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Morphological, Physical and Chemical Properties of Soils from North West Himalayas

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Abstract

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Six representative soil profiles (two each from vegetables, paddy and maize growing areas) from Balh Valley District Mandi, Himachal Pradesh (India) lying in North West Himalayas were studied for their morphological, physical and chemical properties. The results show that soils are deep, well drained, silty loam to silty clay loam with dark brown to brownish yellow in colour. No gravels were noticed upto 0.6 m depth and the soil consistency was firm to loose. Few to many black brown concretions were observed only in rice growing soils. Silty loam was the dominant texture of the soils irrespective of soil depth. Coarse sand fraction was more in all soil profiles. In none of the soils except Dhangu, illuviation of clay had been observed. The values of bulk density, particle density and porosity were variable depending upon organic carbon and other soil characteristics. The soils were slightly acidic to neutral in reaction, medium to high in organic carbon with high contents of exchangeable bases (Ca^{2+} and Mg^{2+}) and moderate in available N, P and K status. The DTPA-extractable Fe, Zn, Cu and Mn were also high in these soils. Similarity in the colour and texture in most of the soils indicated the dominant influence of parent material as reported by Robinson in 1949.

Key words: Morphological and physico-chemical properties; Available nutrients; Balh Valley, North West Himalayas; India

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Introduction

Man is dependent on soil because he obtains all the basic necessities of life like food, fibre, shelter from it, but good soils are also dependent on human civilization. Due to the intimate relationship of man's prosperity with soil, it is very essential that unwise exploitation and misuse of soils be avoided. The knowledge of the soils in respect of its origin and formation, nature and properties and distribution becomes imperative in this connection. Such information's are not only useful in agriculture but are equally important for foresters, geologists and engineers for land use planning and soil management etc.

Some piece meal work has been done on the characterization of the soils of Kullu, Kinnaur, Solan and Shimla districts, but information in this respect of Mandi district is still lacking. Keeping in view the importance of such area and inadequate information available, a present study on the characterization of the soils of Balh Valley in Mandi district (Himachal Pradesh), lying in North West Himalayas was undertaken which is second largest in population after Kangra and is major grain producing district of Himachal Pradesh. This study will help to realize the full potential of the soil resources of Mandi district, there is a need to characterize the Balh Valley soils lying in North Western Himalayan Region.

Materials and Methods

The study area in the Mandi district of Himachal Pradesh in the North Western Himalayas is located between $31^{0}43'19''$ N latitudes and $76^{0}58'31''$ E longitudes. The elevation of Balh Valley varies from 880 to 950 m above mean sea level, covering an area of about 3500 hectare. The mid hill of Mandi district is comprised of rocks mainly of thickly bedded sandstones, boulders, conglomerates and sedimentary rocks. The region as a whole is flat and divided by Suketi River into two parts i.e. eastern and western part. The climate of Balh Valley is sub-humid to sub-tropical with mean annual rainfall of 1112 to 2001 mm and means annual air temperature varies from 5^{0}C to 33^{0}C.

The study area is rain fed; however, ground water table varies from 8 to 28 m. The eastern part of the Valley is having irrigation facility from the water of Beas River. The main crops grown in the area are maize, paddy and wheat. But now due to the availability of irrigation water, more and more area is coming under vegetables production. Keeping in view the important crops grown in Balh Valley, the whole studied area has been divided into three subgroups i.e. maize, paddy and vegetable growing areas. Finally, six typical soil profiles representing two each vegetable growing (Gaggal and Kummi), paddy growing (Dhangu and Chhattar) and maize growing areas (Naulakha and Behna) were selected. The morphological characteristics of soil profiles were recorded in the field by following Standard Techniques as given in the Soil Survey Manual of USDA (Soil Survey Staff, 1995).

