Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

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Differences in distribution of Physico chemical properties and available nutrients status in some red, red laterite and black Soils in semi arid region of Tamil Nadu

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Abstract
The study was carried out in the three new research stations of Tamil Nadu Agricultural University with varied soil types viz., Maize Research Station, Vagarai of Dindigul district, Cotton Research Station, Veppanthatai of Perambalur district and Dryland Agricultural Research Station, Chettinad of Sivagangai district of Tamil Nadu were selected for developing the strong soil resource database for proper appraisal of their productivity potential and their rational use. This study was an embodiment with an objective of distribution of physico-chemical properties, available macro and micro nutrients in some red, red laterite and black soils of semi arid region of Tamil Nadu. Based on the morphological characteristics and land elevation, thirteen representative geo-referenced pedons were selected and horizon wise soil samples were collected. The red laterite soils had lower pH values ranged from moderately acidic to slightly acidic followed by red (neutral to strongly alkaline) and higher pH values in black soils (moderately alkaline to strongly alkaline) with non saline in nature. The organic carbon showed wide variation and the values were found to be vary from low to medium (2.8 to 6.5 g kg^{-1}) in surface horizons whereas in subsurface horizons it was low and ranged from 0.70 to 5.0 g kg^{-1}. The CaCO$_3$, CEC, base saturation and CEC/clay ratios were higher in black soil pedons compared to red and red laterite soils. Higher values of CEC/clay ratios indicating that the black soils are less weathered than the red soils and red laterite soils. The exchangeable bases in the red and black soil pedons are in order of $Ca^{+2} > Mg^{+2} > Na^+ > K^+$ on the exchange complex. The exchangeable bases of red laterite soils were in order $Ca^{+2} > Mg^{+2} > K^+ > Na^+$. The soils are low in available N, low to high in available P in red and black soils and low to medium in red laterite soils, medium to high in available K and high in available S in surface horizons when compared to subsurface horizons. The soils are deficient to sufficient in available Zn, Cu, Fe and B and sufficient in available Mn. The red soils are shallow, marginally suitable to highly suitable for cultivation of maize, greengram, sorghum, redgram and blackgram. The black soils are very deep, moderately suitable to highly suitable for cultivation of cotton, sorghum, soybean, greengram, blackgram, redgram, sunflower, sesamum, maize and pearlmillet. The red laterite soils are very shallow to deep, marginally suitable to moderately suitable for cultivation of groundnut, greengram, blackgram, redgram, horsegram and pearlmillet.

Keywords: Depth wise distribution of physico-chemical propertis; Available Macro and Micro nutrients: Crop suitability of some Red, Red Laterite and Black Soils of semi arid region

Introduction

In the recent past, productivity of agricultural soils worldwide in general on the decline, which prompted the per capita availability of food grain fell from 510 g per day (1991) to 463g per day (2004). These declining trends across the world attributed to ever growing population, raising incomes of populous Asian nations and discovery of new uses such as bio fuels, besides weather based abnormalities owing to climate change (Sidhu and Kamal Vatta, 2008) [38]. Under these circumstances to ensure self sufficiency and food security is challenging tasks before the populous nations like India.

The nutrient 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 19 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.

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The detail field wise study of physico-chemical characteristics, available macro, secondary and micronutrients status in the soil profiles 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, red laterite and black soils to provide a base line data and information in semi arid region of Tamil Nadu.

Location, climate and brief discussion of the study area
Materials and methods
The Maize Research Station (MRS) at Vagarai of Dindigul district is surrounded between $10^0.570'$ N latitude and $77^0.56'$ E longitudes and is situated at an altitude of 254.45 m above Mean Sea Level with physiographically the land is characterized nearly level to gently sloppy in nature. The Cotton Research Station (CRS), Veppanthattai of Perambalur district bounded in between $11^0.326'$ N latitude and $78^0.832'$E longitudes and situated at an altitude of 147 m above Mean Sea Level. Physiographically the land is characterized by flat terrain level to nearly level. The soils of the research station are very deep, calcareous, clayey, moderately well drained with slow permeability and low hydraulic conductivity. The Dryland Agricultural Research Station, Chettinad is surrounded between $10^0.166$ to $10^0.179$ N latitude and $78^0.785$ to $78^0.805$ 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 (1-3%) in nature. The climate of the study area is hot and dry in summer and temperature is low during the month of January and the lowest mean daily temperature is 19.8 to 21.0º C. The temperature begins to rise after March and the hottest month is July during which period the maximum temperature is 36.0 to 40ºC. Mean humidity varies from 65 per cent in July to 80 per cent in December. The mean annual rainfall of the study area is 700-1080 mm. The North East monsoon contributes 45% of the annual rainfall from October to December. South West monsoon also contribute 37 % 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. The soil moisture and soil temperature regimes of the study area are Ustic and Iso-hyperthermic respectively.

The natural vegetation existing in the study area are grasses, shrubs, thorny bushes such as *Cynodon dactylon, Cyprus rotundus, Butea frondosa, Dalbergia latifolia, Azadirachta indica, Tectona grandis, Terminalia tomertose and Acacia spp. Prosopis juliflora, Cacia sp*, broad leaf weeds such as *Selotia, Parthenium, Eucalyptus, Euforbia* sps., etc. The principal crops cultivated and research focused in this station is on maize, cotton, groundnut, redgram, horsegram, greengram, blackgram, pearlmillet and onion.

Collection and processing of soil samples
Based on the morphological characteristics and physiography, geo-referenced three pedons were selected at Maize Research Station, Vagarai, two pedons at Cotton Research Station, Veppanthattai and eight pedons at Dryland Agricultural Research Station Chettinad. Horizon wise soil samples were collected from the representative thirteen pedons for laboratory analysis. A composite sample of about 1kg was taken through mixing of representative soil samples. The soil samples were air-dried in shade, processed and screened through a 2 mm sieve. Particles greater than 2mm were considered as gravel. After sieving, all the samples were packed in the polythene bags for determination of physical, and physico-chemical and chemical properties.

