INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Characterization, Classification And Evaluation Of Chilli Growing Soils Of Khammam District, Andhra Pradesh

R. Sai Kumar
Department Of Soil Science And Agricultural Chemistry, College Of Agriculture
Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, (A.P.), India
Y. S. Satish Kumar
Department Of Soil Science And Agricultural Chemistry, College Of Agriculture
Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, (A.P.), India
Srinivas P
Department Of Soil Science And Agricultural Chemistry, College Of Agriculture
Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, (A.P.), India

Abstract:
Typical pedons representing major land forms of chilli growing soils in Khammam district of Andhra Pradesh were characterized, classified and assessed for their nutrient status. The depth of soils was moderately shallow to deep, yellowish brown to dark red in colour, sandy to clay in texture, slightly acidic to moderately alkaline, non-saline, low in organic carbon content and low to medium in cation exchange capacity. Soils are low to medium in available nitrogen and phosphorus, low to high in available potassium and high in available sulphur. However, the soils were deficient in DTPA-extractable Fe, sufficient in DTPA-extractable Zn, Cu and Mn. However the Entisolpedons did not show the presence of any diagnostic horizon. As per soil Taxonomy, Chintakani, Kusumanchiand Khammam rural, profiles were classified as Alfisols, Palvancha, Bhadrachalam, Chandrugonda and Wazeedu were classified as Inceptisols and Wyra, was classified as Vertisol.

Key words*: Alfisols, Chilli crop, Khammam, Soil Classification and Soil Taxonomy*

1.Introduction

Soil is the most important resource for agriculture and needs to be utilized precisely for sustainable crop production. The availability of land for agriculture has been reduced and is likely to touch the limit of 0.10 ha by 2025 (Sekhon and Velayutham, 2002). There is need to increase productivity of the soils to meet the requirement of increasing population.Characterization of soils gives detailed information about different soil properties and helps in determining the soil potential and identifying the production constraints. Once the constraints for production are identified, suitable management practices can be suggested to increase the productivity. Classification envisages in alleviating the problem, the knowledge of which is essential for utilizing the productivity of soils.

The soils of Chilli growing area Khammam district have been classified as red loams, red earths and black soils. The characterization and classification of these soils were not based on systematic analysis of soils and as per Soil Taxonomy. Hence, the present study was taken up to characterize and classify the chilli growing soils of Khammam district.

2.Materials and Methods

The area selected for the present study of the Khammam District of Andhra Pradesh has a total geographical area of 16, 029 Sq. km. The district is located between 16^{o} 45' and 18^{o}35' North Latitude and 79^{o}47' and 80^{o} 47' East Longitude. The climate of Khammam district is comparatively equitable and although it is very hot in May with mercury rising upto 52^{o}C. The temperature dips to 13^{o}C in winters during the months of December and January.

The annual precipitation is 1124 mm of which 90 percent is received during June to September. The principal crops of the district are paddy, jowar, and pulses under food crops and groundnut, chillies, cotton and tobacco under non-food crops. The area under chillies in Khammam district is around 26,000 hectares with an average yield of 3.6 t $ha^{-1.}$

These eight pedons were studied in detail and the morphological characteristics are presented in table 1. The detailed morphological description of these seven pedons was studied in the field as per the procedure outlined in Soil Survey Manual (Soil Survey Division Staff 2000). The horizon-wise soil samples were collected, processed and analysed for important physical,physico-chemical properties

and available nutrient status using standard analytical techniques (Piper 1950; Richards 1954; Jackson 1973; Watanabe and Olsen 1965; Lindsay and Norvell 1978). The soils were classified taxonomically (Soil Survey Staff 2003).

3.Results and Discussion

3.1.Morphological Properties

The morphometric characterisitcs of the pedons have been given in Table 1. The depth of soils was moderately shallow to deep. It varied from 65 cm in Palvancha to 105 cm in Wyra and Wazeedu.In the surface horizons, the boundary was clear smooth in all the profiles. It varied from clear smooth to clear wavy to diffuse wavy in other horizons.

