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Nutrient status of soils and capsicum foliage under protected cultivation in some vegetable growing areas of Himachal Pradesh

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Abstract
The present investigations were carried out in four districts of Himachal Pradesh i.e. Shimla, Solan, Sirmaur and Bilaspur to estimate the nutrient status of polyhouse soils and capsicum growing inside and to work out their relationships. The pH of the soils ranged from 5.39 – 7.46, whereas, the Electrical conductivity was found to be in a normal range (0.17 to3.32 dS m^{-1}). The organic carbon content of the studied soils varied from 2.20 to 28.50 g kg^{-1}. The available N, P and K content in the surface soils of the polyhouses in the four districts varied from 112.80 – 570.70, 33.60 – 229.60 and 103.04 – 2430 kg ha^{-1}, respectively. The available nitrogen content was found to be low to medium in its status, whereas the phosphorus and potassium were found to be high in the polyhouse soils. The DTPA extractable Fe, Mn, Cu and Zn content in the surface soils of the polyhouses in the four districts varied from 5.97 – 44.06, 0.36 – 20.54, 0.51 – 14.32 and 0.83 – 4.18 mg kg^{-1}, respectively. All the four micronutrients were found to be high in status, in the polyhouse soils. The leaf N, P and K contents in the Capsicum grown under polyhouse conditions, varied from 2.80 – 6.44, 0.20 – 0.90 and 2.06 – 6.23 percent, respectively. The majority of plant samples were found sufficient in N, P and K content. The soil pH showed a significant negative correlation with DTPA extractable Fe, while Organic carbon had positive and significant correlation with many of the soil nutrients, showing its importance in the availability of the nutrients in soil for growth of plants.

Keywords: Soils, capsicum foliage, under protected cultivation, vegetable growing

Introduction
Himachal Pradesh is a state in Northwest Himalayas having diversified climatic conditions. Himachal is known for production of off - season vegetables. Capsicum is one of the important vegetable crops and Himachal is the leading state in the country in terms of area and production only after Karnataka. Its production is 58290 MT covering an area of 2500 hectares in Himachal Pradesh (Anonymous 2017) [1]. Protected cultivation technology has the potential to harness the optimum off-season advantage in the state like Himachal Pradesh. Coloured capsicum varieties are more preferred for polyhouse cultivation with remunerative returns, as these varieties fetches good prices in the nearby big markets like Chandigarh, New Delhi etc. The standard package of practices are still lacking for production of crops inside polyhouses. As the result of high production of crops inside protected condition, high nutrient removal consequently makes the soil exhausted and ultimately multinutrient deficiency appears and yield goes down in 5 to 7 years of continuous cultivation. Some of the farmers go for excess or injudicious use of chemical fertilizers in order to achieve higher yield targets, but disproportionate application of chemical inputs leads to the imbalanced soil nutrition and at the end results in loss of soil fertility and which do hamper the productivity to a larger extent. It is therefore, crucial to assess the soil and plant nutrient status of crops grown under protected conditions in order to help the farmers in better management of soil quality for sustainable production. Therefore, the present study was conducted to assess the impact of intensive cropping on availability of soil nutrients and their uptake in the capsicum leaves

Materials and Methods
The present investigation was carried out on soil samples collected from polyhouses of four district of Himachal Pradesh i.e. Shimla, Sirmaur, Solan and Bilaspur. Fourteen polyhouses growing capsicum were selected randomly from each district and soil samples were taken from two depths i.e. (0-15 cm) and (15-30 cm) by standard sampling procedures in the month of

