Madras Agric. J., 101 (10-12): 340-345, December 2014
https://doi.org/10.29321/MAJ.10.001211

Characterization, Classification and Evaluation of Soils for Maximizing Sugarcane Production in Theni District of Tamil Nadu

M. Vijayakumar[1*] and A.R. Mohamed Haroon[2]
[1]Regional Research Station, Tamil Nadu Agricultural University, Paiyur-635 112
[2] ADAC&RI, Tamil Nadu Agricultural University, Trichy-620 009

A considerable gap between the potential and actual yields of sugarcane has been realized in different parts of Tamil Nadu recently and specifically in Theni district where the average yield (70 t ha^{-1}) is lower than many other parts of the state which is mainly attributed to the deterioration in soil health. Hence, depending on the variability in physiography, nature of soils, irrigation sources and yield of sugarcane (var. CO 86032), three locations were selected for detailed examination of the profile. The soils of the sugarcane dominant regions increased in depth from moderately deep (P2 and P3) to very deep (P1). Soils from weathered granite parent material with medium slopes (P3) have cambic subsurface diagnostic horizon whereas the soils of typical plains have thin to moderately thick argillic horizon. Sand constituted the bulk of the mechanical fractions of soils. The bulk density varied from 1.12 to 1.43 Mg m^{-3} in surface horizons and increased with depth (P1 & P3). Organic carbon content in the surface horizon of soils ranged from 3.3 to 6.0 g kg^{-1} and decreased with depth. Organic carbon was lower in pedon (P3) having high pH and $CaCO_3$ (7.5 to 232.5 g kg^{-1}). The cation exchange capacity of soils varied from 12.6 to 26.2 cmol (p^+) kg^{-1} in different horizons of the pedons. Relatively low CEC (12.6 cmol (p^+) kg^{-1}) was observed in the surface soil of P3. Regarding nutrient status at varied depths, available nitrogen was medium in surface horizon and low in sub surface horizons, medium to high in available phosphorus and available potassium. Further, the soils were deficient (except surface horizon) in available iron, zinc and copper while available manganese was sufficient. The soils were classified up to sub-group level and based on the suitability criteria it was assessed that soils under P1 and P2 are highly suitable and soils of P3 with few limitations can be improved for maximizing sugarcane yield in Theni district of Tamil Nadu.

Key words: Soil variability, Sugarcane, CEC, Suitability, Nutritional status, Horizon

Healthy soil, an essential component of a healthy environment, is the foundation upon which sustainable agriculture is built. In simple terms, soil quality or soil health can be defined as "the fitness of soil for use". Significant decline in soil quality has occurred worldwide through adverse changes in physical, chemical and biological soil properties and contamination by inorganic and organic chemicals. Concern has recently been raised by many authors regarding the degree of soil quality degradation that can occur under sugarcane production where the percentage loss in productivity is estimated to be 4.5 to 7.9 equivalents to a worth of 200 million US dollars (Singh, 2008). Moreover, the percentage growth rate of sugarcane registered a decrease from 1.89 to 1.81, 3.73 to 2.90 and 1.81 to 1.08 in terms of area, production and productivity respectively in nineties when compared to eighties (Srivastava *et al.,* 2013). The impaired soil health or deterioration in soil quality is often cited as one of the reasons for stagnation in cane productivity. In India, sugarcane is the second largest crop cultivated by 35 million farmers in 5 million ha (Mha) of land with an annual production of 350 million tonnes of sugarcane. Based on the recent projections, the country would need to produce 415 million tonnes of sugarcane from an area of 4.5 Mha with a sugar recovery of 11 per cent to meet the per capita requirement of 35 kg sweetness per year by 2020 A.D. Tamil Nadu is one of the leading sugarcane producing states of the country with an average productivity of 105 t ha^{-1}. About 30 million tonnes of cane is produced annually from an area of 2.86 lakh hectares.

