JOURNAL OF PURE AND APPLIED MICROBIOLOGY, June 2016. Vol. **10**(2), p. 1547-1552

A Comparative Study on Properties of Black Soils Derived from Different Parent Materials

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(Received: 25 December 2015; accepted: 06 February 2016)

Three black soils developed on three different parent materials *viz*., Hira black soil derived from schist, Bidar black soil derived from basalt and Shahabad black soil derived from limestone in North-eastern Karnataka were studied horizon wise. The texture of soil was clay throughout the depth in all profiles. The clay content increased with 66 to 78 per cent, whereas, sand content decreased with depth. All the soils had high CEC (72 to 96 cmol(p^+)kg^{-1}) with calcium and magnesium as dominating cations on the soil exchange complex. As the pH of the soil solution is high (pH 7.5 to 8.1) in limestone derived Shahabad soil, the sodium content also high (0.9 to 7.2 cmol(p^+)kg^{-1}) in the soil compare to others two (0.4 to 0.5 cmol(p^+)kg^{-1}). There were some variations in clay charges and vermiculite content among the three black soils but there were no much variations in specific surface area and coagulation threshold of the clays.

Keywords: Parent material, clay properties, specific surface area.

In North-east Karnataka, there are vast stretches of black soils. These black soils have, however, different parentages. These soils have been suggested to have generally developed from Schists of Dharwarian formation, Basalts of Deccan trap formation and Limestone of Bhima formation. The schists are metamorphosed formations of Dharwarian shales, the Deccan traps are effusive igneous formations and Bhima formations are sedimentaries of Bhima basin. The excavation of these formations in North-east Karnataka in the present study are 520 m and 555 m above MSL for schist and basalt formations respectively, and 430 m above MSL for Bhima formation. These three rocks come from different geological provinces and are thus expected to be different mineralogically and chemically. In the present study an attempt has been made to find out if these differences in parent materials have given rise to any differences among the black soils formed or if the process of soil formation in the region has obviated these differences.

In the present study, Hira black soil represents schists of Dharwarian formation, Bidar black soil represents basalts of Deccan trap formation and Shahabad soil represents the limestones of Bhima formation. All these soils have been selected from a broad summit of their respective landscapes. The black soils of Raichur district are said to have formed from granite-gneiss (Dasog and Hadimani, 1980), but there are no studies confirming this. On the other hand, they appear to have developed from schists of Dharwarian formation, which also occur in the district extensively, further, they also opined that the black soils of Northeastern Karnataka have also developed from basalts of Deccan trap and

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Limestones of Bhima formation, and, they studied on the different properties of these three black soils. Tamhane and Namjoshi (1959) compared the black soils formed from different parent rocks, but under similar climatic conditions. They opined that not much variation was observed in physical, chemical and mineralogical properties of the soil, but the content of silica, iron and alumina varied in the soil clays. The soils formed from granite gneiss and limestone parent rock revealed high percentage of silica compared to other parental-rock soils. Further, they observed that basic rocks favour the development of black soils compared to other rocks.

With the above background the present study was conducted with the objectives: to bring out differences in some properties of these black soils derived from different parent materials, and, to differentiate these black soils in respect of its clay properties.

MATERIALS AND METHODS

The soil pH determined potentiometric determination, EC, organic carbon (OC) determined by Walky and Black method (1934), free lime content were determined by C. S. Piper (1966) method

The Cation Exchange Capacity (CEC) of the soil was determined as per NBSS and LUP Staff (1984) and exchangeable cations were extracted and determined as prescribed by Jackson (1967).

The Coefficient of linear extensibility ($COLE_{rod}$) was determined on fine earth (<2 mm) samples using the method of Schafer and Singer (1976) and calculated from the equation-

$$COLE_{rod} = (Lm - Ld)/ Ld$$

Where,

Lm is moist length

Ld is dry length of the rod.

Citrate-bicarbonate-dithionate (CBD) dissolutionfree iron, aluminium and silicon oxides and boiling Na_2CO_3 soluble silicon and aluminium oxides were determined according to Jackson, M.L.(1979).

The soil clays were separated from the soil by following the procedure detailed by Jackson, M. L. (1979). The calcium exchange capacity (CaEC) and potassium exchange capacity (K/EC) after K-fixation of the clay fractions were determined as per Jackson, M.L. (1979). The coagulation threshold for soil clays (van Olphen, 1977) and specific surface area of soil clays (Santamarina *et al*., 2002) were also determined.

