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Assessment of Soil Health under Protected Cultivation by Soil Quality Indexing and Variability Analysis

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Soil quality assessment is of paramount importance to know the appropriate management practices to be adopted for sustainable crop production. Sustainability of intensive agriculture system is intimately linked to maintenance of soil health. Present study was undertaken to investigate the impact of intensive cultivation on soil health under polyhouses located in Bilaspur, Solan and Sirmaur districts of Himachal Pradesh. Studies reveal that the bulk density ranged from 1.09 to 1.13 Mg m^{-3}. The particle density varied between 2.25 to 2.31 Mg m^{-3}, whereas the porosity ranged from 49.47 to 51.09 per cent. The CEC values fell in the range of 14.70 to 15.00 meq./100g. The soil reaction was noted to be neutral (7.08 to 7.34) and EC values were in safe limits (<0.8 dS m^{-1}). The organic carbon content varied from 1.76 to 2.00 per cent. The available N, P and K ranged from 246.1 to 264.8, 49.5 to 61.9 and 587.1 to 682.5 kg ha^{-1}, respectively. The exchangeable Ca and Mg were found to be adequate and sulphur content (15.21 to 16.99 mg kg^{-1}) was found moderate in the soils. Available Zn, Fe, Cu and Mn were medium to high in availability, both under polyhouse and open field conditions. The microbial biomass ranged from 322.65 to 385.343 µg g^{-1}, falling under medium range for categorizing soil health. In light of the soil health index values 36.7, 46.7 and 16.6 per cent of samples were categorized under the very high, high and medium soil health, respectively under polyhouse conditions. Such values for open field condition were noted to be 10, 70 and 20 per cent, respectively. Soil health was found to be affected by the management practices adopted by the farmers and the degree of manure and fertilizer usage over a period of time considerably.

Introduction

Soil health is defined as the continued capacity of a soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health (Doran and Zeiss, 2000). Soil health is extremely valuable but highly vulnerable. The increased cropping intensity had been found to accentuate changes such as rapid increase in degradation of soil physical condition, deterioration of nutrient status and changes in the number and composition of soil organisms (Ayoub, 1999). People in developed countries have realized that over dosing of agricultural soils with fertilizers, pesticides and other toxic chemicals have paved the way for soil ill health and pollution of the environment (Govindarajan and Thangaraju, 2001; Muhammad *et al.,* 2013). In India also, adverse effects on soil health and soil quality primarily arise from nutrient imbalance, soil contamination and injudicious application of fertilizers, pesticides and herbicides. The agricultural land availability is shrinking day by day due to intense industrialization. Therefore, it has almost become a compulsion to increase the per unit yield levels from the available land under agriculture which however, can be achieved by using modern technology such as cultivation in polyethylene-houses. The research data on production potential of protective cultivation for horticultural crops revealed that yield of horticultural crops can be increased from 20 to 30 per cent. This shows that protected cultivation has tremendous scope to improve the economy of the growers as well as fulfill the demand for horticultural crops throughout the year from the small piece of land (Baghel *et al.*, 2003). Protected cultivation has emerged as an alternative to open field production. Among the various floricultural crops carnation (*Dianthus caryophyllus* Linn.) is cultivated widely inside polyhouses especially, in the low and mid hill zones. The present research therefore was focused on carnation. It is pertinent to add that intensive cultivation of flowers under polyhouse condition has lead to injudicious and excess use chemical inputs, resulting in adverse physico-chemical condition of soil (Huang and Zhang, 2004). Therefore, soil quality assessment inside the polyhouses is of paramount importance to study the impact of intensive cultivation on soil health under polyhouses. An index of soil health should be standardized that integrates physical, chemical and biological properties of soils into a single numeral that serves as the soil's "key indicator" for typical soil health.

Materials and Methods

The study was carried out in three districts of Himachal Pradesh i.e. Bilaspur, Solan and Sirmaur for assortment of necessary information about cultivation practices, cropping patterns and problems prevailing in the polyhouses growing carnation. Ten polyhouses growing flower crops were selected at random from each district and soil samples were collected from inside the polyhouse as well as from the open field adjacent to the polyhouse.

