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Research Article

Soil quality assessment in red laterite soils of Chettinad of Sivaganga district of Tamil Nadu

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Summary

A detailed study on soil quality assessment in red laterite soils of Chettinadu, Sivaganaga District, Tamil Nadu was carried out with the objective to assess the available nutrients and their relationship with various physical, physiochemical properties and nutrients status in surface and sub surface soils. Soil samples were collected at a depth of 0-15cm and 15-30cm and analyzed for available macronutrients and micronutrients. The available N, P, K and S ranged from 123.0-209, 14.0-28.0, 126.0-319.0 kg ha^{-1}, and 9.13-18.85 mg kg^{-1}, respectively. The available Zn, Cu, Mn and Fe and B varied from 0.10-3.52, 0.85-3.63, 24.02-49.21, 8.9-22.38 and 0.36-0.44mg kg^{-1} in surface soils, respectively. The available nutrient status indicates that the soils were low in N, low to medium in available P and medium to high in available K, S in the surface soils. The surface soils deficient in available Zn, sufficient in available Cu, Fe ,Mn and deficient in hot water soluble boron. The pH had significant positive correlation with EC, organic carbon and sulphur (r = 0.239*, 0.293* and 0.241*, respectively) and significantly negative correlated with $CaCO_3$ (r = - 0.302**). The pH had positive correlation but not significant with CEC, available P, Zn and Mn and negative correlation with available N, K, Fe and B.

Key words : Soil fertility, Nutrients availability, Physical, Physico chemical properties, Red laterite soils

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Introduction

The soil fertility status exhibits the status of different soils with regard to amount and availability of nutrients essential for plant growth. The crop growth and yield largely depend upon potential of soil resources and their characteristic provides water, nutrients and anchorage for the growth and yield of crops. Soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients *i.e.* macro and micronutrients. Out of the 16 plant nutrients N, P, K, S, zinc, copper, iron, manganese, molybdenum, chlorine and boron are essential for plant growth in high and minute quantity. The availability of nutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such nutrients are organic matter, soil pH, lime content, sand, silt and clay contents revealed from different research experiments. The detail field wise study of physico-chemical characteristics, available macro, secondary and micronutrients status in the surface and sub surface soils aid in determining the soils potential, which are essential for better scientific utilization of land use planning for crop growth. Keeping in view above points, the detailed micro level study was conducted to assess the physical, physico-chemical characteristics and available nutrient status of red and lateritic soil. In order to provide a base line data and information, the detailed field wise study was taken at Dryland agricultural research station at Chettinad, Sivagangai district of Tamil Nadu.

Resource and Research Methods

TNAU has started an exclusive Dryland agricultural research station at Chettinad, Sivaganga district with an objective to cater to the research needs of the dryland agricultural crops of the Tamil Nadu state and to tackle the constraints *viz.,* poor water holding capacity, surface crusting, quick nutrient loss, low nutrient retention capacity, low organic matter content etc. The station was inaugurated on July 2, 2008 with the following mandate such as conducting research on evolving high yielding crop varieties, develop land management technologies and pest and disease management and training to build the capacity of the farmers and extension functionaries.

Location and climatic information :

Research station extending an area of 317 acre and boundary is surrounded between 10.166 to 10.179 N latitude and 78.785 to 78.805 E longitudes and is situated at an altitude of 108 m above mean sea level . Nearly three fourth of the land is under pedi plains and characterized by flat terrain nearly level to gently slope in nature.

The climate of the study area is hot and dry and temperature is low during the month of January and the lowest mean daily temperature is 19.8^{o}C. The temperature begins to rise after March and the hottest month is July during which period the maximum temperature is 36.8^{o}C. Mean humidity varies from 65 per cent in July to 80 per cent in December. The mean annual rainfall of the study area is 1080 mm**.** The north east monsoon contributes 45 per cent of the annual rainfall from October to December. South west monsoon also contribute 37 per cent of rainfall from July to October. The soil moisture control section is dry for more than 90 cumulative days or 45 consecutive days in the months of summer solstice. So it qualifies for ustic soil moisture regime. The natural vegetation includes grasses *Cynodon dactylon, Cyprus rotundus, Azadirata indica, Prosopis juliflora, cacia* sps,. *Prosofis juliflora,* mango *(Manjifera indica)* ,teak *(Tectona grandis) Tamarindus indica,* Tadipalm, broad leaf weeds such as *Selotia, Parthenium, Euforbia* sps, etc. The main source of irrigation to the farm is from borewell and rainfall in the monsoon season.

