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RELATIONSHIP OF SOIL FERTILITY AND LEAF NUTRIENT STATUS IN LITCHI (*Litchi chinensis* SONN.) ORCHARDS

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ABSTRACT

Study on macronutrient status of Litchi (*Litchi chinensis* Sonn.) orchards of Kangra district of Himachal Pradesh, India was undertaken with the objective to study the nutritional status of litchi orchards and the relationship of soil characteristics with leaf nutrient contents. For this, forty soil sampling sites from litchi growing areas were selected randomly. The litchi orchard soils of Kangra district were coarser in nature having sandy loam to sandy clay loam in texture. Most of the soils were acidic except Nagrota Surinya and Nurpur blocks which were neutral in reaction. Phosphorus, potassium, sulphur, calcium and magnesium in soils were found high in status, while nitrogen was medium in status. The available N, P, K, and S content of the litchi orchards soil ranged from 273.82-395.15, 22.40–60.48, 278.09–462.58 and 29.95–64.46 kg ha^{-1}, respectively. Exchangeable Ca and Mg varied from 2.75–5.31 and 2.00–3.59 cmol (p$^+$) kg^{-1}, respectively. Most of the macronutrients in litchi leaf were found sufficient except sulphur which was high in 22.5 per cent samples only. The mean per cent concentration of N, P, K, S, Ca and Mg in the leaf samples of litchi were 1.36, 0.14, 1.12, 0.24, 1.40 and 0.26, respectively. Organic carbon content was positively correlated with all the chemical properties of the soil. Highest significant positive correlation of leaf N, P, K and Ca was found with their respective availability in soil.This assessment will help the litchi growers for adopting better nutrient management plan in their orchards according to the fertility status of the orchard.

(Key words: Litchi, orchards, macronutrient status and correlation)

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical perennial fruit crop grown in the foothill regions of Himachal Pradesh. It is also known as queen of the fruits due to its attractive deep pink/red colour and fragrant aril. India is the second largest producer of litchi after China. In India, litchi is successfully grown in Assam, Bihar, Orissa, West Bengal, Tripura, Punjab, Uttaranchal, Himachal Pradesh and Maharashtra and occupies an area of 92.3 thousand hectare with an annual production of 686.4 thousand metric tonnes and productivity of 7.4 metric tonnes ha^{-1} (Anonymous, 2018). In Himachal Pradesh, litchi is grown in some pockets of Kangra, Hamirpur, Una, Bilaspur, Sirmour, Solan, Chamba and Mandi districts. Himachal Pradesh produces 5467 tonnes of litchi in an area of 5875 hectare (Anonymous, 2018[a]). Kangra in Himachal Pradesh has earned the distinction of being pioneer district in the cultivation of litchi, producing 3817 tonnes of fruit in a year (Anonymous, 2018[a]).

Nutrition of fruit plants depends upon inherent ability of soil to supply nutrient elements. The key to better management of mineral nutrition to the plants is the judicious use of fertilizers based on laboratory analysis values. Plant analysis is used to confirm the suspected deficiencies and toxicities of nutrients and also helps in assessing the efficiency of fertilizer treatments. The physical and chemical characteristics of soil are the main parameters, which affects the productivity of fruit crops. Further, the climatic factors in association with physico-chemical properties help in determining the crop growth. It has been reported that the characteristics of the soil strongly influence the availability of nutrients and ultimately the growth, development and yield of fruit trees (Bhandari and Randhawa, 1985). Plants are the best indicators of the nutrient availability in the soil in a given set of environmental conditions. The leaves are the nutritional centre of the plants; therefore, they form the basis of leaf analysis. Leaf analysis not only serves as a better guide for fertilizer use and planning but it also helps in understanding the relationship between the soil and the plant.Practically, no systematic work has been undertaken

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on the nutritional status of Litchi orchards in Kangra district. The information generated through soil and plant analysis helps in application of the fertilizers in correct doses without putting any economic burden on the farmers.

MATERIALS AND METHODS

The study was conducted during 2018 in Kangra district of Himachal Pradesh, India. Forty orchards of uniform age and growth in the major litchi growing areas of district Kangra were randomly selected. Surface (0-15 cm) and sub-surface (15-30 cm) soil samples were collected during the months of October to November, 2018 after the harvesting of litchi fruit and analyzed for bulk density, texture, pH, EC, organic carbon and available macro-nutrient elements. Litchi leaf samples were collected during August to September, 2018 from the litchi growing areas from where the soil samples were collected and analyzed for all macronutrient elements.

The texture of the soil was determined by Hydrometer method (Bouyoucos, 1927). 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) and organic carbon (Walkley and Black, 1934). Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), available P by Olsen's method (Olsen *et al*., 1954) and determined by stannous chloride reduced ammonium molybdate method (Jackson, 1973), available K by neutral normal ammonium acetate (Merwin and Peach, 1951). Sulphate-S was determined by Turbiditeric method (Chesnin and Yien, 1950). Exchangeable Ca and Mg were determined by using ammonium acetate extract by atomic absorption spectrophotometer (Sarma *et al*., 1987).

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 ± 5°C 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). Total nitrogen was determined by microkjeldhal method, phosphorus by vanadomolybdate phosphoric yellow colour method (Jackson, 1973) and potassium by the flame photometric method (Jackson, 1967). Calcium and Magnesium in the digest were estimated on atomic absorption spectrophotometer and sulphur by turbidimetric method (Chesnin and Yien, 1950).