The soil colour was yellowish red (Hue 10 YR to 2.5 YR) with Values between 3 and 5 and Chroma ranging from 1 to 6. The purity of colour decreased with depth. The soil colour appears to be the function of chemical and mineralogical composition as well as textural makes up of soils and conditioned by topographic position and moisture regime (Walia and Rao 1997). Soil texture varied from sandy loam to clay loam in surface horizons and sandy clay loam to clay loam to clay in sub- surface horizons. In surface horizon, sub angular blocky structure was observed in all the profiles. The structure was sub angular blocky to angular blocky in sub - surface horizons.

3.2.Physico-Chemical Characteristics

All the pedons were slightly acidic (6.62) to strongly alkaline (8.90) in reaction. This wide variation was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium. The KCl-pH values were lower than the water-pH values. All the pedons showed medium to high electrical conductivity with values ranging from 0.13 to 0.81dS m^{-1}, thereby indicating salinenature of the soil (Table 2).

The organic carbon content of these soils was found to be low, ranging from 0.21 to0. 71 % (Table 3). The organic carbon content decreased with depth in all the pedons. This is attributed to the addition of plant residues and farmyard manure to surface horizons. The low organic matter content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils (Nayaket al. 2002). The CEC in all the pedons estimated by ammonium acetate extract varied from 14.10 to 37.60cmol(p^{+})kg^{-1}soil which corresponds to clay content in the horizons, organic carbon content and also type of clay mineral present in these soils. Similar results were reported by Ramprakash and SeshagiriRao(2002).

3.3.Soil Classification

Based on morphological, physical, physico-chemical and chemical properties of the soils and the climate of the district, the profiles of chilli growing soils of Khammam district were classified upto family level (Table 4) as per the specification given by Soil Taxonomy (Soil Survey Staff,1998).The soils were classified into Alfisols, Inceptisols and Vertisols at order level. Bharathi (2008) reported Entisols, Inceptisols and Alfisols in the soils of oil palm growing area of Khammam district.Pedons 1,3 and 5 exhibited thin or thick and patchy cutans and also had an argillic (Bt) sub-surface diagnostic horizon. Hence, these two pedons were classified under order Alfisols. The pedons 1,3 and 5 showed the presence of argillic (Bt) sub-surface diagnostic horizon as evidenced by the fact that the illuvial horizon contained 1.2 times more clay than the eluvial horizon and also had base saturation more than 35% throughout the depth of the profile.

Pedons 2,4,6 and 8 which have cambic (Bw) sub-surface diagnostic horizon, were classified under Inceptisols. The two pedons 2,4,6 and 8 were grouped under Usteps at sub-order level due to ustic soil moisture regime and Haplustepts at great group level because these pedons did not have either duripan or calcic horizon and base satumation was more than 60% at a depth between 0.25 to 0.75 m from the surface. However, pedon 7 had vertic features like cracks of 3 to 5 mm wide to a depth of 35 cm and slickensides in the lower horizons. Due to the presence of these vertic characters, this pedon was classified as VerticHaplustepts (VaraprasadRao et al., 2008).It is an Ustert because this Vertisol, if not irrigated during the year, have cracks in normal years that are 5 mm or more wide, through a thickness of 25 cm or more with in 50 cm of the mineral soil surface, for 90 or more cumulative days per year.The soil temperature class is isohyperthermic for all the studied soils as they have a difference of less than 5°C between mean summer temperature and mean winter temperatures at a depth of 50 cm and a mean annual soil temperature of 22°C or higher.

3.4.Nutrient Status And Soil Fertility

Micronutrients: Soil fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. The available nitrogen content varied from 125 to 307 kg ha^{-1} (Table 3) throughout the depth. However, available nitrogen content was found to be maximum in surface horizons and decreased regularly with depth which is due to decreasing trend of organic carbon with depth and because cultivation of crops is mainly confined to the surface horizon (Rhizosphere) only and at regular interval the depleted nitrogen content is supplemented by the external addition of fertilizers during crop cultivation (Prasuna Rani et al. 1992).

