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Clay mineralogy in some sugarcane growing black red and red Laterite soils of Telangana

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Abstract
The study was carried out to characterise and classify the sugarcane growing soils of Medak district of Telangana State. The selected red soils (Pedon 8, 10, 11, 13 and 14) were developed on weathered granite-gneiss parent material at gently sloping lands, red laterite soils (Pedon 2, 3, 4, 5 and 6) developed on weathered granite-gneiss over hard laterite parent material at gently sloping lands whereas the black soils (Pedon 1, 7, 9 and 12) were formed at nearly level and plain topography on granitic gneiss parent material mixed with calcareous murram. The silt clay ratio was found to be less than 0.5 in black and red laterite soils pedons indicating the moderate weathering, whereas in red soils Pedon silt clay ratio ranged from 0.19 to 0.82 indicating the moderate to high weathering. The dominance of Smectite type clay was also confirmed by the CEC / clay ratio. The CEC /clay ratios of these black soils were high (0.58 to 0.86). It indicates the presence of smectitic type of clay minerals. The CEC /clay ratios of these red soils were medium to high in range (0.43 to 0.77) which is indicates the mixed or illItic mineralogy, where the presence of secondary clay minerals such as kaolinite, Illite and montmorillonite are more or less in equal range. The CEC /clay ratios of the red laterite soils were low to medium in range (0.16 to 0.46), indicating the presence of secondary clay mineral such as kaolinite. Direct conversion of mica to kaolinite might be one of the causes for the synthesis of kaolinite.

Keywords: Black soils, red soils, red laterite soils, clay mineralogy, sub surface hardening

Introduction
Telangana state being under a semi-arid tropical monsoon climate, has a number of soil types which are found in all types of climates, occupying 3.5 per cent (112,077 sq km or 112.077 lakh ha or 11.207 m.ha) of the country's geographical area. The black soils, red soils and red laterite soils are the most common tropically Pedogenic surface deposits in India. Their geotechnical characteristics and field performance are influenced considerably by their Pedogenesis, degree of weathering, morphological characteristics, chemical and mineral compositions as well as prevailing environmental conditions. Based on CEC/clay ratio of black soils of Krishna district, Babu *et al.* (2002) [30] identified the presence of Smectite, Illite and Kaolintie. The CEC / clay ratios of different horizons of Alfisols of Chotanagpur plateau were in between 0.13 and 0.43 and Sarkar *et al*, 2001 [16] had grouped the clay under mineralogical class 'mixed'. The CEC / clay per cent varied from 44 to 54 indicating mixed mineralogy in Ultic Haplustalfs of Bhubaneswar (Nayak *et al*., 2002) [9]. Information on the clay mineral distribution in sugarcane growing soils insemi arid tropical region of Telangana was meager. Distribution of various minerals in three groups of soil pedon state has been worked out in this research article.

Location, climate and brief discussion of the study area
Medak district of Telangana state is with a geographical area of 9,519 km^2 forms a part of Deccan Plateau under Godavari basin and lies between North Latitudes 17^0 27' and 18^0 18' and East longitudes 77^0 28' and 79^0 10'. Sugarcane is cultivated in the district in an area of 22076 hectares producing 1721 thousand tonnes with an average productivity of 74.41 t ha^{-1} (Centre for Monitoring Indian Economy, 2014-15). Based on the morphological characteristics and physiography, fourteen geo-referenced pedons (Table 1) were selected in eight divisions of Medak district such as Aroor (Pedon 1), Paidigummal (Pedon 2), Burdipad (Pedon 3), Kuppanagar (Pedon 4), Basanthpur (Pedon 5), Kothur (Pedon 6), Budera (Pedon 7), Mamdipally (Pedon 8), Andole (Pedon 9), Kaudloor (Pedon 10), Antharam (Pedon 11), Pulakurty (Pedon 12), Mudguntal thanda (Pedon 13) and Ramakkapet (Pedon 14). The selected pedons of the sugarcane growing area of the Medak district are broadly categorized into three groups based on the soil types *viz.*, Black soils (1, 7, 9 and 12), Red laterite soils (2, 3, 4, 5 and 6) and Red soils (8, 10, 11, 13 and 14).

The climate is semi-arid. The mean annual rainfall is 870 mm of which 76 per cent is received during the southwest monsoon (June to September), 14 per cent during the northeast monsoon (October to December) and 8 per cent during the premonsoon period (March to May). The mean maximum and minimum temperature vary from 40° to 26 °C. Mean humidity varies from 65 per cent in July to 74 per cent in December. The soil moisture content is dry for more than 90 cumulative days or 45 consecutive days in the months of summer solstice. The soil moisture and temperature regimes of the study area are Ustic and Isohyperthermic, respectively. The natural vegetation existing in the study area are grasses, shrubs, thorny bushes such as *Cynodon dactylon, Cyprus rotundus, Butea frondosa, Dalbergia latifolia, Azadirachta indica, Tectona grandis, Terminalia tomertosa and Acacia sp. Prosopis juliflora, Cacia sp*, broad leaf weeds such as *Selotia, Parthenium, Eucalyptus, Euforbia* sps., *etc.* The principal crops cultivated are Rice, Maize, Sugarcane, Cotton, Redgram, Greengram, Blackgram, Groundnut and Potato.

Collection and processing of soil samples

The division wise geo-referenced pedons were selected on the basis of soil heterogeneity and land forms in different locations of sugarcane growing areas of the district. Horizon wise soil samples were collected from the representative pedons for laboratory analysis. The soil samples were air-dried in shade, processed and screened through a 2 mm sieve. Particles greater than 2mm were considered as gravel. The samples were air dried and ground to pass through 2 mm sieve. Relevant physical and chemical properties were determined by following standard analytical procedures. The Soil pH, EC (1:2.5 soil water suspension); exchangeable cations (Jackson 1973) [4]; cation exchange capacity (Chapman, 1965); organic carbon (Walkly and black, 1934) [25] and free $CaCO_3$ (Piper 1966) [11].