After collecting soil samples, these were air dried and analyzed for physical and chemical properties. Particle size distribution was carried out by International Pipette method as described by Piper (1966). Bulk density and particle density of the soils were determined by Core Sampler method and Pycnometer method as described by Singh (1980) and Black (1965). The physico-chemical properties of the studied soils like pH, organic car-

Table 1
Morphological characteristics and physical properties of Balh Valley soils

Soil depth, m	Colour (Moist)	Texture*	Consistency	Gravels	Black brown concretions/ mottles	Particle size distribution, %				Bulk density, mg m^{-3}	Particle density, mg m^{-3}	Porosity, %
						Cs	Fs	Si	Cl			
A. Soils of Vegetable Growing Areas												
Profile 1 (Gaggal)												
0.00-0.15	Very dark brown (10YR 2/2)	Sil	Friable	--	--	26.3	9.1	40.1	22.2	0.95	2.30	58.7
0.15-0.30	Very dark greyish brown (10YR 3/2)	Sil	Very friable	--	--	27.5	12.2	40.5	17.3	0.99	2.34	57.7
0.30-0.45	Dark greyish brown											
(10YR 4/2)	Sil	Friable	--	--	24.5	14.1	39.6	19.2	1.21	2.52	51.9	
0.45-0.60	Greyish brown (10YR 5/2)	Sil	Friable	--	--	31.2	9.2	39.5	18.1	1.22	2.53	51.7
0.60-0.75	Brown (10YR 5/3)	Sil	Very friable	Few	--	38.3	14.3	30.8	15.3	1.25	2.56	51.2
0.75-0.90	Yellowish brown (10YR 5/4)	Sil	Very friable	Few	--	40.1	17.9	27.2	12.1	1.32	2.57	48.6
0.90-0.105	Brownish yellow (10YR 6/6)	Sil	Loose	Many	--	41.6	17.1	25.7	11.5	1.40	2.60	46.2
0.105-0.120	Light brownish grey											
(10YR 6/2)	Sil	Loose	Many	--	43.5	13.2	29.7	11.2	1.42	2.60	45.4	
Profile 2 (Kummi)												
0.00-0.15	Very dark brown (10YR 2/2)	Sicl	Firm	--	--	15.2	15.1	41.3	27.2	0.96	2.25	57.3
0.15-0.30	Dark yellowish brown											
(10YR 3/4)	Sicl	Firm	--	--	16.3	11.2	42.1	28.3	1.04	2.31	54.9	
0.30-0.45	Dark yellowish brown											
(10YR 4/4)	Sicl	Firm	--	--	16.5	10.1	41.9	29.1	1.21	2.52	51.9	
0.45-0.60	Dark yellowish brown											
(10YR 4/6)	Sicl	Firm	--	--	15.9	9.9	43.8	27.4	1.23	2.53	51.4	
0.60-0.75	Grey (10YR 5/1)	Sil	Friable	Few	--	15.1	17.3	42.5	22.2	1.32	2.56	48.4
0.75-0.90	Greyish brown (10YR 5/2)	Sil	Friable	Many	--	21.6	16.9	40.0	19.1	1.34	2.60	48.4
0.90-0.105	Grey (10YR 6/1)	Sil	Very friable	Many	--	22.4	19.4	40.1	18.1	1.40	2.61	46.4

***Sil: Silty loam, Sicl: Silty clay loam, Cs: Coarse sand, Fs: Fine sand Si: Silt, Cl: Clay**

Table 1 (Continued)