*Corresponding author email :vijayagri1985@gmail.com

Theni district which is situated in the Southern Zone of Tamil Nadu is a predominant sugarcane growing region covering an area of about 4,427 hectares under cane cultivation with an average annual production of 4.67 lakh tonnes. In more recent times, a considerable gap between the potential and actual cane yields has been realized in different parts of Tamil Nadu and specifically in Theni district where the average yield (70 t ha^{-1}) is lower than many other parts of the state. Indeed, the plateau or decreasing yield levels and declining factor productivity have been the concerns in achieving the potential yield targets. All the above factors call for a paradigm shift in research away from maximizing crop production to the sustainability of crop production systems without degradation of soil health and environment quality. Systematic study of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for various uses (Sehgal, 1996). Although knowledge of important properties of sugarcane growing soils is vital for replenishing and maintaining the soil fertility status, only sporadic information is available on characterization of these soils. Hence the present investigation was taken up to characterize, classify and evaluate the soils of Theni district of Tamil Nadu for maximizing the productivity of sugarcane.

Materials and Methods

Description of the study area

Geographically the study area is located in Theni district lying at the foot of Western Ghats between 9$_o$ 30' and 10$_o$ 12' North latitude and 77$_o$ 10' and 77$_o$ 42' East longitude at 200-400 meters above sea level in the plains which comprises the major sugarcane growing areas. It is bounded by Dindigul district in the north, Madurai in the east, Virudunagar district in the south and Kerala state in the west. The district has a total geographical area of 2,890 sq km. The past decade weather information (2001 -2011) revealed that the area has a bimodal rainfall pattern and the mean annual rainfall was 765mm. The rainy season covers June to December and maximum rainfall (50%) is received during the months of October, November and December through North East monsoon followed by June, July, August and September through South west monsoon which contributes 25% of the annual rainfall. The mean minimum, mean maximum and average air temperatures are 33.3, 23.5 and 28.5$_o$C respectively.

Depending on the variability in physiography, nature of soils, irrigation sources and yield of sugarcane (var. CO 86032), three locations were selected for detailed examination of the profile. The soil profile description and horizon designation were determined according to FAO guidelines (Anon., 1990). Soil colour (dry and moist) was determined using the Munsell colour chart (Munsell Colour Company, 1975). The soil samples collected from each horizon were air dried and passed through 2 mm sieve for the determination of most of the soil parameters. 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). Soils were classified according to key to Soil Taxonomy (Soil Survey Staff, 2006) and were evaluated for sugarcane cultivation using the criteria laid by Naidu and Hunsigi (2001).

Results and Discussion

Morphological characteristics

The site and morphometric characteristics of the pedons were given in Tables 1 and 2 respectively. The soils of the sugarcane dominant regions were increases in depth from moderately deep (P2 and P3) to very deep (P1). Colour of the typical Alfisols (P1 and P2) varies from brownish yellow (10 YR 6/6 M) to dark yellowish brown (10 YR 3/4 M) at surface and in subsurface horizon it is generally observed to be yellowish brown. The colour of Inceptisol (P3) was reddish yellow (5 YR 6/6) both in the surface and subsurface horizons. This might be due to chemical and mineralogical composition as well as textural make up of soils conditioned by topographic position and moisture regime (Walia and Rao, 1997). The sugarcane growing soils of the region showed wide textural variation that sandy loam, sandy clay loam, clay loam and sandy clay. The structure of deep soils (P1) were weak to moderate sub angular blocky while that of moderately deep soils (P2 and P3) had crumb structure at surface and moderate to massive sub-angular blocky in the subsurface. Soils from weathered granite parent material with medium slopes (P3) have cambic subsurface diagnostic horizon with a horizon sequence of A - Bwk - Bck-BC, whereas the soils of typical plains have thin to moderately thick argillic horizon at the subsurface which gives the horizon sequence of Ap- Bt_1 - Bt_2