Methods used for analysis
The soil samples representing each pedon were characterized for physico-chemical properties and chemical properties using standard procedures. Soil pH and EC was determined in 1:2.5 soil water suspensions, exchangeable cations (Jackson, 1973) [11], cation exchange capacity (Chapman, 1965), organic carbon and free calcium carbonate were determined (Walkly and black, 1934 and Piper 1966) [43, 26] respectively. The available nitrogen was determined by kjeldal method (Subbiah and Asija, 1956) [41], available phosphorus was estimated by spectrophotometer and potassium by flame emission method (Jackson, 1973) [11]. Available sulphur in the soil was extracted using 0.15% CaCl2 solution (Williams and Steinbergs, 1959) [44]. The available micronutrients were determined using the method given by Lindsay and Norvell, 1978 [13]. Hot water soluble (HWS) Boron was determined by using method as described by Jackson, (1958) [10].

Results and Discussion
Physico - Chemical Properties
The pedon wise physico-chemical properties of respective research stations are described in Table 1. Soil pH of the pedons showed wide variation and the values found to vary from 4.71 to 8.57 in surface horizons whereas in subsurface horizons ranged from 4.40 to 9.13. The results showed that the pedons of red laterite soils had lower pH values in the range of 4.71 to 6.59 in surface horizons and 4.40 to 6.32 in subsurface horizons (moderately acidic to slightly acidic) followed by red soils in the range of 7.45 to 8.10 in surface horizons and 7.56 to 8.80 in subsurface horizons (neutral to strongly alkaline) and higher pH values recorded in black soils in the range 8.48 to 8.57 in surface horizons and 8.87 to 9.13 in subsurface horizons (moderately alkaline to strongly alkaline). The pH values were increasing with depth in the pedons 1, 3, 4, 9 and 13 might be due to increase in bases with depth and their complete downward leaching. The pedons 10 and 11 showed decreasing trend which might be due to the chemical weathering which leads to accumulation of exchangeable H^+, Al^{3+}, Fe and Al oxides and clay minerals (Bipul Deka *et al.,* 2009) [4]. The distribution was irregular in pedons 2, 5, 6, 7, 8, 11 and 12 which might be due to downward movement of bases and they get adsorbed at different layers irregularly. The lower pH values in surface layers of pedon 1, 3, 4, 5, 7, 8, 9, 11, 12 and 13 which might be due to continuous removal of basic cations by crop plants and leaching (Nagassa and Gebrekidan, 2003) [18], movement of basic cations to deeper layers (Singh and Agarwal, 2003) [40] and / or due to precipitation of calcium carbonate (Balapande *et al.,* 2007) [2]. The pedons of red laterite soils had lower pH values varied from 4.71 to 6.59 in surface horizons and 4.40 to 6.32in subsurface horizons and majority of these soils are moderately acidic in soil reaction and appeared to be related with acidic parent materials and leaching of bases such as calcium, magnesium, potassium and sodium from the soil leading to high hydrogen ion concentration caused by heavy precipitation during rainy season (Nayak *et al.*, 2002) [20].

The EC was very low in red and red laterite soils even in lower horizons because they were formed on relatively higher elevations. The relatively high EC of black soils than red soils

could be due to the location and the high clay content resulting in accumulation of soluble salts. The electrical conductivity of pedons ranged from 0.02 to 0.72 dS m^{-1} indicating that these soils were non saline in nature (Masri Sitanggang *et al.,* 2006) [15]. The EC gradually increased with depth in majority of the pedons. This may be due to the leaching of electrolytes to the lower depth and also due to foraging of nutrient ions by the vegetation in the surface layer. These observations are in agreement with the findings of Renukadevi (2003) [33]. The EC values suggesting low amount of soluble salts which could be attributed to loss of bases (Sidhu *et al.,* 1994) [31] due to heavy rainfall during monsoon.

The organic carbon showed wide variation and the values found to vary from low to medium (2.8 to 6.5 g kg^{-1}) in surface horizons whereas in subsurface horizons it was low and ranged from 0.70 to 5.0 g kg^{-1}. The results showed that the pedons of red laterite soils had lower lower organic carbon values in the range of 2.8 to 6.5 g kg^{-1} in surface horizons and 1.0 to 5.0 g kg^{-1} in subsurface horizons (low to medium) followed by red soils in the range of 5.2 to 5.6 g kg^{-1} in surface horizons and 2.4 to 4.5 g kg^{-1}in subsurface horizons (low to medium) and values recorded in black soils in the range of 5.4 to 5.5 g kg^{-1} in surface horizons and 0.7 to 4.6 subsurface horizons (low to medium). The low to medium content of OC could be attributed to the rapid oxidation and decomposition of added organic matter under tropical condition and lesser addition of organic manures in the block (Saha *et al.,* 1996, Mustapha *et al.,* 2011) [34]. The organic carbon content relatively higher in surface horizons was higher than sub-surface horizons in all the pedons and it decreased with depth. This was attributed to the addition of farmyard manure and plant residues to surface horizons which resulted in higher organic carbon content in surface horizons than that of lower horizons. These observations are in accordance with results of Rajeshwar *et al.* (2009) [28]. Organic carbon had positive relation with the availability of all nutrients (Table 31) which might be due to chelating action (Meena *et al.,* 2006) [17].