RESULTS AND DISCUSSION

Morphologicall characteristics of soil profiles in the study area is depicted in table 1. All selected soils are deep, basalt derived Bidar soil is moderately deep and the schist derived Hira and the limestone derived Shahabad soils are deep. The black soils, in general have very little horizon differentiation as reported by Roy and Barde (1962).The soil structure is sub-angular blocky in the surface horizons and angular blocky in the subsurface horizons of these black soils.The coarse rock fragments were not observed in any of these black soils. A few to common ferro-manganous nodules were found in very fine to medium size in the basalt derived Bidar soil and the schist derived Hira soil, but the nodules were absent in the limestone derived Shahabad soil, calcium carbonate nodules were also observed in these black soils (Dasog and Hadimani, 1980), and further the calcium carbonate nodules in the Bss horizon of basalt derived Bidar soil had fero-manganous coatings.The pressure faces were found in the A2 horizons of the basalt derived Bidar soil and the schist derived Hira soil profiles but they were absent in the limestone derived Shahabad soil. The prominent intersecting slickensides were observed in Bss horizon of the basalt derived Bidar soil, but only non-intersecting slickensides were found in both schist derived Hira soil and limestone derived Shahabad soil.The schist derived Hira soil was calcareous in nature, whereas, Bidar and Shahabad soils were non-calcareous in nature. Even though the Shahabad soil is derived from thelimestone, the soil is not calcareous but many limestone derived soils reported in the literature are calcareous in nature (Dasog and Hadimani, 1980; Khresat and Taimeh, 1998).

Different soil properties of the profiles are depicted in the table 2. Texture of all the three black soils are clay with high clay content followed by silt and sand. The sand content is very less. Generally black soils have less sand (Asio *et al*., 2006).The basalt derived Bidar soil showed higher magnitude of swelling and shrinkage as indicated by high COLE value (0.33) than the limestone derived Shahabad soil and schist derived Hira soil. The pH of the schist derived Hira soil and the basalt derived Bidar soil are neutral whereas the limestone derived Shahabad soil is alkaline, which is related to a relatively higher exchangeable sodium in this soil (Khresat and Taimeh, 1998, Asio *et al*., 2006). The salt content of all three black soils is less, indicated by very low EC values. The organic carbon content was low in all the three soils. The calcium carbonate content as determined by rapid reaction with HCl is high in schist derived Hirasoil where as that of limestone derived Shahabad soil and basalt derived Bidar soil is insignificant.

Free iron oxide, silica and alumina content in the soil of the profiles in the study is depicted in table 3, the CBD dissolved free iron and alumina and the boiling sodium-carbonate-soluble silica and alumina content are more in the limestone derived Shahabad soil (1.28 % Fe_2O_3, 0.43% Al_2O_3;

Table 1. Morphological features of the selected pedons.

Horizon	Depth (cm)	Colour (Munsel)	Texture#	Structure*	Reaction with dil.HCl#	Salient features
Hira soil profile (Schist derived)						
Ap	0-20	10YR3/2	c	2c sbk	e	
A2	20-35	10YR3/1	c	2m sbk	e	Pressure faces on ped surface
A3	35-60	10YR3/2	c	2c abk	e	Non-interesting slicken slides
A4	60-75	10YR3/1	c	3m abk	e	Non-interesting slicken slides
Bidar soil profile (Basalt derived)						
Ap	0-24	10YR3/1	c	3f gr	-	
A2	24-47	10YR2/1	c	3f sbk	-	Pressure faces on ped surface
Bss	47-94	10YR1/1	c	3m abk	-	Slickensides on ped surface
Cr/B	94-135					Bed rock
Shahabad soil profile (Limestone derived)						
Ap	0-22	10YR3/2	c	2f sbk	-	
A2	22-38	10YR2/1	c	2m sbk	-	
A3	38-58	10YR3/1	c	3c abk	-	Non-interesting slicken slides
A4	58-120	10YR2/1	c	3c abk	-	Non-interesting slicken slides

c: clay; e: effervesence
* 2: moderate; 3: strong; f: fine; m: medium; c: coarse; gr: granular; sbk: sub-angular blocky; abk: angular blocky.

Table 2. Soil properties.

