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Nutritional status of apple orchards in Kinnaur region of Himachal Pradesh

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ABSTRACT

The nutritional survey of 82 representative orchards was carried out in apple growing blocks of district Kinnaur of Himachal Pradesh. Maximum variation in leaf N, P, K, Ca and Mg contents was recorded in apple orchards of Nichar block. Deficiencies of N, Mg, Zn, B, Mn and Mo were quite common in the orchards of all the three blocks, but Ca and K were deficient in Nichar and Pooh blocks only. However, the deficiency of P was recorded in Kalpa and Pooh blocks only. Leaf analysis showed that 7.3, 7.3, 12.2, 13.4, 25.8, 31.7, 14.6 and 9.7% orchards were deficient in N, K, Ca, Mg, Zn, B, Mo and Mn, respectively. The soils of apple orchards were moderately acidic to slightly alkaline in soil reaction with normal electrical conductivity and rich in organic carbon. Variability in pH, EC, organic carbon (%), N, P, Ca, Mg, Zn, Cu and Mo contents was also observed the highest in the soils of apple orchards located in Nichar block, while K, Fe, Mn and B were found highly variable in orchards of Pooh block only. All the leaf and soil nutrients showed synergetic effect on fruit yield except Cu and Fe.

Key words: *Malus domestica*, soil and leaf nutrients, spatial variability.

INTRODUCTION

Apple is one of the most important fruit of Himachal Pradesh, since it occupies 49 percent of total area under fruit crops with an estimate production of 777 thousands tones over an area of 110.7 thousand hectares (Anonymous, 1). The yield levels of apple (7.02 t/ha) in the state are, however, far below the international standards of (30 t/ha). Royal Delicious is the most popular cultivar of Himachal Pradesh as table fruit due to its shape, colour, quality and marketability but has the disadvantages of low yield per unit area, high production cost, alternate bearing and susceptibility to disease. The low apple productivity as compared to international standards has been ascribed to various factors such as varietal, soil fertility, imbalanced nutrition, topography of land and incidence of pests and diseases. It is therefore, inevitable to consider the analysis assessing the nutritional availability of fruit growing crops with deep and ramified root system (Najar *et al*., 11). Nutritional imbalances in the soil cause nutritional disorders and consequently affect both quality and quantity of fruit. Soil and plant analysis are complimentary to each other, because at a time one component may or may not provide the requisite information. The nutritional analysis of soil and plant thus provides a valuable tool for understanding the nutrient supplying capacity of soil for ascertaining the relationship between available nutrients and leaf nutrient status and therefore predicting the yield levels (Dar *et al.*, 3).

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Like other hilly areas, the economy of district Kinnaur of Himachal Pradesh mainly dependent upon horticulture. The climate of this area due topographical variations and altitudinal differences provide congenial environment for growing high quality apple fruits. The apples of this region possess qualities at par with international standards for export purposes. In spite of increasing importance of apple as a commercial crop in this temperate region, no adequate scientific study concerning leaf diagnostic and soil fertility status had been made so far. Therefore, the study was conducted to carry out the nutritional survey of apple orchards of Kinnaur district through soil and leaf nutrient status andtheir relationship to use such knowledge as a tool in optimizing fertilizers use for better fruit yield and quality.

MATERIALS AND METHODS

The present study was carried out in Kinnaur region which extends from 30°22'40" to 33°12'40"N latitude and 75°47'55" to 79°04'20"E longitude (Fig 1.1 & 1.2). The district has unique climatic conditions having three typical microclimatic zones, *i.e.* Nichar, Kalpa and Pooh (sub-division/ block). Winters are severe with heavy snowfall (5220 mm) causing glaciers and avalanches particularly in some parts of Kalpa and Pooh blocks. Summers are mild with rainy season in most of the Kalpa and Nichar blocks of the district with lighter snowfall. Pooh block of this district forms a part of the 'Indian Cold Desert' and receives scanty rainfall (< 100 mm) but as it falls in rain-shadow zone of Himalayas.

The field surveys were undertaken on apple orchards with cultivar Royal Delicious, which is the widely cultivated in the district. Eighty-two geographical locations spread over three sub-divisions (Nchar-24, Kalpa-31 and Pooh-27) were selected in the district for collecting soil and leaf samples. Selected sites detail has been given in the Table 1. Geo-referenced

Table 1. Details of the selected apple orchards located in three apple-growing blocks of Kinnaur district.

