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Characterization, classification and evaluation of soils in cotton growing region of Beed District, Maharashtra

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Abstract
Eight representative pedon from different physiographic unit of Beed district were characterized and classified. The cotton growing soils of Beed district are shallow to deep, black (10 YR 2.5/1) to light yellowish brown (10 YR 6/4) in colour, granular to angular blocky in structure, loam to clay in texture. The bulk density of these soils varied from 1.24 to 1.97 Mgm^{-3}, PAWC varied from 82.25 to 301.71 mm and saturated hydraulic conductivity varied from 1.30 to 22.7 cm hr^{-1}. The soils are slightly to moderately alkaline in nature (7.2 to 7.8), the electrical conductivity varied from 0.1 to 0.5 dSm^{-1}. Low to high in organic carbon (0.4 to 0.9) whereas low to very high in calcium carbonate content (4.56 to 23.19 %) and high in cation exchange capacity (36.07 to 80.57 cmol (P^{+}) kg^{-1}). The calcium was the dominant cation fallowed by magnesium, sodium and potassium. The base saturation percent was 78.82 to 97.79 percent. The fertility status of cotton growing soils of Beed district was low to high. Taxonomically these soils were classified as Typic Ustorthents, Typic Haplustepts and Typic Haplusterts and Calcic Haplusterts. The soil-site suitability indicated that the Typic Ustorthents soils were marginally suitable were as Typic Haplustepts were moderately suitable and Typic Haplusterts soils were highly suitable for cotton crop.

Keywords: Soil classification, morphological, physical and chemical characteristic of soil, soil site suitability, cotton.

Introduction
Beed is one of the district of Maharashtra states which, belongs to sub-tropical region, with an average annual rainfall 670 mm. The soils of Beed are formed from weathering of Deccan basalt rock which is rich in Ca, Mg and carbonates but poor in N, P and K. Cotton, (*Gossypium spp.*) is the most important fiber and cash crop not only of India but also of the entire world, grown widely in the tropical and sub-tropical areas and requires uniformly high temperature varying between 21^0C and 30^0C. Cotton is commonly called "White Gold". Cotton (*Gossypium hirsutum*) is grown in varied pedo-edaphic agro-ecoregions of the country under different agro-management. The rainfed cotton is frequently grown mostly in shrink-swells of central India, southern states and Gujarat. These soils are generally productive, but difficult to manage. In Marathwada, cotton is grown predominantly as a rainfed crop in Vertisols (black or regur) and associated soils. These soils are characterized by dark gray to black in colour, high clay content, particularly of smectitic type, neutral to alkaline in reaction, high cation exchange capacity with exchangeable position dominated by Ca^{2+} and Mg^{2+} and in some cases by Na^{+}. The importance of soil survey and mapping for preparing an inventory of a region, the soil properties are used for evaluation of soil for different crop. The value of soil resource inventory for increasing food production and conservation of natural resources has been receiving significant importance not only for soil resource data base generated but also its quality (Eswaran and Gathrie, 1982) [3]. For the proper land resource management in this area, investigation on the land properties and their constraints is a prerequisite. A documentation of soil properties in systematic manner is one of the vital components in formulating effective land use planning programmed (Deshmukh and Bapat, 1993) [2]. Through the present investigation on soils resources of Beed district have been evaluated for land use planning.

Materials and Methods
Geographically Beed is in Maharashtra state. It is located between 18.26 to 19.26 N latitude and 74.54 to 76.57 E longitude. Total geographical area of Beed district is 10615 sq.kms. In the area received mean annual rainfall of 670 mm and mean maximum and mean minimum temperature are 33.1^0C and 18.5^0C respectively. The area has Ustic soil moisture regime, Hyperthermic temperature regime and length of growing period is 145 days. Eight representative pedons were selected from different physiographic unit of the study area.