Horizon	Depth (cm)	Sand (2-0.02 mm)	Silt (0.02-0.002mm)	Clay (<0.002 mm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	COLE
Hira soil profile (Schist derived)									
Ap	0-20	18	16	66	7.5	0.16	0.50	13	0.21
A2	20-35	19	15	66	7.6	0.17	0.32	14	0.26
A3	35-60	19	15	66	7.5	0.18	0.25	15	0.23
Bidar soil profile (Basalt derived)									
Ap	0-24	7	16	77	7.3	0.16	0.32	4	0.25
A2	24-47	8	16	76	7.4	0.24	0.34	6	0.29
Bss	47-94	6	16	78	7.4	0.21	0.18	7	0.33
Shahabad soil profile (Limestone derived)									
Ap	0-22	8	22	70	7.5	0.16	0.36	8	0.19
A2	22-38	4	25	71	7.7	0.20	0.22	5	0.29
A3	38-58	7	22	71	8.0	0.28	0.20	6	0.28
A4	58-120	4	24	71	8.1	0.38	0.14	3	0.30

1.9 % SiO_2, 0.57 % Al_2O_3 respectively) than the schist derived Hira and the basalt derived Bidar soils, similar results were obtained by other researchers. But when their molar ratios are calculated, the CBD dissolved iron to alumina ratio is high in the schist derived Hira soil (2.4) whereas boiling sodium-carbonate-soluble silica to alumina molar ratiois high in the basalt derived Bidar soil. Considering the total silica and total alumina from both the dissolutions, their molar ratio is high in the basalt derived Bidar soil (5.5) than the schist derived Hira soil (4.8) and the limestone derived Shahabad soil (3.4). Exchange properties of soil and clays in the whole and selected horizons of the profile is given in table 4. All three soils had higher CEC the exchangeable calcium and magnesium are the dominant exchangeable cations in these black soils. The exchangeable calcium is

Table 3. Free iron, aluminium and silicon oxide of the soils.

Horizon	Depth (cm)	CBD extract					Boiling sodium carbonate extract				
		Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3/Al_2O_3	SiO_2	Al_2O_3	SiO_2	Al_2O_3	SiO_2/Al_2O_3*
Hira soil profile (Schist derived)											
Ap	0-20	0.96	0.26	6.0	2.55	2.4	1.28	0.19	21.33	1.86	4.8
A2	20-35	1.08	0.34	6.75	3.33	2.0	1.05	0.34	17.50	3.33	2.6
A3	35-60	0.90	0.28	5.63	2.75	2.0	0.90	0.28	15.00	2.75	2.7
Bidar soil profile (Basalt derived)											
Ap	0-24	0.84	0.26	5.25	2.55	2.1	1.28	0.26	21.33	2.55	4.2
A2	24-47	0.70	0.28	4.38	2.75	1.6	1.82	0.28	30.33	2.75	5.5
Bss	47-94	1.02	0.34	6.38	3.33	1.9	1.72	0.23	28.67	2.25	5.1
Shahabad soil profile (Limestone derived)											
Ap	0-22	0.88	0.34	5.5	3.33	1.7	1.37	0.34	22.83	3.33	3.4
A2	22-38	0.88	0.38	5.5	3.33	1.7	0.75	0.34	12.50	3.33	1.9
A3	38-58	1.28	0.43	8.0	4.22	1.9	1.00	0.40	16.67	3.92	2.0
A4	58-120	1.11	0.42	6.94	4.12	1.7	1.90	0.57	31.67	5.59	3.3

*Calculated from total silica and alumina, extracted by CBD and boiling carbonate treatments.

Table 4. Exchange properties of whole soils and clay properties of selected horizons.

Horizon	Depth (cm)	CEC (pH 8.2)	Exchangeable bases (pH 7.0)					(Ca+Mg) / (K+Na) (%)	Ca / Mg (%)	CaEC	K/EC	Vermi-culite (%)	c.c.c (mmol /dm^3)	SSA (m^2/g)
			Ca	Mg	K	Na	Sum			cmol (p^+) kg^{-1}				
Hira soil profile (Schist derived)														
Ap	0-20	85.4	29.2	34.2	0.6	0.4	64.4	63	0.9					
A2	20-35	87.7	35.8	21.0	0.6	0.4	57.7	59	1.7	87.3	76.9	7	19	416
A3	35-60	83.3	48.3	17.8	0.5	0.5	67.2	61	2.7	89.4	69.1	13	18	367
Bidar soil profile (Basalt derived)														
Ap	0-24	91.5	55.8	22.2	1.1	0.5	79.6	49	2.5					
A2	24-47	86.0	44.8	25.6	0.8	0.4	71.6	59	1.8	91.9	61.1	20	22	367
Bss	47-94	72.2	34.5	26.7	0.7	0.4	62.3	56	1.3	92.1	58.0	22	19	367
Shahabad soil profile (Limestone derived)														
Ap	0-22	90.7	29.7	20.4	0.7	0.9	51.7	31	1.5					
A2	22-38	96.7	22.6	29.4	0.6	2.3	54.8	18	0.8	89.4	62.7	17	20	367
A3	38-58	95.1	21.2	45.5	0.6	4.0	71.3	14	0.5	91.2	58.3	21	19	305
A4	58-120	96.8	19.8	37.5	0.6	7.2	65.0	7	0.5	91.6	56.4	23	19	367