Morphological characteristics and physical properties of Balh Valley soils

Soil depth, m	Colour (Moist)	Texture*	Consistency	Gravels	Black brown concretions/ mottles	Particle size distribution, %				Bulk density, mg m^{-3}	Particle density, mg m^{-3}	Porosity, %
						Cs	Fs	Si	Cl			
B. Soils of Paddy Growing Areas												
Profile 3 (Dhangu)												
0.00-0.15	Dark brown (10YR 3/3)	Sil	Friable	--	--	12.1	22.9	42.3	20.2	1.20	2.40	50.0
0.15-0.30	Dark yellowish brown											
(10YR 3/6)	Sil	Friable	--	--	16.6	16.2	45.1	20.3	1.21	2.41	49.7	
0.30-0.45	Dark greyish brown											
(10YR 4/2)	Sil	Friable	--	--	16.3	18.9	42.4	20.5	1.23	2.43	49.4	
0.45-0.60	Dark yellowish brown											
(10YR 4/4)	Sil	Very friable	--	Many	16.9	16.2	49.2	15.2	1.24	2.44	49.2	
0.60-0.75	Dark yellowish brown											
(10YR 4/6)	Sicl	Firm	Few	Few	17.7	11.1	41.2	28.3	1.25	2.46	49.2	
0.75-0.90	Brown (10YR 5/3)	Sicl	Firm	Many	Few	17.9	8.2	45.1	26.4	1.28	2.48	48.4
0.90-0.105	Yellowish brown (10YR 5/6)	Sicl	Firm	Many	Few	20.7	10.3	40.2	25.2	1.32	2.51	47.4
Profile 4 (Chhattar)												
0.00-0.15	Dark yellowish brown											
(10YR 3/4)	Sicl	Firm	--	--	16.5	12.8	40.3	28.2	1.23	2.46	50.0	
0.15-0.30	Dark yellowish brown											
(10YR 3/6)	Sicl	Firm	--	--	16.8	12.3	42.1	26.3	1.25	2.48	49.6	
0.30-0.45	Dark greyish brown											
(10YR 4/2)	Sicl	Firm	--	--	15.3	13.9	43.8	25.2	1.26	2.49	49.4	
0.45-0.60	Dark yellowish brown											
(10YR 4/4)	Sicl	Friable	--	--	15.9	20.2	39.4	21.3	1.27	2.50	49.2	
0.60-0.75	Dark yellowish brown											
(10YR 4/6)	Sicl	Firm	--	Many	21.2	8.1	41.1	27.2	1.27	2.50	49.2	
0.75-0.90	Grayish brown (10YR 5/2)	Sicl	Firm	Few	Few	21.3	7.9	39.6	29.1	1.30	2.54	48.8
0.90-0.105	Yellowish brown (10YR 5/4)	Sil	Very friable	Many	Few	22.4	13.2	40.4	19.4	1.35	2.59	47.8
0.105-0.120	Yellowish brown (10YR 5/8)	Sil	Very friable	Many	Few	29.3	14.1	38.2	16.2	1.39	2.63	47.1

***Sil: Silty loam, Sicl: Silty clay loam, Cs: Coarse sand, Fs: Fine sand Si: Silt, Cl: Clay**

Table 1 (Continued)
Morphological characteristics and physical properties of Balh Valley soils

Soil depth, m	Colour (Moist)	Texture*	Consistency	Gravels	Black brown concretions/ mottles	Particle size distribution, %				Bulk density, mg m^{-3}	Particle density, mg m^{-3}	Porosity, %
						Cs	Fs	Si	Cl			
C. Soils of Maize Growing Areas												
Profile 5 (Naulakha)												
0.00-0.15	Very dark grayish brown (10YR 3/2)	Sil	Friable	--	--	19.2	7.7	46.2	24.3	1.14	2.40	52.5
0.15-0.30	Dark yellowish brown											
(10YR 3/4)	Sicl	Firm	--	--	24.2	4.0	42.3	28.2	1.18	2.43	51.4	
0.30-0.45	Dark yellowish brown											
(10YR 3/6)	Sil	Firm	--	--	28.3	4.2	37.3	28.3	1.23	2.46	50.0	
0.45-0.60	Dark brown (10YR 4/3)	Sil	Firm	Few	--	30.4	3.9	31.1	32.1	1.24	2.48	50.0
0.60-0.75	Dark yellowish brown											
(10YR 4/6)	Sil	Friable	Few	--	32.3	8.7	31.5	24.3	1.24	2.49	50.2	
0.75-0.90	Greyish brown (10YR 5/2)	Sil	Firm	Few	--	34.6	4.9	32.4	25.2	1.26	2.51	49.8
0.90-0.105	Brown (10YR 5/3)	Sil	Firm	Many	--	36.2	5.3	30.6	25.9	1.37	2.55	46.3
Profile 6 (Behna)												
0.00-0.15	Dark brown (10YR 3/3)	Sil	Loose	--	--	45.2	10.3	29.3	12.1	1.15	2.46	53.2
0.15-0.30	Dark yellowish brown											
(10YR 3/6)	Sil	Loose	--	--	44.3	10.7	28.1	14.2	1.20	2.52	52.4	
0.30-0.45	Dark greyish brown											
(10YR 4/2)	Sil	Loose	--	--	46.8	13.4	26.5	11.2	1.27	2.54	50.0	
0.45-0.60	Dark yellowish brown											
(10YR 4/4)	Sil	Very friable	Few	--	48.1	5.1	28.1	16.4	1.28	2.54	49.6	
0.60-0.75	Dark brown (10YR 4/3)	Sil	Loose	Few	--	42.3	10.3	31.3	11.8	1.31	2.57	49.1
0.75-0.90	Grey (10YR 5/1)	Sil	Loose	Few	--	40.5	12.5	34.2	10.3	1.33	2.58	48.4
0.90-0.105	Brown (10YR 5/3)	Sil	Loose	Many	--	40.8	11.4	35.6	10.5	1.37	2.60	47.3