Morphological study of the soil was described as per soil survey manual the soil samples were collected horizon wise, air dried ground and sieved using 2 mm sieve. Particle size analysis of the sample was carried out by international pipette method (Jackson 1979) [6]. Water retention characteristics were determined by pressure plate apparatus and PAWC determined by expression suggested by Gardner *et al.* (1984). Bulk density of the soil was determined by clod coating technique (Black 1965) [1]. EC, pH, organic carbon, $CaCO_3$, exchangeable cations and cation exchange capacity (CEC) were determined by standard procedure (Jackson, 1973) [6]. The soils were classified as per soil Taxonomy (Soil Survey Staff, 1994). Soil site suitability were made as per the criteria suggested by Sys et.al (1991) [11] and modified by NBSS & LUP (1994) [9]. In addition, suitability classes were also derived based on the actual yield as suggested by FAO (1983) [4].

Results and Discussion

Morphological characteristics

The morphological characteristics of soils were presented in table 1. The depth of the soil ranged from very shallow (18 cm) to deep (150 cm) and which was gradually decreases with increasing elevation of the soil profile. The shallow soil were found in elevated area were as deep soils are in low lying area black (10 YR 2.5/1) to light yellowish brown (10 YR 6/4) in colour. The soil structure of the pedon located on elevated area (P_2) are granular in structure whereas pedon located on gently sloping (P_1, P_3 & P_6) are sub angular blocky and low lying area (P_4, P_5, P_7 & P_8) were sub angular blocky to angular blocky in structure.

Table 1: Morphological properties of cotton growing soils of Beed district

Horizon	Depth (cm)	Boundary	Matrix colour	Texture	Structure	Consistency	Pores	Roots	Effervescence
Pedon 1 Shri. Narayan shrihari kendre, Village-umrai, Tq.Ambajogai, Dist. Beed *(Typic Haplustepts)*									
Ap	0-20	cs	10YR3/2	c	m1sbk	sh,fr,ss, sp	vfm, fm	vfm, fm	e
Bw_1	20-40	cs	10YR3/2	c	m2sbk	h,fi,vs, vp	vfm, fm	vfm, fm	e
Cr	40-60	--							
Pedon 2 Shri. Bhivaji Shankar Kakade, Village-Bansarola, Tq.Kaij, Dist. Beed *(Typic Ustorthents)*									
Ap	0-18	cs	7.5YR4/4	c	vf,o,gr	l, ns, np	vfm,fm	vfm, fm	e
Cr	18-60	--							
Pedon 3 Shri. Vijay joshi, Village-Majalgaon, Tq.Majalgoan, Dist. Beed*(Typic Haplustepts)*									
Ap	0-25	cs	10YR3/3	c	f1sbk	l, fr,ss, sp	vfm,fm	vfm,fm	ev
Bw_1	25-42	ai	10YR2.5/4	c	f1sbk	l,fr,ss, sp	vfm,fm	vfm, fm	ev
Ck	42-80	ai	10YR6/4	l	f1sbk	l,fr,ns, np	vfm,fm	vfm, fm	ev
Pedon 4 Shri. Pandurang Gangaram Shinde, Village-Laul, Tq.Majalgoan, Dist. Beed *(Typic Haplusterts)*									
Ap	0-20	cs	10YR3/3	sil	m1sbk	h,fr,vs, vp	vfm, fm	vfm, fm	es
Bw_1	20-40	cs	10YR3/2	c	m1sbk	h,fr.vsvp	vfm, fm	vfm, fm	es
Bw_2	40-60	cs	10YR4/4	sic	m1sbk	h, fr, vsvp	vfm, fm	fm	ev
Bss_1	60-90	cs	10YR4/4	sic	m1sbk	h, fr, vsvp	fm, vfm	fm	ev
Bss_2	90-110	cs	10YR4/4	c	m1sbk	h,fr,vs,vp	vfm,fm	ff,cf	ev
Pedon 5 Shri. Vishanurao Ramchandra Sawant, Village- Kuppa, Tq.Wadwani, Dist. Beed *(Typic Haplusterts)*									
Ap	0-22	cs	10YR2.5/1	c	m1sbk	h,fr,vs,vp	vff,fm	vfm,fm	es
Bw_1	22-40	cs	10YR2.5/2	c	m1sbk	h,fr,vs, vp	vff,fm	vfm, fm	es
Bw_2	40-60	cs	10YR2.5/1	c	m2abk	h,fi, vs, vp	vfm, fm	ff,cf	es
Bss_1	60-85	cs	10YR3/3	c	m1sbk	h,fr,vs, vp	vfm,fm	ff, cf	es
Bss_2	85-110	cs	10YR5/4	c	m1sbk	s,fr, ss,ss	vfm,fm	ff, cf	ev
Ck	110-150	--	10YR6/4	scl	m1sbk	s,fr,ss,sp	vfm,fm	cf	ev
Pedon 6 Shri. Sanjay Babasaheb Mane, Village-Gundewadi, Tq. Beed, Dist. Beed *(Typic Haplustepts)*									
Ap	0-23	cs	10YR3/2	sic	m2sbk	h,fr,vs, vp	vfm, fm	vfm, fm	e
Bw_1	23-43	cs	10YR3/1	sic	m2sbk	h, fr, vs, vp	Vfm	vfm, fm	e
Bw_2	43-80	cs	10YR3/1	sic	m2sbk	h, fr, vs, vp	vff, cf	fm	es
Cr	80-110	c	10YR2/6	cl	m2gr	h,fi,ns,np	cm	cm	ev
Pedon 7 Shri Prakash Sanjairao Hatale, Village-Dhanora, Tq.Beed, Dist. Beed *(Calcic Haplusterts)*									
Ap	0-22	cs	10YR3/3	c	m1abk	h,fr,vsvp	vfm, fm	vfm, fm	es
Bw_1	22-42	cs	10YR3/2	c	m1abk	h,fr,vsvp	vfm, fm	vfm, fm	ev
Bw_2	42-60	cs	10YR3/2	c	m1abk	h,fr,vs, vp	vfm, fm	vfm, vfm	ev
Bss	60-90	cs	10YR3/2	c	m1abk	h,fi,vs, vp	vfm, fm	ff	ev
Cr	90-110	--	10YR5/3	l	gr	i, fi, ns, np	cf	cm	ev
Pedon 8 Sudam Namdev Sarode,village Chobe Nimgoan, Tq.Ashti, Dist Beed *(Typic Haplusterts)*									
Ap	0-22	cs	10YR3/3	c	m1sbk	h, fr,vs,vp	vfm,fm	vfm,fm	ev
Bw1	22-40	cs	10YR4/3	c	m1sbk	h,fr,vs,vp	vfm	vfm,fm	ev
Bw2	40-65	cs	10YR3/3	c	m1sbk	h,fr,vs,vp	vfm	ff,cfm	ev
Bss1	65-90	cs	10YR3/3	c	m1abk	h,fi,vs,vp	vfm	ff,cf	ev
Bss2	90-120	cs	10YR4/3	c	m1sbk	h,fr,vs,vp	vfm	ff,cf	ev
Bss3	120-150	--	10YR4/4	c	m1sbk	h,fr,ss,sp	vfmfm	ffcf	ev