The descriptive statistics *viz*., ranges, mean, standard error and coefficient of variation were derived for each soil and leaf parameter. Also, the data was subjected to statistical analysis by adopting simple correlation to find out the extent of relationship of soil characteristics with leaf nutrient contents (Singh and Chaudhary, 1994).

RESULTS AND DISCUSSION

Physico-chemical properties of the soil

Physical properties of soil

The bulk density of the surface soil (0 to 15 cm) varied from 1.20 to 1.35 Mg m^{-3} with a mean value of 1.27 Mg m^{-3} and in sub-surface layer it varied from 1.22 to 1.39 Mg m^{-3} with a mean value of 1.31, Mg m^{-3} and the highest value was recorded in Rakkarbheri village of Panchrukhi block and lowest value was recorded in Kunsal village of Baijnath block (Table 1). There was increase in bulk density with the increase in soil depth which might be due to lower organic carbon content in sub-surface layer. The result was in the line of the findings of Sharma and Kanwar (2010), who also reported increase in bulk density with increasing depth at Spiti valley of Himachal Pradesh.

In overall eighty per cent of the surface soil samples were found to be sandy loam in texture and remaining twenty per cent were sandy clay loam in texture. Forty seven per cent of sub-surface soil samples were sandy clay loam in texture, 30 per cent were loam, 13 per cent sandy loam and 10 per cent were clay loam in texture. There was a decrease in the percentage of sand and increase in percentage of silt and clay with increase in soil depth, indicating translocation of finer soil particles to lower depths (Table 1).

Chemical properties of soil

Most of the soils of litchi orchards of Kangra district were found to be acidic except NagrotaSurian and Nurpur blocks which were found neutral in reaction (Table 2). For sub-surface layer, soil pH followed similar trend as by the surface layer, however, it increased with the increasing depths which might be due to leaching of bases from surface to sub-surface layer (Kaistha *et al*., 1990,Walia and Rao, 1996 and Sharma *et al*.,2018). The pH of the study area was found to be low which might be due to low degree of base saturation in surface soil. Some soil pH of the study area was found to be near neutral in reaction (6.5-7.7) which corroborates the findings of Kaistha and Gupta (1993), who also observed similar trend in Central Himalayas of Himachal Pradesh.

The electrical conductivity values of all the litchi orchards soils of Kangra district of Himachal Pradesh were under normal range (<1.0). The normal range of the electrical conductivity in the soil is attributed to the leaching of salts to lower depths due to continuous cropping and tillage practices (Table 2). These results are in agreement with those obtained by Verma and Tripathi (2007), who found that the EC value ranged from 0.01 to 0.15 dSm^{-1} in the soils of mid-Shivalik hills of Himachal Pradesh. However, Loria *et al*. (2016) found similar normal range (0.094 to 0.138 dSm^{-1}) of electrical conductivity in agriculture soils of Himachal Pradesh.

The organic carbon content in the surface layer (0-15 cm) ranged from 9.32 to 22.75 g kg^{-1} with the mean value of 14.60 g kg^{-1} whereas; in the sub-surface layer (15-30 cm)

it ranged from 8.33 to 21.45 g kg^{-1} with the mean value of 13.45 g kg^{-1}. In all the blocks the organic carbon followed similar trend in sub-surface layer as by the surface layer, however it decreased with the increase in soil depth (Table 2). The overall results showed that the soils of all the orchards were high in organic carbon content. The CV of 20.69 per cent and 22.85 per cent for organic carbon indicates that, it varied spatially in the surface and sub-surface depths. This might be due to the management practices and variable addition of FYM and plant residues. The results obtained are in accordance with the findings of Sharma *et al*. (2018), who also reported that organic carbon contents were medium to high in most of the soil samples of mango orchards of district Kangra of Himachal Pradesh and ranged from 7.65 – 17.85 g kg^{-1}.

The available nitrogen content in the surface layer (0-15 cm) ranged from 273.82 to 395.15 kg ha^{-1} with an average value of 324.97 kg ha^{-1}. Whereas, in the sub-surface layer the available nitrogen content ranged from 264.42 to 372.64 kg ha^{-1} with an average value of 303.20 kg ha^{-1}. The lowest available nitrogen content was found in Mandal village of Dharamshala block and highest available nitrogen content was found in Nanglailchak village of Indora block of Himachal Pradesh (Table 3). For sub-surface layer, available nitrogen followed similar trend as by the surface layer; however, it decreased with the increasing depths. The CV of 10.78 per cent and 10.23 per cent for available nitrogen content indicates that, it varied spatially in the surface and sub-surface depths. This might be due to nutrient management practices followed by the farmers of the area and leaching losses of the nitrogen from the soil. Similar results (185 to 260 kg ha^{-1}) were found by Nilima *et al*. (2017).

The available phosphorus content in the surface layer (0-15 cm) varied from 22.40 to 60.48 kg ha^{-1} with an average value of 41.33 kg ha^{-1}. While in the sub-surface layer (15-30 cm), the available phosphorus content ranged from 20.14 to 51.52 kg ha^{-1} with an average value of 35.25 kg ha^{-1}. The highest content of available phosphorus was found in PattaJattian village of Fatehpur block and lowest content of available phosphorus was found in TikkaPatola village of Kangra block (Table 3). The available phosphorus content decreased with increasing soil depth was also reported by Dongale (1993). The results obtained are similar to the findings of Sharma *et al*. (2018), who reported that 95 per cent of the soil samples of the mango growing soils of Kangra areas of Himachal Pradesh had high levels of available phosphorus content(22.40 to 67.20 kg ha^{-1}).

