MORPHOLOGICAL AND PHYSICO-CHEMICAL PROPERTIES OF THE KAYAL SOILS OF KUTTANAD, KERALA STATE

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INTRODUCTION

INTRODUCTION

(Kuttanad, comprising an area of about 875 sq.km in the two districts of Alleppey and Kottayam is a unique agricultural region and rice cultivation in this region faces a number of complicated soil fertility problems. A single crop of rice is the usual cropping system followed but an additional short duration crop is also attempted now a days by many cultivators. The rice fields are situated at a depth of 1½ to 2 m below sea level and so it is submerged under water for a major part of the year. It is also periodically inundated with saline water. The vast area is divided into several small blocks by construction of mud embankments 2 to 2½ m high.)

A more or less uniform climate prevails throughout the Kuttanad area with a temperature ranging from 70 - 75^{o}F and humidity from 90 - 100. The South West monsoon from June to August and North East monsoon during October-December contribute an average rainfall of about 2750 mm. During the monsoon periods, fresh water from the rivers enter the area and as the North East monsoon recedes, sea water enters and the whole area becomes saline again. Kuttanad area is therefore faced with peculiar problems and cultivation is rather uncertain and hazardous.

Of the three types of Kuttanad rice soils viz. kari, kayal and karapadom, the present investigation is confined to kayal soils which are reclaimed from the Vembanad lake and occupy roughly about 8000 hectares extending in the two districts of Kottayam and Alleppey. (The reclamation dates back to 1836 A.D. In the early days of reclamation cultivation of a single crop of rice was carried on for 2 to 4 years continuously and the lands left fallow for 1 to 2 years. Continuous cropping decreased the yield.)

The kayal fields are 1½ to 2 m below sea level and so they are submerged under a sheet of water for a period of 5 to 6 months. With the reduction in the intensity of the monsoon, water is pumped out into the canals and germinated rice seeds sown in puddled soil.

These soils are slightly acidic to neutral in reaction, low in organic matter content and poor in total and available nutrients but rich in calcium due to the presence of lime shells of lacustrine origin. They are more seriously affected by salinity than other soil types and crop failure is quite common. Salinity hazards can be averted in these kayal lands if fresh water reserves are provided. A major project to prevent intrusion of sea water into these areas is complete with the construction of a permanent bund at Thanneermukkam in Sherthalai taluk and 2 crops are proposed to be grown in these areas. Another project which has only been implemented in one block of *kayal* lands, viz. the R block, is the construction of rubble ring bunds to permanently cut off saline water intrusion. This construction in R block kayal was completed in 1965. At present, in the R block there is continuous pumping out of the seepage water which seeps through the lower layers and the rain water which collects in the channels inside the R block. A comparison of the soils of the R block, with those of the adjacent *kayal* blocks like the Rani kayal and Chithira kayal has also been attempted in the present study, besides undertaking a study on the morphological, physico-chemical properties and availability of major and minor elements in these soils.

The present investigations is therefore aimed at with the following major objectives.

1. Morphological features of the Kuttanad *kayal* soil profiles and fitting these soils on the classification proposed by the 7th Approximation.
2. Physical characteristics of these soil profiles.
3. Chemical characteristics of the *kayal* soil profiles including their available micronutrient status.

4. Comparison of the properties of the soil from the permanently reclaimed R block with the adjacent Rani and Chithira kayals in respect of prevention of salt water intrusion.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The Kuttanad '<u>Kayal</u>' soils are characterised by alternate inundation of fresh and saline water and they exhibit high salinity due to the sea water intrusion. The soils are slightly acidic to neutral in reaction and rice is extensively cultivated in these areas. The studies so far made on these '<u>Kayal</u>' soils were mostly confined to the surface samples and profile studies have not been attempted by many. The following review of literature comprises the previous work done by various research workers in the State and elsewhere on similar soils.

I. <u>Physical characteristics</u>

Keen and Rackzkowski (1921) studied the interrelationship between pore space, clay content, specific gravity and volume expansion and found a positive correlation between pore space and clay content. A negative correlation was noticed between specific gravity and clay content but the volume expansion was found to be directly related to the percentage of clay.

Merchand (1924) studying the single value constants like pore space, specific gravity, water holding capacity and volume expansion of soils by the Keen Rackzkowski method found that these could be roughly correlated with the clay content of the soil.

Sen and Deb (1941) found that volume expansion, apparent and real specific gravities bear no relation to the clay content of soils.

Joachim and Kandiah (1947) found a high correlation between clay content and water holding capacity.

Subba Rao (1960) reported a positive correlation between clay and pore space and volume expansion with water holding capacity and a negative correlation between pore space and water holding capacity and sand fractions. Dhanapalan Mosi (1960) studying the profile characteristics of red soils of South India found an increase in clay content with increase in profile depth, the values being 28.5 per cent and 44.9 per cent for the top and third horizons respectively. In some profiles the clay content increased progressively from 19.9 per cent in the top to 33.9 per cent in the third horizon.

Drowpathi Devi (1963) in her studies on the interrelationship between physical and chemical properties of Kerala soils found a negative correlation for clay with coarse and fine sand. Silt was positively correlated with clay content.

Parvathappa (1964) found that physical and moisture constants increased down the profiles. Pore space, moisture equivalent, water holding capacity and hygroscopic - coefficient were highly correlated with clay.

Rangaswamy (1965) found that physical and moisture constants tended to increase with depth in red soil. Manickam (1965) studying the profile characteristics of Nilgiri soils found an increase in the apparent and real specific gravities, the values ranging from 1.04 to 1.4 and 1.91 to 2.43 respectively, with an increase in the depth of the profile. Pore space was found to be more or less the same throughout in some profiles whereas in some it decreased upto the 3rd horizon, increased in the 4th and then gradually decreased.

Janardhanan Nair et al (1966) reported true and apparent specific gravities to be a function of coarse soil particles. Water holding capacity, pore space and volume expansion were related to the finer soil particles. Apparent specific gravity was found to be a convenient measure of available phosphorus and potassium as well as of single value constants of physical properties.

Ramaswamy (1966) found that the real and apparent specific gravity of surface soils are highly significant and positively correlated. They are found to be negatively correlated with pore space, volume expansion on wetting and moisture holding capacity. With increase in pore space there is corresponding significant increase in both volume expansion and moisture holding capacity. The higher amounts of organic matter present in the soils lowered the specific gravities of these soils.

Velayutham and Raj (1971) found that the influence of clay was more than that of organic carbon on the water holding capacity. The quantity and nature of clay influenced the moisture constant.

Ghosh _et al_ (1973) reported that the bulk density and particle density of _kari_ soils of Kerala varied from 1.24 to 1.46 and 2.52 to 2.56 g/cc respectively.

II. _Chemical characteristics_

1. _Soil reaction and electrical conductivity:_ Hartwell and Pember (1918); Mirasol (1920) and Conner _et al_ (1922) observed that acid soils are toxic to plants because of easily soluble aluminium salts.

Stephenson (1921) reported high degree of buffering in highly organic soils and clays whereas coarse soils exhibited little of this property. Liming was found essential when the amount of exchangeable hydrogen exceeded the amount of exchangeable calcium in soils.

Subramoney (1960) attributed the high degree of acidity in <u>kari</u> soils to the production of sulphuric acid by sulphur reducing bacteria. Money (1961) found that the lower horizons of most of the profiles of Kuttanad had a low pH, as low as 2.5.

According to Moorman (1962) acid soils containing sulphate content showed extreme variability in soil reaction. Seasonal variations were very high especially when these soils were subjected to inundation. pH value increased to neutral point slowly on inundation and decreased to high acidic range on drying.

Sukumara Pillai (1964) analysing the <u>kari</u> soils found that the surface soils were strongly acidic in reaction while the sub soils were only weakly acidic.

Horn <u>et al</u> (1967) reported that in poorly drained clay soils affected by salt water intrusion, electrical conductivity of saturation extract could be as high as 50 mmhos/cm.

Alexander and Dorairaj (1968) found a negative correlation for soil pH with loss on ignition, organic carbon, total nitrogen and cation exchange capacity of acid soils and a positive correlation with properties like cation saturation per cent, calcium saturation per cent and available phosphorus.

Mahapatra (1968) studying the Louisiana soils found an increase in pH in the case of 18 acid soils (pH 4.7 - 6.7) and decrease in the case of 2 alkaline soils (pH 7.8 - 8.2) after water logging. In all cases the final pH was close to the neutral point.

Bache (1970) working on acidic Scottish soils found that pH of acidic soils in $CaCl_2$ suspension increased with time, in certain cases by 0.4 units in 24 hours. This was attributed to the proton uptake by complex ions of iron and aluminium displaced into solution.