In order to delineate the detail field wise physical, physico-chemical characteristics, available nutrients status in the surface and sub surface soils, 72 surface (0-15 cm) and 72 sub-surface (15-30 cm) soil samples were collected from 5 different blocks of Research station. Five to six pits were dug for each sample in every field. From each pit sample was collected at a depth of 0-15cm and 15-30cm. A composite sample of about 1kg was taken through mixing of represented soil samples. The soil samples were air-dried in shade, processed and screened through a 2 mm sieve. After sieving all the samples were packed in the polythene bags for analysis.

Methods used for analysis :

The soil samples representing each of the fields were characterized for important physical, physico-chemical properties using standard procedures. Particle size analysis was done according to international pipette method (Piper,1966), bulk density (Blake and Hartze, 1986), water holding capacity (Sankaram, 1966), soil pH and EC was determined in 1:2.5 soil water suspensions. exchangeable cations (Jackson,1973), cation exchange capacity (Chapman, 1965), organic carbon and free calcium carbonate were determined (Walkly and black, 1934 and Piper, 1966) respectively. the available nitrogen was determined by kjeldal method, available phosphorus was estimated by spectrophotometer and potassium by flame emission method (Jackson, 1973). Available sulphur in the soil was extracted using 0.15% $CaCl_2$ solution (Williams and Steinbergs, 1959). The available micronutrients were determined using the method given by Lindsay and Norvell (1978). Hot water soluble (HWS) boron was determined by using method as described by Jackson (1958).

Research Findings and Discussion

The results of the present study as well as relevant discussions have been presented under following sub heads:

Physical characteristics :

Physical characteristics of soil are presented in Table 1.The clay, silt and sand contents in the soils varied from 17.9 to 31.7, 3.5to10.5 and 60.6to76.8 per cent in surface soils and 18.1to33.0,4.2 to 11.5 and 59.1 to 74.4 per cent in sub surface soil, respectively. The clay content was more in sub surface soils than surface soils might be due to the mobilization and translocation of clay. The bulk density values ranged from 1.27 to 1.39 Mgm^{-3} in surface soils and in subsurface soils the values varied from 1.32 to 1.41 Mgm^{-3}. The bulk density values in surface soil were low when compared to sub surface samples. Lower bulk density values of surface soil might be due to loose, porous and organic matter content (Walia and Rao, 1996). All the sub surface soils showed increasing trend with depth; this might be due to more compaction of finer particles in deeper layers caused by over head weight of surface soils (Jewitt *et al.*, 1979). The maximum water holding capacity of surface and sub surface soil ranged from 9.35 to 32.85 per cent and 11.98-36.35 per cent, respectively. These differences were due to the variation in the depth and clay, silt and organic carbon content (Rajeshwar *et al.*, 2009).

The red laterite soils being dominated by kaolinite clay with small surface area, retained lower amount of water at different soil water suctions. The data in Table 2 show the water retention at 33 kpa and 1500 kpa. The moisture content at field capacity (33kpa) varied from 13.2 to 20.5 and 13.8 to 22.5 per cent and at permanent wilting capacity (1500kpa) varied from 5.4 to 10.9 and 4.9 to 11.6 per cent, respectively in both the surface and sub surface soils. This variation is attributed to the textural changes in the soils. The soils of C block shows higher water retention as it contained more amount of clay. Soils of B block reveals that the low content of water at field capacity due to considerable amount of sand content in it.

Table 1: Physical characteristics of surface and sub surface soils of DARS, Chettinad