Table 1: Geo-referenced location points of Sugarcane growing pedons in the Medak district

Pedon	Location of Pedon	Latitude º N	Longitude º E	Altitude (m)
1	Aroor	17 º 37'42.34"	77 º 53'10.33"	539
2	Paidigumma	17 º 32'39.17"	77 º 44'14.26"	651
3	Burdipad	17 º 43'43.50"	77 º 33'38.09"	602
4	Kuppanagar	17 º 44'31.90"	77 º 41'38.59"	626
5	Basanthpur	17 º 47'40.52"	77 º 32'50.03"	615
6	Kothur	17 º 43'52.78"	77 º 36'15.96"	611
7	Budera	17 º 38'37.18"	77 º 50'35.00"	585
8	Mamdipally	17 º 36'12.54"	78 º 08'59.68"	514
9	Andole	17 º 49'34.54"	78 º 05'07.31"	492
10	Kaudloor	17 º 57'04.04"	78 º 00'36.82"	489
11	Antharam	17 º 51'52.75"	78 º 11'17.34"	539
12	Pulakurty	17 º 56'45.77"	77 º 42'43.82"	527
13	Mudguntal	18 º 03'34.95"	77 º 49'20.43"	484
14	Ramakkapet	18 º 11'10.10"	78 º 37'47.53"	509

Results and discussion

The data on fine earth fractions of the soil pedons are presented in Table 2. The clay content of the soils ranged from 13.2 per cent (pedon10) to 71.4 per cent (pedon 12) in surface horizons whereas in subsurface horizons it ranged from 14.6 per cent (pedon 10) to 76.2 per cent (pedon 12). The distribution of clay varied widely both within the pedon and among the pedons. Pedon 2, 3, 8, 10, 12, 13 and 14 showed increasing trends with increased soil depth, while all other pedons showed irregular trend with soil depth. The clay content of the soils ranged from 13.2 per cent (pedon13) to 32.4 per cent (pedon 8) per cent in red soil pedons (8, 10, 11, 13 and 14) whereas in red laterite soil pedons (2, 3, 4, 5 and 6) clay content varied from 24.5 per cent (pedon 3) to 60.6 (pedon 4) per cent. The black soil pedons (1, 7, 9 and 12) clay content varied from 37.2 per cent (pedon7) to 76.2 per cent (pedon12). Increase of clay up to certain depth and a decrease was observed in pedon 1, 4, 5, 6, 7, 9 and 11 due to the illuviation process occurring during soil development. Similar observations were also made by Tripathi *et al.* (2006) [23]. The clay content was found gradually increased in pedon 2, 3, 8, 12, 13 and 14. The increased clay content with depth was an evidence of pedogenic development as their formation and distribution is time dependent (Bhaskar *et al.*, 2009) [3]. These variations could be attributed to the parent material, topography, *in situ* weathering and / or pedogenesis. These results were in concurrence with those of Rudramurthy and Dasog (2001); Gabhane *et al*. (2006) and Rajeshwar and Mani (2013b) [14, 28, 12]. The remaining pedon 10 showed irregular trend with soil depth

Table 2: Physical characteristics of Sugarcane growing soil pedons of the Medak district

Pedon	Location	Horizon	Depth (cm)	Gravel (%)	Particle size distribution (%)			B.D (Mg m-3)	Pore space (%)	W.H.C (%)	Volume expansion (%)	COLE
					Sand	Silt	Clay					
Sadasivpet division												
1	Aroor	Ap	0-25	11.50	20.1	19.8	59.6	1.56	55.0	48.0	23.1	0.14
		BA	25-52	10.50	19.0	18.4	62.1	1.59	53.0	51.0	23.7	0.16
		Bss1	52-79	9.00	17.3	17.3	63.9	1.61	50.0	49.0	25.5	0.18
		Bss2	79-115	9.50	16.8	17.2	64.3	1.65	48.0	46.0	26.4	0.19
		Bss3	115-155	8.30	16.4	20.0	61.1	1.68	46.0	45.0	28.4	0.21
		C	155+	Mixed with calcareous murram								
Zaheerabad division												
2	Paidigummal	Ap	0-16	35.6	37.8	10.2	50.7	1.46	39.0	21.0	3.10	-
		Bt1	16-43	41.5	30.8	9.8	57.2	1.52	41.0	23.0	3.20	-
		Bt2	45-68	61.2	33.6	8.3	57.9	1.54	40.0	24.0	3.30	-

