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Soil fertility and leaf nutrient status of macro-nutrients in mango orchards under Kangra district of Himachal Pradesh

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Abstract
Based on uniformity in respect of age and tree vigour, 30 representative orchards were selected and "Dashehri" variety of mango was selected for study. Soil (0-15 and 15-30 cm depths) and plant (leaf) samples collected from mango orchards were analyzed for physico-chemical properties (texture, pH, EC, OC) and macro-nutrients (N, P, K, Ca, Mg, S). The soils were coarser in nature having sandy loam to sandy clay loam texture and were nearly neutral in reaction. The electrical conductivity values were in safe limits (less than 0.8 dSm^{-1}). The organic carbon contents were medium to high. The per cent coefficient of variations found high in soil and plants could be due to variations in parent material and orchard management practices. Organic carbon was positively and significantly correlated with N and P. Available N, K, Mg and S exhibited positive and significant relationship with their respective leaf nutrient contents.

Keywords: mango, orchard, macro-nutrients, coefficient of variation

Introduction
Mango (*Mangifera indica* L.) is an important fruit crop of economic importance in India. The states where commercial cultivation is taken up are Uttar Pradesh, Andhra Pradesh, Bihar, Gujarat, Karnataka, West Bengal, Tamil Nadu and occupies an area of 2163.47 thousand ha with a production of 18526.98 thousand MT and ranks first in India. The corresponding figures for mango in Himachal Pradesh are 41.11 thousand ha and 47.61thousand MT and covers the sub-mountainous parts of Kangra, Hamirpur, Bilaspur and Una district (Anonymous, 2014) [2]. The productivity of this crop is below national average which could be due to imbalanced use of fertilizers and improper orchard management practices. Nutrition of fruit plants depends upon inherent ability of soils to supply nutrient elements. The key to mineral nutrition of the plants is the judicious application of fertilizers based on laboratory analysis values. Plant analysis is used to confirm the suspected deficiencies and toxicities of nutrients and also to assess the efficiency of fertilizer treatments.

Soil nutrition of mango is an important part of orchard management practices (Ravishankar *et al*, 2010) [15]. Essential nutrients have specific role in the plant and their presence is must for the plant to complete its life cycle. Information on mineral nutrient status helps in diagnosis of nutritional problems and estimation of the fertilizer needs of trees. To ascertain these, both soil and plant analyses are necessary as these are complementary to each other and one supplies the information that the other may not. The information on nutritional status of both soil and plant helps understand about adequate fertilization of the orchards. Practically, no systematic work has been undertaken on the nutritional status of mango orchards in Kangra district. The present investigation will help in formulation of future nutritional studies and in working out accurate fertiliser recommendations for this area.

Materials and Methods
The studies were conducted during 2016 in Kangra district of Himachal Pradesh. Thirty representative mango orchards were selected for the study. Trees were of uniform age, size and vigour. Leaf samples were collected from 30 trees in each orchard during 15 June to 15 July. The soil samples from two (0-15 and 15-30 cm) depths were drawn from the basin of the trees from which leaf samples were collected. The soil samples (<2 mm) were processed and air dried. Leaf samples comprising of 25-30 leaves (latest mature flush from middle of the

terminal growth) were collected from 8-10 randomly selected trees in each selected orchard as per the sampling time i.e.15 June- 15 July. Soil analysis was carried out for texture, pH, EC, OC and available macronutrients (N, P, K, Ca, Mg, S). The texture of the soil was determined by Hydrometer method (Bouyoucos, 1927) [4]. The soil pH was estimated in 1:2 soil:water suspension and the electrical conductivity of the supernatant liquid was recorded as per the method detailed by Jackson (1973) [8], organic carbon (Walkley and Black, 1934) [22]. Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [21], available P by Olsen's method (Olsen *et al*. 1954) [12] and determined by stannous chloride reduced ammonium molybdate method (Jackson, 1973) [8], available K by neutral normal ammonium acetate (Merwin and Peach, 1951) [9]. Available Ca and Mg were determined by using ammonium acetate extract by atomic absorption spectrophotometer (Sarma *et al*, 1987) [16]. SO_4^{--}-S was extracted by Morgan's reagent (Morgan, 1937) [11].

