Agropedology, 2001, 11, 83-90

Characteristics and classification of soils of Kathiawar region of Gujarat as influenced by topography

J.P. Sharma, R.J. Landey[1], A.R. Kalbande[2] and C. Mandal

National Bureau of Soil Survey and Land Use Planning (ICAR), Amravati Road, Nagpur 440010, India
[1]Deceased
[2]Present Address : K-4, Bharatnagar, Amravati Road, Nagpur 440 010, India

Abstract

Seven soil series belonging to Entisols (Lithic Ustorthents), Inceptisols (Typic, Lithic, Calcic, Calcic Udic and Vertic subgroups of Haplustepts) and Vertisols (Udic Calciusterts) occurring on residual hummocks and ridges, pediment, piedmont/valley, flood plain and coastal plain in Rajkot district of central Kathiawar region of Gujarat state were studied. The soils differed widely in their morphological, physical and chemical characteristics. Significant variations in soil depth, drainage, colour and texture were observed in relation to toposequence. Soils occurring on upper elements of topography are shallow to moderately deep, somewhat excessively to well drained, clay loam to clay in texture and reddish brown to dark brown in colour, whereas soils occurring on lower elements of topography are deep to very deep, moderately well drained to poorly drained, clay in texture and greyish brown to dark greyish brown in colour. Soils, in general, were low in organic carbon but high in clay content, cation exchange capacity and base saturation, irrespective of their physiographic position. Ca^{2+} dominated the exchange complex. Soils occurring on lower element of topography were strongly calcareous and showed mottling.

Additional key words : Landform - soil relationship, basaltic terrain.

Introduction

Topography is one of the important soil forming factors causing differences in soil characteristics to a great extent. The relationship between landforms and the associated soils had been studied and utilized in precise recognition and mapping of homogeneous soil units in Rajkot district of Gujarat state (Sharma and Raychoudhury 1988). Occurrence of diverse soils on varied landforms necessitates their characterization in order to understand their potential and problems and to make use of such information for land resource management. Therefore, an attempt was made to study salient morphological, physical and chemical characteristics of the soils of Kathiawar region in Gujarat and to classify them into taxonomic units.

Materials and methods

The central Kathiawar region, represented by Rajkot district in Gujarat, covering 11,156 km^2 area, lies between 20°59′ and 23°08′ N and 70°20′ and 71°41′ E having the altitude between 20 and 300 m above MSL (Fig.1). The region is characterized by tropical semi-arid climate with mean annual rainfall of 673 mm (31 per cent of total PET) and mean annual temperature of 26.7 °C.The soil temperature