Block	No. of soil samples	Depth (cm)	Gravel (%)	Particle size distribution (%) Coarse sand (0.22 mm)	Fine sand ((0.02- 0.2mm)	Total sand (<2.0mm)	Silt (0.002-0.02mm)	Clay (<0.002 mm)	B.D ($Mg\ m^{-3}$)	Pore space (%)	Water retention ($kg\ kg^{-1}$) 33 kpa	1500 kpa	Available water (AWC)	W.H.C (%)
A	22	0-15	15.1-39.0	54.9-61.5	11.6-20.5	71.5-76.8	3.5-7.9	18.0-21.9	1.32-1.38	45.4-51.3	13.8-17.4	5.4-8.8	5.7-9.5	11.35-21.36
			(17.6)	(57.9)	(16.6)	(74.5)	(5.5)	(20.0)	(1.34)	(48.2)	(15.1)	(7.37)	(7.7)	(16.4)
	22	15-30	8.4-50.5	50.2-60.1	10.5-16.6	63.8-73.0	4.2-8.1	21.2-28.5	1.33-1.41	43.5-47.9	14.2-17.8	4.9-9.2	5.8-10.7	11.98-23.81
			(20.61)	(55.5)	(13.6)	(69.1)	(5.8)	(25.1)	(1.35)	(45.6)	(15.9)	(7.6)	(8.3)	(17.8)
B	8	0-15	11.0-14.6	57.1-60.5	14.5-18.9	73.2-76.2	4.2-7.1	18.4-19.9	1.36-1.39	45.9-51.4	13.3-16.6	6.4-8.8	4.3-8.8	9.35-19.1
			(12.5)	(58.6)	(16.1)	(74.7)	(6.1)	(19.2)	(1.37)	(48.5)	(14.8)	(7.4)	(7.4)	(15.0)
	8	15-30	6.51-34.0	52.8-61.5	9.6-17.7	68.6-71.6	5.4-7.7	20.0-23.9	1.38-1.42	43.2-49.1	13.8-17.1	6.6-9.8	4.9-9.1	13.35-20.35
			(18.46)	(57.5)	(13.6)	(71.1)	(6.6)	(22.3)	(1.39)	(46.4)	(15.2)	(8.3)	(6.9)	(16.6)
C	20	0-15	2.84-28.7	43.8-61.0	6.8-19.6	60.6-72.1	4.3-9.5	24.0-31.7	1.27-1.35	42.2-49.3	13.9-20.5	5.9-9.4	7.2-13.3	15.1-32.85
			(12.75)	(52.1)	(14.2)	(66.3)	(6.34)	(27.3)	(1.32)	(44.9)	(17.8)	(8.0)	(10.1)	(26.8)
	20	15-30	7.0-25.6	43.6-57.8	7.6-18.2	59.1-68.7	4.5-8.2	27.9-33.0	1.32-1.36	40.1-44.9	17.4-22.5	7.6-9.9	9.2-13.7	25.1-36.35
			(14.56)	(51.1)	(12.6)	(63.8)	(6.6)	(29.6)	(1.34)	(42.5)	(20.1)	(8.8)	(11.3)	(30.3)
D	14	0-15	2.31-26.2	47.9-60.8	8.4-17.5	65.4-73.2	4.3-10.5	17.9-28.5	1.31-1.35	45.3-49.3	13.2-15.5	7.4-10.9	5.5-10.0	14.35-27.1
			(12.43)	(56.2)	(14.2)	(70.3)	(7.0)	(22.6)	(1.32)	(47.7)	(15.2)	(8.0)	(7.0)	(19.5)
	14	15-30	2.91-20.4	45.2-63.9	7.9-16.9	62.1-71.8	5.5-11.5	18.6-30.3	1.33-1.37	42.2-47.6	15.2-19.1	6.5-11.6	7.2-12.8	20.1-34.1
			(13.1)	(53.8)	(13.8)	(67.6)	(8.0)	(24.7)	(1.34)	(44.6)	(16.8)	(8.5)	(8.8)	(24.2)
E	8	0-15	10.1-63.2	57.6-63.4	10.1-16.6	71.1-75.3	4.9-9.1	17.8-22.4	1.31-1.35	44.7-51.3	13.3-15.5	7.8-10.4	5.1-7.1	12.85-19.78
			(33.9)	(60.4)	(13.41)	(73.8)	(6.3)	(19.8)	(1.32)	(47.1)	(14.7)	(8.4)	(6.3)	(16.9)
	8	15-30	19.1-91.2	51.3-62.5	6.8-16.6	63.3-74.4	5.2-9.5	18.1-30.4	1.33-1.37	40.8-48.3	15.8-17.4	7.6-9.6	7.0-9.4	19.6-25.6
			(54.4)	(56.3)	(11.8)	(68.1)	(6.9)	(25.0)	(1.34)	(43.9)	(17.0)	(8.7)	(8.3)	(22.0)
Ovearal range		0-15	2.31-63.2	43.8-63.4	6.8-20.5	60.6-76.8	3.5-10.5	17.9-31.7	1.32-1.41	42.2-51.4	13.2-20.5	5.4-10.9	4.3-13.3	9.35-32.85
Mean			(17.8)	(57.0)	(14.9)	(71.9)	(6.2)	(21.8)	(1.33)	(47.3)	(15.5)	(7.8)	(7.7)	(18.9)
		15-30	2.91-91.2	43.6-63.4	6.8-18.2	59.1-74.4	4.2-11.5	18.1-33.0	1.27-1.39	40.1-49.1	13.8-22.5	4.9-11.6	4.9-13.7	11.98-36.35
			(24.2)	(54.8)	(13.1)	(67.9)	(6.8)	(25.3)	(1.35)	(44.6)	(17.0)	(8.4)	(8.7)	(22.2)

Table 2: Physico-chemical characteristics and available nutrients status of surface and sub surface soils of DARS, Chettinad