The leaf samples were washed with ordinary water and then with 0.1N HCL followed by washing with distilled water. They were dried in an oven at 60 $\pm$ 5ºC for 72 hours. The dried samples were ground in stainless steel grinder to facilitate proper mixing of plant material and stored in paper bags for subsequent analysis (Chapman, 1964) [5]. Total N was determined by microkjeldhal method, P by vanadomolybdate phosphoric yellow colour method (Jackson, 1973) [8] and K by the flame photometric method (Jackson, 1967) [7]. Ca and Mg in the digest were estimated on atomic absorption spectrophotometer and S by turbidimetric method (Chesnin and Yien, 1950) [6]. The data were analyzed in software SPSS version 16.0 and other data analyses were done using MS Excel.

Results and Discussion

Soil analysis

The data on soil texture, pH, EC, OC and available macronutrients are presented in Table 1. The soils were coarser in nature having sandy loam to sandy clay loam texture. The pH of surface soils varied from 6.03 to 7.59 with mean value of 6.82, whereas the sub-surface soils had a pH range of 6.01 to 7.64 with mean value of 6.95 indicating that orchard soils are having pH near neutrality. The EC values of surface soils ranged from 0.08 to 0.32 dSm^{-1} with the mean value of 0.18 dSm^{-1}, whereas, in sub-surface soils ranged from 0.07 to 0.28 dSm^{-1} with mean value of 0.15 dSm^{-1}. The organic carbon content varied from 7.65 to 17.85g kg^{-1} in surface and 6.75 to 16.65 g kg^{-1} in sub-surface soils with the mean value of 12.49 g kg^{-1} and 11.48 g kg^{-1}, respectively.

Table 1: Available macro-nutrient content in the orchard soils

Soil parameter	Surface soil (0 to 15 cm)			Sub-surface soil (15 to 30 cm)		
	Range	Mean	CV(%)	Range	Mean	CV(%)
Texture	Sandy loam			Sandy clay loam		
Sand	56-77	64.43	8.06	47-57	51.50	5.88
Silt	17-26	19.80	9.51	22-35	26.90	13.82
Clay	5-23	15.90	32.46	17-27	21.60	13.52
pH	6.03-7.59	6.82	7.37	6.01-7.65	6.95	6.92
EC (dSm^{-1})	0.08-0.32	0.18	34.08	0.07-0.28	0.15	34.01
OC (g kg^{-1})	7.65-17.85	12.49	24.52	6.75-16.65	11.48	25.99
N (kg ha^{-1})	266.56-398.27	313.70	22.03	257.15-363.77	299.49	10.13
P (kg ha^{-1})	22.40-67.20	43.46	28.64	20.16-62.72	38.30	30.50
K (kg ha^{-1})	292.32-749.28	479.29	25.95	271.04-715.68	437.47	27.88
Ca[cmol (p^+) kg^{-1}]	3.07-5.91	4.69	24.54	3.01-5.62	4.36	24.43
Mg[cmol (p^+) kg^{-1}]	2.02-3.30	2.50	24.77	1.34-2.90	2.18	24.89
S (kg ha^{-1})	12.60-19.74	15.95	21.21	9.80-15.82	13.98	21.68

A perusal of data in Table 1 shows that the available contents of N, P, K, Ca, Mg and S in surface soils ranged from 266.56 to 398.27 kg ha^{-1}, 22.40 to 67.20 kg ha^{-1}, 292.32 to 749.28 kg ha^{-1}, 3.07 to 5.91 [cmol (p^+) kg^{-1}], 2.02 to 3.30 [cmol (p^+) kg^{-1}] and 12.60 to 19.74 kg ha^{-1}, respectively; whereas their respective contents in the sub-surface layers ranged from 257.15 to 363.77 kg ha^{-1}, 20.16 to 62.75 kg ha^{-1}, 271.04 to 715.68 kg ha^{-1}, 3.01 to 5.62 [cmol (p^+) kg^{-1}], 1.34 to 2.90 [cmol (p^+) kg^{-1}] and 9.80 to 15.82 kg ha^{-1}, respectively. As regards the depthwise distribution of available macronutrient elements, the concentration of N, P, K, Ca, Mg and S decreased as the soil depth increased. Similar pattern of distribution of these elements has also been reported by Singh (1987) [19] and Sharma (1988) [17].