Physical properties

Physical properties of soils were presented in table 2. The soil situated in elevated area P_2 are sandy clay loam in texture and high amount of coarse fragments varies from 2.05 to 49.70 per cent. The soils developed on sloping land P_1, P_3 and P_6 are clay loam to clayey in texture where as pedon located on low lying area P_4, P_5, P_7 & P_8 are clayey in texture. Topography and slope were found to affect particle size distribution. Bulk density of soil ranged from 1.24 to 1.97 Mgm^{-3}. The available water content (AWC) of the soil ranged from 6.9 to 22 per

cent followed the trend of clay distribution. The maximum available water content at soils of Typic Haplusterts followed by Typic Haplustepts and Typic Ustorthents (Table 2). The capacity of soil to store moisture for plant use is largely a function of their clay content, depth of soil and mineralogy of soil. Therefore a significant positive linear correlation of soil depth with PAWC (r = 0.83) and clay content with PAWC (r = 0.74) were obtained. This suggests that the soil depth, texture and PAWC are interrelated to each other and in turn influence the crop yield. The saturated hydraulic conductivity of soil varies from 1.30 to 22.7 cm hr^{-1}, this variation attributed to textural variation. This variation may be attributed to application of irrigation water; similar observation was reported by Vaidya *et al*. (2007) [21].

