Status and Distribution of Micronutrient in Litchi (*Litchi Chinensis* Sonn.) Orchards Under Subtropical Conditions of Himachal Pradesh

ABSTRACT

Management of micronutrients require special attention in orchard soils as the requirement of micronutrients for nutrition, physiological need and quality control is more in fruit crops. Distribution and variability of micronutrients in the soil and leaf of litchi orchards of Kangra district of Himachal Pradesh was studied. Results revealed that all the micronutrients in soil were found high in status except zinc which was medium in status. Most of the micronutrient contents of litchi leaf were sufficient. All the DTPA-extractable micronutrients were negatively correlated with soil pH, EC, available P, K and S and exchangeable calcium and magnesium. Highest significant positive correlation of leaf iron, copper, manganese and zinc was found with their respective availability in soil.

Keywords: Micronutrient, litchi, soil, leaf and correlation

1. INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical perennial fruit crop grown in the foothill regions of Himachal Pradesh and is grown in some pockets of Kangra, Hamirpur, Una, Bilaspur, Sirmour, Solan, Chamba and Mandi districts. Himachal Pradesh produces 5469 metric tonnes of litchi in an area of 5673 hectare (Anonymous, 2017). Kangra in Himachal Pradesh has earned the distinction of being pioneer district in the cultivation of litchi, producing 3231 metric tonnes of fruit in a year (Anonymous, 2017). The main litchi varieties under cultivation in Himachal Pradesh are Dehradun and Culcuttia.

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). In orchard soils, micronutrients availability is a function of soil management systems across land use and therefore, an urgent view is needed for systematic information on micronutrient status of existing orchards so that effective and efficient orchard management practices could be adopted in a holistic manner. Therefore, the current study was carried out with the aim to explore the current status of micronutrients of litchi orchards of Kangra district and their correlation of soil characteristics with the available soil and leaf nutrient contents under subtropical conditions of Himachal Pradesh.

2. MATERIALS AND METHODS

2.1 Site Description

Present study was carried out in some litchi orchards of Kangra district of Himachal Pradesh, India. The entire area of the district is crossed by the variable altitude of the Shivaliks, Dhauladhar and the Himalayas from north-west to south-east. The climate of the district varies considerably from subtropical in low hills, valleys and sub-humid in mid hill to temperate in high hills. The district receives an average annual rainfall of around 2050 mm which increase from about 1000 mm in the southern parts to about 2500 mm in the north-eastern areas. Most of the rain, around 80 per cent is received in the months of June to September. Snowfall is also received in the northern parts around the areas of Dharamshala, Palampur and Baijnath. The average maximum temperature ranges from about 25^{o} C in northern parts to around 35^{o} C in southern areas.

Soils of the district are mainly derived from lesser or outer Himalayas and Shivalik formation. The soils in the foothills of Dhauladhar range show well developed, deep, fine texture and both A and B horizons, which are distinctly expressed. In case of the soils of Shivalik formation, shallow to moderately deep profiles with relatively less expressed horizons and coarse to medium texture are found. In other words, climate and topography play a dominant role in determining the soil characteristics.

2.2 Sample Collection and Analysis

Forty orchards of uniform age and growth in the major litchi growing areas of district Kangra were randomly selected and composite soil samples were collected from two depths *i.e* 0-15 and 15-30 cm, from the tree basin of 10 trees in the selected litchi orchards. The soil samples were air dried in shade, grounded with the help of wooden pestle and mortar and passed through a 2 mm sieve. The processed samples were stored in butter paper/cloth bags for further laboratory analysis. Available Zn, Cu, Mn and Fe (DTPA extractable) in the soil were measured by atomic absorption spectrophotometer (AAS) as per the procedure outlined Lindsay and Norvell (1978).