Table 1. Site characteristics of sugarcane growing pedons

Pedon	P1 (Pothampatti)	P2 (Muthuthevanpatti)	P3 (RSCL farm)
Lattitude and	09$_o$ 56’ 05.6" N	09$_o$ 58’ 53.1’’ N	10$_o$ 02’ 50.0’’ N
Longitude	77$_o$ 47’ 49.9’’ E	77$_o$ 27’ 04.9’’ E	77$_o$ 36; 26.2’’ E
Elevation (m) above mean sea level	208	320	264
Physiography/Topography	Gently sloping, undulating	Upper terrace, undulating	Upper terrace, undulating
Geology/Parent material	Colluvium	Granitic rock	Weathered granite
Slope (%)	0-1	0-1	1-3
Erosion	Slight	Slight	Moderate
Drainage (Soil)	Moderately well	Moderately well	Well

Table 2. Morphological properties of soils

Horizon	Depth (cm)	Boundary		Colour	Texture	Structure	Consistence			Pores		Roots		Efferv-escence
		D	T				D	M	W	S	Q	S	Q	
Pedon 1: Pothampatti [Fine, loamy (mixed), isohyperthermic Typic Rhodustalf]														
Ap	0-20	c	s	10 YR 6/6	scl	w3sbk	sh	fi	ss	mf	f	f	cr	-
Bt1	20-65	a	s	10 YR 4/6	cl	w4abk	h	fi	sp	vf	f	f	m	-
Bt2	65-200	a	s	10 YR 3/5	cl	w4sbk	-	fi	ssp	vf	m	f	vf	-
Pedon 2: Muthuthevanpatti [Fine, loamy (mixed), isohyperthermic Typic Haplustalf]														
Ap	0-20	c	s	10 YR 3/4	scl	cr	sh	fi	ss	f	vf	m	f	-
Bw	20-70	c	s	10 YR 3/4	cl	m3sbk	sh	fi	ss	f	vf	f	vf	-
Bt1	70-90	c	s	10 YR 3/4	l	m3sbk	h	fi	ssp	f	f	f	vf	e
Bt2	>90	a	s	10 YR 3/4	sl	m4abk	h	fi	ssp	f	vf	f	vf	es
Pedon 3: RSCL farm site [Fine, loamy (mixed), isohyperthermic Typic Ustropept]														
Ap	0-20	c	s	5 YR 6/6	sl	cr	sh	fi	sssp	f	vf	f	vf	-
Bwk	20-45	a	s	5 YR 6/6	cl	m3sbk	sh	fi	sssp	f	vf	f	vf	e
B/ck	45-80	c	s	5 YR 6/6	l	m3sbk	l	fr	sssp	f	vf	f	vf	e
BC	80+	c	s	5 YR 6/6	sl	m4sbk	l	fr	sssp	f	vf	f	vf	-

(P1) and Ap - Bw- Bt_1- Bt_2 (P2). These variations in morphometric properties may be due to variations in parent material, topography, in-situ weathering and translocation of clay.

Physical and Chemical characteristics

The soils of Alfisols (P1 and P2) are sandy clay loam to clay loam in texture with sand and clay content between 60.7 to 75.9 and 13.4 to 30.4 per cent respectively (Table 3). Soils of Inceptisol (P3) are sandy loam to clay loam with sand and clay content between 63.1 to 80.05 and 8.9 to 25.4 per cent, respectively. There is a significant increase in clay in subsurface horizons due to vertical migration or translocation of clay due to variations in cultural management practices in sugarcane (Sarkar *et al*., 2002). Silt content in all the pedons exhibited an irregular trend with depth, probably due to variation in weathering of parent material (Bhaskar *et al*., 2004). Sand constituted the bulk of the mechanical fractions of soils. The bulk density varied from 1.12 to 1.43 Mg m^{-3} in surface horizons and increased with depth (P1 & P3) which might be due to more compaction, low organic matter and less aggregation.