The available phosphorus varied from 3.6 to 28.6 kg ha^{-1} in this district. However, the highest available phosphorus content was observed in the surface horizons and decreased with depth. The lower phosphorus content in sub-surface horizons could be attributed to the fixation of releasing phosphorus by clay minerals and oxides of iron and aluminium.

The available potassium content of soils varied from 118 to 319 kg ha^{1}. The highest available potassium content was observed in the surface horizons and showed more or less decreasing trend with depth. This might be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward trans-location of potassium from the lower depths along with the capillary rise of ground water.

Micronutrients: The DTPA extractable Znranged from 0.53 to 1.44 mg kg^{-1} soil in surface soils. Vertical distribution of Zn exhibited little variation with depth. Considering 0.6 mg kg^{1} as critical level (Lindsay and Norvell 1978) the surface soils are sufficient in Zn. While sub-surface soils are deficient in Zn. The relatively high content of available zinc in surface soils may be attributed to variable intensity of the pedogenic processes and more complexing with organic matter which, resulted in chelating of Zn (Vermaet al 2005). Similarly all the pedons were found to be sufficient in available copper (0.20 to 4.05 mg kg^{-1}) as all the values were well above the critical limit of 0.20 mg kg^{-1} proposed by Lindsay and Norvell (1978).The DTPA extractable Fe content varied from 1.64 to 19.40 mg kg^{-1} soil. According to critical limit of 4.5 mg kg^{-1} of Lindsay and Norvell (1978) the soils were low in available iron. Available Mn varied from 3.20 to 15.00 mg kg^{-1}soil and almost decreased with depth which might be due to higher biological activity and organic carbon in the surface horizons. The higher content of available Mn in surface soils was attributed to its chelation by organic compounds released during the decomposition of organic matter left after harvesting of the crop. These observations are in accordance with the findings of Vermaet al. (2005).

The micronutrient analysis of the Khammam districtindicated that the surface soils are sufficient while sub-surface soils are deficient in DTPA extractable zinc, deficient in Fe and sufficient in DTPA extractable Cu and Mn.

Location	Depth (cm)	Colour		Effervesence *	Structure **	Consistence #		
		Dry	Moist			Dry	Moist	Wet
Chintakani	0-15	Reddish brown 2.5YR 4/3	Dark reddish brown 2.5YR 3/3	se	f1 sbk	l	fr	so&po
	15-22	Reddish brown 2.5YR 4/4	Dark reddish brown 2.5 YR 5/6	se	f1 sbk	sh	fr	ss&po
	22-70+	Reddish brown 2.5YR 5/4	dark reddish brown 2.5 YR 3/4	se	m2sbk	sh	fr	ss&ps
Palvancha	0-20	Dark greyish brown 10YR5/1	Vey dark greyish brown 10YR3/2	me	m2 sbk	h	fi	ss&sp
	20-35	Dark greyish brown 10YR5/1	Vey dark greyish brown 10YR3/2	me	m2 abk	h	li	ss&sp
	35-65+	Dark greyish brown 10YR5/1	Vey dark greyish brown 10YR3/2	ve	m2 abk	sh	fi	s&p
Kusumanchi	0-15	Reddish brown 2.5YR4/3	Dark reddish brown 2.5YR3/3	me	f1 sbk	l	fr	so&po
	15-30	Reddish brown 2.5YR4/2	Dark reddish brown 2.5YR3/3	ve	m2 sbk	sh	fi	ss&po
	30-45	Reddish brown 2.5YR4/2	Dark reddish brown 2.5YR3/3	se	m2 sbk	sh	fi	s&p
	45-90+	Reddish brown 2.5YR4/2	Dark reddish brown 2.5YR3/3	me	f1 sbk	h	fi	s&p
Bhadrachalam	0-15	Dark brown 10YR 3/3	Very dark brown 10YR 2/2	–	f1 sbk	sh	fi	ss&sp
	15-35	Dark brown 10YR 3/3	Very dark brown 10YR 2/2	–	m2 abk	sh	fi	ss&sp
	35-55	Dark brown 10YR 3/3	Very dark brown 10YR 2/2	–	m2 abk	h	fi	s&p
	55-95+	Dark brown 10YR 3/3	Very dark brown 10YR 2/2	–	f1 abk	h	fi	s&p
Khammam rural	0-25	Reddish brown 5YR 4/3	Dark reddish brown 5YR 3/2	ve	f1 sbk	l	fr	so&po
	25-35	Reddish brown5YR4/4	Dark reddish brown 5YR 3/2	ve	f2sbk	sh	fr	ss&po
	35-75+	Reddish grey5YR5/2	Reddish brown 5YR4/4	ve	m2 sbk	sh	fi	ss&ps