Block	No. of soil samples analysed	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	CEC (c mol (p+) kg^{-1})	$CaCO_3$ ($g\ kg^{-1}$)	Available macronutrients ($kg\ ha^{-1}$) N	P	K	Available S ($mg\ kg^{-1}$)
A	22	0-15	4.8-6.4	0.10-0.41	3.6-6.0	6.1-7.1	1-2	129-174.0	20-28	126-201	10.53-18.61
			(5.5)	(0.15)	(5.2)	(6.5)	(1.7)	(157.0)	(24.0)	(177.0)	(14.90)
	22	15-30	4.7-6.0	0.10-0.27	1.8-4.7	6.2-6.8	2-3	77.0-141.0	8.0-19	101-171	5.43-13.92
			(5.3)	(0.13)	(3.3)	(6.712)	(2.3)	(113.0)	(13.0)	(132.0)	(9.70)
B	8	0-15	4.5-5.1	0.10-0.16	4.2-5.7	5.7-6.4	2-5	123-173.0	14-21	184-211	9.13-17.53
			(4.8)	(0.12)	(4.9)	(6.1)	(3.0)	(153.0)	(18.0)	(201.0)	(13.31)
	8	15-30	4.6-5.0	0.11-0.16	2.4-3.9	6.2-6.8	2-5	65-126.0	7.0-13	98-164.0	7.25-11.51
			(4.7)	(0.12)	(3.1)	(6.4)	(3.1)	(101.0)	(10.0)	(136.0)	(9.0)
C	20	0-15	4.7-6.5	0.10-0.13	4.3-6.7	6.3-6.8	0	131-195.0	18-27	153-284	11.36-18.85
			(5.4)	(0.10)	(5.7)	(6.5)	0	(171.0)	(23.0)	(236.0)	(15.33)
	20	15-30	4.6-6.1	0.09-0.16	2.8-4.6	6.5-7.1	0	74-128.0	9-18	101-186	5.13-12.63
			(5.3)	(0.11)	(3.9)	(6.7)	0	(104.0)	(14.0)	(156. 0)	(9.54)
D	14	0-15	4.5-5.7	0.09-0.14	3.0-6.0	6.3-6.8	0	176-209.0	16-27	186-319.0	10.45-18.41
			(5.0)	(0.11)	(5.0)	(6.5)	0	(195.0)	(24.0)	(270.0)	(14.88)
	14	15-30	4.5-5.6	0.09-0.14	1.2-4.6	6.5-7.1	0	89-124.0	11-19	107-191	5.63-13.03
			(5.0)	(0.11)	(2.6)	(6.8)	0	(119.0)	(15.0)	(148.0)	(9.48)
E	8	0-15	4.6-5.6	0.09-0.15	4.5-6.8	5.1-7.1	0-2	138-208.0	21-26	185-283	10.85-17.16
			(4.8)	(0.12)	(5.5)	(6.4)	(2.0)	(191.0)	(23.0)	(247.0)	(14.10)
	8	15-30	4.5-5.1	0.10-0.23	1.6-5.4	5.4-7.3	2-3	97-141.0	13-18	85-167	8.12-12.78
			(4.7)	(0.12)	(3.6)	(6.77)	(2.2)	(117.0)	(15.0)	(130.6)	(10.33)
Ovearal range		0-15	4.5-6.5	0.09-0.41	3.0-6.8	5.1-7.1	2.0-4.0	123 -209.0	14.0-28.0	126.0-319.0	9.13-18.85
Mean			(5.2)	(0.12)	(5.26)	(6.4)	(1.3)	(173.0)	(22.0)	(226.0)	(14.50)
		15-30	4.5-6.1	0.09-0.27	1.2-5.4	5.4-7.3	2.0-5.0	65.0-141.0	7.0-19.0	85.0-164.0	5.13-13.92
			(5.0)	(0.11)	(3.3)	(6.7)	(1.6)	(111.0)	(13.4)	(109.0)	(9.61)

Physico-chemical characteristics :

The pH of the soils ranged from 4.5 to 6.5 in surface soil (average 5.2) and 4.5 to 6.1 (average 5.0) sub-surface soil and majority of these soils are in moderately acidic in soil reaction and appeared to be related with acidic parent materials and leaching of bases caused by heavy precipitation. The decreasing trend in pH in subsurface soil, in general, could be due to the exchangeable H^+, $Al3^+$, Fe and Al oxides, soil organic matter and clay minerals (Fundamentals of Soil Science, 2009). The EC values varied from 0.09 to 0.41 dS m^{-1} (average 0.12) and 0.09 to 0.27 dS m^{-1} (average 0.11), suggesting low amount of soluble salts could be attributed to loss of bases (Sidhu *et al.,* 1994) due to heavy rainfall. The organic carbon content ranged from 0.3 to 0. 68 per cent and 0.12 to 0.54 per cent in surface soil (average 0.53%) and subsurface soil (average 0.33%), respectively. Higher organic carbon content was recorded in surface samples as compared to subsurface samples (Table 2).