Table 2: Physical properties of cotton growing soils of Beed district

Horizons	Depth (cm)	Coarse Fragment (%)	BD (Mgm^{-3})	HC (cm hr^{1})	Particle size analysis (%)			Moisture retention (%)		AWC (%)	PAWC (%)
					sand	silt	clay	33kPa	1500kPa		
Pedon 1 Shri. Narayan shrihari kendre, Village-umrai, Tq.Ambajogai, Dist. Beed *(Typic Haplustepts)*											
Ap	0-20	3.50	1.41	7.3	13.2	36.5	50.3	21.2	9.3	11.9	82.25
Bw_1	20-40	2.63	1.59	8.3	33.1	23.5	43.4	18.8	10.7	8.1	
Cr	40-60	49.70	1.80	18.8	37.6	35.2	27.2	17.9	11	6.9	
Pedon 2 Shri. Bhivaji Shankar Kakade, Village-Bansarola, Tq.Kaij, Dist. Beed *(Typic Ustorthents)*											
Ap	0-18	5.80	1.24	8.4	14.7	37.1	48.2	22.03	10.4	11.6	87.71
Cr	18-60	48.03	1.97	17.7	61.2	24.6	14.2	19.4	12.3	7.1	
Pedon 3 Shri. Vijay joshi, Village-Majalgaon, Tq.Majalgoan, Dist. Beed*(Typic Haplustepts)*											
Ap	0-25	3.40	1.57	8.7	12.9	37.2	49.9	10.6	8.4	12.2	136.18
Bw_1	25-42	2.55	1.52	9.8	12.3	36.8	50.9	20.9	8.1	12.8	
Ck	42-80	16.21	1.74	16.5	46.4	36.2	17.4	18.6	10.5	8.1	
Pedon 4 Shri. Pandurang Gangaram Shinde, Village-Laul, Tq.Majalgoan, Dist. Beed *(Typic Haplusterts)*											
Ap	0-20	2.43	1.53	4.1	9.7	46.9	43.4	41.8	25.9	15.9	234.90
Bw_1	20-40	2.61	1.62	3.9	10.3	39.1	50.6	42.3	26.0	16.3	
Bw_2	40-60	2.82	1.64	2.6	7.5	42.9	49.6	45.8	27.7	18.4	
Bss_1	60-90	4.50	1.74	2.4	4.4	44.9	50.7	50.1	30.7	19.4	
Bss_2	90-110	4.52	1.72	1.3	4.2	30.5	65.3	50.5	32.3	8.4	
Pedon 5 Shri. Vishanurao Ramchandra Sawant, Village- Kuppa, Tq.Wadwani, Dist. Beed *(Typic Haplusterts)*											
Ap	0-22	4.39	1.59	4.4	6.2	34.8	59	36.3	21.7	14.6	281.58
Bw_1	22-40	6.08	1.63	5.7	5.5	27.3	67.2	38.7	21.9	16.8	
Bw_2	40-60	6.12	1.67	6.1	5.9	32.7	61.4	42.5	23.1	19.4	
Bss_1	60-85	5.03	1.71	4.8	5.1	23.9	71	44.6	25.9	18.7	
Bss_2	85-110	5.08	1.71	4.7	3.3	26.1	70.6	44.9	26.1	18.8	
Pedon 6 Shri. Sanjay Babasaheb Mane, Village-Gundewadi, Tq. Beed, Dist. Beed *(Typic Haplustepts)*											
Ap	0-23	2.10	1.73	4.7	9.7	43.3	47	45.7	25.1	18.6	279.79
Bw_1	23-43	3.12	1.75	5.1	8.8	42.7	48.5	44.2	24.9	19.3	
Bw_2	43-80	2.05	1.75	5.4	9.1	42.8	48.1	44.8	26.6	18.3	
Cr	80-110	38.93	1.76	17.2	36.5	34.2	29.3	28.5	19.1	9.4	
Pedon 7 Shri Prakash Sanjairao Hatale, Village-Dhanora, Tq.Beed, Dist. Beed *(Calcic Haplusterts)*											
Ap	0-22	3.82	1.57	4.4	8	27.2	64.8	42.3	22.5	19.8	301.71
Bw_1	22-42	5.42	1.66	13.8	4.1	31.7	64.2	44	23.1	20.9	
Bw_2	42-60	4.98	1.82	13.7	3.9	32.2	63.9	43.7	23	20.7	
Bss	60-90	4.48	1.86	12.9	3	28.4	68.6	46.4	24.4	22	
Cr	90-110	39.92	1.46	22.7	43.5	35.9	20.6	27.1	18.3	8.8	
Pedon 8 Sudam Namdev Sarode,village Chobe Nimgoan, Tq.Ashti, Dist Beed *(Typic Haplusterts)*											
Ap	0-22	4.02	1.41	7.4	6.7	25.1	68.2	45.7	29.8	15.9	243.53
Bw_1	22-40	6.11	1.40	6.9	6.2	30.2	63.6	47.8	31.1	16.7	
Bw_2	40-65	5.49	1.39	6.8	5.7	29.67	64.63	47.6	31.3	16.3	
Bss_1	65-90	4.05	1.45	6.3	4.9	29.4	65.7	46.8	29.6	17.2	
Bss_2	90-120	3.98	1.43	6.3	4.7	28.6	66.7	47.8	30.5	17.3	
Bss_3	120-150	4.15	1.43	7.2	4.6	28.3	67.1	48	29.1	18.9	