Location	Depth (cm)	Dry	Moist	Effervesence *	Structure **	Dry	Moist	Wet
Chandrugonda	0-15	Dark grey 10YR 4/1	Very dark grey 10YR 3/1	se	m1 sbk	h	fi	ss&ps
	15-33	Dark grey 10YR 4/1	Very dark grey 10YR 3/1	me	m2 abk	h	fi	ss&ps
	30-55	Dark grey 10YR 4/1	Very dark grey 10YR 3/1	se	f2 abk	sh	fi	s&p
	55-85+	Dark grey 10YR 4/1	Very dark grey 10YR 3/1	se	f3 abk	sh	fi	s&p
Wyra	0-15	Very dark greyish brown10YR3/2	Very dark grey10YR3/1	ve	m1 sbk	h	fi	ss&ps
	15-33	Very dark greyish brown10YR3/2	Very dark grey10YR3/1	ve	m1 abk	h	fi	ss&ps
	33-65	Very dark greyish brown10YR3/2	Very dark grey10YR3/1	ve	m2 abk	sh	fi	ss&ps
	65-105	Dark greyish brown10YR4/2	Very dark grey brown10YR3/2	ve	m2abk	sh	fi	s&p
Wazeedu	0-30	Dark greyish brown 10YR 4/2	Very dark greyish brown10YR3/2	se	m1 sbk	h	fi	ss&ps
	30-63	Dark greyish brown 10YR 4/2	Very dark greyish brown10YR3/2	se	m2 abk	h	fi	ss&ps
	63-105	Dark greyish brown 10YR 4/2	Very dark greyish brown10YR3/2	–	f2 abk	sh	fi	s&p

Table 1: Morphological Properties Of Soils

Note: *Effervesence;
Se- Slightly Effervesence,
Me- Medium Effervesence,
Ve- Violent Effervescence; Consistence;
L- Loose,
Sh- Slightly Hard,
H- Hard,
Vh- Very Hard;
So-Nonsticky,
Ss- Slightly Sticky,
S-Sticky,
Vs- Very Sticky;
Po-Non Plastic,
Sp- Slightly Plastic,
P- Plastic,
Vp- Very Plastic # Consistence;
L- Loose,
Sh- Slightly Hard,
H- Hard,
Vh- Very Hard;
So Nonsticky,
Ss- Slightly Sticky,
S-Sticky,
Vs- Very Sticky;
Po-Non Plastic,
Sp- Slightly Plastic,
P- Plastic,
Vp- Very Plastic.