The available potassium in the surface (0-15 cm) and sub-surface layer (15-30 cm) varied from 278.09 to 462.58 kg ha^{-1} and 263.51 to 438.17 kg ha^{-1} with the mean values of 367.87 kg ha^{-1} and 339.51 kg ha^{-1}, respectively (Table 3). The lowest content of available potassium for both surface and sub-surface layer was found in Bhadguhar village of Bhawarna block and highest was found in Kaisthwari village of NagrotaBagwan block of Kangra district of Himachal Pradesh. A decrease in potassium content (271.04 to 715.68 kg ha^{-1}) in the sub-surface layer was also reported by Sharma *et al*. (2018).

The available sulphur in surface layer (0-15 cm) ranged from 29.95 to 64.46 kg ha^{-1} with a mean value of 47.59 kg ha^{-1}. Whereas, in the sub-surface layer (15-30 cm) the available sulphur ranged from 23.44 to 61.20 kg ha^{-1} with a mean value of 39.64 kg ha^{-1}. The lowest available sulphur was found in Kudail village of Baijnath block and highest available sulphur was found in Thangar village of Nagrota Surian block(Table 3). In sub-surface layer, available sulphur followed similar trend as by the surface layer; however, it decreased with the increasing depths. Both surface and sub-surface soils were found higher in available sulphur content. The higher content of available sulphur in the soils might be due to the presence of gypsiferrous minerals and ferruginous nature of parent material (Wadia, 1966). Similar trend (59.7 to 81.13 and 39.20 to 61.40 kg ha^{-1}) has also been observed by Jamio (2014) and Sharma *et al*. (2018) for Himachal Pradesh soils(12.60 to 19.74 kg $ha^{-1}$and 9.80 to 15.82 kg ha^{-1}).

The exchangeable calcium in surface (0-15 cm) and sub-surface layer (15-30 cm) ranged from 2.75 to 5.31 [cmol (p^+) kg^{-1}] and 2.51 to 4.75 [cmol (p^+) kg^{-1}] with a mean values of 4.07 and 3.64 [cmol (p^+) kg^{-1}], respectively.The highest exchangeable calcium content was found in Sudran village of Fatehpur block and lowest exchangeable calcium content was found in Chobin village of Baijnath block (Table 4). These finding are in accordance with the findings of Sharma *et al*. (2002), who also reported that soils of Fatehpur block in Himachal Pradesh were sufficient in calcium which varied from 56 to 1303 kg ha^{-1}.In case of sub-surface layer, exchangeable calcium followed similar trend as by the surface layer, however, it decreased with the increasing depths. Sharma *et al*. (2018) also reported higher content of exchangeable calcium which decreased with increasing depth in mango orchards of Kangra district of Himachal Pradesh.

The exchangeable magnesium in surface layer (0-15 cm) ranged from 2.00 to 3.59 [cmol (p^+) kg^{-1}] with a mean value of 2.85 [cmol (p^+) kg^{-1}] and in the sub-surface layer (15-30 cm) it ranged from 1.82 to 3.36 [cmol (p^+) kg^{-1}] with a mean value of 2.52 [cmol (p^+) kg^{-1}]. In surface and sub-surface soils, the lowest content of exchangeable magnesium was found in Chobin village of Baijnath block, while highest content of exchangeable magnesium in surface soil was found in Nanglail Chak village of Indora block and in sub-surface it was highest in Ganoh village of Nurpur block(Table 4). These results are in conformity with the findings of Sharma *et al*. (2018), who also reported decline in magnesium content(2.02 to 3.30 [cmol (p+) kg^{-1}in surface and 1.34 to 2.90 [cmol (p+) kg^{-1}] in sub surface soil) with depth in mango orchards of Kangra district.

Nutrient indices of soil

Nutrient indices of surface soil

The data presented in Table 5 represents nutrient indices of surface soils of litchi orchards of Kangra district

which reveals that the status of nitrogen was found low in 5.0 per cent samples and the rest of the samples (95 per cent) were under medium category. Overall status of nitrogen was found medium for the litchi orchards of Kangra district. All other nutrients were high in status. The nutrient index values for nitrogen, phosphorus, potassium, sulphur, calcium and magnesium were 1.95, 2.90, 3.00, 3.00, 3.00 and 3.00, respectively.

Nutrient indices of sub-surface soil

The data depicted in Table 6 for sub-surface soils shows that nitrogen was low in 32.5 per cent samples; however, 67.5 and 20 per cent samples fell under medium category for nitrogen and phosphorus, respectively. All the samples fell in high category for potassium, sulphur, calcium and magnesium. The nutrient index values for nitrogen, phosphorus, potassium, sulphur, calcium and magnesium were 1.67, 2.80, 3.00, 3.00, 3.00 and 3.00, respectively. The overall status of the litchi orchards of Kangra district was found medium for nitrogen and rest of the nutrients were found high.

Macronutrient content of leaves

Primary macronutrient content

The leaf nitrogen content in the litchi orchards of Kangra district of Himachal Pradesh varied from 1.21 to 1.56 per cent with a mean value of 1.36 per cent (Table 7). The highest leaf nitrogen content was found in Bhuana village of Panchrukhi block and lowest content of leaf nitrogen was found in Kunsal village of Baijnath block of Himachal Pradesh.Leaf phosphorus content in the litchi orchards of Kangra district of Himachal Pradesh ranged from 0.12 to 0.18 per cent with a mean value of 0.14 per cent (Table 7).Leaf potassium content in the litchi orchards of Kangra district ranged from 0.81 to 1.44 per cent with a mean value of 1.12 per cent. The lowest content of leaf potassium was found in Malog village of Sulah block and highest was found in Jach village of Nurpur block (Table 7).

