and Gorah Galli, respectively, while at

sub surface soil it had a positive correlation with r value 0.55, 0.57, and 0.15, respectively. The K contents at surface and sub surface soil depth had positive correlation with foliage contents of apple orchards with r = 0.69, 0.50, respectively, at the site of Punjab Fruit Research Hill Station Sunny Bank, followed by the sites of union council Murree (r = 0.68 and 0.50), Ghora Galli (r = 0.60, 0.54) Daryia galli (r = 0.46, 0.03) and Tret (r = 0.16, 0.41) at surface and sub surface soil depth, respectively.

The S contents of surface and sub surface soil had positive correlation with foliage nutrient contents of apple orchards at the site of Tret union council (r = 0.81 and 0.41) followed by the sites of Ghora Galli (r = 0.76 and 0.20), Punjab Fruit Research Hill Station, Lower Topa (0.30, 0.27) and Sehr Bagla (r = 0.15, 0.03), respectively. Most of the correlation exponent (r) had weak relationships. This poor soil plant relationship might be an effect of malnutrition of fruit trees due to infertile soils. The soil Ca



(PFR= Punjab fruit research hill station, Lower Topa, Sunny Bank = Punjab fruit research hill station, Sunny Bank)

Figure 1. Soil macronutrients status of apple orchards in Murree area (A. Nitrogen, B. Phosphorus, C. Potassium, D. Sulphur, E. Magnesium and F. Calcium)

contents at surface and subsurface, had positive correlation at the sites of Murree (r = 0.91, 0.51), Punjab Fruit Research Hill Station, Lower Topa (r = 0.79, 0.67), Gail (r = 0.50, 0.24) and Daryia Galli (r = 0.04, 0.16) with plant Ca. Soil Mg contents had also positive correlation at the sites of Devil (r = 0.92, 0.25), Punjab Fruit Research Hill Station, Lower Topa (r = 0.76, 0.05), Gail (0.75, 0.18) and Tret (r = 0.58, 0.58), respectively at the surface and subsurface soil depth. These findings are also supported by Zatylny and St-Pierre (2006). He described a significant correlation between the soil and foliar nutrient contents N, P and S in apple orchards.

Table 4. Foliar macronutrient status of apple orchards in Murree area

	%					
	N	**P**	**K**	**S**	**Ca**	**Mg**
Mean	0.80	0.74	0.61	0.0061	3.22	0.22
Minimum	0.52	0.54	0.46	0.0046	1.87	0.13
Maximum	1.00	1.12	0.84	0.0158	4.82	0.30
Standard Deviation	±0.123	±0.166	±0.129	±0.003	±0.817	±0.048

No. of samples per mean= 65

Contrary to the positive correlation in certain surveyed apple orchards, a negative correlation was also established in rest of the sites, which might be an effect of shallowness of the soil profile in hilly area. This variable trend of relation between soil and plant nutrients in surveyed apple orchards is also supported by the work of Khattak and Hussain (2007).

Conclusion

The findings of the present study demonstrate a general deficiency of soil nitrogen, potassium, calcium and sulphur in the region of apple orchards while plants exhibit nitrogen, potassium, magnesium and sulphur deficiency. The soil and the plant macronutrients content had site specific positive correlation. To cure these deficiencies in the region, there is a need of application of nutrients to the apple orchards for economical yield. Further more this information may be used as a guideline for fertilizer application and response of apple plants to applied nutrients in the region.

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Table 5a. Relation between foliage and surface, subsurface soil macronutrients of apple orchards in Murree area

Union Council	r					
	N		P		K	
	Surface[a]	Subsurface[b]	Surface	subsurface	surface	Subsurface
Ghel	0.40	0.86	-0.06	-0.33	-0.75	-0.67
Darya Gali	0.46	0.93	0.19	-0.78	0.46	0.03
Charhan	-0.74	-0.23	-0.29	0.38	-0.35	-0.45
Tret	-0.28	0.69	0.35	-0.28	0.16	0.41
Rawat	0.90	0.76	-0.76	-0.89	-0.44	-0.54
Sehrbagla	-0.37	0.74	-0.34	0.20	-0.56	-0.49
Murree	-0.51	0.18	-0.86	-0.86	0.69	0.50
Gorah Galli	-0.64	0.34	0.26	0.15	0.60	0.54
Phugwari	-0.85	0.70	0.12	0.57	-0.13	-0.10
Alyot	0.32	0.82	0.11	-0.06	0.22	-0.10
Sunny Bank	-0.09	0.43	0.00	0.00	0.63	0.91
PFR	-0.52	0.30	-0.61	0.41	-0.47	-0.74
Dewal	-0.21	0.32	0.72	0.55	-0.23	-0.26

