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GENESIS AND CLASSIFICATION OF FOUR SOIL PEDONS FROM WESTERN HIMACHAL PRADESH

KARAN SINGH AND K P TOMAR*

Dr Y S Parmar University of Horticulture and Forestry
Nauni-Solan (HP) 173 230, India

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Morphological and partial elemental chemical analysis data on four soil pedons from Bhota (P_1), Rishikesh (P_3), Nauni(P_{12}) and Dhaulakuan (P_{14}) representing the western districts of Himachal Pradesh are discussed. The soils were developed on sandstone and conglomerates (P_1, P_3 and P_{14}) to shales and dolomitic limestones (P_{12}) under subhumid subtropical climate. Sand/silt ratios corroborated with field observations to suggest that lithologic discontinuities existed in three (P_1, P_3 and P_{14}) out of the four pedons studied in this transect.

There has been a significant contribution of climate, topography and parent material as factors coupled with the lessivage and gleization as processes in the pedogenic evolution of these soils.

According to soil Taxonomy, these mountainous soils have been classified as Typic Hapludalfs (P_1 and P_{14}), Fluventic Eutrochrepts (P_3) and Typic Udorthents (P_{12}) at sub-group level.

Key Words: Genesis; Classification of Soil Pedons; Morphology of Soil; Soil Lessivage; Gleization; Taxonomy; Typic Hapludalfs; Fluventic Eutrochrepts; Typic Udorthents

Introduction

Soil development is influenced by the pedogenic factors and processes operating in a particular area through their reflection on the morphological, physicochemical and mineralogical characteristics of the soils. This is especially true for the mountainous soils of Himachal Pradesh where the variability in soil characteristics is realised at short distances owing to the differences in soil forming factors, mainly climate, topography and parent materials[1-3].

Lack of information on the properties and genesis of these soils has been an obstacle to assessment of production potential and formulation of management recommendations. Based on the morphological, physicochemical and mineralogical evidences, an attempt has been made to establish their pedogenic evolution and classify them in accordance with Soil Taxonomy of USDA[4].

Material and Methods

Himachal Pradesh forms a part of North-Western Himalayas and lies between the East Longitude 75°47'55" and North Latitude 30°21'40" to 33°12'40". The mean annual rainfall varied from 1150mm in Nauni to 1340mm in Bhota. The study area constitutes a part of Agro-ecoregion 15-A 15C4 (Sehgal *et al.*, 1990)[5].

*Indian Institute of Soil Science, Bhopal-462 011, India.

Taking into consideration the variation in geology, climate and topography, four representative pedon sites were selected for the present investigation. The pedon sites are Bhota (P_1), Rishikesh (P_3), Nauni (P_{12}) and Dhaulakuan (P_{14}). Morphological characteristics of each profile were recorded (Table I) following the terminology and techniques given in Soil Survey Manual[6] (Soil Survey Staff, 1962). Soil samples collected from each horizon were airdried, crushed in wooden pestle and mortar and passed through 2mm sieve for detailed laboratory determinations.

The particle size analysis, electrical conductivity *p*H, organic carbon, calcium carbonate, cation exchange capacity and chemical analysis for Si, Al, Fe and K in total fine earth (< 2mm) were made by standard methods[7-9].

Table I

Morphological characteristics of the soils

Horizon	Depth (cm)	Colour (M)	Texture	Structure	Consistency	Gravels/ Concretions	Mottlings
			Bhota Pedon (Typic Hapludalfs)				
Al	0-15	10 YR 4/3	SL	fl gr	dsh, mfr, wss	few & fine	—
Bl	15-42	10 YR 4/4	SL	ml gr	dsh, mfr, wss	few Fe & Mn	—
Bt2	42-78	10 YR 4/4	L	ml gr to sbk	msfi, wss	concretions -do-	Common, fine 5 YR 2/1
C	78-110	10 YR 5/4	SL	massive	mfr, wso	-do-	-do-
IIC	110-175	10 YR 4/4	LS	massive	mfr, wso	few coarse Fe, Mn concretions	Common, medium 5 YR 2/1
			Rishikesh Pedon (Fluventic Eutrophrepts)				
Al	0-12	10 YR 5/4	LS	sg	dl, mfr, wso	—	—
Bl	12-48	10 YR 4/4	LS	sg to gr	dsh, mfr, wso	—	—
IIB2	48-82	10 YR 4/4	SL	gr to sbk	dsh, msfi, wso	—	—
IIC	82-115	10 YR 4/4	LS	sg to sbk	dsh, mfr, wso	—	—
IIIC	115-150	10 YR 3/4	SL	-do-	dsh, mfr, wso	—	—
			Nauni Pedon (Typic Udorthents)				
Al	0-15	10 YR 3/3	L	gr	dsh, mfr, wss	many gravels	—
A3	15-35	10 YR 4/3	L	gr to m2 sbk	dh, mfi, wss	-do-	—
C	35-75	10 YR 4/4	SCL	m2 sbk	dh, mvfi, wvs	-do-	Common, fine, 5 YR 2/1
			Dhaulakuan Pedon (Typic Hapludalfs)				
Al	0-15	10 YR 4/2	SL	gr	mfr, wss	—	—
A3	15-30	10 YR 4/2	SL	m2 sbk	-do-	—	—
Bt	30-70	10 YR 3/3	L	m2 sbk to abk	mfr, ws	few gravels	—
Cl	70-90	10 YR 3/3	SL	m2 sbk	mfr, wss	-do-	—
IIC2	90-130	10 YR 3/3	LS	sg	mfr, wso	many gravels	—