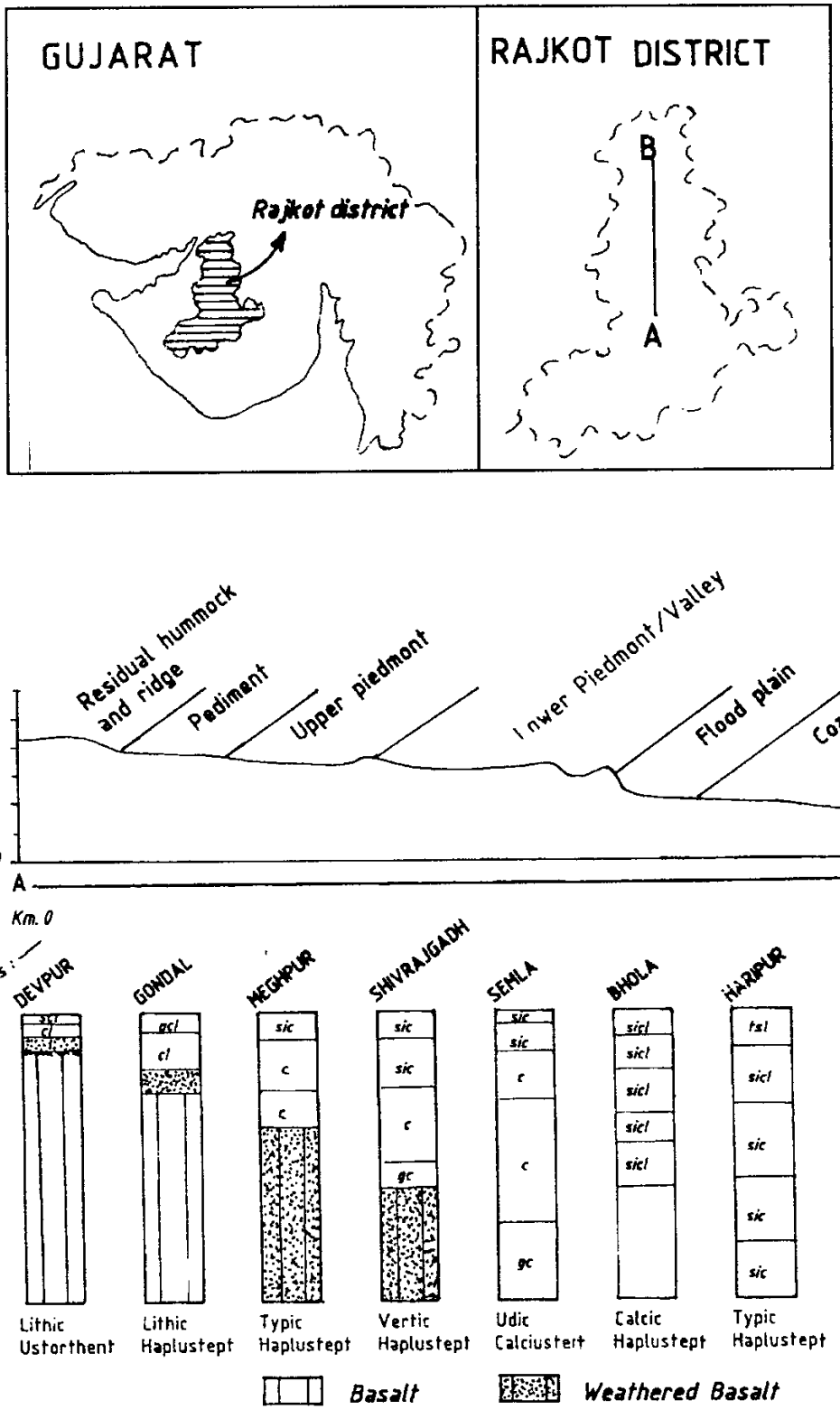

Fig.1 Landform - soil relationship in a transect from Rajkot to Morvi in Rajkot district (Gujarat)

regime is h*yperthermic* and the soil moisture regime is u*stic*. Basalt, in horizontal layers, horizontal layers, characterizes the main geological formation of the area. The natural flora include thorny vegetation. The pearlmillet, sorghum and groundnut are the crops generally grown in this district.

Typical pedons of seven identified soil series occurring on different landforms in a toposequence were studied for morphological characteristics (Soil Survey Staff 1951). Horizon-wise soil samples were collected and analysed for physical and chemical properties using standard procedures (Jackson 1973). The soils were grouped based on similar characteristics and classified by following Soil Taxonomy (Soil Survey Staff 1998).

Results and discussion

Morphological properties: Soil colour varied from red to grey with hues of 5 YR, 7.5 YR, 10 YR, values of 3 to 4 and chromas of 2 to 4 (Table 1). Significant variations in soil colour indicate the release of iron oxides and their occurrence in various hydrated forms due to variation in internal drainage of soil as influenced by toposequence (Sarkar *et al.* 2001). The reddish brown to dark brown colours of somewhat excessively to well drained soils of Devpur, Gondal and Meghpur series may be attributed to the presence of non-hydrated iron oxides, indicating well drained nature of these soils (Gerrard 1981). The soils of Shivrajgadh, Bhola, Semla, Haripur and Vavniya series with restricted drainage have greyish colours ranging between greyish brown to very dark greyish brown. Presence of yellowish brown mottles in the lower horizons of Semla and Vavniya series may be attributed to poor drainage and permeability. Drainage, as influenced by topography seems to be an important factor for the differences in hue, value and chroma of these soils (Tiwary *et al.* 1989, Singh *et al.* 1995).