Table 2: Nutrient indices of surface and sub-surface soils of Kangra district

Nutrient	Percentage of samples rating			Nutrient Index	Nutrient Status
	Low	Medium	High		
Surface Soil Depth (0-15 cm)					
N	15	85	-	1.83	Medium
P	-	5	95	2.93	High
K	-	-	100	3.00	High
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High
S	-	-	100	3.00	High
Sub-surface Soil Depth (15-30 cm)					
N	30	70	-	1.70	Medium
P	-	10	90	2.90	High
K	-	5	95	2.93	High
Ca	-	-	100	3.00	High

Mg	-	-	100	3.00	High
S	-	5	95	2.93	High

The perusal of data in Table 2 indicate that the nutrient indices of surface soils, as regards the nutrient status were high in available phosphorus (2.93), potassium (3.00), available calcium (3.00), available magnesium (3.00) and sulphate sulphur (3.00). In the sub-surface layers, the nutrient status were high in available phosphorus (2.90), potassium (2.93), available calcium (3.00), available magnesium (3.00) and sulphate sulphur (2.93)

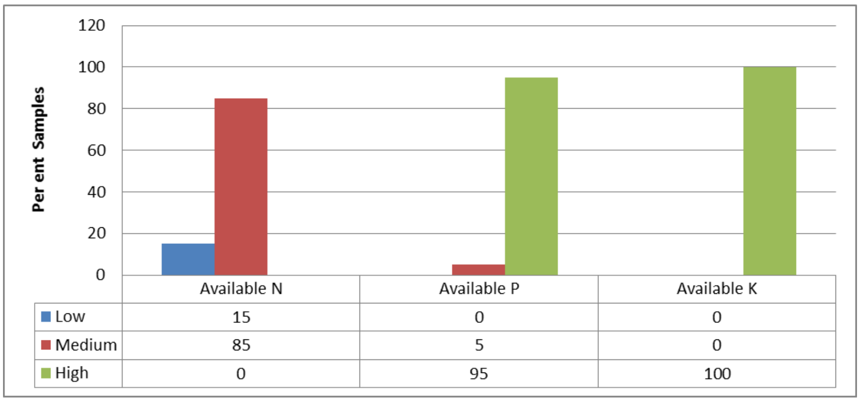

Fig 1: Per cent surface soil samples in different categories for N, P and K

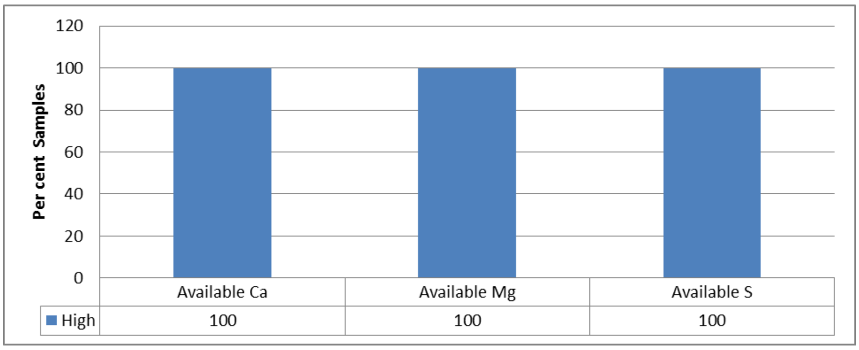

Fig 2: Per cent surface soil samples in different categories for Ca, Mg and S

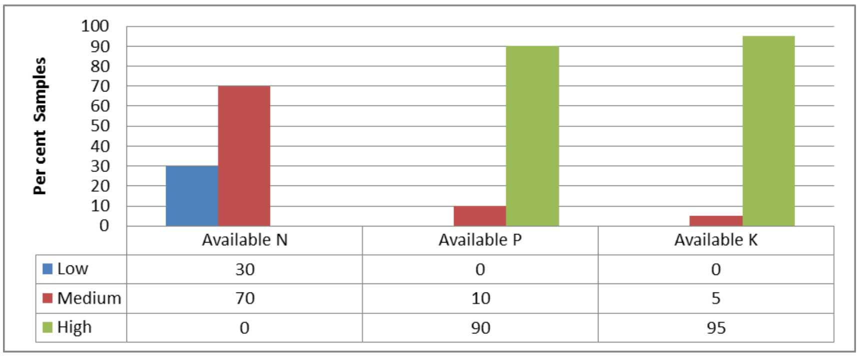

Fig 3: Per cent sub-surface soil samples in different categories for N, P and K

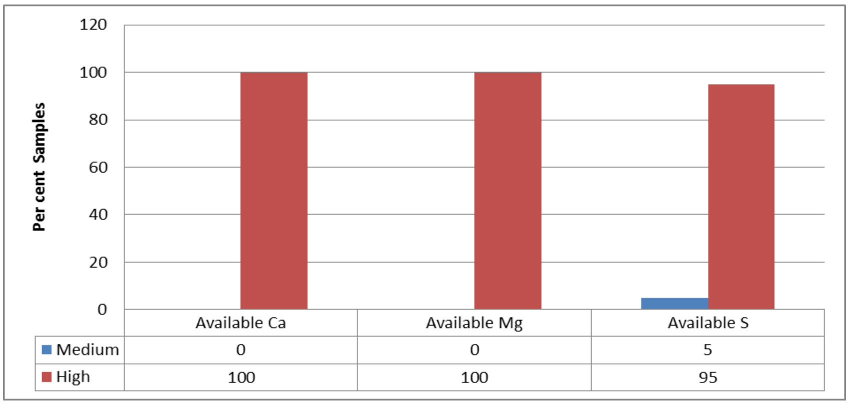

Fig 4: Per cent sub-surface soil samples in different categories for Ca, Mg and S

Leaf analysis