The calcium carbonate content of red laterite soil pedons (6 to 13) was very low ranging from 0.00 to 0.4 per cent. The red soil pedons (1, 2 and 3) is having low to high (0.5 to 15.3 per cent) whereas, in the black soil pedons (4 and 5) containing 7.3 to 15.5 per cent (medium to high). The difference in the content among red and black soils was due to the variation in elevation, drainage and parent material. The black soils were developed over granitic gneiss mixed with calcareous murram on plain topography and had higher clay content resulting in the accumulation of calcium carbonate. The content was relatively higher in deeper layers than in surface layers might be due to the downward movement of it along with percolating water (pedogenic and / or lithogenic) in soils of semi-arid regions (Pal *et al.,* 2000) [23]. Maji *et al.* (2005) [14] stated that increase in the calcium carbonate content down the depth was attributed to the leaching of bicarbonate from upper layer during rainy season and their subsequent precipitation as carbonate in the lower layer. The irregular distribution of CaCO$_3$ in pedons 2, 4 and 5 with depth could be due to the variable nature of the geological material (Rajkumar *et al.,* 2005) [32]. The calcium carbonate content of red laterite soil was very low which is in non-calcareous followed by red soil which is in the range of non-calcareous to calcareous whereas, in the black soil pedons containing medium to high amount in the range of slightly calcareous to calcareous. The relation between pH and CaCO$_3$ were positively correlated

(r=0.789**) (Table 3). Similar types of correlations were reported by Satyavathi and Reddy (2004) [35], Basavaraju *et al.* (2005) [3] and Thangasamy *et al.* (2005) [42] in red and black soils of Andhra Pradesh.

The exchange capacity in black soil pedons ranged from 44.6 to 45.5 c mol (p+) kg^{-1} in surface horizons and 46.4 to 48.8 c mol (p+) kg^{-1} in subsurface horizons. The high CEC of black soils was attributed to the smectitic clay mineralogy. The CEC/clay ratios were found to vary from 0.75 to 0.84 than in red soils pedons and red laterite soil pedons. Since CEC was the charge behaviour of soils, where clay was the fundamental block contributing towards cation exchange, the high CEC of the black soils was attributed to the high clay content and smectitic clay mineralogy (Pal and Deshpande, 1987) [21]. The low cation exchange capacity (CEC) values varied from 5.3 to 7.5 c mol (p+) kg^{-1} in red laterite soils pedons of whereas CEC/clay ratio ranged from 0.16 to 0.36. The CEC of the red laterite soils was quite low despite high clay content indicating that the dominance of low activity clay minerals. The CEC values of red soil pedons were ranged from 15.0 to 35.6 c mol (p+) kg^{-1}, whereas CEC/clay ratios was found to vary from 0.55 to 0.77. The CEC values are indicating that the black soils are less weathered than the red soils and red laterite soils. Higher values of CEC/clay ratio indicate the less weathered nature of the soils with weather able primary minerals (Buol *et al.,* 1998) [5]. The relation between CEC and clay were positively correlated (r=0.886**).

The exchangeable bases in the red and black soil pedons (1, 2, 3, 4 and 5) were in order of Ca^{+2} > Mg^{+2} > Na$^+$ > K$^+$ on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it is evident that Ca^{+2} shows the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K$^+$ and Na$^+$) it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility. These results are in conformity with findings of Thangasamy *et al.,* 2005 [42]. The exchangeable cations of red laterite soils (pedons 6 to 13), the exchangeable bases were in order Ca^{+2} > Mg^{+2} > K$^+$ > Na$^+$. Low exchangeable Na and K percentage was noticed in all the pedons as the exchange complex was dominated by divalent cations like Ca and Mg.

The percent base saturation was very high in black soils pedons (4 and 5). This could be due to the dominance of smectitic type of clays and moderate to strongly alkaline reaction. These results were in accordance with the findings of Singh and Agarwal (2005) [39] and Gabhane *et al.* (2006) [8]. The red soils (pedons 1, 2 and 3) were having either mixed or illitic mineralogy in clay fraction and neutral to slightly alkaline reaction, hence, the base saturation values were lower than those of black soils. Pillai and Natarajan (2004) [25] reported similar extent of base saturation. The red laterite soils pedons (6, 7, 8, 9, 10, 11, 12 and 13), were exhibited kaolinite mineralogy in clay fraction and moderately acidic to slightly acidic reaction, hence, the base saturation values were lower than those of black soils and red soils. The correlation studies also revealed that BSP was positively influenced by soil pH (0.908**) and CEC (0.820**).

The Exchangeable Sodium Percentage (ESP) was ranges between 0.29 percent in pedon 11 and 5.20 percent in pedon 4 in surface horizons whereas in subsurface horizons ranged from 0.44 percent in pedon 6 to 7.56 percent in pedon 5. The pedons 5 and 11 was found to follow an increasing trend with the increase in depth for ESP and the pedons 3, 6, 7 and 10 exhibited decreasing trend. All other pedons exhibited an irregular distribution pattern with the increase in depth. Similar observations reported by Patel *et al.* (2012). The

Sodium absorption Ratio (SAR) was ranges between 0.014 in pedon 11 and 0.41 in pedon 4 in surface horizons, whereas in subsurface horizons ranged from 0.021 percent in pedon 7 to 0.58 in pedon 5. The pedons 1 and 5 were found to follow an increasing trend with the increase in depth for SAR and the pedons 3, 6, 7 and 10 exhibited decreasing trend. All other pedons exhibited an irregular distribution pattern with the increase in depth.

Available major nutrient status
The available nitrogen content of all the pedons were low in range varied from104.0 kg ha^{-1} to 200.0 kg ha^{-1} (Table 2) in surface horizons, whereas in subsurface horizons ranged from 40.0 to 115.0 kg ha^{-1}. However, available N content was found to be relatively high in surface horizons and decreased in sub surface horizons, which might possibly be due to decreasing trend of organic carbon with depth. These observations are in accordance with the findings of Rajeshwar and Mani (2013) [30].

The available P content of soils was medium to high in surface horizons of red and black soils respectively. The available phosphorus content of the pedons varied from 16.3 kg ha^{-1} to 23.2 kg ha^{-1} in surface horizons, whereas in subsurface horizons ranged from 7.8 to 20.8 kg ha^{-1} where the soil pH is more than 7.0 (Olsen method). The reason for higher P in surface horizon might possibly be the confinement of crop cultivation to the rhizosphere and supplementing of the depleted phosphorus through external sources i.e. fertilizers. Similar results were reported by Thangasamy et al. (2005) [42].