Representative leaf samples were collected from the same tree from where the soil samples were collected. The second pair of leaflets was collected during August to September (Bhargava and Chadha, 1988) for leaf analysis in accordance with the procedure recommended by Chapman (1964). The leaf samples were washed with ordinary water and then wash with 0.1 N HCl followed by washing with distilled water. After washing, the samples were spread on filter paper for air drying and were subsequently put in paper bags for drying in hot air oven at 60± 5^{o}C for 72 hours (Kenworthy, 1964). After complete drying, the samples were ground and analyzed for different nutrients by digesting 1 g tissue in di-acid mixture (9:4 ratio of nitric acid and perchloric acid) by using standard analytical methods.The micronutrients *viz*. Fe, Mn, Cu and Zn were analyzed using atomic absorption spectrophotometer (Vogel, 1978).

2.3 Soil Data Analysis

The critical limits of the soil properties were followed for categorizing nutrients and the results were interpreted using these critical limits which are given in Table 1.

Table 1. Critical limits used for interpretation of micronutrients

Sr. No.	Nutrient element	Soil fertility class			Reference
		Low	Medium	High	
1	Zn (mg kg^{-1})	<1.0	1.0-3.0	>3.0	Lindsay and Norvel (1978)
2	Cu (mg kg^{-1})	<0.3	0.3-0.8	>0.8	Lindsay and Norvel (1978)
3	Fe (mg kg^{-1})	<4.0	4.0-6.0	>6.0	Lindsay and Norvel (1978)
4	Mn (mg kg^{-1})	<1.2	1.2-3.5	>3.5	Lindsay and Norvel (1978)

After categorization of the soil samples according to soil fertility class, soil nutrient indices were prepared to represent the available status of each micro-nutrient using the formula given by Parker *et al*. (1951) as indicated below:

$$\mathrm{SNI} = \frac{(\mathrm{NL\ x\ 1}) + (\mathrm{NM\ x\ 2}) + (\mathrm{NH\ x\ 3})}{\mathrm{NT}}$$

Where,

SNI = Soil nutrient indices

NL = Number of samples falling in low category of nutrient status

NM = Number of samples falling in medium category of nutrient status

NH = Number of samples falling in High category of nutrient status

NT = Total number of samples analyzed for a given nutrient.

A SNI value <1.67, 1.67 to 2.33 and >2.33 indicates low, medium and high nutrient status of soils, respectively (Ramamurthy and Bajaj, 1969).

2.4 Plant Data Analysis

The critical limits of the nutrients for plant samples given in Table 2 were followed for categorizing and the results were interpreted.

Table 2. Critical limits of nutrients for plant samples

Sr. No	Nutrient element	Concentration (ppm)				Reference
		Deficient	Low	Sufficient	High	
1	Fe	<34	34-70	71-214	>214	Raghupathi and Bhargava (1999)
2	Mn	<15	15-28	29-89	>89	
3	Zn	<8	8-13	14-72	>72	
4	Cu	<7	7-28	29-72	>72	

2.5 Statistical Analysis

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 the available soil and leaf nutrient contents (Singh and Chaudhary, 1994).

3. RESULTS AND DISCUSSION

3.1 Distribution of Micronutrients

The DTPA-extractable iron content in surface and sub-surface soil varied from 6.04 to 13.76 mg kg^{-1} and 5.27 to 13.64 mg kg^{-1} with a mean value of 9.72 and 9.09 mg kg^{-1}, respectively (Table 3). In surface and sub-surface soils, the highest contents of iron were observed in Bhawarna village of Bhawarna block and lowest content of iron was observed in Ganoh village of Nurpur block of Himachal Pradesh. The surface soils had higher iron content as compared to sub-surface soils, however followed similar trend as by the surface layer. Similar results (4.02-7.81 mg kg^{-1}) were reported by Aanchal *et al*. (2023), who also observed decline trend in iron content with depth in Shivalik hills soils of Himachal Pradesh which might be due to conversion of iron to insoluble forms with the increase in pH.