The soils of Devpur series had fine, weak, subangular blocky structure whereas others possessed medium to coarse, moderate to strong subangular to angular blocky structure with the exceptions in the Ck horizon of Semla and the BCk horizon of Bhola series. The cracks and pressure faces are the common features in the soils of Shivrajgarh, Bhola, semla (slickensides also) and Vavniya series. These soils also had few fine, lime concretions except Vavniya soils. Haripur soils had sand pockets, showing depositional features.

Soil depth, in general, has shown increasing trend down the slopes with very shallow to shallow soils of Devpur series on moderately steep residual hummocks and ridges, shallow to moderately deep soils of Gondal series on gently to strongly sloping pediment, moderately deep to deep soils of Meghpur series on very gently sloping upper piedmont developed over basalt. The erosional processes associated with slope and relief characteristics seem to have influenced the soil depth to a great extent (Sharma and Raychoudhury 1988). The deep to very deep soils of Shivarajgadh, Bhola and Semla are associated with nearly level to very gently sloping lower piedmont/valley

Table 1. Morphological characteristics of soils*

Hori-zon	Depth (cm)	Colour (moist)	Tex-ture	Structure	Special features
Devpur series **: Clayey-skeletal, smectitic Lithic Ustorthents**					
A1	0-7	5 YR ¾	gcl	f1sbk	-
A2	7-14	5 YR 3/3	gcl	f1sbk	-
Cr	14-25	----------Weathered Basalt ----------			
Gondal series **: Clayey, smectitic Lithic Haplustepts**					
Ap	0-6	5 YR 3/4	cl	m2 sbk	-
Bw	6-27	5 YR 3/4	gc	m2 sbk	-
Cr	27-30	----------Weathered Basalt ----------			
Meghpur series **: Clayey, smectitic Typic Haplustepts**					
Ap	0-16	7.5 YR 3/2	c	m2 sbk	-
Bw1	16-31	7.5 YR 3/2	c	m2 sbk	-
Bw2	31-49	7.5 YR 3/2	c	c3 sbk	-
Cr	49-76	----------Weathered Basalt ----------			
Shivrajgadh series **: Fine, smectitic Vertic Haplustepts**					
Ap	0-16	10 YR 3/2	c	m2 sbk	few lime concretions;1-2 cm wide cracks
Bk1	16-39	10 YR 3/2	c	m2 sbk	few lime concretion; 1-2 cm wide cracks; shiny pressure faces
Bk2	39-81	10 YR 3/2	c	c3 sbk	few lime concretion; 1 cm wide cracks; shiny pressure faces
Ck	81-94	10 YR 5/4	gc	m	many coarse lime concretion
Semla series**: Very-fine, smectitic Udic Calciusterts**					
Ap	0-10	10 YR 3/2	c	c2 sbk	few lime concretions, 2-4 cm wide cracks
BA	10-23	10 YR 3/2	c	c3 sbk	few lime concretion; 2-4 cm wide cracks
Bssk1	23-45	10 YR 3/2	c	c2 abk	slickensides; 1-2 cm wide cracks
Bssk2	45-115	10 YR 5/4	c	c3 abk	slickensides; 1-2 cm wide cracks; few fine faint mottles (10 YR 5/6); few lime concretions
BCk	115-156	10 YR 3/2	c	c3 abk	intersecting slickensides, many lime concretions
Ck	156-170	10 YR 5/3	sic	m	
Bhola series **: Fine, smectitic Calcic Haplustepts**					
A1	0-16	10 YR 3/3	sc	m2 sbk	few lime concretions; 1-2 cm wide cracks
A2	16-33	10 YR 3/3	sc	m2 sbk	few lime concretions; 1-2 cm wide cracks
Bk1	33-56	10 YR 3/2	c	c3 sbk	many lime concretions; 1-2 cm wide cracks
Bk2	56-73	10 YR 3/2	c	c3 sbk	many lime concretions
BCk	73-96	10 YR 4/4	gc	m	many lime concretions
Ck	96-113	Pebbles,cobbles, gravels and lime nodules			
Haripur series **: Fine- loamy mixed, Fluventic Haplustepts**					
Ap	0-19	10 YR 3/2	scl	m1 sbk	few sand pockets
Bw1	19-50	10 YR 4/2	scl	m2 sbk	few sand pockets
Bw2	50-91	10 YR 4/2	cl	c3 sbk	few sand pockets
Bk1	91-124	10 YR 3/2	sc	c3 sbk	few sand pockets
Bk2	124-140	10 YR 3/2	sc	c3 sbk	few sand pockets
Vavniya series **: Fine, smectitic Calcic Udic Haplustepts**					
Ap	0-15	10 YR 4/4	sc	m2 sbk	1-1.5 cm wide
A2	15-39	10 YR 4/4	cl	m2 sbk	1-1.5 cm wide cracks
2Bk1	39-94	10 YR 3/2	c	c3 sbk	common fine faint mottle (10 YR 5/6); 1 cm wide cracks
2Bk2	94-117	10 YR 3/2	c	c3 sbk	common fine faint mottles (10 YR 5/6)
2Ck	117-150	10 YR 6/2	gc	c3 sbk	common fine distinct mottles (10 YR 5/8)