The available phosphorus content was low to medium in red laterite soils pedons varied from 11.0 to 29.0 kg ha^{-1} in surface horizons, whereas in subsurface horizons ranged from 7.0 kg ha^{-1} to 22.0 kg ha^{-1} where the soil pH is less than 7.0 (Brays method). The availability of P in laterite soils was low which might be due to due to low CEC, clay content and low pH of these soils causes P fixation with Fe or Al ions and hydroxides resulting in deficiency of phosphorus in the form of insoluble compound of $Al_2(H_2PO_4)_3$ and FeH_2PO_4. The results are in conformity with the findings of Pandey et al (2000). However, relatively higher available P was observed in the surface horizons and decreased regularly with depth. The available phosphorous shows non significant positive correlation (Table 3) with clay (r=0.058) and significant correlation with organic carbon (r =0.733**) content (Yadav and Meena, 2009) [45].

The content of available potassium in all the pedons varied from low (101.0 kg ha^{-1}) to high (598 kg ha^{-1}) in surface horizons, whereas in subsurface horizons ranged from 42.0 to 390 kg ha^{-1}. The highest available K content was noticed in the surface horizons and showed decreasing trend with depth in all the pedons. The available K was more in surface horizons could be attributed to release of labile-K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water. Similar results were reported by Pal and Mukhopadyay (1992) [22] and Rajeshwar and Mani (2013) [30].

The available sulphur content ranged from 25.27 to 68.85 mg kg^{-1} in surface horizons and in subsurface horizons ranged from 17.25 to 59.19 mg kg^{-1}. The availability of S was more in surface horizon than the subsurface horizons might be due to soil sulphur is continuously cycled between inorganic and organic forms of sulphur (Ghosh et al., 2012) [9]. 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 (Pasricha and Fox, 1993) [24]. The available sulphur shows significantly positive correlation with zinc (r = +0.368**), organic carbon (r = + 0.367**) content of soils and with CaCO$_3$ (r = 628**). These results are in conformity with findings of Sharma et al., (2004) [36].

Available micronutrients
The DTPA extractable Zn content varied from 0.66 to 2.62 mg kg^{-1} in surface horizons, whereas in subsurface horizons ranged from 0.20 to 1.13 mg kg^{-1} (Table 2). The available zinc content decreased with the depth in all pedons. The availability was more in surface soils which might be due to accumulation of comparatively more amount of organic matter and supplementing ZnSO$_4$ through external sources as reported by Jalali et al., (1989) [12] and Nayak et al., (2000) [19]. The available zinc content in soil shows significantly positive correlation with OC (r = 0.692**), clay (r = 0.166) and phosphorous (r = 606**), N, K S, Cu and B content of soils (Yadav and Meena, 2009) [45].

The DTPA extractable Cu varied from 0.58 to 3.13 mg kg^{-1} in surface horizons, whereas in subsurface horizons ranged from 0.46 to 2.65 mg kg^{-1}. A decreasing trend with depth was noticed in all the pedons except 11 and 12, which were showing irregular trend with depth. The available copper was more in surface layers and decreases with depth. Dipak Sarkar and Sahoo (2000) [7] and Rajeshwar et al. (2009) [28] also reported similar findings. The available Cu content in soil shows significantly positive correlation (Table 3) with OC (r = 0.626**). Similar types of correlations were reported by Thangasamy et al. (2005) [42].

The available Mn content of these soils varied from 9.27 to 28.22 mg kg^{-1} in surface horizons, whereas in subsurface horizons ranged from 5.15 to 30.84 mg kg^{-1}. A decreasing trend with depth was noticed in pedons 1, 2, 3, 4, 5, 7 and 10. The remaining pedons 6, 8, 9, 11,12 and 13 showing irregular trend with depth where increase in manganese content up to certain depth and decreased in its bottom layer. The higher Mn status in the surface soils may be attributed to the lower oxidation, acidic nature of the soils and also due to the release of chelated Mn from the organic compounds. Similar findings were reported by Sharma and Chaudhary (2007) [37], Rajeshwar and Ariff Khan (2007) [29] and Arokiyaraj et al., (2011) [1]. The relation between pH and manganese (r = -0.682**), CaCO$_3$ and manganese (r = 0.679**) and clay and manganese (r = 0.529**) were negatively correlated. Similar types of correlations were reported by Satyavathi and Reddy (2004) [35]; Basavaraju et al. (2005) [3]; Thangasamy et al. (2005) [42]; Meena et al. (2012) [16].

The available Fe content ranged from 3.79 to 26.96 mg kg^{-1} in surface horizons whereas in subsurface horizons ranged from 1.45 to 23.61 mg kg^{-1}. A decreasing trend with depth was noticed in pedons 1, 2, 3, 4, 5, 6, 8, 9, 10, 12 and 13 and the reverse trend was noticed in pedon 11. The pedon 7 showing irregular trend with depth. It was high in the surface horizon when compared to the subsurface layers which might be due to accumulation of humic material in the surface soils besides prevalence of reduced conditions in subsurface soils. The findings were in agreement with the findings of Prasad and Sakal (1991) [27]. The available Fe gave significantly and negative correlation with pH (r=-0.716**), CaCO$_3$ (r = -0.628**), clay (r = -0.788**) and CEC (r = -0.670**), while positive correlation was observed with organic carbon (r = -

0.160). Similar types of correlations were reported by Meena *et al.* (2012) [16] and Thangasamy *et al.* (2005) [42].

The hot water soluble B content varied from 0.44 to 1.96 mg kg^{-1} in surface horizons whereas in subsurface horizons ranged from 0.33 to 1.98 mg kg^{-1}. A decreasing trend with depth was noticed in pedons 3, 4, 5, 6, 7, 8, 9, 10, 12 and 13 and the remaining pedons 1 and 2 showing irregular trend with depth. It was high in the surface horizons when compared to the sub surface horizons which might be due to accumulation of organic matter. The relation between pH and B, EC and B, OC and B, CEC and B, CaCO$_3$ and B, and with all other nutrients were positively correlated.