Results

Morphology of the Soil

Important morphological characteristics, viz., colour, mottlings, structure, thickness of solum, concrections and presence of clay argillans are indicative of considerable weathering and soil profile development to marked depths (Table I). Among all pedons, minimal profile development was found in Nauni pedon where thickness of the solum was only 35cm which may be attributed to its topographic position with 20% slope. Mean weathering index varying between 7.4 and 7.5 in the C and Al horizons respectively further suggests the initial stage of development in this pedon (Tables II & III).

Chemical Composition of the Soil

The elemental chemical data, in general, show that – (i) silica content maintains almost a constancy with depth in Bhota, Rishikesh and Nauni ped-

Table II

Physicochemical characteristics of the soils

Horizon	Depth (cm)	Coarse sand (%)	Fine sand	Silt (%)	Clay (%)	Sand/ silt ratio	Texture	O.C. (%)	*p*H (1:2.5)	ECG (dsm^{-1})	$CaCO_3$ equivalent (%)
					Bhota Pedon (Typic Hapludalfs)						
Al	0-15	12.0	60.2	10.8	15.8	6.7	SL	0.47	6.8	0.25	0.60
Bl	15-42	14.0	58.4	10.5	16.0	6.8	SL	0.19	6.9	0.25	0.85
Bt2	42-78	14.6	50.8	12.8	20.4	5.1	L	0.09	6.9	0.25	0.65
C	78-110	12.8	58.8	10.0	16.8	7.2	SL	0.09	6.9	0.30	0.45
IIC	110-175	18.4	52.2	18.0	9.8	3.9	LS	0.16	7.2	0.25	0.35
					Rishikesh Pedon (Fluventic Eutrochrepts)						
Al	0-12	4.2	66.0	18.6	9.8	3.8	LS	0.27	6.9	0.30	1.05
Bl	12-48	3.8	65.8	18.0	10.8	3.8	LS	0.19	7.1	0.30	1.60
IIB2	48-82	3.2	70.6	10.0	15.2	7.4	SL	0.12	7.0	0.30	2.35
IIC	82-115	3.0	75.4	11.2	9.0	7.4	LS	0.14	7.2	0.30	2.55
IIIC	115-150	2.6	70.4	12.2	13.4	5.9	SL	0.14	7.5	0.30	2.65
					Nauni Pedon (Typic Udorthents)						
Al	0-15	18.8	25.0	31.2	24.0	1.4	L	0.77	6.7	0.35	1.00
A3	15-35	17.0	25.4	30.2	26.2	1.4	L	0.36	6.2	0.80	1.00
C	35-75	11.2	35.2	27.2	25.4	1.9	SCL	0.05	6.0	0.80	1.20
					Dhaulakuan Pedon (Typic Hapludalfs)						
Al	0-15	19.6	52.2	9.2	18.0	7.8	SL	0.57	7.3	0.25	1.00
A3	15-30	17.8	53.4	9.2	18.8	7.9	SL	0.30	7.1	0.40	0.35
Bt	30-70	20.8	46.0	8.6	23.0	7.7	SL	0.33	7.1	0.40	0.50
Cl	70-90	16.4	57.0	8.8	16.2	8.3	SL	0.26	7.0	0.45	0.50
IIC2	90-130	24.2	48.4	17.4	8.2	4.17	LS	0.30	6.9	0.50	0.40

Table III

Partial chemical composition of the soil (Oven dry basis)