		C	67+	Weathered Laterite hard pan								
3	Burdipad	Ap	0-16	24.2	68.4	5.6	24.5	1.45	41.0	23.0	3.13	-
		Bt1	16-38	28.9	53.2	6.2	39.2	1.49	45.0	25.0	3.25	-
		Bt2	38-70	34.5	51.2	6.1	41.2	1.51	43.0	27.0	3.26	-
		Bt3	70-95	51.2	48.6	8.9	41.9	1.51	42.0	27.0	3.42	-
		C	95+	Weathered Laterite hard pan								
4	Kuppanagar	Ap	0-14	31.2	45.6	12.4	41.2	1.46	44.0	19.0	3.10	-
		Bt1	14-30	36.5	37.5	12.1	50.1	1.47	42.0	20.0	3.35	-
		Bt2	30-50	38.9	30.5	8.3	60.6	1.49	46.0	20.0	3.36	-
		Bt3	50-81	67.8	28.5	18.3	52.5	1.51	49.0	21.0	3.81	-
		C	81+	Weathered Laterite hard pan								
5	Basanthpur	Ap	0-20	35.0	56.1	8.2	35.2	1.47	39.0	24.0	2.88	-
		Bt1	20-38	46.3	53.2	9.3	37.1	1.48	41.0	23.0	3.12	-
		Bt2	38-56	52.1	51.0	8.4	40.3	1.50	42.0	21.0	3.30	-
		Bt3	56-70	61.3	53.3	11.6	34.6	1.51	44.0	19.0	3.45	-
		C	70+	Hard lithic contact which roots cannot penetrated								
6	Kothur	Ap	0-15	29.2	55.3	8.4	35.6	1.39	47.0	23.0	2.95	--
		Bt1	15-45	39.2	34.8	8.9	55.6	1.41	49.0	22.0	3.12	-
		Bt2	45-75	45.3	32.2	7.2	60.2	1.44	49.0	26.0	3.81	-
		Bt3	75-105	58.3	30.2	10.3	58.6	1.49	53.0	24.0	3.66	-
		C	105+	Hard lithic contact which roots cannot penetrated								
7	Budera	Ap	0-14	12.30	41.2	18.6	38.7	1.43	46.0	32.0	23.10	-
		Bw1	14-41	14.00	42.3	17.3	40.1	1.52	52.0	38.0	26.24	-
		Bwss1	41-58	14.50	43.2	18.6	37.2	1.50	55.0	36.0	27.13	-
		Bwss2	58-79	17.00	42.5	17.9	39.3	1.61	61.0	38.0	29.14	-
		BC	79-100	17.60	39.9	17.2	42.1	1.62	62.0	39.0	29.10	-
Sangareddy division												
8	Mamdipally	Ap	0-15	15.6	73.6	6.1	19.8	1.38	38.0	36.0	2.91	-
		Bt1	15-40	23.1	66.4	6.5	26.5	1.39	41.0	39.0	3.36	-
		Bt2	40-65	32.4	63.9	5.8	29.9	1.42	46.0	42.0	3.90	-
		Bt3	65-95	36.3	59.4	7.8	32.4	1.44	49.0	41.0	3.75	-
		C	95+	Weathered gneiss								
Jogipet division												
9	Andole	Ap	0-25	10.9	28.2	16.5	54.2	1.51	45.0	44.0	22.8	0.13
		BA	25-65	10.4	25.4	16.9	57.6	1.50	48.0	47.0	23.7	0.14
		Bss1	55-85	11.1	23.2	17.4	58.9	1.54	51.0	49.0	25.8	0.16
		Bss2	85-117	12.6	20.1	18.0	61.7	1.58	52.0	51.0	26.8	0.18
		Bss3	117-145	12.3	19.0	17.7	63.1	1.58	52.0	48.0	30.4	0.18
		Bss4	145-178	12.5	18.8	19.6	61.4	1.60	55.0	53.0	30.1	0.17
Medak division												
10	Kaudloor	Ap	0-11	26.8	74.6	10.8	13.2	1.46	41.0	31.0	2.94	-
		A21	11-22	38.9	76.5	8.1	14.6	1.43	46.0	30.0	2.98	-
		A22	22-41	45.3	77.1	7.2	15.6	1.49	47.0	36.0	3.13	-
		C	41+	Weathered gneiss								
Narsapur division												
11	Antharam	Ap	0-18	23.0	72.3	4.6	22.6	1.44	39.0	22.0	3.60	-
		Bt1	18-35	25.5	66.4	7.9	25.6	1.46	41.0	23.0	4.10	-
		Bt2	35-50	29.1	60.1	8.2	31.2	1.49	44.0	27.0	4.22	-
		Bt3	50-90	33.2	59.6	11.6	28.7	1.49	46.0	29.0	4.35	-
		C	90+	Weathered granite- gneiss								
Narayankhed division												
12	Pulkurty	Ap	0-27	10.0	10.3	17.5	71.4	1.49	45.0	46.0	23.5	0.14
		BA	27-55	9.4	8.2	18.1	73.4	1.55	48.0	47.0	24.6	0.15
		Bss1	55-87	8.9	6.3	18.4	75.1	1.62	51.0	49.0	26.8	0.17
		Bss2	88-124	10.1	4.3	19.5	75.7	1.66	53.0	51.0	28.6	0.19
		Bss3	124-150	10.5	3.6	20.1	76.2	1.66	53.0	52.0	30.1	0.20
13	Mudguntalthanda	Ap	0-13	22.5	74.2	4.4	20.4	1.41	43.0	21.0	2.90	-
		Bt1	13-25	26.3	65.1	6.8	27.4	1.43	45.0	25.0	4.10	-
		Bt2	25-46	35.3	60.1	9.3	29.9	1.49	47.0	29.0	5.22	-
		Bt2	46-65	45.9	56.4	11.1	32.2	1.51	51.0	33.0	5.75	-
		C	65+	Weathered granite								
Dubbaka division												
14	Ramakkapet	Ap	0-12	17.9	75.1	4.1	20.2	1.42	46.0	25.0	2.96	-
		Bt1	12-35	35.9	72.1	4.6	23.2	1.45	45.0	28.0	3.25	-
		Bt2	35-46	51.1	67.1	7.3	25.4	1.52	46.0	30.0	3.65	-
		Bt3	46-70	60.2	57.3	12.5	27.1	1.54	47.0	31.0	5.21	-
		C	70+	Weathered granite-gneiss								

Sand (0.02-2.0 mm); Silt (0.002- 0.02mm) and Clay (<0.002mm)

Ratios of fine earth fractions

To confirm the presence or absence of lithological discontinuity among adjacent horizons in different soil pedons, the ratios of fine earth fractions were computed (Table 3). The red laterite soils (pedons 2, 3, 4, 5 and 6) contained relatively higher sand / silt (1.56 (pedon 4) to 12.21 (pedon 3)), silt / clay (0.12 (pedon 6) to 0.35 (pedon 4)) and sand / (silt + clay) (0.40 (pedon 4) to 2.27 (pedon 3)) ratios followed by the red soils pedon 8, 10, 11, 13 and 14 (sand / silt (4.58 (pedon 14) to 18.32 (pedon 14)), silt / clay (0.19 (pedon 8) to 0.82 (pedon 10)) and sand / (silt + clay) (1.06 (pedon 13) to 3.38 (pedon 10)) and black soils pedon 1, 7, 9 and12 had shown ratios of sand / silt (0.18 (pedon 12) to 2.45 (pedon 7)), silt / clay (0.25 (pedon 12) to 0.50 (pedon 7)) and sand / (silt + clay) (0.04 (pedon 12) to 0.77 (pedon 7)). The silt clay ratio was found to be less than 0.5 in black soils and red laterite pedons indicating the moderate weathering, whereas in red soils pedon silt clay ratio ranging from 0.19 (pedon 8) to 0.82 (pedon 10) indicating the moderate to high weathering. Similar finding was reported by Rajeshwar and Mani (2013b) [12] in red, red laterite and black soils of Tamil Nadu. The ratios of sand / silt silt / clay, sand / (silt + clay) were comparatively higher in red soil pedons indicating the translocation and / or migration of finer particles down the depth (Satyavathi and Reddy, 2003) [17].

