PHYSICO - CHEMICAL CHARACTERISATION OF RED SOILS IN DIFFERENT REGIONS OF KERALA

By

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THESIS

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Faculty of Agriculture
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DECLARATION

I hereby declare that this thesis entitled "Physico-chemical characterisation of red soils in different regions of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Betty Bastin
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College of
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May, 1985.

CERTIFICATE

Certified that this thesis entitled "Physico-chemical characterisation of red soils in different regions of Kerala" is a record of research work done independently by Smt. Betty Bastin, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. V.K. Venugopal,
Chairman,
Advisory Committee.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Smt. Betty Bastin, a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled "Physico-chemical characterisation of red soils in different regions of Kerala" may be submitted by Smt. Betty Bastin in partial fulfilment of the requirement for the degree.

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Betty Bastin

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INTRODUCTION

INTRODUCTION

Soils, like water, forest and minerals constitute the basic resources of a country. All developmental programmes in agriculture are dependent to a great extent on scientific knowledge of all these basic resources, of which soil occupies an important place. Comprehensive inventories on soils are therefore a prerequisite for its efficient utilization.

The area between the meridian of Cancer and Capricon conveniently referred to as the tropics cover approximately 40 per cent of the earth's surface and receives half of the world's total rainfall. Temperature and solar radiation remain favourable for plant growth throughout the year, thus making it possible to grow several crops in the same land, provided there is moisture. With the increasing pressure of population on land, the main strategy for increasing productivity is through economic maximisation of production per unit area to feed the ever increasing population.

Soils with red colour occur extensively in the tropical regions of the world and are considered to have great potentials for crop production. Most of them are characterised by featureless profiles with reddish brown and yellowish red colours. The physical properties are highly favourable for crop production, while chemical characteristics are less satisfactory (Sanchez and Buol, 1975). According to Mandal et al. (1982) the acid soils in Peninsular India are primarily sedentary in nature belonging to laterites, ferruginous red and other red soils which are derived from ancient crystalline and metamorphic rocks.

A perusal of the literature would reveal that considerable amount of work has been carried out in 'tropical red earths' occurring in different regions of the world covering various climatic regions and geologic materials. Specific mention may be made of the work carried out by Lissonite (1960), Aubert (1962), Lotse et al. (1974), Rengaswamy et al. (1978) and Greenland (1981).

In Kerala, deep red soils occur in patches along the mid upland laterite regions as catenary sequences associated with soils having a laterite pan. They occupy the upper midslope regions and have been identified in different regions of Kerala (Venugopal, 1980). Earlier investigations on red soils occurring in some parts of Trivandrum district have been carried out by Venugopal (1969), Nair (1973) and Iyer (1979). However, detailed investigations on various red soil series occurring in different locations of Kerala have not been undertaken so far.

The intensive multiple cropping strategies now in vogue in the mid upland laterite regions of the State covering these soils and the extension of irrigation to these areas under the Command Area Development Project highlight the need for detailed understanding of these soils occurring in different regions in terms of potential for crop production.

With this objective in view the present investigation was undertaken covering six soil series from different locations of Kerala with emphasis on morphology, physico-chemical characteristics and available nutrient status. This has been achieved by a systematic study of the following aspects:

(1) Morphological features of soil profiles
(2) Physical and chemical characteristics of soils
(3) Extractable iron in relation to genesis of soils
(4) Chemical composition of clay and molar ratios
(5) Available nutrient status of surface samples

It is hoped that present study would open up avenues for further site specific investigations on soil-plant-water systems and other management aspects for sustaind use of these soils to the best advantage.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Considerable amount of research information on various characteristics of tropical 'red earth' have accumulated over the years. In this chapter an attempt is made to review in a systematic manner the work carried out till recently in India and elsewhere on various physico-chemical characteristics of soils of the tropics, particularly the red soils.

1. Genesis and classification of red soils

Lotse et al. (1974) in their study of some red and black soils of India found that the red soils were formed from granites and gneiss under conditions of good drainage. They also suggested that the red soils had developed in materials eroded from old laterite layer covering southern India during the latest epochs of the tertiary period.

Laterite and red soils are found to be associated with different landscapes in Nandi Hill region of the eastern Mysore plateau of India. The land surface covered by the laterite soils is smooth whereas red soils occur in rugged terrain. Laterite mounds and laterite plateau remnants are found scattered over the landscape, bearing testimony to geomorphic changes and climatic history (Rengaswamy et al., 1978).

Iyer (1979) observed that the laterites and red soils of Kerala are associated with different landscapes and together account for more than 60 per cent of the area of the State. The presence of highly weathered material with very fine granular grains in the red soils is indicative of the transported nature of the lateritic soil material to the foot slope. This observation is very much in favour of the hypothesis of transportation and deposition of the laterite material itself, followed by in situ weathering giving rise to laterite and red soil association of the present age.

Greenland (1981) reported that the tropical red earths and latosols are highly weathered to the extent that the clay fraction consists almost entirely of kaolinite and oxides of iron and aluminium. However, the influence of original parent material often appears to persist in relation to physical and chemical properties. Thus soils on more basic parent materials have a higher clay content and have stable aggregation than similar soils developed from intermediate or acidic parent material.

2. Physical properties

2.1. Bulk density and mechanical composition

Janardhanan *et al*. (1966) in their studies on cultivated soils of Kerala found that the absolute specific gravity and apparent specific gravity appeared to be a function of the coarser particles of the soil while water holding capacity, pore space, volume of expansion and organic carbon were related to the finer particles of the soil both in quantity and quality.

Venugopal (1980) reported a bulk density range of 0.58 to 2.00 g/cm^3 for the red soil profiles in a study of a lateritic catena in Varkala area of Kerala.

Ushakumari (1983) in a study of the physical properties of Kerala soils showed the bulk density values to vary from 1 to 1.54 g/cm^3 for the different soil groups. The clay content in general was found to increase the porosity and decrease the bulk density of the soils.

Satyanarayana (1968) reported a textural range between clayey and sandy for the red soils from various districts of Andhra Pradesh. The coarse sand fraction was negatively correlated with clay. Clay and silt contents were positively correlated.

Rajagopalan (1969) observed an increase in the coarse sand and clay fractions with depth in a red soil profile at Patchalloor in Kerala State. Silt and fine sand contents decreased with depth.

Praseedom (1970) in an investigation on the soils of Kerala observed an increase in the clay and coarse sand fractions with depth, while the silt and fine sand fractions tended to decrease.

Urego and Holmes (1977) observed that the soils from granites and gneiss had relatively higher proportions of coarse sand and clay and low contents of silt reflecting the predominance of quartz and feldspar in their parent materials. Soils derived from argillaceous materials were dominated by fine sand, silt and clay. The clay, silt and sand contents increased with depth when fine earth fractions alone were considered.

Ushakumari (1983) reported that the soils of Kerala exhibited an appreciable variation in texture ranging from clay to loam. The red loams had shown striking similarity to laterites in texture. All the soil groups viz., laterite, black cotton, red loam, riverine alluvium and coastal alluvium showed downward migration of clay.

2.2. Moisture retention characteristics

Ali (1965) studied the influence of organic carbon on moisture retention in soils and observed a beneficial effect of soil organic carbon in improving soil moisture retention characters irrespective of the texture and mineralogical composition of clays. Organic carbon and available moisture were found to be positively correlated.

Gupta and Narin (1971) working on the alluvial soils of Uttar Pradesh concluded that the available moisture capacity of soils can be predicted from the values of silt and clay.

Thiyagarajan (1978) studying the red and black soils of Coimbatore district reported that the moisture retention properties increased with depth. In red soils, the 15 bar moisture had a very significant linear relationship with clay ($r = 0.963$).

Thulaseedharan (1983) reported in the case of laterite soils of Kerala that most of the available water was removed at a tension less than three bars. More than 50 per cent of available water occurred at this tension. Organic carbon was found to have no bearing on the moisture retention at the various tensions. The content of clay showed significant positive correlations with the moisture content of the fine earth fraction at various tensions ranging from 0.3 bar to 15 bars. The effect of silt was significant and positive at tensions higher than three bars only. Significant negative correlation was obtained between the contents of coarse fractions (fine and coarse sand) and moisture retention at different tensions.

Ushakumari (1983) reported a positive correlation between clay and water retention in laterite, black cotton, riverine alluvium, red loam and coastal alluvial soils of Kerala.

3. Chemical properties

3.1. Total elemental composition

Raychaudhuri (1941) found that the red soils of India are rich in alkali soluble silica.

Lall (1955) observed the silica content in surface layers of red soils of Bihar to be 80 per cent which however decreased with depth to a constant value.

Mosi (1960) reported a decrease in the silica content progressively from the top to the parent material for some red soils of South India.

Thiyagarajan (1980) in his study on availability of iron in red and black soils of Tamil Nadu reported a total Fe_2O_3 content of 6.71 per cent and Al_2O_3 content of 6.98 per cent.

Venugopal (1980) found the Fe_2O_3 content of soil profiles of Varkala toposequence to range between 1.16 per cent and 10.93 per cent. The Al_2O_3 content varied from 3.13 to 25.28 per cent.

Bhattacharya et al. (1983) investigating the red soils of Karnataka derived from granite gneiss attributed the higher values of total Fe_2O_3 at lower depths of soil to pedogenic factors like weathering, fluctuating water table, temperature fluctuation and seasonal pH change of the underground water. The total iron content varied from 7.2 to 29.0 per cent.

Aubert (1962) observed that the important limitations to the crop production potential of highly weathered soils include lack of reserves of nutrients in weatherable minerals, lack of organic matter and rapid oxidation of what is present.

Praseedom (1970) obtained an organic carbon content ranging between 0.20 to 0.43 per cent for the red soils at Patchalloor of Trivandrum district.

Thiyagarajan (1978) recorded the organic carbon content of red soils of Coimbatore to range between 0.05 and 0.183 per cent in the profile and observed a decrease in organic carbon content with depth.

Parvathappa (1964) in his studies on the productivity of red soils of Mysore state indicated that total nitrogen and carbon/nitrogen ratio were medium in surface soils and decreased with depth.

Venugopal (1969) found the nitrogen content of red soil profile at Trivandrum to vary from 0.02 to 0.04 per cent.

Raguraj (1981) studying the red, black, alluvial and laterite soil groups of Madurai district reported the total N content of red soils to range from 0.015 to 0.071 per cent in the profiles. It decreased with depth in all profiles except in red soils.

Iyer (1979) in his study on laterite and red soil associations of Kerala obtained a C/N ratio varying from 10.6 to 12.7 for the red soil profiles. Organic carbon and nitrogen were found to be significantly and positively correlated ($r = 0.804$).

Goel and Agarwal (1959) investigating soils of Indo-Gangetic alluvium in Kanpur found the total phosphorus content of the soil to decrease with increasing maturity and the iron and aluminium bound phosphorus to increase with soil maturity at the expense of calcium bound phosphorus.

Koshy and Britomuthunayagam (1961) found the level of total phosphorus of soil profiles of Kerala to vary from 0.024 to 0.256 per cent. The phosphorus fixing capacity varied widely, with the maximum in acid soils having high sesquioxide content.

Raychaudhuri and Reddy (1963) reported that the red soils of Bangalore district having sand to clay loam texture are low in available P_2O_5 ranging between 11.2 and 22.4 kg/ha.

Iyer (1979) reported a total P_2O_5 content which ranged from 0.025 to 0.41 per cent in the profiles of red soil at Trivandrum.

Raguraj (1981) observed the available phosphorus content for the red soil profiles of Tamil Nadu to range from 0.04 to 22.40 kg/ha.

Nad <u>et</u> <u>al</u>. (1975) determined the phosphorus fixing capacity of the different major soil groups of India. Clay and free iron oxide contents of the soils were the two dominant factors determining the phosphorus fixing capacity. Amongst the various soils groups, black, red, laterite, mixed red and black, red and yellow and coastal alluvial soils exhibited higher phosphorus fixation than alluvial, grey brown, desert and other soils. The ranges of phosphorus fixation were 44.0 to 70.2 per cent for black, 12 to 47.0 per cent for alluvial, 21 to 55 per cent for laterite and 38 to 85.2 per cent for red soils.

Kothandaraman and Krishnamoorthy (1978) investigated phosphorus fixing capacity of red, black, alluvial and laterite soils of Tamil Nadu. The phosphorus fixing capacity of soils ranged from 20 to 183 mg P/100 g soil with a mean of 85 mg P/100 g. The soils were found to differ widely in their phosphorus fixing capacity the highest values being for the high level laterites of Ootacammund and the lowest for alluvial soils. The phosphorus fixing capacity was found to be positively correlated with clay, total sesquioxides and total alumina. Red soils recorded a phosphorus fixing capacity of 51 mg P/100 g soil.

Halim *et al*. (1963) investigating the potassium status of the U.A.R. soils found that total potassium varied between 2.5 me/100 g in coarse textured soils to 15 me/100 g in fine textured soils. The total potassium content was highly correlated with the clay percentage and exchangeable potassium.

Nair (1973) found the total K_2O content of red soils of Kerala to vary from 0.92 to 1.44 per cent for the surface samples and from 0.87 to 1.37 per cent for the subsurface samples.

Hassan (1977) observed that the calcium and magnesium status of laterite soils of Kerala were very poor in the sub surface layers of the soil profiles as well as surface samples. Total calcium increased with depth while magnesium decreased with depth.

Thiyagarajan (1978) reported that profile weight of calcium increased with depth in majority of the soil prorlles examined in Coimbatore district. The mean magnesium content was high in black soils than red soils.

Iyer (1979) reported the CaO content of red soil profiles of Kerala to range from 0.026 to 0.419 per cent. The MgO content varied from 0 to 0.255 per cent.

Pisharody (1965) reported that the total iron content of dry rice soil profiles of Kerala ranged from 19,200 to 1,36,000 ppm. The subsoil was richer in total and exchangeable iron than surface soils in the majority of the profiles studied. Total iron was found to increase with increase in finer fractions. The total manganese content ranged from 355 to 625 ppm in surface soils and from 367 to 764 ppm in subsoils.

Arunachalam and Mosi (1973) reported a positive correlation between total iron and organic matter content of soils.

Rajagopalan (1969) reported that the total manganese in Kerala soils ranged from 103.8 to 950.0 ppm, the average being 445.9 ppm. As regards the variation down the profile, increase as well as decrease and accumulation in intermediate layers were observed.

Balaguru and Mosi (1972) on a study of Tamil Nadu soils obtained a range of 521 to 1168.3 ppm for total manganese while the available manganese varied from 0.37 to 8.76 ppm. They also reported a positive correlation between manganese and finer fractions of the soil.

Kanwar and Randhawa (1967) reported that in most Indian soils total zinc content ranged from 2 to 1,600 ppm.

Praseedom and Koshy (1975) in a study of zinc status of Kerala soils reported that total zinc content of surface layer varied from 3.5 ppm in red soil from Patchalloor to 72.0 ppm in the alluvial soil profile from Alwaye. Significant positive correlation was obtained between total and available zinc. The downward distribution of zinc did not follow any regular pattern.

Gupta et al. (1980) reported that the alluvial soil profiles of south western Haryana did not show any consistent trend in DTPA extractable zinc, copper, manganese and iron content. Available zinc and copper, correlated significantly with organic carbon and clay.

Pack et al. (1953) observed that the A horizons of the soils were generally higher in total copper than B horizons indicating the removal of copper from lowest horizons by plant roots and subsequent deposition on the surface as a constituent of organic matter.

Mehta et al. (1964) found that the total copper in black cotton soil was maximum in the surface layer and it decreased with depth in the profile.

Randhawa and Kanwar (1964) reported the total copper content of Punjab soils to range from 6.6 to 36.4 ppm. They also observed a significant relationship between total copper and the silt and clay fractions.

Praseedom (1970) reported that the total copper content of the laterite soils of Kerala ranged from 9.0 to 78.0 ppm with a mean value of 34.3 ppm. In the red soil profile the copper content varied from 5 to 34.0 ppm with a mean of 17.3 ppm. An increasing trend in copper content was noted with depth in the profile.

Gupta *et al.* (1980) in a study of the alluvial profiles of Haryana found the available copper content to be significantly correlated with organic carbon and clay.

Domigo and Kyuma (1983) reported the total copper content of Indian soils to range from a minimum of 12 ppm to a maximum of 138 ppm in the paddy soils.

Reaves and Berrow (1984) found the copper content to increase with depth in the Scottish profiles. Copper content or organic soils was less than that of mineral soils. Copper content was also found to be inversely related to sand content.

3.2. Cation exchange properties

Venugopal and Koshy (1976) reported that the red soils of Kerala state were poor in exchangeable bases. The occurrence of bases decreased in the order of calcium > magnesium > potassium > sodium. The cation exchange capacity ranged from 1.62 me/100 g for a laterite to 49.56 me/100 g for black soil. For the Patchalloor red soils it varied from 2.12 to 2.54 me/100 g. In the laterite profiles, calcium formed the predominant exchangeable base followed by magnesium.

Thiyagarajan (1978) reported exchangeable potassium to be the lowest of all bases in the red and black soils of Coimbatore district. In red soils, 64.62 per cent of the exchange complex was calcium, 33.03 per cent magnesium, 1.77 per cent potassium and 0.96 per cent sodium.

Grant (1975) reported that aluminium extracted by 1N KCl was found to be lower as organic matter content increased at any given pH level. This accounted for some of the benefits of organic amendments on acid soils.

Raguraj (1981) in a study of the red laterite, alluvial and black soils of Madurai district reported that the pH ranged in the profiles from 6.0 to 10.1 in red soils, from 8.2 to 9.9 in black soils, 8.2 to 9.9 in alluvial soils and 3.4 to 6.3 in laterite soils. The low pH (below 6.0) in the laterite soils was attributed to the high organic matter content and also leaching of bases. The pH of the surface soil was high compared to subsurface layer.

Profile analysis of selected Oxisols and Ultisols of South America by Sanchez (1981) revealed that the Oxisols and Ultisols show extremely low pH values throughout the profile (3.7 to 5.9 in 1:1 soil: water ratio), moderate soil organic matter contents, high levels of exchangeable aluminium (0.2 to 11.6 mg/100 g), low levels of exchangeable calcium, magnesium and potassium, a low effective cation exchange capacity due to the low activity clays, and a high proportion of the exchange sites saturated by aluminium (3 to 98 per cent).

3.3. Iron fractions and active iron ratio of soils

Blume and Schwertmann (1969) reported that the elements iron, aluminium and manganese were greatly affected by the processes of soil profile genesis. The distribution of their pedogenic oxides and hydroxides in the soil profile helped therefore in describing the type, the direction and the extent of pedogenic processes and might be used to define great soil groups and other soil classes.

Iyer (1979) in her study of red soils of Kerala found that the dithionite extractable iron content of Varkala profile ranged from 75.0 to 175 ppm. At Pilicode it ranged from 146.30 to 190.00 ppm and at Patchalloor it ranged from 129.00 to 193.42 ppm. The dithionite extractable iron content increased with depth in all the three profiles.

Bhattacharya et al. (1983) reported that the citrate-bicarbonate-dithionite extractable iron content in red soils of Karnataka derived from granite gneiss ranged from 0.88 to 4.37 per cent and constituted 20.6 to 73.7 per cent of the total iron content.

Mitra and Mandal (1983) reported that the total and free iron in rice soils of West Bengal varied within a narrow range. The free iron oxide constituted on an average 30 to 40 per cent of the total iron present in the soils in different districts. It was found to have a strong positive correlation with organic carbon ($r = 0.508$) and total iron content ($r = 0.870$).

Arduino et al. (1984) reported that the relative ages of soils can be estimated from the amounts of iron, extractable by dithionite and oxalate. The larger the proportion of total iron (Fe_t) extracted by these reagents especially by dithionite (Fe_d), the older the terrace. The proportions of total iron extracted by dithionite over and above those removed by oxalate (Fe_o) offer the best basis for discriminating the ages. They found the total iron content to range between 2.14 to 8.30 per cent and that of Fe_o from 0.04 to 0.85 per cent in the soils of western Po Valley in Italy.

Blume and Schwertmann (1969) in a study of depth functions of pedogenic oxides in profiles of various great soil groups of the temperate region found that for the Entisols and Rendolls a Fe_d maximum was obtained in the A1 horizon. In the brown forest soils, Fe_d, Fe_o, Al_o and clay increased from the B_3 to B_2 horizon and Fe_d and Fe_o increased again in the A horizon. In these forest soil profiles, top soil Fe_o maxima coincided with high Fe_o/Fe_d ratios indicating a low degree of aging. This might be caused by an actual low age or by unfavourable conditions for crystallisation. Thus the high Fe_o/Fe_d ratios in surface soils were usually due to organic matter. The subsoils of acid brown forest soils low in organic matter also showed high Fe_o and Fe_o/Fe_d values compared to grey brown podzolic soils. This was attributed to high rate of iron liberated from silicates in acid soils, some downward movement of mobile organic matter as well as slow aging at low pH values.

Moore (1973) studied horizon wise samples from soils located near Aberdeen which represented freely, imperfectly, poorly and very poorly drained soils, composed of a mixture of acid and basic igneous rocks and metamorphic rocks of Tipperty, Birness and Dorbs series respectively. The Fe_d content ranged between 0.25 to 4.14 per cent. The Fe_o ranged from 0.17 to 3.41 per cent and the active iron ratio from 0.18 to 0.86. This ratio increased due to variations in the rate of aging and crystallisation of amorphous iron oxides and hydroxides.

Juo et al. (1974) reported that the amount of amorphous iron oxides of the Alfisols and Ultisols derived from acidic parent rocks of West Africa was relatively small. The content of oxalate extractable iron oxides in these soils ranged from 0.05 to 0.2 per cent, which comprised less than 10 per cent of the total free iron oxides.