Bandyopadhya et al (1970) reported close association between salinity in the soil profile with the rise and fall of ground water table.

Venu Reddy et al (1971) reported higher pH in soils of heavier texture. At higher pH (upto 8.7) higher available nitrogen was found while phosphorus was low.

Nair and Money (1972) reported that the salt affected rice soils of Kerala showed high conductivity ranging from 4.2 to 14 mmhos/cm. Eventhough the conductivity was high the soil was found still acidic, pH ranging from 3 to 6.8. High negative correlation between pH and sulphate content was reported. High degree of positive correlation between conductivity on the one hand and sulphate, chloride and sesquioxide content on the other was also reported. Conductivity was also correlated with percentage of silt and clay. This was because, in the soils containing more finer fractions, the salt was not freely washed away as in sandy soils (Lunin and Gallatin, 1960).

Padmaja and Verghese (1972) reported that liming red loam soils of Kerala @ 2.5 m.mhos/ha CaO raised the soil pH by 1 to 1.5 units.

Kurup and Aiyer (1973) reported that for all the three major types of Kuttanad soils viz. kari, kayal and karapadom, the maximum and minimum values for soil pH and minimum and maximum values for electrical conductivity were during the periods of October-November and March-April respectively, when sampled.

Verghese and Aiyer (1973) found that 1:2.5 soil solution ratio made with 0.01 M $CaCl_2$ with a shaking period of one hour gave fairly accurate and reproducible value of pH for the acid sulphate soils of Kuttanad, Kerala State.

2. Organic carbon and C/N ratio: Nair (1945) studied the kari soils of different localities and found that organic

matter, exchangeable hydrogen, pH and C/N ratio are interrelated and have got a bearing on the low fertility status noticed.

Satyanarayana et al (1946) in a study of the uncultivated soils of India observed that the general level of carbon and nitrogen in most soils was low and the C/N ratios fluctuated from 5 to 25.

Drowpathy Devi (1963) found a positive correlation for organic carbon with nitrogen in Kerala soils. Sukumara Pillai (1964) investigating the properties of kari soils found that they are rich in organic matter and low in major nutrients.

Ramaswamy (1966) studying the properties of Madras soils found an increase in the major plant nutrients N, P and K with high organic matter content in soil.

Tabatabai and Hanway (1968) studying the chemical and physical properties of different sized natural aggregates of Iowa soils found that organic carbon increased as the aggregate size decreased. The bulk densities of the aggregates were found inversely related to the percentage of organic carbon in the aggregates.

Koshy (1970) found that C/N ratio ranged from 12.17 in a submerged rice soil to 23.67 in a kari soil.

Koshy and Verghese (1971) reported that the peaty or kari soil contained a high percentage of organic carbon. Ghosh et al (1973) and Aiyer and Money (1959) found a high percentage of organic carbon in Thottappally kari and Kattampally swamp soils.

Aditya Chowdhury and Saha (1973) in their studies made on the distribution of organic matter in the profiles of water logged rice soils of alluvial origin found remarkable variation in the organic matter content and total nitrogen percentage in the top and bottom layers, top layer containing higher quantities of both.

Vittal and Gangwar (1974) examining the profiles of Nainital tarai found that organic carbon ranged from low (0.5 per cent) to high (0.75 per cent). A general trend to decrease with depth was also noticed.

3. Major nutrients

(a) Nitrogen: Jenny (1941) found that the general trend of the nitrogen depth curve was exponential. He found that nitrogen generally penetrated deeper into the soil with increase in rainfall.

Allison (1957) working on the various soils of U.S.A. reported that the percentage of nitrogen varied from

0.15 to 0.3 in the chernozems of Eastern Dakotas and Kansas, from 0.10 to 0.25 in the Prairie soils of Central States and 0.05 to 0.2 in the Brown forest soils of the north east.

McDowell and Smith (1958) found that ammonium fixation increased with increasing clay content of the soil. Palpavi (1958) studying the effects of lime on a calcium poor soil found that liming progressively decreased the organic matter and total nitrogen and increased the level of nitrate and ammoniacal nitrogen.

Nambiar (1960) in his studies on the effect of liming on laterite soils of West coast found that liming favoured mineralization of soil nitrogen.

Money (1961) found that nitrogen content of Kuttanad soils varied from 0.2 to 0.85 per cent.

Abbichandani and Patnaik (1961) studying the effect of lime on nitrogen availability and yield of rice in water logged soils found that addition of 2000 lb lime under field conditions, increased the ammoniacal nitrogen content nearly two fold and significantly increased the yield of rice.

Unnikrishnan (1961) and Vijayachandran (1963) observed that nitrogen content increased with rainfall in the soils of Madras and Kerala.

Drowpathi Devi (1963) found that available nitrogen was a linear function of the total nitrogen.

Borthakur and Mazumdar (1968) found that liming increased the average mineral nitrogen content significantly under low moisture level but under water logged conditions the difference was not significant. According to them nitrogen uptake by paddy seedlings was significantly higher under limed conditions irrespective of moisture levels. Nitrogen uptake by paddy seedlings correlated with the mineral nitrogen content of soils only under limed water logged conditions.

A negative correlation between soil pH and total nitrogen was reported by Alexander and Durairaj (1968). Verghese (1972) studying the acid soils of Kerala recorded 0.49 to 0.55 per cent of nitrogen in <u>kari</u> soils. The total nitrogen content of the saline soils of Kerala was reported to be 0.05 to 0.38 (Nair and Money, 1972).

Padmaja and Verghese (1972) reported an increase in nitrogen availability by the application of Ca or Mg or both in red loam soils.

(b) <u>Phosphorus:</u> Bartholomew (1931) reported increased solubility of phosphate when the soil is submerged.

Karim and Khan (1956) in a study on the vertical distribution of nutrients in the soils of East Pakistan found that phosphorus increased upto a depth of 7" and then decreased sharply upto 35".

Mack and Barber (1960) observed that incubating the soil for 74 days at 23°C under 40, 70 and 100 per cent water holding capacity considerably increased the phosphate availability.

Raychaudhuri and Landey (1960) found that soils containing high amounts of clay and silt retained more phosphorus and showed low availability of this element.

Koshy (1960) reported that lime when applied in acid soils at high rates had a depressing effect upon phosphorus absorption. Availability of phosphorus in Kuttanad soils of Kerala was found low due to precipitation of both Fe and Al oxides (Gopalaswami, 1961) and fixation of the element in clay (Koshy and Brito-mutunayagam, 1965). Acidity coupled with high sesquioxide content favoured phosphorus fixation. This confirmed the earlier observations made by Raychaudhuri and Mukerjee (1941) and Chandler (1941).

Patel and Mehta (1962) in their studies on the vertical distribution in Gujarat soil profiles found that top layer is richer in both total and available phosphorus than sub soil layers. In all the profiles studied the sub soil layers contained less available phosphorus than those below which a response to applied phosphorus was obtained. No significant relation between any of the single factors of the soil and the total and available phosphorus was reported. The integrated action of all these factors affected the phosphate status of the profiles.

Koshy and Brito-mutunayagam (1961 and 1965) in their study on the Kerala soil profiles found the level of total phosphorus varying from 0.024 to 0.0256 per cent. The phosphorus fixing capacity varied widely, acid soils with high sesquioxide having high fixation capacity. Downward movement of phosphorus in Kuttanad soils was found to be very low. In kari soils rich in organic matter, the penetration of phosphorus was much higher.

Nair and Aiyer (1966) found that among the 4 extractants (Bray No.1, No.2, Olsen's method and Saunder's method), Olsen's method was found to give better correlation with actual phosphorus taken up by plants. The efficiency of extraction by the alkaline extractants was found positively influenced by pH, exchangeable and soluble iron. Olsen's reagent was also found to be least affected by the variations in the different soil chemical characteristics. Iron phosphate was found to be the predominant form of phosphate in the soils studied and it is this form that is plant available.

Kurup (1967) reported that phosphorus availability is increased in the limed than in unlimed samples of Kuttanad soils.

According to Holmen (1968) peat soils are often deficient in phosphorus and potassium and sometimes nitrogen.

Hanley and Murphy (1970) reported that all forms of phosphorus were highest in the clay fraction and lowest in the sands. The inorganic phosphorus of the clays and silts was mainly iron phosphate whereas calcium phosphate was the dominant form in the sand fraction. Well-drained soil also had a higher content of total phosphorus in their clay and silt fraction than similar fractions in poorly drained soils.