The DTPA-extractable copper content in surface and sub-surface soil ranged from 1.23 to 4.10 mg kg^{-1} and 0.94 to 3.80 mg kg^{-1} with a mean value of 2.43 and 1.81 mg kg^{-1}, respectively. In surface soil the highest contents of copper were observed in Chobin village of Baijnath block and lowest contents of copper was observed in Jach village of Nurpur block of Himachal Pradesh (Table 3). Aanchal *et al*. (2023) found similar results (0.31-2.32 mg kg^{-1}) of copper content and also reported decline in copper content with increase in soil depth may be due to the fact of their positive correlation with organic carbon as the OC content decreased with increase in soil depth in Shivalik hills soils of Himachal Pradesh. Also, solubility of Cu decreases by approximately 100-fold for each unit increase of soil pH. The overall status of DTPA-extractable copper was found high in litchi growing areas of Kangra district. These results are in conformity with the findings of Tripathi *et al*. (1994) and Mahajan (2001), who also found high levels DTPA-extractable copper in soils of Himachal Pradesh.

The DTPA-extractable manganese in the surface layer (0-15 cm) varied from 4.34 to 15.24mg kg^{-1} with a mean value of 8.64 mg kg^{-1} and in sub-surface layer (15-30 cm) it varied from 3.04 to 14.80 mg kg^{-1} with a mean value 7.47mg kg^{-1}. The lowest content of DTPA-extractable manganese was found in Nanglailchak village of Indora block and highest content of DTPA-extractable manganese was observed in Sulah village of Sulah block. The DTPA-extractable manganese decreased with increasing in soil depth (Table 3). Aanchal *et al*. (2023), also reported higher content of DTPA-extractable manganese which decrease with increasing depth in Shivalik hills soils of Himachal Pradesh. In overall DTPA-extractable manganese content was found high for all the soils of litchi orchards of Kangra district.

The DTPA-extractable zinc in the surface layer (0-15 cm) varied from 1.21 to 3.60 mg kg^{-1} with a mean value of 2.53 mg kg^{-1} and in sub-surface layer (15-30 cm) it varied from 0.90 to 3.14 mg kg^{-1} with a mean value of 2.05 mg kg^{-1}. Highest content of DTPA-extractable zinc was found in Bhuana village of Panchrukhi block and lowest content was found in Thangar village of Nagrota Surian block. The DTPA-extractable zinc was found to decrease with increasing depth of soil. Similar results (1.04-3.52 mg kg^{-1}) get strength from the findings of Aanchal *et al*. (2023), who also found decline in zinc content with increase in depth in Shivalik hills soils of Himachal Pradesh (Table 3). The high content of DTPA-extractable zinc in surface layer may be due to higher organic carbon content and more favourable soil reaction. Among different blocks Fatehpur, Nagrota Surinya, Nurpur and Indora have lower content of DTPA-extractable zinc as compared to the other blocks.

Table 3. DTPA-extractable micronutrients content (mg kg^{-1}) of the litchi orchards soils of Kangra district.