Schwertmann and Taylor (1977) reported that the solubility of iron in acid ammonium oxalate solution expressed as the active iron ratio, Fe_o/Fe_d was usually interpreted as indicating the degree of crystallinity of iron oxides in the samples.

Juo (1981) reported that the active iron ratio (the ratio of 'amorphous' Fe_2O_3 divided by total 'free' Fe_2O_3 (Fe_{ox}/Fe_{dcb}) generally decreased with increased depth within any one profile. This indicated that a larger proportion of the free iron oxides existed in a crystalline form in the subsoil horizons than in the surface soil.

4. Chemical composition of clay fraction and molar ratios

Satyanarayana (1968) reported the silica content of the clay fraction of red soils of Andhra Pradesh to range from 30.20 to 41.90 per cent.

Iyer (1979) reported the silica contents of the red soil clays to vary from 31.41 to 32.33 at Varkala, 33.33 to 35.11 per cent at Pilicode and 33.9 to 36.2 per cent at Patchalloor.

In a study of a laterite toposequence in Varkala area of Kerala, Venugopal (1980) observed the silica content of soils to range from 31.42 to 54.72 per cent in the profiles. The Fe_2O_3 and Al_2O_3 contents ranged from 14.77 to 28.41 per cent and 12.99 to 31.10 per cent respectively.

Lissonite (1960) used the silica sesquioxide ratio for characterising the clays from red earths of Italy and found the values to range from 1.6 to 2.09.

Bouma and Schuylenborgh (1969) reported that when applied to soil clays, the usefulness of the ratios like SiO_2/R_2O_3, SiO_2/Al_2O_3 has met with varying degrees of acceptance. They appeared to be more relevant as an index in soil formation process. Decreasing SiO_2/R_2O_3 and SiO_2/Al_2O_3 ratios with depth in the pedon were believed to be indicative of movement of aluminium and iron or clay migration whereas increasing ratios were interpreted as movement of silica to lower depth in the pedon.

Ameer (1970) studying the physical and chemical properties of Tamil Nadu soils reported a SiO_2/R_2O_3 ratio of 1.97 for red soils and 1.23 for laterites. He obtained significant positive correlation between clay content and SiO_2/R_2O_3.

Krishnamoorthy and Govindarajan (1977) reported the silica sesquioxide ratios of different horizons to range from 2.1 to 2.2. This was much lower than the black soil with a range from 3.3 to 3.6. The clay of the red soil was identified as kaolinite by X-ray analysis. Since its SiO_2/R_2O_3 value was about 2.2 they suspected possible inclusion of montmorillonite in its mineralogy which was responsible for increasing the ratio a little above 2.0.

Iyer (1979) studying laterite red soil associations of Kerala obtained SiO_2/R_2O_3 values for the red soils ranging from 1.01 to 1.04 at Varkala, 1.25 to 1.30 at Pilicode and 1.84 to 1.95 at Patchalloor.

Bigham et al. (1978) reported that the amounts of iron, aluminium and especially silicon extracted with acid ammonium oxalate were consistently quite small. Since acid ammonium oxalate was selective for amorphous iron compounds it was observed that only less than seven per cent of the free iron (dithionite-citrate-bicarbonate extractable iron) in these clays occurred in noncrystalline form or disordered state. The dithionite-citrate-bicarbonate extractable iron contents of Dark Red Ustox and Red Yellow Ustox were 10.83 and 14.17 per cent while the oxalate extractable iron contents were 0.47 and 0.34 per cent respectively.

Greenland (1981) was of the view that the 'free iron oxides' of the clay fractions of humid tropical soils act as cementing agents, stablising their porosity and these soils possessed free drainage characteristics.

MATERIALS AND METHODS

MATERIALS AND METHODS

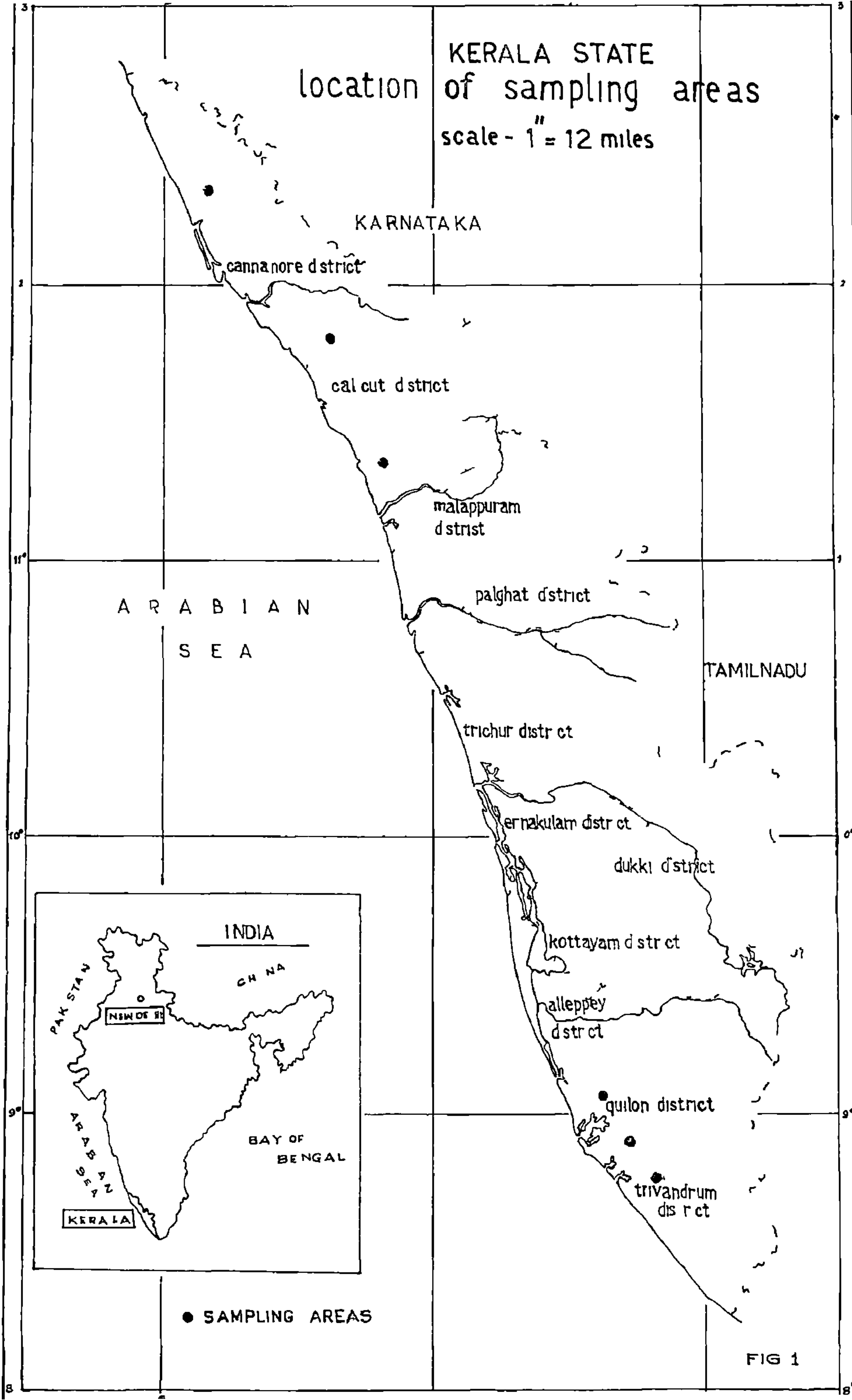
The investigations carried out in the present study relate mainly to six soil series from different red soil regions of Kerala identified using soil maps prepared by the Spil Survey Unit of the Department of Agriculture, Kerala state. The areas selected for the study are indicated in Figure 1.

1. Field studies

Profile pits were dug in the typical areas identified and the morphological features were observed and recorded as per Soil Survey Manual (1970). The salient features of the areas in respect of location, physiography, drainage, vegetation and land use were also recorded. The morphological descriptions of profiles are presented in Appendix.

1.1. Sample collection

After morphological examination of the profiles, soil samples representing the different horizons in a profile were collected for laboratory examination. Core samples were also collected from each horizon for determination of bulk density. Surface samples, 0-15 cm were also collected from widely distributed areas in a soil series for estimating the available nutrient status. The particulars of sample collected are presented in Tables 1 and 2.



KERALA STATE
location of sampling areas
scale - 1" = 12 miles
KARNATAKA
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ARABIAN SEA
KERALA
SAMPLING AREAS

FIG 1

Table 1. Details of profile samples collected

Profile No.	Soil series	Location (district)	Sample No.	Horizon	Depth (cm)
I	Vellayani	Trivandrum	1	Ap	0 - 19
			2	B_{21}	19 - 76
			3	B_{22}	76 - 150+
II	Cherniyoor	Quilon	4	Ap	0 - 16
			5	B_1	16 - 37
			6	B_{21}	37 - 65
			7	B_{22}	65 - 151+
III	Bharanikkavu	Quilon	8	Ap	0 - 20
			9	B_{22}	20 - 49
			10	B_3	49 - 145+
IV	Beypore	Calicut	11	Ap	0 - 19
			12	B_{21}	19 - 100
			13	B_{22}	100 - 145+
V	Chirakkal	Cannanore	14	Ap	0 - 14
			15	B_1	14 - 32
			16	B_{21}	32 - 80
			17	B_{22}	80 - 165+
VI	Kunhimangalam	Cannanore	18	Ap	0 - 20
			19	B_1	20 - 47
			20	B_{21}	47 - 93
			21	B_{22}	93 - 143+

Table 2. Details of surface samples collected

Sample No.	Soil series	Location
1	Vellayani	Trivandrum
2		
3		
4		
5		
6		
7		
8		
9		
10		
11	Cherniyoor	Quilon
12		
13		
14		
15		
16		
17		
18		
19		
20		
21	Bharanikkavu	Quilon
22		
23		
24		
25		
26		
27		
28		
29		
30		

Contd....

Table 2. Contd.....

Sample No.	Soil series	Location
31	Beypore	Calicut
32		
33		
34		
35		
36		
37		
38		
39		
40		
41	Chirakkal	Cannanore
42		
43		
44		
45		
46		
47		
48		
49		
50		
51	Kunhimangalam	Cannanore
52		
53		
54		
55		
56		
57		
58		
59		
60		

2. Laboratory studies

2.1. Preparation of samples

The soil samples collected were air dried, ground with a wooden mallet and passed through 2 mm sieve. The sieved samples were utilized for further studies.

2.2. Physical properties

The particle size distribution was carried out by the International Pipette Method (Piper, 1942). Bulk density was determined by the core method outlined by Dakshinamurti and Gupta (1968). Moisture retention studies were carried out in a pressure plate apparatus using ceramic plates (Richards, 1954).

3. Chemical properties

The chemical properties of samples were determined by standard analytical procedures and expressed on moisture free basis.

3.1. Analysis of profile samples

Soil reaction was determined in a 1:2.5 soil water suspension using a Systronics pH meter and electrical conductivity in a 1:2.0 soil water suspension was read using an Elico conductivity meter. Organic carbon was determined by Walkley and Black's method and total nitrogen was determined by semi micro-Kjeldahl method (Soil Survey Investigations Report No.1, 1967).

Total SiO_2, Al_2O_3, Fe_2O_3, P_2O_5, K_2O, CaO and MgO were determined in the perchloric-nitric acid (1:2) extracts (Hesse, 1971). Total SiO_2 was determined gravimetrically. Total iron and aluminium were determined by o-phenanthroline and xylenol orange method respectively while total CaO and MgO were estimated by EDTA titration method as outlined by Hesse (1971). Total P_2O_5 content was estimated by vanadophosphoric yellow colour method (Jackson, 1958) and total potassium by flame photometry using an EEL flame photometer.

The micronutrient elements manganese, zinc and copper were estimated in the di-acid extract using IL 257 atomic absorption spectrophotometer.

Effective cation exchange capacity was calculated as the sum of exchangeable bases and KCl extractable aluminium (Soil Survey Staff, 1967). Exchangeable calcium and magnesium in the neutral 1N NH_4OAc extract was determined using an atomic absorption spectrophotometer. Exchangeable potassium and sodium were read using EEL flame photometer (Jackson, 1958). Exchange acidity, exchangeable aluminium and hydrogen were estimated in the 1N KCl extracts (Soil Survey Investigation Reports No.1, 1967).

Free iron oxide was extracted using dithionite-citrate-bicarbonate method (Mehra and Jackson, 1960) and determined colorimetrically by the o-phenanthroline method. Amorphous iron oxide was extracted using ammonium oxalate (Schwertmann, 1964) and determined by the o-phenanthroline method (Hesse, 1971).

3.2. Analysis of surface samples

Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija, 1956). Available P_2O_5 was extracted using Bray I extractant (0.03 N NH_4F in 0.025 N HCl) and determined by molybdophosphoric acid method as outlined by Jackson (1958). Available potassium was extracted using neutral 1N NH_4OAc and determined using a flame photometer (Jackson, 1958). Phosphorus fixing capacity was determined by the method described by Hesse (1971).

The micronutrients iron, manganese, zinc and copper were extracted using DTPA (Lindsay and Norwell, 1978) and di-acid (0.05 N HCl + 0.025 N H_2SO_4) proposed by Perkins (1970). The contents were estimated using an atomic absorption spectrophotometer.

3.3. Separation and analysis of clay fraction

The clay fraction of samples was separated by the method suggested by Jackson (1975).

The total SiO_2, Al_2O_3, Fe_2O_3 and free iron oxide fractions or the clay were determined in the sodium carbonate fusion extract as outlined by Hanna (1964) adopting the methods mentioned earlier.

4. Statistical analysis

Simple correlation coefficients between the various physico-chemical characteristics of soils were calculated as suggested by Snedecor and Cochran (1967). The significance of the correlation coefficients was tested by using Student's 't' test.

RESULTS

RESULTS

1. Profile morphology

A brief comparative presentation of major morphological features are given in Table 3. The morphological descriptions of pedons are presented in Appendix.

The predominant hue of the soils of Vellayani and Cherniyoor series was 2.5 YR. In the case of Bharanikkavu series the dominant colour hue was 7.5 YR, while for Beypore, Chirakkal and Kunhimangalam it was 5 YR. In all the cases, the value varied from 3 to 5, while chroma was between 6 and 8. An increase in redness with depth was a feature common to all the soil profiles examined.

The surface horizons in Vellayani, Beypore and Chirakkal series were medium weak granular while medium weak subangular blocky structure was observed for the surface horizons of Cherniyoor, Bharanikkavu and Kunhimangalam series. The subsurface horizons in all the soil series studied had predominantly medium to coarse subangular blocky structure.

The textural class of the soils varied from sandy loam to sandy clay. The surface horizons in all the soil series had lighter textures with slightly finer textures in the subsurface horizons as a result of clay illuviation. Wide variations in texture were not observed between the soil series and also within the soil profile.

Table 3. Abbreviated morphological descriptions* of the soil profiles

Horizon	Depth (cm)	Munsell colour dry	Munsell colour moist	Texture	Structure	Consistence	Boundary	Remarks
I Vellayani series								
Ap	0- 19	-	2.5 YR 4/6	sl	m1gr	mvfr,wss,wps	cs	Plentiful fine roots
B_{21}	19- 76	-	2.5 YR 3/6	sl	m1 sbk	mfr,wss,wps	gs	Plentiful fine to medium roots
B_{22}	76-150+	-	2.5 YR 3/6	sc	c2 sbk	mfr,ws,wp		Few medium roots
II Cherniyoor series								
Ap	0- 16	5 YR 4/6	2.5 YR 3/6	sl	m2 sbk	mfi,wss,wps	cs	Plentiful fine to medium roots
B_1	16- 37	-	2.5 YR 4/6	sl	c2 sbk	mfi,wss,wps	gs	Many medium to coarse roots
B_{21}	37- 65	-	2.5 YR 3/6	sc	c2 sbk	mfi,ws,wps	gs	Many fine to medium roots
B_{22}	65-151+	-	2.5 YR 4/8	sc	c2 sbk	mfi,ws,wps		Few coarse and fine roots.
III Bharanikkavu series								
Ap	0- 20	7.5 YR 6/6	7.5 YR 5/6	sl	m1 sbk	dh,mfr,vs,wps	cs	Plentiful fine to medium roots
B_{22}	20- 49	-	7.5 YR 5/6	sc	m2 sbk	mfr,ws,wps	gw	Plentiful medium to coarse roots
B_3	49-145+	-	5 YR 4/6	sc	m2 sbk	mfr,ws,wps		Many coarse roots, few fine roots

Contd.......

Table 3. Contd......

Horizon	Depth (cm)	Munsell colour dry	Munsell colour moist	Texture	Structure	Consistence	Boundary	Remarks
IV Beypore series								
Ap	0- 19	7.5 YR 5/6	5 YR 4/6	sl	m1gr	dsh,mvfr,ws0,wp0	cs	Abundant fibrous fine roots
B_{21}	19-100	-	5 YR 4/6	scl	m1 sbk	mvfr,wss,wp0	gw	Plentiful coarse roots
B_{22}	100-145+	-	2.5 YR 4/6	scl	m2 sbk	mfr,wss,wps		Few coarse and fine roots
V Chirakkal series								
Ap	0- 14	7.5 YR 5/6	5 YR 4/6	scl	m2 gr	dsh,mfr,wss,wp0	cs	Plentiful fine to coarse roots
B_1	14- 32	-	5 YR 5/8	sl	m2 sbk	mfi,wss,wps	gs	Plentiful fine roots, few coarse roots
B_{21}	32- 80	-	5 YR 4/6	scl	c2 sbk	mfi,ws,wp	gw	Many coarse roots
B_{22}	80-165+	-	2.5 YR 4/6	cl	c2 sbk	mfi,ws,wp		Many coarse roots
VI Kunhimangalam series								
Ap	0- 20	7.5 YR 5/6	5 YR 4/6	sl	m1 sbk	dl,mvfr,ws0,wp0	cs	Many coarse roots
B_1	20- 47	5 YR 5/6	5 YR 4/6	sl	m1 sbk	dsh,mfr,wss,wps	gs	Many fine roots
B_{21}	47- 93	5 YR 6/6	5 YR 4/6	scl	m2 sbk	dsh,mfr,wss,wps	gw	Few coarse roots
B_{22}	93-143+	-	2.5 YR 3/6	scl	m2 sbk	mfr,wss,wps		Few coarse roots

* Symbols are as suggested by Soil Survey Staff (1951)

Ill defined horizons, very deep soils and absence of coarase fragments in the profile were features common to all the soils investigated.

The soils from all the locations under investigation were in general well drained both externally and internally, being located in upland positions. The well drained nature of the profiles was well expressed in the morphology by the intense redness in colour hues and complete absence of mottles.

2. Physical properties

Mechanical composition and bulk density data are given in Table 4.

2.1. Mechanical composition

As mentioned earlier, the texture of the soils varied from sandy loam to sandy clay. The coarse sand fraction ranges from 2.67 per cent (No.13) for the Beypore series to 28.29 per cent (No. 4) for the Cherniyoor series. The fine sand fraction varied from 41.1 per cent (No. 3) of Vellayani series to 78.68 per cent (No. 11) of Beypore series. Sand formed the predominant size fraction in all the soils investigated. The distribution of sand in the profiles indicated a decrease in the coarse sand content with depth in the case of Beypore series while a similar trend for the fine sand fraction was observed in the case of Bharanikkavu series. Silt was the lowest among the size fractions

Table 4. Mechanical composition and bulk density of soils

Sample No.	Depth (cm)	Mechanical composition (per cent) Coarse sand	Fine sand	Silt	Clay	Textural class	Silt/Clay	Bulk density (g/cm^3)
Profile I (Vellayani)								
1	0- 19	23.53	57.32	9.07	10.08	Sandy loam	0.899	1.40
2	19- 76	19.47	61.91	2.01	16.61	Sandy loam	0.121	1.49
3	76-150+	20.98	41.10	3.54	34.38	Sandy clay	0.103	1.33
Profile II (Cherniyoor)								
4	0- 16	28.29	53.53	3.03	15.15	Sandy loam	0.200	1.46
5	16- 37	24.43	54.85	7.58	13.14	Sandy loam	0.577	1.34
6	37- 65	11.72	53.52	3.06	31.70	Sandy clay	0.097	1.40
7	65-151+	24.31	42.05	2.58	31.06	Sandy clay	0.083	1.32
Profile III (Bharanikkavu)								
8	0- 20	10.87	61.95	8.70	18.48	Sandy loam	0.471	1.35
9	20- 49	8.37	48.23	3.66	39.74	Sandy clay	0.092	1.22
10	49-145+	15.71	47.07	2.25	34.97	Sandy clay	0.064	1.32
Profile IV (Beypore)								
11	0- 19	6.52	78.68	3.57	11.22	Sandy loam	0.318	1.44
12	19-100	5.26	75.15	1.06	18.53	Sandy clay loam	0.057	1.41
13	100-145+	2.67	76.67	2.58	18.08	Sandy clay loam	0.143	1.46
Profile V (Chirakkal)								
14	0- 14	9.43	66.93	4.20	19.44	Sandy clay loam	0.216	1.49
15	14- 32	16.32	72.18	1.05	10.45	Sandy loam	0.100	1.45
16	32- 80	13.52	55.96	5.90	24.62	Sandy clay loam	0.240	1.44
17	80-165+	16.03	45.63	8.97	29.37	Clay loam	0.305	1.50
Profile VI (Kunhimangalam)								
18	0- 20	26.61	56.01	0.49	16.89	Sandy loam	0.029	1.53
19	20- 47	9.91	68.70	3.65	17.74	Sandy loam	0.206	1.43
20	47- 93	10.91	62.26	1.46	25.37	Sandy clay loam	0.058	1.53
21	93-143+	8.52	63.59	1.50	26.39	Sandy clay loam	0.057	1.55

and its content ranged from 0.49 per cent (No. 18) in Kunhimangalam series to 9.07 per cent (No. 1) of Vellayani series. A definite decrease in silt content with depth was observed for Bharanikkavu series. No definite trend in distribution of silt with depth was noted for the other soils under investigation. The highest clay content 39.74 per cent (No. 9) was observed in Bharanikkavu series and the lowest, 10.08 per cent (No. 1) was obtained for Vellayani series. In all the soils investigated clay movement was observed by way of increase in its content with depth. Maximum accumulation of clay in the lowest layer of the soil profile was observed in the case of Vellayani, Chirakkal and Kunhimangalam series while clay accumulation in intermediate layers was noted in the case of Cherniyoor, Bharanikkavu and Beypore series. Correlations between coarse sand and fine sand against clay were negative.