Kurup and Koshy (1968) found that water soluble phosphorus from superphosphate was as efficient as citric acid soluble phosphorus in the Kuttanad soils. Kurup and Ramankutty (1969) studying the effect of superphosphate, rockphosphate, hyperphosphate and bonemeal with and without lime in acid soils of Kuttanad found that superphosphate, rockphosphate and hyperphosphate increased the yield significantly over control and bone meal. No favourable influence was exerted by lime either independantly or in association with different phosphates.

Nair and Money (1972) found the phosphorus content of some of the saline soils of Kerala ranged from 0.038 to 0.166 per cent P_2O_5.

Padmaja and Verghese (1972) reported increase in available P_2O_5 by the application of silica alone or with Ca or Mg or both. Ghosh et al (1973) in their studies on kari soils of Kerala reported low phosphorus content.

Kar (1974) studying the relative influence of Ca^{++}, pH and lime on the release of native phosphorus found that with rise in pH, available phosphorus increased significantly during the first few days of incubation. Maximum release of native phosphorus was noted on liming due to cumulative effects of increase in both Ca content and pH of the soil.

(c) Potassium: According to McIntire (1927) release of potassium was retarded by excess of soil acidity but in some cases it favoured its fixation.

Karim and Khan (1956) in their study on the vertical distribution of potassium in the soils of East

Pakistan found that it decreased to a depth of 7" and thereafter increased progressively upto 35".

Halim et al (1963) investigating the potassium status in the U.A.R. soils found total potassium varying between 2.5 meq. in coarse textured soils to 15.0 meq/100 g in fine textured soils and was highly correlated with clay percentage and exchangeable potassium.

According to Grewal and Kanwar (1966) the surface soil samples from different soil zones of Punjab contained on an average 1925 mg K_2O/100 g. Nearly 30 per cent of the total potassium was present in HCl soluble form, 6.1 per cent in fixed form, 0.98 per cent in water soluble and exchangeable form and 0.93 per cent in available form.

According to Badiger and Rao (1969) potassium fixation was more in black soils containing more of montmorillonite clay than in red soils containing Kaolinite type of clay.

Rajakannu et al (1970) reported positive significant correlation of available potassium with pH in red and alluvial soils. No significant correlation was noticed with organic carbon and available nitrogen in any of the soil studied. In black soils available potassium was not related to the lime content.

Nair and Money (1972) found that potash content ranged from 0.087 to 0.286 per cent K_2O in some of the saline soils of Kerala.

Acid soils of Maharashtra, formed either by leaching or by acid parent material are rich in lattice potassium but low in HCl soluble and available potassium as reported by Kadrekar (1973).

Sreedevi and Aiyer (1974) studying the potassium status of five major acid rice soils of Kerala viz., *kari*, *karapadom* and *kayal* of Kuttanad region, *kole* of Trichur district and the low level laterites of ribbon valleys in the midland regions found the magnitude of exchangeable K in the order of *kari* *karapadom* *kayal* *kole* low level laterites. Difficultly exchangeable K was in the order *kayal* low level laterites *kole* *karapadom* *kari* while that of HCl soluble K was in the order *karapadom* *kayal* *kole* low level laterites *kari*. Total K and HCl soluble K on the one hand and difficultly exchangeable and HCl soluble K on the other were significantly correlated. Comparatively high values of total, exchangeable, difficultly exchangeable and HCl soluble K found in *kari*, *karapadom* and *kayal* soils of Kuttanad were attributed to submergence in salt water from adjoining back waters and due to silt deposition by flood water.

4. Cation exchange capacity and exchangeable cations

Mitchell and Muir (1937) found that cation exchange capacity of soil depended mainly on its clay content and composition. Donahue (1958) considered C.E.C. to be a single index of fertility. The more clayey a soil the more was its C.E.C. and hence greater the chances of its being fertile.

Gopalaswamy (1961) reported a high C.E.C. for kari soils of Kerala due to the high organic matter content and due to the probable presence of illitic and montmorilloniti type of clay.

Roy and Landey (1962) found that the clay content and C.E.C. were maximum in the intermediate layers of the soil profile. Wilding and Rutledge (1966) reported that in A horizons organic matter contributed most to C.E.C., while in B horizons clay usually contributed most.

Yuan et al (1967) studying the Florida surface soils found a significant correlation between C.E.C., clay content and organic matter level, the relationship between organic matter and C.E.C. having the highest correlation.

Alexander and Durairaj (1968) found that C.E.C. of black soils increased with increase in pH. In acid soils, C.E.C. was negatively correlated with pH. Lavti et al (1969) reported a significant correlation of the C.E.C. with clay, silt and organic matter content.

Wright and Foss (1972) reported significant relationship between clay, organic matter and C.E.C. 88 per cent of the variability in the C.E.C. was attributed to the clay and organic matter content. Sreedevi and Aiyer (1974) reported that kari soils had the highest cation exchange capacity among the major rice soil types of Kerala.

Menon et al (1957) found increase in C.E.C. with depth of soil profile. Of the various exchangeable cations 80 per cent was occupied by calcium. Calcium and magnesium increased with profile depth.

Makitie and Virri (1965) reported clear relationship between soil reaction and base saturation in the clay soils of Finland, which are generally heavy clays, acidic and half base saturated. The exchangeable cations were reported to be mainly Ca^{++} and Mg^{++}. The sum of their concentrations increased and the ratio between them approached unity with increase in depth.

Nambiar (1947) found calcium as the important replaceable base followed by Na and K in the rice soils of Kerala. This has been noted by a number of other later workers also. The low exchangeable calcium content in the surface layers was attributed to the leaching effect of heavy rains since an increase in exchangeable calcium was noticed in the lower layers.

According to Bear and Toth (1948) an ideal soil should contain 65 per cent calcium, 10 per cent magnesium 5 per cent potassium and 20 per cent hydrogen in the exchange complex.

Drowpathi Devi (1963) found close correlation between C.E.C. and exchangeable Ca. Magnesium content was found to be a linear function of calcium content.

Mahapatra (1968) studying the effect of flooding on the mobilisation of nutrients, found that water soluble Ca^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+} and phosphorus increased by water logging.

Milton and Wadleigh (1951) found a positive correlation between exchangeable Na and pH and concluded that the exchangeable Na could be predicted from the pH value.

Wild (1971) found a low exchangeable potassium content in soils containing low percentage of clay, especially Kaolinitic clay.

Thomas Varghese and Money (1965) reported significant increase in pH, available phosphorus and potassium by the application of calcium and magnesium.

Pierre et al (1932) stated that soils of relatively high percentage base saturation at low pH values yielded in general less aluminium in solution than soils of low percentage base saturation. Aluminium solubility was increased by high concentration of soluble salts.

According to Russel (1950) mineral soils are aluminium soils and not hydrogen soils. He found that exchangeable aluminium contributed markedly to exchange acidity in such soils.

Pratt and Blair (1961) found that extraction with 1 Normal KCl allowing a minimum time of contact with the first portion of the extractant probably gave the most reliable estimate of exchangeable aluminium.

Middleton (1965) in his work on Malayan soils found that aluminium extracted correlated very significantly with pH of the extracting solution. Determinations of aluminium were significantly correlated with percentage of clay in the soil.

Clark (1966) analysing the soluble and exchangeable aluminium in acid soils found no direct relationship between pH and concentration of soluble aluminium.

Horn et al (1967) reported more than 500 ppm extractable aluminium in acid sulphate soils of pH values 2.6 to 4.0.

Helias and Coppenet (1970) found that a considerable quantity of exchangeable aluminium existed in the various horizons of uncultivated Breton soils with a pH below 5.5. When the pH increased to 5.7 to 5.8 the exchangeable aluminium disappeared.

Kabeerathumma and Chitharanjan Nair (1973) reported that the soils of Kuttanad are highly acidic and have a high concentration of exchangeable hydrogen and aluminium, toxic concentration of ferrous iron and aluminium and extremely low microbial activity. Ferrous iron content and exchangeable aluminium were effectively reduced by liming. A high negative correlation of these elements with pH was noticed.

5. Micronutrients

Their distribution in soil profile and availability with respect to other soil characteristics:-

(a) Available zinc

Sharma and Motiramani (1969) in their investigation on the zinc status of Madhya Pradesh soils found a negative correlation between pH and available zinc. No consistent relationship between available zinc and $CaCO_3$ or any positive correlation with organic carbon was found. Available zinc was more abundant in 0-50 cm layer.

Tripathi et al (1969) found the available zinc content of U.P. soils varying from 0.9 to 8.8 ppm with a mean of 4.4 ppm. Soil pH, $CaCO_3$ and organic matter have no significant relationship with available zinc. This was supported by the findings of Grewal et al (1969) who found that available zinc decreased with depth of the profile.