*Symbols used are according to Soil Survey Manual (Soil Survey Staff 1951)

whereas Haripur and Vavniya on nearly level to very gently sloping flood plain and coastal plain respectively. These soils have been developed in basaltic alluvium.

Physical characteristics: The particle size data (Table 2) indicate that sand is the dominant fraction in Haripur series, surface and sub-surface horizons of Bhola and Vavniya series, surface horizons of Devpur and Gondal series and clay is proportionately higher in other horizons of soil series. Exceptionally higher (>55%) smectitic clay was noticed in Semla and Shivrajgadh soils. Thus, Shivrajgadh and Semla soils qualify for fine and very-fine textural family classes, respectively. In general, clay increased while sand and silt decreased with depth barring few exceptions.

It seems that degree of weathering, lateral translocation of finer particles, distance from the source area and deposition pattern of sediments are the major factors responsible for textural variation as affected by topography.

Chemical characteristics: Soils of Devpur and Gondal series are neutral to mildly alkaline in reaction and others are moderately to strongly alkaline. The increase in pH down the slope may be attributed to the migration of bases, particularly Na^+, from the higher to the lower element of topography and the impeded drainage in low lying areas. Similar findings were observed by Sharma *et al.* (1996) in a toposequence of basaltic terrain.

The content of organic carbon in the soils, in general, is low because of low rainfall and high temperature. The soils of Devpur series, being under forest, showed comparatively higher values for organic carbon (7.0 to 9.1 g kg^{-1}) and other soils were either barren or under cultivation, both the situations being conducive to organic matter accumulation.

Soils of Shivrajgadh, Bhola, Semla, Haripur and Vavniya series occurring down the slope showed more accumulation of calcium carbonate. This may be attributed to their relatively poor drainage and high water table conditions associated with the high evaporative demands from the soil.

The soils have high cation exchange capacity (CEC) and high base saturation with dominance of Ca^{2+} followed by Mg^{2+} in the exchange complex. The Na^+ and Mg^{++} increased with depth particularly in Semla, Bhola, Haripur and Vavniya which indicated that these soils suffer from sub-soil sodicity. High CEC is due to dominance of smectitic clay minerals. Increase in CEC values with depth in the profile may be due to gradual increase in clay content.

Classification : Based on the presence of ochric epipedon, thin solum (14 cm) underlain by lithic contact, ustic moisture regime, the soils of Devpur series have been classified as Lithic Ustorthents at sub-group level. More than 35 per cent clay in fine-earth fraction associated with more than 35 per cent gravels (v/v), these soils are grouped as clayey-skeletal, smectitic, hyperthermic Lithic Ustorthents at family level. The Gondal soils had ochric epipedon, cambic horizon (21 cm thick) developed over weathered basalt and underlain by lithic contact. Thus, they are classified as Lithic Haplustepts.