Location	Depth (cm)	pH (1:2.5)	EC (dS m^{-1})	Exchangeable bases(cmol(p^+)kg^{-1})				CEC (cmol(p^+) kg^{-1})	ESP (%)	Base Saturation (%)
				Ca^{2+}	Mg^{2+}	Na^+	K^+			
Chintakani	0-15	7.01	0.19	16.0	4.0	0.6	0.3	29.50	2.03	71
	15-22	6.62	0.34	13.8	4.2	0.4	0.3	20.40	1.96	91
	22-70+	6.86	0.18	12.0	3.5	0.3	0.1	19.90	1.50	80
Palvancha	0-20	8.00	0.14	16.3	6.3	3.6	0.8	33.20	10.84	81
	20-35	7.45	0.23	11.0	5.6	3.2	1.1	31.10	10.28	67
	35-65+	7.95	0.19	18.4	5.6	3.5	1.3	37.60	9.30	76
Kusumanchi	0-15	7.27	0.14	15.6	5.0	1.8	0.20	27.60	6.52	82
	15-30	7.02	0.15	13.0	4.2	2.0	0.60	24.80	8.06	80
	30-45	7.02	0.23	10.0	3.6	2.2	0.60	20.50	10.73	80
	45-90+	8.10	0.23	8.7	2.8	2.0	0.40	18.50	10.81	75
Bhadrachalam	0-15	7.80	0.14	9.0	2.3	0.8	0.51	16.80	4.76	75
	15-35	7.52	0.19	8.0	2.2	1.2	0.41	15.30	7.84	77
	35-55	7.80	0.18	10.0	1.0	0.6	0.40	15.10	3.97	79
	55-95+	7.68	0.23	8.0	2.0	0.6	0.20	14.10	4.25	77
Khammam rural	0-25	7.10	0.31	8.0	2.5	1.6	0.35	16.32	9.80	76
	25-35	7.34	0.15	9.0	2.8	1.6	0.38	17.42	9.10	79
	35-75+	7.48	0.77	8.8	2.6	1.7	0.45	18.62	9.10	73
Chandrugonda	0-15	8.80	0.16	8.6	6.8	8.3	0.50	28.51	29.11	85
	15-33	8.90	0.30	8.2	4.2	5.5	0.44	25.42	21.63	72
	30-55	8.55	0.26	11.0	4.4	7.3	0.40	30.80	23.70	75
	55-85+	8.56	0.81	9.2	4.2	6.5	0.40	27.10	23.98	75
Wyra	0-15	8.32	0.13	12.1	2.8	2.3	0.41	25.10	9.16	70
	15-33	8.25	0.36	11.2	2.4	2.0	0.30	22.80	8.77	70
	33-65	8.48	0.52	12.9	1.2	2.6	0.30	20.10	12.90	85
	65-105	8.38	0.19	19.8	2.3	2.6	0.30	28.30	9.18	83
Wazeedu	0-30	8.00	0.13	16.2	6.8	1.4	0.40	31.00	4.51	80
	30-63	8.10	0.19	18.6	5.2	1.6	0.40	31.60	5.06	82
	63-105	8.12	0.27	16.8	3.5	1.4	0.30	29.30	4.77	75