Prasad and Sinha (1969) found significant correlation for dithizone extractable zinc with pH in Bihar soils while Rai et al (1970) found that available zinc was not significantly related to pH, organic carbon or $CaCO_3$.

Praseedom (1970) found no regular distribution for available zinc in the profiles of Kerala soils studied. Laterite soils contained maximum average content of available zinc and kari soils the minimum.

Prasad and Pagel (1970) reported that available zinc (Ammonium acetate soluble at pH 4) in soils was higher in humid regions (1.666 ppm) than in arid regions (0.364 ppm). Available zinc showed positive correlations with clay and silt and humus levels and negative correlations with pH, exchangeable Ca, degree of saturation, K supply as well as available P. Its level decreased with profile depth.

Valsaji (1972) found no definite trend in the downward distribution of available zinc.

Rai et al (1972) found significant negative and positive relations for available zinc to soil pH and organic carbon respectively.

Gupta and Singh (1972) reported 0.9 to 3.25 ppm available zinc in the Indore soils, the availability decreasing with increasing soil pH.

Balasubramaniam et al (1973) reported 1.6 ppm available zinc in Tamil Nadu soils. A positive significant correlation was noticed with organic matter and a significant negative relation with pH.

Gopinath (1973) studying the distribution of zinc in the acid peat soils of Kerala found that it varied from 0.8 to 1.6 ppm with an average of 1.38 ppm in the surface samples and 0.7 to 1.84 ppm with an average of 1.36 ppm in the sub surface samples. No regularity in the downward distribution was noticed for available zinc but in some profiles it increased with depth. Significant positive relation with pH was obtained in the sub surface layers.

Vittal and Gangwar (1974) found that dithizone extractable zinc was related to drainage conditions and decreased with depth. Accumulation of extractable zinc was observed in the surface horizons due to heavy turn over of zinc by vegetation and its deposition on the surface. The common trend of increase in pH with depth leads to the formation of insoluble zincates. In addition, pH also caused increased stability of the complexes formed by zinc with organic compounds. No linear correlation was observed for dithizone extractable zinc to soil properties. It was more between pH 6 to 7, then it decreased with increase in pH.

Vuletic and Mijatovic (1967) reported 0.1 to 3.2 ppm of dithizone extractable zinc with highest values in top soil and lowest in the calcareous horizons.

Deb and Sharma (1973) in a survey made to study the zinc status of Delhi soils found that available zinc content in dithizone + ammonium acetate extract varied from 0.6 to 7.7 ppm with a mean of 2 ppm. In 1 N ammonium acetate (pH 4.8) 0.4 to 5.7 ppm with a mean of 1.9 ppm was reported. It was reported that physiologically available zinc lies in the range of traces to 0.49 ppm. The organic matter content did not show any significant relation with available zinc in rice soils.

Bansal et al (1969) investigating the distribution of micronutrients in the soil profiles found that exchangeable zinc tended to accumulate in sub surface soil and then decreased with depth. Zinc was significantly correlated with Mg.

Bandyopadhya and Adhikari (1971) found that available zinc decreased with depth in the alluvial, lateritic and coastal saline soils of W.Bengal.

According to Hodgson et al (1966) zinc deficiencies are more common than copper deficiencies in calcareous soils. Zinc levels in displaced solutions from 20 calcareous soils were below 0.002 ppm and 30 - 75 per cent of the zinc was complexed. Cu levels in solution ranged from 0.005 to 0.016 ppm with 98 - 99 per cent present as organic complexes. The high content of complexed Cu partly explained the lack of Cu deficiency in calcareous soils which are deficient in zinc.

Kabata-Pendias (1968) found available zinc concentrated in the upper horizons of peats and black earth and in the lower horizons of podzolic and brown soils.

Chatterjee and Das (1964) observed that extractable zinc was more in soils predominant with minerals like chlorite and illite as compared to montmorillonite due to their low zinc fixing capacity.

Gangir et al (1973) found the available zinc ranging from 0.21 in alluvial to 16.0 ppm in medium black soils of Madhya Pradesh. These soils were reported to be highly deficient in available Zn.

Nowosielska (1966) studying the effect of different long term treatments on the zinc content of soil found that all forms of zinc decreased with increasing soil depth.

Rajagopal et al (1974) studying the relation between organic carbon and available micronutrients in the Nilgiri soils (acidic in reaction with a pH range of 4.5 to 5.6) reported 9 per cent of the soil deficient in available zinc. Available Zn was also negatively correlated with organic carbon. Some organic complexing agents present in greater amount in these organic soils affected zinc availability.

(b) Available copper

Holmes (1943) concluded that the differences in the copper content of various soils and in the horizons of the same soil are associated more with the amount of clay than organic matter.

Lees (1948) reported that organic matter, because of its copper fixing capacity, is responsible for low availability of copper in organic soils.

Vermaat and Vander Bie (1950) concluded from the study of the Indonesian soils that major part of the copper adsorbed in the exchangeable form was by clay. According to Gilbert (1952) Cu deficiency is most frequent on very sandy and gravelly soils.

Copper is reported to be less susceptible to pH changes. Pack *et al* (1953) obtained a non-significant correlation between available Cu and pH. According to Reuther (1957) soils hold copper most securely in the range from pH 7 to 8, appreciably less securely at pH 6, and progressively less securely as the soil becomes more acidic.

According to Tobia and Hanna (1958) Cu retention in Egyptian soils is correlated with organic matter and soil reaction.

Neelakantan and Mehta (1962) in their studies on Gujarat soils found a decreasing trend in the case of available Cu as pH increased but statistical analysis showed a non-significant negative correlation between pH and available Cu. It was also reported that available Cu gradually increased with increasing amounts of organic matter in some cases but in others there was either no change or a decline.

Statistically a positive non-significant relationship between organic matter and available Cu was found in all cases. Finer fractions of the soil were considered to be the main store house of available nutrients.

Kavimandan et al (1964) obtained a non-significant correlation between pH and available Cu whereas Mehta et al (1964) reported a significant negative correlation.

Agarwal and Motiramani (1966) reported that black soils were richest and alluvial soils poorest in available Cu. A negative correlation between pH and available Cu was reported but no consistent relationship with $CaCO_3$ or organic matter was found.

Semb and Oien (1966) reported that low Cu content occurred in sandy, silty and peat soils and in soils under recent cultivation whereas clayey soils contained more Cu. Distinct deficiency symptoms in crops are associated with 1 mg cu/kg soil. This critical value of Cu may be higher in soils rich in organic matter and inorganic soils.

Rai and Mishra (1967) reported no correlation of available copper with pH. As organic carbon and finer fractions increased the availability of copper also increased but as the $CaCO_3$ content increased availability of Cu decreased.

Furlan and Stupar (1967) reported a mean copper value in peat soils as 3.3 ppm.

Jones and Belling (1967) studying the movement of copper using ^{64}Cu in peat, calcareous sand, terra rosa, deep sand and laterite under the influence of various fertilizer treatments found that Cu remained near the soil surface after all the fertilizer treatments and several year's rainfall. With light soils and low C.E.C. some penetration of copper occurred.

Bandyopadhya and Adhikari (1968) reported adequate amounts of Cu, Zn and Mn in the rice soils of West Bengal. Correlations were shown for these elements with extractable Zn, Cu and Mn.

Savic and Jekic (1968) reported the available Cu in soils ranging between 4.6 and 8.4 mg/kg, soils of heavier texture containing higher quantities.

Mishra et al (1969) reported available copper ranging from 1.2 to 10.6 ppm in the U.P. soils. No significant relationship was noticed between available Cu and pH as well as silt plus clay content of soils. $CaCO_3$ gave a significant negative correlation with available Cu.

Bansal et al (1969) reported accumulation of Cu in sub surface and a decrease with depth as in the case of Zn.

Significant correlation was noticed with pH.

Grewal et al (1969) reported significant negative relations for available Cu with pH and possible correlation with organic matter. Exchangeable Cu decreased with depth of the profile.

Praseedom (1970) studying the distribution of copper in the Kerala soils found the highest amount in sandy soils and lowest in forest soils. No significant correlation was noticed for available copper with pH as well as finer fractions of soil and organic matter.

Rai et al (1970) found that available Cu was not significantly related with pH, organic carbon or $CaCO_3$.

Available Cu in Rajasthan soils ranged from 0.05 to 5.6 ppm according to Lodha and Baser (1971). No consistent relationship in different soil groups was observed between available Cu and pH as well as $CaCO_3$ content. With increase in organic matter content, available nutrients increased although such increases were significant in some of the soils only.