c.c.c: Critical coagulation concentration
SSA: Specific Surface Area

high in the basalt derived Bidar soil (55.8cmol (p^+) kg^{-1}) than the schist derived Hira (48.3cmol (p^+) kg^{-1}) and the limestone derived Shahabad soils (29.7cmol (p^+) kg^{-1}). Whereas the exchangeable magnesium is high in the limestone derived Shahabad soil than (45.5cmol (p^+) kg^{-1})the schist derived Hira (34.2cmol (p^+) kg^{-1}) and the basalt derived Bidar (26.7cmol (p^+) kg^{-1}) soils. The exchangeable sodium and potassium are very low in these soils. However the limestone derived Shahabad soil had higher exchangeable sodium (7.2cmol (p^+) kg^{-1}) than the schist derived Hira soil (0.5cmol (p^+) kg^{-1}) and the basalt derived Bidar soil (0.5cmol (p^+) kg^{-1}). And further the content of exchangeable sodium increased with depth as also found by Dasog and Hadimani (1980), Khresat and Taimeh (1998).

When the ratios of exchangeable cations were calculated, the ratio of di-valent cations to mono-valent cations is higher in the schist derived Hira soil than the basalt derived Bidar soil and is lowest in the limestone derived Shahabad soil (Table 4). Indicating that relatively higher proportion of mono-valent cation are present in the limestone derived Shahabad soil than the Bidar and the Hira soils. And when the ratio of calcium to magnesium is calculated, the ratio is comparatively higher in the basalt derived Bidar soil than the schist derived Hira soil. Both these soils have calcium dominant exchange complex. Contrastingly, the limestone derived Shahabad soil has magnesium dominant exchange complex.

Other clay properties of selected horizons of the profiles in the study are in depicted in table 4, the specific surface area of soil clays in the three different soils is in the range of 300-400m^2/g and there is no significant difference among the three soils. The critical coagulation concentration (c.c.c) of the three black soil clays is in the range of 18 to 22 mmol/$dm^3$and showen no significant difference among the three soils. However, considering the magnitude of c.c.c., the schist derived Hira soil clays have less c.c.c than that of the basalt derived Bidar soil clays and the limestone derived Shahabad soil clays. The charge of soil clays is obtained from calcium exchange capacity (CaEC). From the table 4, it is seen that these soils have the clay charge in the range of 87-92 cmol (p^+) kg^{-1} of clay. Comparing the charge of soil clays of these three black soils, the CaEC of the schist derived Hira soil clays is relatively less than those of Bidar and Shahabad soil calys, similar results were found by Krale, *et al.*(1969), but the CEC of clays calculated from soil CEC is higher in Hira and Shahabad soil clays than in the basalt derived Bidar soil clays. Whereas, the clays of these three black soils fix K at high temperatures generally. The magnitude of K-fixed always increased with depth (Table 4). The K/EC after K-fixation was relatively more in the schist derived Hira soil clays than the basalt derived Bidar soil clays and the limestone derived Shahabad soil clays. This indicates that, these soils have smectitic mineralogy with significant amounts of vermiculite. The vermiculite content is estimated in this study by the magnitude of K-fixation as per Jackson (1966). The calculated vermiculite content in these soil clays is in the range of 7-23 per cent of soil clays. The basalt derived Bidar soil clays and the limestone derived Shahabad soil clays had higher vermiculite content than the schist derived Hira soil clays.

All the three soils derived from three different parent materials showed that the soils are rich in clay content which can be confirmed by pressure faces and non- intersecting slickensides in subsurface horizon, which yield in high CEC in all three soils. Apart from soil reaction (pH), all three soils are not significantly differentiated, but, there are variations and differences in respect of exchangeable sodium percent, calcium-magnesium ratio, divalent to monovalent ratio, vermiculite content and charges on clays.

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