Horizon	Depth (cm)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	K_2O (%)	DCB – Fe_2O_3 (%)	SiO_2/R_2O_3	Fe_2O_3 – d/clay	Mean weathering index
				Bhota Pedon (Typic Hapludalfs)					
Al	0-15	65.3	11.8	5.3	2.53	1.8	3.8	0.11	8.1
Bl	15-42	67.2	10.8	6.0	3.13	1.6	4.0	0.10	ND
Bt2	42-78	66.6	10.0	5.7	2.41	1.6	4.2	0.08	8.2
C	78-110	66.0	9.8	5.7	2.57	1.5	4.2	0.09	ND
IIC	110-175	65.6	10.4	6.1	2.65	1.6	4.0	0.02	8.2
				Rishikesh Pedon (Fluventic Eutrochrepts)					
Al	0.12	66.3	11.5	4.3	2.48	1.6	4.2	0.16	8.2
Bl	12-48	68.2	10.5	5.0	2.09	1.5	4.4	0.14	ND
IIB2	48-82	67.6	9.8	4.7	2.24	1.5	4.7	0.10	8.1
IIC	82-115	66.0	10.5	4.7	2.20	1.6	4.3	0.10	ND
IIIC	115-150	66.5	9.0	6.3	2.08	1.6	4.3	0.12	8.0
				Nauni Pedon (Typic Udorthents)					
Al	0-15	61.3	11.2	8.0	2.02	3.0	3.2	0.12	7.5
A3	15-35	59.6	10.8	8.3	2.11	3.2	3.1	0.12	ND
C	35-75	59.2	11.2	8.7	1.81	3.2	3.0	0.11	7.4
				Dhaulakuan Pedon (Typic Hapludalfs)					
Al	0-15	64.4	10.8	8.2	1.70	2.2	3.4	0.12	8.0
A3	15-30	65.0	11.6	8.5	1.75	2.6	3.2	0.13	ND
Bt	30-70	66.8	12.0	8.6	1.76	2.7	3.2	0.12	8.0
Cl	70-90	68.2	12.2	9.8	1.74	3.0	3.1	0.18	ND
IIC2	90-130	68.4	11.4	8.0	1.70	2.9	3.5	0.25	7.9

ND = Not determined

ons. In Dhaulakuan pedon, it increases from 64.4 per cent in Al horizon to 68.4 per cent in IIC2 horizon. (ii) The alumina content tends to decrease in Bhota and Rishikesh pedons, maintains a constancy in Nauni pedon and increases slightly in Dhaulakuan pedon. (iii) Iron content exhibits slight increase in Dhaulakuan pedon. (iv) Fe_2O_3-*d* increases from 2.2 per cent in Al horizon to 3.0 per cent in Cl horizon of Dhaulakuan pedon only. The other three pedons show very small variations with depth; Nauni pedon showing slight increase, Bhota pedon slight decrease and Rishikesh pedon a constancy with depth (Table III).

Physico-chemical Characteristics of the Soil

Organic carbon content is invariably high in surface horizons and decreases down the profile in all the pedons (Table II). Irregular distribution of

organic carbon in Bhota, Rishikesh and Dhaulakuan pedons indicate the stratified nature of the parent material.

Data on the cation exchange capacity and exchangeable cations (Table IV) show that wide variation in CEC values exists among the studied pedons. The CEC values range from 7.7 to 14.3 c mol (P^+) Kg^{-1}. Two maxima of cation exchange capacity are usually observed in the pedons, one in the surface horizon which is to be ascribed to high organic matter content and another in Bt horizon containing higher amounts of clay. A glance at the data further suggests that base saturation percentage does not show any distinct pattern with depth and varies from 52.8 to 84.6 per cent.

Discussion

These soils have developed from sedimentary type of geological formations[10]. A mean deviation of more than 0.02 in sand/silt ratios[11] supported by field ob-

Table IV

Cation exchange capacity, exchangeable cations and base saturation percentage of the soils

Horizon	Depth cm	CEC	Ca + Mg	Na	*K*	Base saturation (%)
		C mol (P^+) Kg^{-1}				
		Bhota Pedon (Typic Hapludalfs)				
A1	0-15	12.4	6.73	0.03	0.09	52.2
B1	15-42	11.6	6.67	0.03	0.11	58.7
Bt2	42-78	14.3	8.10	0.03	0.16	57.9
C	78-110	11.2	7.00	0.03	0.15	64.1
IIC	110-175	10.0	6.50	0.03	0.17	67.0
		Rishikesh Pedon (Fluventic Eutrochrepts)				
A1	0-12	11.2	8.11	0.01	0.09	73.3
B1	12-48	8.8	6.40	0.01	0.10	73.9
IIB2	48-82	8.4	5.80	0.01	0.15	70.9
IIC	82-115	8.0	6.61	0.02	0.14	84.6
IIIC	115-150	7.7	5.85	0.02	0.17	78.4
		Nauni Pedon (Typic Udorthents)				
A1	0-15	11.4	6.92	0.03	0.38	64.2
A3	15-35	8.5	4.80	0.01	0.28	59.8
C	35-75	10.0	6.20	0.02	0.18	64.0
		Dhaulakuan Pedon (Typic Hapludalfs)				
A1	0-15	10.3	6.95	0.02	0.13	68.9
A3	15-30	9.5	5.90	0.02	0.18	64.2
Bt	30-70	8.9	5.20	0.02	0.12	60.0
C1	70-90	9.8	5.60	0.02	0.10	58.3
IIC2	90-130	10.1	6.20	0.02	0.10	62.5