The sufficient concentration of leaf nitrogen, phosphorus and potassium in the litchi orchards of Kangra district may be ascribed to the medium availability of nitrogen and high availability of phosphorus and potassium in these soils to the plants. Similar findings were given by Marathe *et al.* (2016), who reported that leaf N was sufficient to high and varied from 0.42 to 2.74 per cent in majority of the orchards of Maharashtra and Andhra Pradesh, while it was low in Karnataka. Leaf P content was deficient in as many orchards of Maharashtra and Andhra Pradesh, while it was comparatively better in Karnataka. Leaf K was sufficient in majority of orchards in all the states.Sharma *et al.* (2018) also observed sufficient content of N (1.12 to 2.24 per cent), P (0.14 to 0.27 per cent) and K (0.35 to 0.94 per cent) in mango orchards of Kangra district of Himachal Pradesh.

Secondary macronutrient content

The leaf sulphur content of litchi orchards ranged from 0.17 to 0.29 per cent with a mean value of 0.24 per cent (Table 7). Highest content of leaf sulphur was observed in Jach village of Nurpur block, Surjpur village of Indora block, Thangar village of NagrotaSurian block and Bhadguhar village of Bhawarna block and lowest content of leaf sulphur was observed in Bhawarna village of Bhawarna block.

The leaf calcium content varied from 1.26 to 1.52 per cent with a mean value of 1.40 per cent. The lowest content of leaf calcium was found in Chobin village of Baijnath block and highest content of leaf calcium was found in Sunher village of NagrotaSurian block (Table 7).

The leaf magnesium content in the litchi orchards of Kangra district of Himachal Pradesh ranged from 0.16 to 0.33 per cent with a mean value of 0.26 per cent (Table 7). Highest content of leaf magnesium was found in PattaJattian village of Fatehpur block and lowest content of leaf magnesium was found in the Kunsal village of the Baijnath block. The observations are in agreement with those of Kumar *et al.* (2012), who reported that leaf Ca and Mg concentration of mango varied from 1.40 to 4.90 and 1.54 to 2.58 per cent with an average values of 3.21 and 1.92, respectively.Kumar and Rehalia (2007) and Sharma *et al.* (2018) also observed medium concentration of sulphur (0.24 to 0.65 per cent), calcium (2.20 to 5.14) and magnesium (0.42 to 1.48) in mango leaves of mango orchards of Kangra district of Himachal Pradesh.

Plant nutrient status

The perusal of the data given in Table 8 revealed that all the plant nutrients were medium in the leaves of litchi orchards of Kangra district except sulphur which was found medium in 77.5 per cent samples and high in 22.5 per cent samples which may be ascribed to high availability of these nutrients from the soil. These findings are in conformity with the findings of Sharma *et al.* (2018), who observed that 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.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**.**

Relationship of soil characteristics with the leaf nutrient content

The insight of the data depicted in Table 9 on relationship of surface soil characteristics with the leaf nutrient content revealed that leaf nitrogen was highly significantly negatively correlated with sand content (-0.495**) and highest significant positive correlation was observed with available nitrogen (0.498**). Leaf phosphorus content was highly significantly positively correlated with available phosphorus (0.567**) followed by soil pH (0.354*) and EC (0.340*). Highest significant positive correlation of leaf potassium was noticed with

Table 1.Physical properties of the litchi orchards soils of Kangra district

Orchard No.	Block	Village	Bulk density (Mg m^{-3})		Textural Class	
			Soil depth (cm)		Soil depth (cm)	
			0-15	15-30	0-15	15-30
1	Sulah	Bhadaldevi	1.22	1.25	sl	scl
2		Sulah	1.28	1.31	scl	scl
3		Garla	1.25	1.29	sl	l
4		Majehr	1.26	1.31	sl	l
5		Malog	1.31	1.33	sl	l
6	Bhawarna	Guga -Saloh	1.26	1.30	scl	scl
7		Bhedumahadev	1.27	1.32	scl	l
8		Bhawarna	1.23	1.25	sl	l
9		Sehol	1.34	1.37	sl	scl
10		Bhadguhar	1.25	1.29	sl	scl
11	Panchrukhi	Saliyana	1.30	1.33	sl	scl
12		Panchrukhi	1.28	1.32	sl	cl
13		Bhuana	1.24	1.27	sl	l
14		Ladoh	1.31	1.35	scl	l
15		Rakkarbheri	1.35	1.39	sl	sl
16	NagrotaBagwan	Amtrar	1.27	1.33	sl	l
17		Chahri	1.28	1.31	sl	l
18		Kaisthwari	1.27	1.31	sl	l
19		Nagrota Bagwan	1.21	1.24	sl	scl
20		Hatwas	1.29	1.33	sl	l
21	Kangra	Ichhi Khas	1.33	1.35	sl	l
22		Tikka Patola	1.32	1.34	sl	cl
23		Ghurkarikhas	1.25	1.31	sl	scl
24		Birta	1.26	1.33	sl	scl
25	Rait	Ansui	1.29	1.33	sl	cl
26		Rait	1.24	1.29	sl	scl
27		Shahpur	1.23	1.28	sl	scl
28	Baijnath	Chobin	1.29	1.32	sl	cl
29		Kudail	1.26	1.30	scl	scl
30		Kunsal	1.20	1.22	sl	scl
31	Fatehpur	Sudran	1.25	1.30	scl	sl
32		Patta Jattian	1.23	1.26	scl	sl
33	NagrotaSurian	Sunher	1.30	1.34	scl	scl
34		Thangar	1.31	1.34	sl	sl
35	Nurpur	Jach	1.32	1.35	sl	scl
36		Ganoh	1.29	1.34	sl	scl
37	Indora	Nanglailchak	1.21	1.23	sl	scl
38		Surjpur	1.23	1.28	sl	scl
39	Dharmshala	Mandal	1.27	1.30	sl	sl
40	Lambagaon	Lower lambagaon	1.32	1.36	sl	scl
		Range	**1.20-1.35**	**1.22-1.39**		
		Mean	**1.27**	**1.31**		
		SE±	**0.01**	**0.01**		
		CV (%)	**2.97**	**2.94**		