Location	Latitude	Longitude	Elevation (m)
Nichar block			
Bari-I	31° 33' 09" N	077° 56'20.4"E	2195
Bari-II	31° 33'09.6" N	077° 56'32.9" E	2205
Bari-III	31° 33'11.7" N	077° 56'31.3" E	2179
Bari-IV	31° 33'09.7" N	077° 56'37.1"E	2230
Sungra-I	31° 33'28.3" N	077° 56'01" E	2020
Sungra-II	31° 33'16.5" N	077° 56'10.5" E	2089
Sungra-III	31° 33'09.4" N	077° 56'14.6" E	2180
Nichar	31° 33'24.6" N	077° 56'37.4"E	2045
Bara Kamba	31° 34'34.75" N	077° 53'09.1" E	2085
ChhotaKamba-I	31° 34'06.4" N	077° 54'32.9" E	2070
ChhotaKamba-II	31° 34'07.4" N	077° 54'29.2" E	2037
ChhotaKamba-III	31° 34'05.9" N	077° 54'36" E	2100
Chaura	31° 34'09.83" N	077° 51'10.7" E	1735
Nigulsari	31° 33'24.2" N	077° 52'52.16" E	1700
Kafnu	31° 36'48.1" N	078° 01'34.6" E	2447
Huri	31° 36'59.75" N	078° 01'34.81" E	2476
Kafnoo	31° 36'56.7" N	078° 01'27.6"E	2440
Yangpa	31° 36'56.2" N	078° 01'43.6" E	2546
Katgaon	31° 35'34.9" N	078° 02'12.7" E	2254
Chagaon-I	31° 32'08" N	078° 05'31.1" E	2523
Chagaon-II	31° 32'03.5" N	078° 05'28.9" E	2500
Chagaon-III	31° 32'03.36"N	078° 05'28.1"E	2488
Urni	31° 31'44.61"N	078° 07'50.5" E	2288
Urni	31° 31'37.2" N	078° 07'52.18" E	2240
Kalpa block			
Sangla	31° 25'29.25" N	078° 15'41.54" E	2587
Rakchham	31° 23'51" N	078° 20'40.70" E	3000
Batseri	31° 24'13.7" N	078° 18'17.6" E	2829
Sangla	31° 25'46.6" N	078° 16'14.4" E	2780
Kuppa-I	31° 25'59.1" N	078° 14'50.95" E	2578
Kuppa-II	31° 25'57.1" N	078° 14'46.8" E	2572
Kilba	31° 29'19.7" N	078° 08'11.7" E	1836
Purbani	31° 35'13.1" N	078° 17'51.76" E	2435
Talampi	31° 32'56.84" N	078° 18'00.92" E	2270
Tangling	31° 31'34.11" N	078° 16'54.4" E	1972
Barang	31° 30'24.20" N	078° 16'05.65" E	2373
Sharbo-I	31° 32'21.37" N	078° 16'34.81" E	2142
Sharbo-II	31° 32'16.65" N	078° 16'35.4" E	2160
Mebar-I	31° 35'31" N	078° 15'20.5" E	2810
Mebar-II	31° 35'28.2" N	078° 15'24.7" E	2758
Mebar-III	31° 35'29.6" N	078° 15'21.9" E	2795
Rali-I	31° 29'33.58" N	078° 12'24.03" E	2220
Rali-II	31° 29'35.17" N	078° 12'26.35" E	2170
Talangi	31° 33'32.9" N	078° 16'01.8" E	2501
Khwangi	31° 33' 28.7" N	078° 16'25.3" E	2244
Roghi	31° 30' 51.58" N	078° 13'50.84" E	2767
Kalpa	31° 32' 24" N	078° 15'02" E	2871
Duni-I	31° 32' 43.1" N	078° 15'23.5" E	2737
Duni-II	31° 32' 42.1" N	078° 15'25.3" E	2717
Pangi	31° 35' 29.8" N	078° 16'40.5" E	2737
Boktu	31° 34' 41.4" N	078° 16'30.7" E	2530
Kothi	31° 32' 51.9" N	078° 16'08" E	2394
Shaung	31°26' 39.82" N	078° 1155.22" E	2748
Brua	31° 27' 58.47" N	078° 10'43.71" E	2135
Sapni	31° 28' 52.9" N	078° 10'08.30" E	2420
Sudarang	31° 31'17.85" N	078° 15'50.40" E	2325
Pooh block			
Giabong-I	31° 46'31.2" N	078° 26'41.35" E	2891
Giabong-II	31° 46'53.79"N	078° 26'37.1" E	2985
Giabong-III	31° 46'51" N	078° 26'30.9" E	2965
Ropa	31° 47'49" N	078° 25'13" E	3035
Rushkulang	31° 46'11" N	078° 26'55.9" E	2814
Sunnam	31° 45' 40.92"N	078° 27'58.37" E	2823
Shialkhar	32° 00' 31.48"N	078° 34'13" E	3040
Chango	31° 58' 42.66"N	078° 35'43.67" E	3054
Nako	31° 53'32.1" N	078° 37'31.65" E	3459
Leo	31° 53'11" N	078° 35'31" E	2971
Dubling	31° 44'49.54" N	078° 38'01.63" E	2804
Pooh-I	31° 45'39.75" N	078° 35'10.95" E	2587
Pooh-II	31° 45'57.92" N	078° 35'26.3" E	2811
Nesang	31° 38'43.26" N	078° 31'12.97" E	3064
Spello	31° 39'45.88" N	078° 26'16.27" E	2694
Labrang	31° 40'57.31" N	078° 26'36.65" E	2830
Kanam-I	31° 40'33.6" N	078° 27'06" E	2766
Kanam-II	31° 40'34.8" N	078° 27'08.66" E	2805
Moorang	31° 35'54.5" N	078° 26'46.5" E	2475
Thangi	31° 33'23.29" N	078° 28'42" E	2815
Lippa	31° 39'32.4" N	078° 23'07" E	2660
Asrang	31° 40'02" N	078° 19'06" E	3242
Jangi	31° 36'36.2" N	078° 25'40.8" E	2705
Akpa	31° 35'18.8" N	078° 23'09" E	2500
Rarang	31° 36'06.6" N	078° 21'13.7" E	2668
Rispa	31° 34'35.4" N	078° 25'18.3" E	2447
Ribba	31° 35'06.8" N	078° 21'37.6" E	2564