Bade et al (1971) reported marginal levels of available Cu in the Maharashtra soils. Significant negative correlation between pH and a significant positive correlation with organic carbon was observed for available Cu.

Valsaji (1972) reported significant negative correlation between available copper and pH. A positive significant correlation was noticed between available copper and organic carbon. No significant relation was noticed between available copper and soil constituents like silt and clay.

Rai et al (1972) found that organic matter, clay and interaction between them affected Cu availability in the deep black soils of Madhya Pradesh. A significant relationship was observed between plant available Cu and clay x O.C.

Kishk et al (1973) studying the Cu status in calcareous and non-calcareous soils of Egypt found that alluvial and sandy soils had the highest and lowest values for Cu extractable with normal neutral ammonium acetate. Calcareous soils showed intermediate values.

Gopinath (1973) studying the distribution of copper in the acid peat soils of Kerala found that available copper content varied from 0.4 to 1.5 ppm with an average of 0.9 ppm in the surface layers. In the sub surface layers it varied from 0.3 to 1.6 ppm with an average of 0.79 ppm. Available copper decreased with depth significantly and a negative significant correlation was obtained between available copper and pH in the surface layers. No significant relation was seen with pH in the sub surface layer. Available copper was positively and significantly related to organic carbon in the surface layer but a negative non-significant relation was obtained in the sub surface layer.

Francisco Duque Macias (1973) reported 0.3 to 1.3 ppm (average 0.5 ppm) of copper extractable with N ammonium acetate. Positive correlation significant at 1 per cent and 5 per cent levels were found for copper extracted with N ammonium acetate with pH and organic matter respectively.

Rajagopal et al (1974) reported negative correlation between available copper and organic carbon in the Nilgiri soils. The soils were found highly deficient in available copper.

(c) Available iron

Tayel et al (1966) analysing the soil samples from different parts of Egypt reported 1 to 15 ppm of normal ammonium acetate (pH 3) soluble Fe and it was usually less than 7 ppm. No correlation was found between the extractable Fe and soil pH.

Takkar and Bhumbla (1968) studying the distribution of Fe in acidic and neutral soils of Himachal pradesh reported 2.2 ppm exchangeable Fe (normal ammonium acetate at pH 3).

Bansal et al (1969) reported that exchangeable Fe did not vary much with soil depth but significant correlation was noticed with pH.

Rai et al (1970) found significant and positive correlation between exchangeable Fe and organic carbon in the deep black soils of Madhya Pradesh.

Lodha and Baser (1971) investigating the micronutrient status of Rajasthan soils found 0.3 to 15.7 ppm of available Fe. No consistent relationship in different soil groups was observed between available Fe and pH as well as $CaCO_3$ content.

Balaguru and Dhanapalan Mosi (1972) studying the forms of distribution of Fe and Mn in Tamil Nadu soils found that available Fe ranged from 50 - 107 ppm. The distribution was uniform in black soils while in red soils the trend was opposite. Alluvial soils showed a decreasing tendency with depth. No significant association between organic matter and available Fe was observed and it was also not correlated with pH. Aiyer (1963) indicated that below 2 ppm of Fe, deficiency symptoms appeared in rice.

Rai et al (1972) found significant negative relation between soil pH and available Fe. $CaCO_3$ was negatively related to available Fe.

Shukla and Singh (1975) reported that available Fe ranged from 2.2 to 107.2 per cent in the sierozem soils of Haryana. It was positively related to organic carbon.

CaCO3 content did not affect significantly the availabl
or reducible Fe.

Arunachalam and Dhanapalan Mosi (1973) reported that total, exchangeable and dilute acid extractable iron were more closely associated with organic carbon than exchangeable ferrous Fe. Both forms were closely associated with organic carbon.

Rajagopal et al (1974) reported a positive correlation between organic carbon and available iron in the Nilgiri soil. The close positive relation between iron and organic carbon increased the iron availability to plants with increase in organic carbon.

(d) Available manganese

Robinson (1929) found that laterite soils have an appreciable supply of exchangeable Mn and Boken (1955) observed that manganese of this category was higher in soils in the presence of ferrous iron.

Biswas (1953) and Saxena and Baser (1964) reported very low amounts of water soluble Mn, often below 1 ppm in soils of varying texture and alkaline reaction. Biswas also observed a positive correlation between exchangeable Mn and organic matter.

A high level of exchangeable Mn was reported in clayey soils by Biswas (1953); Zende and Pharande (1961), while Yadav (1964) observed that Mn in this form increased progressively with increase in clay content. Dharmija et al (1956) found that water soluble Mn occurred only in traces and sometimes is absent in paddy soils of Bihar, Uttar Pradesh and Punjab.

Gopalaswamy and Soundararajan (1962) found that alluvial laterite soils contained more of water-soluble and exchangeable Mn ranging from 0.2 to 10.5 ppm. A gradual decrease was found throughout the profile and a maximum concentration was found in the surface layer. These forms of Mn were found to have a non-significant negative relationship with clay but a significant correlation with organic matter indicating that they are the major fraction in organic matter in soils.

Yadav and Kalra (1964) and Sharma and Motiramani (1964) observed a high content of exchangeable Mn in acidic soils as compared to other soils and found a negative correlation between pH and available Mn. Biswas and Gawande (1964) observed that the Mn content of soil was lower in top layer and that exchangeable Mn was more related to pH than clay content.

Bhatnagar et al (1966) found moderate to high availability of Mn in the medium black soils of Rajasthan.

Active Mn content was positively correlated with size of clay and silt fractions and negatively with $CaCO_3$ content.

Pisharody and Brito-mutunayagam (1966) reported 1.8 to 14.8 ppm of water soluble Mn in the profiles of water-logged soils. The higher content of this form of Mn in the rice soils of Kerala was attributed to their acidic nature and submerged condition.

Exchangeable Mn which constituted a bigger fraction of total Mn than the water soluble form varied from 10.2 to 80 ppm. These high values were reported to be due to the lateritic origin and ferruginous nature of the soils.

The easily reducible Mn was found to be between 8.9 to 12.42 ppm. High values were recorded in profiles rich in organic matter whereas sandy profiles recorded low values.

The active or available Mn in submerged profiles ranged from 35.5 to 159.6 ppm. It was highest in alluvial soils and lowest in sandy profile. A high positive correlation was reported between active manganese and clay content and a close relationship with organic carbon.

Mehta and Patel (1967) reported 4.8 to 27.6 ppm water soluble plus exchangeable Mn in the soil profiles in Gujarat. A gradual increase in active forms with increase in depth and a reverse trend for exchangeable Mn including water soluble form was noticed. Factors like pH, organic matter, microbial action and drying governed the distribution of exchangeable plus water soluble manganese.

Tembhare and Rai (1967) reported 1.2 to 10.3 ppm available Mn in the soil samples of Jabalpur District. It decreased significantly with increasing pH and $CaCO_3$ content and tended to decrease with increasing clay content. Organic matter did not affect available Mn significantly.

Sharma and Shinde (1968) found a low status of available manganese in the black soils of Indore district. A significant positive correlation was observed between available manganese and organic carbon and clay content. No correlation was noticed between available manganese and $CaCO_3$ content.

Grewal et al (1969) found significant negative correlation between exchangeable and active manganese and pH and positive correlation with organic carbon. Exchangeable Mn decreased with depth of the profile.

Rai et al (1970) found a negative relationship for ammonium acetate extractable Mn with pH and positive relation with organic carbon.

Baser and Saxena (1970) investigating the Manganese status of Rajasthan soils found that exchangeable and reducible

Mn decreased with increase in pH in sandy loam soils. With increase in organic matter exchangeable Mn first decreased and then increased slightly, while reducible Mn increased steadily. As the texture of the soil changed from sandy to clay, the average values of exchangeable Mn decreased while those of reducible Mn increased.

Badhe et al (1971) reported significant negative correlation between pH and available Mn.

Mishra and Tripathi (1972) found that exchangeable Mn decreased with profile depth in some soils and was reversed in some others. Soil pH influenced the variability observed in exchangeable and available forms.

Balaguru and Dhanapalan Mosi (1972) investigating the forms and distribution pattern of Mn in Tamil Nadu reported 0.17 to 2.76 ppm of water soluble and 0.2 to 6.0 ppm exchangeable Mn. In non-calcareous red and alluvial soil profiles exchangeable Mn decreased with depth. It was not related to clay content. A significant negative correlation existed between clay and available Mn (water soluble plus exchangeable). pH was not associated with available Mn.

Mohapatra and Kibe (1972) reported 1.5 to 67.0 ppm available Mn in Maharashtra soils. Soils from arid to semi arid and transition zones were richer in their active Mn status compared to laterites. Rainfall was the most potent factor to increase the available Mn. Higher the pH and C.E.C. lesser was the available Mn and vice versa.