sl: Sandy loam, scl: Sandy clay loam, l: Loam, cl: Clay loam

Table 2. Soil pH, electrical conductivity and organic carbon content of the litchi orchards soils of Kangra district

Orchard No.	Block	Village	pH		EC (dS m^{-1})		Organic carbon(g kg^{-1})	
			Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
			0-15	15-30	0-15	15-30	0-15	15-30
1	Sulah	Bhadaldevi	5.05	5.15	0.17	0.15	14.35	12.15
2		Sulah	4.89	4.95	0.16	0.14	13.50	11.65
3		Garla	5.32	5.40	0.12	0.11	10.12	9.21
4		Majehr	5.16	5.24	0.10	0.08	12.21	10.72
5		Malog	5.28	5.34	0.11	0.09	13.65	12.75
6	Bhawarna	Guga -Saloh	5.17	5.24	0.18	0.15	11.61	10.65
7		Bhedumahadev	4.82	4.87	0.13	0.11	12.64	11.75
8		Bhawarna	5.00	5.18	0.16	0.15	13.85	12.14
9		Sehol	5.40	5.49	0.13	0.12	12.14	11.23
10		Bhadguhar	5.15	5.25	0.16	0.15	11.25	10.45
11	Panchrukhi	Saliyana	5.13	5.20	0.13	0.11	14.15	12.05
12		Panchrukhi	4.65	4.71	0.09	0.08	13.15	12.42
13		Bhuana	4.78	4.95	0.07	0.06	12.25	11.05
14		Ladoh	4.97	5.02	0.11	0.09	15.46	14.56
15		Rakkarbheri	4.89	4.92	0.14	0.13	13.58	12.75
16	Nagrota Bagwan	Amtrar	5.70	5.74	0.17	0.14	12.18	11.23
17		Chahri	5.67	5.70	0.13	0.12	15.30	14.25
18		Kaisthwari	5.97	6.02	0.16	0.15	13.06	11.95
19		Nagrota Bagwan	5.88	5.93	0.14	0.10	14.12	13.45
20		Hatwas	5.93	6.00	0.13	0.11	15.21	13.52
21	Kangra	Ichhi Khas	5.45	5.59	0.19	0.17	13.42	11.65
22		Tikka Patola	5.69	5.72	0.18	0.15	12.46	10.55
23		Ghurkarikhas	5.76	5.89	0.21	0.19	10.45	9.17
24		Birta	5.85	5.90	0.18	0.18	16.85	15.92
25	Rait	Ansui	5.79	5.81	0.16	0.15	17.25	16.34
26		Rait	5.90	5.92	0.14	0.12	19.45	18.35
27		Shahpur	5.97	6.18	0.17	0.16	21.75	20.55
28	Baijnath	Chobin	4.87	4.95	0.08	0.07	19.25	18.00
29		Kudail	4.95	5.12	0.06	0.05	14.15	12.19
30		Kunsal	5.21	5.28	0.10	0.07	16.25	15.00
31	Fatehpur	Sudran	6.18	6.21	0.28	0.25	14.22	13.15
32		Patta Jattian	6.34	6.41	0.26	0.23	15.95	14.85
33	NagrotaSurian	Sunher	7.37	7.43	0.24	0.21	14.65	13.75
34		Thangar	7.49	7.56	0.22	0.19	16.18	17.35
35	Nurpur	Jach	6.46	6.50	0.25	0.24	15.75	14.15
36		Ganoh	6.88	6.95	0.32	0.27	16.25	15.75
37	Indora	Nanglailchak	6.22	6.30	0.29	0.26	20.85	19.35
38		Surjpur	6.21	6.27	0.27	0.23	22.75	21.45
39	Dharmshala	Mandal	5.32	5.38	0.07	0.06	9.32	8.33
40	Lambagaon	Lower lambagaon	6.01	6.14	0.11	0.09	13.12	12.33
	Range		**4.65-7.49**	**4.71-7.56**	**0.06-0.32**	**0.05-0.27**	**9.32-22.75**	**8.33-21.45**
	Mean		**5.62**	**5.70**	**0.16**	**0.14**	**14.60**	**13.45**
	SE±		**0.11**	**0.11**	**0.01**	**0.01**	**0.48**	**0.49**
	CV (%)		**12.11**	**11.82**	**39.77**	**41.41**	**20.69**	**22.85**

Table 3. Available N, P, K and S content (kg ha^{-1}) of the litchi orchards soils of Kangra district