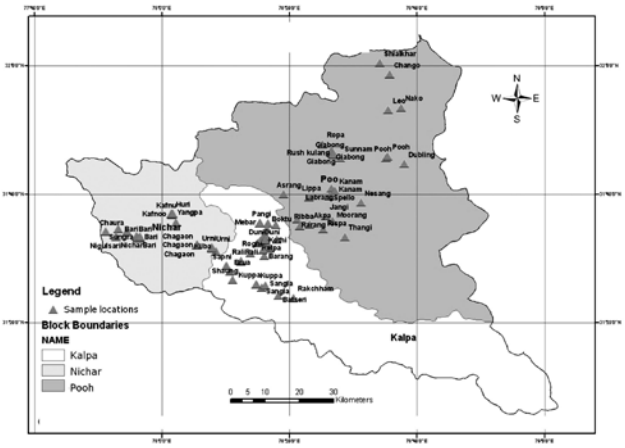

Fig. 1. Geographical location of the study area.

and stratified soil and leaf samples were collected at a grid size varying from 1.0 to 1.5 km^2 depending on the homogeneity of the area from the selected locations/ orchards. Four hundred and ten surface (30 cm) soil samples covering three blocks of district Kinnaur were collected with an auger during first week of November to third week of December. Leave samples (about fifty leaves per tree from middle of terminal shoot growth) were collected from the same tree/ orchard from which soil samples were collected between July 20 and end of the August during the year 2011-12.

The soil samples were ground and passed through 2 mm stainless steel sieve. These samples were analyzed for pH, electrical conductivity (EC), and organic carbon (OC) by standard methods (Jackson, 6). Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 16) and available P by Olsen *et al*., (12). Available K and exchangeable Ca and Mg were extracted using 1N neutral ammonium acetate solution (Jackson, 6) and were estimated using atomic absorption spectrophotometer(AAS Model AA-7000, Lab India).Available Cu, Zn, Fe and Mn were extracted as per the procedure described by Lindsay and Norvell (9) and estimated using atomic absorption spectrophotometer (AAS Model AA-7000, Lab India). Available B and Mo were extracted in hot water and acid ammonium oxalate of pH 3.3 solution and then determined by Carmine (Hatcher and Wilcox, 5) and stannous chloride (Johnson and Arkley, 7) methods, respectively.