Orchard No.	Block	Village	Fe		Cu		Mn		Zn	
			Soil depth (cm)							
			0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	Sulah	Bhadaldevi	11.63	10.30	3.27	2.60	11.80	10.24	3.01	2.87
2		Sulah	12.04	11.24	3.84	2.92	15.24	14.80	3.34	2.94
3		Garla	9.62	9.14	2.30	1.70	10.14	9.91	3.36	3.09
4		Majehr	10.84	10.49	2.98	2.24	11.69	10.03	3.27	2.98
5		Malog	9.82	8.30	2.48	2.14	10.74	9.48	2.58	1.96
6	Bhawarna	Guga -Saloh	10.46	9.54	2.94	2.18	9.00	7.80	2.80	2.46
7		Bhedumahadev	12.48	11.07	3.80	3.20	12.64	11.84	3.46	2.87
8		Bhawarna	13.76	13.64	3.80	2.62	10.64	8.94	3.16	2.70
9		Sehol	10.54	9.78	2.25	1.36	11.08	10.48	3.30	2.98
10		Bhadguhar	11.40	10.75	3.01	2.08	10.02	8.19	3.00	2.32
11	Panchrukhi	Saliyana	11.46	10.36	3.04	2.29	10.44	9.58	3.04	2.36
12		Panchrukhi	12.26	11.69	3.72	3.25	14.00	13.20	3.56	2.95
13		Bhuana	13.64	13.34	3.30	3.00	13.40	12.40	3.60	3.14
14		Ladoh	11.79	10.49	3.64	2.48	11.01	10.54	3.18	2.28
15		Rakkar bheri	12.24	11.78	3.92	2.62	12.20	11.34	3.39	2.98
16	NagrotaBagwan	Amtrar	9.05	8.72	1.96	1.56	7.15	6.81	2.17	1.87
17		Chahri	9.19	8.94	2.18	1.20	7.64	6.76	2.23	1.74
18		Kaisthwari	8.24	7.95	1.74	1.52	6.12	4.72	1.92	1.00
19		NagrotaBagwan	8.42	7.82	1.83	1.42	6.51	5.29	2.00	1.66
20		Hatwas	8.30	8.01	1.76	1.18	6.44	4.74	1.94	1.12
21	Kangra	Ichhi Khas	9.25	8.97	2.20	1.84	7.72	6.22	2.24	1.78
22		Tikka Patola	9.16	8.84	1.98	1.07	7.60	7.02	2.19	1.85
23		Ghurkarikhas	8.93	8.30	1.96	1.45	7.04	6.30	2.16	1.94
24		Birta	8.42	7.98	1.92	1.52	6.71	5.44	2.12	1.55

25	Rait	Ansui	8.55	8.12	1.96	1.06	6.96	5.30	2.14	1.77
26		Rait	8.36	8.80	1.78	1.49	6.49	5.40	1.99	1.14
27		Shahpur	8.11	7.60	1.65	1.07	5.95	3.82	1.84	1.20
28	Baijnath	Chobin	12.24	11.89	4.10	3.80	12.21	11.47	3.40	3.10
29		Kudail	11.79	10.82	3.76	2.61	11.34	9.80	3.31	2.73
30		Kunsal	10.34	9.78	2.66	1.55	10.96	9.63	3.36	3.14
31	Fatehpur	Sudran	7.21	6.85	1.56	1.12	5.79	4.84	1.74	1.09
32		Patta Jattian	6.08	5.37	1.45	1.10	4.72	3.26	1.54	1.05
33	Nagrota Surian	Sunher	7.88	6.44	1.37	1.17	4.85	3.25	1.30	1.08
34		Thangar	6.49	6.24	1.35	1.10	4.79	3.46	1.21	0.90
35	Nurpur	Jach	6.59	6.01	1.23	0.94	5.40	3.40	1.45	1.10
36		Ganoh	6.04	5.27	1.36	1.00	4.92	3.36	1.30	1.00
37	Indora	Nanglailchak	6.24	5.46	1.48	0.96	4.34	3.04	1.68	1.12
38		Surjpur	6.72	6.25	1.50	0.97	5.60	4.24	1.73	1.15
39	Dharmshala	Mandal	12.66	11.25	1.61	1.24	5.85	4.35	3.48	3.02
40	Lambagaon	Lower lambagaon	10.59	9.90	2.39	1.91	8.52	7.93	2.76	2.21
	Range		**6.04-13.76**	**5.27-13.64**	**1.23-4.10**	**0.94-3.80**	**4.34-15.24**	**3.04-14.80**	**1.21-3.60**	**0.90-3.14**
	Mean		**9.72**	**9.09**	**2.43**	**1.81**	**8.64**	**7.47**	**2.53**	**2.05**
	SE±		**0.35**	**0.34**	**0.14**	**0.12**	**0.47**	**0.51**	**0.12**	**0.13**
	C.V (%)		**22.54**	**23.49**	**36.80**	**42.14**	**34.68**	**43.07**	**29.98**	**38.55**

3.2 Nutrient Indices of Soil

For surface soils, the status of all the micronutrients was high in status and the nutrient index values for iron, copper, manganese and zinc were 3.00, 3.00, 3.00 and 2.40, respectively.