The CEC values ranged from 5.1 to 7.1 and 5.4 to 7.4 c mol (p+) kg^{-1} in surface and sub surface soil which corresponds to clay content in the respective depths of soil sampling. $CaCO_3$ content was ranged from 2.0 to 5.0g kg^{-1} and soils were non calcareous in nature.

Soil fertility status :

The soil fertility status exhibits the status of different soils with regard to amount and availability of nutrients essential for plant growth (Table 3). The available nitrogen content of all the fields were low ranging from 123 to 209 kg ha^{-1} in surface soil and in subsurface soil varied from 65-141 kg ha^{-1}. However, available N content was found to be more in surface samples and decreased in sub surface samples, which might possibly be due to decreasing trend of organic carbon with depth. These observations are in accordance with the findings of Prasuna Rani *et al.* (1992). The available P content of soils was low to medium and varied from 14.0-28.0 kg ha^{-1} in surface samples and was low varied from 7.0 to 19.0 kg ha^{-1} in the sub surface soils. In majority of the surface soil the available P was low due to the fixation of released P by clay minerals and oxides of $Fe^{2+}$and Al $^{3+}$ Rajeshwar *et al* .(2009).

Table 3 : Available micronutrient status of surface and sub surface soils of DARS, Chettinad

Block	No of soil samples analysed	Depth (cm)	Available micronutrients (mg kg^{-1})				
			Zn	Cu	Mn	Fe	B
A	22	0-15	0.59-3.52	0.85-3.62	24.98-49.21	8.92-22.38	0.36-0.56
			(1.33)	(2.29)	(33.67)	(13.88)	(0.45)
	22	15-30	0.1-1.92	0.84-2.84	21.03-35.23	8.42-17.79	0.14-0.44
			(0.71)	(1.49)	(30.6)	(11.94)	(0.28)
B	8	0-15	0.29-1.29	1.51-2.91	26.18-36.89	11.72-17.42	0.42-0.47
			(0.81)	(1.88)	(31.12)	(13.72)	(0.45)
	8	15-30	0.16-1.88	0.79-1.43	25.1-35.75	9.63-15.33	0.14-0.39
			(0.69)	(1.15)	(30.67)	(12.54)	(0.25)
C	20	0-15	0.31-1.29	1.25-3.63	24.02-38.0	9.29-13.6	0.37-0.58
			(0.81)	(1.82)	(28.19)	(11.37)	(0.47)
	20	15-30	0.15-1.06	0.77-1.76	20.2-33.71	7.56-12.67	0.15-0.39
			(0.59)	(1.24)	(26.75)	(9.99)	(0.25)
D	14	0-15	0.50-2.29	0.94-3.48	30.14-48.28	11.08-21.95	0.40-0.64
			(1.307)	(2.25)	(35.93)	(14.61)	(0.46)
	14	15-30	0.21-1.92	0.72-2.82	23.08-40.28	9.21-18.07	0.14-0.39
			(0.79)	(1.69)	(32.21)	(12.55)	(0.23)
E	8	0-15	0.45-1.76	0.92-1.91	27.95-31.65	9.03-16.98	0.42-0.62
			(0.96)	(1.46)	(29.67)	(11.2)	(0.49)
	8	15-30	0.17-0.49	0.76-1.26	20.2-28.55	7.77-15.78	0.15-0.26
			(0.34)	(0.99)	(24.8)	(9.89)	(0.22)
Ovearal range		0-15	0.10-3.52	0.85-3.63	24.02-49.21	8.9-22.38	0.36-0.64
Mean			(1.04)	(1.94)	(31.71)	(12.95)	(0.46)
		15-30	0.29-1.92	0.72-2.84	20.2-40.28	7.56-18.07	0.14-0.44
			(0.62)	(1.31)	(29.06)	(11.38)	(0.25)

The data in parenthesis ( ) indicate the average values

The availability of K content of soils medium to high and varied from 126 to 319 kg ha^{-1-} in surface soils and 85.0 to 164.0 kg ha^{-1} in sub surface soils. The high available K in surface soils could be attributed to more intensive weathering, release of labile-K from organic residues of cultivated crop plants and upward translocation of K from lower depths along with capillary rise of ground water. Similar results were reported by Pal and Mukhopadhyay (1992). The available S content of soils low to medium varied from 9.13 to 18.85 and 5.13 to 13.92 mg kg^{-1} in both the surface and sub surface soil, respectively. In soil sulphur is continuously cycled between inorganic sulphur and organic forms of sulphur (Pasricha and Fox, 1993). Similarly, the organic sulphur is also in equilibrium with inorganic counterpart and if there is any decline in inorganic $SO^{4-}S$ level by means of crop uptake or leaching loss, it will be adequately replenished by the organic fraction.