Merodio (1972) reported significant correlation for available Mn with pH, decreasing with increasing pH values. The same relation was noticed between reducible Mn and organic matter. The reducible Mn/available Mn ratio increased with increasing pH, available Mn being highest in acid soils.

Mishra and Tripathi (1972) showed an increase in easily reducible forms of Mn in sub surface depths, whereas exchangeable and available Mn showed a reverse trend. Soil pH and organic matter influenced the level of exchangeable, easily reducible and available Mn.

Lakshmanan <u>et al</u> (1972) found that the distribution of water soluble + exchangeable Mn in the alluvial soils of Tanjore district was not uniform in the profile layers. Reducible and active Mn contents were lower in the top layer compared to the second layer. Exchangeable and active Mn were negatively correlated with clay content. Water soluble and exchangeable Mn was positively correlated with organic carbon. Positive correlations were obtained between reducible Mn and loss on ignition and active Mn and C/N ratio.

Agarwal and Reddy (1972) found that all forms of Mn except water soluble decreased with depth and were related to pH. Exchangeable Mn was related to clay and $CaCO_3$ content. Red soils were the richest in water soluble Mn, which decreased with depth and clay content but increased with organic carbon percentage.

Patel et al (1972) found accumulation of water soluble + exchangeable Mn in surface layers and active Mn in middle layers. Organic matter and clay content governed the distribution pattern of water soluble + exchangeable Mn and active Mn respectively. Among the soil characteristics organic matter showed significant positive and pH negative relationship with water soluble and exchangeable Mn whereas the levels of easily reducible and active Mn showed highly significant positive relationship with clay.

Arunachalam and Dhanapalan Mosi (1973) could not find any association for water soluble and exchangeable forms with soil properties.

Borowiec and Glinski (1974) reported highest concentration of Mn near the surface and at the base of the profiles.

MATERIALS AND METHODS

MATERIALS AND METHODS

The soils used in the investigation were collected from the Government and private kayals of the Kuttanad region. Altogether four profiles were selected, two from the Rani kayal (D and G blocks) comprising an area of about 587 acres, one from the Chithira kayal comprising an area of 740 acres and one from the R block private kayal. Profiles were dug and horizons marked and examined for morphological features according to the F.A.O. System. The description and morphological features of the profiles are presented in tables I to IV. Composite soil samples from each horizon were collected using a chromium plated steel sampling implement, thoroughly mixed and put separately in polythese bags and brought to the laboratory for the study.

Laboratory studies

I. Preparation of the samples:

After recording the pH of the fresh soil samples they were air dried on a sheet of paper and during the process of drying the lime shells in the sample were separated. The clods in the dried samples were broken with a wooden mallet, sieved through a 2 m.m plastic sieve and stored in

TABLE 1

SOIL DESCRIPTION

I. Information on the site

(a) Profile number : 1

(b) Soil name : Kuttanad '*Kayal*' (Lacustrine) soil

(c) Higher category classification : Entisol

(d) Date of examination : 15-3-1974

(e) Author : P.K. Gangadhara Menon

(f) Location : Rani kayal, plot D (Alleppey District)

(g) Elevation : 1.5 meters below sea level

(h) Land form

  (i) Physiographic position : Kayal, water logged

  (ii) Surrounding land form : Vembanad lake

  (iii) Microtopography : Flat

(i) Slope : Level

(j) Vegetation : Paddy

(k) Climate : Tropical humid climate with wet and dry periods

  Rainfall : 2700 mm

  Temperature : 70 - 75°F

TABLE 1

(Continued..)

II. General information on the soil

(a)	Parent material	Mixed silty alluvium
(b)	Drainage	Poorly drained
(c)	Moisture condition in profile	Wet
(d)	Depth of ground water	About 100 cm
(e)	Presence of surface stones rock outcrops	Nil
(f)	Evidence of erosion	Nil
(g)	Presence of salt and alkali	Moderate with seasonal fluctuations
(h)	Human influence	Reclaimed from lake. cultivated area

III. Brief description of the profile

Kayal soil containing low amount of organic matter, more in the deeper layers. Colour ranges from dark brown to black. Acidic in reaction. Moderate salinity due to salt water inundation during certain parts of the year. Texture ranges from loam to sandy clay loam.

TABLE 1

(Continued..)

IV. Profile description	1	2	3
(a) Depth	0-25	25-40	40-92
(b) Colist	7.5 YR 3/2 dark brown	10 YR 2/2 Very dark brown	10 YR 2/1 Black
(ii) Dry	10 YR 4/4 Dark yellowish brown	10 YR 4/4 Dark yellowish brown	10 YR 3/2 Very dark greyish brown
Mottlings	Nil	Nil	Nil
Texture	Loam	Sandy clay loam	Silty loam
(e) Structure	Structureless	Structureless	Structureless
(f) Consistence			
(i) Wet	Sticky	Slightly sticky	Non-sticky
(ii) Moist	Firm	Friable	Friable
(iii) Dry	Hard	Hard	Hard
(g) Cutans	Nil	Nil	Nil
(h) Cementation	Weakly cemented	Weakly cemented	Weakly cemente
(i) Pores	Discontinuous	Discontinuous	Discontinuous
(j) Content of rocks & mineral fragments	Nil	Nil	Nil
(k) Content of mineral nodules	Nil	Nil	Nil

TABLE 1

(Continued...)

(l)	Pans	Nil	Nil	Nil
(m)	Carbonates/salts	Lime shells present in all the layers. More in the middle layer		
(n)	Roots	Abundant	None	None
(o)	Boundary	Diffuse, wavy	Diffuse, wavy	Diffuse, wavy
(p)	pH	5.2 Strongly acid	5.6 Medium acid	5.6 Medium acid

TABLE II

SOIL DESCRIPTION

I. Information on the site

(a)	Profile number	: 2
(b)	Soil name	: Kuttanad '<u>Kayal</u>' soil (Lacustrine)
(c)	Higher category classification	: Entisol
(d)	Date of examination	: 15-3-1974
(e)	Author	: P.K.Gangadhara Menon
(f)	Location	: Rani kayal, Plot G (Alleppey District)
(g)	Elevation	: 1.5 meters below sealevel
(h)	Land form	
(i)	Physiographic position	: Kayal, water logged
(ii)	Surrounding land form	: Vembanad lake
(iii)	Microtopography	: Flat
(i)	Slope	: Level
(j)	Vegetation	: Paddy
(k)	Climate	: Tropical humid climate with we and dry periods
	Rainfall	: 2700 mm
	Temperature	: 70 - 75°F

TABLE II

(Continued...)

II. General information on the soil

(a)	Parent material	: Mixed silty alluvium
(b)	Drainage	: Poorly drained
(c)	Moisture condition in profile	: Moist
(d)	Depth of ground water	: About 90 cm
(e)	Presence of surface stones rock outcrops	: No stones and rocks
(f)	Evidence of erosion	: Nil
(g)	Presence of salt and alkali	: Moderate with seasonal fluctuations
(h)	Human influence	: Reclaimed from lake, cultivated area

III. Brief description of the profile

Kayal soil, texture ranging from silty loam to clay loam. Slightly to very stpongly acidic in reaction. Low in organic matter. Cohour ranges from very dark brown to black. Lime shells present in the surface and bottom layers.

TABLE II

(Continued...)

IV. <u>Profile description</u>	1	2	3
(a) Depth in cm	0-20	20-44	44-67
(b) Colour			
(i) Moist	10 YR 2/2 Very dark brown	10 YR 2/1 Black	10 YR 2/1 Black
(ii) Dry	10 YR 4/4 Dark yellowish brown	10 YR 3/4 Dark yellowish brown	10 YR 4/2 Dark greyish brown
(c) Mottlings	Nil	Nil	Nil
(d) Texture	Silty loam	Silty loam	Clay loam
(e) Structure	Structureless	Structureless	Structureless
(f) Consistence			
(i) Wet	Slightly sticky	Slightly sticky	Sticky
(ii) Moist	Firm	Firm	Firm
(iii) Dry	Very hard	Very hard	Very hard
(g) Cutans	Nil	Nil	Nil
(h) Cementation	Weakly cemented	Weakly cemented	Weakly cemented
(i) Pores	Discontinuous	Discontinuous	Discontinuous
(j) Content of rocks & mineral fragments	Nil	Nil	Nil

TABLE II

(Continued..)