Table 2: Physico-Chemical Properties Of Soils

Location	Depth (cm)	OC (%)	$CaCO_3$ (%)	Available macronutrients (kg ha^{-1})			Available micronutrients (mg kg^{-1})			
				N	P_2O_5	K_2O	Fe	Mn	Cu	Zn
Chintakani	0-15	0.62	12.52	301	26.8	185	6.11	3.80	0.26	1.14
	15-22	0.45	12.92	257	18.8	162	5.36	3.75	0.20	0.70
	22-70+	0.32	13.64	232	10.8	140	4.56	3.38	0.29	0.69
Palvancha	0-20	0.52	11.48	251	20.6	302	8.02	12.04	2.90	1.15
	20-35	0.32	11.62	220	16.1	235	7.00	7.56	2.37	0.97
	35-65+	0.25	10.52	188	9.0	202	6.98	6.30	1.46	0.7
Kusumanchi	0-15	0.65	10.84	306	18.8	207	5.54	9.30	0.45	0.99
	15-30	0.40	12.52	263	9.9	168	5.38	8.70	0.36	0.96
	30-45	0.32	10.54	230	7.2	129	4.98	7.82	0.34	0.82
	45-90+	0.21	6.56	194	6.3	118	4.68	7.17	0.23	0.71
Bhadrachalam	0-15	0.68	1.46	307	28.6	308	19.40	7.20	1.69	1.44
	15-35	0.60	2.02	263	17.0	241	6.40	6.90	0.86	1.36
	35-55	0.46	2.56	245	12.5	202	5.40	5.00	0.76	1.33
	55-95+	0.36	3.12	180	6.3	168	5.40	3.2	0.65	1.20
Khammam rural	0-25	0.52	6.24	238	20.6	252	5.38	8.80	1.60	0.97
	25-35	0.34	7.16	220	10.8	224	3.00	5.60	1.22	0.80
	35-75+	0.21	7.96	176	3.6	179	2.00	4.80	0.49	0.55
Chandrugonda	0-15	0.54	1.68	270	30.4	319	9.24	15.1	4.05	1.07
	15-33	0.43	2.12	254	17.9	263	8.9	15.00	1.94	0.98
	30-55	0.35	2.52	201	10.8	213	6.56	8.80	1.77	0.84
	55-85+	0.22	2.52	169	6.3	174	6.10	8.70	0.73	0.65
Wyra	0-15	0.71	6.81	307	28.6	269	4.82	7.36	1.12	0.94
	15-33	0.45	7.30	238	16.1	218	3.16	4.42	0.86	0.81
	33-65	0.34	7.72	125	8.1	185	2.66	3.64	0.83	0.75
	65-105	0.32	7.16	119	7.2	162	2.16	3.52	0.82	0.72
Wazeedu	0-30	0.61	2.28	251	27.7	308	3.72	8.60	1.07	0.77
	30-63	0.57	3.12	238	12.5	224	2.20	6.56	0.97	0.68
	63-105	0.42	2.88	220	7.2	179	1.64	4.82	0.71	0.53

Table 3: Chemical Properties Of Soils

S. No	Location	Order	Sub-order	Great group	Subgroup	Family
1	Chintakani	Alfisols	Ustalfs	Rhodustalfs	Lithic Rhodustalfs	Fine loamy superactiveisohyperthermic Lithic Rhodustalfs
2	Palvancha	Inceptisols	Ustepts	Haplustepts	TypicHaplustepts	Fine loamy superactive, isohyperthermic Typic Haplustepts
3	Kusumanchi	Alfisols	Ustalfs	Rhodustalfs	TypicRhodustalfs	Fine loamy superactiveisohyperthermicTypic Rhodustalfs
4	Bhadrachalam	Inceptisols	Ustepts	Haplustepts	VerticHaplustepts	Fine loamy superactiveisohyperthermic Vertic Haplustepts
5	Khammam rural	Alfisols	Ustalfs	Haplustalfs	Lithic Haplustalfs	Fine loamy superactiveisohyperthermic Lithic Haplustalfs
6	Chandrugonda	Inceptisols	Ustepts	Haplustepts	VerticHaplustepts	Fine loamy superactiveisohyperthermic VerticHaplustepts
7	Wyra	Vertisols	Usterts	Haplusterts	TypicHaplusterts	Fine loamy superactive calcareous isohyperthermic Typic Haplusterts
8	Wazeedu	Inceptisols	Ustepts	Haplustepts	TypicHaplustepts	Fine loamy isohyperthermic Typic Haplustepts