Table 1: Physico-chemical characteristics of pedons of the research stations

Pedon	Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (g kg^{-1})	Ca	Mg	Na	K	Total Ex. Bases	BSP (%)	CEC (cmol (p+) kg^{-1})	CaCO$_3$ (%)	ESP (%)	SAR	CEC/Clay ratio
						Exchangeable Cations (c mol (p+) kg^{-1})										
Maize Research Station, Vagarai (Red Soils)																
1	Ap	0-11	7.49	0.08	5.2	7.1	3.1	0.69	0.88	12.77	76.0	16.8	0.5	4.1	0.23	0.73
	Bt1	11- 23	7.58	0.09	3.9	7.4	3.3	0.52	0.79	12.01	77.0	15.6	0.7	3.3	0.17	0.66
	Bt2	23-40	7.85	0.11	2.7	7.5	3.4	0.43	0.64	11.97	78.8	15.2	0.9	2.8	0.14	0.55
	C	40-47	7.88	0.18	2.4	8.1	3.7	0.42	0.54	12.76	85.6	15.0	1.5	3.0	0.13	0.66
2	AP	0-20	8.10	0.25	5.6	14.4	7.8	1.14	0.74	24.08	67.6	35.6	2.6	3.2	0.24	0.77
	A1	20-31	8.00	0.20	4.5	6.9	3.6	0.76	0.78	12.04	73.4	16.4	1.2	4.6	0.25	0.66
	Bwk	31-50	8.50	0.31	3.6	10.2	5.7	0.58	0.69	17.17	89.4	19.2	7.3	2.8	0.16	0.70
	Ck	50-60	8.80	0.46	3.0	14.4	5.6	0.61	0.47	21.08	94.5	22.3	15.3	2.0	0.12	0.77
3	AP	0-10	7.45	0.15	4.9	7.2	3.2	0.92	0.71	12.03	72.9	16.5	0.7	5.5	0.31	0.74
	Bt	10 -28	7.56	0.18	3.5	7.8	3.4	0.66	0.65	12.51	75.4	16.6	1.2	3.9	0.21	0.65
	C	28-40	7.86	0.27	3.2	8.2	3.5	0.54	0.57	12.81	84.3	15.2	1.4	3.5	0.17	0.72
Overall range of surface horizons			7.45-8.10	0.08-0.25	5.2-5.6	7.1-14.4	3.1-7.8	0.69-1.14	0.71-0.88	12.03-24.08	67.6-76.0	16.5-35.6	0.5-2.6	3.2-5.5	0.23-0.31	0.73-0.77
Mean			7.68	0.16	5.23	9.57	4.70	0.92	0.78	16.29	72.17	22.97	1.27	4.27	0.26	0.75
Overall range of Sub surface horizons			7.56-8.80	0.09-0.46	2.4-4.5	6.9-14.4	3.2-5.7	0.42-0.76	0.47-0.79	11.97-21.08	73.4-89.4	15.0-22.3	0.7-15.3	2.0-4.6	0.12-0.25	0.55-0.77
Mean			8.00	0.23	3.35	8.81	4.03	0.57	0.64	14.04	82.30	16.94	3.69	3.24	0.17	0.67
Cotton Research Station, Veppanthattai (Deep Black Soils)																
4	Ap	0-31	8.48	0.14	5.5	27.2	8.2	2.32	1.04	38.76	86.9	44.6	9.8	5.2	0.41	0.84
	Bss1	31-73	8.87	0.16	4.6	27.8	9.2	2.81	0.91	39.72	85.4	46.5	8.2	3.8	0.31	0.84
	Bss2	73-101	8.97	0.28	3.5	28.3	9.8	2.84	0.83	41.77	87.9	47.5	7.3	5.9	0.49	0.81
	Bss3	101-134	8.98	0.44	1.5	28.9	9.9	3.34	0.77	42.91	89.0	46.2	9.7	6.9	0.57	0.78
	Ck	134-170	9.13	0.72	0.7	29.2	9.4	3.41	0.56	42.57	92.1	48.2	15.0	7.4	0.58	0.81
5	Ap	0-25	8.57	0.21	5.4	26.8	8.4	1.71	0.95	37.86	83.2	45.5	9.6	3.7	0.30	0.83
	Bss1	25-71	9.04	0.23	4.2	27.9	9.8	1.86	0.75	40.31	86.9	46.4	8.1	4.0	0.32	0.83
	Bss1	71-100	8.96	0.38	3.6	27.8	9.8	3.13	0.77	41.50	88.8	46.7	8.6	6.7	0.54	0.81
	Bss2	100-125	9.08	0.46	1.8	28.4	10.3	3.41	0.81	42.92	89.8	48.8	11.5	7.1	0.58	0.75
	Ck	125-155	9.10	0.68	1.5	29.8	9.8	3.45	0.68	43.73	91.4	47.9	15.5	7.6	0.58	0.83
Overall range of surface horizons			8.48-8.57	0.14-0.21	5.4-5.5	26.8-27.2	8.2-8.4	1.71-2.32		37.86-38.76	83.2-86.9	44.6-45.5	9.6-9.8	3.7-5.2	0.30-0.41	0.83-0.84
Mean			8.53	0.18	5.45	27.00	8.30	2.02	1.00	38.31	85.05	45.05	9.70	4.45	0.36	0.84
Overall range of Sub surface horizons			8.87-9.13	0.16-0.72	0.7-4.6	27.8-29.8	9.2-10.3	1.86-3.45	0.95-1.04	39.72-43.73	85.4-92.1	46.4-48.8	7.3-15.5	3.8-7.6	0.31-0.58	0.75-0.84
Mean			9.02	0.42	2.68	28.51	9.75	3.03	0.76	41.93	88.91	47.28	10.49	6.18	0.50	0.81
Dryland Agricultural Research Station, Chettinad (Red Laterite Soils)																
6	Ap	0-14	6.59	0.20	6.5	1.85	0.84	0.09	0.28	3.06	40.8	7.5	-	1.0	0.069	0.36
	A	14-25	6.32	0.14	5.0	1.34	0.61	0.08	0.31	2.34	36.0	6.5	-	1.2	0.062	0.29
	Bt1	25-39	6.10	0.05	4.8	1.48	0.65	0.05	0.31	2.49	37.7	6.6	-	0.7	0.037	0.26
	Bt2	39-63	6.06	0.05	3.0	1.32	0.62	0.05	0.32	2.31	35.5	6.5	-	0.7	0.039	0.24
	Bt3	63-97	6.23	0.07	1.7	1.41	0.64	0.04	0.33	2.42	39.6	6.1	-	0.5	0.030	0.23
	Bt4	97-143	6.25	0.05	1.4	1.31	0.57	0.04	0.34	2.26	32.7	6.9	-	0.5	0.031	0.23
	C	143-150	5.94	0.04	1.0	0.99	0.43	0.03	0.38	1.83	32.6	5.6	-	0.4	0.027	0.21
7	Ap	0-20	4.85	0.03	4.9	1.41	0.63	0.06	0.22	2.32	38.0	6.1	-	0.9	0.045	0.29
	Bt	20-51	5.12	0.03	3.6	1.72	0.51	0.04	0.25	2.52	41.3	6.1	-	0.6	0.028	0.22
	C	51-93	4.78	0.04	2.9	1.76	0.39	0.03	0.27	2.45	39.5	6.2	0.3	0.5	0.021	0.27
8	Ap	0-25	5.03	0.04	5.5	1.31	0.93	0.06	0.31	2.61	41.4	6.3	-	0.9	0.045	0.25
	Bt1	25-32	5.07	0.03	3.5	1.61	0.81	0.05	0.28	2.75	43.6	6.3	-	0.7	0.035	0.20
	Bt2	32-56	5.33	0.04	2.4	1.81	0.89	0.06	0.31	3.07	46.5	6.6	-	0.9	0.039	0.17
	Bt3	56-82	5.44	0.04	1.7	1.84	0.96	0.04	0.34	3.18	48.1	6.7	-	0.6	0.026	0.16
	C	82-105	5.28	0.05	1.4	1.94	1.01	0.04	0.36	3.35	50.0	6.6	-	0.6	0.025	0.21
9	Ap	0-10	5.02	0.04	5.3	1.8	0.98	0.03	0.21	3.02	48.7	6.2	-	0.4	0.019	0.33
	Bt1	10-31	5.48	0.05	3.3	2.1	1.08	0.04	0.28	3.50	53.0	6.6	0.2	0.6	0.024	0.27
	Bt2	31-64	5.65	0.13	3.1	2.3	1.14	0.04	0.32	3.80	56.7	6.7	0.2	0.5	0.023	0.19
	Bt3	64-98	6.07	0.11	2.6	2.5	1.16	0.06	0.32	4.04	59.4	6.8	0.2	0.8	0.034	0.18