The silt/clay ratios of the soils ranged from 0.029 (No. 18) of Kunhimangalam series to 0.899 (No. 1) of Vellayani series. The ratio showed a decreasing trend with depth in the case of Vellayani and Bharanikkavu series while in the other soils no definite pattern of variation was observed with depth.

2.2. Bulk density

The bulk density values range from 1.22 g/cc (No. 9) of Bharanikkavu series to 1.55 g/cc (No. 21) of

Kunhimangalam series. No definite trend in bulk density with depth was observed in any of the profiles. A negative relationship was obtained between bulk density on one hand and clay and organic matter on the other.

2.3. Moisture retention characteristics

The amounts of water held at various moisture tensions are presented in Table 5 and the moisture curves depicted in Figures 2 to 7.

The amount of water held at 1/3 bar often taken as field capacity of the soil, varied from 6.74 to 12.78 per cent, 9.44 to 12.30 per cent, 12.46 to 13.79 per cent, 7.12 to 7.84 per cent, 6.79 to 13.10 per cent and 7.51 to 10.86 per cent for Vellayani, Cherniyoor, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series respectively. It was maximum for Bharanikkavu series while the minimum value was recorded for Vellayani series. The field capacity values showed slight increase with depth in the case of Bharanikkavu series while in all other soils no definite pattern of distribution with depth was noted.

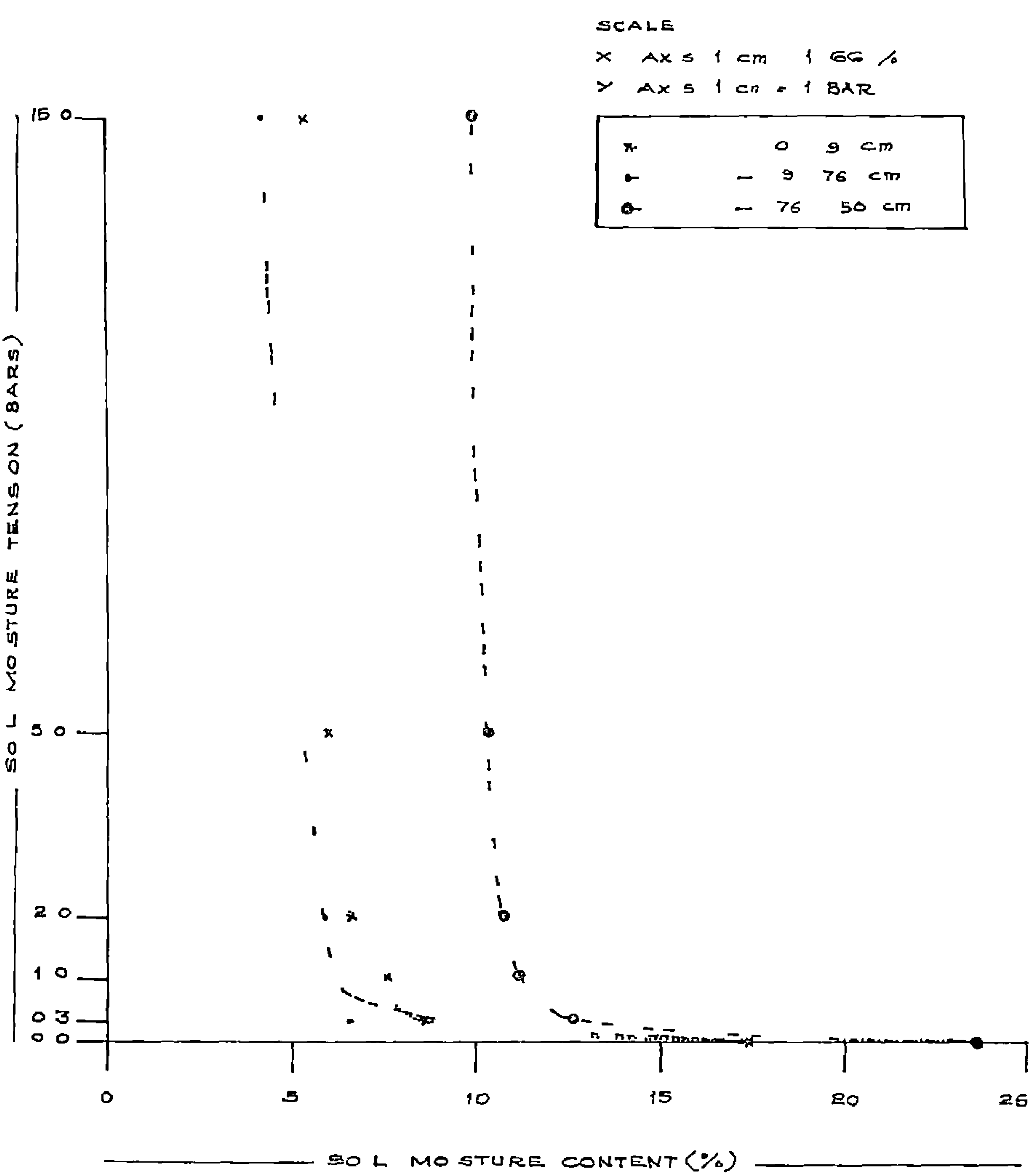
The quantities of water held at 1, 2 and 5 bar showed similar trend as in the case of field capacity.

The 15 bar moisture often designated as wilting point was highest in Bharanikkavu series with 10.62 per cent (No. 10), the lowest value, 3.21 per cent (No. 15)

Table 5. Moisture retention characteristics of soils (percentage by weight)

Sample No.	Depth (cm)	Soil moisture tension (bars)						Available water
		0	0.3	1	2	5	15	
Profile I (Vellayani)								
1	0- 19	16.71	8.62	7.67	6.62	6.00	5.31	3.31
2	19- 76	17.35	6.74	6.70	6.10	5.29	4.16	2.58
3	76-150+	23.87	12.78	11.28	11.14	10.46	9.85	2.93
Profile II (Cherniyoor)								
4	0- 16	16.07	10.20	8.41	7.71	7.35	6.00	4.20
5	16- 37	18.82	9.44	9.06	7.87	7.71	6.67	2.77
6	37- 65	21.00	11.51	11.20	10.12	8.53	8.13	3.38
7	65-151+	23.66	12.30	11.81	10.87	9.13	8.24	4.06
Profile III (Bharanikkavu)								
8	0- 20	20.74	12.46	10.70	9.19	8.72	7.63	4.83
9	20- 49	24.83	12.64	10.85	10.18	9.78	9.21	3.43
10	49-145+	20.61	13.79	12.26	11.16	10.70	10.62	3.17
Profile IV (Beypore)								
11	0- 19	16.32	7.12	6.41	5.30	4.47	3.62	3.50
12	19-100	19.74	7.84	7.11	6.81	6.41	5.67	2.17
13	100-145+	18.57	7.23	6.77	6.35	6.05	5.02	2.21
Profile V (Chirakkal)								
14	0- 14	17.87	10.30	8.49	7.65	7.13	5.71	4.59
15	14- 32	15.70	6.79	5.28	5.11	4.45	3.21	3.58
16	32- 80	22.53	10.41	8.81	8.25	7.62	5.74	4.67
17	80-165+	24.70	13.10	12.63	11.47	10.76	9.14	3.96
Profile VI (Kunnimangalam)								
18	0- 20	14.05	7.51	6.83	6.04	4.99	3.52	3.99
19	20- 47	16.87	7.94	7.13	6.56	6.48	4.44	3.50
20	47- 93	19.05	10.86	7.73	7.40	7.20	5.27	5.59
21	93-143+	12.54	8.28	7.56	7.19	7.02	5.25	3.03