The DTPA extractable Zn content varied from 0.10 to 3.52 mg kg^{-1} and 0.29 to 1.92 mg kg^{-1} in surface and sub surface soils(Table 3). Considering 1.2 mg kg^{-1} as critical level (Muhr *et al.*, 1965), it was found that 70 per cent of the surface soils are deficient in Zn availability. The availability was low in subsurface soil than surface soil which might be due to accumulation of comparatively more amount of organic matter as reported by Jalali *et al.* (1989) and Nayak *et al.* (2000). The DTPA extractable Cu content varied from 0.85-3.63 mg kg^{-1} and 0.72-2.84 mg kg^{-1} in surface and subsurface soils, respectively. Considering 1.2 mg kg^{-1} as critical level (Muhr *et al.*, 1965), it was found that 90 per cent of the surface soils are sufficient. The available Cu was more in surface soils than sub surface soils, with depth, which might be due to its association with organic carbon affecting its availability in surface layers (Rajeshwar and Ariff khan,2007).The available Mn content of these soils varied from 24.0-49.21mg kg^{-1} and 20.2 to 40.28 mg kg^{-1} soil in both the surface and sub surface soils, respectively. Considering 2.0 mg kg^{-1} as critical level (Muhr *et al.*, 1965), it was found that all the surface subsurface soils are high in availability. It was high in the surface soils and gradually decreased in sub surface soils might be due to its presence in the reduced forms in surface and subsurface soils and higher biological activity and organic carbon in the surface soils. These observations were in agreement with the findings of Murthy *et al.* (1997) and Nayak *et al.*(2000).The DTPA extractable Fe content varied from 8.9-22.38 mg kg^{-1} and 7.56 to 18.07 mg kg^{-1} soil in both the surface and sub surface soils, respectively. Considering 3.7 mg kg^{-1} critical limit (Muhr *et al.*, 1965), the soils were sufficient in available Fe. It was high in the surface soils when compared to the sub surface soils might be due to accumulation of humic material in the surface soils besides prevalence of reduced conditions in sub surface soils. The findings are in agreement with the findings of Prasad and Sakal (1991). The hot water soluble boron content varied from 0.36 - 0.64 $mgkg^{-1}$ and 0.14 - 0.44 mg kg^{-1} soil in both the surface and sub surface soils, respectively. Considering the critical limit of 0.46 mg kg^{-1}, the soils were very low in availability. It was high in the surface soils when compared to the sub surface soils might be due to accumulation of organic matter and well drained condition in the surface soils.

The nutrient index value was worked out to know the fertility rating of available macro and micronutrients in the surface and sub surface soils of different blocks of Research station (Table 4). Based on Nutrient Index values and soil fertility ratings the soil samples found to be very low of N (1.00), P (1.4 and 1.0), Zn (1.39 and 1.05) and B (1.23 and 1.00) in both the surface and sub surface soil respectively. Adequate values recorded in availability of K (2.15 and 1.90), high and low (2.47 and 1.47) in availability of S and high in availability of Cu (2.91 and 2.58), Mn (3.00) and Fe (3.00) in surface and subsurface soils, respectively. Very high Fe fertility in the soils might be attributed to acidic soil reaction (Sood *et al.*, 2009). Very high fertility rating of Mn in the soils of could be attributed to the oxidation of divalent Mn^{++} to trivalent Mn^{+++} by certain fungi and by the organic compounds synthesized by micro- organisms and plants (Vijayakumar *et al.*,2011). The low nutrient index values of surface and sub surface soils may be attributed to several factors. Among these some of the factors causing low availability and deficiency in the red and lateritic soils are inherent to soil properties and others are induced by manmade activities. Among these low native nutrients content, coarse texture, inherent low organic matter content and soil conditions that favour leaching losses.

Correlation studies :

Simple linear correlation studies of nutrient availability were made with various physio-chemical characteristics in surface and sub surface soils are shown in Table 5 and 6, respectively.

Table 4: Nutrient index values of soil available nutrients status of DARS, Chettinad

Sr. No.	Depth (cm)	No. of samples	Nutrient index values and fertility ratings								
			N	P	K	S	Zn	Cu	Mn	Fe	B
1.	0-15	72	1.00	1.40	2.15	2.47	1.39	2.91	3.00	3.00	1.23
			(Very low)	(Low)	(Adequate)	(High)	(Low)	(Very high)	(Very high)	(Very high)	(Very low)
2.	15-30	72	1.00	1.00	1.90	1.47	1.05	2.58	3.00	3.00	1.00
			(Very low)	(Very low)	(Marginal)	(Low)	(Very low)	(High)	(Very high)	(Very high)	(Very low)

Soil fertility ratings: > 1.33 – Very Low; 1.33 – 1.66 – Low, 1.67 – 2.00 – Marginal, 2.0 – 2.33 – Adequate ; 2.33 – 2.67 – High; < 2.67 – Very high.