Table 3: Ratios of fine earth fractions of pedons (Particle size-analysis)

Pedon	Location	Horizon	Depth (cm)	Sand+ Silt	Silt + Clay	Sand / Silt	Silt / Clay	Sand / (Sand + Silt)	Sand / (Silt + Clay)
Sadasivpet division									
1	Aroor	Ap	0-25	39.9	79.4	1.02	0.33	0.50	0.25
		BA	25-52	37.4	80.5	1.03	0.30	0.51	0.24
		Bss1	52-79	34.6	81.2	1.00	0.27	0.50	0.21
		Bss2	79-115	34.0	81.5	0.98	0.27	0.49	0.21
		Bss3	115-155	36.4	81.1	0.82	0.33	0.45	0.20
		C	155+	Mixed with calcareous murram					
Zaheerabad division									
2	Paidigummal	Ap	0-16	48.0	60.9	3.71	0.20	0.79	0.62
		Bt1	16-43	40.6	67.0	3.14	0.17	0.76	0.46
		Bt2	45-68	41.9	66.2	4.05	0.14	0.80	0.51
		C	67+	Weathered Laterite hard pan					
3	Burdipad	Ap	0-16	74.0	30.1	12.21	0.23	0.92	2.27
		Bt1	16-38	59.4	45.4	8.58	0.16	0.90	1.17
		Bt2	38-70	57.3	47.3	8.39	0.15	0.89	1.08
		Bt3	70-95	57.5	50.8	5.46	0.21	0.85	0.96
		C	95+	Weathered Laterite hard pan					
4	Kuppanagar	Ap	0-14	58.0	53.6	3.68	0.30	0.79	0.85
		Bt1	14-30	49.6	62.2	3.10	0.24	0.76	0.60
		Bt1	30-50	38.8	68.9	3.67	0.14	0.79	0.44
		Bt2	50-81	46.8	70.8	1.56	0.35	0.61	0.40
		C	81+	Weathered Laterite hard pan					
5	Basanthpur	Ap	0-20	64.3	43.4	6.84	0.23	0.87	1.29
		Bt1	20-38	62.5	46.4	5.72	0.25	0.85	1.15
		Bt2	38-56	59.4	48.7	6.07	0.21	0.86	1.05
		Bt3	56-70	64.9	46.2	4.59	0.34	0.82	1.15
		C	70+	Hard lithic contact which roots cannot penetrated					
6	Kothur	Ap	0-15	63.7	44.0	6.58	0.24	0.87	1.26
		Bt1	15-45	43.7	64.5	3.91	0.16	0.80	0.54
		Bt2	45-75	39.4	67.4	4.47	0.12	0.82	0.48
		Bt3	75-105	40.5	68.9	2.93	0.18	0.75	0.44
		C	105+	Hard lithic contact which roots cannot penetrated					
7	Budera	Ap	0-14	59.8	57.3	2.22	0.48	0.69	0.72
		Bw1	14-41	59.6	57.4	2.45	0.43	0.71	0.74
		Bwss1	41-58	61.8	55.8	2.32	0.50	0.70	0.77
		Bwss2	58-79	60.4	57.2	2.37	0.46	0.70	0.74
		BC	79-100	57.1	59.3	2.32	0.41	0.70	0.67
Sangareddy division									
8	Mamdipally	Ap	0-15	79.7	25.9	12.07	0.31	0.92	2.84
		Bt1	15-40	72.9	33.0	10.22	0.25	0.91	2.01
		Bt2	40-65	69.7	35.7	11.02	0.19	0.92	1.79
		Bt3	65-95	67.2	40.2	7.62	0.24	0.88	1.48
		C	95+	Weathered gneiss					
Jogipet division									
9	Andole	Ap	0-25	44.7	70.7	1.71	0.30	0.63	0.40
		BA	25-65	42.3	74.5	1.50	0.29	0.60	0.34
		Bss1	55-85	40.6	76.3	1.33	0.30	0.57	0.30
		Bss2	85-117	38.1	79.7	1.12	0.29	0.53	0.25
		Bss3	117-145	36.7	80.8	1.07	0.28	0.52	0.24
		Bss4	145-178	38.4	81.0	0.96	0.32	0.49	0.23
Medak division									

10	Kaudloor	Ap	0-11	85.4	24.0	6.91	0.82	0.87	3.11
		A21	11-22	84.6	22.7	9.44	0.55	0.90	3.37
		A22	22-41	84.3	22.8	10.71	0.46	0.91	3.38
		C	41+	Weathered gneiss					
Narsapur division									
11	Antharam	Ap	0-18	76.9	27.2	15.72	0.20	0.94	2.66
		Bt1	18-35	74.3	33.5	8.41	0.31	0.89	1.98
		Bt2	35-50	68.3	39.4	7.33	0.26	0.88	1.53
		Bt3	50-90	71.2	40.3	5.14	0.40	0.84	1.48
		C	90+	Weathered granite- gneiss					
Narayankhed division									
12	Pulkurty	Ap	0-27	27.8	88.9	0.59	0.25	0.37	0.12
		BA	27-55	26.3	91.5	0.45	0.25	0.31	0.09
		Bss1	55-87	24.7	93.5	0.34	0.25	0.26	0.07
		Bss2	88-124	23.8	95.2	0.22	0.26	0.18	0.05
		Bss3	124-150	23.7	96.3	0.18	0.26	0.15	0.04
13	Mudguntal thanda	Ap	0-13	78.6	24.8	16.86	0.22	0.94	2.99
		Bt1	13-25	71.9	34.2	9.57	0.25	0.91	1.90
		Bt2	25-46	69.4	39.2	6.46	0.31	0.87	1.53
		Bt2	46-65	67.5	43.3	5.08	0.34	0.84	1.30
		C	65+	Weathered granite					
Dubbaka division									
14	Ramakkapet	Ap	0-12	79.2	24.3	18.32	0.20	0.95	3.09
		Bt1	12-35	76.7	27.8	15.67	0.20	0.94	2.59
		Bt2	35-46	74.4	32.7	9.19	0.29	0.90	2.05
		Bt3	46-70	69.8	39.6	4.58	0.46	0.82	1.45
		C	70+	Weathered granite- gneiss					