A total number of 60 soil samples (0 to 20 cm), were collected from different locations with the help of spade and auger, thereafter samples were air dried, crushed in a wooden pestle and mortar, passed through 2 mm sieve and were subjected to the following analytical procedures. The obtained data of physical, chemical and biological characteristics were subjected to student t-test for variability analysis (Gomez and Gomez, 1984).

Selecting appropriate indicators is the foundation of soil health assessment. A total of 19 indicators were considered, including the physical indicators such as bulk density, particle density and porosity. Chemical indicators such as pH, electrical conductivity (EC), organic carbon, bicarbonate, chloride, soil nutrient indicators such as available nitrogen, available phosphorous, available potassium, calcium, magnesium, sulphur, zinc, iron, manganese, copper and biological indicators such as microbial biomass were used for soil health assessment under protected and open field conditions (Table 1). Soil property threshold levels, interpretations, and associated soil index values are listed in table 2. The individual index values for all the soil properties measured were summed to give a total SQI (Michael *et al.*, 2007).

Total SQI = Σ individual soil property index values

The maximum value of the total SQI is 28 if all 19 soil properties are measured. The total SQI is then expressed as a percentage of the maximum possible value of the total SQI for the soil properties that are calculated:

SQI, % = (total SQI / maximum possible total SQI for properties measured) x 100

Results and Discussion

Table 4 represent that the calculated values through student t-test when compared with table value at 5% level of significance (2.101) revealed that there was significant difference in the electrical conductivity, phosphorous, zinc, copper, particle density and bicarbonate content in different locations of Bilaspur. Gao *et al.*, (2012) also documented that soil physical and chemical properties in newly-built greenhouse such as contents of available phosphorus and available micronutrients in soil increased after one growing season of tomato.

Table.1 Methods employed for estimating important soil properties

Particular	**Method employed**	**Reference(s)**
Bulk Density	Core tube method	
Particle Density	Pycnometer method	
Porosity	Empirical formula [(1-BD*/PD)**X100]	
pH	1:2 soil:water suspension,with the help of digital pH meter	Jackson, (1973)
Electrical Conductivity	1:2 soil:water suspension,with the help of digital EC meter	Jackson, (1973)
Organic carbon	Rapid titration method	Walkley and Black (1934)
$CaCO_3$	Rapid titration method	Puri,(1930)
Cation Exchange Capacity	Sodium and ammonium acetate, Centrifuge method	Bower *et.al.* (1952)
CO_3, HCO_3^-, Cl^-	Rapid titration method	Reitemeier (1943)
Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
Available P	Olsen's method	Olsen *et al.*, (1954)
Available potassium, calcium and magnesium	Ammonium acetate method	Merwin and Peech (1951)
Available sulphur (SO_4-S)	Turbidimetric method (0.15% $CaCl_2$)	Williams and Steinbergs (1959)
DTPA Extractable Zinc, Iron, Manganese, Copper	Atomic Absorption Spectrophotometer (AAS)	Lindsay and Norvell (1978)
Microbial biomass	Soil Fumigation-Extraction Method	Vance *et al.*, (1987)

Table.2 Soil health index values and associated soil property threshold values and interpretations

Parameter	Level	Interpretation	Index
Bulk density(g/cc)	>1.5	Possible adverse effect	0
	<1.5	Adverse effect unlikely	1
Porosity (%)	>40	Adverse effect unlikely	1
	<40	Possible adverse effect	0
Soil pH	<3.0	Severe acidic (no plant will grow in this environment	-1
	3.01-4	Strongly acidic	0
	4.01-5.5	Moderately acidic	1
	5.51-6.8	Slightly acidic	2
	6.81-7.2	Near neutral	2
	7.21-7.5	Slightly alkaline	1
	7.5-8.5	Moderately alkaline	1
	>8.5	Strongly alkaline	0
Bicarbonate (meq/l)	<2.5	Usual range for most of the crop	2
	2.5 -5.0	Satisfactory	1
	>5.0	High- Toxic to plants	0
Chloride (meq/l)	<5.0	Usual range for most of the crop	2
	5.0-10	Satisfactory	1
	>10	High- Toxic to plants	0
EC (dS/m)	<0.8	Low	2
	0.8-2.5	Medium	1
	>2.5	High	0
Organic carbon (%)	<0.5	Low-indicate loss of C from erosion and other processes.	0
	0.5-1.5	Moderate- adequate level	1
	>1.5	High- Excellent buildup of OC with all possible benefits.	2
N (kg/ha)	<280	Low –Possible deficiencies	0
	280-560	Moderate-adequate level for most of plant	1
	>560	High-excellent reserve	2
P (kg/ha)	<12.4	Low –Possible deficiencies	0
	12.4-24.2	Moderate-adequate level for most of plant	1
	>24.2	High-excellent reserve	2