The data on N content in mango leaves presented in Table 3 indicate a variation in content from 1.12 to 2.24 per cent with the mean value of 1.61 per cent. Forty five per cent of the orchards fell in optimum range for N, whereas 55 per cent orchards were found in high categories. The P concentration ranged from 0.14 to 0.27 per cent with the mean value of 0.20 per cent. Eighty and 20 per cent of the samples fell in medium and high categories, respectively. The K content varied from 0.35 to 0.94 per cent with an average value of 0.59 per cent. Ninety per cent orchards were found to be in medium range and 10 per cent were of high range (Table 4).

Table 3: Macro-nutrient contents in the leaves of mango

Nutrient element	Range	Mean	CV (%)
Macronutrients (per cent)			
N	1.12-2.24	1.61	24.39
P	0.14-0.27	0.20	20.70
K	0.35-0.94	0.59	26.72
Ca	2.20-5.14	3.29	29.70
Mg	0.42-1.48	0.85	32.64
S	0.24-0.65	0.45	27.79

Table 4: Plant nutrient status of mango orchards of Kangra district

Nutrient	Percent samples		
	Low	Medium	High
N	-	45	55
P	-	80	20
K	-	90	10
Ca	-	80	20
Mg	-	10	90
S	-	100	-

The data in Table 3 shows that Ca, Mg and S content ranges from 2.20 to 5.14, 0.42 to 1.48 and 0.24 to 0.65 per cent with the mean value of 3.29, 0.85 and 0.45 per cent, respectively. Eighty and 10 per cent samples were found in medium category for Ca and Mg whereas, 20 and 90 per cent were found in high category for Ca and Mg. Hundred per cent samples were found in medium category for S (Table 4).