Exchangeable properties

The cation exchange capacity was higher in black soil pedons varied from 24.4 c mol (p^+) kg^{-1} (pedon 7) to 56.2 c mol (p^+) kg^{-1} (pedon 12) in surface layers and 24.5 c mol (p^+) kg^{-1} (pedon 7) to 65.2 c mol (p^+) kg^{-1} (pedon 12) in sub surface layers than in red soils pedons varied from 7.8c mol (p^+) kg^{-1}(pedon 10) to 16.1 c mol (p^+) kg^{-1} (pedon 11) in surface layers and 11.1 c mol (p^+) kg^{-1}(pedon 10) to 20.1 c mol (p^+) kg^{-1}(pedon 8) in sub surface layers and red laterite soil pedons varied from 7.7 c mol (p^+) kg^{-1}(pedon 4) to 11.5 c mol (p^+) kg^{-1} (pedon 4) in surface layers and 8.2 c mol (p^+) kg^{-1}(pedon 4) to 15.4 c mol (p^+) kg^{-1}(pedon 4) in sub surface layers. Since CEC was the charge behaviour of soils, where clay was the fundamental block contributing towards cation exchange, the high CEC of the black soils was attributed to the high clay content and smectitic clay mineralogy (Pal and Deshpande, 1987) [10]. Confirming the above statement it showed the increasing trend of clay content with depth. Similar results were reported by Rudramurthy and Dasog (2001); Kadao *et al.* (2003); Gabhane *et al.* (2006); Balapande *et al.* (2007) [14, 6, 28, 2].

Soil exchange complex was dominated with Ca in all the pedons compared to other exchangeable cations. The Exchangeable Calcium was higher in black soil pedons varied from 11.4 c mol (p^+) kg^{-1} (pedon 7) to 25.2 (pedon 12) in surface layers and 12.2 (pedon 7) to 30.9 (pedon 12) in sub surface layers than in red soils pedons (3.1 c mol (p^+) kg^{-1} (pedon 10) to 8.2 c mol (p^+) kg^{-1} (pedon 13) in surface layers and 5.5 c mol (p^+) kg^{-1} (pedon 10) to 9.5 c mol (p^+) kg^{-1}(pedon 11) in sub surface layers) and red laterite soil pedons varied from 1.1 c mol (p^+) kg^{-1} (pedon 5) to 2.4 c mol (p^+) kg^{-1} (pedon 4) in surface layers and 1.5 c mol (p^+) kg^{-1} (pedon 2) to 3.0 c mol (p^+) kg^{-1} (pedon 6) in sub surface layers. In general, exchangeable Ca content increased with depth in pedons 3, 5, 6, 7, 10, 11, 12, 13 and 14 and it was decreased with depth in pedon 2, 4 and 9. There was no regular pattern of distribution with depth was noticed in pedon 1 and 8. The Exchangeable magnesium higher in black soils varied from 6.0 c mol (p^+) kg^{-1} (pedon 7) to 16.3 c mol (p^+) kg^{-1} (pedon 12) in surface layers and 8.4 c mol (p^+) kg^{-1} (pedon 9) to 20.6 c mol (p^+) kg^{-1} (pedon 12) in sub surface layers than in red soils pedons (2.0 c mol (p^+) kg^{-1} in pedon 10) to 4.9 c mol (p^+) kg^{-1} in pedon 11 in surface layers and 2.7 c mol (p^+) kg^{-1} (pedon 14) to 6.8 c mol (p^+) kg^{-1} (pedon 11) in sub surface layers) and red laterite soil pedons 0.9 c mol (p^+) kg^{-1} (pedon 5) to 1.8 c mol (p^+) kg^{-1} (pedon 4) in surface and 0.9 c mol (p^+) kg^{-1} (pedon 4) to 1.9 c mol (p^+) kg^{-1} (pedon 3) in sub surface layers. Pedons 1, 5, 6, 7, 8, 11, 12 and 14 showed increasing trend with soil depth, while in the other pedons did not show a clear trend with depth**.**

The exchangeable sodium was higher in black soils varied from (1,7,9 and 12) varied from 0.7 c mol (p^+) kg^{-1} (pedon 9) to 0.81 c mol (p^+) kg^{-1} (pedon 12) in surface layers and 0.8 c mol (p^+) kg^{-1} (pedon 9) to 1.13 c mol (p^+) kg^{-1} (pedon 12) in sub surface layers. In the red soils pedons (8,10,11,13 and 14) the exchangeable sodium ranged from 0.1 c mol (p^+) kg^{-1} (pedon 10) to 0.14 c mol (p^+) kg^{-1} (pedon 8) in surface layers and 0.10 c mol (p^+) kg^{-1} (pedon 10) to 0.25 c mol (p^+) kg^{-1}(pedon 13) in sub surface layers. The red laterite soil pedons (2,3,4,5 and6) exchangeable sodium ranged from 0.10 c mol (p^+) kg^{-1} (pedon 2) to 0.14 c mol (p^+) kg^{-1} (pedon 3) in surface and 0.10 c mol (p^+) kg^{-1} (pedon 2) to 0.16 c mol (p^+) kg^{-1}(pedon 3) in sub surface layers. The exchangeable Na content increased with depth in pedons 1, 2, 5, 6. 7, 13 and 14. In the rest of the pedons, the depth wise distribution was irregular**.** The exchangeable potassium higher in black soils varied from 0.5 c mol (p^+) kg^{-1} (pedon 9) to 0.80 c mol (p^+) kg^{-1} (pedon 12) in surface layers and 0.2 c mol (p^+) kg^{-1} (pedon 9) to 1.6 c mol (p^+) kg^{-1} (pedon 1) in sub surface layers than in red soils pedons (0.3 c mol (p^+) kg^{-1} (pedon 11) to 0.96 c mol (p^+) kg^{-1} (pedon 13) in surface layers and 0.2 c mol (p^+) kg^{-1} (pedon 10) to 0.6 c mol (p^+) kg^{-1} (pedon 13) in sub surface layers and red laterite soil pedons (0.45 c mol (p^+) kg^{-1} (pedon 4) to 0.96 c mol (p^+) kg^{-1} (pedon 3) in surface and 0.37 c mol (p^+) kg^{-1} (pedon 3) to 0.87 c mol (p^+) kg^{-1}(pedon 6) in sub surface layers. The pedon 3, 10, 11, 12, 13 and 14 shows that the exchangeable K content decreased with depth and an increasing pattern was recorded in pedons 8. The remaining pedons showed inconsistent pattern with depth. The exchangeable cations were found to be low in red laterite soils when compared to red soils.