December-January. The collected soil samples were air dried and passed through 2 mm sieve and finally stored in plastic containers for subsequent analysis. The upper youngest mature leaf samples of capsicum were collected in the month of June and July of the following crop season at the flowering and early fruiting stage. The leaf samples were first washed with ordinary water then with 0.1 N HCl followed by washing with distilled water. Leaf samples were dried in Hot air oven at 65 °C for 72 hours. Soil pH, EC were estimated in 1: 2 soil: water suspension, Organic carbon was estimated by wet digestion method (Walkely and Black, 1934), Available nitrogen was analyzed by alkaline potassium permanganate method, available phosphorus by Olsen's method, available potassium by ammonium acetate method and DTPA extractable Fe, Mn, Cu, Zn by atomic absorption spectrophotometer (Lindsey and Norvell, 1978) [13]. Nitrogen content in capsicum leaves was estimated by microkjeldhal distillation, phosphorus by vanado-molybdo-phosphoric yellow colour method, potassium by flame photometer and micronutrients by atomic absorption spectrophotometer. The data was subjected to statistical analysis by adopting simple correlations to find out the extent of relationship between soil characteristics and leaf nutrient contents.

Results and Discussion

Soil pH, EC and OC

The mean pH values in studied soils ranged from 6.51 to 7.27 and 6.37 to 7.26 in surface and subsurface soils, respectively, suggesting soils are slightly acidic to neutral in soil reaction. It is observed that surface soils have a higher pH than sub surface soils due to more salt accumulation in the surface soils as compare to subsurface soils. The results are further in conformity with those of Minhas *et al.* (1997) [15]. The data on electrical conductivity reveals that soils are low in soluble salts concentration with mean EC values ranging from 0.83 to 1.33 dS/m and 0.42 to 0.59 dS/m in the surface and subsurface soils, respectively. The higher values in surface soils are indicative of the accumulation of salts in the root zone due to fertigation of the crop continuously. But, overall low values indicate the responsiveness of soil to fertiliser application. These results are similar to Singh *et al.* (1991) [25] and Kaistha and Gupta (1993) [8]. The polyhouse soils of the study area are rich in organic carbon content which ranged from 11.59 to 19.51 g kg^{-1} and 7.30 to 12.64 g kg^{-1} in surface and sub surface soils, respectively. This may be due to the management practices and more addition of the FYM under protective cultivation systems.

Soil Macronutrients

The available nitrogen of polyhouse soils ranged from 244.99 to 323.41 kg ha^{-1} in the surface 0 – 15 cm depth and 143.77 – 261.15 kg ha^{-1} in the subsurface 15 – 30 cm depth. Out of the total samples analyzed, 48.2 percent samples fell in low category, whereas 50 and 1.8 percent samples fell in medium and high categories, respectively (Table 6). The low to medium levels of N may be due to the cultivation of high nutrient requirement crops. The available nitrogen decreased with soil depth. Similar results were also reported by Verma *et al.* (1976) [30], Mahajan (2001) [14] and Sharma *et al.* (2013) [23]. Among different districts, highest nitrogen content of 323.41 kg ha^{-1} was reported in Solan. This may be attributed to soil properties, crop management practices, high organic matter and application of higher doses of fertiliser nutrients. The available phosphorus content in the different districts varied from 109.60 to 137.20 kg ha^{-1} and 64.80 to 84.32 kg ha^{-1} in surface and subsurface soils, respectively. In the light of suggested critical limits, polyhouse soils are rated as high in their available P Status. The high available P in these soils may be due to higher organic matter and more addition of phosphatic fertilisers for vegetable crop production. Also, the availability of P is highly pH dependent with maximum availability near neutral pH which explains its high contents in these soils. The results are in agreement with the findings of Zhaohui *et al.* (2002) [33] and Quan *et al.* (2011) [16]. The available potassium content was found in the range of 474.01 to 873.19 kg ha^{-1} and 346.32 to 597.59 kg ha^{-1} in surface and subsurface soils, respectively. Out of the total samples, 10.7 percent samples fell in medium category of availability, while the rest were high in available potassium (Table 6). Verma *et al.* (1985) [31] also reported that potassium content in the soils of Himachal Pradesh varied from 40.26 – 1507.00 kg ha^{-1}, which they ascribed to the presence of feldspars and quartzite as parent materials. The high available potassium may be due to more application of potassic fertilisers under polyhouse condition. It has been also observed that older polyhouses recorded higher available potassium.