[a]0-15 cm depth
[b]15-30 cm depth

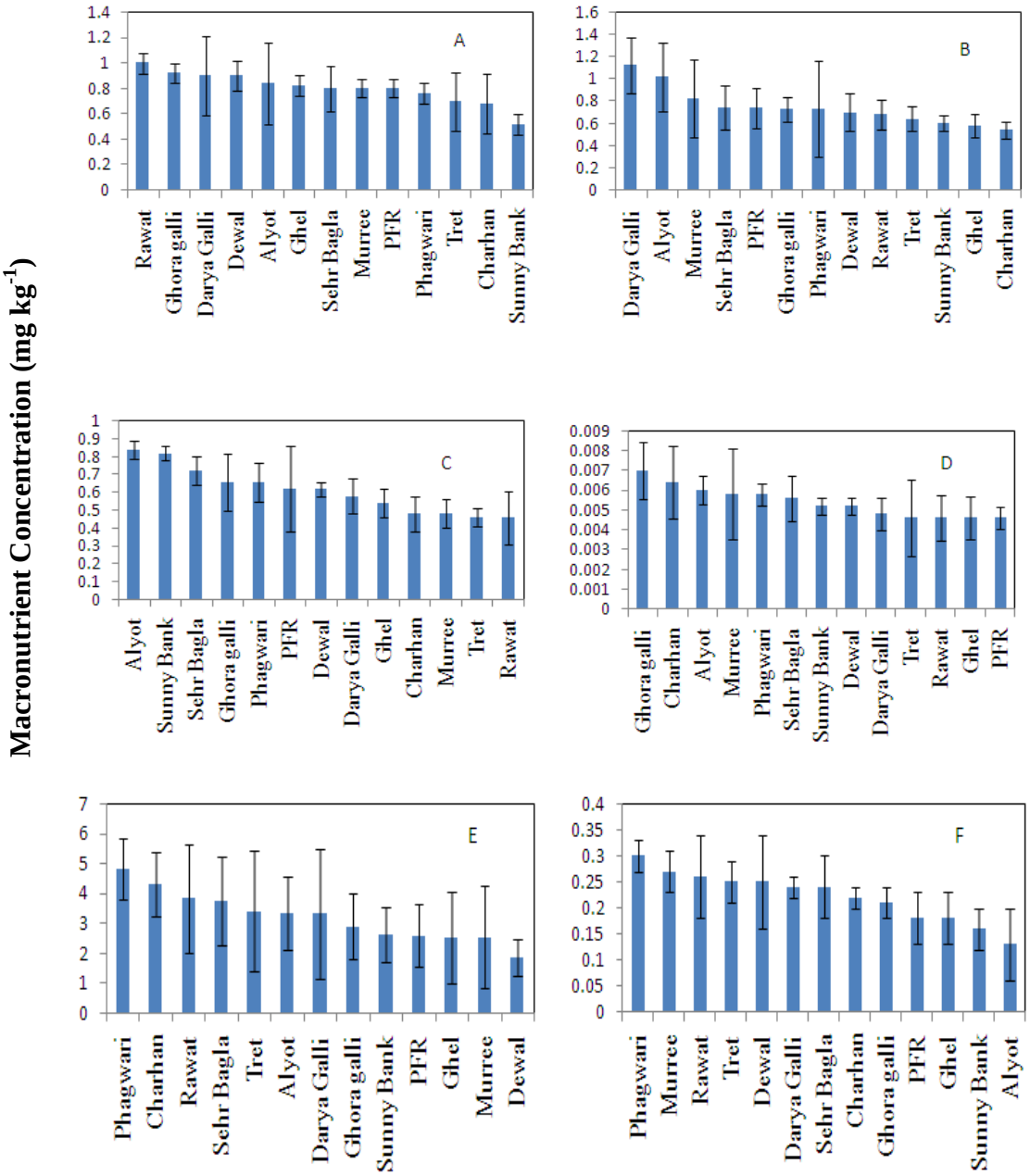
Table 5b. Relation between foliage and surface, subsurface soil macronutrients of apple orchards in Murree area

Union Council	r					
	Ca		Mg		S	
	surface	subsurface	surface	subsurface	surface	Subsurface
Ghel	0.50	0.24	0.75	0.18	-0.21	0.21
Darya Gali	0.04	0.16	0.02	-0.12	-0.25	-0.88
Charhan	-0.65	-0.67	-0.35	0.25	-0.04	0.41
Tret	-0.72	0.40	0.58	0.58	0.81	0.41
Rawat	-0.30	-0.16	0.35	-0.13	-0.66	-0.37
Sehrbagla	-0.52	0.19	-0.80	0.42	0.15	0.03
Murree	0.91	0.51	-0.19	-0.46	-0.57	-0.45
Gorah Galli	-0.76	-0.79	0.27	-0.22	0.76	0.20
Phugwari	-0.56	-0.84	-0.80	0.40	-0.35	-0.44
Alyot	-0.15	0.54	-0.06	-0.04	0.00	0.08
Sunny Bank	0.45	-0.36	-0.70	0.81	-0.08	-0.35
PFR	0.79	0.67	0.76	0.05	0.30	0.27
Dewal	-0.46	-0.70	0.92	0.25	0.09	-0.29

Table 6. Guideline criteria for classification of soil macronutrients

Element	Estimated Critical Level mg kg $^{-1}$		
	Deficiency	Normal	Excess
NO_3-N	<11	11-20	>20
P	<8	8-15	>15
K	<100	100-150	>150
Ca	<0.175	0.175-0.25	>0.25
Mg	<0.008	0.125-0.20	>0.41
SO_4-S	<10	11-30	>31

Cottenie *et al.* (1976), Soltanpour (1985)



(PFR= Punjab fruit research hill station, Sunny Bank= Punjab fruit research hill station, Sunny Bank)

Figure 2. Foliar Nutrient status of apple orchards in Murree area (A. Nitrogen, B. Phosphorus, C. Potassium, D. Sulphur, E. Calcium and F. Magnesium)

Table 7. Guideline criteria for classification of foliage macronutrients

Element	Estimated Critical Level %		
	Deficiency	**Normal**	**Excess**
N	<2.05	2.47-2.89	>3.31
P	<0.093	0.139-0.185	>0.231
K	<0.85	1.31-1.81	>2.31
Ca	<0.71	0.91-1.11	>1.31
Mg	<0.134	0.22-0.306	>0.392
SO_4-S	<0.15	0.15-0.40	>0.40

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