***Sil: Silty loam, Sicl: Silty clay loam, Cs: Coarse sand, Fs: Fine sand Si: Silt, Cl: Clay**

bon cation exchange capacity (CEC) and exchangeable bases (Ca^{2+} and Mg^{2+}) were determined by standard procedures. Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956); available P by Olsen's method (Olsen et al., 1954); available K by 1N NH_4OAc (Hanway and Heidal, 1952) and available DTPA-extractable micronutrient cations like Fe, Zn, Cu and Mn by Lindsay and Norvell (1978) on atomic absorption spectrophotometer. The simple correlation co-efficient at 1 per cent of significance were worked out by standard statistical procedures as given in Table 3.

Results and Discussion

Morphological characteristics

It is discerned from the data regarding morphological characteristics (Table 1) that in general all the soils were characterized by brown colour mixed with shades of grey and yellow. Majority of the soils either have silty loam (Gaggal, Naulakha and Behna) or silty clay loam (Kummi, Dhangu and Chhattar) texture. The variations in the texture of soils obtained here in the present study evinced the general statement of Robinson (1949) that in case the parent material is the dominant factor in soil formation, the most obvious way in which it affects the soils is through similarity in colour and texture. Similar results had already been obtained by Kaistha and Gupta (1992) while studying the soil genesis in Himalayas. However, very dark brown colour (10YR 2/2) in the surface (0.0-0.15 m depth) soils of vegetable growing areas could be attributed to the presence of more content of organic carbon in these soils (Table 2). It is point to mention that most of the farmers of vegetable growing area add lot of FYM, sometimes more than 10 t ha^{-1}, which is amenable to impart more organic carbon in these soils.

The soil consistency exhibited varying behavior i.e. firm, friable, very friable to loose. In vegetable soils, it was, however, ranged from firm to loose, whereas, in paddy and maize soils it varied from firm to friable. This might be due to the presence of more organic matter content in vegetable growing soils. Similar results have been reported by Sidhu et al. (1994). Another important morphological characteristic of these soils is the presence of gravels in the lower layers of these soils (Table 1) which might be explained due to the prevailing alluvial conditions earlier in the area as the river Suketi still flows into its eastern and western parts. Black brown concretions were noticed in few of the horizons of paddy growing soils only (Table 1). The presence of very dark brown to dark reddish brown mottles (mostly 10YR 5/6 to 7.5 YR 5/8) was the common phenomenon in the rice growing soils (Table 1).

Physical properties

Silty loam was the dominant texture of the soils irrespective of soil depth. Generally silt was the dominant fraction (25.7 to 49.2%) followed by that of sand (coarse and fine sand). The content of coarse sand fraction was in the range of 12.1 to 48.1 per cent (Table 1). More content of coarse sand in all the soils under study could be explained due to presence of sandy type of rocks *viz.*, sandstones, silt stones, granites etc. prevailed in the area. In none of the profiles except Dhangu, illuviation of clay had been observed indicating, thereby, less development of soil profiles. However, in Dhangu profile, there was an accumulation of clay at 0.60 to 0.75 and 0.75-0.90 m depth. The bulk density in surface soils