Soil Micronutrients

The DTPA extractable iron in different district was recorded from 14.95 to 16.60 mg kg^{-1} and 15.93 to 18.97 mg kg^{-1} in surface and sub surface soils, respectively. Similar comparable values of DTPA-Fe were also reported by Tripathi *et al.* (1994) [28] and for the soils of Himachal Pradesh. Only 1.8 percent samples fell in medium category of Fe availability and the rest samples were high in iron. The DTPA extractable Fe content increased with the increase in soil depth. This might be due to more removal of DTPA Fe from surface soils. If 4.5 mg kg^{-1} of DTPA extractable iron is taken as critical level as suggested by Lindsay and Norvell (1978) [13] the soils are well supplied with available Fe. The DTPA extractable manganese content in different district varied from 3.20 to 9.04 mg kg^{-1} for surface soils and 3.35 to 7.93 mg kg^{-1} in subsurface soils, under polyhouse conditions. Taking the critical levels of Mn into consideration, 10.72, 19.64 and 69.64 percent samples falls under low, medium and high categories of nutrient levels, respectively. Similar, values of DTPA extractable Mn was also reported by Sood *et al.* (2009) [27]. The DTPA extractable Cu content in the soils of different district ranged from 2.36 to 4.80 mg kg^{-1} and 1.92 to 4.68 in surface and subsurface soils, respectively. According to critical limit suggested, 5.4 percent samples were found to be medium while 94.6 percent samples were high in DTPA extractable Cu. The probable reason for high copper content in these soils may be due to the application of micronutrient fertilizers coupled with blitox application which may increase the concentration of copper in the soils. The DTPA extractable Cu was also found to be positively correlated with soil organic matter. Badhe *et al*. (1971) [2] have also reported positive relationship with available Cu and soil organic matter content. The DTPA-Zn content in the different districts was found to vary from 2.52 to 3.03 mg kg^{-1} and 1.83 to 2.67 mg kg^{-1}, respectively. Therefore, in the light of suggested critical limits (Lindsay and Norvell, 1978) [13], 3.6, 50 and 46.4 percent samples were found to be low, medium and high, respectively in Zn status. High content of zinc in these soils may be explained by application of $ZnSO_4$ by the farmers.

Plant Nutrient Contents

A perusal of the data in table 2 revealed that the N, P and K in the capsicum leaves varied from 4.81 to 5.67, 0.33 to 0.41 and

3.74 to 4.65 percent, respectively, in different districts of Himachal Pradesh. Considering the critical limits, the majority of samples are sufficient in N, P and K. The soil analysis data shows that soils are medium in available nitrogen and rich in available P and K. It appears the extractant used for available P and K are quite suitable for soils of the area as soil and plant analysis data are in complete agreement with each other. The sufficiency may be attributed to the better fertiliser management practices adopted by the farmers to the polyhouse crop. The observations are in agreement with those made by Campbell (2000) [5]. The content of Fe and Mn in the capsicum leaves ranged 310.09 to 386.49 ppm and 137.46 to 218.84 ppm, respectively. Taking into consideration the established critical limits, the plants were found to be sufficient to high in Fe and Mn, as none of leaf samples were found to be deficient. This is in confirmation with the sufficiency of these nutrients in the polyhouse soils and corroborates the findings of the content of Cu and Zn in the capsicum leaves varied from 37.04 to 49.60 and 42.49 to 53.32 ppm, respectively. After classifying the data into various classes of nutritional levels, as per the critical limits, it was seen that Zn content was in the low to high range and copper in high range. This is also in confirmation with the sufficiency status of these nutrients in the polyhouse soils. The data indicates that DTPA extractant is quite suitable for the estimation of micronutrients in the polyhouse soils.