The leaf samples were washed and dried as per the method described byKenworthy (8). Total N was determined by micro-Kjeldahl method, P by vanadomolybdate-phosphoric yellow colour method as suggested by Jackson (6). The K, Ca, Mg, Cu, Zn, Fe and Mn in the digest were estimated on atomic absorption spectrophotometer. The leaf B and Mo were determined by carmine (Hatcher and Wilcox, 5) and thiocyanate stannous chloride (Johnson and Arkley, 7) methods, respectively. The data were then categorized as deficient, low, optimum and high (above optimum) in leaf nutrient content in accordance with the working standards for apples (Kenworthy, 8). Orchards found between deficient and optimum range have been categorized as low and those above the optimum range as high (above optimum) in leaf nutrient status. About five to six trees per location was selected to record yield per tree and total fruit yield was estimated, accordingly. The data were analyzed statistically as per Panse and Sukhatme (13) and to establish the relationship between various parameters, the data were subjected to correlation analysis.

RESULTS AND DISCUSSION

The concentration of N, P, K, Ca and Mg in the leaves varied from 1.60-2.60, 0.18-0.33, 0.9-1.80, 0.9-2.10 and 0.24-0.45 percent, respectively (Table 2). The respective mean values for these nutrients were 2.25, 0.24, 1.50, 1.52 and 0.31 percent. The data further revealed that the maximum variation in leaf N, P, K, Ca and Mg contents were found in Nichar block with the highest values of coefficient of variation (12.30, 13.16, 14.82, 20.90 and 18.15%, respectively) followed by Kalpa and Pooh block orchards. Categorization of the leaf samples (Table 3) on the basis of standard concentrations of nutrient elements for foliar analysis of apple, revealed that in the different blocks 3.2-20.8% orchards were found deficient in leaf N, 79.2-96.8% in optimum and 0-11.1% were above optimum range in N (1.81-2.50%) with an overall mean values of 7.30, 89.0 and 3.7% in the district, respectively. Similarly, 0-6.5% orchards in different blocks with an overall mean value of 2.4% were deficient in leaf P, 74.1-93.5% in different blocks with mean value of 85.4% were in optimum range and 12.5-25.9% were above optimum range (0.19-0.28%) in different blocks in leaf P status with an average value of 12.2%. In K status, 7.4-16.7% orchards were deficient and 83.3-92.6% were in optimum range (1.21-1.80%) in different blocks with average values of 7.3 and 92.7%, respectively. However, 7.4-29.2% orchards were found to be in the insufficient range of leaf Ca in different blocks with an average value of 11.0% and 66.6-100% were in optimum range (1.21-1.80%) in different blocks with mean value of 82.9% along with 0-14.8% were in above optimum range in different blocks. While leaf Mg was found deficient in 11.1-16.1% orchards in different blocks with an average value of 13.4% and 66.7-83.9% were in optimum range(0.25-0.36%) in different blocks with mean value of 74.4% and 18.6-20.8% above optimum with an average value

Table 2. Leaf nutrient contents in orchards located in three blocks of Kinnaur district.

Nutrient	Nichar		Kalpa		Pooh		Overall mean	
	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)
				Macronutrient				
N(%)	1.60-2.40 (2.07)	12.30	1.80-2.50 (2.27)	6.42	2.10-2.60 (2.37)	6.50	1.60-2.60 (2.25)	9.80
P(%)	0.20-0.32 (0.25)	13.16	0.18-0.26 (0.22)	9.20	0.21-0.33 (0.26)	12.00	0.18-0.33 (0.243)	13.26
K(%)	0.90-1.70 (1.42)	14.82	1.30-1.70 (1.55)	6.43	1.20-1.80 (1.53)	11.00	0.90-1.80 (1.50)	11.20
Ca(%)	0.90-1.80 (1.40)	20.90	1.30-1.70 (1.52)	6.62	1.20-2.10 (1.62)	15.51	0.90-2.10 (1.52)	15.60
Mg(%)	0.24-0.45 (0.32)	18.15	0.24-0.36 (0.29)	12.0	0.24-0.40 (0.32)	15.54	0.24-0.45 (0.31)	15.80
				Micronutrient				
Fe(ppm)	164-390 (278.60)	25.16	98-337 (216.45)	27.44	98-358 (209.44)	39.80	98.00-390.00 (232.33)	32.90
Mn(ppm)	23-71 (46.67)	28.61	24-78 (47.06)	31.75	29-80 (52.00)	27.64	23.00-80.00 (48.60)	29.51
Zn(ppm)	11-35 (23.42)	28.80	15-45 (27.00)	27.45	15-46 (29.00)	28.85	11.00-46.00 (26.60)	29.30
Cu(ppm)	10-28 (14.03)	29.41	8.50-25 (16.06)	26.06	12.4-24.6 (14.37)	21.40	8.50-28.00 (14.91)	26.12
B(ppm)	17.7-36.5 (27.1)	25.67	24-38 (29.85)	11.00	18-45 (31.06)	19.05	17.70-45.00 (29.46)	16.80
Mo(ppm)	0.48-0.78 (0.61)	17.20	0.48-0.84 (0.59)	15.10	0.44-0.85 (0.63)	18.10	0.44-0.85 (0.61)	16.04

Figure in the parentheses are mean values.