Table 2
Chemical and physico-chemical properties of Balh Valley soils

Soil depth, m	pH (1: 2.5)	OC, %	CEC	Ca2+	Mg2+	Available nutrients, kg ha^{-1}			DTPA-extractable micro-nutrients, ppm			
			(Cmol[p+] kg^{-1})			N	P	K	Fe	Zn	Cu	Mn
A. Soils of Vegetable Growing Areas												
Profile 1 (Gaggal)												
0.00-0.15	7.1	0.98	12.4	5.02	2.09	472.4	22.7	289.1	99.3	3.53	2.76	8.13
0.15-0.30	7.0	0.93	10.7	4.30	2.06	405.2	20.3	240.8	88.7	2.73	2.68	6.40
0.30-0.45	6.8	0.90	10.2	4.10	2.01	365.0	18.2	238.0	82.1	2.41	2.35	7.01
0.45-0.60	6.9	0.87	10.0	3.42	1.79	348.2	16.4	204.9	72.6	2.39	2.36	5.20
0.60-0.75	7.0	0.79	9.8	3.21	1.76	312.7	14.9	170.4	65.6	2.04	2.20	3.90
0.75-0.90	7.0	0.71	9.5	2.98	1.75	299.9	13.2	159.5	61.7	2.01	2.01	3.10
0.90-0.105	7.1	0.86	9.3	2.16	1.32	289.1	11.7	148.5	57.2	1.99	1.98	2.94
0.105-0.120	7.2	0.62	9.0	2.07	1.28	271.5	10.2	141.3	49.2	1.84	1.91	2.85
Profile 2 (Kummi)												
0.00-0.15	6.8	1.10	12.9	5.12	2.37	494.2	21.9	294.6	91.0	2.63	2.67	8.32
0.15-0.30	6.8	0.97	12.0	4.82	2.11	465.7	19.1	263.4	74.2	2.63	2.12	8.04
0.30-0.45	6.9	0.93	11.2	3.67	2.90	422.1	17.9	222.5	70.1	2.36	2.04	7.12
0.45-0.60	7.2	0.85	10.6	4.31	1.98	387.0	15.5	180.0	56.2	2.50	2.09	6.01
0.60-0.75	7.1	0.74	10.1	3.17	1.89	334.9	12.3	140.9	39.2	1.96	2.00	5.32
0.75-0.90	7.1	0.70	9.9	2.73	1.73	289.6	10.9	133.4	30.1	1.91	1.97	4.12
0.90-0.105	7.0	0.64	9.1	2.24	1.69	268.2	10.5	129.2	28.2	1.92	1.87	3.02
B. Soils of Paddy Growing Areas												
Profile 3 (Dhangu)												
0.00-0.15	7.0	0.72	11.8	4.03	1.79	391.2	17.4	246.5	128.4	1.18	1.71	6.00
0.15-0.30	7.0	0.68	11.6	3.72	1.89	351.7	14.3	210.6	110.5	1.07	1.41	5.10
0.30-0.45	7.1	0.64	10.9	3.55	1.74	322.8	13.7	174.2	119.3	1.10	1.49	5.77
0.45-0.60	6.8	0.60	10.1	2.85	1.71	282.6	11.1	148.0	107.1	0.98	1.52	3.11
0.60-0.75	6.9	0.55	9.5	2.43	1.64	271.0	10.5	117.2	101.5	0.92	1.32	4.28