(k)	Content of mineral nodules	Nil	Nil	Nil
(l)	Pans	Nil	Nil	Nil
(m)	Carbonates/ salts	Lime shells present	-	Lime shells present in large amount
(n)	Roots	Few	None	None
(o)	Boundary	Gradual, wavy	Diffuse, wavy	Diffuse, wavy
(p)	pH	6.3 Slightly acid	5.0 Very strongly acid	5.0 Very strongly acid

TABLE III

SOIL DESCRIPTION

I. Information on the site

(a) Profile : 3

(b) Soil name : Kuttanad 'Kayal' soil (Locustrine)

(c) Higher category classification : Entisol

(d) Date of examination : 15-3-1975

(e) Author : P.K.Gangadhara Menon

(f) Location : R.Block, Vth Sub block, 1st field (Alleppey district)

(g) Elevation : 1.5 meters below sea level

(h) Land form

(i) Physiographic position : Kayal, water logged

(ii) Surrounding land form : Vembanad lake

(iii) Microtopography : Flat

(i) Slope : Level

(j) Vegetation : Paddy

(k) Climate : Tropical humid climate with wet and dry periods

Rainfall : 2700 mm per annum

Temperature : 70 - 75°F

TABLE III

(Continued...)

II. General information on the soil

(a) Parent material : Mixed silty alluvial

(b) Drainage : Poorly drained

(c) Moisture condition in profile : Wet

(d) Depth of ground water : About 75 cm

(e) Presence of surface stones rock outcrops : Nil

(f) Evidence of erosion : Nil

(g) Presence of salt and alkali : Moderate with seasonal fluctuations

(h) Human influence : Reclaimed from lake. cultivated area

III. Brief description of the profile

Kayal soil. Silty loam to sandy clay loam in texture. Colour ranging from dark brown to black. Slightly sticky in consistency. Lime shells present in all the layers with a higher per cent in the intermediate layers. More of organic matter in the deeper layers. Neutral to strongly acid in reaction. Less of salt water inundation and salinity is comparatively less.

TABLE III

(Continued..)

IV. Profile description

	1	2	3
(a) Depth in cms	0 - 15 cm	15 - 52 cm	52 cm downwards
(b) Colour			
(i) Moist	10 YR 2/2 Very drak brown	7.5 YR 3/2 Dark brown	10 YR, 2/1 Black
(ii) Dry	10 YR 5/4 Yellowish brown	10 YR 4/4 Dark yellowish brown	10 YR 3/2 Very dark greyish brown
(c) Mottlings	Nil	Nil	Nil
(d) Texture	Silty loam	Sandy clay loam	Silty loam
(e) Structure	Structureless	Structureless	Structureless
(f) Consistence			
(i) Wet	Slightly sticky	Slightly sticky	Slightly sticky
(ii) Moist	Firm	Friable	Firm
(iii) Dry	Very hard	Hard	Very hard
(g) Cutans	Nil	Nil	Nil
(h) Cementation	Weakly cemented	Weakly cemented	Weakly cemented
(i) Pores	Discontinuous	Discontinuous	Discontinuous
(j) Content of rocks & mineral fragments	Nil	Nil	Nil

TABLE III

(Continued....)

(k)	Content of mineral nodules	Nil	Nil	Nil
(l)	Pans	Nil	Nil	Nil
(m)	Carbonates/ salts	Lime shells present in all the layers. More in the middle layer		
(n)	Roots	Abundant	Nil	Nil
(o)	Boundary	Gradual, wavy	Diffuse, wavy	Diffuse, wavy
(p)	pH	6.6 Neutral	6.5 Slightly acidic	5.3 Strongly acidic

TABLE IV

SOIL DESCRIPTION

I. Information on the site

(a) Profile number	4
(b) Soil name	Kuttanad 'Kayal' soil (Lacoustrine
(c) Higher category classification	Entisol
(d) Date of examination	15-3-1974
(e) Author	P.K.Gangadhara Menon
(f) Location	Chithira kayal, sub block-1 (Alleppey district)
(g) Elevation	15 meters below sea level
(h) Land form	
(i) Physiographic position	Kayal
(ii) Surrounding land form	Vembanad lake
(iii) Microtopography	Flat
(i) Slope	Level
(j) Vegetation	Paddy
(k) Climate	Tropical humid climate with wet and dry periods
Rainfall	2700 mm per annum
Temperature	70 - 75°F

TABLE IV

(Continued...)

II. General information on the soil

(a) Parent material : Mixed silty alluvium

(b) Drainage : Poorly drainage

(c) Moisture condition in profile : Wet

(d) Depth of ground water : About 65 cm

(e) Presence of surface stones rock outcrops : Nil

(f) Evidence of erosion : Nil

(g) Presence of salt and alkali : Moderate with seasonal fluctuations

(h) Human influence : Reclaimed from lake cultivated area

III. Breif description of the profile

Kayal soil, silty loam to clay in texture. Extremely acidic to neutral in reaction. Very dark brown to black in colour. Moderate salinity due to salt water inundation. Slightly sticky to very sticky in consistency. Low in organic matter with an increasing trend towards the deeper layers.

TABLE IV

(Continued..)

IV. Profile description

	1	2	3	4
(a) Depth in cms	0-12 cm	12-20 cm	20-44 cm	44 cm and below
(b) Col				
(i) Moistu	2.5 Y 3/2 Very dark greyish brown	2.5 Y 3/2 Very dark greyish brown	10 YR 2/2 Very dark brown	10 YR 2/1 Black
(ii) Dry	2.5 Y 4/4 Olive brown	2.5 Y 3/4 Olive brown	10 YR 4/4 Dark yellowish brown	2.5 Y 3/2 Very dark greyish brown
(c) Mottlings	Nil	Nil	Nil	Nil
(d) Texture	Clay	Clay loam	Silty loam	Silty clay loam
(e) Structure	Structureless	Structureless	Structureless	Structureless
(f) Consistence				
(i) Wet	Very sticky	Sticky	Slightly sticky	Sticky
(ii) Moist	Very firm	Firm	Friable	Very firm
(iii) Dry	Extremely hard	Very hard	Hard	Extremely hard

TABLE IV

(Continued...,

(g)	Cutans	Nil	Nil	Nil	Ni
(h)	Cementation	Weakly cemented	Weakly cemented	Weakly cemented	Weakly cemented
(i)	Pores	Disconti-nuous	Disconti-nuous	Disconti-nuous	Disconti-nuous
(j)	Content of rocks & mineral fragments	Nil	Nil	Nil	Nil
(k)	Content of mineral fragments	Nil	Nil	Nil	Nil
(l)	Pans	Nil	Nil	Nil	Nil
(m)	Carbonates/ salts	-	Lime shells present	-	-
(n)	Roots	Few	Nil	Nil	Nil
(o)	Boundary	Diffuse wavy	Diffuse wavy	Difuse wavy	Diffuse wavy
(p)	pH	5.9 Medium acid	7.2 Neutral	3.9 Extremely acidic	2.9 Extremely acidic

stoppered bottles.

II. Determination of physical constants:

(1) Single value constants

A portion of the processed soil samples were sieved through 40 mesh sieve and used for the determination of apparent density, absolute specific gravity, maximum water holding capacity, pore space and volume expansion by Keen Raczkowski method (Keen-Raczkowski, 1921).

(2) Mechanical analysis

The mechanical composition of the soil was determined by the International pipette method described by Piper, (1950).

(3) Moisture

About 5 g air dry soil was put in a clean, dry, weighed silica crucible and the exact weight recorded. It was then dried in an air oven at 105°C to constant weight. The difference in weight was expressed as the percentage moisture on oven dry basis.

III. Determination of chemical constituents:

(1) Soil reaction

The pH of the soil was measured in the fresh sample in 1: 2.5 soil water suspension. The pH of air dry soil was also measured in 1:2.5 soil water suspension and 1:2.5 soil-0.01 M calcium chloride solution using a Photovolt pH Meter.

(2) <u>Electrical conductivity</u>

Soluble salts were determined by measuring the electrical conductivity of 1:2 soil water suspension using solubridge and the results expressed in millimhos/c.m.

(3) <u>Cation exchange capacity</u>

The cation exchange capacity of the soil was determined by the method described by Hanna, 1964.

20 g air dry soil was leached with neutral N ammonium acetate to displace all the cations by ammonium ions. 500 ml of the leachate was collected and set apart for the estimation of 'total exchangeable bases' and 'individual exchangeable cations'. Excess ammonium acetate in the soil was removed by washing with neutral ethanol. The adsorbed ammonium ions were further displaced by leaching with 10 per cent sodium chloride and the leachate distilled with 1 Molar sodium hydroxide in a Kjeldahl distillation unit. The ammonia that distilled over was collected in 4 per cent boric acid containing few drops of mixed indicator (prepared by dissolving 0.5 g bromocresol green and 0.1 g methyl red in 100 ml 95 per cent ethanol and adjusting the solution to

reddish purple with 0.1 N sodium hydroxide). The distillate was titrated against standard HCl and the C.E.C. calculated.