Table 2. Physical and chemical characteristics of soils

Horizon	Depth	Gravel (>2mm) (%)	Sand (2.0-0.05 mm)	Silt (0.05-0.002mm)	Clay (<0.002mm)	O.C. (%)	$CaCO_3$ (%)	pH (1:2.5)	E.C. (dSm^{-1})	CEC	Exchangeable cations			
											Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
											[cmol (p^{+}) kg^{-1}]			
Devpur series **: Clayey-skeletal, smectitic, hyperthermic Lithic Ustorthents**														
A1	0-7	69	42.9	21.9	35.2	0.91	1.5	7.0	0.30	34.3	18.8	13.2	0.4	0.9
A2	7-14	56	36.2	25.5	38.3	0.70	0.8	7.2	0.35	35.4	20.9	12.8	0.4	0.6
Gondal series **: Clayey, smectitic, hyperthermic Lithic Haplustepts**														
Ap	0-6	11	38.9	23.1	38.0	0.28	3.2	7.4	0.20	35.1	20.4	13.2	0.4	0.8
Bw	6-27	29	37.0	17.5	45.5	0.11	3.3	7.5	0.30	45.4	28.2	15.6	0.5	0.5
Meghpur series **: Clayey, smectitic, hyperthermic Typic Haplustepts**														
Ap	0-16	2	15.9	22.6	61.5	0.33	2.0	8.1	0.35	57.8	44.8	11.2	0.4	0.8
Bw1	16-31	2	15.0	22.2	62.8	0.28	1.5	8.0	0.45	60.7	46.0	13.6	0.4	0.5
Bw2	31-49	3	14.8	20.0	65.2	0.14	2.0	8.2	0.35	61.5	44.2	15.6	0.5	0.5
Shivrajgadh series **: Fine, smectitic, hyperthermic Vertic Haplustepts**														
Ap	0-16	-	21.0	23.5	55.5	0.70	18.9	8.2	0.70	49.3	38.0	8.4	1.4	0.8
Bk1	16-39	2	19.0	19.1	61.9	0.48	18.3	7.9	0.90	55.2	40.8	10.4	1 6	0.4
Bk2	39-81	-	24.0	17.0	59.0	0.35	17.9	8.2	0.30	53.6	42.0	8.8	1.6	0.5
Ck	91-94	2	37.0	16.5	46.5	0.29	22.8	8.0	0.40	45.7	30.4	11.6	1.6	0.4
Semla series**: Very-fine, smectitic, hyperthermic Udic Calciusterts**														
Ap	0-10	-	22.6	20.5	56.9	0.72	21.8	8.5	0.50	47.8	32.3	12.0	1.4	1.0
Bw	10-23	-	20.5	19.5	60.0	0.67	21.1	8.8	0.70	58.9	37.6	16.8	2.7	0.9
Bssk1	23-45	-	23.6	15.5	60.9	0.62	24.7	8.8	0.80	55.7	34.8	16.4	2.9	0.6
Bssk2	45-115	3	19.4	18.7	61.9	0.59	21.7	9.0	1.10	56.1	30.8	20.0	3.8	0.8
BCk	115-156	2	16.6	25.6	57.8	0.43	22.1	8.9	0.90	51.7	27.6	19.6	3.1	0.4
Bhola series **: Fine, smectitic, hyperthermic Calcic Haplustepts**														
A1	0-16	1	45.4	12.6	42.0	0.70	21.8	8.1	1.05	37.9	24.0	12.4	0.87	0.3
A2	16-33	1	45.5	13.5	41.0	0.62	14.3	8.7	1.80	37.1	22.4	11.6	2 1	0.4
Bk1	33-56	2	27.5	21.9	50.6	0.45	18.2	8.6	3.80	44.3	26.8	13.2	4.3	0.4
Bk2	56-73	6	25.5	26.0	48.5	0.29	23.2	8.7	4.10	41.9	22.8	10.0	4.6	0.4
BCk	73-96	39	31.5	28.0	40.5	0.27	26.6	8.7	0.50	38.9	22.8	10.0	4.6	0.4
Haripur series **: Fine loamy, mixed, hyperthermic Fluventic Haplustepts**														
Ap	0-19	-	51.8	14.2	34.0	0.62	9.6	7.3	0.20	25.2	14.4	8.0	1.1	0.9
Bw1	19-50	-	48.0	18.7	33.3	0.45	11.8	7.5	0.20	29.9	19.6	7.2	1.6	0.7
Bw2	50-91	-	41.0	22.5	36.5	0.37	12.9	9.1	1.50	34.9	18.6	11.4	2.3	0.6
Bk1	91-124	-	46.0	16.5	37.5	0.37	17.0	9.0	1.40	33.8	19.6	9.6	3.2	0.9
Bk2	124-140	-	46.0	11.5	42.5	0.13	20.6	8.5	0.25	37.0	20.2	10.4	4.7	1.1
Vavniya series **: Fine, smectitic, hyperthermic Calcic Udic Haplustepts**														
Ap	0-15	5	46.1	14.9	39.0	0.67	13.6	7.7	0.20	26.7	16.0	7.6	1.4	1.1
A2	15-39	3	44.4	17.6	38.0	0.61	10.8	8.0	0.20	29.3	16.0	9.6	2.7	0.9
2Bk1	39-94	3	33.7	15.3	51.0	0.56	17.8	8.3	0.60	36.8	20.2	12.4	3.2	0.7
2Bk2	94-117	4	30.7	19.2	52.1	0.44	20.8	8.2	0.60	41.1	20.3	12.4	4.1	0.8
2Ck	117-150	21	32.5	10.7	56.8	0.25	40.8	8.3	1.15	35.1	16.4	13.2	4.6	0.4