Table 3. Leaf nutrient status of orchards located in three apple-growing blocks of Kinnaur district.

Nutrient	Nichar				Kalpa				Pooh				Overall mean			
	D	L	O	H	D	L	O	H	D	L	O	H	D	L	O	H
N	-	20.8	79.2	-	-	3.2	96.8	-	-	-	88.9	11.1	-	7.3	89.0	3.7
P	-	-	87.5	12.5	-	6.5	93.5	-	-	-	74.1	25.9	-	2.4	85.4	12.2
K	4.2	12.5	83.3	-	-	-	100	-	-	7.4	92.6	-	1.2	6.1	92.7	-
Ca	4.2	29.2	66.6	-	-	-	100	-	-	7.4	77.8	14.8	1.2	11.0	82.9	4.9
Mg	-	12.5	66.7	20.8	-	16.1	83.9	-	-	11.1	70.3	18.6	-	13.4	74.4	12.2
Fe	-	-	-	100	-	-	12.9	87.1	-	37.1	62.9	-	-	-	17.1	82.9
Mn	4.2	12.5	83.3	-	3.2	6.5	90.3	-	-	3.7	96.3	-	2.4	7.3	90.3	-
Zn	16.6	20.8	62.5	-	-	19.4	80.6	-	-	25.9	74.1	-	4.9	20.9	73.2	-
Cu	-	4.2	87.5	8.3	-	3.2	80.7	16.1	-	-	92.6	7.4	-	2.4	86.6	11.0
B	16.7	25.0	58.3	-	-	25.8	74.2	-	3.7	25.9	70.4	-	6.1	25.6	68.3	-
Mo	-	12.5	87.5	-	-	16.1	83.9	-	-	14.8	85.2	-	-	14.6	85.4	-

D = Deficient, L = Low, O = Optimum, H = High (Above optimum).

of 12.2% in the district. Thus, on an average 7.3% of the orchards were below N optimum level because farmers apply nitrogenous fertilizers, 2.4% in P, while 7.3% deficient in K suggesting a need to incorporate of muriate of potash in fertilizer schedule. About twelve percent of the orchards were categorized as low in Ca level because there is abundant leaching of $CaCO_3$in sand rich soils and also Ca has tendency of lesser translocation in plant system from soil, thus suggesting application of Ca based fertilizers and foliar sprays and 13.4% orchards were also deficient in Mg and low Mg status has been explained by antagonistic effect of soil Ca on Mg uptake by plants.

The leaf overall Fe, Mn, Zn, Cu, B, and Mo contents of Kinnaur apple orchards ranged from 98-390, 23-80, 11-46, 8.50-28, 17.7-45 and 0.44-0.85 ppm, respectively (Table 2) and the respective mean values for these nutrient elements were 232.3, 48.6, 26.6,14.91, 29.46 and 0.61 ppm. The data further indicates that the maximum variation in leaf Cu and B contents was observed in Nichar and for Mn in Kalpa block with the highest values of coefficient of variation i.e. 29.4, 25.67 and 31.75%, respectively. However, the variation in leaf Fe, Zn and Mo contents were maximum in Pooh block with highest coefficient of variation values. Regarding the status of leaf Fe content, 12.9-62.9% samples were in optimum range in different blocks with an average value of 17.1% (20.1-50.0 ppm)in the district (Table 3) and in Kalpa and Nicharblocks 87.1 and 100% leaf samples were found in high category, respectively. The leaf Mn status indicated that 0-4.2% samples were deficient, 3.7-12.5% low and 83.3-96.3% were in optimum range (30.1-150 ppm)in different blocks with an average values of 2.4, 7.3 and 90.3%, respectively. Similarly, 0-16.6% samples in different blocks were deficient in leaf Zn with an average value of 4.9%, and 20.8-25.9% was low with mean value of 20.9% and 62.5-80.6% was in optimum range (20.1-50.0 ppm)with an average value of 73.2% in the district. However, 0-4.2% samples were in the insufficient rangewith respect to leaf Cu in different blocks with an average value of 2.4%, 80.7-92.6% samples were in optimum range (10.1-20.0 ppm) in different blocks with mean value of 86.6%, and 7.4-16.1% was in above optimum range with a mean value of 11% in the district. While leaf B was found to be deficient in 0-16.7% samples in different blocks with an overall average value of 6.1%, whereas 25-25.9% samples were in low category with mean value of 25.6% and 58.3-74.2% samples were in optimum range (28.1-50.0 ppm) with an average value of 68.3% in the district. Similarly, 12.5-16.1% samples were low in leaf Mo in different blocks with a mean value of 14.6% and 83.9-87.5% samples in optimum range (0.51-1.50 ppm) in different blocks with an overall average of 85.4% in the apple orchards of the Kinnaur. Thus, on an average 31.7, 26.8, 14.6, 9.7, and 2.4 % samples were deficientwith respect toleaf B, Zn, Mo, Mn and Cu contentsin apple orchards of Kinnaur. This may be partially because orchardistsof area are not well aware of the usefulness of applications of micronutrients, whereas it is a common practice in other districts of the state. All the orchards were adequate in Fe and Cu because their solubility and availability has increased in slightly acidic soil reaction prevalent in these areas.However, based on overall average about 11.0 and 82.9% samples were found in above optimum range for leaf Cu and Fe contents in apple orchards because farmers are applying Fe micronutrient formulations without getting their soil and leaf tested and Cu based fungicides but toxicity symptoms are not recordedany of the orchards under investigations