Table 3. Physical properties of soils

Horizon	Depth (cm)	Particle size distribution (%)			Sand/ Siltratio	Hydraulic conductivity	Bulk Density
		Sand	Silt	Clay		(cm hr^{-1})	(Mg m^{-3})
Pedon 1: Pothampatti [Fine, loamy (mixed), isohyperthermic Typic Rhodustalf]							
Ap	0-20	76.3	5.0	22.5	15.3	10.5	1.12
Bt1	20-65	60.7	16.6	25.9	3.7	9.2	1.25
Bt2	65-200	64.1	12.5	22.1	5.0	7.3	1.30
Pedon 2: Muthuthevanpatti [Fine, loamy (mixed), isohyperthermic Typic Haplustalf]							
Ap	0-20	66.6	10.5	22.4	6.3	4.4	1.25
B w	20-70	62.7	6.6	30.4	9.5	2.2	1.28
Bt1	70-90	64.4	15.0	20.0	4.3	3.8	1.21
Bt2	>90	75.9	10.4	13.4	7.3	8.6	1.28
Pedon 3: RSCL farm site [Fine, loamy (mixed), isohyperthermic Typic Ustropept]							
Ap	0-20	80.05	8.6	10.9	9.3	2.7	1.30
Bwk	20-45	63.1	11.2	25.4	5.6	1.8	1.33
B/ck	45-80	78.6	6.6	14.6	10.4	8.4	1.25
BC	80+	76.9	14.1	8.9	4.9	9.5	1.43

The pH of soils from all the pedons ranged from 7.36 to 8.29 (Table 4) indicating that the soils are neutral to slightly alkaline and are suitable for sugarcane cultivation. The higher pH in soils of subsurface horizons may be due to more accumulation of bases removed from soils of surface horizon. The pH also had strong positive correlation with $CaCO_3$ (r = 0.655**) and negatively correlated with organic carbon (r = - 0.093). Electrical conductivity of soils (0.11 to 0.51 dS m^{-1}) from all the pedons showed that the soils are non-saline in nature. Organic carbon content in the surface horizon of soils ranged from 3.3 to 6.0 g kg^{-1} and decreased with depth. Organic carbon was lower in pedon (P3) having high pH and $CaCO_3$ (7.5 to 232.5 g kg^{-1}). The high $CaCO_3$ in the soils may be due to tropical conditions which is responsible for the pedogeneic processes resulting in the depletion of Ca^{2+} ions from the soil solution in the form of calcretes with concomitant increase in ESP with depth (Vaidya and

Table 4. Physico-chemical properties of soils

Horizon	Depth (cm)	pH (1:2.5)	EC (1:2.5) (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Exchangeable cations (Cmol (p^+) kg^{-1})				CEC (Cmol (p^+) kg^{-1})	BSP	ESP	CEC/ Clayratio
						Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}				
Pedon 1: Pothampatti [Fine, loamy (mixed), isohyperthermic Typic Rhodustalf]													
Ap	0-20	7.36	0.14	5.2	15.0	14.0	9.5	0.35	0.19	26.2	91.75	1.3	1.16
Bt1	20-65	7.72	0.11	3.5	20.0	12.0	7.5	0.43	0.18	23.6	85.21	1.8	0.91
Bt2	65-200	7.67	0.11	3.3	17.5	10.0	6.0	0.65	0.15	21.7	77.42	2.9	1.19
Pedon 2: Muthuthevanpatti [Fine, loamy (mixed), isohyperthermic Typic Haplustalf]													
Ap	0-20	8.09	0.30	6.0	7.5	14.0	3.0	0.42	0.36	22.5	79.02	1.9	0.74
Bw	20-70	7.86	0.34	4.0	12.5	8.0	7.0	0.76	0.19	21.1	75.59	3.6	0.94
Bt1	70-90	7.51	0.30	3.8	107.5	11.0	2.0	0.73	0.22	19.0	73.42	3.8	0.95
Bt2	>90	8.19	0.43	3.5	212.5	7.5	1.0	0.72	0.12	13.2	70.76	5.5	0.99
Pedon 3: RSCL farm site [Fine, loamy (mixed), isohyperthermic Typic Ustropept]													
Ap	0-20	7.85	0.26	5.5	10.0	7.0	2.0	0.85	0.54	12.6	82.44	6.7	1.16
Bwk	20-45	8.29	0.19	4.2	225.0	11.0	2.0	0.22	0.40	24.2	87.15	0.9	0.95
B/ck	45-80	8.25	0.25	3.8	232.5	13.0	3.3	0.84	0.50	21.1	83.60	4.8	1.44
BC	80+	7.97	0.51	3.7	205.0	10.5	3.0	0.25	0.20	17.6	79.26	1.2	0.83