Relation between soil physical properties and organic carbon:

Correlation co-efficients physical properties and organic carbon of surface soils found that (Table 5) the sand was negatively correlated with silt, clay, organic carbon, water retention at field capacity, available water content and maximum water holding capacity (r = -0.382**, -0.933**,-0.253*-0.648*,-0.621* and -0.792*, respectively) and it was positively correlated with bulk density and pore space (r = 0.384** and 0.662**, respectively). The silt negatively correlated with bulk density (r = -0.276*). The clay content positively correlated with organic carbon, water retention at field capacity, available water content and maximum water holding capacity (r = 0.291*,0.729**0.682**and 0.823**, respectively) and it was negatively correlated with bulk density and porespace (r = -0.309**and-0.704**). The bulk density significantly positively influenced by porespace(r=0.304**) and it is negatively correlated with wilting point and maximum water holding capacity (r= -0.250* and 0.284*, respectively). The porosity negatively correlated with water retention at field capacity, available water content and maximum water holdingcapacity (r = -0.556 **, -0.549**and -0.681 **, respectively). The water retention at field capacity is positively correlated with wilting point, available water content and maximum water holding capacity (r = 0.336**, 0.814**and 0.838**, respectively).

Relation between physico-chemical properties and nutrient availability of soils :

In surface soils pH had significant positive correlation with EC, organic carbon and sulphur (r = 0.239*, 0.293* and 0.241*, respectively) similar relationship was reported by Kumar and Babel (2011) and significantly negative correlated with $CaCO_3$ (r =- 0.302**). The pH had positive correlation but not significant with CEC, available P, Zn and Mn and negative correlation with available N, K, Fe and B. The positive non-significant correlation between Zinc and soil pH with value of r= 0.114. Similar results were studied by Sadashiva *et al.* (1995) and Patiram *et al.* (2000). The correlation co-efficient (r) obtained between hot water soluble boron and soil pH was -0.118. The result was negative non-significant and this result was supported by Abid *et al.* (2002). The EC was

Table 5: Correlation between soil physical properties of surface soils and organic carbon

	Sand	Silt	Clay	OC	BD	Pore space	33 kpa	1500 kpa	AWC	MW.H.C
Sand	1.00	-0.382**	-0.933**	-0.253*	0.384**	0.662**	-0.648**	-0.159	-0.621**	-0.792**
Silt		1.00	0.030	-0.035	-0.276*	-0.019	-0.042	-0.036	-0.006	0.115
Clay			100	0.291*	-0.309**	-0.704**	0.729**	0.180	0.682**	0.823**
OC				1.00	-0.051	-0.189	0.216	0.031	0.177	0.255*
BD					1.00	0.304**	-0.191	-0.250*	-0.081	-0.284*
Pore space						1.00	-0.556**	-0.126	-0.549**	-0.681**
33 kpa							1.00	0.336**	0.814**	0.838**
1500 kpa								1.00	-0.170	0.041
AWC									1.00	0.879**
MW.H.C										1.00

AWC-Available water content MWHC-Maximum water holding capacity, *. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 6 : Correlation between soil physico-chemical properties and available nutrients

	pH	EC	OC	CEC	$CaCO_3$	N	P	K	S	Zn	Cu	Mn	Fe	B
pH	1.00	0.239*	0.293*	0.131	-0.302**	-0.127	0.201	-0.128	0.241*	0.114	0.233*	0.021	-0.022	-0.118
EC	.	1.00	-0.153	0.103	0.033	-0.152	0.078	-0.190	0.090	0.092	0.228	-0.001	-0.114	-0.142
OC			1.00	0.071	-0.096	0.051	0.115	0.069	0.000	0.108	0.024	-0.060	-0.111	0.115
CEC				1.00	-0.296*	0.258*	0.273*	0.259*	-0.073	-0.002	0.241*	-0.023	-0.242*	-0.055
$CaCO_3$					1.00	-0.139	-0.437**	-0.088	-0.279*	-0.118	-0.088	0.043	-0.103	-0.020
N						1.00	0.184	0.671**	0.073	-0.024	-0.031	0.146	-0.135	0.046
P							1.00	0.024	0.131	-0.280*	0.192	0.056	0.018	-0.070
K								1.00	0.067	-0.033	0.014	0.035	-0.119	-0.021
S									1.00	0.001	0.045	0.086	0.162	0.078
Zn										1.00	0.390**	0.220	0.269*	-0.280*
Cu											1.00	0.103	0.052	-0.194
Mn												1.00	0.723**	0.030
Fe													1.00	0.092
B														1.00