Table 3: Chemical properties of cotton growing soils of Nanded district.

Horizons	Depth (cm)	pH	EC (dSm^{1})	OC (%)	$CaCO_3$ (%)	CEC ($cmol(P^{+})kg^{1}$)	Exchangeable Cations (cmol(P+)kg-1)				Sum of cations	B.S. (%)
							Ca^{++}	Mg^{++}	K^{+}	Na^{+}		
Pedon 1 Shri. Narayan shrihari kendre, Village-umrai, Tq.Ambajogai, Dist. Beed *(Typic Haplustepts)*												
Ap	0-20	7.5	0.4	0.7	9.2	53.28	36.02	11.8	0.39	1.17	49.38	92.68
Bw_1	20-40	7.3	0.4	0.8	14.65	54.51	26.40	14.2	0.18	1.10	41.88	78.82
Cr	40-60	7.5	0.3	0.4	23.19	40.02	23.05	12.4	0.21	1.20	36.86	92.10
Pedon 2 Shri. Bhivaji Shankar Kakade, Village-Bansarola, Tq.Kaij, Dist. Beed *(Typic Ustorthents)*												
Ap	0-18	7.4	0.3	0.8	11.55	50.22	30.0	13.5	0.42	1.21	46.03	91.65
Cr	18-60	7.5	0.1	0.4	22.12	41.54	17.6	12.8	0.17	1.40	35.17	84.66
Pedon 3 Shri. Vijay joshi, Village-Majalgaon, Tq.Majalgoan, Dist. Beed*(Typic Haplustepts)*												
Ap	0-25	7.4	0.2	0.6	4.56	43.08	26.9	10.9	0.40	1.27	39.47	91.62
Bw_1	25-42	7.3	0.3	0.5	13.65	51.82	25.8	19.3	0.32	1.14	46.56	89.84
Ck	**42-80**	**7.5**	**0.4**	**0.5**	**17.59**	**36.07**	**20.1**	**10.7**	**0.26**	**1.82**	**31.88**	**88.38**