Orchard No.	Block	Village	Nitrogen		Phosphorus		Potassium		Sulphur	
			Soil depth (cm)		Soil depth (cm)					
			0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	Sulah	Bhadaldevi	283.69	267.43	49.28	44.80	309.09	279.17	38.41	26.69
2		Sulah	285.86	276.73	31.36	26.88	306.70	289.69	40.37	37.11
3		Garla	293.82	284.14	40.32	33.60	302.42	287.12	46.23	39.30
4		Majehr	310.41	285.41	35.84	29.12	327.86	319.69	33.86	29.95
5		Malog	291.56	278.45	56.00	40.32	285.75	268.19	34.44	27.16
6	Bhawarna	Guga -Saloh	361.23	348.58	24.64	22.40	325.44	293.10	51.44	16.93
7		Bhedumahadev	375.62	364.66	42.56	31.36	314.87	300.36	55.34	49.48
8		Bhawarna	370.54	345.44	53.76	42.56	323.65	273.23	56.60	54.69
9		Sehol	303.05	281.14	49.30	39.10	299.89	282.68	45.58	37.34
10		Bhadguhar	325.18	306.22	38.08	34.64	278.09	263.51	59.90	36.46
11	Panchrukhi	Saliyana	342.72	317.27	38.08	35.84	297.42	275.60	50.79	30.60
12		Panchrukhi	375.20	346.19	47.04	44.80	293.59	269.78	40.37	34.09
13		Bhuana	352.40	321.18	33.60	31.36	289.27	274.28	45.39	35.62
14		Ladoh	367.24	333.79	26.88	24.60	327.86	319.69	31.90	26.69
15		Rakkarbheri	275.73	268.34	50.32	43.60	336.73	332.08	39.06	28.65
16	Nagrota Bagwan	Amtrar	284.34	270.58	38.11	33.53	375.46	317.11	54.04	48.83
17		Chahri	287.25	272.64	43.70	39.06	417.11	357.10	45.58	36.46
18		Kaisthwari	284.36	274.25	52.46	50.02	462.58	438.17	47.30	41.02
19		Nagrota Bagwan	315.60	293.74	45.58	42.84	335.11	330.10	48.83	39.06
20		Hatwas	287.80	273.73	34.64	28.02	427.57	410.27	56.65	53.39
21	Kangra	Ichhi Khas	314.64	286.41	26.78	22.40	441.77	420.86	37.76	29.95
22		Tikka Patola	293.56	278.12	22.40	20.14	435.14	415.93	52.09	46.23
23		Ghurkarikhas	302.14	273.72	26.88	21.60	377.26	311.31	34.51	27.34
24		Birta	317.84	276.87	29.13	24.64	356.22	313.04	36.60	25.00
25	Rait	Ansui	336.59	295.82	47.04	29.13	438.48	419.01	51.44	43.62
26		Rait	356.40	343.86	42.46	35.74	389.58	349.35	63.81	58.60
27		Shahpur	394.00	358.06	40.22	33.50	419.79	307.79	51.44	43.62
28	Baijnath	Chobin	368.81	342.72	29.12	26.88	323.38	319.69	34.51	28.88
29		Kudail	306.23	285.41	25.66	21.20	362.38	256.56	29.95	23.44
30		Kunsal	327.28	311.50	23.40	21.16	353.94	346.37	36.46	31.25
31	Fatehpur	Sudran	302.17	285.13	58.24	47.04	434.29	411.20	63.16	59.90
32		Patta Jattian	327.16	295.92	60.48	51.52	447.70	428.17	43.62	33.20
33	NagrotaSurian	Sunher	338.58	318.68	53.76	49.28	442.28	423.85	58.60	57.95
34		Thangar	317.87	301.04	56.00	49.30	413.25	404.83	64.46	61.20
35	Nurpur	Jach	371.28	327.38	58.24	50.00	418.70	401.40	59.25	50.13
36		Ganoh	327.38	304.29	51.52	40.32	435.47	409.74	56.65	54.04
37	Indora	Nanglailchak	395.15	372.64	53.76	44.80	404.84	399.34	61.86	57.30
38		Surjpur	355.50	321.08	51.52	42.56	443.25	386.53	49.48	42.97
39	Dharmshala	Mandal	273.82	264.42	35.74	33.50	391.01	376.38	60.55	55.00
40	Lambagaon	Lower lambagaon	298.72	274.83	29.12	26.88	349.73	297.94	35.39	26.62
	Range		**273.82-395.15**	**264.42 -372.64**	**22.40-60.48**	**20.14-51.52**	**278.09-462.58**	**263.51-438.17**	**29.95-64.46**	**23.44-61.20**
	Mean		**324.97**	**303.20**	**41.33**	**35.25**	**367.87**	**339.51**	**47.59**	**39.64**
	SE±		**5.54**	**4.90**	**1.80**	**1.51**	**9.07**	**9.18**	**1.61**	**1.90**
	CV (%)		**10.78**	**10.23**	**27.52**	**27.14**	**15.60**	**17.10**	**21.39**	**30.29**

Table 4. Exchangeable calcium and magnesium content [cmol (p^+) kg^{-1}] of the litchi orchards soils of Kangra district