Table 4: Classification Of Soils

4.References

1. AIS&LUS (1970) Soil Survey Manual, All India Soil and Land Use Survey Organisation, IARI, New Delhi, pp. 1-63.
2. Bharathi 2008 Characterization, classification and soil related constraint analysis of certain oil palm growing orchards in Andhra Pradesh.MSc(Ag) Thesis is submitted to Acharya NG Ranga Agricultural University.
3. Gjems, O. (1967) Studies on clay minerals and clay mineral formations in soil profiles in Scandinavia. Meddelelserfra De NorsekSkogforsoksvesen21, 303.
4. Jackson, M.L. (1973) Soil Chemical Analysis, Prentice Hall Pvt. Ltd., New Delhi.
5. Jackson, M.L. (1979) Soil Chemical Analysis - Advance Course (Published by the author) Department of Soil Science, University of Wisconsin: Madison, WI, USA).
6. Leelavathi, G.P., Naidu, M.V.S., Ramavatharam, N. and KarunaSagar, G. (2009) Studies on genesis, classification and evaluation of soils for sustainable land use planning in Yeredumandal of Chittoor District, Andhra Pradesh. Journal of the Indian Society of Soil Science57, 109-120.
7. Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for zinc, iron, manganese and copper.Soil Science Society of America Journal42, 421-428.
8. Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for zinc, iron, manganese and copper.Soil Science Society of America Journal42, 421-428.
9. Nayak, D.C., Sarkar, D. and Das, K. (2002) Forms and distribution of pedogenic iron, aluminium and manganese in some Benchmark soils of West Bengal. Journal of the Indian Society of Soil Science50, 89-93.
10. Piper, C.S (1950) Soil and Plant Analysis, Interscience publisher, Inc. New York. 368.
11. Prasad, S.N. and Sakal, R. (1991) Availability of iron in calcareous soils in relation to soil properties. Journal of the Indian Society of Soil Science39, 658-661,
12. Prasuna Rani, P., Pillai, R.N., Bhanu Prasad, V. and Subbaiah, G.V, (1992) Nutrient status of some red and associated soils of Nellore District under Somasila Project in Andhra Pradesh.The Andhra Agricultural Journal39, 1-5.
13. Ramprakash, T. and SeshagiriRao, M. (2002) Characterisation and classification of some soils in a part of Krishna District, Andhra Pradesh.The Andhra Agricultural Journal49, 228-236.
14. Richards, L.A. (1954) Diagnosis and Improvement of saline and Alkali Soils. USDA Agricultural Hand book No.60 Washington, D.C.
15. Sekhon G S and Velayutham M 2002 Soil Fertility Evaluvation.Fundamentals of Soil Science.The Indian Society of Soil Science Publication.ISBN 81-901470-0-5.
16. SeshagiriRao, Prasuna Rani P Ramesh K and Vikram D (2004) Morphology and classification of southern coastal agro-eco sub region soils of Andhra Pradesh. Journal of Andhra Agriculture 51 (1&2) 71-76.

17. Sharma, S. S., Totawat, K. L. and Shyampura, R. L. (2004) Characterization and classification of salt-affected soils of southern Rajasthan. Journal of the Indian Society of Soil Science 52, 209-213.
18. Singh, I.S. and Agrawal, H.P. (2005) Characterization, genesis and classification of rice soils of Eastern Region of Varanasi, Uttar Pradesh. Agropedology15, 29-38.
19. Soil Survey Division Staff (2000) Soil Survey Manual (Indian Print), USDA Handbook No. 18.US C Printing Office, Washington, DC.
20. Soil Survey Staff (2003) Keys to Soil Taxonomy, Ninth Edition.USDA, Natural Resources Conservation Service, Washington, D.C.
21. VaraprasadRao, A.P., Naidu, M.V.S., Ramavatharam, N. and Rama Rao, G. (2008) Characterization, classification and evaluation of soils on different landforms in Ramachandrapurammandal and Chittoor district in Andhra Pradesh for sustainable land use planning. Journal of the Indian Society of Soil Science56 (1), 23-33.
22. Walia, C.S. and Rao, Y.S. (1997) Characteristics and classification of some soils of Trans-Yamuna plains.Journal of the Indian Society of Soil Science45, 156-162.
23. Watanabe, F.S. and Olsen, S.R. (1965) Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Science Society of America Proceedings29, 677-678.