Nutrient indices for sub-surface soil showed that zinc was low in 2.5 per cent samples, however, 15 and 85 per cent samples were fell under medium category for manganese and zinc, respectively. All the samples fell in high category for iron and copper. The nutrient index values for iron, copper, manganese and zinc were 3.00, 3.00, 2.85 and 2.10, respectively. The overall status of the litchi orchards of Kangra district was found medium for zinc and rest of the micronutrients were found high (Table 4).

Table 4. Nutrient indices of the litchi orchards soils of Kangra district

Nutrient	Percentage of samples under each category			Nutrient Index	Nutrient Status
	Low	Medium	High		
			Surface soils (0-15 cm)		
Fe	-	-	100	3.00	High
Cu	-	-	100	3.00	High
Mn	-	-	100	3.00	High
Zn	-	60	40	2.40	High
			Sub-surface soils (15-30 cm)		
Fe	-	-	100	3.00	High
Cu	-	-	100	3.00	High
Mn	-	15	85	2.85	High
Zn	2.5	85	12.5	2.10	Medium

3.3 Plant Nutrient Status

The perusal of the data given in Table 5 revealed that all the plant micronutrients were medium in the leaves of litchi orchards of Kangra district which may be ascribed to high availability of these nutrients from the soil. These findings are in conformity with the findings of and Kunwar and Singh (1993) and Kotur and Singh (1994).

Table 5. Plant nutrient status of litchi orchards of Kangra district

Nutrient	Percent samples		
	Low	**Medium**	**High**
Fe	-	100	-
Cu	-	100	-
Mn	-	100	-
Zn	-	100	-

3.4 Micronutrient 3.4 Content of Leaves

The data depicted in Table 6 revealed that the leaf iron content in the litchi orchards of Kangra district of Himachal Pradesh ranged from 72.40 to 139.80 ppm with a mean value of 101.16 ppm.

The lowest content of leaf iron was found in the Patta Jattian village of Fatehpur block and highest content of leaf iron was observed in Bhawarna village of Bhawarna block of Himachal Pradesh. The CV of 19.13 per cent for leaf iron showed that it varied spatially. The concentration of leaf iron was in sufficient range in all the litchi orchards of Kangra district of Himachal Pradesh.

Leaf copper content in the litchi orchards of Kangra district of Himachal Pradesh given in Table 6 and ranged from 33.20 to 56.60 ppm with a mean value of 44.16 ppm. The highest leaf copper content was found in Bhedumahadev village of Bhawarna block and lowest leaf copper content was found in the Sunher village of Nagrota Surian block of Himachal Pradesh. The CV for leaf copper was 15.82 which indicated that it varied spatially. The concentration of the leaf copper in the litchi orchards of Kangra district was in sufficient range.

The data presented in Table 6 revealed that the leaf manganese content ranged from 32.20 to 74.40 ppm in the litchi orchards of Kangra district of Himachal Pradesh with a mean value of 57.50 ppm. The highest content of leaf manganese was found in Majehr village of Sulah block and lowest content of leaf manganese was found in Thangar village of Nagrota Surniya block. The CV of 19.81 per cent for leaf manganese indicates its spatial variation. The concentration of leaf manganese in all the litchi orchards of Kangra district of Himachal Pradesh was in sufficient range.

The leaf zinc content in the litchi orchards of Kangra district ranged from 22.00 to 48.80 ppm with a mean value of 35.08 ppm. The lowest leaf zinc content in the litchi orchards was observed in Sunher village of Nagorta Surniya block and highest content of leaf zinc was observed in Bhuana village of Panchrukhi block. The leaf zinc content varied spatially as indicated by the CV of 21.54 per cent (Table 6). The concentration of leaf zinc was observed sufficient in all the litchi orchards of Kangra district of Himachal Pradesh. These results are in accordance with the findings of Hundal and Arora (1993), Kunwar and Singh (1993) and Joon *et al*. (1997).