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

positively correlated but not significant with CEC, $CaCO_3$, available P, S, Zn and Cu and non-significant negative correlation with OC, available N, K, Fe and B. The OC was positively correlated but not significant with availability of N, P, K, Cu and B. Availability of N, P, K and Cu in the soils was significantly influenced by exchangeable CEC (r= 0.258*, 0.273* and 0.259* and 0.241*, respectively) and it was negatively correlated with $CaCO_3$ and Fe (r= -0.296* and -0.242*, respectively). Similar results were reported by Chaudhari *et al*. (2012).The $CaCO_3$ negatively correlated with available P and S (r = -0.437** and -0.279*) and it was non-significant negatively correlated with N, K, Zn,Cu and B. The result showed that there was negative non-significant correlation between copper and lime. These results are similar to those of Sudhir *et al.* (1997)

The availability of N positively correlated with available K (r = 0.671**) and have positive correlation but not significant with available P,S, Mn and B. The availability of P was negatively correlated with availability of Zn (r= -0.280*) and have positive correlation but not significant with available K, S, Cu, Mn and except B. The availability of Zn was positively and significantly correlated with availability of Cu and F and negatively correlated with B (r= 0.390**, 0.269* and -0.280, respectively).The availability of Mn was positively and significantly correlated with Fe (r= 0.723**).

Constraints and management :

These soils have light surface texture and gravelliness with kaolinite clay mineralogy resulting in poor water holding capacity. Surface crusting is common problem in this soil. The low water-holding capacity does not permit post-rainy season cropping without irrigation. Surface soils are denuded and subject to serious erosion problems by runoff process. Laterite soils have moderate acidity and are deficient in phosphorus. They are deficient in nitrogen, calcium, magnesium, zinc and boron. Improved soil management practices with suited crops have good potential to enhance the crop productivity on these soils.

Application of lime :

Spreading lime remains the most effective remedy for soil acidity. It is the only cost-effective option for acidic agricultural soils. Liming may result in substantial crop yield responses for several years, as well as allowing or improving crop production.

Application enriched rock phosphate:

Recommended quantity of FYM enriched rock phosphate and zinc sulphate to be applied for different crops to enhance the phosphorus and zinc use efficiency and maintain the soil quality.

Green manuring :

Pre-monsoon sowing of green manures and incorporation at flowering stage will enhance the nitrogen availability and reduce surface crusting problem by creating favourable soil physical environment.

Application of organic manures :

Available quantity of farmyard manure, composted coirpith and other organic sources will be recommended to neutralize the soil pH and other soil quality attributes such as CEC, organic carbon and microbial load of the low pH soil.

Application of biochar :

Application of biochar @ 5 -10 t ha^{-1} in red laterite soil increased the pH from 5.7 to 6.1. Hence, it is recommended to convert the available quantity crop waste in to biochar and apply in low pH red laterite soil not only enhance the soil pH and also enhance the carbon sequestration potential.

Application of lime :

Based on the soil pH, required quantity of lime must be applied to rise soil pH and enhance the crop productivity. Commonly lime 2 t ha^{-1} is recommended to ameliorate the acid soil. Maintenance of surface pH above 5.5 to allow movement of lime into the subsurface. More than one application of 1.0-1.5 t/ha of lime is likely to be required over a number of years or application of higher rates of lime (2-5 t/ha) to reach the desired surface pH. Using higher rates of lime may expose crops to nutrient deficiencies, particularly manganese and zinc.

Raising of soil pH :

Decreases the level of available aluminum and manganese in the soil. Increases the availability of phosphorus, magnesium, calcium and molybdenum. Improves plant establishment and vigour. Improves nodulation in legumes and Improves the persistence of different crops.

Reduce leaching of nitrogen :

Use split application of nitrogen fertilizers along with phosphorus and Zn for maximizing the crop yield; use lower rates of less acidifying fertilizers; avoid acidifying fertilizers such as mono ammonium phosphate or sulphate of ammonia.

Crop rotation :

Growing legume plants tend to take up more cations in proportion to anions. As a consequence, H^+ ions are excreted from their roots to maintain the electrochemical balance within their tissues. This leads to a rise in soil acidification. Hence, crop rotation with cereals crop is mandatory.

Conclusion :

Soils of the study area were deficient in nutrients like N, P, S, Zn and boron. Surface crusting and surface droughtiness are the major problems that are associated with these soils because of the low organic matter content, low exchangeable bases and the sandy texture of the soils. These soils are deep and ideal for growing food crops, horticultural and very deep rooted perennial crops. The soils are well drained both internally and externally. They don't possess the problems of alkalinity, calcareousness and salinity. Maintenance of enhanced soil fertility, improved soil aggregation and reduced surface sealing and crusting, decreased runoff, soil erosion and increased structural stability of the soils are to be needed to sustain the soil health as well as improving the crop yields.

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