0.75-0.90	7.0	0.51	9.3	2.13	1.43	224.6	9.8	112.3	99.7	0.86	1.12	5.00
0.90-0.105	7.2	0.49	8.9	1.72	1.16	218.9	8.8	98.7	98.9	0.61	0.91	1.02
Profile 4 (Chhattar)												
0.00-0.15	6.9	0.70	11.7	3.93	1.73	384.3	16.9	230.7	124.1	1.26	1.61	4.21
0.15-0.30	6.9	0.66	11.2	2.85	1.67	361.7	13.2	192.0	117.3	1.09	1.03	3.71
0.30-0.45	7.0	0.64	10.7	2.17	1.57	304.6	12.8	167.3	104.5	0.98	1.22	3.91
0.45-0.60	7.0	0.60	10.2	2.09	1.53	299.9	12.1	128.5	101.0	0.82	0.92	4.01
0.60-0.75	6.8	0.57	9.8	1.93	1.37	279.6	10.7	109.2	99.2	0.79	0.93	4.09
0.75-0.90	6.7	0.54	9.2	1.87	1.19	261.1	9.6	92.6	98.1	0.72	0.87	2.22
0.90-0.105	6.7	0.50	8.8	1.82	1.11	256.2	8.8	90.2	97.2	0.52	0.81	1.73
0.105-0.120	7.0	0.47	8.5	1.67	0.99	220.0	8.6	84.0	97.0	0.42	0.70	1.68
C. Soils of Maize Growing Areas												
Profile 5 (Naulakha)												
0.00-0.15	6.7	0.77	12.1	4.62	2.12	442.6	20.2	260.5	101.7	1.25	1.96	6.71
0.15-0.30	6.8	0.72	11.8	4.53	2.01	412.7	19.5	243.2	99.2	1.09	1.72	6.01
0.30-0.45	6.9	0.67	11.4	3.89	1.83	384.0	17.3	197.6	100.1	1.01	1.49	4.23
0.45-0.60	7.1	0.64	10.9	3.76	1.74	357.0	15.9	146.1	92.6	0.82	1.54	5.24
0.60-0.75	7.1	0.60	10.4	2.75	1.81	312.6	14.1	132.7	80.7	0.99	1.41	3.98
0.75-0.90	7.2	0.55	9.7	2.17	1.47	293.1	10.3	124.0	87.5	0.76	1.27	3.02
0.90-0.105	7.0	0.51	9.2	2.07	1.10	282.7	9.9	107.9	76.2	0.72	1.25	2.98
Profile 6 (Behna)												
0.00-0.15	6.9	0.75	12.2	4.04	2.29	453.0	19.3	271.2	99.7	1.52	1.87	5.51
0.15-0.30	6.8	0.70	11.5	3.67	2.15	422.7	16.4	227.3	89.2	1.12	1.53	4.04
0.30-0.45	7.0	0.67	10.9	3.22	1.79	366.9	15.1	172.7	81.5	1.32	1.32	4.01
0.45-0.60	7.0	0.63	10.2	2.73	1.89	349.9	12.1	165.0	79.1	0.99	1.17	3.22
0.60-0.75	7.0	0.59	9.8	2.64	1.63	316.0	11.7	147.1	73.6	0.82	1.07	2.72
0.75-0.90	7.1	0.54	9.2	2.57	1.87	297.6	9.7	121.7	69.1	0.87	0.98	2.12
0.90-0.105	7.0	0.50	9.0	2.22	1.93	279.1	9.2	112.0	62.2	0.69	0.82	1.80