servations suggests the discontinuity of parent material in Bhota, Rishikesh and Dhaulakuan pedons. Since the stratificaion in Rishikesh pedon is very near the surface, just at a depth of 48cm as compared to 110cm in Bhota pedon and 90cm in Dhaulakuan pedon, the discussion on the genesis of Rishikesh pedon is bound to be less precise.

A comparison between the Bhota and Dhaulakuan pedons show that both these pedons have developed on sandstones and conglomerates with 2 per cent slope and exhibit slight increase in total Fe_2O_3 content with depth. The per cent clay also increases to the extent of developing an argillic horizon in both these pedons. However, the major differences lie in the fact that Fe_2O_3-*d* in Bhota pedon tends to decrease from 1.8 per cent in Al horizon to 1.5 per cent in C horizon; an overall tendency to increase from 2.2% in Al horizon to 3.0% in Cl horizon was observed in Dhaulakuan pedons. As a result, the ratio of $DCB - Fe_2O_3$ to clay also exhibits decreasing trend with depth in Bhota pedon, whilst it maintains almost a constancy with depth in Dhaulakuan pedon. This suggests comigration of clay and Fe-oxides in Dhaulakuan pedon[12]. In Bhota pedon, however, the decreasing trend of Fe_2O_3-*d*/clay may be attributed to higher Fe_2O_3-*d*/clay of the weathering products than overall lithogenic Fe_2O_3-*d*/clay[13]. According to Blume and Schwertzman[12] both type of trends are represented in Gray Brown Podzolic soils (Udalfs) presumably the higher Fe_2O_3-*d*/clay in top soil occurring at a little later stage of weathering. The higher mean weathering index[14] varying from 8.1 to 8.2 in Bhota pedon as compared to 7.9 to 8.0 in Dhaulakuan pedon corroborates the above view.

In contrast, in Nauni pedon, though developed on more easily weatherable dolomitic limestone parent material, field observations showed minimal profile development in this pedon. Moreover, this pedon did not exhibit any significant increase either in clay, Fe_2O_3-*d* or their ratio. This is further corroborated by comparably low values of mean weathering index varying from 7.4 to 7.5[14]. This peculiar observation may be attributed to the role played by topography in profile development in this mountainous transect. Bhota and Dhaulakuan pedons developed on 2 per cent slopes as compared to 20 per cent slope for Nauni pedon, permit easy percolation of water through solum leading to the lessivage of clay to make it an argillic horizon and hence advancement of pedogenesis. Such argillic horizons developed by eluviation of clay and lacking clay argillans have been reported and discussed by Nettleton *et al.*[15].

Classification

The soils under investigation have been classified in accordance with Soil Taxonomy of USDA (Soil Survey Staff, 1975)[4]. These soils are classed as "hyperthermic" with respect to soil temperature and 'Udic' for soil moisture regimes.

Applying the criterion stipulated in respect of epipedons and subsurface diagnostic horizons in Soil Taxonomy, ochric epipedon was found to be present in all the soils. While two pedons, namely, Bhota and Dhaulakuan were found to have argillic horizon, no subsurface diagnostic horizon was observed in case of Nauni pedon. Rishikesh pedon showed the presence of cambic horizon below the ochric epipedon. In view of the presence of epipedons and sub-

surface diagnostic horizons, they have been placed in the orders: Alfisols, Inceptisols and Entisols. At family level these soils have further been classified as follows:

Pedon 1, Bhota	Fine loamy, mixed, non-acid, hyperthermic, Typic Hapludalfs.
Pedon 3, Rishikesh	Coarse loamy, mixed, non-acid, hyperthermic, Fluventic Eutrochrepts.
Pedon 12, Nauni	Fine loamy, illitic, non-acid, thermic, Typic Udorthents.
Pedon 14, Dhaulakuan	Fine loamy, mixed, non-acid, thermic, Typic Hapludalfs.

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