Table 6. Leaf Fe, Cu, Mn and Zn content (ppm) in litchi orchards of Kangra district of Himachal Pradesh

Orchard No.	Block	Village	Fe ppm	Cu ppm	Mn ppm	Zn ppm
1	Sulah	Bhadaldevi	118.60	50.40	71.60	41.60
2		Sulah	120.40	52.00	72.20	45.80
3		Garla	96.40	42.60	70.00	47.60
4		Majehr	105.20	48.20	74.40	42.20
5		Malog	98.60	44.40	60.40	36.60
6	Bhawarna	Guga -Saloh	106.40	48.40	61.20	38.60
7		Bhedumahadev	126.40	56.60	58.00	44.80
8		Bhawarna	139.80	54.60	60.20	40.60
9		Sehol	108.20	42.60	62.20	42.80
10		Bhadguhar	118.40	50.20	70.60	40.00
11	Panchrukhi	Saliyana	116.80	50.20	60.00	39.00
12		Panchrukhi	125.00	56.40	64.80	44.80
13		Bhuana	139.40	52.70	63.40	48.80
14		Ladoh	119.80	54.00	62.80	40.20
15		Rakkar bheri	125.80	53.60	57.60	42.40

16	NagrotaBagwan	Amtrar	90.60	38.20	51.00	32.20
17		Chahri	93.80	42.40	56.80	34.40
18		Kaisthwari	84.80	36.60	51.80	29.40
19		NagrotaBagwan	88.20	39.40	55.20	30.40
20		Hatwas	82.00	36.60	54.40	28.80
21	Kangra	Ichhi Khas	95.401	44.00	67.80	34.60
22		Tikka Patola	93.60	39.20	66.40	32.60
23		Ghurkarikhas	88.60	37.20	60.80	34.80
24		Birta	86.80	34.40	58.60	32.00
25	Rait	Ansui	87.60	36.40	59.40	30.00
26		Rait	81.40	37.40	54.20	28.60
27		Shahpur	80.80	51.20	49.80	26.40
28	Baijnath	Chobin	125.40	55.20	70.80	42.20
29		Kudail	120.60	44.60	71.60	40.60
30		Kunsal	105.60	38.80	68.80	43.00
31	Fatehpur	Sudran	76.20	45.40	48.60	26.80
32		Patta Jattian	72.40	44.20	38.60	24.00
33	Nagrota Surian	Sunher	88.00	33.20	40.00	22.00
34		Thangar	74.20	35.60	32.20	24.20
35	Nurpur	Jach	76.40	34.20	37.40	26.00
36		Ganoh	80.40	39.40	44.80	23.40
37	Indora	Nanglailchak	82.40	40.20	39.60	25.40
38		Surjpur	87.20	42.60	33.80	28.60
39	Dharmshala	Mandal	128.20	38.40	50.20	36.20
40	Lambagaon	Lower lambagaon	110.60	44.80	68.00	30.80
		Range	**72.40-139.80**	**33.20-56.60**	**32.20-74.40**	**22.00-48.80**
		Mean	**101.16**	**44.16**	**57.50**	**35.08**
		SE±	**3.06**	**1.10**	**1.80**	**1.19**
		C.V (%)	**19.13**	**15.82**	**19.81**	**21.54**

3.5 Relationship of General Soil Properties with the Available Soil Micronutrient Content

In surface soils, DTPA-extractable micronutrients showed a non-significant correlation with all the physical properties of soil. Among chemical properties of soil, micronutrients showed significant relationship with all properties except available nitrogen. Significant negative correlations of micronutrients were observed with soil pH, EC, available potassium, available sulphur, exchangeable calcium and exchangeable magnesium. Highest positive significant correlation of iron, copper, manganese and zinc was found with DTPA-extractable zinc (0.932**), DTPA-extractable manganese (0.924**), DTPA-extractable copper (0.924**) and DTPA-extractable iron (0.932**), respectively (Table 7).