Correlation Studies

Relationships among soil physico-chemical properties

The simple correlations were worked out to find out the degree of relationships among the soil physico-chemical properties (Table 3). The pH was found to be negatively and significantly correlated with DTPA extractable Fe (r= -0.46**), which may be attributed to the decrease in solubility and availability of micronutrients cations at neutral and higher pH. Similar results were worked out by Katyal and Agarwala (1982) [9], Rajkumar *et al.* (1990) [17], Verma *et al*. (2007) [29], Sharma and Kanwar (2011) [24] and Kumar *et al.* (2012) [12]. The EC had a highly significant and positive correlation with organic carbon (0.56**), available P (r=0.49**), K (r=0.48**) and DTPA Fe (r=0.40**). The results are in line with the findings of Ramana Murthy and Srivastava (1994). The availability of N (r=0.55**), P (r=0.56**), K (r=0.49**), DTPA-Fe (r=0.43**), Mn (r=0.27*), Cu (r=0.45**) and Zn (r=0.55**) is significantly and positively influenced by the Organic carbon. This is understandable as the organic matter is one of the major sources of nutrient supply in the soil. The availability of Fe increased with the increase in organic matter content because Fe is held in the chelates as soluble complex. This result finds support from who explained that the complexing agents generated by organic matter decomposition promote availability of these nutrients in soil. The results are in conformity with the findings of Sauchelli (1969) [21], Bhandari and Randhawa (1985) [4], Sakal *et al.* (1986) [20], Kanthalia and Bhatt (1991) [7], Singh *et al*. (2006) [26] and Kumar *et al.* (2011) [11]. Available N showed significantly positive correlation with Available K (r=0.29*), DTPA Fe (r=0.48**), Cu (r=0.27*) and Zn (r=0.29*). Zn was found to be positively correlated with Mn (r=0.37**) and Cu (r=0.45**). This is in agreement with the findings of Katyal and Sharma (1991) [10]. This positive relationship indicates that similar factors influence the availability of these metals in soil and soil rich in these micronutrients.

Relationships of soil characteristics and leaf nutrient content

The data given in table 4 and 5, clearly indicates that the leaf Nitrogen content had positive and significant correlation with soil organic carbon (r=0.36** and 0.34*), DTPA Cu (r=0.34* and 0.26) and DTPA Zn (r=0.30* and 0.38**) in both surface and sub surface soils, suggesting the soil organic matter as one of the major sources of nitrogen for the plant.

The leaf Fe was found to be positively correlated with soil nitrogen (r=0.36** and 0.37**) in surface and sub surface soils. Leaf manganese content was positively correlated with DTPA Mn(r=0.40**) and leaf copper content was also found to be positively correlated with DTPA Cu content (r=0.39**) in surface soils only, suggesting that surface soils are contributing more towards the nutrient uptake by the roots of capsicum plants, in the polyhouse soils.

Table 1: Chemical properties of vegetable growing polyhouse soils in Himachal Pradesh