K(kg/ha)	<98.6	Low –Possible deficiencies	0
	98.6-280.0	Moderate-adequate level for most of plant	1
	>280.0	High-excellent reserve	2
Ca(cmol (p^+)/ kg)	<1.5	Low-possible deficiency	0
	>1.5	High- Excellent reserve	1
Mg(cmol(p^+)/ kg)	<1.0	Low-possible deficiency	0
	>1.0	High- Excellent reserve	1
SO_4-S (ppm)	<10	Low-possible deficiency	0
	>10	High- may indicate gypsum soils atmospheric deposition.	1
Zn (ppm)	<0.6	Low-possible deficiency in calcareous and sandy soil.	0
	>0.6	Sufficient	1
Fe(ppm)	<4.5	Low-possible deficiency	0
	>4.5	High- Excellent reserve	1
Mn(ppm)	<3.5	Low-adverse effect unlikely	0
	>3.5	Sufficient	1
Cu(ppm)	<0.2	Low-indicate possible deficiencies in organic, calcareous or sandy soils.	0
	>0.2	Sufficient	1
CEC(cmol(p^+)/kg)	<10	Low-possible deficiency of exchangeable cations	0
	>10	High- Excellent reserve of OC, exchangeable cations	1
Microbial biomass (µg/g)	<300	Low	0
	300-400	Medium	1
	>400	High	2

The soil health of polyhouse and open condition were categorized following the rating given by Gugino *et al.*, (2009) (Table 3).

Table.3 Rating of soil according to soil health index

Sl. no.	Interpretation	SHI
1.	>85%	Very high
2.	70-85%	High
3.	55-70%	Medium
4.	40-55%	Low
5.	<40%	Very low

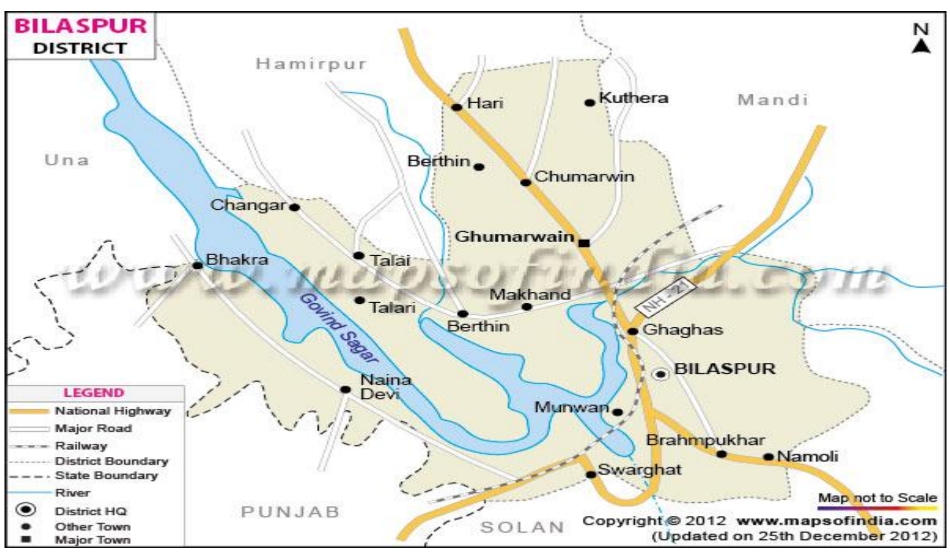
Table.4 Status of soil health indicators under different conditions of the selected districts