of vegetable growing areas was lower than those of paddy and maize growing soils (Table 1). This could be attributed to higher content of organic carbon in these soils which had resulted in bringing about low bulk density from the average value (1.33 mg m^{-3}). Moreover, the bulk density values had significantly negative relationship with organic carbon (r = -0.723) as shown in Table 3. The value of this physical constant generally increased with depths which were obvious because of decreasing trend of organic carbon (Sharma et al., 1997). It seems from Table 1 that particle density increased with depth of the soil in almost all the profiles. Its value in vegetable growing soils was higher in comparison to paddy and maize growing soils. However, this increased trend was not significant which might be due to the dominance of light minerals in these soils as reported by Gupta (1992) for the soils of Jammu and Kashmir Himalayas. The per cent soil porosity in vegetable soils was higher in comparison to paddy and maize soils, which could be due to the presence of higher organic matter in the former groups of soils (Table 1). In general, the per cent soil porosity decreased with the depth (Singh et al., 2000).

Chemical and physico-chemical properties

The overall pH values of the studied soils ranged from 6.7 to 7.2, indicating slightly acidic to neutral in reaction (Table 2). Kaistha and Gupta (1993) also found that soils of Central Himalayas of Himachal Pradesh had pH of 6.7-7.7. There is no specific trend in pH values of different crop growing areas except Naulakha paddy soils where pH values were found to increase with depth possibly due to leaching of bases. The organic carbon content in vegetable growing soils was higher in comparison to paddy and maize growing soils, which was due to the addition of FYM in vegetable soils (Table 2). The maximum accumulation of organic carbon was at the surfaces and then decreased with depth. The greater accumulation of organic carbon in the surface is due to the incorporation of leaf litter and addition of decayed roots to the upper layers. Similar distribution pattern of organic carbon with depth had been reported by Minhas et al. (1997). A significant positive relationship of organic carbon was found with available N, P and K (r = 0.796, 0.834 and 0.823), exchangeable Ca and Mg (r = 0.804 and 0.705) and DTPA extractable Zn, Cu and Mn (r = 0.900, 0.901 and 0.824).

The CEC of the soils of different profiles showed consistence trend and decreased with the increase in depth (Table 2). The CEC values of the surface layers in vegetable growing soils were higher as compared to paddy and maize growing soils. The higher CEC values might be due to the higher organic matter and clay contents at the surface of vegetable soils. The results were in conformity with the findings of Minhas et al. (1997). Available N, P and K, exchangeable Ca and Mg and DTPA-extractable Mn were found to have significant positive correlation with CEC (r = 0.924, 0.888, 0.903, 0.877, 0.719 and 0.745). The exchangeable Ca content in vegetable growing soils was higher in surface horizons in comparison to paddy and maize growing soils (Table 2). This indicated that vegetable crops were richer in available Ca than soils of other crops which might be due to regular use of organic manures through addition of mixed fertilizers. A significant positive relationship of exchangeable Ca was found with

Table 3
Values of co-efficient of correlation ("r") amongst available nutrient content in the soil

Soil properties	OC	CEC	Ca	Mg	N	P	K	Fe	Zn	Cu	Mn
BD	-0.723*	-0.815*	-0.833*	-0.646*	-0.825*	-0.865*	-0.825*	-0.383*	-0.544*	-0.604*	-0.827*
PD	-0.560*	-0.796*	-0.735*	-0.478*	-0.700*	-0.739*	-0.731*	-0.542*	-0.365*	-0.450*	-0.759*
pH	-0.148	-0.285*	-0.228	-0.189	-0.290*	-0.278*	-0.295*	-0.354*	0.070	0.013	-0.210
OC	--	0.654*	0.804*	0.705*	0.796*	0.834*	0.823*	-0.139	0.900*	0.901*	0.824*
CEC	0.654*	--	0.877*	0.719*	0.924*	0.888*	0.903*	0.412*	0.393*	0.497*	0.745*
Ca	0.804*	0.877*	--	0.780*	0.930*	0.948*	0.925*	0.174	0.629*	0.734*	0.872*
Mg	0.705*	0.719*	0.780*	--	0.816*	0.760*	0.765*	-0.063	0.563*	0.598*	0.728*
N	0.796*	0.924*	0.930*	0.816*	--	0.941*	0.941*	0.176	0.581*	0.646*	0.821*
P	0.834*	0.903*	0.948*	0.760*	0.941*	--	0.953*	0.228	0.642*	0.745*	0.868*
K	0.823*	0.888*	0.925*	0.765*	0.941*	0.953*	--	0.249*	0.628*	0.718*	0.828*
Fe	-0.139	0.412*	0.174	-0.063	0.176	0.228	0.249*	--	-0.386*	-0.291*	0.144
Zn	0.900*	0.393*	0.629*	0.563*	0.581*	0.642*	0.628*	-0.386*	--	0.927*	0.685*
Cu	0.901*	0.497*	0.734*	0.598*	0.646*	0.745*	0.718*	-0.291*	0.927*	--	0.741*
Mn	0.824*	0.745*	0.872*	0.728*	0.821*	0.868*	0.828*	0.144	0.685*	0.741*	--

Note: Significance of correlation has been expressed on 1 per cent level

organic carbon (r = 0.804), CEC (r = 0.877), exchangeable Mg (r = 0.780), available N, P and K (r = 0.930, 0.948 and 0.925) and DTPA-extractable Zn, Cu and Mn (r = 0.629, 0.734 and 0.872). The exchangeable Mg content in vegetable growing soils was higher in comparison to paddy and maize growing soils which were due to use of phosphatic fertilizers in vegetable soils (Table 2). In general, the exchangeable Mg content of Balh Valley soils decreased with soil depth due to mild leaching of magnesium from upper most to lower most horizons. In Behna maize soils, exchangeable Mg content showed irregular distribution in the profile which may be attributed to stratification of the soil. The exchangeable Mg content was significantly positive relationship with organic carbon (r = 0.705), CEC (r = 0.719), available N, P and K (r = 0.816, 0.760 and 0.765) and DTPA-extractable Mn (r = 0.728).