The exchangeable bases in the black and red soil pedons were in order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it is evident that Ca^{+2} shows the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility. These results are in conformity with findings of Thangasamy *et al.*, (2005) [22]. The exchangeable cations of red laterite soils (pedons 6 to 13), the exchangeable bases were in order $Ca^{+2} > Mg^{+2} > K^{+} > Na^{+}$. Low exchangeable Na and K percentage was noticed in all the pedons as the exchange complex was dominated by divalent cations like Ca and Mg. The BS was higher in black soil pedons ranged from 75.0 per cent (Pedon 7) to 87.4 per cent (Pedon 9) in surface layers and 60.69 per cent (Pedon 9) to 87.40 per cent (Pedon 9) in sub surface layers. This could be due to the dominance of smectitic type of clays and moderate to strongly alkaline reaction. The high CEC of black soils was attributed to the smectitic clay mineralogy (Pal and Deshpande, 1987) [10]. These results were in accordance with the findings of Singh and Agarwal (2005) [20] and Gabhane *et al. (*2006) [28].

The BSP in red soils pedons was low to high and ranged from 62.50 per cent (Pedon 10) to 85.09 per cent (Pedon 11) in surface layers and 58.36 per cent (Pedon 8) to 95.52 per cent (Pedon 13) in sub surface layers might be due to either mixed or Illitic mineralogy in clay fraction. The BSP was low to medium in red laterite soil pedons ranged from 28.66 per cent (Pedon 6) to 53.48 per cent (Pedon 4) in surface and 21.17 per cent (Pedon 4) to 49.25 per cent (Pedon 2) in sub surface layers might be due to kaolinite mineralogy in clay fraction and moderately acidic to slightly acidic reaction. An increasing trend with increased depth was noticed in pedons 10, while a reverse trend was observed in Pedon 2, 4 and 9. The base saturation increased up to certain depth and then decreased in Pedon 5, 6, 8, 11 and 12. Other pedons did not exhibit any regular pattern of distribution. These results were in accordance with the findings of Singh and Agarwal (2005) [20] and Gabhane *et al. (*2006) [28].

CEC / clay ratio and mineralogy

The dominance of smectite type clay was also confirmed by the CEC / clay ratio (Table 4). The CEC /clay ratios of these black soils were high (0.58 to 0.86). It indicates the presence of smectitic type of clay minerals. Similar type of clay mineralogy in black soils was reported by Rudramurthy *et al.* (1997) [15], Ratnam *et al.* (2001) [13], Kadao *et al.* (2003) [6], Nayak *et al.* (2006) [8] and Balapande *et al.* (2007) [2]. The black soils (1, 7, 9 and 12) were formed at lower topographic positions (nearly level plains to gently sloping). The soluble weathering products including finer soil constituents, calcium carbonate and basic cations and eroded products from surrounding slopes had moved laterally and vertically down the slope and accumulated at the plain topography. Because of the slow permeability, low hydraulic conductivity and restricted drainage of the black soils formed at lower topography these constituents were accumulating in the profile and not leached / removed out of the profile. Because of the semi-arid type of climate, the ionic environment was concentrated by basic cations and the base saturation was very high (60.69 to 87.40 per cent). At the same time there was precipitation and deposition of calcium carbonate resulted either pedogenically or lithogenically. The texture of these soils was very heavy (clay textural class). Because of these conditions, the soil reaction was moderately to strongly alkaline (Pedon 1, 9, and 12). Thus, the soil environment had created a favourable pathway for the synthesis of smectite type of clay minerals. Formation of smectite took place under such congenial conditions in black soils of Karanataka (Rudramurthy *et al.*, 1997) [15].

Table 4: Physico-chemical characteristics Sugarcane growing soil pedons of the Medak district