Soil Parameter		District							
		Shimla		Sirmaur		Solan		Bilaspur	
		Soil Depth (cm)							
		0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
pH	Range	5.39 - 7.22	5.11 - 7.55	5.86 - 7.70	5.62 - 7.82	6.43- 7.43	6.15 - 7.47	7.10 - 7.46	7.00 - 7.45
	Mean	6.51	6.37	6.93	6.84	7.04	7.02	7.27	7.26
EC	Range	0.44-2.36	0.22-0.59	0.36-2.00	0.17-1.05	0.25-2.76	0.22-1.20	0.25-3.32	0.17-1.50
	Mean	0.87	0.42	0.83	0.55	1.33	0.59	1.18	0.57
OC	Range	2.80-27.00	2.70-18.60	2.40-25.80	4.60-19.20	5.20-28.50	3.70-22.50	3.00-28.50	2.20-12.30
	Mean	11.59	7.97	14.26	9.64	19.51	12.64	13.16	7.3
N	Range	156.80-457.85	112.89-376.30	112.89-470.40	181.80-439.00	232.10-489.20	144.20-313.60	112.80-570.70	81.50-200.70
	Mean	280.01	242.37	309.55	261.15	323.41	253.08	244.99	143.77
P	Range	33.6-207.20	22.40-124.32	44.80-168.00	28.00-100.80	39.20-168.00	28.00-100.80	44.80-229.60	22.40-159.60
	Mean	109.6	64.8	114	66.8	117.2	70.4	137.2	84.32
K	Range	103.04-949.76	75.04-618.20	358.40-1493.5	258.70-1028.2	390.8-2218.7	315.8-1451.5	229.6-2430	151.5-1587.6
	Mean	474.01	346.32	803.11	597.59	873.19	579.9	852.74	543.51
Fe	Range	5.97-30.78	6.35-36.38	6.59-29.64	6.08-29.32	7.94-21.68	7.52-25.44	7.52-44.06	7.67-49.98
	Mean	16.37	18.97	15.94	17.02	14.95	15.93	16.6	18.23
Mn	Range	0.36-10.15	0.37-10.03	2.58-16.91	3.37-15.50	2.49-15.26	2.51-13.22	5.05-20.54	1.96-13.71
	Mean	3.2	3.35	7.03	6.93	6.85	5.89	9.04	7.93
Cu	Range	0.51-4.55	0.42-3.29	0.65-6.11	0.39-5.87	1.37-14.32	1.45-15.00	1.16-5.54	1.13-10.07
	Mean	2.36	1.92	2.74	2.15	4.8	4.68	3.2	3.23
Zn	Range	0.83-3.99	0.31-3.40	1.01-4.18	1.38-4.01	1.56-4.12	0.94-4.00	1.29-4.03	0.80-3.72
	Mean	2.52	1.83	2.77	2.27	3.03	2.67	2.76	2.25

Table 2: Leaf nutrient content of capsicum grown under polyhouse condition in H.P.

Leaf Parameter		District			
		Shimla	Sirmaur	Solan	Bilaspur
N	Range	2.80-6.16	4.76-6.16	5.04-6.44	3.36-6.44
	Mean	4.81	5.39	5.67	5.02
P	Range	0.23- 0.71	0.25- 0.85	0.20-0.64	0.23-0.90
	Mean	0.37	0.41	0.33	0.39
K	Range	2.06-5.89	2.66- 5.58	3.12-6.23	2.07- 6.10
	Mean	3.83	4.57	4.65	3.74
Fe	Range	95.90-735.00	186.80-649.60	199.20-587.60	174.40-463.60
	Mean	378.61	386.49	310.09	320.49
Mn	Range	58.10-209.40	114.80-379.70	130.80-328.00	79.90-375.40
	Mean	137.46	180.53	213.74	218.84
Cu	Range	18.90- 78.96	18.90- 106.20	18.00- 93.00	24.10- 96.50
	Mean	42.43	49.6	37.04	37.54
Zn	Range	7.90- 85.90	16.40- 82.10	15.70- 108.01	15.90- 118.20
	Mean	46.2	42.49	53.32	51.55

Table 3: Relationships (r-values) among different soil physico-chemical properties

	pH	EC	OC	N	P	K	Fe	Mn	Cu
pH									
EC	-0.15								
OC	-0.10	0.56**							
N	-0.25	0.35**	0.55**						
P	0.14	0.49**	0.56**	0.10					
K	0.13	0.48**	0.49**	0.29*	0.53**				
Fe	-0.46**	0.40**	0.43**	0.48**	0.21	0.35**			
Mn	-0.10	0.25	0.27*	0.20	0.09	0.17	0.30*		
Cu	0.14	0.18	0.45**	0.27*	0.33*	0.27*	0.16	0.08	
Zn	-0.15	0.26	0.55**	0.29*	0.56**	0.22	0.19	0.37**	0.45**