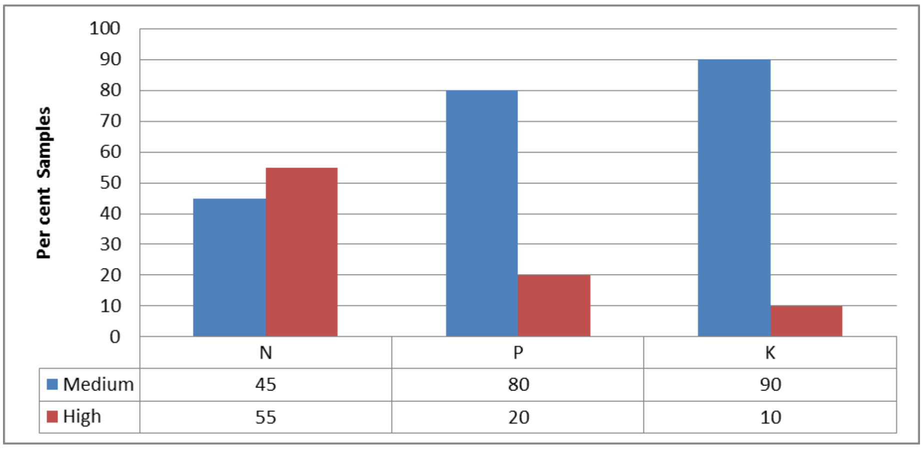

Fig 5: Per cent leaf samples in different categories for N, P and K

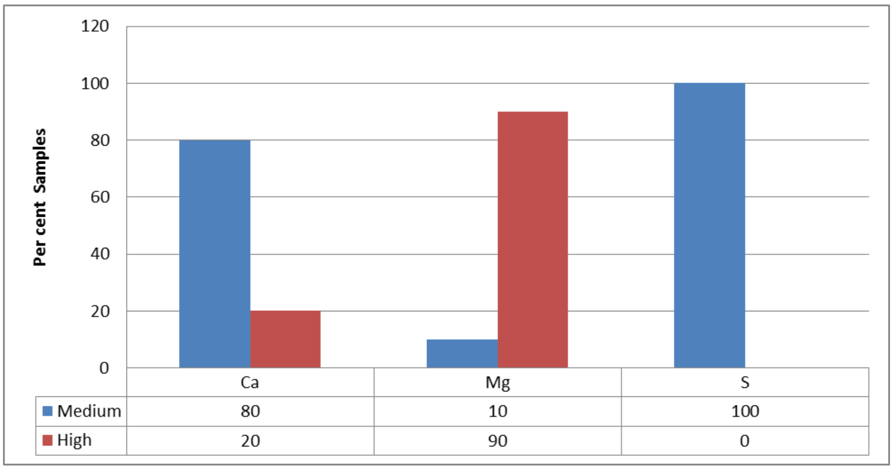

Fig 6: Per cent leaf samples in different categories for Ca, Mg and S

Relationship between chemical properties of soil and available macro-nutrients

The perusal of the data in Table 5 shows the relationship of nutrient elements with soil pH, EC and organic carbon contents. The data reveals that the soil pH of the surface layers was significantly and positively correlated with available P (r = 0.38*). For the sub-surface layers, the soil pH was significantly and positively correlated with available P (r = 0.36*). The electrical conductivity of the surface layers was found to be significantly and positively correlated with available P (r = 0.36*) and Mg (r = 0.46**). For the sub-surface layers, a significantly positive correlation existed between EC and Mg (r = 0.42**). The organic carbon content in the surface soils was significantly and positively correlated with available N (r = 0.97**) and P (r = 0.45**). For the sub-surface layers the organic carbon was found to be positively correlated with soil N (r = 0.91**) and P (r = 0.46**) which were found to be significant.

Table 5: Relationship (r-values) of soil chemical properties with available macro-nutrients

Property	Soil pH		Electrical Conductivity		Organic carbon	
Nutrient Element	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-15	15-30	0-15	15-30	0-15	15-30
N	0.16	0.17	-0.29	-0.27	0.97**	0.91**
P	0.38*	0.36*	0.36*	0.34	0.45**	0.46**
K	-0.18	-0.07	0.23	0.21	-0.18	-0.03
Ca	0.12	-0.04	0.14	0.11	-0.19	-0.15
Mg	0.18	0.11	0.46**	0.42**	-0.09	-0.10
S	-0.03	-0.02	-0.18	-0.15	0.31	0.22

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Soil pH is considered as the driver of soil fertility because of its direct impact on nutrient availability and plant growth. It has been reported that solubility and availability of nutrient ions are pH dependent. Mishra *et al*. (1990) [10] observed a positive relationship of soil pH with available P in foot hills of Himalayas. The relationship obtained for electrical conductivity are supported by the findings of Ramana Murthy and Srivastava (1994) [14] who observed a positive and significant correlation of EC with available P. Organic matter besides being a major source of nutrient ions such as N and P, promotes the availability of micronutrients through its chelating effects (Raina and Goswami, 1988) [13].