Ped on	Location	Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (g kg^{-1})	Exchangeable Cations (c mol (p+) kg^{-1})				Total Ex. Bases	BS (%)	CEC (Cmol (p+) kg^{-1})	Free $CaCO_3$ (%)	ESP (%)	SAR	CEC/ Clay ratio
							Ca	Mg	Na	K							
Sadasivpet division																	
1	Aroor	Ap	0-25	8.1	0.24	7.5	18.6	11.6	0.55	1.70	32.45	80.32	40.4	5.6	1.36	0.11	0.68
		BA	25-52	8.2	0.28	5.4	21.4	12.4	0.66	1.52	35.96	84.61	42.5	7.4	1.55	0.13	0.68
		Bss1	52-79	8.3	0.33	5.1	22.4	12.5	0.73	1.53	37.13	78.83	47.1	8.3	1.55	0.14	0.74
		Bss2	79-115	7.9	0.33	3.7	22.1	12.8	0.75	1.55	37.25	77.28	48.2	9.3	1.56	0.14	0.75
		Bss3	115-155	8.5	0.34	1.7	22.4	13.1	0.81	1.50	37.81	76.69	49.3	11.6	1.64	0.15	0.81
		C	155+	Mixed with calcareous murram													
Zaheerabad division																	
2	Paidigumma l	Ap	0-16	6.0	0.17	4.9	2.2	1.3	0.1	0.81	4.41	50.11	8.8	-	1.14	0.48	0.17
		Bt1	16-43	5.9	0.13	3.6	2.0	1.7	0.1	0.78	4.58	49.25	9.3	-	1.08	0.46	0.16
		Bt2	45-68	6.4	0.11	2.2	1.5	1.3	0.1	1.17	4.07	39.90	10.2	-	0.98	0.80	0.18
		C	67+	Weathered Laterite hard pan													
3	Burdipad	Ap	0-16	5.8	0.10	5.5	2.0	1.5	0.14	0.96	4.60	41.07	11.2	-	1.25	0.58	0.46
		Bt1	16-38	6.4	0.10	4.3	2.4	1.9	0.15	0.86	5.31	43.88	12.1	-	1.24	0.47	0.31
		Bt2	38-70	6.3	0.11	2.2	2.7	1.3	0.16	0.57	4.73	35.83	13.2	-	1.21	0.31	0.32
		Bt3	70-95	6.0	0.10	2.6	2.8	1.2	0.15	0.37	4.52	32.06	14.1	-	1.06	0.20	0.34
		C	95+	Weathered Laterite hard pan													
4	Kuppanagar	Ap	0-14	5.6	0.08	5.7	2.4	1.8	0.11	0.45	4.76	53.48	8.9	-	1.24	0.25	0.22
		Bt1	14-30	6.1	0.09	4.9	2.2	1.2	0.16	0.69	4.25	41.67	10.2	-	1.57	0.41	0.20
		Bt1	30-50	6.4	0.08	2.7	2.0	1.2	0.15	0.65	4.00	25.81	15.5	-	0.97	0.40	0.26
		Bt2	50-81	6.5	0.09	2.6	1.7	0.9	0.12	0.54	3.26	21.17	15.4	-	0.78	0.37	0.29
		C	81+	Weathered Laterite hard pan													
5	Basanthpur	Ap	0-20	5.1	0.07	5.5	1.2	0.9	0.10	0.66	2.78	36.10	7.7	-	1.30	0.45	0.22
		Bt1	20-38	5.6	0.08	3.6	1.5	1.0	0.11	0.80	3.41	41.59	8.2	-	1.34	0.57	0.22
		Bt2	38-56	6.1	0.10	3.1	2.4	1.2	0.11	0.72	4.43	47.63	9.3	-	1.18	0.42	0.23

		Bt3	56-70	6.1	0.12	3.0	2.5	1.3	0.12	0.69	4.61	38.10	12.1	-	0.99	0.39	0.35
		C	70+	Hard lithic contact which roots cannot penetrated													
6	Kothur	Ap	0-15	5.4	0.06	4.9	2.0	1.1	0.10	0.85	4.05	35.21	11.5	-	0.87	0.31	0.32
		Bt1	15-45	5.9	0.11	2.7	2.4	1.6	0.10	0.77	4.87	36.07	13.5	-	0.74	0.43	0.24
		Bt2	45-75	6.3	0.09	2.5	2.9	1.8	0.15	0.87	5.72	39.18	14.6	-	1.03	0.45	0.24
		Bt3	75-105	6.5	0.09	1.5	3.0	1.8	0.15	0.65	5.60	38.10	14.7	-	1.02	0.33	0.25
		C	105+	Hard lithic contact which roots cannot penetrated													
7	Budera	Ap	0-14	6.5	0.21	6.6	11.4	6.0	0.14	0.76	18.30	75.00	24.4	2.8	0.57	0.04	0.63
		Bw1	14-41	6.8	0.26	4.5	12.2	6.0	0.15	0.52	18.87	66.68	28.3	3.2	0.53	0.04	0.71
		Bwss1	41-58	7.0	0.29	5.0	13.1	6.2	0.15	0.51	19.96	66.98	29.8	3.9	0.50	0.04	0.80
		Bwss2	58-79	6.7	0.31	3.5	13.2	6.4	0.20	0.55	20.35	81.08	25.1	4.7	0.80	0.05	0.64
		BC	79-100	7.0	0.34	2.4	13.3	6.5	0.21	0.55	20.56	83.92	24.5	4.7	0.86	0.05	0.58
Sangareddy division																	
8	Mamdipally	Ap	0-15	6.6	0.19	5.3	6.5	3.9	0.14	0.20	10.74	74.58	14.4	3.2	0.97	0.05	0.73
		Bt1	15-40	6.8	0.15	2.7	6.8	3.8	0.13	0.30	11.03	58.36	18.9	4.6	0.69	0.04	0.71
		Bt2	40-65	7.1	0.16	2.3	8.8	4.1	0.20	0.34	13.44	68.57	19.6	5.2	1.02	0.06	0.66
		Bt3	65-95	7.3	0.12	2.1	7.5	4.9	0.20	0.35	12.95	64.43	20.1	5.5	1.00	0.06	0.62
		C	95+ Weathered gneiss														
Jogipet division																	
9	Andole	Ap	0-25	8.2	0.21	7.9	24.6	8.2	0.7	0.5	34.00	87.40	38.9	5.5	1.80	0.13	0.72
		BA	25-65	8.2	0.29	5.1	21.3	11.6	0.8	0.3	34.00	87.40	38.9	6.3	2.06	0.15	0.68
		Bss1	55-85	8.4	0.28	4.5	20.4	10.9	0.9	0.3	32.50	79.08	41.1	6.5	2.19	0.18	0.70
		Bss2	85-117	8.4	0.34	3.3	19.1	11.3	1.2	0.3	31.90	75.06	42.5	6.6	2.82	0.24	0.69
		Bss3	117-145	8.9	0.36	3.3	18.3	12.3	1.0	0.2	31.80	70.51	45.1	7.8	2.22	0.20	0.71
		Bss4	145-178	9.2	0. 40	2.9	18.1	8.4	1.3	0.3	28.10	60.69	46.3	9.9	2.81	0.28	0.75
Medak division																	
10	Kaudloor	Ap	0-11	6.5	0.19	4.3	3.1	2.0	0.1	0.3	5.50	62.50	7.8	1.3	1.14	0.05	0.59
		A21	22-Nov	6.3	0.16	3.5	5.5	3.7	0.2	0.2	9.60	67.13	11.3	1.4	1.40	0.07	0.77
		A22	22-41	6.0	0.11	2.5	7.2	2.9	0.1	0.2	10.4	68.87	11.1	1.4	0.66	0.03	0.71
		C	41+	Weathered gneiss													
Narsapur division																	
11	Antharam	Ap	0-18	6.9	0.20	5.9	6.5	4.9	0.1	0.3	13.70	85.09	16.1	3.1	0.62	0.03	0.71
		Bt1	18-35	7.1	0.22	4.6	7.2	5.1	0.15	0.3	12.95	79.45	16.3	3.8	0.92	0.05	0.64
		Bt2	35-50	7.3	0.26	4.5	7.4	5.3	0.14	0.2	14.54	94.42	13.4	4.3	0.91	0.04	0.43
		Bt3	50-90	7.5	0.29	2.4	9.5	6.8	0.19	0.2	9.89	71.67	13.8	4.8	1.38	0.05	0.48
		C	90+	Weathered granite- gneiss													
Narayankhed division																	
12	Pulkurty	Ap	0-27	7.9	0.16	8.4	25.2	16.3	0.81	0.80	43.11	76.71	56.2	7.8	1.44	0.14	0.79
		BA	27-55	8.1	0.18	6.7	26.6	18.5	0.86	0.60	46.56	82.85	60.2	8.4	1.43	0.14	0.82
		Bss1	55-87	8.0	0.20	4.8	29.2	19.6	0.89	0.60	50.29	83.54	64.7	8.6	1.38	0.14	0.86
		Bss2	88-124	8.2	0.22	4.6	30.5	20.1	1.11	0.60	52.31	80.85	64.2	10.1	1.73	0.17	0.85
		Bss3	124-150	8.4	0.23	3.6	30.9	20.6	1.13	0.50	53.13	82.76	65.2	11.2	1.73	0.18	0.86
13	Mudguntal thanda	Ap	0-13	6.8	0.22	6.6	7.6	2.3	0.12	0.96	10.98	83.18	13.2	1.8	0.91	0.04	0.65
		Bt1	13-25	6.7	0.19	4.9	8.2	3.6	0.15	0.60	12.55	95.08	14.3	3.2	1.05	0.05	0.52
		Bt2	25-46	6.6	0.16	4.1	8.3	4.6	0.21	0.55	13.66	95.52	16.5	3.4	1.27	0.06	0.55
		Bt2	46-65	6.5	0.13	3.9	8.6	4.8	0.25	0.30	13.95	84.55	16.9	5.1	1.48	0.08	0.52
		C	65+	Weathered granite													
Dubbaka division																	
14	Ramakkapet	Ap	0-12	6.8	0.24	6.8	7.6	2.5	0.11	0.25	10.46	79.24	13.2	2.1	0.83	0.04	0.65
		Bt1	Dec-35	7.1	0.21	5.2	8.0	2.7	0.13	0.36	11.19	63.58	17.6	2.8	0.74	0.04	0.76
		Bt2	35-46	7.2	0.19	4.5	8.7	2.9	0.15	0.36	12.11	77.63	15.6	3.2	0.96	0.05	0.61
		Bt3	46-70	7.4	0.21	2.9	8.7	3.1	0.15	0.28	12.23	90.59	13.5	4.5	1.11	0.05	0.50
		C	70+	Weathered granite- gneiss													