Pal, 2002; Ashok Kumar and Jagdish Prasad, 2010). The $CaCO_3$ content was positively correlated with pH (r = 0.655**) but exhibited a strong negative correlation with organic carbon (r = - 0.441*) and CEC (r = - 0.167*) were observed.

The cation exchange capacity of soils varied from 12.6 to 26.2 cmol (p^+) kg^{-1} in different horizons of the pedons. Relatively low CEC (12.6 cmol (p^+) kg^{-1}) in the surface soil of P3 may be due the dominance of sand (80.05%) in this horizon and presence of hydrous oxides of iron and aluminium in these soils (Sarkar *et al*., 2002). The CEC of soils was positively correlated with the clay content (r= 0.857**). However, it was negatively correlated with sand (r= - 0.863**), $CaCO_3$ (r = - 0.167*) and pH (r = - 0.147*). In general, Ca^{2+} was the dominant cation followed by Mg^{2+}, Na^+ and K^+. The base saturation varied from 61.21 to 96.23 per cent and higher base saturation of P1 and P2 can be attributed to continuous addition of bases from organic residues due to the presence of Ca- bearing soil modifiers namely zeolites (Pal *et al.,* 2006; Rashmi *et al.,* 2012). The presence of zeolites even in the present day climate indicates that loss of bases during leaching of soils has been continuously replenished by the steady supply of bases from these zeolites and is responsible for more base saturation (Bhattacharya *et al*., 1999). Among the exchangeable cations, Ca^{2+} dominates the exchange complex followed by Mg^{2+}, Na^+, and K^+. The CEC / clay ratio vertically increases in pedons P1 and P2 which indicates deposition of eluviated clay in the subsurface horizons.

Soil fertility status

The surface and sub-surface horizons were analysed for fertility status. The soils are rated as low (< 280 kg ha^{-1}), medium (280- 450 kg ha^{-1}) and high (> 450 kg ha^{-1}) in case of available nitrogen; low (< 11 kg ha^{-1}), medium (11-22 kg ha^{-1}) and high (> 22 kg ha^{-1}) for available phosphorus; and low (< 110 kg ha^{-1}), medium (110 to 280 kg ha^{-1}) and high (> 280 kg ha^{-1}) for available potassium (Arora, 2002). According to these soil fertility classes, available nitrogen status was medium in P1 and P2 and low in P3. The relatively higher status of available N in P1 and P2 may be due to high organic matter content of the soils which is also justified by the significant correlation between the organic carbon and available N (r = 0.799**). The available phosphorus status among the profiles varied from a minimum of 12 to a maximum of 70 kg ha^{-1} in P2. The P status was found to be higher in the surface horizons of all the pedons which might be due to continuous application of phosphatic fertilisers without assessing the available soil P status. The lower phosphorus status in sub surface horizons could be attributed to the fixation of released phosphorus by clay minerals and oxides of calcium, iron and aluminium (Thangasamy *et al.,* 2005).

The available potassium status in the surface horizons ranged from 222(P3) to 437(P1) kg ha^{-1} and generally all the profiles exhibited a decreasing trend of K availability with depth (Table 5). This might be attributed to more intense weathering, release of labile K from organic residues, application of inorganic K fertilisers and upward translocation of potassium from lower depths along with capillary rise of ground water. The organic carbon was significant positive correlation with available potassium (r = 0.463*). Similar results were reported from soils of Chitoor district of Andhra Pradesh (Thangasamy *et al.,* 2005).