	C	98-123	6.37	0.06	1.5	3.0	1.21	0.11	0.38	4.70	66.1	6.7	0.4	1.5	0.057		0.24
10	A	0-15	5.08	0.04	2.8	1.65	0.66	0.05	0.22	2.58	46.9	5.5	-	0.9	0.035		0.28
	C	15-27	4.41	0.09	1.4	1.48	0.43	0.04	0.22	2.17	40.9	5.3	-	0.7	0.030		0.31
11	A	0-18	4.72	0.03	5.0	1.49	0.75	0.02	0.24	2.50	36.7	6.8	-	0.2	0.014		0.30
	Bt1	18-44	4.69	0.03	3.8	1.49	0.73	0.04	0.26	2.52	36.5	6.9	-	0.5	0.029		0.27
	Bt2	44-80	4.47	0.04	3.0	1.81	0.87	0.04	0.35	3.17	45.9	6.9	-	1.9	0.093		0.25
	C	80-110	4.40	0.04	1.2	2.11	1.01	0.09	0.31	3.52	49.5	5.9	-	1.2	0.055		0.22
12	A	0-10	4.71	0.03	5.1	1.56	0.71	0.06	0.31	2.64	41.2	6.6	0.2	0.9	0.043		0.29
	Bt1	10-41	4.82	0.04	3.2	1.75	0.66	0.04	0.36	2.81	42.5	6.9	0.3	0.6	0.027		0.26
	BC	41-67	4.77	0.04	1.9	1.81	0.83	0.07	0.36	3.07	44.5	6.4	0.2	1.0	0.046		0.28
	C	67+	Weathered granite-gneiss over lateritic parent material														
13	A	0-10	4.76	0.04	5.3	1.61	0.66	0.07	0.37	2.71	38.7	7.0	-	1.0	0.050		0.28
	Bt1	10-32	4.98	0.03	2.6	1.69	0.58	0.06	0.41	2.74	38.6	7.1	0.3	0.8	0.042		0.23
	Bt2	32-80	5.01	0.02	1.7	1.75	0.56	0.07	0.42	2.80	38.9	7.2	0.2	0.9	0.049		0.21
	C	80-110	5.26	0.03	1.4	1.81	0.71	0.05	0.45	3.02	41.4	7.0	0.2	0.7	0.033		0.32
Overall range of surface horizons			4.71-6.59	0.03-0.20	2.8-6.5	1.31-1.85	0.63-0.98	0.02-0.09	0.21-0.37	2.32-3.06	36.7-41.4	5.5-7.5	0.0-0.2	0.2-1.0	0.014-0.069		0.25-0.36
Mean			5.10	0.06	5.05	1.59	0.77	0.06	0.27	2.68	41.55	6.50	0.03	0.78	0.04		0.30
Overall range of Sub surface horizons			4.40-6.32	0.02-0.14	1.0-5.0	0.99-3.0	0.39-1.21	0.03-0.11	0.22-0.45	1.83-4.70	32.6-66.1	5.3-7.2	0.0-0.3	0.4-1.9	0.021-0.093		0.16-0.32
Mean			4.97	0.05	2.34	1.63	0.71	0.05	0.31	2.70	40.63	6.04	0.09	0.73	0.03		0.22