Orchard No.	Block	Village	Calcium		Magnesium	
			Soil depth (cm)		Soil depth (cm)	
			0-15	15-30	0-15	15-30
1	Sulah	Bhadaldevi	4.36	3.06	2.78	2.27
2		Sulah	3.05	2.96	3.23	2.13
3		Garla	4.49	3.04	3.52	2.50
4		Majehr	4.43	3.21	2.43	2.63
5		Malog	3.03	2.87	2.92	2.39
6	Bhawarna	Guga -Saloh	3.00	2.78	2.48	2.19
7		Bhedumahadev	3.44	3.13	2.33	2.15
8		Bhawarna	3.27	3.17	2.25	2.10
9		Sehol	3.37	3.23	2.38	2.06
10		Bhadguhar	3.66	3.54	2.48	2.09
11	Panchrukhi	Saliyana	4.19	4.00	2.89	2.60
12		Panchrukhi	4.23	3.62	2.26	2.12
13		Bhuana	4.01	3.52	2.32	1.99
14		Ladoh	3.78	3.58	2.85	2.67
15		Rakkarbheri	3.90	3.40	2.81	2.56
16	NagrotaBagwan	Amtrar	4.60	3.86	2.87	2.72
17		Chahri	3.33	3.29	2.93	2.62
18		Kaisthwari	4.07	4.03	2.99	2.50
19		Nagrota Bagwan	4.32	4.22	2.65	2.48
20		Hatwas	4.46	3.54	3.03	2.64
21	Kangra	Ichhi Khas	4.83	3.46	3.21	3.04
22		Tikka Patola	4.52	4.07	3.16	2.74
23		Ghurkarikhas	4.80	4.75	3.22	3.02
24		Birta	4.21	3.91	3.17	3.08
25	Rait	Ansui	4.08	3.44	3.14	2.49
26		Rait	3.96	3.78	2.99	2.62
27		Shahpur	3.14	3.00	2.85	2.77
28	Baijnath	Chobin	2.75	2.51	2.00	1.82
29		Kudail	2.92	2.69	2.02	1.89
30		Kunsal	2.81	2.65	2.17	1.84
31	Fatehpur	Sudran	5.31	4.75	3.40	2.37
32		Patta Jattian	5.25	4.71	3.25	2.46
33	NagrotaSurian	Sunher	5.15	4.60	3.12	3.05
34		Thangar	4.41	4.27	3.26	3.00
35	Nurpur	Jach	4.50	3.85	3.18	3.09
36		Ganoh	4.86	4.25	3.47	3.36
37	Indora	Nanglailchak	5.06	4.46	3.59	3.23
38		Surjpur	4.81	4.12	3.24	2.99
39	Dharmshala	Mandal	3.48	3.21	2.09	1.83
40	Lambagaon	Lower lambagaon	4.82	4.01	2.97	2.69
	Range		**2.75-5.31**	**2.51-4.75**	**2.00-3.59**	**1.82-3.36**
	Mean		**4.07**	**3.64**	**2.85**	**2.52**
	SE±		**0.12**	**0.10**	**0.07**	**0.07**
	CV (%)		**17.99**	**16.95**	**15.47**	**16.45**

Table 5. Nutrient indices of surface soils of the litchi orchards of Kangra district

Nutrient	Percentage of samples under each category			Nutrient Index	Nutrient Status
	Low	Medium	High		
N	5	95	-	1.95	Medium
P	-	10	90	2.90	High
K	-	-	100	3.00	High
S	-	-	100	3.00	High
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High

Table 6.Nutrient indices of sub-surface soils of the litchi orchards of Kangra district

Nutrient	Percentage of samples under each category			Nutrient Index	Nutrient Status
	Low	Medium	High		
N	32.5	67.5	-	1.67	Medium
P	-	20	80	2.80	High
K	-	-	100	3.00	High
S	-	-	100	3.00	High
Ca	-	-	100	3.00	High
Mg	-	-	100	3.00	High

Table 7. Leaf N, P, K, S, Ca and mg content (per cent) in litchi orchards of Kangra district of Himachal Pradesh

Orchard No.	Block	Village	N	P	K	S	Ca	Mg
1	Sulah	Bhadaldevi	1.36	0.15	0.98	0.27	1.42	0.25
2		Sulah	1.26	0.14	1.12	0.24	1.31	0.30
3		Garla	1.28	0.16	1.05	0.28	1.42	0.23
4		Majehr	1.24	0.15	0.97	0.19	1.44	0.22
5		Malog	1.34	0.15	0.81	0.22	1.32	0.26
6	Bhawarna	Guga -Saloh	1.46	0.13	0.99	0.26	1.30	0.22
7		Bhedumahadev	1.36	0.12	1.21	0.24	1.33	0.21
8		Bhawarna	1.28	0.13	1.13	0.17	1.31	0.20
9		Sehol	1.40	0.18	0.95	0.23	1.32	0.21
10		Bhadguhar	1.50	0.16	0.85	0.29	1.35	0.22
11	Panchrukhi	Saliyana	1.40	0.18	0.90	0.26	1.40	0.26
12		Panchrukhi	1.52	0.14	0.85	0.28	1.41	0.20
13		Bhuana	1.56	0.12	0.93	0.24	1.39	0.21
14		Ladoh	1.42	0.12	0.96	0.21	1.36	0.26
15		Rakkarbheri	1.23	0.16	1.04	0.27	1.38	0.26
16	NagrotaBagwan	Amtrar	1.29	0.17	0.92	0.20	1.45	0.25
17		Chahri	1.34	0.14	1.29	0.23	1.32	0.27
18		Kaisthwari	1.28	0.15	1.37	0.25	1.39	0.29
19		NagrotaBagwan	1.36	0.15	0.98	0.22	1.42	0.24
20		Hatwas	1.30	0.12	1.31	0.19	1.43	0.28
21	Kangra	IchhiKhas	1.32	0.14	1.33	0.26	1.47	0.30
22		TikkaPatola	1.30	0.13	1.28	0.24	1.44	0.29
23		Ghurkarikhas	1.29	0.12	1.14	0.27	1.46	0.30
24		Birta	1.32	0.13	1.02	0.28	1.41	0.28
25	Rait	Ansui	1.42	0.15	0.98	0.21	1.39	0.26
26		Rait	1.49	0.12	1.00	0.28	1.38	0.29
27		Shahpur	1.36	0.15	1.36	0.22	1.30	0.26
28	Baijnath	Chobin	1.26	0.13	1.21	0.20	1.26	0.21
29		Kudail	1.37	0.14	1.18	0.25	1.30	0.18
30		Kunsal	1.21	0.12	1.07	0.22	1.40	0.16
31	Fatehpur	Sudran	1.41	0.13	1.41	0.24	1.51	0.32
32		PattaJattian	1.48	0.18	1.38	0.22	1.50	0.33
33	NagrotaSurian	Sunher	1.43	0.17	1.43	0.23	1.52	0.29
34		Thangar	1.39	0.17	1.26	0.29	1.45	0.30
35	Nurpur	Jach	1.46	0.18	1.44	0.29	1.47	0.28
36		Ganoh	1.32	0.14	1.32	0.25	1.44	0.32
37	Indora	Nanglailchak	1.42	0.15	1.23	0.25	1.51	0.30
38		Surjpur	1.37	0.16	1.29	0.29	1.46	0.29
39	Dharmshala	Mandal	1.28	0.12	0.97	0.22	1.36	0.19
40	Lambagaon	Lower lambagaon	1.34	0.13	1.05	0.24	1.49	0.27
	Range		**1.21-1.56**	**0.12-0.18**	**0.81-1.44**	**0.17-0.29**	**1.26-1.52**	**0.16-0.33**
	Mean		**1.36**	**0.14**	**1.12**	**0.24**	**1.40**	**0.26**
	SE±		**0.01**	**0.01**	**0.03**	**0.01**	**0.01**	**0.01**
	CV (%)		**6.24**	**13.39**	**16.31**	**12.90**	**4.89**	**16.55**