With more than 35 per cent clay these soils are grouped under clayey Lithic Haplustepts with smectitic mineralogy. Absence of lithic contact (within 50 cm) in Meghpur soils justify its placement in Typic Haplustepts. Based on the occurrence of cracks (>5 mm wide) through a thickness of 30 cm and solum depth 94 cm, the Shivrajgadh soils have been grouped under Vertic Haplustepts (fine textural family class).

The soils of Semla series with slickensides (>25 thick zone) and calcic hoizon have been classified as Calciusterts. With 5 mm or more wide cracks through a thickness of 25 cm or more within 50 cm under unirrigated condition, these soils are placed under Udic Calciusterts at subgroup level. Further due to >60 per cent clay in control section, these have been classified as very-fine, smectitic, hyperthermic Udic Calciusterts.

Due to the presence of ochric epipedon underlain by calcic horizon within 100 cm of the mineral surface layer, soils of Bhola series are placed as Calcic Haplustepts (fine textural family). The soils of Haripur had cambic horizon and meet the central concept of Typic and its placement as Typic Haplustepts (fine-loamy, mixed) is justified. The presence of cracks (non-irrigated environment), coupled with calcic horizon, the soils of Vavniya series are placed as calcic Udic Haplustepts, with fine textural family class and smectitic mineralogy.

Acknowledgements

The authors are highly grateful to the Director, National Bureau of Soil Survey and Land Use Planning and the Head, Regional Centre, Nagpur for providing necessary facilities.

References

Gerrad, A.J.(1981). 'Soils and Landforms' (Allen and Unwin : London).

Jackson, M.L. (1973). 'Soil Chemical Analysis' (Prentice Hall of India Pvt. Ltd. : New Delhi).

Sarkar, Dipak, Gangopadhyay, S.K. and Velayutham, M. (2001). Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau. *Agropedology* **11**, 29-36.

Sharma, J.P. and Raychowdhury, C. (1988). Soil-landform relationship in a basaltic terrain. *Journal of the Indian Society of Soil Science* **36**, 755-760.

Sharma, S.S., Totawat, K.L., and Shyampura, R.L. (1996). Characterization and classification of soils in a toposequence over basaltic terrain. *Journal of the Indian Society of Soil Science* **44,** 470-475

Singh, S.K., Das, K., Shyampura, R.L., Giri, J.D., Singh, R.S., and Sehgal, J. L.(1995). Genesis and taxonomy of black soils from basalt and basaltic alluvium in Rajasthan. *Journal of the Indian Society of Soil Science* **43**, 430-436.

Soil Survey Staff (1951) 'Soil Survey Manual' Agriculture Handbook No. **18** (USDA: Washington, D.C.)

Soil Survey Staff (1998) 'Keys to Soil Taxonomy' (8th edition). United States Department of Agriculture, Natural Resource Conservation Service, Washington, D.C.

Tiwary, J.R., Jha, P.P., and Mishra, B.B. (1989). Characteristics and classification of red, black and yellow soils of Rajmahal Trap of Bihar. *Journal of the Indian Society of Soil Science* **37**, 518-523.

(Received: March, 1998; Accepted: August, 2001)