FIG 2 MO STURE RETENTION CURVE - VELLAYAN SERIES



F G 3- MOISTURE RETENT ON CURVE CHERN OOR SER ES

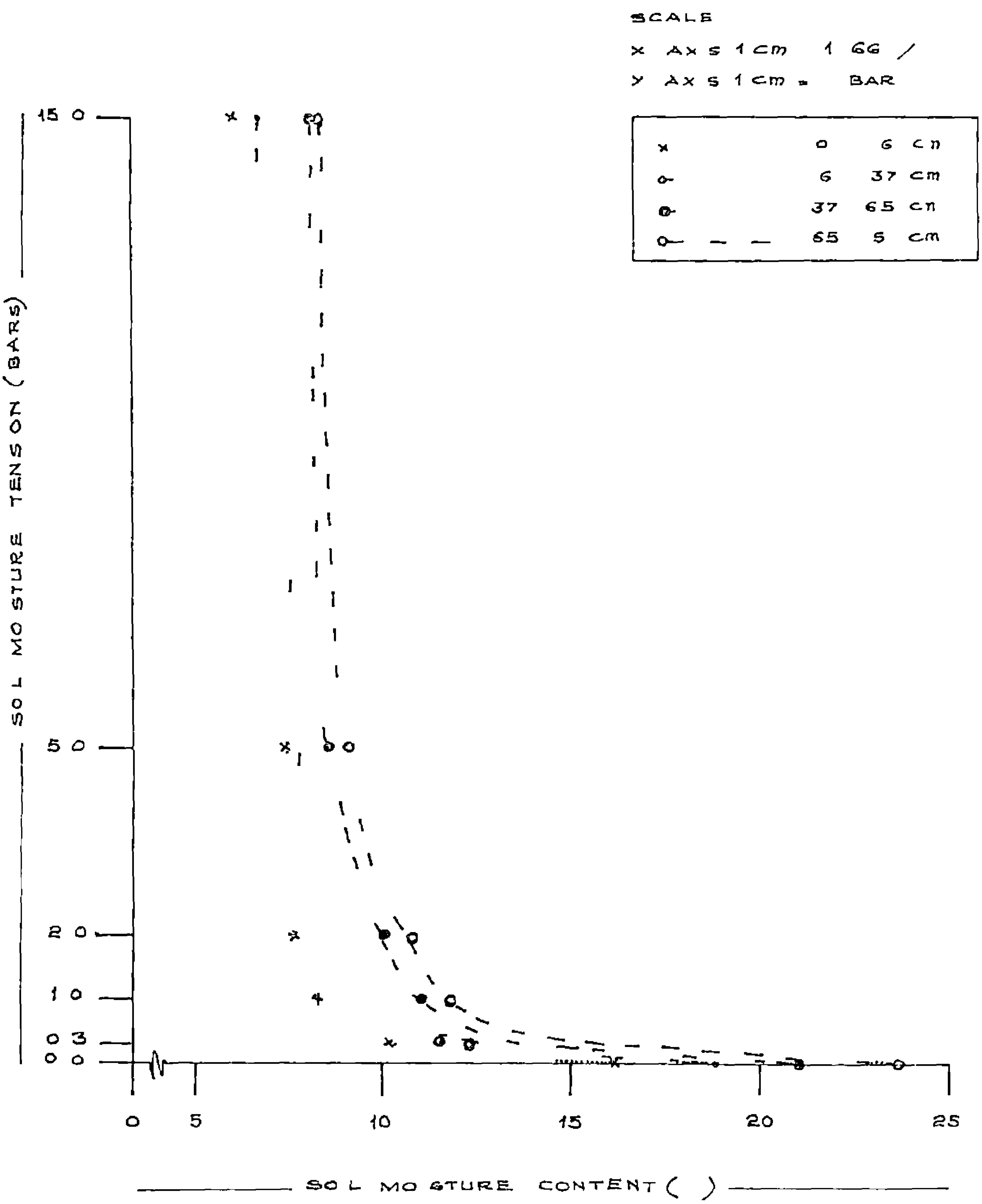


FIG 4. MOISTURE RETENTION CURVE BHARANIKKAVU SERIES

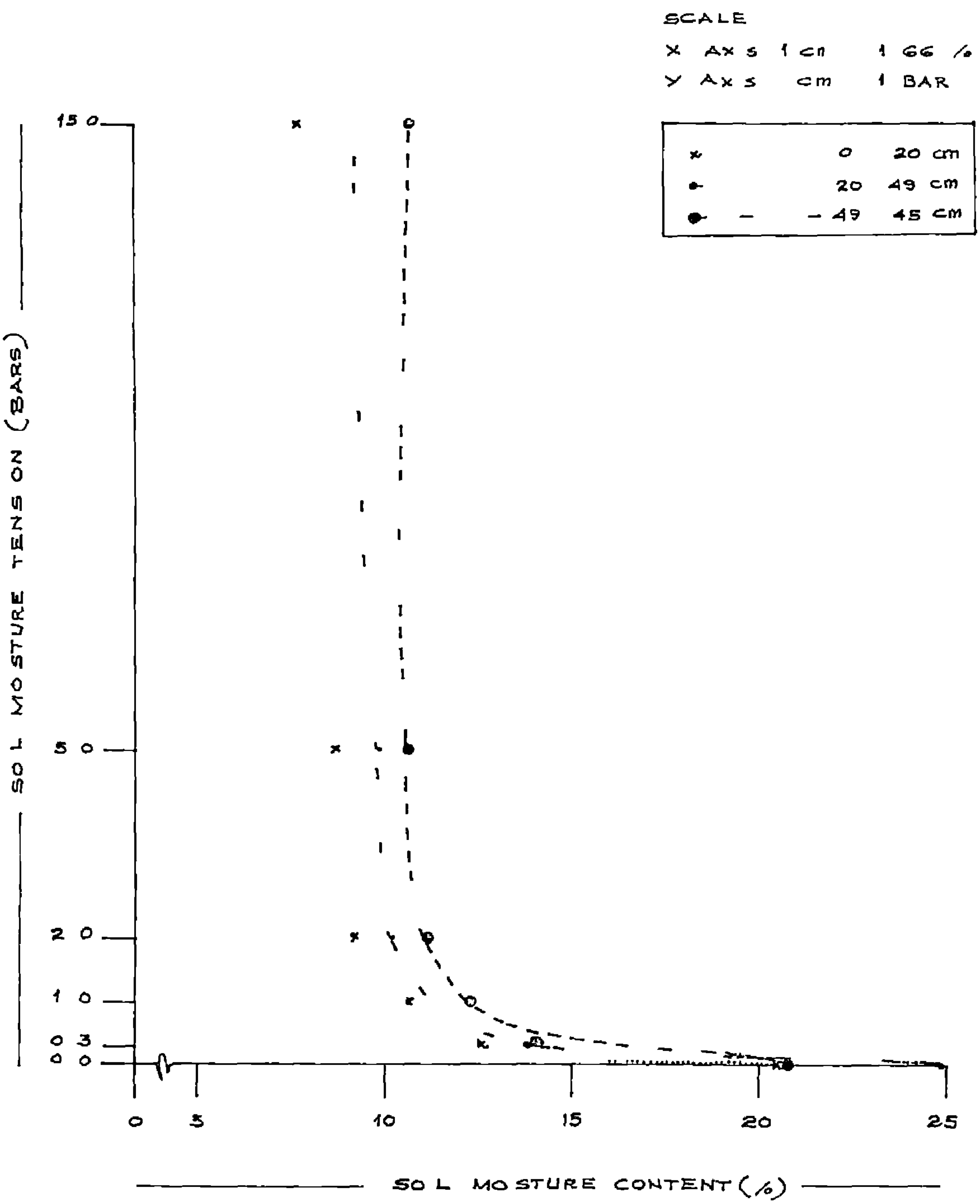


FIG 5 - MOISTURE RETENTION CURVE BEYPORE SER ES

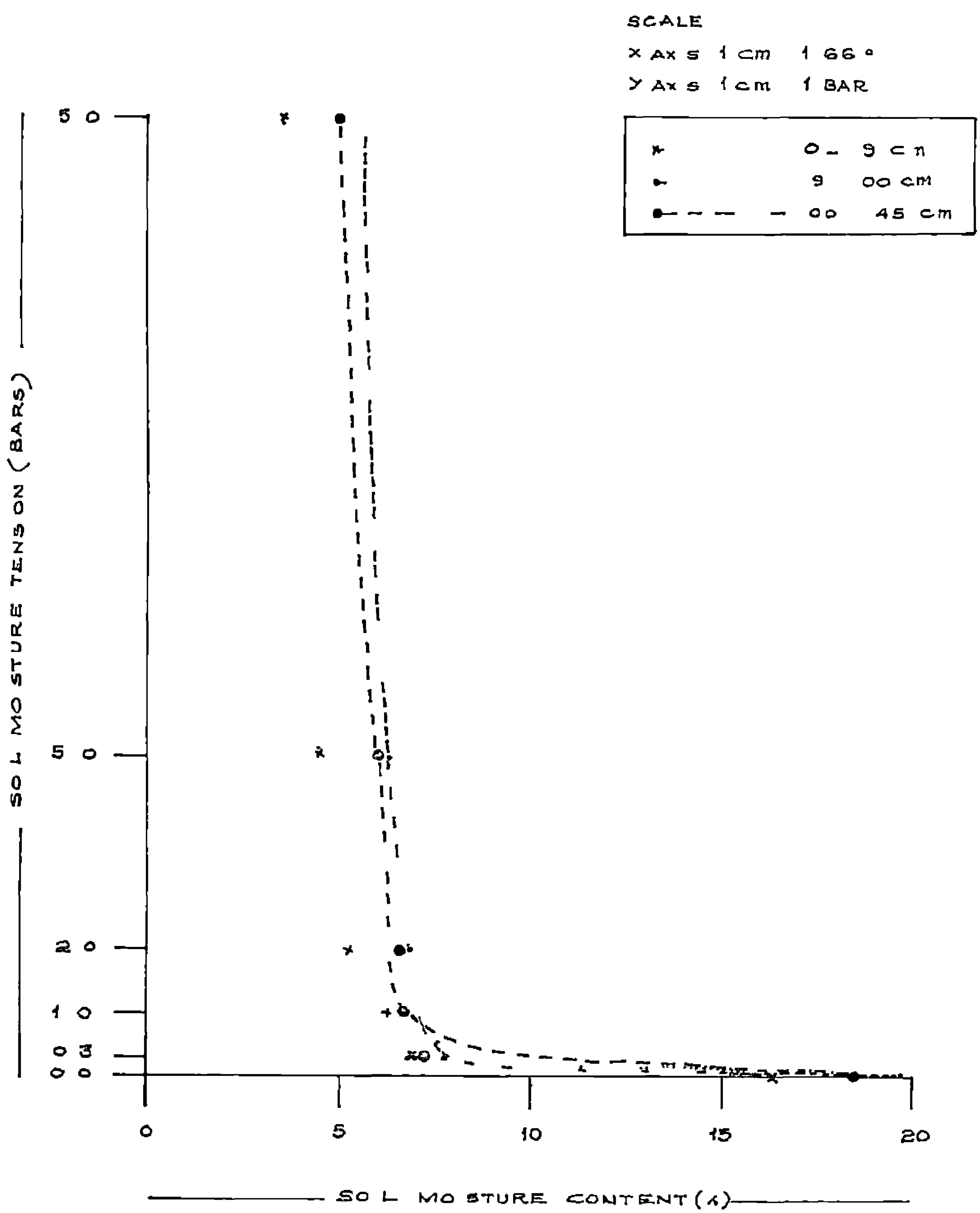


FIG 6 - MOISTURE RETENT ON CURVE CHIRAKKAL SERIES

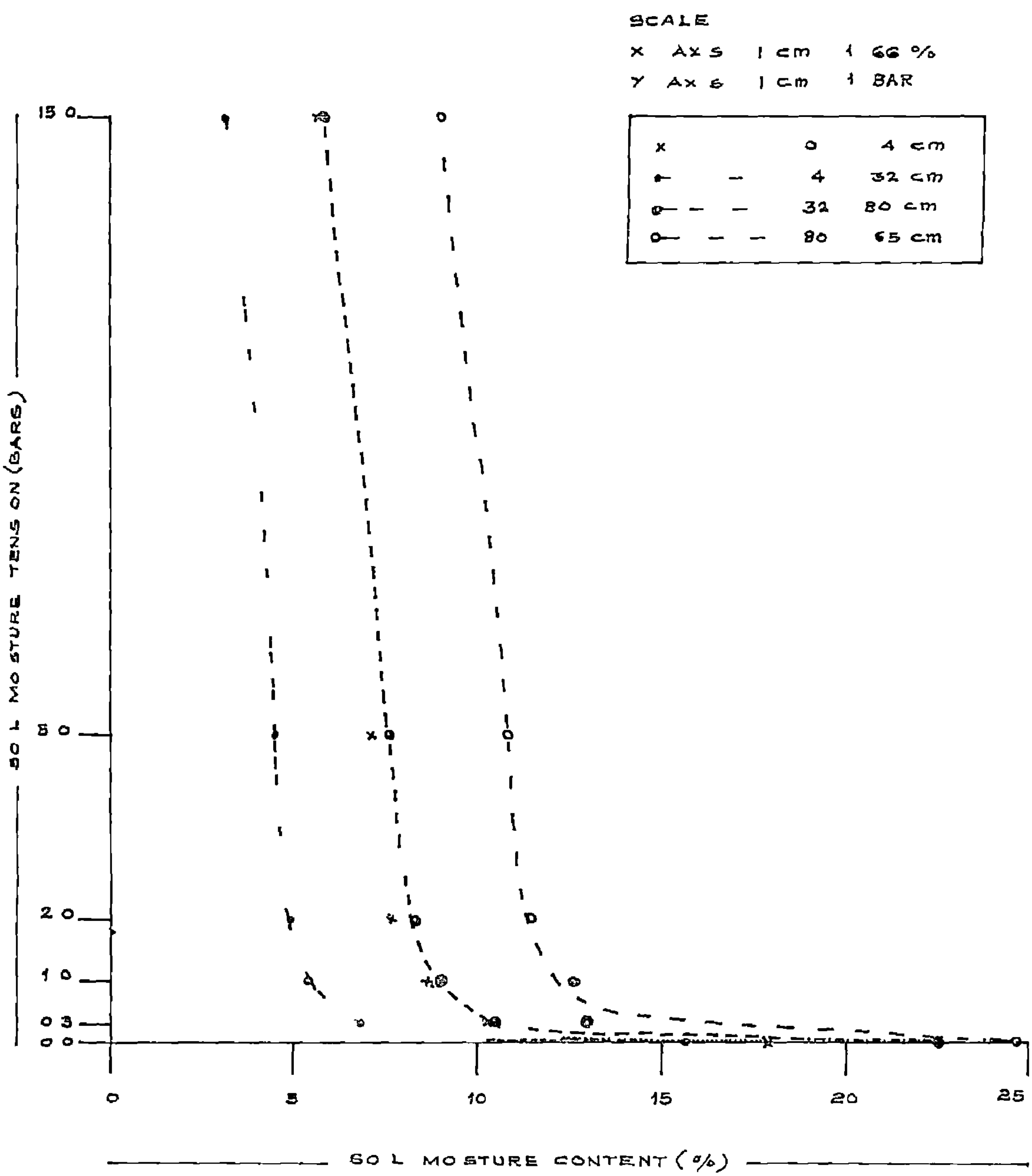
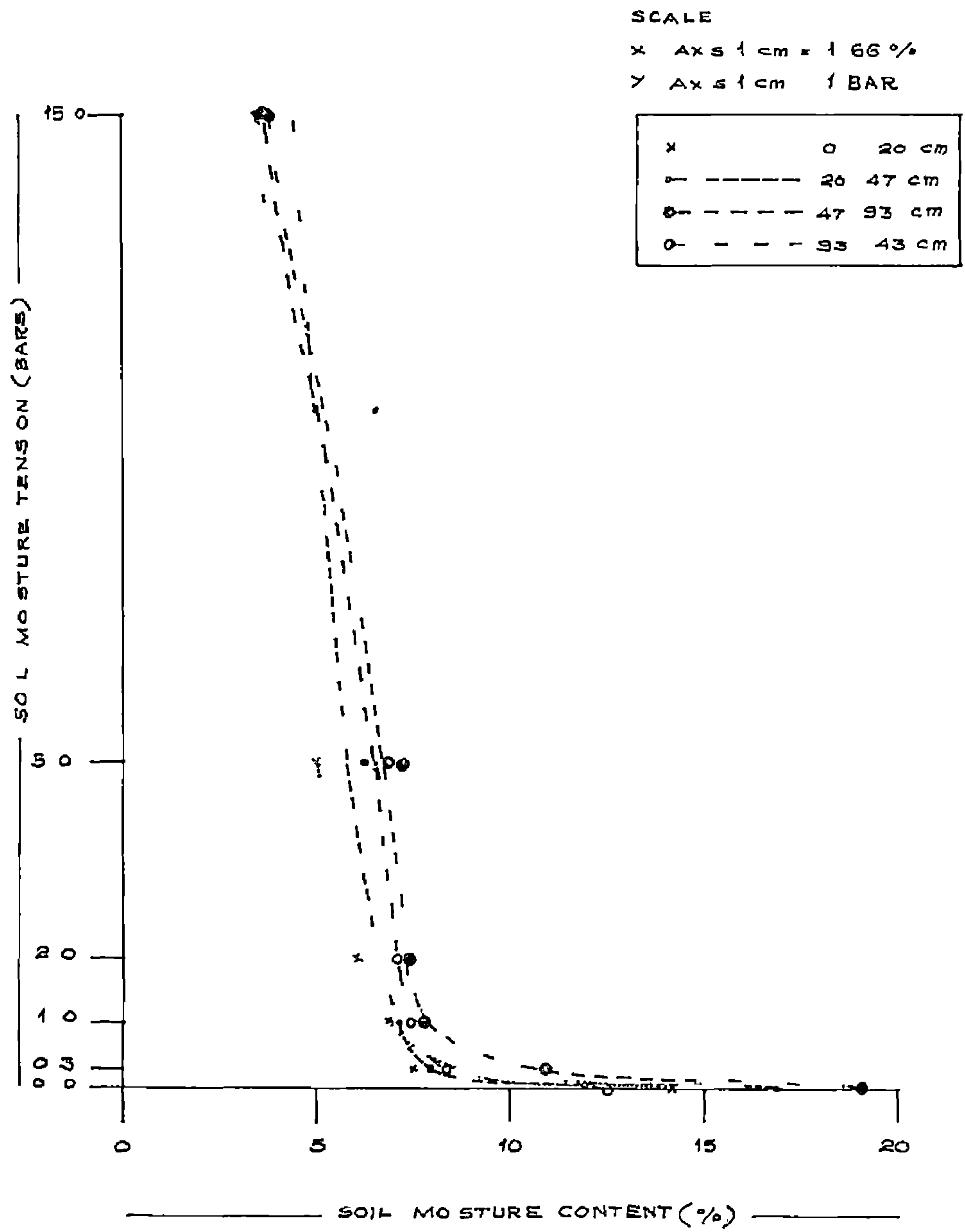


FIG 7- MOISTURE RETENTION CURVE KUNHIMANGALAM SERIES



being recorded in Chirakkal series. The moisture content varied from 4.16 to 9.85 per cent, 6.0 to 8.24 per cent, 3.62 to 5.67 per cent and 3.52 to 5.27 per cent in Vellayani, Cherniyoor, Beypore and Kunhimangalam series respectively.

Correlations worked out between moisture retention at 1,2,5 and 15 bars and clay content were positive. Highly significant positive correlations were obtained between clay and 5 bar moisture (r = 0.608**) and 15 bar moisture (r = 0.590**).

The available water content which is the difference between water held at 0.3 bar and 15 bars was highest in Kunhimangalam series (No. 20) with a value of 5.59 percent. The lowest moisture content 2.17 per cent (No.12) was observed in Beypore series. For the other soils, the available water content varied from 2.58 to 3.31 per cent, 2.77 to 4.20 per cent, 3.17 to 4.83 per cent and 3.58 to 4.67 per cent for Vellayani, Cherniyoor, Bharanikkavu and Chirakkal series respectively. Correlation of available water content with clay was negative (r = -0.025).

3. Chemical characteristics

3.1. Soil reaction, electrical conductivity and organic constituents

The pH, conductivity and organic constituents of samples are given in Table 6 and organic carbon

Table 6. Soil reaction, electrical conductivity and organic constituents

Sample No.	Depth (cm)	Soil reaction 1:2.5	Electrical conductivity 1:2.0 (mmho/cm)	Organic carbon %	Total nitrogen %	Carbon/nitrogen ratio
Profile I (Vellayani)						
1	0- 19	4.75	0.08	0.589	0.102	5.77
2	19- 76	4.85	0.03	0.322	0.096	3.35
3	76-150+	4.75	0.02	0.324	0.057	5.68
Profile II (Cherniyoor)						
4	0- 16	5.40	0.35	0.742	0.068	10.91
5	16- 37	5.15	0.13	0.628	0.080	7.85
6	37- 65	4.80	0.03	0.534	0.068	7.85
7	65-151+	4.85	0.02	0.248	0.057	4.35
Profile III (Bharanikkavu)						
8	0- 20	4.90	0.01	0.709	0.109	6.50
9	20- 49	4.70	0.03	0.403	0.086	4.65
10	49-145+	4.75	0.02	0.327	0.097	3.37
Profile IV (Beypore)						
11	0- 19	4.85	0.02	0.552	0.085	6.49
12	19-100	4.80	0.02	0.383	0.075	5.11
13	100-145+	4.80	0.01	0.248	0.096	2.58
Profile V (Chirakkal)						
14	0- 14	4.95	0.03	0.632	0.136	4.65
15	14- 32	4.80	0.04	0.493	0.113	4.36
16	32- 80	4.80	0.02	0.382	0.114	3.35
17	80-165+	4.80	0.01	0.191	0.092	2.08
Profile VI (Kunhimangalam)						
18	0- 20	5.00	0.02	0.589	0.125	4.71
19	20- 47	4.75	0.01	0.400	0.120	3.33
20	47- 93	4.60	0.02	0.267	0.074	3.61
21	93-143+	4.55	0.02	0.173	0.069	2.51

distribution with depth is shown in Figure 8.

The soils were in general acidic with pH ranging from 4.55 (No. 21) in Kunhimangalam series to 5.40 (No. 4) in Cherniyoor series. A general decrease in pH with depth was noted.

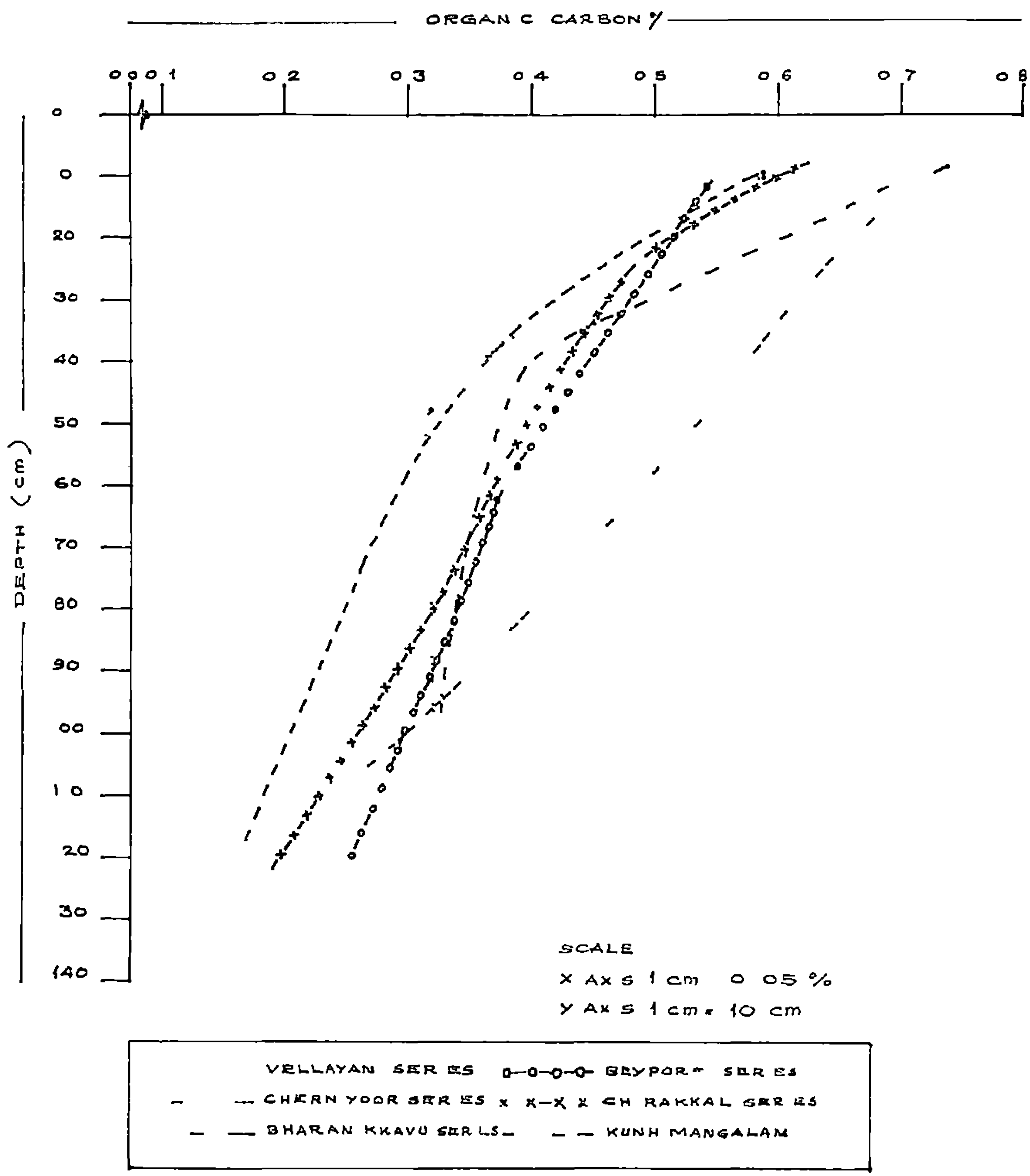
The electrical conductivity of the soils are very low and show very little variations within the profile and between the soil series. The range observed was from 0.01 mmho/cm to 0.35 mmho/cm.

The organic carbon content of the soils varied from 0.173 per cent (No. 21) of Kunhimangalam series to 0.742 per cent (No. 4) of Cherniyoor series. The organic carbon variations in the profile showed a steady decrease with depth for all the soil series except in the case of Vellayani soils.

Total nitrogen content showed maximum accumulation in the surface horizons, but did not reveal any pattern of distribution with depth in the soil profile. The total nitrogen content varied from 0.057 per cent (No. 3) of Vellayani series and No. 7 of Cherniyoor series to 0.136 per cent (No. 14) of Chirakkal series. Correlation of total nitrogen with organic carbon was positive, but not significant (r = 0.385).

The C/N ratio was maximum in the surface horizons in all the soils investigated and a definite decrease with depth was observed in Cherniyoor, Bharanikkavu,

FIG 8 - DISTRIBUT ON OF ORGANIC CARBON N
SOIL PROF LES



Beypore and Chirakkal. The C/N ratio varied from 2.08 (No. 17) of Chirakkal series to 10.91 (No. 4) of Cherniyoor series.

3.2. Total elemental composition of soils

The total elemental composition of soils is given in Table 7. The SiO_2 content of all the soils recorded high values ranging from 73.79 per cent (No. 10) in Bharanikkavu series to 89.38 per cent (No. 18) of Kunhimangalam series. A definite decrease with depth in the content of silica was noted in Cherniyoor and Bharanikkavu series while the other soils showed no definite trend in variation with depth.

The Al_2O_3 content varied from 3.37 per cent (No. 15) in Chirakkal series to 12.15 per cent (No. 9) in Bharanikkavu series. Al_2O_3 content showed irregular distribution with depth in all soils investigated except in the case of Vellayani series where a steady increase with depth was observed.

In the case of Fe_2O_3 the range observed was from 2.30 per cent (No. 15) in Chirakkal series to 7.16 per cent (No. 10) in Bharanikkavu series. Increase in the content of iron with depth was observed in Vellayani and Bharanikkavu series while the reverse was noted in Beypore series. In all other cases irregular distribution with depth was observed.

Table 7. Total elemental composition of soils

Sample No.	Depth (cm)	Total content (per cent)						
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5
Profile I (Vellayani)								
1	0- 19	83.67	7.94	3.07	0.171	0.239	0.034	0.039
2	19- 76	85.85	7.97	3.15	0.069	0.119	0.033	0.021
3	76-150+	77.38	9.05	6.87	0.017	0.958	0.059	0.030
Profile II (Cherniyoor)								
4	0- 16	83.95	9.34	3.21	0.086	0.119	0.042	0.030
5	16- 37	81.07	10.01	3.55	0.069	0.119	0.031	0.050
6	37- 65	79.91	12.08	5.28	0.087	0.119	0.045	0.039
7	65-151+	78.45	11.63	5.13	0.052	0.119	0.057	0.034
Profile III (Bharanikkavu)								
8	0- 20	79.46	11.66	4.39	0.104	0.361	0.084	0.039
9	20- 49	76.84	12.15	5.48	0.087	0.121	0.114	0.039
10	49-145+	73.79	9.46	7.16	0.070	0.121	0.087	0.034
Profile IV (Beypore)								
11	0- 19	88.99	5.56	4.09	0.052	0.358	0.043	0.059
12	19-100	86.14	8.53	3.18	0.035	0.602	0.078	0.066
13	100-145+	86.52	7.74	3.17	0.035	0.720	0.083	0.059
Profile V (Chirakkal)								
14	0- 14	86.56	7.76	4.83	0.072	0.237	0.202	0.082
15	14- 32	88.62	3.37	2.30	0.069	0.597	0.110	0.049
16	32- 80	83.13	8.49	4.11	0.035	0.240	0.207	0.059
17	80-165+	78.74	11.65	4.68	0.052	0.481	0.330	0.059
Profile VI (Kunhimangalam)								
18	0- 20	89.38	7.94	2.44	0.051	0.952	0.085	0.071
19	20- 47	86.64	5.90	3.65	0.017	0.360	0.122	0.039
20	47- 93	85.43	8.21	3.76	0.035	0.958	0.195	0.057
21	93-143+	87.02	6.69	3.28	0.070	0.725	0.220	0.025

The variation with regard to total CaO content of soils was from 0.017 per cent (Nos. 3 and 19) for Vellayani and Kunhimangalam series to 0.171 per cent for the surface layer (No. 1) of Vellayani series. The surface layers of profiles from Vellayani, Bharanikkavu, Beypore and Chirakkal series showed higher values for CaO than subsurface layers. However, no pattern of distribution with depth was observed in any of the soils studied.

MgO content of soils also showed no definite depthwise variation in the profile. The MgO status was higher than that of CaO and ranged from 0.119 per cent (No. 2) of Vellayani series and (Nos. 4,5,6 and 7) of Cherniyoor series to 0.958 per cent (No. 3) of Vellayani series and (No. 20) of Kunhimangalam series.

Total potassium showed increase in the contents with depth with the lowest layer of all soils recording the highest content except in the case of Bharanikkavu series. In the case of Beypore and Kunhimangalam series a definite increase with depth was observed in the distribution of potassium. All other soils showed irregular pattern of variation with depth. The K_2O content varied from 0.031 per cent (No. 5) of Cherniyoor series to 0.330 per cent (No. 17) of Chirakkal series.

Total P_2O_5 content recorded lower values than that of total K_2O and varied from 0.021 per cent (No. 2) for

Vellayani series to 0.082 per cent (No. 14) for the surface layer of Chirakkal series.

3.3. Total micronutrient content in soils

Distribution of iron, manganese, zinc and copper of soils is presented in Table 8.

The content of iron was highest in Bharanikkavu profile varying from 30705 to 50080 ppm; while the lowest was observed in Chirakkal series ranging from 16087 to 33783 ppm. The contents of iron recorded in the other soils investigated were 21473 to 48052 ppm, 22452 to 36930 ppm, 22172 to 28607 ppm and 17066 to 26299 ppm in Vellayani, Cherniyoor, Beypore and Kunhimangalam series respectively. Increase in content of iron with depth was observed in Bharanikkavu and Vellayani series while a reverse trend in the iron content was noted with depth in Beypore series. Significant positive correlation was observed between total iron and clay content (r = 0.595**).

Highest manganese content, 355.46 ppm (No. 19) was observed in Kunhimangalam series while Cherniyoor series recorded 24.68 ppm (No. 6), the lowest content among the soils under study. Profile variations of manganese did not reveal any definite trend. The fine sand fraction of soil was found to have positive and significant correlation to manganese content (r = 0.486*).

Table 8. Distribution of iron, manganese, zinc and copper in soils

Sample No.	Depth (cm)	Total content, ppm			
		Fe	Mn	Zn	Cu
Profile I (Vellayani)					
1	0- 19	21473	44.66	13.11	10.48
2	19- 76	22032	60.79	7.05	9.56
3	76-150+	48052	60.79	9.00	17.30
Profile II (Cherniyoor)					
4	0- 16	22452	44.15	14.65	7.68
5	16- 37	24830	59.44	3.84	4.35
6	37- 65	36930	24.68	7.59	Trace
7	65-151+	35881	25.44	9.12	13.99
Profile III (Bharani-kkavu)					
8	0- 20	30705	63.22	15.45	17.08
9	20- 49	38329	108.39	28.19	24.93
10	49-145+	50080	93.93	Trace	27.60
Profile IV (Beypore)					
11	0- 19	28607	88.69	4.58	19.70
12	19-100	22242	210.01	6.10	47.09
13	100-145+	22172	188.13	7.29	40.73
Profile V (Chirakkal)					
14	0- 14	33783	231.38	7.13	28.89
15	14- 32	16087	115.41	Trace	11.28
16	32- 80	28747	153.70	Trace	26.02
17	80-165+	32734	100.58	16.26	27.43
Profile VI (Kunhi-mangalam)					
18	0- 20	17066	216.65	13.10	23.88
19	20- 47	25529	355.46	5.66	20.22
20	47- 93	26299	284.80	27.80	24.87
21	93-143+	22941	181.05	8.56	23.23

In the case of zinc, the range of variation observed was from traces (No. 10) in Bharanikkavu series and (Nos. 15 and 16) of Chirakkal series to 28.19 ppm (No. 9) of Bharanikkavu series. Subsurface horizons showed accumulation of zinc in the case of Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series while accumulation in the surface layers was observed in the case of Cherniyoor and Vellayani series. Steady increase in zinc content with depth was noticed in the case of Beypore series. Zinc content was found to be positively correlated with clay, but was not significant (r = 0.288).