The surface horizons of vegetable growing soils had more available N in comparison to paddy and maize growing soils, and their contents decreased with the increase in depth (Table 2). As discussed earlier, the organic carbon content of the soil profile samples also showed a similar distribution. Higher amount of organic carbon in the surface layer of vegetable growing soils was responsible for higher amount of available N. The available N bore a close positive relationship with organic carbon (r = 0.796) and CEC (r = 0.924) which was also reported by Ramesh et al. (1994). The available P content in vegetable growing soils was higher in comparison to paddy and maize growing soils and decreased with increase in depth (Table 2). Among soil properties, organic carbon, CEC and DTPA-extractable micronutrients possessed significant positive related with available P. The similar relationship of available P with organic carbon (r = 0.834) and CEC (r = 0.903) had also been reported by Ghosh and Kothandaraman (1996). The available K content was higher in vegetable growing soils than paddy and maize growing soils (Table 2). The available K content decreased with the depth in all the soils. The higher available K content in vegetable soils which could be ascribed to more organic matter in these soils. However, addition of potassic fertilizers by the farmers while cultivating vegetables which eventually increased K content in these soils could not be ruled out. The available K content was found to have significant positive relationship with organic carbon (r = 0.823) and CEC (r = 0.888). Basumatary and Bordoloi (1992) had also reported positive relationship of available K with organic carbon and CEC.

The soils of paddy growing area were high in DTPA-extractable Fe content as compared to vegetable and maize growing areas (Table 2) which might be due to suitable moisture regimes that accelerate the reduction process causing more availability of Fe. DTPA-extractable Fe content decreased with increased depth might be due to regular addition of Fe through plant residues on the surface. These results were in conformity with the findings of Jalali *et al.* (1998). Among soil properties, DTPA-extractable Fe were found to be significantly and positively correlated with CEC (r = 0.412). The DTPA-extractable Zn content in vegetable growing soils was slightly more in comparison to paddy and maize growing soils and it also decreased with the depth (Table 2). The higher available Zn content in vegetable soils might be due to the release of organic acids from added FYM and thus converting insoluble Zn into chelating or soluble Zn. The DTPA-extractable Zn bore significant and positive relationship with organic carbon (r = 0.900) and DTPA-extractable Cu (r = 0.927). Similar results had been reported by Jalali et al. (1998).

The DTPA-extractable Cu content was found to decrease with the increase in depth, but in the soils of paddy growing area, it did not follow any definite trend which might be due to stratification of soils (Table 2). Similar results were by Vadivelu and Bandyopadhyay (1995). The DTPA-extractable Cu showed a significantly positive relationship with organic carbon (r = 0.901) and CEC (r = 0.497) which was in conformity with the findings of Singh et al. (1990). Like Cu, the DTPA-extractable Mn did not follow any depth-wise distribution pattern in paddy growing area (Table 2). The DTPA-extractable Mn had a significant positive relationship with organic carbon (r = 0.824), CEC (r = 0.745) and available N, P and K (r = 0.821, 0.868 and 0.828).

Taking into consideration the rating limits fixed and given in Soil Manual issued by Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, none of the soils had deficiency of Zn, Cu, Fe and Mn has been noticed in the surface horizons. It is because of the application of organic manures by the farmers in these soils. However, in view of intensive cultivation of these soils, the deficiency of micro-nutrient like Zn and Cu is likely to be occurred in the near future.

Conclusion

Thus, the present study clearly showed that Balh Valley soils are deep, having good drainage and put under intensive cultivation without deteriorating its health for growing different cereals and vegetable crops by using recommended doses of balanced use of N, P and K fertilizers.

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