	Bilaspur			Solan			Sirmaur		
Particular	Poly (mean)	Open (mean)	t-cal	Poly (mean)	Open (mean)	t-cal	Poly (mean)	Open (mean)	t-cal
BD (Mg m^{-3})	1.08	1.16	NS	1.03	1.14	NS	1.06	1.2	NS
PD (Mg m^{-3})	2.19	2.50	NS	2.24	2.26	NS	2.27	2.25	NS
Porosity (%)	51.49	50.69	NS	53.24	48.24	NS	52.46	46.49	NS
CEC(meq./100 g)	15.66	14.33	NS	14.92	14.37	NS	14.89	14.61	NS
pH	7.12	7.57	NS	7.15	7.33	NS	7.06	7.1	NS
EC (dS m^{-1})	0.77	0.53	2.14*	0.44	0.23	2.12*	0.43	0.24	NS
OC (%)	1.86	1.66	NS	1.97	1.70	NS	2.50	1.50	2.29*
N (kg ha^{-1})	250.57	241.7	NS	268.13	251.51	NS	277.45	252.17	NS
P (kg ha^{-1})	80.64	43.23	2.42*	85.57	34.27	2.48*	66.3	32.7	NS
K (kg ha^{-1})	760.03	482.38	NS	752.86	488.66	NS	802.03	563.02	NS
Ca cmol(p^+)/kg	8.76	13.17	NS	17.08	11.47	NS	14.24	13.56	NS
Mg cmol(p^+)/kg	0.98	1.02	NS	1.01	1.06	NS	0.97	1.13	2.29*
S (mg kg^{-1})	19.44	14.54	NS	14.69	16.47	NS	13.63	16.79	NS
Zn (mg kg^{-1})	3.32	2.63	2.21*	2.98	2.43	NS	3.44	2.94	NS
Fe (mg kg^{-1})	4.68	6.00	NS	7.78	7.67	NS	9.38	5.86	NS
Cu(mg kg^{-1})	7.25	2.89	2.43*	2.76	4.63	NS	3.44	2.32	NS
Mn (mg kg^{-1})	5.79	3.41	NS	7.75	9.48	NS	10.26	9.41	NS
Chloride(cmol (p+)/kg)	0.04	0.03	NS	0.05	0.04	NS	0.06	0.05	NS
Bicarbonate (cmol (p+)/kg)	1.57	0.46	3.01*	1.3	0.74	NS	1.07	0.63	NS
MB (µg g^{-1})	393.63	377.04	NS	372.41	354.76	NS	335.08	310.21	NS

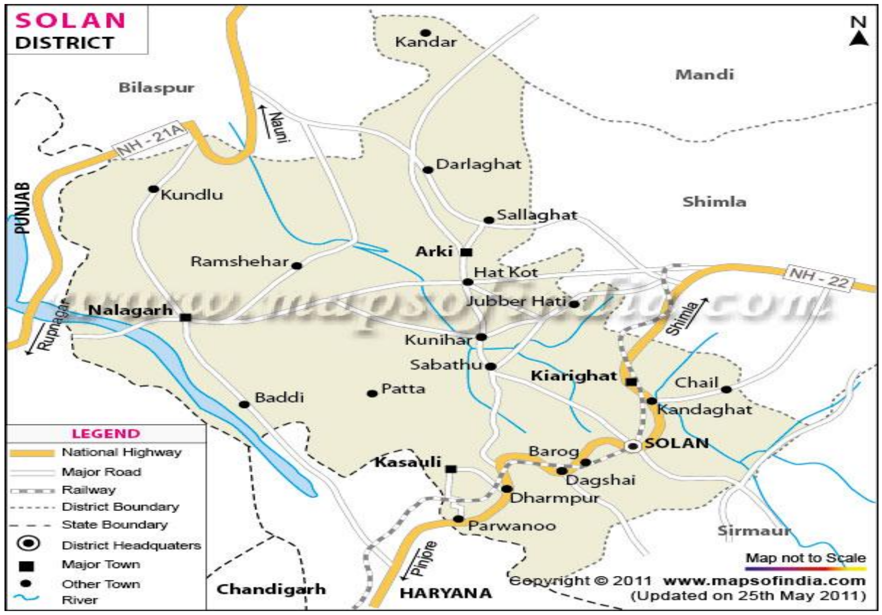
Table.5 Soil Health Index in polyhouses and open condition of different district