The soils of the apple orchards surveyed were sandy loam to sandy clay loam in texture (feel method). The soil pH varied from 5.53 to 7.55 in different bocks with an average value of 6.69 (Table 4). Apple trees can thrive well in nearly acidic to slightly alkaline soil environment. These values were within the range for apple crop. The pH values of the district indicate that soil reaction is not a major constraint for obtaining higher yields of apple. The electrical conductivity indicates about salt concentration of soil and it varied from 0.11 to 0.86 dS m^{-1} in apple orchards of the district with an average value of 0.26 dS m^{-1} (Table 4). The EC values were also within the optimum range for the growth of apple crop. The organic carbon content varied from 0.84-5.55% with an average value of 3.25% (Table 4). The higher addition of organic manure mostly FYM during winter months and the continuous mineralization of organic matter in the surface soils may be responsible for higher values of organic carbon.

The perusal of data in table 5 shows that the available N, P, K, Ca and Mg in the soils varied from 250-672 Kg/ha, 14-188 Kg/ha, 168-829 Kg/ha, 570-2090 ppm and 395-1663 ppm, respectively in different blocks of the district Kinnaur. The respective mean values for these macronutrient elements were 508.7 kg/ha, 72.04 kg/ha, 439.2 kg/ha, 1431.6 ppm and 995.9 ppm. The high altitude soils under temperate climate have high contents of macronutrients as compared to the low altitude, warm, humid and sub-tropical climates(Singh and Datta, 15). This can be attributed to reduced rate of mineralization under temperate climate of the region and fertilizer P accumulation in the surface soils because of its low mobility to lower depths. High K status could

Table 4. Soil characteristics of orchards located in three apple-growing blocks of Kinnaur district.

Parameter	Nichar		Kalpa		Pooh		Overall mean	
	Range	CV(%)	Range	CV(%)	Range	CV(%)	Range	CV(%)
pH	5.53-7.19 (6.46)	6.80	5.86-7.14 (6.65)	5.08	6.13-7.55 (6.94)	5.30	5.53-7.55 (6.69)	6.3
EC (dS m^{-1})	0.14-0.86 (0.24)	61.5	0.11-0.62 (0.26)	37.0	0.17-0.51 (0.28)	27.70	0.11-0.86 (0.26)	41.9
OC (%)	1.35-4.50 (2.71)	35.0	0.84-4.73 (3.37)	26.7	1.29-5.55 (3.60)	32.34	0.84-5.55 (3.25)	32.5

Figure in the parentheses are mean values.

Table 5. Available soil macro- and micro-nutrient concentration in orchards located in three apple-growing blocks of Kinnaur district.