Likewise for sub-surface soils, Soil pH and EC had significant negative correlation with all the micronutrients (Table 7). DTPA-extractable iron was highly positively correlated with zinc (0.870**), manganese (0.829**) and with copper (0.819**). DTPA-extractable copper was highly significantly positively correlated with manganese (0.871**). DTPA-extractable manganese was highly significantly positively correlated with copper (0.871**) and DTPA-extractable zinc was highly significantly correlated with iron (0.870**).

Table 7. Relationship of DTPA extractable micronutrients with soil characteristics

	B.D	Sand	Silt	Clay	pH	EC	OC	N	P	K	S	Ca	Mg	Fe	Cu	Mn	Zn
									Surface Soils (0-15 cm)								
Fe	0.081^{NS}	-0.045^{NS}	-0.018^{NS}	0.096^{NS}	-0.868**	-0.781**	0.480**	-0.037^{NS}	-0.432**	-0.755**	-0.395*	-0.604**	-0.757**	1			
Cu	0.073^{NS}	-0.037^{NS}	-0.147^{NS}	0.275^{NS}	-0.853**	-0.623**	0.261^{NS}	0.102^{NS}	-0.368*	-0.746**	-0.518**	-0.584**	-0.629**	0.878**	1		
Mn	0.104^{NS}	-0.124^{NS}	-0.022^{NS}	0.224^{NS}	-0.862**	-0.673**	0.358*	-0.020^{NS}	-0.352*	-0.823**	-0.555**	-0.567**	-0.582**	0.857**	0.924**	1	
Zn	0.027^{NS}	-0.051^{NS}	-0.046^{NS}	0.147^{NS}	-0.914**	-0.797**	0.466**	-0.067^{NS}	-0.455**	-0.800**	-0.485**	-0.601**	-0.718**	0.932**	0.848**	0.893**	1
									Sub-surface Soils (15-30 cm)								
Fe	0.006^{NS}	-0.379*	0.393*	-0.001^{NS}	-0.854**	-0.764**	0.439**	0.027^{NS}	-0.397*	-0.692**	-0.387*	-0.637**	-0.730**	1			
Cu	0.032^{NS}	-0.366*	0.317*	0.102^{NS}	-0.778**	-0.592**	0.286^{NS}	0.215^{NS}	-0.258^{NS}	-0.679**	-0.484**	-0.560**	-0.600**	0.819**	1		
Mn	0.083^{NS}	-0.487**	0.338*	0.256^{NS}	-0.852**	-0.662**	0.417**	0.011^{NS}	-0.354*	-0.743**	-0.529**	-0.617**	-0.637**	0.829**	0.871**	1	
Zn	-0.044^{NS}	-0.310^{NS}	0.188^{NS}	0.191^{NS}	-0.845**	-0.724**	0.434**	-0.050^{NS}	-0.417**	-0.709**	-0.502**	-0.696**	-0.736**	0.870**	0.745**	0.869**	1