					Soil Health Index (%)				
S.No	**Bilaspur**	**Poly**	**Open**	**Solan**	**Poly**	**Open**	**Sirmaur**	**Poly**	**Open**
1.	Sakred-1	78.57	64.29	Oachghat	82.14	78.57	Kanogata	78.57	82.14
2.	Sakred-2	71.43	75.00	Mahog-1	82.14	82.14	Paviana	85.71	82.14
3.	Jukhala	85.71	78.57	Mahog-2	89.29	82.14	Chakhal-1	85.71	82.14
4.	Noa	67.86	78.57	Budlayana	85.71	82.14	Chakhal-2	85.71	78.57
5.	Nauni	75.10	85.71	Patrar	89.29	89.29	Kasar	85.71	75.12
6.	Patialog	78.57	67.86	Kathar	85.71	64.29	Kotli	89.29	96.43
7.	Thandora	78.57	71.43	Sodi	78.57	78.57	Talon	67.86	67.86
8.	Lanjhata-1	60.71	71.43	Basal	85.71	75.00	Dhamla	78.57	78.57
9.	Lanjhata-2	71.43	75.20	Riwalsar-1	57.14	60.71	Rajgarh	75.00	71.43
10.	Ghumarwin	82.14	82.14	Riwalsar-2	64.29	75.00	Nohra	78.57	67.86
	MEAN	75.01	75.02	MEAN	79.99	76.78	MEAN	81.07	78.23

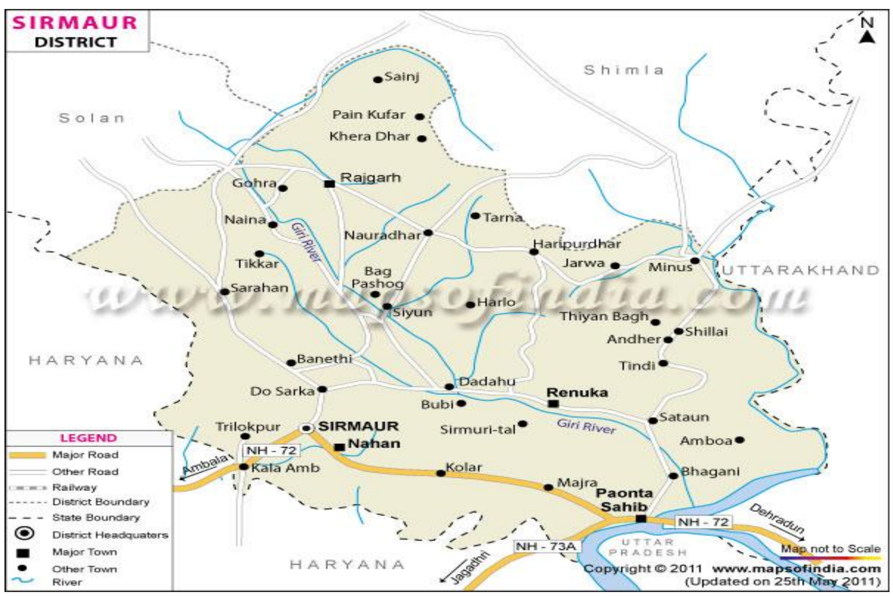
Fig.1 The study area (maps of Solan, Sirmaur and Bilaspur districts)