Pedon 4 Shri. Pandurang Gangaram Shinde, Village-Laul, Tq. Majalgoan, Dist. Beed *(Typic Haplusterts)*												
Ap	0-20	7.2	0.5	0.9	6.15	57.81	32.5	21.4	0.52	1.2	55.62	96.21
Bw_1	20-40	7.4	0.5	0.9	8.12	55.52	32.1	10.6	0.43	1.10	53.23	92.07
Bw_2	40-60	7.4	0.4	0.8	8.55	59.03	31.8	20.2	0.49	1.09	53.58	90.76
Bss_1	60-90	7.5	0.5	0.8	10.25	66.92	39.7	22.5	0.25	1.39	63.84	95.39
Bss_2	90-110	7.5	0.5	0.8	16.34	80.57	37.8	18.3	0.21	1.48	78.58	97.53
Pedon 5 Shri. Vishanurao Ramchandra Sawant, Village- Kuppa, Tq.Wadwani, Dist. Beed *(Typic Haplusterts)*												
Ap	0-22	7.4	0.4	0.9	9.21	62.92	41.5	16.8	0.62	1.63	60.55	96.23
Bw_1	22-40	7.6	0.3	0.8	9.6	68.52	42.9	19.1	0.59	1.43	64.02	93.43
Bw_2	40-60	7.4	0.3	0.8	10.14	69.01	42.2	18.8	0.52	1.20	62.72	90.88
Bss_1	60-85	7.6	0.2	0.8	10.45	70.57	44.7	19.4	0.31	1.51	65.72	93.41
Bss_2	85-110	7.3	0.3	0.7	11.48	71.28	43.7	19.2	0.22	1.77	65.09	91.31
Ck	110-150	7.3	0.2	0.7	14.45	56.59	30.8	20.5	0.25	1.32	52.87	93.42
Pedon 6 Shri. Sanjay Babasaheb Mane, Village-Gundewadi, Tq. Beed, Dist. Beed *(Typic Haplustepts)*												
Ap	0-17	8.0	0.4	0.3	11.5	48.20	30.6	12.6	0.29	1.08	44.57	92.46
Ac	17-47	8.1	0.3	0.4	35.9	40.50	24.0	13.4	0.13	1.04	38.62	95.35
Cr	47-70	8.1	0.1	0.2	31.3	35.40	21.0	11.7	0.12	1.13	33.95	95.90
Pedon 7 Shri Prakash Sanjairao Hatale, Village-Dhanora, Tq.Beed, Dist. Beed *(Calcic Haplusterts)*												
Ap	0-22	7.4	0.4	0.9	10.54	63.52	37.80	22.09	0.71	1.52	62.12	97.79
Bw_1	22-42	7.5	0.4	0.7	11.84	60.82	32.50	21.82	0.69	1.49	56.05	92.89
Bw_2	42-60	7.5	0.3	0.7	13.54	59.91	33.02	22.82	0.67	1.45	57.96	96.74
Bss	60-90	7.5	0.3	0.5	15.62	62.03	35.35	20.96	0.25	1.47	58.03	93.55
Cr	90-110	7.5	0.2	0.4	16	36.90	19.67	10.02	0.29	1.98	32.14	87.10
Pedon 8 Sudam Namdev Sarode,village Chobe Nimgoan, Tq.Ashti, Dist Beed *(Typic Haplusterts)*												
Ap	0-22	7.3	0.3	0.8	7.89	63.98	38.07	22.28	0.61	1.60	62.56	97.78
Bw_1	22-40	7.4	0.3	0.8	8.51	60.15	33.81	21.23	0.60	1.45	57.09	94.91
Bw_2	40-65	7.4	0.2	0.8	10.25	59.87	32.73	22.06	0.58	1.41	56.78	94.83
Bss_1	65-90	7.5	0.3	0.7	11.36	60.72	35.36	21.92	0.24	1.40	58.92	97.03
Bss_2	90-120	7.5	0.2	0.6	11.54	59.72	37.26	18.05	0.23	1.42	56.96	95.04
Bss_3	120-150	7.4	0.3	0.4	13.81	60.58	37.09	17.84	0.29	1.92	57.14	94.32

Table 4: Soil classification of cotton growing soils of Beed district.

Sr. No.	Order	Sub Order	Great group	Subgroup	Family
1.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Clayloam, montmorillonitic, hyperthermic
2.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Sandy clay loam, montmorillonitic, hyperthermic
3.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Clay, montmorillonitic, hyperthermic
4.	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Loam, montmorillonitic, hyperthermic
5.	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Clay, montmorillonitic, hyperthermic
6.	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Silty loam, montmorillonitic, hyperthermic
7.	Vertisols	Usterts	Haplusterts	Calcic Haplusterts	Clay, montmorillonitic, hyperthermic
8.	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Clay, montmorillonitic, hyperthermic

Table 5: Degree and kind of major constraints, suitability and yield of cotton.