Copper content recorded higher values than zinc and varied from trace in Cherniyoor series (No. 6) to 47.09 ppm (No. 12) in Beypore series. The subsurface horizons of all the soils investigated showed accumulation of this element though no definite pattern or distribution was observed in any of the profiles. Fine sand fraction was positively correlated with the total copper content (r = 0.337).

4. Cation exchange properties

The effective cation exchange capacity (e.c.e.c.) and the exchangeable cations of the soils are presented in Table 9.

4.1. Cation exchange capacity

The e.c.e.c. of soils as expected, recorded very low values ranging from 0.862 me/100 g (No. 10) of

Table 9. Exchangeable cations and effective cation exchange capacity of soils, me/100 g soil

Sample No.	Depth (cm)	Exchangeable cations						e.c.e.c.
		Ca	Mg	K	Na	H	Al	
Profile I (Vellayani)								
1	0- 19	0.580	0.134	0.026	0.149	0.394	0.166	1.06
2	19- 76	0.468	0.091	0.003	0.114	0.404	0.341	1.02
3	76-150+	0.634	0.052	0.015	0.202	0.427	0.697	1.60
Profile II (Cherniyoor)								
4	0- 16	0.583	0.505	0.300	0.149	0.203	0.171	1.71
5	16- 37	0.672	0.319	0.062	0.272	0.401	0.255	1.58
6	37- 65	0.461	0.159	0.010	0.237	0.221	0.481	1.35
7	65-151+	0.155	0.214	0.003	0.096	0.308	0.442	0.91
Profile III (Bharanikkavu)								
8	0- 20	0.554	0.232	0.036	0.133	0.419	0.523	1.48
9	20- 49	0.461	0.175	0.031	0.274	0.424	0.612	1.55
10	49-145+	0.245	0.118	0.010	0.151	0.605	0.338	0.862
Profile IV (Beypore)								
11	0- 19	0.399	0.102	0.016	0.220	0.421	0.608	1.35
12	19-100	0.341	0.114	0.037	0.203	0.246	0.884	1.58
13	100-145+	0.441	0.141	0.026	0.238	0.589	0.161	1.01
Profile V (Chirakkal)								
14	0- 14	0.636	0.170	0.043	0.301	0.429	0.493	1.64
15	14- 32	0.399	0.110	0.041	0.166	0.306	0.300	1.02
16	32- 80	0.785	0.223	0.029	0.255	0.422	0.609	1.90
17	80-165+	0.745	0.183	0.029	0.380	1.75	0.041	1.38
Profile VI (Kunhimangalam)								
18	0- 20	0.577	0.132	0.039	0.219	0.415	0.518	1.49
19	20- 47	0.430	0.105	0.034	0.185	1.18	0.410	1.16
20	47- 93	0.420	0.124	0.052	0.185	0.911	0.728	1.51
21	93-143+	0.433	0.089	0.050	0.239	1.20	0.683	1.49

Bharanikkavu series to 1.90 me/100 g (No. 16) of Chirakkal series. The e.c.e.c. values showed no definite variations with depth in the soils except for Cherniyoor series where a definite decreasing trend was hoted. The e.c.e.c. was positively correlated to organic carbon content of soils (r = 0.490*) which was significant. Clay was also positively correlated with e.c.e.c. (r = 0.430), but was not significant.

4.2. Exchangeable cations

The exchangeable calcium content of the different soils studied varied from 0.155 me/100 g (No. 7) of Cherniyoor series to 0.785 me/100 g (No. 16) in Chirakkal series. Definite decrease in exchangeable calcium with depth was noticed in Bharanikkavu series only. The exchangeable calcium showed positive significant correlation (r = 0.765**) with e.c.e.c.

In the case of exchangeable magnesium, the range observed was from 0.052 me/100 g (No. 3) in Vellayani series to 0.505 me/100 g (No. 4) in Cherniyoor series. Maximum accumulation of exchangeable magnesium was noted in surface layers of Vellayani, Cherniyoor, Bharanikkavu and Kunhimangalam series while intermediate layers showed accumulation in Chirakkal series. However, Beypore soils showed maximum accumulation in the last layer of the profile. Exchangeable magnesium was also positively and significantly correlated to effective c.e.c. (r = 0.539*).

The content of exchangeable potassium varied from 0.003 me/100 g (Nos. 2 and 7) in Vellayani and Cherniyoor series to 0.300 me/100 g (No. 4) also recorded in Cherniyoor series. The exchangeable sodium content showed a slightly higher range of 0.096 me/100 g (No. 7) of Cherniyoor series to 0.380 me/100 g (No. 17) of Chirakkal series. Both these exchangeable bases showed no definite pattern of variation with depth in the profiles. The correlation coefficients of exchangeable potassium and sodium with e.c.e.c. were 0.374 and 0.488* respectively.

Among the exchangeable cations, the acid generating cation, hydrogen, recorded values ranging from 0.203 me/100 g (No. 4) of Cherniyoor series to 1.75 me/100 g (No. 1 for Chirakkal series. The exchangeable hydrogen showed maximum accumulation in the lower most layer of Vellayani, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series. Definite increase in exchangeable hydrogen with depth was observed in the case of Bharanikkavu series.

Exchangeable aluminium recorded slightly lower values than exchangeable hydrogen varying from 0.041 me/100 g (No. 17) of Chirakkal series to 0.884 me/100 g (No. 12) of Beypore series. Irregular variations in the profile were observed in the exchangeable aluminium content in all the soils except

Vellayani series where a definite increase was noted with depth.

4.3. Exchange acidity, percentage base saturation and unsaturation

The exchange acidity, percentage base saturation and unsaturation of soils are presented in Table 10.

The exchange acidity represents the total of both the acid generating cations, hydrogen and aluminium. Being acid soils, the exchange acidity values are fairly high corresponding to higher amounts of these exchangeable cations. Kunnimangalam series recorded the highest exchange acidity value or 1.88 me/100 g (No. 21) while the lowest value noted in the case of Cherniyoor series was 0.374 me/100 g (No. 4). Increase in the exchange acidity value for the sub-surface layer was a common feature in all the soils under investigation. Definite increase with depth in exchange acidity values was observed in Vellayani, Cherniyoor and Kunhimangalam series. Exchange acidity was positively and significantly correlated to the soil pH (r = 0.508*).

Cherniyoor series showed the highest base saturation values of 80.63 per cent (No. 4) while the lowest value, 30.15 per cent (No. 21) was obtained in Kunhimangalam series. The surface soils showed the highest values for base saturation in the case of Vellayani, Cherniyoor, Bharanikkavu and Kunhimangalam while in other soils irregular variation of base

Table 10. Exchange acidity, percentage base saturation and unsaturation of soils

Sample No.	Depth (cm)	Exchange acidity me/100 g	Total bases me/100 g	Percentage base saturation	Percentage base unsaturation
Profile I (Vellayani)					
1	0- 19	0.560	0.889	61.31	38.69
2	19- 76	0.745	0.676	47.61	52.39
3	76-150+	1.24	0.903	42.20	57.80
Profile II (Cherniyoor)					
4	0- 16	0.374	1.54	80.63	19.37
5	16- 37	0.656	1.33	66.83	33.17
6	37- 65	0.701	0.867	55.22	44.78
7	65-151+	0.750	0.468	38.36	61.64
Profile III (Bharanikkavu)					
8	0- 20	0.942	0.955	50.26	49.74
9	20- 49	1.04	0.941	47.53	52.47
10	49-145+	0.943	0.524	35.65	64.35
Profile IV (Beypore)					
11	0- 19	1.03	0.737	41.64	58.36
12	19-100	1.13	0.695	37.98	62.02
13	100-145+	0.750	0.846	52.88	47.12
Profile V (Chirakkal)					
14	0- 14	0.922	1.15	55.56	44.44
15	14- 32	0.606	0.716	54.24	55.76
16	32- 80	1.03	1.29	55.60	44.40
17	80-165+	1.80	1.34	42.68	57.32
Profile VI (Kunhimangalam)					
18	0- 20	0.933	0.967	50.89	49.11
19	20- 47	1.59	0.754	32.22	67.78
20	47- 93	1.64	0.781	32.27	67.73
21	93-143+	1.88	0.811	30.15	69.85

saturation with depth was observed. Percentage base saturation was found to be significantly correlated to exchangeable calcium (r = 0.485*), exchangeable magnesium (r = 0.781**), exchangeable potassium (r = 0.605**) and exchangeable sodium (r = 0.028).

The percentage base unsaturation was consistent with the exchange acidity values for the various soils. The lowest value of unsaturation, 19.37 per cent (No. 4) of Cherniyoor series had the lowest exchange acidity value while Kunhimangalam series with percentage base unsaturation of 69.85 (No. 21) recorded the maximum exchange acidity value.

5. Extractable iron and active iron ratio

The total Fe_2O_3, dithionite-citrate-bicarbonate extractable iron (Fe_d), oxalate extractable iron (Fe_o) and active iron ratio are presented in Table 11. The depthwise variations in clay and free iron oxides, total iron and free iron oxides are shown in Figures 9 and 10.

The Fe_d ranges from 1.24 per cent (No.11) in Beypore series to 3.56 per cent (No. 17) in Chirakkal series. The Fe_d showed maximum accumulation in the lower most layer of profile in Vellayani, Cherniyoor, Chirakkal and Kunhimangalam series while intermediate layers showed accumulation in Bharanikkavu and Beypore

Table 11. Iron oxide fractions in soils

Sample No.	Depth (cm)	% Fe_2O_3 Total iron (Fe_t)	Dithionite-citrate-bicarbonate extractable iron (Fe_d)	Oxalate extractable iron (Fe_o)	$\frac{Fe_d \times 100}{Fe_t}$	Active iron ratio $\frac{Fe_o}{Fe_d}$
Profile I (Vellayani)						
1	0- 19	3.07	1.91	0.001	62.21	0.0006
2	19- 76	3.15	1.73	0.001	44.92	0.0006
3	76-150+	6.87	3.40	0.004	49.49	0.0011
Profile II (Cherniyoor)						
4	0- 16	3.21	2.28	0.001	71.03	0.0004
5	16- 37	3.55	2.48	0.001	69.86	0.0004
6	37- 65	5.28	2.29	0.001	43.37	0.0004
7	65-151+	5.13	3.53	0.002	68.81	0.0006
Profile III (Bharanikkavu)						
8	0- 20	4.39	2.35	0.001	53.53	0.0004
9	20- 49	5.48	3.01	0.001	54.93	0.0003
10	49-145+	7.16	2.41	0.001	32.66	0.0004
Profile IV (Beypore)						
11	0- 19	4.09	1.24	0.001	30.32	0.0008
12	19-100	3.18	1.84	0.001	57.86	0.0005
13	100-145+	3.17	1.49	0.001	47.00	0.0007
Profile V (Chirakkal)						
14	0- 14	4.83	2.36	0.002	48.86	0.0008
15	14- 32	2.30	1.48	0.001	64.35	0.0007
16	32- 80	4.11	2.68	0.004	65.21	0.0015
17	80-165+	4.68	3.56	0.004	76.07	0.0011
Profile VI (Kunhimangalam)						
18	0- 20	2.44	2.27	0.003	93.03	0.0013
19	20- 47	3.65	1.83	0.001	50.14	0.0005
20	47- 93	3.76	2.48	0.001	65.96	0.0004
21	93-143+	3.28	2.70	0.004	82.32	0.0015