Table 4: Relationships (r-values) of surface soil characteristics with leaf nutrient contents

Leaf Soil	N	P	K	Fe	Mn	Cu	Zn
pH	0.01	0.02	-0.06	-0.20	0.25	0.09	0.07
EC	0.02	-0.11	-0.06	-0.10	-0.02	-0.06	-0.11
OC	0.36**	-0.04	0.21	0.06	-0.08	0.03	-0.14
N	0.18	-0.16	0.13	0.36**	-0.16	0.19	-0.06
P	0.03	0.16	-0.08	-0.05	-0.17	0.06	-0.10
K	0.13	-0.06	0.24	-0.02	-0.10	0.12	-0.16
Fe	-0.04	-0.12	0.06	0.13	-0.17	0.01	-0.07
Mn	0.18	-0.04	0.09	-0.07	0.40**	-0.22	0.08
Cu	0.34*	-0.04	0.22	-0.07	-0.07	0.39**	-0.04
Zn	0.30*	0.08	0.04	0.10	-0.05	0.04	0.14

Table 5: Relationships (r-values) of sub surface soil characteristics with leaf nutrient contents

Leaf Soil	N	P	K	Fe	Mn	Cu	Zn
pH	-0.04	0.00	-0.06	-0.16	0.25	0.09	0.07
EC	-0.10	-0.10	-0.06	-0.13	-0.03	-0.09	-0.22
OC	0.34*	-0.07	0.22	-0.12	0.05	0.04	0.02
N	0.20	-0.01	0.19	0.37**	-0.10	0.31*	0.06
P	0.11	0.25	-0.12	-0.06	-0.16	0.11	-0.06
K	0.18	0.07	0.17	0.04	-0.16	0.13	-0.17
Fe	-0.13	-0.15	-0.06	-0.02	-0.28*	-0.07	-0.19
Mn	0.03	-0.15	0.08	-0.12	0.08	-0.20	-0.13
Cu	0.26	-0.12	0.11	-0.02	0.09	0.15	0.12
Zn	0.38**	0.04	0.12	0.14	-0.07	0.11	0.14

Table 6: Overall fertility status of surface soils and Nutrient Index values of the studied soils.

Nutrient	Percent Samples			Nutrient Index	Nutrient Status
	Low	Medium	High		
Nitrogen	48.21	50.00	1.79	1.53	Low
Phosphorus	0.00	0.00	100.00	3.00	High
Potassium	0.00	10.71	89.29	2.89	High
Iron	0.00	1.79	98.21	2.98	High
Manganese	10.72	19.64	69.64	2.59	High
Copper	0.00	5.36	94.64	2.95	High
Zinc	3.57	50.00	46.43	2.43	High

Table 7: Percent plant samples falling in various categories of nutrient levels.

Leaf Nutrient	Sufficiency Levels		
	Deficient	Intermediate	High
Nitrogen	0	1.8	98.2
Phosphorus	0	71.4	28.6
Potassium	0	21.4	78.6
Iron	0	1.8	98.2
Manganese	0	7.1	92.9
Copper	0	0	100
Zinc	23.2	66.1	10.7

Conclusion

On the basis of overall results, it may be concluded that the soil reaction in polyhouse soils of Himachal Pradesh is slightly acidic to near neutral, hence is suitable for the availability of nutrients in soil and crop growth. The soils are in safe limits of soil salinity. The polyhouse soils are rich in organic matter content. The organic carbon content was found to be highly correlated with the availability of majority of the nutrients. The soils were found to be low to medium in N and medium to high in Zn. All other soil nutrients were found to be high. The plant samples are sufficient in all the nutrients, except for Zn, which was reported to be deficient to intermediate in most samples.

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