Table 8. Relationship of soil characteristics with the leaf nutrient content

Soil characteristic	B.D	Sand	Silt	Clay	pH	EC	OC	Available N	Available P	Available K	Available S	Exchang. Ca	Exchang. Mg	DTPA-Fe	DTPA-Cu	DTPA-Mn	DTPA-Zn
								Surface Soils (0-15 cm)									
Leaf Fe	0.066^{NS}	-0.092^{NS}	-0.007^{NS}	0.154^{NS}	-0.819**	-0.676**	-0.407**	0.047^{NS}	-0.351*	-0.737**	-0.355*	-0.552**	-0.738**	0.972**	0.873**	0.831**	0.905**
Leaf Cu	-0.023^{NS}	-0.183^{NS}	-0.010^{NS}	0.298^{NS}	-0.725**	-0.381*	-0.095^{NS}	0.310^{NS}	-0.130^{NS}	-0.633**	-0.321*	-0.409**	-0.477**	0.711**	0.834**	0.759**	0.681**
Leaf Mn	0.046^{NS}	0.070^{NS}	-0.115^{NS}	0.062^{NS}	-0.790**	-0.696**	-0.454**	-0.240^{NS}	-0.658**	-0.644**	-0.627**	-0.466**	-0.475**	0.723**	0.715**	0.775**	0.773**
Leaf Zn	0.002^{NS}	-0.028^{NS}	-0.071^{NS}	0.149^{NS}	-0.905**	-0.717**	-0.483**	-0.079^{NS}	-0.435**	-0.824**	-0.504**	-0.568**	-0.608**	0.873**	0.846**	0.930**	0.953**
								Sub-surface Soils (15-30 cm)									
Leaf Fe	-0.012^{NS}	-0.202^{NS}	0.228^{NS}	0.014^{NS}	-0.806**	-0.663**	-0.445**	0.108^{NS}	-0.295^{NS}	-0.684**	-0.383*	-0.587**	-0.699**	0.940**	0.833**	0.811**	0.874**
Leaf Cu	-0.063^{NS}	-0.236^{NS}	0.260^{NS}	-0.057^{NS}	-0.711**	-0.373*	-0.130^{NS}	0.363*	-0.108^{NS}	-0.616**	-0.380*	-0.461**	-0.512**	0.694**	0.816**	0.740**	0.617**
Leaf Mn	0.011^{NS}	-0.628**	0.374*	0.281^{NS}	-0.781**	-0.686**	-0.519**	-0.214^{NS}	-0.654**	-0.631**	-0.636**	-0.629**	-0.552**	0.736**	0.642**	0.769**	0.764**
Leaf Zn	-0.050^{NS}	-0.423**	0.307^{NS}	0.218^{NS}	-0.901**	-0.701**	-0.521**	-0.015^{NS}	-0.412**	-0.746**	-0.529**	-0.689**	-0.695**	0.867**	0.790**	0.930**	0.944**

NS: Non-significant
**Significant at the 0.01 level
* Significant at the 0.05 level

Organic matter is also a major source of micronutrients which stored as constituent of soil organic matter from which they are slowly released by mineralization also metals are made more available to plants as micronutrients are kept in soluble and chelated form. Bhandari and Randhawa (1985) also showed a positive correlation of organic carbon with available micronutrient elements in soils of Himachal Pradesh. Similar results have also been reported by Raina (1988) and Sharma *et al*. (2018) in orchard soils of district Sirmourand district Kangra, respectively.

3.6 Relationship of Available Soil Micronutrient Content with the Leaf Nutrient Content

For surface soils, highest significant negative correlations of all the micronutrients in litchi leaves were found with soil pH. Leaf iron was highly significantly positively correlated with DTPA-extractable iron (0.972**). Leaf copper was positively correlated with DTPA-extractable copper (0.834**). Leaf manganese was highly significantly positively correlated with DTPA-extractable manganese (0.775**). Leaf zinc was highly significantly positively correlated with DTPA-extractable zinc (0.953**). Likewise for sub-surface, leaf iron, copper, manganese and zinc were highly significantly negatively correlated with soil pH (-0.806**, -0.711**, -0.781** and -0.901**, respectively). Leaf iron, copper, manganese and zinc was highly significantly positively correlated with DTPA-extractable iron (0.940**), DTPA-extractable copper (0.816**), DTPA-extractable manganese (0.769**) and DTPA-extractable zinc (0.944**), respectively (Table 8). Similar significant and positive correlations of leaf micronutrient contents with their respective contents in leaves were also reported by Sharma and Bhandari (1992) and Awasthi *et al*. (1998).

4. CONCLUSIONS

All the micronutrients in soil were found high in status except zinc which was medium in status. Most of the micronutrient contents of litchi leaf were sufficient except. All the DTPA-extractable micronutrients were negatively correlated with soil pH, EC, available P, K & S and exchangeable calcium and magnesium. Highest significant positive correlation of leaf iron, copper, manganese and zinc was found with their respective availability in soil.

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