FIG 9(a). DISTR BUTION OF CLAY AND FREE IRON OX DE N SO L PROF LES

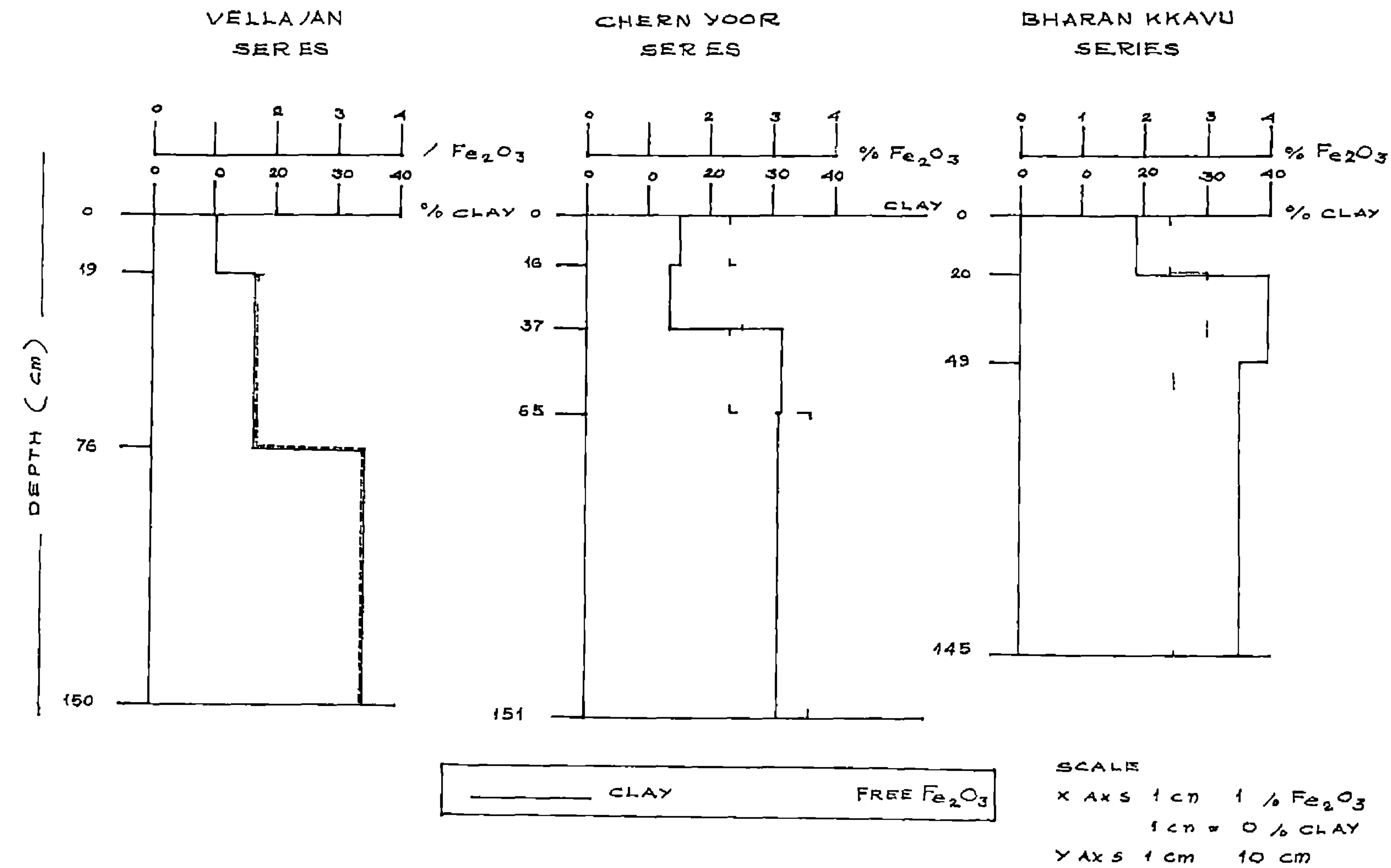


FIG 9(b) DISTR BUTION OF CLAY AND FREE RON OXIDE IN SO L PROF LES

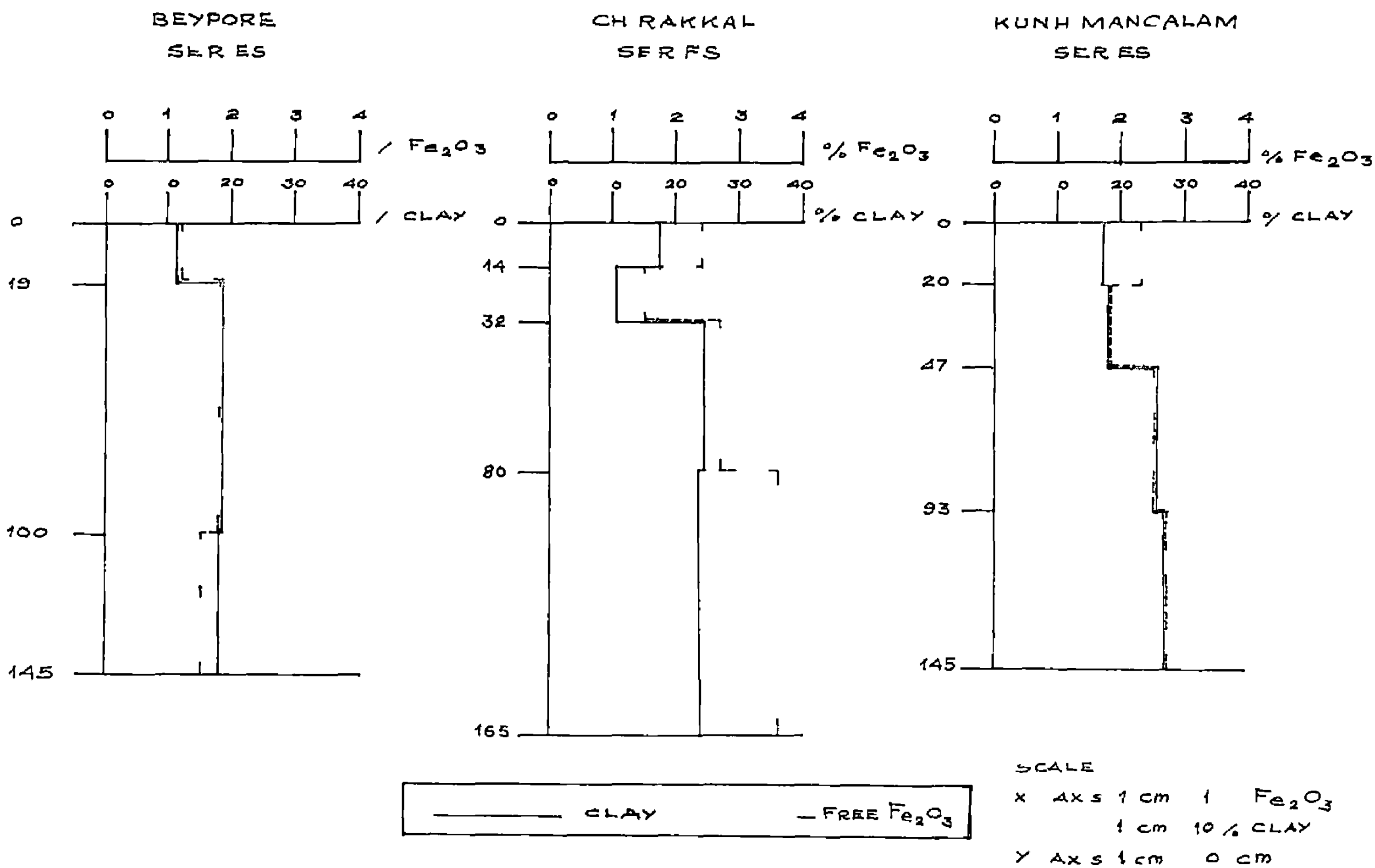


FIG 10(a) DISTRIBUTION OF TOTAL AND FREE IRON OXIDE IN SOIL PROFILES

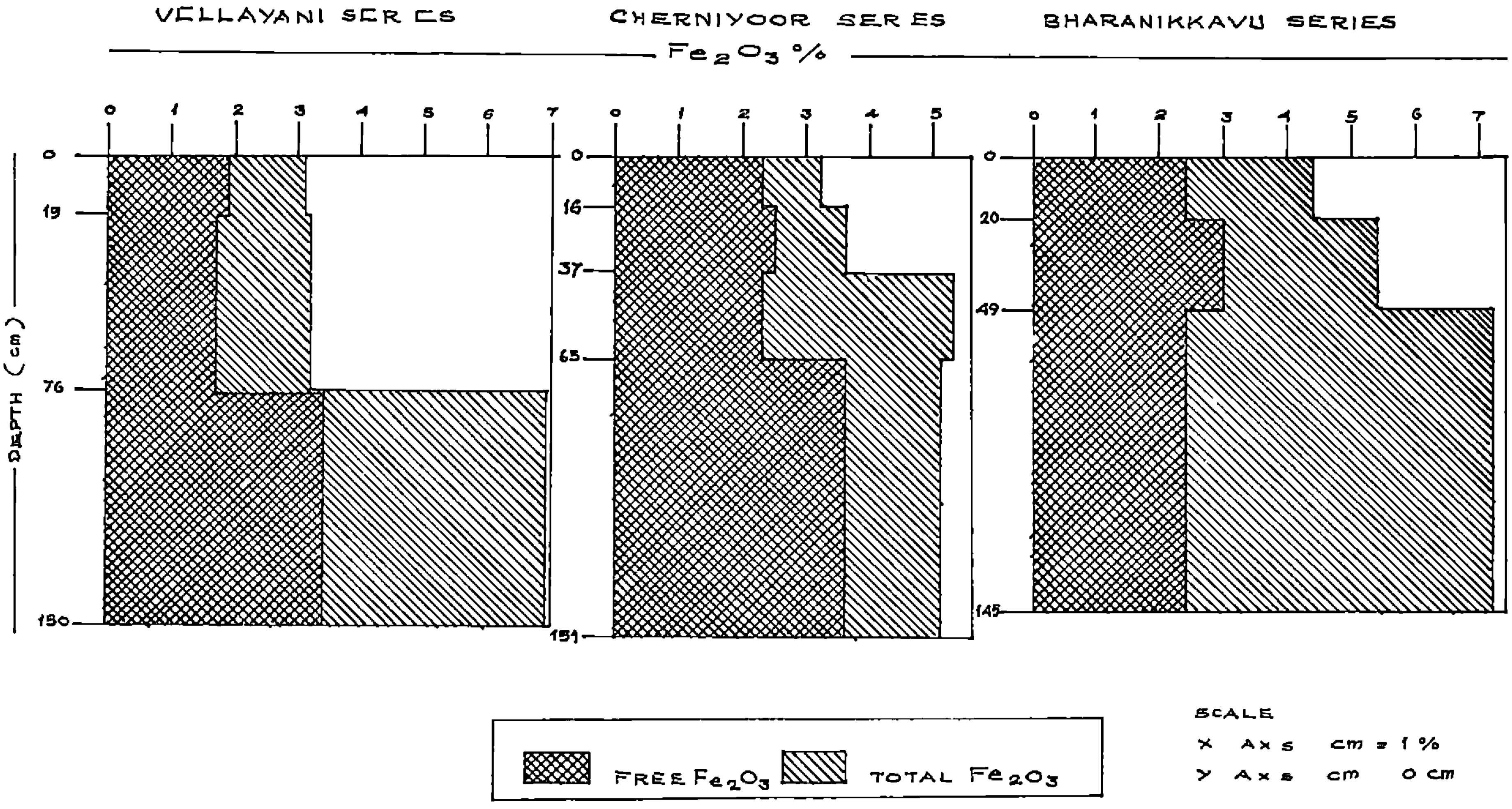
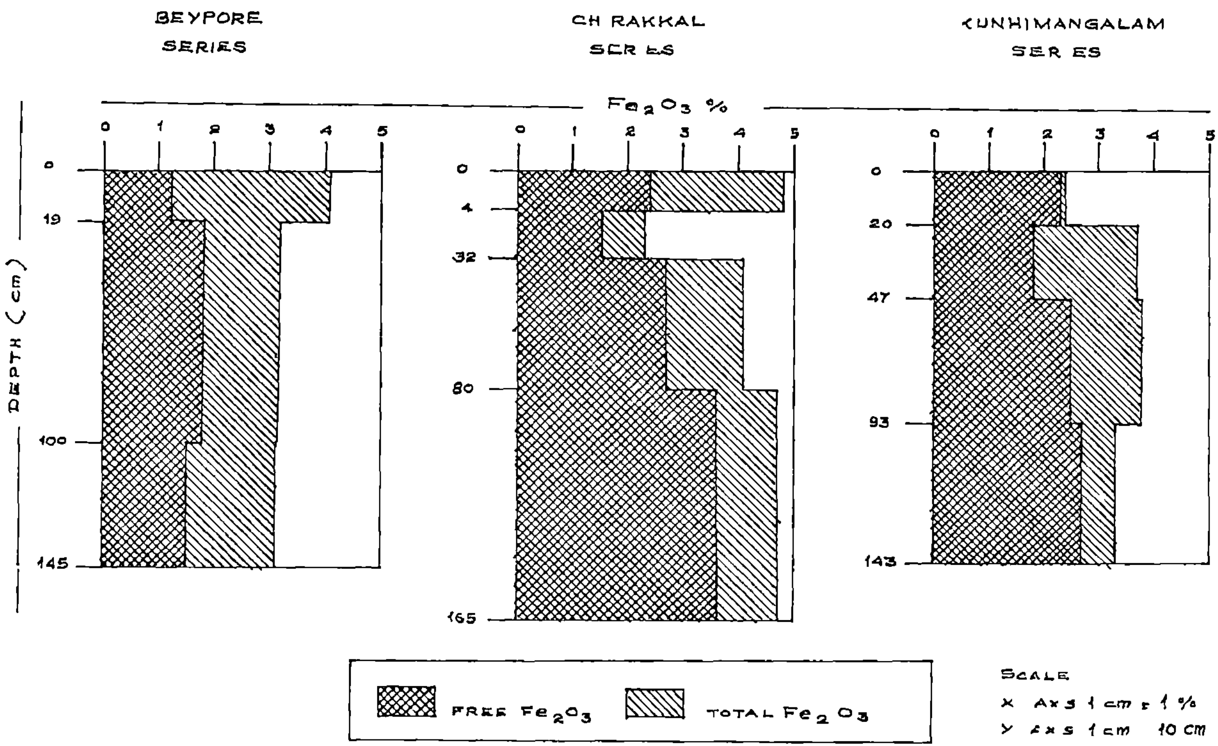


FIG 10(b) DISTRIBUTION OF TOTAL AND FREE IRON OXIDE IN SOIL PROFILES



series. The Fe_d showed positive and significant correlation with total iron (r = 0.573**) and negative and significant correlation with fine sand (r = -0.853**). Correlation of Fe_d with coarse sand was positive (r = 0.277), but not significant. Positive correlations were also obtained between Fe_d and silt and clay fractions, but were not significant.

Fe_d expressed as percentage of total iron often referred to as 'degree of freeness of iron oxide' was found to be maximum in Kunhimangalam series (50.14 to 93.03 per cent) followed by Chirakkal series (48.86 to 76.07 per cent), Cherniyoor series (43.37 to 71.03 per cent), Vellayani series (44.92 to 62.21 per cent), Beypore series (30.32 to 57.86 per cent) and Bharanikkavu series (32.66 to 54.93 per cent).

The oxalate extractable iron recorded low values compared to Fe_d and ranged from 0.001 to 0.004 per cent. Correlations of oxalate iron with fine sand was negative but not significant while with coarse sand, silt, clay and total iron were positive and not significant. Ratio of Fe_o to Fe_d termed the active iron ratio was also very low with values ranging from 0.0003 (No. 9) of Bharanikkavu series to 0.0015 (No. 16) of Chirakkal series and (No. 21) of Kunhimangalam series. Both the oxalate extractable iron and active iron ratios do not show any trend of variation in the profile.

6. Analysis of surface samples

6.1. Available nitrogen, phosphorus and potassium

The available nutrients, nitrogen, phosphorus and potassium contents for the surface samples are presented in Table 12.

The available nitrogen content was the highest for Beypore series ranging from 92.09 ppm to 190.34 ppm followed by 141.73 to 179.00 ppm for Kunhimangalam series. In the case of the other soils under study, its content varied from 143.40 to 178.58 ppm, 134.02 to 170.21 ppm, 101.39 to 155.83 ppm for Bharanikkavu, Chirakkal and Cherniyoor series respectively. However, Vellayani series recorded the lowest content of available nitrogen ranging from 82.01 to 135.46 ppm.

The available phosphorus content of soils was in general high, the maximum being recorded for Beypore series with a range of 114.01 to 770.60 ppm. The lowest value was observed in Kunhimangalam series and varied from 18.99 to 136.84 ppm. For the other soils, the variations in phosphorus contents were 52.62 to 99.38 ppm, 11.56 to 111.48 ppm, 25.31 to 188.58 ppm and 64.63 to 639.25 ppm for Vellayani, Cherniyoor, Bharanikkavu and Chirakkal series respectively.

In the case of available potassium, the highest value was recorded in Chirakkal series varying from 12.09 to 113.58 ppm. The lowest content was noted in

Table 12. Available nutrient content of soils (surface samples)

Series	Sample No.	N (ppm)	P (ppm)	K (ppm)
Vellayani	1	112.14	58.04	24.22
	2	82.01	66.29	16.09
	3	88.48	80.84	12.09
	4	114.93	52.98	23.61
	5	108.63	62.52	26.94
	6	112.63	99.38	16.23
	7	125.92	52.62	20.22
	8	121.25	81.63	36.63
	9	123.78	81.50	32.51
	10	135.46	81.40	28.41
Cherniyoor	11	128.82	111.48	28.35
	12	125.46	63.99	22.32
	13	103.13	75.15	68.10
	14	108.12	69.71	20.28
	15	101.39	58.10	32.33
	16	116.55	106.82	63.25
	17	114.10	47.09	28.30
	18	155.83	41.59	42.47
	19	116.69	93.77	12.30
	20	114.69	31.56	24.19
Bharanikkavu	21	145.73	64.60	28.29
	22	178.58	188.58	63.00
	23	156.03	25.31	32.40
	24	151.50	71.53	28.35
	25	151.62	185.59	52.69
	26	151.73	92.78	38.56
	27	143.40	57.98	52.67
	28	163.62	31.71	75.07
	29	149.65	38.09	52.64
	30	169.26	64.60	20.44

Contd.....

Table 12. Contd ....

Series	Sample No.	N	ppm P	K
Beypore	31	136.25	121.25	6.04
	32	152.74	114.01	10.08
	33	142.02	770.60	52.50
	34	133.39	346.80	112.66
	35	135.32	703.19	32.21
	36	106.34	483.30	14.08
	37	92.09	651.50	48.84
	38	127.36	579.66	20.31
	39	190.34	451.68	36.95
	40	129.53	647.27	34.37
Chirakkal	41	141.74	121.30	12.09
	42	134.02	64.63	14.15
	43	142.79	336.67	28.24
	44	136.22	347.08	22.15
	45	165.37	185.73	113.58
	46	146.51	152.32	32.30
	47	147.00	193.88	50.64
	48	160.00	209.27	39.35
	49	165.96	594.64	56.68
	50	170.21	639.25	39.04
Kunhimangalam	51	148.35	114.15	34.34
	52	141.73	57.56	4.50
	53	145.87	136.84	12.13
	54	153.27	78.14	34.28
	55	148.11	44.45	8.72
	56	177.40	18.99	12.16
	57	170.28	51.27	16.19
	58	169.13	19.07	32.67
	59	156.88	25.51	28.58
	60	179.00	47.52	12.20

Kunhimangalam series varying ffom 4.50 to 34.34 ppm. The contents of this nutrient element for the other soils studied varied from 12.09 to 36.63 ppm, 12.30 to 68.10 ppm, 20.44 to 75.07 ppm and 6.04 to 112.66 ppm for Vellayani, Cherniyoor, Bharanikkavu and Beypore series respectively.

6.2. Soil reaction, electrical conductivity and phosphorus fixing capacity

The soil reaction, electrical conductivity and phosphorus fixing capacity of soils are given in Table 13.

The soil reaction was in general acidic with pH values ranging from 4.60 (No. 18) of Cherniyoor series to 5.95 (No. 45) of Chirakkal series.

The electrical conductivity did not show much variation between the soil series and recorded very low values. The range observed was from 0.01 to 0.07 mmho/cm.

The phosphorus fixing capacity of the soils varied from 119.4 to 136.1 mg P/100 g for Vellayani series, 106.0 to 135.9 mg P/100 g for Cherniyoor series and 112.7 to 136.0 mg P/100 g for Bharanikkavu series. In the case of other soils, the values varied from 86.1 to 120.5 mg P/100 g, 95.3 to 120.2 mg P/100 g and 112.8 to 133.2 mg P/100 g for Beypore, Chirakkal and Kunhimangalam series respectively.

Table 13. Soil reaction, electrical conductivity and phosphorus fixing capacity (surface samples)

Series	Sample No.	Soil reaction 1:2.5	Electrical conductivity 1:2.0 mmho/cm	Phosphorus fixing capacity mg P/100 g soil
Vellayani	1	5.75	0.02	120.1
	2	5.75	0.03	120.7
	3	5.75	0.03	120.2
	4	5.80	0.02	119.4
	5	5.85	0.03	134.5
	6	5.25	0.03	123.2
	7	5.15	0.03	136.1
	8	5.65	0.03	119.4
	9	5.50	0.02	119.5
	10	5.20	0.02	135.9
Cherniyoor	11	4.90	0.03	120.2
	12	4.85	0.03	112.5
	13	5.35	0.03	113.0
	14	5.10	0.02	135.9
	15	4.95	0.03	112.9
	16	5.10	0.02	106.0
	17	5.20	0.03	123.5
	18	4.60	0.07	123.5
	19	5.30	0.03	122.4
	20	5.30	0.02	113.8
Bharanikkavu	21	5.10	0.02	112.9
	22	4.95	0.01	119.9
	23	5.15	0.02	136.0
	24	5.05	0.02	112.8
	25	5.90	0.01	112.7
	26	4.60	0.02	123.2
	27	5.50	0.01	120.2
	28	5.40	0.02	119.6
	29	5.10	0.02	114.3
	30	5.20	0.03	120.0

Contd.....

Table 13. Contd.....

Series	Sample No.	Soil reaction 1:2.5	Electrical conductivity 1:2.0 mmho/cm	Phosphorus fixing capacity mg P/100 g soil
Beypore	31	5.05	0.02	120.2
	32	5.00	0.02	120.5
	33	5.10	0.03	97.5
	34	5.40	0.04	114.8
	35	5.20	0.03	86.1
	36	5.00	0.04	103.6
	37	5.90	0.04	102.5
	38	4.90	0.02	102.7
	39	4.80	0.03	107.4
	40	5.15	0.02	103.2
Chirakkal	41	5.00	0.03	120.2
	42	5.30	0.02	120.0
	43	5.20	0.03	97.6
	44	5.15	0.03	103.5
	45	5.95	0.03	102.9
	46	5.35	0.03	103.3
	47	5.50	0.03	108.7
	48	5.10	0.03	95.3
	49	5.00	0.04	103.1
	50	5.00	0.02	95.7
Kunhimangalam	51	4.70	0.05	120.0
	52	4.90	0.02	120.4
	53	4.50	0.05	114.4
	54	4.70	0.05	120.1
	55	5.15	0.02	114.6
	56	4.85	0.03	114.2
	57	5.10	0.03	112.8
	58	5.00	0.02	119.6
	59	5.00	0.02	133.2
	60	4.85	0.03	128.2

7. Extractable micronutrient content of soils

The extractable micronutrient contents of surface samples are given in Table 14.

The DTPA extractable iron varied from 19.87 to 50.57 ppm for Bharanikkavu and was the lowest value recorded among the soils investigated. Chirakkal series showed the highest value for DTPA extractable iron ranging from 37.22 to 72.06 ppm. The values for the other soils varied from 32.29 to 52.04 ppm, 26.02 to 41.62 ppm, 30.38 to 64.16 ppm and 28.15 to 53.56 ppm for Cherniyoor, Vellayani, Beypore and Kunhimangalam series respectively.

The di-acid (0.05 N HCl + 0.025 N H_2SO_4) extracted lesser quantities of iron than DTPA. The lowest values were observed for Bharanikkavu series with a range of 1.46 to 15.91 ppm. Cherniyoor series showed the highest values varying from 10.45 to 46.92 ppm. The iron contents of the other soils investigated were in the range of 11.60 to 18.53 ppm, 8.32 to 27.46 ppm, 12.94 to 26.63 ppm and 10.66 to 26.54 ppm for Vellayani, Beypore, Chirakkal and Kunhimangalam series respectively.

In the case of manganese also DTPA extracted higher amounts in most of the soils investigated. Vellayani series recorded the highest manganese content varying from 17.99 to 68.07 ppm. The lowest range 2.82 to 9.05 ppm was observed for Beypore series. The other soils viz., Cherniyoor, Bharanikkavu, Chirakkal and

Table 14. Extractable micronutrient content of soils (surface samples)

Sample No.	Fe		Mn		Zn		Cu	
	ppm							
	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4
Vellayani								
1	34.32	13.36	17.99	11.35	0.602	0.96	0.283	0.299
2	41.62	16.98	38.36	21.64	0.519	7.15	0.479	1.380
3	36.34	12.25	32.83	17.61	0.844	7.26	0.191	0.411
4	26.02	18.53	41.52	27.32	1.220	7.10	0.856	2.060
5	36.49	13.43	43.31	27.11	2.750	8.38	1.000	1.320
6	38.86	13.76	34.64	28.98	0.438	1.61	0.197	0.507
7	36.70	15.18	53.48	22.69	0.512	3.83	Trace	0.732
8	33.44	11.60	68.07	23.52	0.547	2.26	0.267	0.513
9	35.65	14.51	61.52	30.47	0.362	1.84	0.278	0.492
10	32.43	16.80	23.84	24.27	1.310	14.30	0.124	0.718
Cherniyoor								
11	40.23	10.45	6.36	4.54	1.150	0.99	0.093	0.405
12	32.29	46.92	17.74	10.23	0.747	6.74	0.185	1.080
13	40.06	13.05	8.87	Trace	0.790	0.69	0.278	0.339
14	37.78	16.47	5.78	6.12	0.939	2.62	0.233	0.876
15	38.05	13.34	7.38	5.42	0.705	1.56	0.129	0.420
16	52.04	19.45	4.67	5.02	0.632	4.04	0.212	0.541
17	37.64	18.64	8.49	8.65	0.536	3.35	0.111	0.942
18	34.70	10.92	13.69	0.28	2.340	4.43	0.362	0.558
19	33.94	35.48	6.93	6.73	0.562	14.93	0.189	1.360
20	33.91	11.85	8.45	5.48	0.581	0.94	0.131	0.419
Bharanikkavu								
21	50.57	13.86	14.93	0.20	0.891	1.16	0.440	1.580
22	19.87	9.96	14.35	9.51	0.332	1.86	0.601	0.595
23	25.29	1.46	23.43	14.09	1.190	0.84	0.324	0.745
24	35.78	11.30	20.27	13.89	0.749	1.27	0.492	0.705
25	33.17	12.12	11.17	28.94	2.180	1.56	0.338	0.600
26	37.01	9.13	10.37	5.28	0.593	1.49	0.436	0.500
27	30.79	10.29	10.27	8.91	0.243	1.58	0.332	0.539
28	42.22	11.52	32.61	Trace	1.380	2.64	0.970	1.280
29	36.78	15.91	4.35	0.36	0.725	11.52	0.344	1.730
30	20.79	12.53	9.46	11.92	0.408	1.39	0.515	0.501

Contd

Table 14. Contd......

Sample No.	Fe (ppm)		Mn (ppm)		Zn (ppm)		Cu (ppm)	
	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4	DTPA	0.05N HCl + 0.025N H_2SO_4
Beypore								
31	42.04	9.18	5.86	4.03	2.12	0.596	0.711	0.95
32	35.41	9.64	8.07	5.16	0.70	1.090	0.872	1.21
33	49.39	8.32	6.60	3.76	1.05	0.872	0.636	0.84
34	46.27	9.90	9.05	6.04	0.81	0.475	0.660	0.95
35	48.87	9.92	5.96	4.95	3.78	0.866	0.769	1.14
36	53.19	9.78	5.07	2.86	1.40	0.805	0.499	0.63
37	40.15	13.68	7.39	11.86	4.70	5.540	1.000	1.57
38	49.95	12.63	2.82	2.40	1.50	1.340	0.967	1.34
39	30.38	8.98	4.43	3.49	1.43	1.400	0.813	1.25
40	64.16	27.46	3.78	4.81	1.68	1.520	0.971	1.39
Chirakkal								
41	54.31	15.15	8.71	7.01	2.00	5.080	0.611	1.19
42	58.73	13.34	17.00	13.58	0.74	0.566	0.633	0.95
43	72.06	26.63	9.95	6.33	1.71	1.400	1.390	1.72
44	63.19	16.63	14.24	0.12	1.15	0.664	0.757	1.12
45	37.22	22.88	34.60	12.49	1.31	1.170	0.935	1.40
46	60.24	15.62	20.19	35.00	2.37	12.230	1.180	1.75
47	45.67	18.11	29.37	21.75	1.44	6.380	0.725	1.39
48	57.12	16.70	33.91	19.59	3.42	1.080	1.050	1.19
49	68.06	17.37	22.55	4.49	1.56	1.200	1.450	1.93
50	52.83	12.94	12.04	5.96	0.72	0.518	0.861	1.31
Kunhimangalam								
51	52.03	11.72	8.04	3.51	2.01	0.675	0.410	0.83
52	44.37	10.66	5.49	1.97	0.62	1.120	0.348	1.26
53	43.44	14.59	6.35	3.11	0.39	10.470	0.522	1.38
54	43.36	15.49	9.66	Trace	0.38	0.311	0.470	1.08
55	41.78	16.09	4.66	1.98	2.60	5.670	0.171	2.01
56	28.15	17.35	14.25	6.57	0.51	11.410	0.257	2.63
57	29.96	21.90	13.04	10.81	3.04	2.320	0.387	1.37
58	36.57	12.49	16.66	7.27	3.39	3.030	0.490	1.09
59	35.86	21.43	13.43	6.70	0.41	3.200	0.492	1.23
60	53.56	26.54	8.85	4.53	2.15	1.140	0.560	0.12

Kunhimangalam series recorded values ranging from 4.67 to 17.74 ppm, 4.35 to 32.61 ppm, 8.71 to 34.60 ppm and 4.66 to 16.66 ppm respectively.

Manganese extracted by di-acid was the lowest in Cherniyoor series varying from trace to 10.23 ppm, the highest being recorded in Chirakkal series with a range 0.12 to 35.00 ppm. Vellayani, Bharanikkavu, Beypore and Kunhimangalam series recorded values ranging from 11.35 to 30.47 ppm, trace to 28.94 ppm, 2.40 to 11.86 ppm and trace to 10.81 ppm respectively.

Zinc extracted by DTPA recorded the highest values in the case of Beypore series and varied from 0.70 to 4.70 ppm. This was followed by Chirakkal, Kunhimangalam, Vellayani, Cherniyoor and Bharanikkavu with values ranging from 0.72 to 3.42 ppm, 0.38 to 3.39 ppm, 0.362 to 2.75 ppm, 0.536 to 2.34 ppm and 0.243 to 2.18 ppm respectively.