Table 2: Available nutrient status of pedons of the research stations

Pedon	Horizon	Depth (cm)	Available Macronutrients (kg ha⁻¹)			Available S (mg kg⁻¹)	Available Micronutrients (mg kg⁻¹)				
			N	P	K		Zn	Cu	Mn	Fe	B
Maize Research Station, Vagarai (Red Soils)											
1	Ap	0-11	180.0	20.0	488.0	52.12	1.09	2.06	17.09	9.72	1.72
	Bt1	11- 23	100.0	16.0	330.0	40.25	0.67	1.28	16.06	5.12	1.62
	Bt2	23-40	81.0	14.7	208.0	38.32	0.66	0.95	15.06	4.90	1.75
	C	40-47	50.0	10.6	159.0	31.25	0.64	0.58	9.95	4.04	1.54
2	AP	0-20	200.0	23.0	598.0	54.51	0.87	2.18	14.65	6.53	1.71
	A1	20-31	112.0	20.8	390.0	51.75	0.69	1.95	13.74	4.38	1.91
	Bwk	31-50	90.0	19.4	168.0	47.52	0.54	1.53	9.15	3.56	1.98
	Ck	50-60	65.0	12.2	158.0	46.25	0.52	1.04	6.61	3.23	1.84
3	AP	0-10	150.0	16.3	404.0	53.75	0.66	1.94	15.69	8.97	1.43
	Bt	10 -28	65.0	13.7	292.0	48.22	0.42	1.81	14.29	7.99	1.15
	C	28-40	52.0	7.8	104.0	43.75	0.36	1.67	12.04	4.85	1.01
Overall range of surface horizons			150-200	16.3-23	404-598	25.12-54.51	0.66-1.09	1.94-2.18	14.65-17.09	6.53-9.72	1.43-1.72
Mean			176.7	19.8	496.7	53.5	0.9	2.1	15.8	8.4	1.60
Overall range of Sub surface horizons			50-112	7.8-20.8	104-390	31.2551.75	0.36-0.69	0.58-1.95	6.61-16.06	3.23-7.99	1.01-1.98
Mean			76.88	14.40	226.13	43.41	0.56	1.35	12.11	4.76	1.60
Cotton Research Station, Veppanthattai (Deep Black Soils)											
4	Ap	0-31	168.0	23.2	257.0	68.85	1.51	1.81	11.02	7.03	1.95
	Bss1	31-73	110.0	18.0	180.0	47.72	0.74	1.05	8.24	3.27	1.89
	Bss2	73-101	92.0	16.1	163.0	47.54	0.54	1.01	8.03	2.65	1.68
	Bss3	101-134	84.0	12.3	114.0	42.22	0.27	0.78	7.96	2.84	1.41
	Ck	134-170	50.0	9.2	100.0	41.91	0.25	0.64	5.15	2.40	1.11
5	Ap	0-25	188.0	20.8	244.0	59.85	1.46	1.03	9.27	3.79	1.95
	Bss1	25-71	118.0	16.9	202.0	59.19	0.84	0.95	8.23	2.67	1.64
	Bss1	71-100	101.0	14.5	147.0	59.15	0.51	0.85	7.40	2.13	1.58
	Bss2	100-125	69.0	12.1	113.0	48.25	0.48	0.71	6.81	2.08	1.47
	Ck	125-155	48.0	9.9	103.0	43.36	0.41	0.68	5.17	1.45	1.27
Overall range of surface horizons			168-188	20.8-23.2	244-257	59.85-68.85	1.46-1.51	1.03-1.81	9.27-11.02	3.79-7.03	1.95-1.95
Mean			178.0	22.0	250.5	64.4	1.5	1.4	10.1	5.4	1.95
Overall range of Sub surface horizons			48-118	9.2-18.0	100-202	41.91-59.19	0.36-0.69	0.58-1.95	6.61-16.06	3.23-7.99	1.01-1.98
Mean			84.0	13.6	140.3	48.7	0.5	0.8	7.1	2.4	1.5
Dryland Agricultural Research Station, Chettinad (Red Laterite Soils)											
6	Ap	0-14	200.0	24.0	210.0	25.51	2.62	1.92	19.60	26.96	0.51
	A	14-25	115.0	13.0	171.0	20.54	1.13	1.64	22.54	22.61	0.49
	Bt1	25-39	106.0	10.0	140.0	23.21	0.62	1.62	24.26	16.55	0.48
	Bt2	39-63	90.0	13.0	100.0	23.54	0.58	1.57	27.30	14.51	0.48
	Bt3	63-97	77.0	11.0	91.0	22.25	0.39	1.32	22.88	15.06	0.46
	Bt4	97-143	60.0	10.0	57.0	17.25	0.24	1.04	13.58	10.78	0.38
	C	143-150	44.0	9.0	48.0	18.26	0.22	0.83	8.358	8.85	0.39
7	Ap	0-20	114.0	14.0	147.0	26.56	0.25	1.58	13.93	8.18	0.62
	Bt	20-51	98.0	15.0	80.0	24.75	0.23	0.50	13.24	5.02	0.44
	C	51-93	55.0	8.0	50.0	17.32	0.20	0.46	9.81	7.54	0.36