The CEC /clay ratios of these red soils (pedon 8, 10, 11, 13 and 14) were also medium to high in range (0.43 to 0.77). The CEC / clay ratios of these red soils also indicated the mixed or illitic mineralogy, where the presence of secondary clay minerals such as kaolinite, tillite and montmorillonite more or less in equal range. Similar findings were were reported by Sarkar *et al.* (2001) [16], Thangasamy *et al.* (2004) [29] and Singh and Agarwal (2005) [20] in the clay fraction of red soils / Alfisols. The illite might have been inherited from the parent material (Mall and Mishra, 2000; Singh and Sawhney, 2006) [7, 21]. The geology of the study area was granitic gneiss complex. Granitic gneiss was an acid rock containing some mica as essential mineral. Transformation / alteration of mica (primary mineral) of parent rock into illite (secondary mineral) were possible (Sehgal *et al.*, 1974) [19].

The CEC /clay ratios of these red laterite soils (pedon 2,3,4,5 and 6) were low to in range (0.16 to 0.46). The CEC / clay ratios of these red laterite soils also indicated the presence secondary clay mineral such as kaolinite. Direct conversion of mica to kaolinite might be one of the causes for the synthesis of kaolinite (Singh and Agarwal, 2005) [20]. According to Verma *et al.* (1994) [24], acid leaching and tropical climate were favourable for the formation of kaolinite. The kaolinite clays might have been formed in the earlier tropical humid climate and preserved or persisted in the present semi-arid climate (Agarwal and Singh, 1995) [1]. Sehgal (1996) [18] suggested the intensity or the stage of weathering of soils based on the clay minerals present in the soil clay fraction. According the weathering index of clay size minerals (Jackson, 1964) [5], montmorillonite was 9th while kaolinite was 10th stage of weathering. Black soils (dominated by montmorillonite type of minerals) were grouped under intermediate weathering stage, while, red laterite soils because of the significant proportion of kaolinite could be grouped under advanced weathering stage according to the stages in weathering of soil minerals as suggested by Sehgal (1996) [18]. Black soils were having relatively high CEC/clay ratios followed by red and red laterite soils. Hence, the black soils were comparatively less weathered than red and red laterite soils. Similar conclusions were drawn by Satyavathi and Reddy (2003) [17] and Singh and Agarwal (2005) [20].

Conclusion

The dominance of smectite type clay was also confirmed by the CEC / clay ratio. The CEC /clay ratios of these black soils were high (0.58 to 0.86). It indicates the presence of smectitic type of clay minerals. The CEC /clay ratios of these red soils were medium to high in range (0.43 to 0.77) which is indicates the mixed or illitic mineralogy, where the presence of secondary clay minerals such as kaolinite, illite and montmorillonite are more or less in equal range. The CEC /clay ratios of the red laterite soils were low to medium in range (0.16 to 0.46), indicating the presence of secondary clay mineral such as kaolinite. Direct conversion of mica to kaolinite might be one of the causes for the synthesis of kaolinite.

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