The content of di-acid-extractable zinc was higher compared to DTPA. In this case, the highest value was observed for Cherniyoor series ranging from 0.69 to 14.93 ppm. The lowest values were observed for Kunhimangalam series with a range of 0.311 to 11.41 ppm. Vellayani, Bharanikkavu, Chirakkal and Beypore series showed values varying from 0.96 to 14.3 ppm, 0.84 to 11.52 ppm 0.518 to 12.23 ppm and 0.475 to 5.54 ppm respectively.

Among the trace elements studied copper recorded low levels for both the extractants. The DTPA extractable copper varied from trace to 1.00 ppm for Vellayani series, 0.093 to 0.362 ppm for Cherniyoor series, 0.324 to 0.970 ppm for Bharanikkavu series, 0.499 to 1.00 ppm for Beypore series, 0.611 to 1.45 ppm for Chirakkal series and 0.171 to 0.560 ppm for Kunhimangalam series.

The di-acid extracted more copper than DTPA and the values recorded for different soils investigated were 0.299 to 2.06 ppm, 0.339 to 1.36 ppm, 0.50 to 1.73 ppm, 0.63 to 1.57 ppm, 0.95 to 1.93 ppm and 0.12 to 2.63 ppm for Vellayani, Cherniyoor, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series respectively.

8. Chemical composition of clay fraction and molar ratios

The results of chemical analysis of clay and molar ratios are presented in Table 15.

Silica formed the major constituent of the clay and it varied from 33.20 per cent (No. 3) of Vellayani series to 52 per cent (No. 18) of Kunhimangalam series. The silica content showed a decrease with depth in the case of Bharanikkavu and Kunhimangalam series. In respect of other soils, no definite pattern of distribution with depth was obtained.

The content of Al_2O_3 was the highest in Chirakkal series (No. 17) with 32.56 per cent while the lowest

Table 15. Chemical composition and molar ratios of clay fraction

Sample No.	Depth (cm)	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	SiO_2/R_2O_3	Fe_d %
Profile I (Vellayani)								
1	0- 19	38.00	24.93	22.67	2.58	4.45	1.58	0.257
2	19- 76	34.20	32.16	17.44	1.81	5.22	1.33	0.223
3	76-150+	33.20	18.78	24.42	3.01	3.61	1.64	0.166
Profile II (Cherniyoor)								
4	0- 16	41.80	20.78	24.42	3.41	4.55	1.95	0.362
5	16- 37	41.00	12.32	34.88	5.64	3.13	2.01	0.347
6	37- 65	44.00	19.55	29.65	3.81	3.94	1.94	0.187
7	65-151+	42.80	12.98	36.62	5.61	3.11	2.00	0.266
Profile III (Bharanikkavu)								
8	0- 20	44.60	25.33	22.67	2.99	5.23	1.90	0.196
9	20- 49	39.80	25.58	24.42	2.64	4.33	1.64	0.176
10	49-145+	39.40	19.26	33.14	3.47	3.15	1.65	0.196
Profile IV (Beypore)								
11	0- 19	36.40	29.62	19.18	2.08	5.05	1.47	0.455
12	19-100	39.60	29.07	20.93	2.31	5.03	1.58	0.416
13	100-145+	39.40	28.42	19.18	2.35	5.47	1.64	0.470
Profile V (Chirakkal)								
14	0- 14	43.00	32.45	13.95	2.25	8.23	1.77	0.580
15	14- 32	50.00	22.58	17.42	3.76	7.63	2.52	0.891
16	32- 80	45.00	27.50	15.70	2.77	7.64	2.04	0.610
17	80-165+	37.20	32.56	17.44	1.94	5.68	1.45	0.305
Profile VI (Kunhimangalam)								
18	0- 20	52.00	18.20	21.80	4.83	6.31	2.73	0.426
19	20- 47	41.20	26.82	19.18	2.61	5.72	1.79	0.739
20	47- 93	39.20	25.87	20.93	2.57	4.98	1.69	0.357
21	93-143+	39.00	20.38	24.42	3.25	4.24	1.84	0.415

value of 12.32 per cent (No. 5) was recorded for the Cherniyoor series. Irregular distribution with depth in the Al_2O_3 content was a feature common to all the soils investigated.

In respect of the Fe_2O_3 content of the clay Cherniyoor series (No. 7) showed the highest value of 36.62 per cent while Chirakkal series (No. 14) recorded the lowest value of 13.95 per cent. The depth wise variation in the Fe_2O_3 content of the clay fraction showed a steady increase in the case of Bharanikkavu series while in all other soils no definite pattern of distribution was observed.

The SiO_2/Al_2O_3 ratio of the clay fraction did not reveal variation with depth in the soil profile. The highest value 5.64 (No. 5) was observed for Cherniyoor series while the lowest 1.81 (No. 2) was recorded for Vellayani series.

In the case of SiO_2/Fe_2O_3 ratio, decreasing trend with depth was a feature in Bharanikkavu and Kunhimangalam series. The ratio varied from 3.11 (No.7) of Cherniyoor series to 7.64 (No. 16) in Chirakkal series. The silica/sesquioxide ratio recorded low values compared to the other molar ratios. The range observed was 1.33 (No. 2) in Vellayani series to 2.73 (No. 18) in Kunhimangalam series. The ratio showed a tendency to increase down the profile in the case of Beypore series with no trend of variation observed in the other soils under investigation.

The dithionite extractable iron content of clay fraction was highest in Chirakkal series with a value of 0.891 per cent (No. 15), the lowest being 0.166 (No. 3) noted for Vellayani series.

9. Simple correlations

Correlations between various physico-chemical characteristics were worked out and the results are presented in Table 16.

Table 16. Coefficients of simple linear correlation (r) between soil characteristics (number of pairs = 21)

Sl.No.	Soil characteristics x	y	r
1	Clay	Bulk density	-0.186
2	Clay	Moisture retention at 1/3 bar	0.419
3	Clay	Moisture retention at 1 bar	0.480*
4	Clay	Moisture retention at 2 bars	0.538*
5	Clay	Moisture retention at 5 bars	0.608**
6	Clay	Moisture retention at 15 bars	0.590**
7	Clay	Available water	-0.025
8	Clay	Coarse sand	-0.325
9	Clay	Fine sand	-0.361
10	Clay	Total Fe_2O_3	0.595**
11	Clay	Total P_2O_5	-0.039
12	Clay	Total K_2O	0.363
13	Clay	Total Al_2O_3	0.355
14	Clay	Cation exchange capacity	0.430
15	Clay	Fe_d	0.376
16	Clay	Fe_o	0.259
17	Silt	Fe_d	0.249
18	Silt	Fe_o	0.095
19	Fine sand	Fe_d	-0.853**
20	Fine sand	Fe_o	-0.320
21	Coarse sand	Fe_d	0.277
22	Coarse sand	Fe_o	0.119
23	Total iron	Fe_d	0.573**
24	Total iron	Fe_o	0.142
25	Organic carbon	Total nitrogen	0.385

Contd.

Table 16. Contd.....

Sl.No.	Soil characteristics x	y	r
26	Exchangeable calcium	Cation exchange capacity	0.765**
27	Exchangeable magnesium	Cation exchange capacity	0.539**
28	Exchangeable potassium	Cation exchange capacity	0.374
29	Exchangeable sodium	Cation exchange capacity	0.488*
30	Organic carbon	Cation exchange capacity	0.490*
31	Exchangeable calcium	Percentage base saturation	0.485*
32	Exchangeable magnesium	Percentage base saturation	0.781**
33	Exchangeable potassium	Percentage base saturation	0.605**
34	Exchangeable sodium	Percentage base saturation	0.028
35	pH	Exchange acidity	0.508*
36	Clay	Total manganese	0.081
37	Clay	Total zinc	0.298
38	Clay	Total copper	0.226
39	Silt	Total iron	0.124
40	Silt	Total manganese	-0.343
41	Silt	Total zinc	0.103
42	Silt	Total copper	-0.232
43	Fine sand	Total iron	-0.617**
44	Fine sand	Total manganese	0.486*
45	Fine sand	Total zinc	-0.263
46	Fine sand	Total copper	0.337
47	Coarse sand	Total iron	0.037
48	Coarse sand	Total manganese	-0.542*
49	Coarse sand	Total zinc	-0.148
50	Coarse sand	Total copper	-0.583*

* Significant at 5% level

** Significant at 1% level

DISCUSSION

DISCUSSION

The results of profile morphology and physico-chemical characteristics of red soils occurring in different regions of Kerala and the interrelationships between various properties are discussed below:

1. Profile morphology

Colour is a predominant and observable feature that is often taken as a diagnostic property of agricultural importance. The soils from different locations had a striking similarity in respect of colour with predominant red hues, the intensity of which was found to increase with depth in all the soils investigated. According to Schwertmann and Taylor (1977) haematite notedly has bright red colours (5 R to 2.5 YR) and has strong pigmenting effect on soil materials. It appears largely confined to better drained soils in warm temperate to tropical regions since rapid decomposition of organic matter seems to be essential for its formation. Venugopal (1980) has reported high haematite contents in the sand fractions of red soils from the upper slope members of catenary sequences in different regions in Kerala. The intense red colours of soils observed in the present investigation can be attributed to the predominance of haematite in the sand fraction. Webster (1965) has associated red colours with the content of free iron oxides. In the present study, free iron oxide content was found to increase with depth in all the soil series. The increase in redness with depth can therefore be explained as due to the content of free iron oxides in these soils.

The structure of soils from all locations was mostly subangular blocky with medium granular structure being observed in the surface horizons of Vellayani, Beypore and Chirakkal series. All the soils investigated are well drained with relatively large amounts of sesquioxides which act as cementing agents and hence the conditions are conducive for the development of good structure as expressed in the morphology of soils. The results agree with the findings of Venugopal (1980) who observed good structural development in the upper slope members of the catena which was attributed to the well drained conditions prevailing in these soils.

In respect of soil depth, the soils from all locations were very deep with complete absence of coarse fragments. This morphological feature does not set any limit on the rooting volume which determines to a great extent the soil's capacity to supply water and nutrients. Very deep red soils devoid of gravel have been reported by Iyer (1979) on a study of red and laterite soil associations in different parts of Kerala. Venugopal (1980) has observed that the red soils are products of colluviation and slope processes from adjacent laterite hills and the very deep soils with weakly expressed horizons as observed in the morphology can be explained as due to the rejuvenation and erosion of the landscape.

2. Physical properties

2.1. Mechanical composition

The textural class of soils varied from sandy loam to clay with finer textures in the subsurface horizon indicative of clay illuviation. Textural variations between the soils of different locations and also within the profiles were narrow.

Among the size fractions, sand predominated in the soils from all the locations. Silt was the lowest among the size fractions and showed no trend in distribution in the profile. Low values of silt have been observed in the red and laterite soils which is characteristic of soils of the tropics. Under tropical situations, as a result of intense weathering the fieldspars are completely transformed to clays with insignificant proportions of silt (Radwanski and Ollier, 1959).

The clay fraction showed migration to the lower layers in all the series and is indicative of the intense leaching and consequent illuviation of clay under the high rainfall conditions in Kerala. Ushakumari (1983) observed sandy clay texture for the red loams of Kerala with downward migration of clay in soil profiles. She also reported striking similarity in texture with laterite soils. The results of the present study are in conformity with the above observations.

2.2. Silt/Clay ratio

The values for the silt/clay ratios did not reveal much variations between locations. The soils of the tropics being generally low in silt content the silt/clay ratios tend to be small. According to Van Wambeke (1962) soils with silt/clay ratios less than 0.15 are considered to be highly weathered and derived from old erosion surfaces in dissected topography. Based on the above observation all the soils under investigation are developed from fairly old parent materials.

2.3. Bulk density

The bulk density values of soils did not show any appreciable differences between the various soil series. It varies from 1.22 to 1.55 g/cm^3. All soils in the present study had a preponderance of the sand fraction as revealed by the mechanical analysis. Ushakumari (1983) obtained higher bulk density values for laterite and red soils compared to the other soil groups of Kerala and has concluded that the predominance of coarser fraction has been responsible for the higher bulk density values which agrees with the findings of the present study. Bharanikkavu series with the lowest bulk density value had evidently the lowest content of the sand as well. Similar views have been expressed by Thiyagarajan (1978) on Tamil Nadu soils.

2.4. Moisture retention characteristics

The variations observed in the moisture held at 1/3 bar were narrow and could be attributed to differences in clay content of soils as is evident from the positive relationship (r = 0.419) of clay and field capacity moisture. The increase in the field capacity moisture in the subsurface layers followed the clay distribution. In most of the soils the finer fraction was found to increase with depth. Bharanikkavu series with the highest field capacity moisture recorded the highest clay content.

The moisture held at other tensions, viz., 1, 2, 5 and 15 bar also showed similar trend as in the case of field capacity. The moisture retained at 15 bar often designated as wilting point was again maximum in Bharanikkavu series. Correlation between wilting point moisture and clay was positive and significant. Thus it may be inferred that the nature and quantity of clay in a soil primarily governs the water retention at different tensions and agrees with the observations made by Venkitaraman (1976), Antony (1982) and Ushakumari (1983).

The available water was maximum in Kunhimangalam and the lowest was recorded in Beypore series. The values for other soils did not reveal appreciable variation. The correlation of available water with clay was negative, but not significant. This can be explained by the fact that the clay fraction increased the moisture content both at field capacity and wilting point which would naturally bring down the available water content. Ushakumari (1983) has designated the laterite, red and coastal alluvial soils of Kerala as "poor' in respect of available water. Lal (1979) also has reported low available water content for the highly weathered soils of the tropics. Similar views have been expressed by De Melo (1974).

3. Chemical characteristics

3.1. pH and electrical conductivity

The soils from all the locations were in general acidic as expected for the highly weathered and leached soils of the tropics (Vine, 1956). The heavy rainfall of the State (>2500 mm) has been responsible for the intense leaching of bases and consequent increase in acidity (Venugopal, 1980). Decrease in pH in the subsurface layers was a feature common to all soil series investigated and is in line with the observations of Loganathan and Krishnamoorthy (1976) on red soils of Tamil Nadu.

As regards electrical conductivity, the values recorded were very low as all the soils were from mid upland regions of the State and were practically non-saline in nature.

3.2. Organic carbon, nitrogen and C/N ratio

Organic carbon content of soils was rather low and showed decreasing trend with depth in profiles. The total nitrogen showed maximum accumulation in the surface layers but did not reveal depth wise pattern as in the case of organic carbon. The C/N ratios varied from 2.08 to 10.91. Low values of organic carbon for red soils have been reported by Nair (1973) who attributed the low fertility of these soils to the low organic carbon and nitrogen content. Low values for organic matter in the tropics was attributed to rapid decomposition and depletion due to high temperatures (Raychaudhuri et al., 1943).

3.3. Total elemental composition

The silica content of all the soils recorded high values ranging from 73.79 per cent in Bharanikkavu series to 89.38 per cent in Kunhimangalam series. The mechanical analysis of soils show a predominance of sand in all the soils investigated. Another interesting observation is the decrease in silica content with depth in the soil profile of Bharanikkavu series in consonance with decrease in sand content. Close relationship between silica content and sand fraction of soils was observed by Agarwal et al. (1957) on catenary soils of Indian plateau. Quartz was the predominant mineral of the fine sand fraction of red and laterite soils of Kerala (Venugopal, 1980). The higher values of silica observed in the present investigation can therefore be explained as due to the higher content of sand fraction with predominance of quartz.

The variations in Al_2O_3 and Fe_2O_3 contents in the different soil series were not appreciable. Clay content was positively correlated to Al_2O_3 ($r = 0.355$) while with Fe_2O_3 it was positive and significant ($r = 0.595^{**}$). In the case of both these constituents the variations in the profiles were parallel to clay distribution and is suggestive of the capacity of the clays to retain these oxides. This observation agrees with the findings of Nair (1977) who pointed out that kaolinite clays fix sesquioxides descending in the profile as a result of illuviation processes. Similar observations have been made by Nair (1973) and Loganathan and Krishnamoorthy (1976).

The total reserves of CaO, MgO and K_2O recorded very low values in all the soils investigated. The total P_2O_5 content was low compared to K_2O content and agrees with the findings of Nair (1973) on red soils of

Trivandrum district. The total reserves of plant nutrients is mainly a function of the mineralogy of the sand fraction (Hughes, 1981). The fine sand fraction of red and laterite soils in Kerala showed quartz as the dominant mineral with few weatherable minerals. The soils of the State are derived mainly from acid crystalline rocks which are again poor in weatherable minerals. Thus the low reserves of major nutrients in the soil is a reflection of the fine sand mineralogy and parent geology of the soils as revealed by the present study.

3.4. Total micronutrients

Among the micronutrients, iron recorded very high values characteristic of tropical soils. As mentioned earlier little variation existed between different soil series in respect of the content of iron. Higher contents of iron and aluminium oxides in red and laterite soils of Kerala have been reported by Nair (1973) and Iyer (1979). The predominance of iron bearing minerals like haematite and ilmenite in sand fraction of these soils has contributed to the large content of iron in these soils (Venugopal, 1980). The findings of the present investigation are in conformity with the above observations.

The manganese content was highest in Kunhimangalam series while the lowest was noted in Cherniyoor series. Correlations of total manganese with clay was very low ($r = 0.081$) while with the fine sand fraction the relationship was positive and significant ($r = 0.486^{*}$). Inconsistent pattern of distribution of total manganese in the soil as observed in the present study have been reported by Rajagopalan (1969) in Kerala soils. Positive correlations between fine sand and total manganese as observed in the present study have been reported by Iyer (1979) in red and laterite soils of Kerala. The negative relationship observed with coarse sand ($r = -0.542^{*}$) can be attributed to the very low content of this fraction in the soils under investigation.

The zinc content of soils was very low ranging from traces to 28.19 ppm. Appreciable variations were not observed between soil series. Positive relationship of zinc with silt and clay has been brought out in Bharanikkavu, Beypore, Chirakkal and Kunhimangalam series where the variations follow the pattern of clay distribution in the soil profiles. Praseedom and Koshy (1975) observed low values as reported in the present study for red and laterite soils in Kerala and attributed this to the highly weathered nature of soils. Appavu and Sreeramulu (1981) observed a positive relationship of total zinc and fine fractions in soils of Tamil Nadu.

The contents of total copper recorded was higher compared to total zinc. Similar relationship as in the case of zinc was observed with the finer fraction and agrees with the findings of Randhawa and Kanwar (1964) and Praseedom (1970).

4. Cation exchange capacity

The effective cation exchange capacity (e.c.e.c.) recorded very low values and did not reveal appreciable variations within the soil profile and also between the different soil series. Positive significant relationship was obtained between e.c.e.c. and organic carbon ($r = 0.490^*$) highlighting the key role of this fraction in increasing the cation exchange capacity of the soils. In the highly weathered soils of the tropics maintenance of organic matter is almost synonymous to maintenance of cation exchange capacity (Sanchez, 1976). The relationship of clay with e.c.e.c. was positive ($r = 0.430$). Venugopal (1980) has reported a predominance of kaolinite type of minerals in the red soils of Kerala and hence the low e.c.e.c. is mainly due to the predominance of kaolinite in the clay fraction. Contrary to the previous reports of cation exchange capacity determined with neutral <u>N</u> NH_4OAc on these soils, the e.c.e.c. in the present study showed strikingly lower values as expected of clays in highly weathered soils with a predominance of pH dependent charge (Coleman and Thomas, 1967).

Effective c.e.c. values higher than 4 me/100 g as reported by the above workers suggest sufficient cation exchange capacity to prevent serious leaching losses. Judged from the above value, all the soils of the present investigation are below this level suggested and highlights the crucial role of soil management methods to increase cation exchange capacity of soils. Leon (1967) comparing different methods for cation exchange capacity determination in Colombian soils obtained very low e.c.e.c. values of 1 me/100 g for an Ustox with kaolinite intergrade mineralogy. The findings of the present study agree with the above observations.

4.1. Exchangeable cations

The exchangeable bases, calcium, magnesium, sodium and potassium recorded low values characteristic of soils formed under high rainfall conditions, temperature and intense leaching. The predominant cation was calcium followed by magnesium, sodium and potassium. Positive significant relationship was observed between e.c.e.c. and exchangeable calcium (r = 0.765**), exchangeable magnesium (r = 0.539*) and exchangeable sodium (r = 0.488*), while with exchangeable potassium the correlation was positive but not significant (r = 0.374). Thiyagarajan (1978) reported exchangeable potassium to be the lowest of all the bases in red soils of Coimbatore. Low values of exchangeable bases for red and laterite soils of Kerala have been reported by Venugopal and Koshy (1976) and they have attributed this to the intense leaching conditions existing in these soils. Findings of the present study agree with these observations.

Among the acid generating cations, exchangeable hydrogen recorded the highest values in Chirakkal series and the lowest in Cherniyoor series. As expected, the variations of exchangeable hydrogen with depth in the different series were in accordance with changes in pH values recorded. Venugopal (1980) observed the exchangeable bases to decrease with increase in rainfall and consequent differences in leaching intensities. The soils of Cherniyoor are located in areas with a lower rainfall (2238 mm) whereas both Chirakkal and Kunhimangalam series with high exchangeable hydrogen occur in areas with a rainfall as high as 3663 mm. The differences in exchangeable hydrogen can be explained as due to the variations in rainfall and consequent leaching out of bases.

The exchangeable aluminium recorded lower values than exchangeable hydrogen and did not reveal any pattern of distribution in the soil profile. The differences between the soil series are not appreciable. The findings agree with the results of Iyer (1979) on red and laterite soil associations in Kerala.