Nutrient	Nichar		Kalpa		Pooh		Overall mean	
	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)
				Macronutrient				
N(Kg ha^{-1})	250-672 (474.1)	27.9	280-650 (505.1)	19.3	350-652 (543.7)	17.8	250.0-672.0 (508.7)	21.7
P(Kg ha^{-1})	16-183 (73.0)	67.5	21-188 (74.8)	54.9	14-161 (67.9)	61.4	14.0-188.0 (72.04)	60.2
K(Kg ha^{-1})	251-827 (475.5)	32.0	168-826 (480.0)	36.7	177-829 (360.2)	38.2	168.0-829.0 (439.2)	37.5
Ca(ppm)	570-1890 (1258.2)	30.8	650-1920 (1428.4)	22.8	950-2090 (1589.5)	18.2	570.0-2090.0 (1431.6)	24.8
Mg(ppm)	395-1663 (933.5)	33.6	470-1350 (972.4)	23.9	598-1400 (1078.5)	18.1	395.0-1663.0 (995.9)	25.4
				Micronutrient				
Fe(ppm)	7.0-42.2 (22.28)	45.60	3.7-69.7 (32.09)	48.00	2.80-24.70 (11.41)	54.80	2.80-69.70 (22.41)	64.00
Mn(ppm)	13-31 (21.94)	26.12	12-33 (19.70)	28.00	11.50-37.00 (20.87)	35.30	11.50-37.00 (20.74)	30.00
Zn(ppm)	0.50-4.90 (2.29)	50.46	0.9-4.1 (2.62)	35.42	1.0-3.80 (2.17)	41.87	0.50-4.90 (2.37)	42.17
Cu(ppm)	0.90-2.70 (1.53)	30.80	1-2.90 (1.80)	24.36	0.80-2.10 (1.42)	27.00	0.80-2.90 (1.60)	28.50
B(ppm)	0.36-0.80 (0.52)	21.65	0.42-1.00 (0.72)	22.60	0.38-1.70 (0.79)	42.21	0.36-1.70 (0.68)	35.90
Mo(ppm)	0.14-0.39 (0.25)	30.05	0.12-0.36 (0.25)	20.40	0.17-0.40 (0.28)	22.75	0.12-0.40 (0.26)	24.66

Figure in the parentheses are mean values.

be ascribed to the fact that the clay complex of this region is a mixture of muscovite, smectite, vermiculite and kaolinite. The apple orchards of the area are well supplied with available Ca and Mg as the soils are young and there was not much leaching of base cations. The maximum variation in soil N, P, Ca and Mg contents were observed in the apple orchards located in Nichar block with highest coefficient of variation values, i.e. 27.9, 67.5, 30.8 and 33.6% respectively. However, the variation was highest in Pooh block for soil K content, having maximum coefficient of variation value (38.2%). The data in table 5 also revealed that available Fe, Mn, Zn, Cu, B, and Mo contents in the soils ranged from 2.80-

69.7, 11.5-37.00, 0.50-4.90, 0.80-2.90, 0.36-1.70 and 0.12-0.40 ppm, respectively and the respective mean values for these micro nutrient elements were 22.41, 20.74, 2.37, 1.60, 0.68 and 0.26 ppm. The data further indicate that the maximum variation in available Zn, Cu and Mo contents was observed in Nichar block with the highest value of coefficient of variation, respectively. However, the variation in available Fe, Mn and B contents were highest in Pooh block with the maximum values of coefficient of variation.

For comparing soil analysis data with leaf composition values, simple correlation coefficients were worked out (Table 6). Correlation between soils and leaf analysis values showed significant and positive relationship for N, Mg, Mn, Zn, Cu, B and Mo. The other soil nutrient had positive but non-significant correlation with their contents in the leaf. The nitrogen in the soil showed significant and positive relation with leaf P, K, Ca, Mg, Mn, Zn, B and Mo contents. Similarly, soil Ca and Mg showed positive and significant correlation with leaf Mo only. However, Fe content in the soil had negative correlation with most of the nutrients and significant only with P and Mn contents in the leaf. The relationship between soilMn was found positive and significant with leaf Zn contents only. Similarly, available soil Zn showed positive and significant correlation with leaf N, K, Ca, Cu and B content but negative with Mo only. However, Cu content in the soil have negative and significant relationship for most of the nutrients in the leaf except for Ca contents, where it has positive but non-significant correlation. However, B content in the soil had significant and positive correlation with most of the leaf nutrient contents and negative and non-significant only with Fe and Mo. The relationship between soil Mo was found positive and significant with leaf Mg contents only. Similarly, Walker and Mason (17) also reported significant and positive correlation between leaf and soil samples for Ca, K and P in apple orchards.