	Contents													
Pedon	**LGP**	**Slope**	**CF**	**Depth**	**Texture**	**Drainage**	**$CaCO_3$**	**OC**	**EC**	**pH**	**Suitability class**	**Yield (qha^{-1})**	**(%) yield to optimum**	**Suitability based on actual yield**
P_1	*	*	**	***	-	-	**	**	-	-	S2	14	58.33	S2
P_2	*	***	***	****	*	-	**	**	-	-	N1	9.6	40	S3
P_3	*	*	*	**	-	***	*	**	-	-	S2	14.2	59.16	S2
P_4	*	-	-	*	-	**	*	*	-	-	S2	22	91.66	S1
P_5	*	-	*	-	-	**	*	*	-	-	S2	23	95.83	S1
P_6	*	*	*	*	-	-	*	**	-	-	S2	13.8	57.5	S2
P_7	*	-	*	*	-	**	*	**	-	-	S2	22.8	95	S1
P_8	*	-	-	-	-	**	*	**	-	-	S2	21.8	90.83	S1

Chemical properties of soil

The pH data are presented in table 2. The soils are slightly to moderately alkaline in nature. The pH ranged from 7.2 to 7.83. The pH of the soil was decreased with increasing altitude. The surface soil layers were moderately in nature. This is due to leaching of appreciable amount of exchangeable bases. The $CaCO_3$ content in soils ranged from 4.56 to 23.19 per cent indicating soils are calcareous in nature. High $CaCO_3$ affects the physical and chemical properties of soil and which has a great influence on crop production under rainfed condition. These soils were low to high in organic carbon varied from 0.4 to 0.9 per cent and which was decreased with depth. The cation exchange capacity (CEC) ranged from 36.07 to 80.57 cmol(p+) kg^{-1}. The maximum cation exchange capacity in Calcic Haplusterts. The high CEC of black soil is attributed to the high amount of clay and semectitic clay mineralogy (Pal and Deshpande, 1987). The relationship of cation exchange capacity (CEC) with crop yield suggested that the yield of crop was influenced by the CEC of soil and it was positively correlation between CEC of soil and yield of cotton (r = 0.88). The exchangeable Ca^{++}, Mg^{++}, Na^{+} and K^{+} ranged between 17.6 to 44.7, 10.6 to 22.82, 0.88 to 1.98 and 0.17 to

0.71 cmol (p+) kg^{-1} respectively. The exchangeable sodium percent were < 5 indicating there is no sodicity.

Soil classification

The pedon located on elevated topography (P_2) does not have any diagnostic horizon and thus these soil are qualified as order Entisols and due to the presence of Ustic moisture regime soils were grouped into Ustorthents. At subgroup level, these soils classified as Typic Ustorthents because these soils do not key out for other subgroup. The pedon located on sloping topography (P_1, P_3 and P_6) having ochric epipedons followed by cambic sub-surface diagnostic horizons and hence, grouped under Inceptisols. Due to ustic moisture regime, these pedons qualify for ustepts suborder. These pedons do not have duripan horizon and hence are classified under Haplustepts great group. At subgroup level these soil classified as Typic Haplustepts. The pedon located on lower topographic position (P_4, P_5 P_7 & P_8) were deep to very deep black colour, clayey (>50%) and characterized by deep, wide cracks and well developed slickenside and pressure faces. Therefore, these soils were classified under the order Vertisols and due to presence of Ustic moisture regime soils are group into Haplusterts and subgroup Typic Haplusterts.

Soil site suitability evaluation

Soil site suitability evalution were presented in table 5 and it was carried out by using criteria suggested by NBSS and LUP, 1994. The soils of Typic Ustorthents (P_2) are currently not suitable; Typic Haplustepts (P_1, P_3 and P_6), Typic Haplusterts and Calcic Haplusterts (P_4, P_5, P_7 and P_8) were moderately suitable (S2) for cotton in Beed district. According to FAO 1983, the suitability based on optimum yield basis the soils of Typic Ustorthents (P_2) were marginally suitable and Typic Haplustepts (P_1, P_3 and P_6) were moderately suitable (S2) and Typic Haplusterts and Calcic Haplusterts (P_4, P_5, P_7 and P_8) were highly suitable (S1) for cotton crop.

This investigation clearly indicated that the productivity of very shallow soil (Typic Ustorthents) is very low comparatively than Typic Haplustepts and Typic Haplusterts. This may be attributed to limitation of the soil depth, clay content, PAWC and cation exchange capacity. This limitation may be improved by application of tank silt as suggested earlier (Vaidya and Dhawan, 2010) [20].

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