4.2. Percentage base saturation and exchange acidity

Percentage base saturation of soils varied from 30.15 in Kunhimangalam to 80.63 in Cherniyoor series. Theabove two series recorded the lowest (0.374 me/100 g soil) and the highest (1.88 me/100 g soil) exchange acidity values respectively. The findings agree with the observations of Parsons and Balster (1966).

4.3. Extractable iron and active iron ratio

The dithionite extractable iron (Fe_d) referred to as free iron oxide was the predominant iron fraction. Fe_d expressed as per cent over total iron is often referred to as 'degree of freeness of iron' and indicates the age of the soil (Alexander, 1974). Based on the degree of freeness of iron in soils, Kunhimangalam series was the oldest in respect of age followed by Chirakkal, Cherniyoor, Vellayani, Beypore and Bharanikkavu. Similar observations on relative age of soil and degree of freeness of iron were made by Arduino et al. (1984) on Alfisols of Po Valley in Italy and they ascribed the degree of freeness to the age of soil.

The oxalate extractable iron (Fe_o) recorded very low values and did not reveal much variations between soil series. Juo et al. (1974) have reported low values of Fe_o in soils derived from acidic rocks. The soils under investigation being products of weathering of acidic rocks explains the low values of Fe_o observed in the present investigation.

Consistent with the very low values of iron extracted by oxalate the active iron ratios also recorded very low values and did not reveal any pattern of variation in the profile and also between soil series. Alexander (1974) observed that oxalate extracted less iron from mineral soils than did dithionite-citrate-bicarbonate and has reported that the iron ratio approached zero in old tropical soils. The strikingly low values for this ratio in the present study lend support to the contention that the soils are developed from associated laterite terraces and are the products of catenary evolution (Venugopal, 1980).

5. Analysis of surface samples

5.1. Available nitrogen, phosphorus, potassium and phosphorus fixing capacity

The status of available nitrogen of the surface samples was low to medium in Vellayani, Cherniyoor and Bevpore series and medium in Bharanikkavu, Chirakkal and Kunhimangalam series. In the case of available phosphorus, all the soils had high levels while available potassium status was low to medium in Chirakkal, Bharanikkavu, Beypore and Cherniyoor series while Kunhimangalam and Vellayani series showed low values. Nair (1973) obtained low values for nitrogen, phosphorus and potassium and attributed this to the low organic matter and low cation exchange capacity of soils. All the areas sampled have been intensively cultivated to coconut and other intercrops and the soil management practices can be a possible reason for the fairly high levels of phosphorus in the plough layer.

The phosphorus fixing capacity of soils was high characteristic of the highly weathered soils rich in sesquioxides. Nair and Padmaja (1983) reported high rates of fixation of phosphorus as observed in the present study and attributed this to the silt, clay, total calcium, total iron and sesquioxides.

5.2. Extractable micronutrients

The DTPA extracted more iron and manganese than the diacid (0.05 N HCl + 0.025 N H_2SO_4) in all the soils investigated. Rajendran (1981) obtained similar results using DTPA and acid extractants on lateritic alluvium in Kerala and concluded that DTPA is a versatile extractant for all soils of Kerala in respect of manganese. Rajagopal et al. (1977) has reported fairly high levels of available iron and manganese in soils from different regions of Kerala. The results of the present investigation agree with the findings of the above workers.

In respect of extractable zinc also DTPA was found to be versatile as a common extractant for zinc in all soil groups of Kerala (Rajendran, 1981). However di-acid extracted much more zinc than DTPA which agrees with the findings of the above study. Satisfactory levels of dithizone extractable zinc have been reported by Praseedom and Koshy (1975) in all soil groups of Kerala.

The content of copper extracted by di-acid was more compared to DTPA in all the soils investigated which agrees with the findings of Cottenie et al. (1981) working on Nigerian soils who observed progressive increase in copper and zinc content when extracted with acids. Adequate levels of NH_4OAc extractable copper in Kerala soils have been reported by Rajagopal et al. (1977)

Comparing the extractable micronutrients in the surface soils with published critical values of Viets and Lindsay (1973) the following general conclusions are drawn in respect of DTPA extractable micronutrient content of surface soils of the various series investigated.

Wide variations in the amounts of iron extracted by DTPA do not exist in various soil series investigated. The DTPA critical values indicate that the surface soils from all the series are more than adequate with regard to the content of extractable iron.

The level of manganese showed appreciable variation between various soil series, however the DTPA extractable manganese was more than adequate in all soils as in the case of iron.

The status of extractable zinc did not show much variation between soil series. It was deficient to adequate in Vellayani, Bharanikkavu and Kunhimangalam series and marginal to adequate in Cherniyoor, Beypore and Chirakkal series.

Variations in the amounts of extractable copper were narrow between the various soil series. Deficient to adequate levels were observed in Vellayani, Cherniyoor and Kunhimangalam series while adequate status of this element was found in Bharanikkavu, Beypore and Chirakkal series.

6. Chemical composition of clay fraction and molar ratios

Determination of chemical composition of clay and molar ratios are of relevance in soil formation processes and is often made use of as a tool in identification of clays. Molar ratios, viz., SiO_2/Al_2O_3, SiO_2/Fe_2O_3 and SiO_2/R_2O_3 of the clays of soils from different locations showed little variations and the values recorded were higher than the stipulated values for typical laterite soils. Higher molar ratios of red soils as obtained in the present investigation has been reported by Iyer (1979). The major processes affecting composition of soils and clays in humid climates is the differential leaching of silica preferential to iron and aluminium.

The variations observed in the molar ratios are suggestive or the above processes in operation under the high rainfall conditions (>2500 mm) and consequent high level of leaching prevailing in the different locations (Crompton, 1960). Venugopal (1980) has observed a predominance of kaolinite in residual laterites and an admixture of kaolinite, chlorite and illite in laterites derived from detrital sediments. Slightly higher values obtained for the molar ratios in the present investigation are, reflection of the difference in the mineralogy of clays.

SUMMARY

SUMMARY

In the present investigation an attempt has been made to evaluate the morphological, physical and chemical characteristics of red soils occurring in different regions of Kerala. Six soil series representing red soils identified by the Soil Survey Unit of the Department of Agriculture, Kerala state were selected for the investigation. The series identified were Vellayani, Cherniyoor, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam located in Trivandrum, Quilon, Calicut and Cannanore districts. Profile pits were dug at these different locations and examined for their morphological features. Soil samples representing the different horizons were collected for laboratory studies. The physico-chemical characteristics of the soils and chemical composition of clays of the profile samples were investigated with a view to study the interrelationship between the various properties and to relate these characteristics to the genesis of these soils. Surface samples collected from different locations under each series were also analysed for available nutrients. The salient findings are summarised below:

1. The soils from different locations had predominant red hues with the intensity of redness increasing with depth in the soil profiles from all locations.

2. All the soil series investigated were very deep with ill defined horizons, devoid of coarse fragments, well drained and exhibited good structural development.

3. Sand was the predominant size fraction in all the soils with the fine sand fraction predominating. Very low content of silt and clay illuviation to lower layers were features common to all the soils.

4. Very low values for silt/clay ratios were observed for all the soil series indicating the fairly old parent material from which these soils were derived.

5. Kunhimangalam series had the highest available water content, while Beypore series recorded the lowest value. No appreciable variation in available water content was observed in respect of the other soil series.

6. In general all soils were acidic in reaction with low values for electrical conductivity.

7. Organic carbon, nitrogen and carbon/nitrogen ratios showed little variation between soil series. However the surface layers were found to be relatively *richer* in organic carbon.

8. The silica content recorded high values for all the soils, the highest being in Kunhimangalam series and the lowest in Bharanikkavu series.

9. Variations in total Fe_2O_3 and Al_2O_3 were not appreciable between the soil series. Correlations between clay content and the above constituents were positive and significant.

10. Total reserves of CaO, MgO, K_2O and P_2O_5 were very low and is mainly a reflection of the mineralogy of the sand fraction which was dominated by quartz.

11. Among the micronutrients, total iron and manganese recorded high values for all the soils. Total iron showed positive relationships with clay content while in the case of manganese the same relationship was observed w th the fine sand fraction.

12. The contents of zinc and copper were low and did not reveal appreciable differences between soil series. Zinc showed positive relationships with the finer fractions viz., silt and clay while in the case of copper only clay showed such relationship.

13. The effective cation exchange capacity values recorded for all soil series were very low and less than the cation exchange capacity values determined by the neutral N NH_4OAc method. Effective c.e.c. showed positive significant relationship with organic matter. The exchangeable base content of the soils was in the order Ca > Mg > Na > K.

14. Among the acid generating cations, hydrogen and aluminium, the exchangeable hydrogen content was higher than exchangeable aluminium.

15. The highest percentage base saturation was recorded for Cherniyoor series while the lowest was noted for Kunhimangalam series. The percentage base unsaturation observed in these soils was consistent with the changes in exchange acidity.

16. The Fe_d (dithionite extractable iron) formed the predominant iron fraction. Based on the 'degree of freeness of iron' in soils, Kunhimangalam series was the oldest in respect of age followed by Chirakkal, Cherniyoor, Vellayani, Beypore and Bharanikkavu.

17. The Fe_o (oxalate extractable iron) and the iron oxide ratio (Fe_o/Fe_d) recorded very low values for all the soil series.

18. Among the available nutrients of surface soils, phosphorus showed high levels in the case of soils from all the series. Nitrogen was low to medium in Vellayani, Cherniyoor and Beypore while it was medium in Chirakkal, Bharanikkavu and Kunhimangalam series. In the case of available potassium, low to medium levels were observed in Chirakkal, Bharanikkavu, Beypore and Cherniyoor series while Kunhimangalam and Vellayani series showed low levels of available potassium.

19. The phosphorus fixing capacity for all the soil series was high.

20. The DTPA extractable iron and manganese were more than adequate in the surface horizons of all the series. Zinc was deficient to adequate in Vellayani, Bharanikkavu and Kunhimangalam series and marginal to adequate in Cherniyoor, Beypore and Chirakkal series. Copper was deficient to adequate in Vellayani, Cherniyoor and Kunhimangalam series while adequate levels were observed in Bharanikkavu, Beypore and Chirakkal series.

21. Silica formed the predominant element of the clay fraction. The SiO_2/Al_2O_3, SiO_2/Fe_2O_3 and SiO_2/R_2O_3 ratios recorded for all the soils were higher than the values reported for typical laterite soils.

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*Originals not seen

APPENDIX

APPENDIX

Description of soil profiles

Profile I

Location	Koliyoor, Thiruvallam village in Trivandrum district.
Topography	2% slope, terraced nearly level land.
Drainage	Well drained, medium run off, moderate permeability .
Ground water table	30 metres.
Land use	Coconut and tapioca.
Remarks	Soils are very deep and have very little coarse fragments. Entire profile is predominantly red with indistinct horizon differentiation.
Series	Vellayani.

Horizon	Depth (cm)	Description
Ap	0 - 19	Red (2.5 YR 4/6) sandy loam; medium weak granular; very friable, slightly sticky and slightly plastic; plentiful fine roots; moderately rapid permeability; clear smooth boundary.
B_{21}	19 - 76	Dark red (2.5 YR 3/6) sandy loam; weak, fine to medium sub angular blocky; friable, slightly sticky and slightly plastic; plentiful fine to medium roots; moderately rapid permeability; gradual smooth boundary.
B_{22}	76 - 150+	Dark red (2.5 YR 3/6) sandy clay; moderate coarse sub angular blocky; friable, sticky and plastic; few medium roots; moderate permeability.

Profile II

Location	Cherniyoor, Chemmaruthy village, Quilon district.
Topography	1 to 2% slope, terraced land.
Drainage	Well drained with moderate permeability.
Ground water table	10 metres.
Land use	Coconut, tapioca and cashew.
Parent material	Colluvial sediments from laterites.
Remarks	Entire profile is devoid of coarse fragments and has dominant red colour with ill drained horizons.
Series	Cherniyoor.

Horizon	Depth (cm)	Description
Ap	0 - 16	Yellowish red (5 YR 4/6) sandy loam; darm red (2.5 YR 3/6) moist; weak medium subangular blocky; firm, slightly sticky and slightly plastic; plentiful fine to medium roots; moderately rapid permeability; clear smooth boundary.
B_1	16 - 37	Red (2.5 YR 4/6) sandy loam; moderate coarse subangular blocky; firm, slightly sticky and slightly plastic; many medium to coarse roots; moderately rapid permeability; gradual smooth boundary.
B_{21}	37 - 65	Dark red (2.5 YR 3/6) sandy clay; moderate to coarse subangular blocky; firm, sticky and slightly plastic; many fine to medium roots; moderate permeability; gradual smooth boundary.

Horizon	Depth (cm)	Description
B_{22}	65 - 151+	Red (2.5 YR 4/8) sandy clay; moderate, coarse sub-angular blocky; firm, sticky and slightly plastic; few fine to coarse roots; moderate permeability.

Profile III

Location	Ambalathumbhagam, Poruvazhy village, Quilon district.
Topography	Gently sloping, 3 to 5% south east aspect, terraced.
Drainage	Well drained, medium run off, moderately rapid permeability.
Ground water table	20 metres.
Land use	Cashew, coconut and tapioca.
Parent material	Colluvial sediments from laterites.
Remarks	Surface horizon is lighter in colour with increasing red hue with depth. Surface horizon has few gravel with sub surface layers completely devoid of coarse fragments.
Series	Bharanikkavu.

Horizon	Depth (cm)	Description
Ap	0 - 20	Reddish yellow (7.5 YR 6/6) sandy loam; strong brown (7.5 YR 5/6) moist; weak medium subangular blocky; hard, friable, sticky and slightly plastic; plentiful fine to medium roots; moderate permeability; clear smooth boundary.

Horizon	Depth (cm)	Description
B_{22}	20 - 49	Strong brown (7.5 YR 5/6) sandy clay; moderate medium subangular blocky; friable, sticky and slightly plastic; plentiful medium to coarse roots; moderately slow permeability; gradual wavy boundary.
B_3	49 - 145+	Yellowish red (5 YR 4/6) sandy clay; weak medium subangular blocky; friable, sticky and slightly plastic; many coarse roots, few fine roots; moderately slow permeability.

Profile IV

Location	Thiruvengoor village, Quilandy taluk, Calicut district.
Topography	Gently sloping, terraced land
Drainage	Well drained.
Ground water table	10 metres.
Land use	Coconut, banana and yams.
Parent material	Colluvial laterite sediments.
Remarks	Very deep soil, predominantly sandy profile, completely devoid of gravel or other coarse fragments. Increasing redness is observed with depth.
Series	Beypore.

Horizon	Depth (cm)	Description
Ap	0 - 19	Strong brown (7.5 YR 5/6) sandy loam; yellowish red (5 YR 4/6) moist; medium weak granular; dry slightly hard, very friable, non sticky and non plastic; few quartz gravels present abundant fine fibrous roots; very rapid permeability; clear smooth boundary.
B_{21}	19 - 100	Yellowish red (5 YR 4/6) sandy clay loam; weak medium subangular blocky; moist very friable, slightly sticky and nonplastic; plentiful coarse roots; rapid permeability; gradual wavy boundary.
B_{22}	100 - 145+	Red (2.5 YR 4/6) sandy clay loam; weak medium subangular blocky; friable, slightly sticky and slightly plastic; few coarse and fine roots; moderately rapid permeability.

Profile V

Location	Kalliassery village, Cannanore taluk, Cannanore district
Topography	Partly terraced land, nearly level.
Drainage	Well drained.
Ground water table	10 metres.
Land use	Cashew, coconut and tapioca.
Parent material	Colluvial sediments from laterite.
Remarks	Very deep loamy soils with ill defined horizons, completely devoid of gravel.
Series	Chirakkal.

Horizon	Depth (cm)	Description
Ap	0 - 14	Strong brown (7.5 YR 5/6) sandy clay loam; yellowish red (5 YR 4/6) moist; moderate medium granular; slightly hard, friable, slightly sticky and nonplastic; plentiful fine to coarse roots; moderately rapid permeability; clear smooth boundary.
B_1	14 - 32	Yellowish red (5 YR 5/8) sandy loam; moderate medium subangular blocky; firm, slightly sticky and slightly plastic; plentiful fine and few coarse roots; moderate permeability; gradual smooth boundary.
B_{21}	32 - 80	Yellowish red (5 YR 4/6) sandy clay loam; moderate coarse subangular blocky; firm, sticky and plastic; many coarse roots; moderately slow permeability; gradual wavy boundary.
B_{22}	80 - 165+	Red (2.5 YR 4/6) clay loam; moderate coarse subangular blocky; firm, sticky and plastic; many coarse roots; moderately slow premeability.

Profile VI

Location	Kalikadavu, Karivallur village, Taliparamba taluk, Cannanore district.
Topography	Gently sloping land.
Drainage	Well drained.
Ground water table	8 metres.
Land use	Coconut and cashew.

Parent material		Colluvial sediments.
Remarks		Very deep sandy soil, devoid of gravels, red colour predominant and increasing with depth.
Series		Kunhimangalam.

Horizon	Depth (cm)	Description
Ap	0 - 20	Strong brown (7.5 YR 5/6) sandy loam; yellowish red (5 YR 4/6) moist; weak medium subangular blocky; loose, very friable, nonsticky and nonplastic; many coarse roots; moderate permeability; clear smooth boundary.
B_1	20 - 47	Yellowish red (5 YR 5/6) sandy loam; Yellowish red (5 YR 4/6) moist; weak medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many fine roots; moderate permeability; gradual smooth boundary.
B_{21}	47 - 93	Reddish yellow (5 YR 6/6) sandy clay loam; yellowish red (5 YR 4/6) moist; moderate medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; few coarse roots; moderate permeability; gradual wavy boundary.
B_{22}	93 - 143+	Dark red (2.5 YR 3/6) sandy clay loam; moderate medium subangular blocky; friable, slightly sticky and slightly plastic; few coarse roots; moderately slow permeability.

PHYSICO - CHEMICAL CHARACTERISATION OF RED SOILS IN DIFFERENT REGIONS OF KERALA

By

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ABSTRACT OF THE THESIS

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ABSTRACT

In the present study an attempt has been made to evaluate the morphological, physical and chemical characteristics of red soils occurring in different regions of Kerala. Six soil series representing red soils identified by the Soil Survey Unit of the Department of Agriculture, Kerala state were selected for the investigation. The series identified were Vellayani, Cherniyoor, Bharanikkavu, Beypore, Chirakkal and Kunhimangalam located in Trivandrum, Quilon, Calicut and Cannanore districts. Profile pits were dug at these different locations and examined for their morphological features. Soil samples representing the different horizons were collected for laboratory studies. The physico-chemical characteristics of the soils and chemical composition of clays of the profile samples were investigated with a view to study the interrelationship between the various properties and to relate these characteristics to the genesis of these soils. Surface samples collected from different locations under each series were also analysed for available nutrients.

The morphological features of the soil profiles revealed prominent red hues with increase in redness with depth. All the soil profiles were well drained, with ill

defined horizons, exhibited good structural development and were devoid of coarse fragments.

The soils were all sandy in nature, with the fine sand fraction predominating. Clay illuviation was observed in all the profiles. In respect of available water content appreciable variation was not observed between soil series. The highest available water content was recorded in Kunhimangalam series while Beypore series had the lowest.

All soils were acidic with very low electrical conductivity. The organic carbon, nitrogen and C/N ratios were low and showed little variation between soil series. Silica recorded very high values for all the soils while total Fe_2O_3 and Al_2O_3 did not reveal much variations between soil series. The total reserves of CaO, MgO, K_2O and P_2O_5 were very low and is mainly a reflection of minerology of sand fraction which was dominated by quartz.

In respect of total micronutrients iron and manganese recorded high values while zinc and copper were low and did not reveal much variations between the different soils. Iron, zinc and copper showed positive relationship with finer fraction while in the case of manganese, the relationship holds good in the case of fine sand fraction only.

The e.c.e.c. values obtained were very low and less than the c.e.c. values determined by neutral N NH_4OAc method. Effective c.e.c. showed positive significant relationship with organic matter. The content of exchangeable bases were in the order Ca Mg Na K. Exchangeable hydrogen was more than exchangeable aluminium. Cherniyoor series recorded the highest percentage base saturation while the lowest value was obtained for Kunhimangalam series.

The dithionite extractable iron was the predominant iron fraction in all the soils and based on the 'degree of freeness of iron' Kunhimangalam series was the oldest in respect of age followed by Chirakkal, Cherniyoor, Vellayani, Beypore and Bharanikkavu. The ammonium oxalate extractable iron and iron oxide ratio, recorded very low values for all the soil series.

The available nutrients of the surface samples showed high levels of phosphorus in all the soils. Nitrogen was low to medium in Vellayani, Cherniyoor and Beypore while it was medium in Bharanikkavu, Chirakkal and Kunhimangalam series. In the case of available potassium low to medium levels were observed in Chirakkal, Bharanikkavu, Beypore and Cherniyoor series while Kunhimangalam and Vellayani series showed low levels of available potassium. The phosphorus fixing capacity for all the series was high.

The DTPA extractable iron and manganese were more than adequate in the surface horizons of all the series. Zinc was deficient to adequate in Vellayani, Bharanikkavu and Kunhimangalam series and marginal to adequate in Cherniyoor, Beypore and Chirakkal series. Copper was deficient to adequate to Vellayani, Cherniyoor and Kunhimangalam series, while adequate levels were observed in Bharanikkavu, Beypore and Chirakkal series.

Silica formed the predominant element of the clay fraction. The SiO_2/Al_2O_3, SiO_2/Fe_2O_3 and SiO_2/R_2O_3 ratios recorded for all the soils were higher than the values reported for typical laterite soils.