The available micronutrient contents of Fe, Mn, Zn and Cu of different horizons of the sugarcane growing regions varied between 1.04 to 12.72, 7.36 to 17.32, 0.4 to 1.42 and 0.28 to 1.20 mg kg^{-1} respectively. In general, the surface horizons had higher concentration of DTPA micronutrient cations which may be attributed to higher organic carbon content (Likhar and Jagadish Prasad, 2011). The significant positive correlation of micronutrients *viz*., Fe (r = 0.638**), Mn (r = 0.207*), Zn (r = 0.914**) and Cu (r = 0.546**) with organic carbon suggests that the micronutrient contents form complexes with organic matter and consequently remained in the forms easily available to plants. Though sufficient Fe was observed in the surface horizons, sub-surface horizons of all the three pedons were deficient with DTPA-Fe. However, all the pedons of the sugarcane dominant zones were deficient in Zn. Similar observations were made by Ashokkumar

Table 5. Macro and micro-nutrients status of sugarcane growing soils

Horizon	Depth (cm)	Major nutrients (kg ha^{-1})			Micronutrients (mg kg^{-1})			
		N	P	K	Fe	Mn	Zn	Cu
Pedon 1: Pothampatti [Fine, loamy (mixed), isohyperthermic Typic Rhodustalf]								
Ap	0-20	324	51	437	6.26	17.32	1.42	1.20
Bt1	20-65	216	25	289	3.34	17.04	1.28	0.56
Bt2	65-200	179	14	271	2.58	15.46	0.78	0.50
Pedon 2: Muthuthevanpatti [Fine, loamy (mixed), isohyperthermic Typic Haplustalf]								
Ap	0-20	297	70	335	12.72	11.50	1.36	1.10
B w	20-70	188	23	287	4.32	11.26	1.30	0.82
Bt1	70-90	182	21	241	2.80	9.76	0.42	0.58
Bt2	>90	118	12	225	1.18	7.36	0.40	0.28
Pedon 3: RSCL farm site [Fine, loamy (mixed), isohyperthermic Typic Ustropept]								
Ap	0-20	314	37	397	2.66	12.94	0.72	0.46
Bwk	20-45	198	35	222	1.34	11.00	0.60	0.54
B/ck	45-80	193	30	234	1.22	10.84	0.50	0.50
BC	80+	135	13	242	1.04	8.40	0.46	0.36

and Jagdish Prasad (2010) in sugarcane growing soils of Ahmadnagar district. The pH and $CaCO_3$ had significant negative correlation with Fe (r = -0.166 and r = -0.635), Mn (r = -0.615** and r = -0.693), Zn (r = -0.107 and r = - 0.472*) and Cu (r = -0. 400* and r = -0.589) respectively and all micronutrient cations had significant positive correlation among themselves.

Soil Classification

Based on morphological, physical and physico-chemical characteristics of the soils and climate data, the soils were classified according to keys to Soil Taxonomy (Soil Survey Staff, 2006). Pedon 1 and 2 are classified as Alfisols due to the presence of an argillic (B_t) sub-surface diagnostic horizon. Pedon 3 is classified under Inceptisols due to the absence of any other diagnostic horizon other than cambic (B_w) horizon. Moisture regime of P3 is Ustic and the Pedon 1 and 2 are classified as Ustalf at sub order level. These pedons are classified as Haplustalf at great group level because other than argillic horizon they do not have any horizons like natric, petro calcic, duripan or plinthite horizons. Further, Pedon 1 did not have vertic properties and lithic contact within 50 cm from the soil surface. Hence, these pedons are classified as Typic Haplustalfs at sub group level.