In the present study, correlations were not perfect for some nutrient elements, which may probably be due to the influence of weather and ion antagonism as observed by Walker and Mason (17). The plausible explanation for this may also be because the nutritional status of the majority of the orchard soil was moderate. In fact, above critical level in the plant only small changes in the plant nutrient contents may occur despite marked increase in the nutrient availability in the soil. On the other hand, several factors other than nutritional status have great influence on leaf composition, *e.g.* atmospheric temperature and moisture conditions etc. Further confirmations for the present findings also come from studies on other fruit orchards such as grapes, apples, pear, and peaches (Azad *et al*., 2).

Statistically highly significant and positive correlation was found with soil organic carbon, available soil N, Zn, B and Mn with fruit yield (Table 7). Singh (14) also reported the positive effects of N on fruit yield. Significant and positive correlations between fruit yield and soil OC, N and Zn have also been reported earlier (Singh, 14; Mamgain, 10). However, other soil nutrients showed positive but non-significant correlation with the fruit yield except Cu and Fe content, which has negative but non-significant relationship. Similarly, leaf N, P, K, Ca, and Mg showed highly significant positive correlation with fruit yield (Table 8). The positive relationship of macronutrients with fruit yields seems to be mediated through their involvement in vital physiological processes of the plants and enhanced photosynthesis (Delvin and Witham, 4). As far as micronutrients

Table 6. Correlation between soil and leaf nutrient contents of apple orchards.

Soil nutrient	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Mo
N	0.770**	0.339**	0.517**	0.577**	0.294**	-0.098	0.381**	0.766**	-0.043	0.359**	0.242*
P	0.113	-0.049	0.001	0.051	0.091	0.021	0.111	0.126	0.053	0.051	-0.121
K	0.073	0.019	-0.002	-0.104	0.119	-0.056	0.046	0.073	0.195	0.092	-0.063
Ca	0.138	0.067	0.072	0.044	0.216	-0.086	0.037	0.097	-0.111	0.138	0.395**
Mg	0.057	0.109	0.001	-0.009	0.258*	-0.067	0.072	0.058	-0.108	0.133	0.397**
Fe	-0.162	-0.368**	0.043	-0.124	-0.211	0.079	-0.219*	-0.145	0.193	-0.124	-0.185
Mn	0.155	0.057	0.068	0.101	-0.087	0.076	0.667**	0.297**	-0.093	0.048	0.058
Zn	0.316**	0.061	0.372**	0.304**	-0.009	0.108	0.208	0.321**	0.223*	0.240*	-0.257*
Cu	-0.146	-0.162	-0.148	0.148	-0.279*	-0.063	-0.327**	-0.236*	0.625**	-0.062	-0.337**
B	0.382**	0.253*	0.289**	0.350**	0.109	-0.008	0.046	0.295**	0.119	0.687**	-0.142
Mo	0.101	0.118	-0.030	0.073	0.281*	-0.046	-0.040	0.118	-0.109	0.163	0.566**

*,**Significant at 1 and 5% levels

Table 7. Correlation of soil characteristics and available nutrients with yield of apple orchards.

Parameter	Yield	Soil macronutrient	Yield	Soil micronutrient	Yield
pH	0.12	N	0.84**	Fe	-0.06
EC	0.14	P	0.13	Mn	0.26*
OC	0.67**	K	0.06	Zn	0.33**
		Ca	0.12	Cu	-0.27*
		Mg	0.05	B	0.36**
				Mo	0.13

*,**Significant at 1 and 5% levels

Table 8. Correlation of leaf nutrients with yield of apple orchards.

Macronutrient	Yield	Micronutrient	Yield
N	0.84**	Fe	-0.09
P	0.44**	Mn	0.40**
K	0.54**	Zn	0.85**
Ca	0.60**	Cu	0.01
Mg	0.31**	B	0.52**
		Mo	0.19

*,**Significant at 1 and 5% levels

are concerned, Zn, Mn, and B showed a significant positive relationship with fruit yield. Zinc and B controls the auxin level and nucleic acid in plants and found closely related to plant growth, differentiation and crop yield.

Thus, the results of the present study amply elucidated variability in soil properties, plant available soil nutrients and leaf nutrient contents in the apple orchards of Kinnaur region. Spatial variability consolidated a strong need and potential for the development of site-specific recommendation for the management of soil fertility and plant health besides improving yield levels for higher quality and sustained productivity of apple in the district. It is important to emphasize here that spatial leaf and soil nutrients database provides a strong reason to develop a more reliable site-specific fertilization programme that involves a consistent reduction in fertilizers in order to avoid economic and potential environmental problems derived from a homogeneous/blanket fertilizer usage in the orchards and useful to apple farmers of the region also.

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