Relationship between soil and leaf analysis values

Correlation between the soil and leaf analysis values showed a significant and positive relationship for N, K, Mg and S for both the surface as well as for sub-surface layers. However, positive and highly significant relationship (r= 0.42**) of S was found only for the surface soil.

Table 6: Relationship (r-values) of available macro-nutrients in soils (surface) with leaf nutrient contents

Leaf / Soil	N	P	K	Ca	Mg	S
Surface Soil Depth (0-15 cm)						
pH	0.14	-0.05	-0.36*	-0.04	-0.15	-0.11
EC	0.07	0.36*	-0.11	-0.08	0.08	-0.14
OC	0.22	0.01	-0.36*	0.22	0.38*	-0.10
N	0.38*	0.02	-0.32	0.15	0.19	-0.13
P	-0.05	0.19	0.28	0.16	0.26	0.04
K	-0.02	0.52**	0.38*	-0.45**	0.37*	0.18
Ca	-0.03	-0.07	0.17	0.24	0.25	0.14
Mg	-0.23	0.10	-0.06	0.07	0.42**	-0.47**
S	-0.07	-0.17	-0.02	0.10	0.38*	0.38*

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Relationship (r-values) of available macro-nutrients in soils (sub-surface) with leaf nutrient contents

Leaf / Soil	N	P	K	Ca	Mg	S
Sub-surface Soil Depth (15-30 cm)						
pH	0.13	-0.03	-0.32	-0.03	-0.13	-0.07
EC	0.02	-0.34	-0.09	-0.07	0.07	-0.05
OC	0.20	0.01	-0.35	0.17	0.36*	-0.13
N	0.36*	-0.09	-0.23	0.12	0.18	-0.12
P	-0.03	0.24	-0.24	0.14	0.24	0.02
K	-0.02	0.50**	0.36*	-0.42**	0.36*	0.14
Ca	-0.08	-0.08	0.15	0.23	0.12	0.12
Mg	-0.23	0.05	-0.05	-0.02	0.40*	-0.45**
S	-0.07	-0.09	-0.02	0.09	0.37*	0.36*

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

According to Anderson and Albrigo (1977) [1] more significant correlation coefficient occurred with surface soils in macronutrient elements as compared to sub-surface soils. Sharma and Bhandari (1992) [18] and Awasthi *et al*. 1998 [3] also reported significant and positive correlation among leaf and soil samples. Various types of correlations obtained or lack of correlation between any soil or plant nutrient may be due to the interaction involved between them. The fact that correlation were not very perfect for some nutrient elements may also be due to the influence of weather, size of crop, time of sampling, ion antagonism and the method of estimation. The highly significant correlations indicate that either of the two measurements may be satisfactorily used to predict the nutrient status of the orchards (Sharma and Bhandari, 1992) [18].

Conclusion

The studies revealed that the orchard soils of Kangra district were coarser in nature having sandy loam to sandy clay loam texture which calls for addition of organic manures to increase the water and nutrient retentivity. Soil pH was found to be nearly neutral in reaction. The soils are in safe limits of electrical conductivity as the values were less than 0.8 dsm^{-1}. On the basis of nutrient index, it was concluded that the soil samples were low in N and high in P, K, Ca, Mg and S. All the nutrient elements in the surface and sub-surface layers had a positive correlation with their respective leaf nutrient contents. The organic carbon contents were highly correlated with N and P. The coefficient of variations in soil and leaf samples were high. This variation indicated a need of standardize the available nutrient extraction methods or the change in the critical limits suiting our conditions.

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