8	Ap	0-25	108.0	20.0	180.0	27.62	0.38	1.74	18.32	9.50	0.63
	Bt1	25-32	107.0	14.0	150.0	27.52	0.35	1.68	18.12	9.42	0.61
	Bt2	32-56	102.0	12.0	132.0	31.61	0.30	1.53	21.08	9.38	0.56
	Bt3	56-82	80.0	10.0	70.0	37.22	0.28	1. 22	21.90	8.11	0.45
	C	82-105	74.0	9.0	42.0	35.23	0.21	0.71	8.32	6.57	0.39
9	Ap	0-10	108.0	19.0	174.0	25.27	0.80	3.13	28.22	19.13	0.59
	Bt1	10-31	103.0	12.0	155.0	21.12	0.61	2.65	30.84	18.09	0.55
	Bt2	31-64	94.0	15.0	113.0	25.55	0.43	1.92	27.31	17.69	0.43
	Bt3	64-98	71.0	13.0	55.0	21.12	0.34	1.54	16.06	11.78	0.37
	C	98-123	55.0	7.0	50.0	17.71	0.23	1.01	15.68	8.88	0.35
10	A	0-15	104.0	11.0	101.0	26.42	0.30	1.09	25.89	17.61	0.44
	C	15-27	40.0	13.0	86.0	24.81	0.26	0.82	24.28	14.47	0.35
11	A	0-18	110.0	20.0	157.0	28.72	0.50	0.58	17.23	18.39	0.61
	Bt1	18-44	107.0	16.0	130.0	27.25	0.35	0.62	20.45	19.21	0.57
	Bt2	44-80	90.0	12.0	100.0	22.22	0.23	1.01	25.08	19.73	0.47
	C	80-110	40.0	10.0	51.0	20.12	0.20	0.95	21.29	23.61	0.36
12	A	0-10	128.0	19.0	118.0	29.28	0.67	1.60	14.70	17.51	0.64
	Bt1	10-41	115.0	17.0	98.0	26.22	0.46	0.63	24.40	13.05	0.58
	BC	41-67	70.0	9.0	62.0	24.12	0.29	0.79	16.96	12.49	0.50
	C	67+	Weathered granite-gneiss over lateritic parent material								
13	A	0-10	140.0	29.0	146.0	45.21	0.81	1.80	15.80	17.33	0.49
	Bt1	10-32	113.0	22.0	93.0	36.55	0.41	0.75	21.53	16.87	0.48
	Bt2	32-80	90.0	20.0	64.0	22.52	0.29	0.53	28.17	16.64	0.42
	C	80-110	47.0	8.0	44.0	17.32	0.24	0.48	14.99	12.14	0.33
Overall range of surface horizons			104.0-200.0	11.0-29.0	101-210	25.27-45.21	0.30-2.62	0.58-3.13	13.93-28.22	8.18-26.96	0.44-0.64
Mean			126.5	19.5	154.1	29.3	0.8	1.7	19.2	19.2	0.6
Overall range of Sub surface horizons			40.0-115.0	7.0-22.0	50.0-171.0	17.25-37.22	0.20-1.13	0.46-2.65	8.32-30.84	5.02-23.61	0.33-61
Mean			75.7	11.4	82.7	22.4	0.3	1.0	18.5	12.6	0.4

Table 3: Correlation coefficient (r) values between physico-chemical and chemical soil properties

	pH	EC	OC	BS	CEC	CaCO$_3$	N	P	K	S	Zn	Cu	Mn	Fe	B
pH	1		ss												
EC	.798**	1													
OC	.096	-.140	1												
BS	.908**	.766**	.026	1											
CEC	.860**	.781**	.059	.820**	1										
CaCO$_3$	.789**	.887**	-.064	.783**	.877**	1									
N	.103	-.136	.817**	-.006	.151	-.043	1								
P	.072	-.097	.733**	.025	.135	.000	.785**	1							
K	.423**	.127	.631**	.372**	.288*	.069	.672**	.543**	1						
S	.758**	.533**	.367**	.779**	.770**	.628**	.426**	.447**	.615**	1					
Zn	.332*	.090	.692**	.168	.227	.122	.741**	.606**	.492**	.368**	1				
Cu	-.035	-.176	.626**	-.055	-.176	-.253	.499**	.416**	.526**	.123	.419**	1			
Mn	-.682**	-.630**	.068	-.654**	-.676**	-.679**	.134	.079	-.094	-.556**	-.012	.384**	1		
Fe	-.716**	-.572**	.160	-.745**	-.670**	-.628**	.180	.158	-.200	-.614**	.186	.301*	.793**	1	
B	.863**	.569**	.326*	.872**	.762**	.658**	.300*	.330*	.638**	.866**	.358**	.068	-.595**	-.687**	1

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

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

Conclusion

The lower pH values ranged from moderately acidic to slightly acidic in red laterite soils followed by neutral to moderately alkaline in red soils and moderately alkaline to strongly alkaline in black soils with non saline in nature. The organic carbon content higher in surface horizons than sub-surface horizons in the range of low to medium. The calcium carbonate content of red laterite soil was very low which is in non-calcareous followed by red soil which is in the range of non-calcareous to calcareous whereas, in the black soil pedons containing medium to high amount in the range of slightly calcareous to calcareous. The CEC of the red laterite soils was quite low despite high clay content indicating that the dominance of low activity clay minerals. The CEC values of red soil medium to high in range. The CEC values are indicating that the black soils are less weathered than the red soils and red laterite soils. The exchangeable bases in the red and black soil pedons were in order of $Ca^{+2} > Mg^{+2} > Na^+ > K^+$ on the exchange complex. The exchangeable bases of red laterite soils were in order $Ca^{+2} > Mg^{+2} > K^+ > Na^+$. Low exchangeable Na and K percentage was noticed in all the pedons as the exchange complex was dominated by divalent cations like Ca and Mg. The percent base saturation was very high in black soils than red and red laterite soils.

The available nitrogen content of all the pedons were low in range and was found to be relatively high in surface horizons and decreased in sub surface horizons. The available P content of soils was medium to high in surface horizons. The available P content was low to medium in red laterite soils The highest available K content was noticed in the surface horizons and showed decreasing trend with depth in all the pedons. The availability of S was more in surface horizon than the subsurface horizons due to soil sulphur is continuously cycled between inorganic and organic forms of

sulphur. These soils are low to medium in organic carbon, low in available N, low to medium in available P and medium to high in available K. the soils are sufficient to deficient in Zn, Cu, boron and sufecient in Fe and Mn. Maintenance of enhanced soil fertility of the soils was needed. The red soils are shallow in depth, marginally suitable to highly suitable for cultivation of maize, greengram, sorghum, redgram and blackgram. The black soils are deep, moderately suitable to highly suitable for cultivation of cotton, sorghum, soybean, greengram, blackgram, redgram, sunflower, sesamum, maize and pearlmillet. The red laterite soils are very shallow to deep, marginally suitable to moderately suitable for cultivation of groundnut, greengram, blackgram, redgram, horsegram and pearlmillet.

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