Suitability Assessment

The ideal soils for sugarcane are deep (60 cm), well drained, well structured, clay loam to sandy loam with lots of organic matter. The physico-chemical characteristics of soils which influence yield and quality of cane are pH, CEC, texture, structure, bulk density, organic matter content and water retention capacity. Crop growth and yield was high at a pH range of 5.5 to 7.5 whereas lower limit is 4.5 and upper limit is 8.5. Sugarcane growing soils should have minimum CEC of 15 cmol (p^+) kg^{-1} of soil (Hunsigi, 2001). The general soil limiting factors identified in all the pedons include coarse texture, poor organic carbon status, high amount of $CaCO_3$ and low CEC in Pedon 3. All the pedons examined were suitable for growing sugarcane crop since these pedons possess all the suitability criteria of requirement except climatic regime for Pedon1. The pedon 3 has limitations with shallow depth, pH, and CEC and soil texture. The P2 and P3 had limitations with $CaCO_3$ and rated as moderately suitable. Sys *et al*. (1993) proposed a good commercial yield of 110 to 150 t ha^{-1} as ideal under irrigated condition in sugarcane from healthy soils. However, the average cane yields recorded from the sites of Pedon 2 and 3 were 115 and 105 t ha^{-1} , whereas Pedon 1 recorded an average yield of 127 t ha^{-1}. Pedon 1 and 2 are found to be highly suitable and Pedon 3 is found to be moderately suitable as these soils are low in available N, deficient in Fe, Zn and Cu for sugarcane crop which might affect the scope of maximising the sugarcane yield and quality.

Management practices for improving sugarcane productivity

(i) Application of gypsum based on the soil reaction and leaching with good quality water and providing good drainage for reclamation of alkaline soils.

(ii) Factory bio-compost/green manure should be applied to build-up organic matter and nitrogen status of soil.

(iii) Application of 37.5 kg zinc sulphate ha^{-1} and 100 kg ferrous sulphate ha^{-1} to alleviate the Zn and Fe deficiencies for sugarcane crops.

(iv) The use of balanced fertilizers based on soil testing and close monitoring of Zn, Cu, Fe and Mn in these soils besides the application of major plant nutrients in recommended amount should be emphasized to enhance the productivity of sugarcane in a sustainable manner.

Conclusion

The characterization and classification of profiles from the sugarcane dominant study area showed that the soils were neutral to moderately alkaline in soil reaction, non-saline and low to medium in organic carbon content. Further, the CEC was also low to medium and exchangeable complex was dominated by Ca^{2+}. Regarding nutrient status, the soils were medium in available nitrogen (P1 and P2), low in P3, and medium to high in available phosphorus and available potassium. Further, the soils were deficient (except surface horizon) in available iron, zinc and copper while available manganese was sufficient. Invariably higher status of available P and K in the sugarcane growing soils of Theni district has necessitated the need for refinement of P and K fertilization schedule in terms of quantity and time of application of nutrients to the sugarcane crop. In this regard, following soil test crop response based fertilizer recommendations through Integrated Plant Nutrition System (STCR-IPNS) would pave way for enhanced crop productivity, fertilizer use and profitability. The increasing deficiency of Zn and also Cu in these soils is of much concern and soil test based application of zinc has to be taken up for sustaining the soil fertility status and enhancing the sugarcane crop productivity in these soils. The soils were classified up to sub-group level and based on the suitability criteria it was assessed that soils under P1 and P2 are highly suitable and soils of P3 with few limitations can be improved for maximizing sugarcane yield in Theni district of Tamil Nadu.

References

Anonymous, 1990. Guidelines for soil profile description. Food and Agriculture Organization of the United Nations (FAO) and International Soil Reference Center (ISRIC), p.70.

Arora, C. L. 2002. Analysis of soil, plant and fertilizers, In Fundamentals of Soil Science (G.S. Sekhon, P. K. Chhonkar, D.K. Das, N.N. Goswami, G. Narayanasamy, S.R. Poonia, R.K. Rattan and J. Sehgal, Eds), Indian Society.

Ashokkumar, H. P. and Jagdish Prasad, 2010. Some typical sugarcane-growing soils of Ahmednagar district of Maharashtra: Their characterization and classification and nutritional status of soil and plants. *J. Indian Soc. Soil Sci.,* **58** (3): 257-266.