Table 8. Plant nutrient status of litchi orchards of Kangra district

Nutrient	Percent samples		
	Low	Medium	High
N	-	100	-
P	-	100	-
K	-	100	-
S	-	77.5	22.5
Ca	-	100	-
Mg	-	100	-

Table 9. Relationship of surface soil characteristics with the leaf nutrient content

Soil characteristics	Leaf N	Leaf P	Leaf K	Leaf S	Leaf Ca	Leaf Mg
B.D	-0.085^{NS}	0.210^{NS}	0.030^{NS}	0.060^{NS}	-0.034^{NS}	0.180^{NS}
Sand	-0.495**	-0.221^{NS}	0.159^{NS}	-0.085^{NS}	0.053^{NS}	-0.007^{NS}
Silt	0.382*	0.245^{NS}	-0.261^{NS}	0.066^{NS}	-0.011^{NS}	0.001^{NS}
Clay	0.202^{NS}	-0.020^{NS}	0.141^{NS}	0.033^{NS}	-0.066^{NS}	0.011^{NS}
pH	0.130^{NS}	0.354*	0.610**	0.169^{NS}	0.623**	0.671**
EC	0.164^{NS}	0.340*	0.599**	0.290^{NS}	0.600**	0.754**
OC	0.127^{NS}	0.076^{NS}	0.376*	0.033^{NS}	-0.069^{NS}	0.316*
Available N	0.498**	-0.052^{NS}	0.106^{NS}	0.032^{NS}	-0.102^{NS}	-0.117^{NS}
Available P	0.273^{NS}	0.567**	0.269^{NS}	0.098^{NS}	0.291^{NS}	0.352*
Available K	-0.052^{NS}	0.079^{NS}	0.790**	-0.011^{NS}	0.498**	0.628**
Available S	0.323*	0.169^{NS}	0.294^{NS}	0.116^{NS}	0.238^{NS}	0.251^{NS}
Exchang. Ca	0.197^{NS}	0.279^{NS}	0.349*	0.244^{NS}	0.943**	0.670**
Exchang. Mg	0.030^{NS}	0.280^{NS}	0.438**	0.332*	0.630**	0.895**

NS: Non significant

**Significant at the 0.01 level

* Significant at the 0.05 level

available potassium (0.790**) followed by soil pH (0.610**), EC (0.599**), exchangeable magnesium (0.438**), and exchangeable calcium (0.349*). Leaf sulphur showed significant positive correlation with exchangeable magnesium (0.332*). Leaf calcium was highly significantly positively correlated with exchangeable calcium (0.943**) followed by exchangeable magnesium (0.630**), soil pH (0.623**), EC (0.600**) and soil available potassium (0.498**). Leaf magnesium was highly positively correlated with exchangeable magnesium (0.895**) followed by EC (0.754**), soil pH (0.671**), exchangeable calcium (0.670**), soil available potassium (0.628**) and phosphorus (0.352*). Various types of correlations obtained or non significant correlation between soil property and plant nutrient may be due to the interaction involved between them. Correlation was not very perfect for sulphur due to the influence of climate and ion antagonism.

From the present study, it is inferred that the litchi orchard soils of Kangra district were coarser in nature having sandy loam to sandy clay loam texture. Most of the soils were acidic except Nagrota Surian and Nurpur blocks which were neutral in reaction. All the nutrients in soil were found high in status except nitrogen which was medium in status. Most of the macronutrient contents of litchi leaf were sufficient except sulphur which was high in 22.5 per cent samples. Bulk density and available nitrogen had non-significant relationship with most of the soil properties. Organic carbon content was positively correlated with all the chemicals properties of the soil. Highest significant positive correlation of leaf nitrogen, phosphorus, potassium, calcium and magnesium was found with their respective availability in soil.

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