Source: www.mapsofindia.com



Source: www.mapsofindia.com



Source: www.mapsofindia.com

The electrical conductivity in the surface soil layer also increased to some degree. But the other soil health indicators ware found non-significant. In Solan district electrical conductivity and phosphorous show significant difference between polyhouse and open condition at 5% level of significance as compared to other soil health indicators which were found statistically non significant. Lou *et al*., (2012) also reported that soil electrical conductivity increased significantly in comparison with open field condition mainly due to the reckless application of nitrogenous fertilizer with higher rate in the greenhouses. Similar findings were also reported by several researchers (Cao *et al*., 2012, Gao *et al*., 2012). Organic carbon and magnesium content were statistically significant at 5% level of significance, under polyhouse and open condition in different locations of Sirmaur district (Table 4). This might have caused by the long-term combined application of inorganic fertilizers along with organic manure mainly FYM, plant residues and vermicompost (Cao *et al*., 2012, Tida *et al*., 2011). Remaining indicators registered no significant variation. This consequence might have taken place due to the fact that at different districts, the locations are situated in the nearby area. These significant indicators emerged through variability analysis can plausibly be of immense help for soil and plant sampling in the studied area for further study as it gives a better idea of the soil health status.

Soil health index value in Bilaspur varied from 60.71-85.71 per cent (Table 5). The soil health index under protected cultivation of Jukhala and Lanjhata-1 areas registered maximum (85.71) and minimum (60.71) values, respectively. Under open field condition however, soils of Nauni and Sakred-1 areas registered highest (85.71%) and lowest (64.29%) values, respectively. According to soil health rating 10, 70 and 20 per cent of surveyed polyhouse in Bilaspur district were rated as very high, high and medium in soil health status, respectively. Even as under open field condition, 10%, 70% and 20% soils were in very high, high and medium soil health conditions, respectively. In Solan district soil health index value fell in the range of 57.14 to 89.29 per cent (Table 5). The soil health index in the polyhouse of Mahog-2, Patrar registered the highest value of 89.29% and Riwalsar-1 (57.14%) registered the lowest value, respectively. However, under open field conditions Patrar (89.29%) and Riwalsar-1 (60.71%) registered the maximum and minimum values, respectively (Table 5). According to soil health rating, 50, 30 and 20 percent of surveyed polyhouse in Solan district were rated as very high and high and medium in soil health status, respectively. However, under open condition, 10%, 70% and 20% soils were in very high, high and medium soil health conditions, respectively. Soil health index value in Sirmaur district varied from 67.86-96.43 per cent. The soil health index in the polyhouse of Kotli and Talon registered maximum (89.29%) and minimum (67.86%) values, respectively.

Under open field condition however, Kotli (96.43%) registered the highest value while, Talon and Nohra registered the lowest value of 67.86 % (Table 5). According to soil health rating 50, 40 and 10 per cent of surveyed polyhouse in Sirmaur district were considered as very high and high and medium in soil health status, respectively. However, under open condition, 10, 70 and 20 per cent soils were in very high, high and medium soil health conditions, respectively. Taking into account all the selected indicators, it was found that amongst the polyhouses 36.66, 46.67 and 16.67 percent have very high, high & medium soil health, respectively. Whereas, under open field conditions 10%, 70% and 20% have very high, high and medium soil health, respectively. Soil health was found to be influenced by the management practices adopted by the farmers and the degree of manure and fertilizer usage over a period of time. It has been observed that soil indicators *viz*. pH, N, K, Ca, Mg, S, micronutrients and chloride had less impact on soil health; while EC, phosphorus, organic carbon, porosity, bicarbonates and microbial biomass greatly varied in the present study. Similar finding have earlier been reported by Juan *et al*. (2013).

It can be recapitulated that health status of soil under polyhouse condition is at higher level as compared to corresponding open field conditions. This may be accredited to proper cropping pattern and relatively lesser use of harmful chemical inputs, which sustain the quantity and quality of soil organic matter and improve physical and chemical status of the soil. Adequate application of fertilizers along with farmyard manure may further improve soil nutrient status and soil organic carbon content. The soil indicators like pH, N, K, Ca, Mg, S, micronutrients and chloride had less effect on soil health, while, EC, phosphorus, organic carbon, porosity and microbial biomass significantly influenced the soil health both under polyhouse and open field conditions. Status of soil under polyhouse condition as compared to corresponding open field conditions was found to be healthier. Adequate application of fertilizers along with farmyard manure may further improve soil nutrient status and soil organic carbon content. There is a necessity for screening of soil health status under polyhouse production system at regular intervals and well-timed adoption of counteractive measures to retain good soil health for sustainable productivity.

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