Bhaskar, B.P., Saxena, R.K., Vadivelu, S., Baruah, U., Butte, P. S. and Dutta, D. P. 2004. Pedogenesis in high altitude soils of Meghalaya plateau. *Agropedology,* **14**: 9-23.

Bhattacharya, T., Pal, D.K. and Srivastava, P. 1999. Role of zeolites in persistence of high altitude ferruginous Alfisols of the humid tropical Western Ghats, India. *Geoderma,* **90**: 263-276.

Hunsigi, G. 2001. Sugarcane in Agriculture and Industry. Prism Books Pvt. Ltd., Bangalore.

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

Likhar, C.K. and Jagdish Prasad, 2011. Characterization and classification of orange-growing soils developed from different parent materials in Nagpur district, Maharashtra. *J. Indian Soc. Soil Sci.,* **59**(3): 209-217.

Lindsay, W.L. and Norvell, W. A. 1978.Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.,* **42**: 421-428.

Munsell Color Company, 1975. Munsell soil colour charts. Munsell Colour Company Inc., Batimore 18, Mary land, USA.

Naidu, L.G.K. and Hunsigi, G. 2001. Application and validation of FAO frame work and soil potential ratings for land suitability evaluation of sugarcane soils of Karnataka. *Agropedology,* **11**: 91-100.

Pal, D.K., Bhattacharyya, T., Ray, S.K., Chandran, P., Srivastava, P., Durge, S.L. and Bhuse, S.R. 2006. Significance of soil modifiers (Ca-zeolites and gypsum) in naturally degraded Vertisols of the Peninsuldia in redefining the sodic soils. *Geoderma,* **136**: 228.

Piper, C.S. 1950. Soil and Plant Analysis, Interscience Publisher, Inc. New York. 368.

Rashmi, R. Bante, Rajeev Srivastava, M.S., Nagaraju, S. and Jagdish Prasad, 2012. Characterization and evaluation of land resources for watershed management in Vidarbha region of Maharashtra using RS and GIS. *J. Indian Soc. Soil Sci.,* **60** (4): 261-268.

Richards, L. A. 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Hand book No. 60 Washington, D.C.

Sarkar Dipak, Baruah, U., Gangopadhyay, S. K., Sahoo, A. K. and Velayutham, M. 2002. Characteristics, classification of soils for Loktak command area of Manipur for sustainable land use planning. *J. Indian Soc. Soil Sci.,* **50** (2): 196-204.

Sehgal, J. 1996. *Pedology*: Concepts and Applications, Kalyani Publishers, New Delhi.

Singh, A.K. 2008. Soil resource management – Key to food and health security. *J. Indian Soc. Soil Sci.,* **56**: 348 -357.

Soil Survey Staff, 2006. Keys to Soil Taxonomy. 10th Edition. USDA, Natural Resource Conservation Service, Washington, D.C.

Srivastava, T.K., Singh, A.K. and Visha Kumari, V. 2013. Fertilizer best management practices in sugarcane. *Indian J. Ferti.,* **9**(4): 96- 107.

Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F. 1993. Land Evaluation. Part III. Crop Requirements. Agricultural Publication No 7.

Thangasamy, A., Naidu, M.V.S., Ramavatharam, N. and Rhagava Reddy, C. 2005. Characteristics, classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor district, Andhra Pradesh for sustainable land use planning. *J. Indian Soc. Soil Sci.,* **53** (1): 11-20.

Vaidya, P.H. and Pal, D.K. 2002. Micro topography as a factor in the degradation of Vertisols in Central India. *Land Degrad. and Develop.,* **13**: 429-445.

Walia, C.S. and Rao, Y.S. 1997. Characteristics and classification of some soils of Tans-Yamuna plains. *J. Indian Soc. Soil Sci.,* **45**: 156-162.

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 Sci. Soc. Am. Proc.,* **29**: 677-678.

Received: August 1, 2013; Revised: December 12, 2014; Accepted: December 24, 2014