(4) Total exchangeable bases

The method described by Hanna, 1974 was followed in estimating the total exchangeable bases. A 100 ml aliquot from the ammonium acetate leachate set apart under C.E.C. was evaporated to dryness in a tall beaker over a low flame until no more fumes evolved, rotating the beaker for uniform heating on all parts. When there is no more whitening of the residue, the flame was reduced and the contents allowed to cool slowly. 50 ml of standard HCl was added to the beaker scrubbing the sides and bottom of the beaker with a rubber policeman. Rinsed the policeman with a little water into the beaker. The beaker was covered with a watch glass and digested the contents for about an hour over a low flame. Filtered the solution into a conical flask washing with hot water a number of times. The excess HCl was titrated against standard NaOH using methyl red as indicator and the total exchangeable bases calculated.

(5) Organic carbon

Organic carbon was estimated by Walkley and Black's rapid titration method described in Piper, 1950 with the difference that ferrous ammonium sulphate was used instead of ferrous sulphate.

0.5 g of the soil passed through 80 mm sieve was accurately weighed into a 500 ml conical flask and 10 ml of 1 N potassium dichromate and 20 ml conc. H_2SO_4 (96 per cent) added to it. Swirled the flask gently and kept on an asbestos pad for half an hour for the material to digest. The contents were then diluted with 200 ml distilled water and 10 ml of 85 per cent phosphoric acid and 1 ml of diphenyl amine indicator added to it. The excess chromic acid was determined by titrating against standard ferrous ammonium sulphate to a green end point and the percentage of organic carbon calculated. Organic matter was computed by multiplying the organic carbon values with the factor 1.724.

(6) Total nitrogen

Total nitrogen was estimated by the Kjeldahl method described by Jackson, 1967 with the following modifications.

Digestion

1 g powdered soil, passed through 80 mesh sieve was weighed into a dry 100 ml Kjeldahl digestion flask. 5 cc conc. H_2SO_4 and a pinch of digestion mixture were added to it. The contents were digested initially over a low flame until frothing ceased and then at a high temperature for about an hour until the solution became clear (bluish green).

Cooled the contents, diluted with distilled water, swirled and kept aside.

The digestion mixture was prepared by mixing 20 g dried and powdered copper sulphate ($CuSO_4.5\ H_2O$) with 100 g of K_2SO_4 and mixing this with 2 g selenium metal powder in a clean butter paper.

Distillation

The digested material was transferred to a distillation flask (macro distillation unit) with repeated washings and diluted with distilled water. About 40 ml of 45 per cent sodium hydroxide was added and the contents distilled, collecting the distilled ammonia in about 25 ml of 4 per cent boric acid containing 3 to 4 drops of mixed indicator. When about 100 to 150 ml of the distillate was collected it was titrated against standard HCl and the percentage of nitrogen calculated.

(7) Total phosphorus

Preparation of triple acid extract

1 g powdered soil passed through 40 mesh sieve was weighed into a clean dry 50 ml Kjeldahl digestion flask to which 15 ml conc. HNO_3, 3 ml 60 per cent perchloric acid, 2 ml conc. H_2SO_4 and 2 glass beads were added. Digested the contents initially over a low flame until the brown

fumes ceased to evolve after which it was heated strongly so that the HNO3 was evaporated in an hour. Continued heating till white fumes of sulphur trioxide evolved and the digest became clear. Cooled the mass and washed the sides of the flask with distilled water, warmed and filtered into a 100 ml volumetric flask, washed with distilled water and the volume made up (Piper, 1950).

Total phosphorus was estimated by precipitating phosphorus in 50 ml of the triple acid extract as ammonium phosphomolybdate in nitric acid medium. The precipitate was filtered and washed free of acid and dissolved in an excess, known volume of standard NaOH and the excess alkali determined by back titration with standard H_2SO_4 using phenolphthalein as indicator (Method described by Sankaram, 1962).

(8) Analysis of Hydrochloric acid extract

Preparation of the extract

20 g air dry soil was taken in a 500 ml conical flask and 20 ml HCl of constant boiling point (prepared by diluting 675 ml conc.HCl to 1 litre) added to it. The mouth of the flask was covered with a small funnel and the contents digested over a low flame for about an hour and a half. Cooled and filtered the contents through Whatman No.42,

collecting the filtrate in a 500 ml volumetric flask. Transferred the residue to the filter paper and washed with acidulated water followed by boiling water till the filtrate was free of chloride. The filtrate was made up to the mark (Piper, 1950).

The following estimations were done in the extract.

(a) Total potassium

Total potassium was measured in a sample of the extract using EEL flame photometer vide method described in Jackson, 1967.

(b) Total calcium

Elimination of iron and alumina

20 ml of the HCl extract was taken in a 250 ml beaker to which 1 g of ammonium chloride was added and boiled. Added conc. ammonium hydroxide slowly, stirring the contents till it was alkaline as indicated by litmus paper. Allowed the contents to boil for a few minutes to dispel the ammonia and set aside for half an hour for the precipitate to settle down. Filtered hot through Whatman No.3 filter paper. Transferred the residue to the filter with hot water and washed the precipitate till free of chloride. The filtrate was made up to 100 ml for the estimation of Ca and Mg by the Versenate method (Described by Richards, 1954) and the

residue used for the estimation of sesquioxides.

To 20 ml aliquot of the filtrate contained in a 250 ml conical flask, 2 ml 16 per cent NaOH and a pinch of ammonium purpurate indicator powder (prepared by mixing 0.5 g ammonium purpurate and 100 g powdered K_2SO_4) were added and titrated against standard versenate until the solution changed from orange red to violet. From the titre value obtained, total calcium was calculated.

(c) <u>Total magnesium</u>

To 20 ml of the aliquot, 2 ml of ammonium chloride-hydroxide buffer and 4 drops of eriochrome black-T indicator were added and it was titrated against standard versenate until the colour changed from red to blue. From the titre value obtained, total (Ca + Mg) was calculated from which the total calcium estimated under (b) was deducted to get the total Mg.

(d) <u>Total iron</u>

Iron was estimated in an aliquot of the HCl extract by reducing the ferric form to ferrous state with nascent hydrogen, produced by sulphuric acid and zinc using potassium thiocyanate as external indicator. The ferrous iron thus obtained was titrated against standard potassium permanganate (Method described by Sankaram, 1962).

Procedure

Reagents: (1) Potassium permanganate - 0.1 N
(2) Zinc clippings
(3) Potassium thiocyanate - 2 per cent aqueous solution
(4) Conc. sulphuric acid

Evaporated 20 ml of the HCl extract in a porcelain basin. Added 10 ml of concentrated sulphuric acid and heated on a water bath till the whole mass became colourless or whitish. The contents were transferred to a 250 ml conical flask with a jet of water and few zinc clippings added. Covered the mouth of the flask with a funnel and digested over a low flame. More H_2SO_4 was added wherever found necessary testing for the completion of the reduction with potassium thiocyanate as external indicator. Removed the flask from the flame and filtered the contents through glass wool washing with hot water. The filtrate was titrated against 0.1 N potassium permanganate and expressed as percentage of Fe_2O_3 in soil from the relation

$$1 \text{ ml of } 0.1 \text{ N } KMnO_4 = 0.008 \text{ g } Fe_2O_3$$

(9) Sesquioxides

The precipitate obtained under item 8(b) was dried, ignited and weighed and expressed as sesquioxide percentage.

(10) Aluminium oxide

The aluminium oxide present in the soil was calculated by substracting the values of iron oxide from the sesquioxide (A.O.A.C., 1960).

(11) Available phosphorus

Available phosphorus was estimated vide procedure described in Jackson, 1967 using Bray No.2 as the extractant instead of Bray No.1.

Reagents

1. Bray No.2: 0.03 Normal NH4F in 0.1 normal HCl.

2. Ammonium molybdate solution (1.5%) in 3.5 N HCl. 50 gm boric acid ~~were~~ was added to avoid fluoride interference.

3. Stannous chloride: 10 g $SnCl_2.2H_2O$ in 25 ml conc. HCl was prepared and used as the stock solution.

Working solution: 1 ml of the stock solution was diluted with 60 ml distilled water.

Procedure

2 g soil sample was taken in a 250 ml conical flask to which 50 ml of Bray No.2 was added. Shook the

contents well in a shaker for 10 minutes and filtered. 5 ml of this filtrate was taken in a 50 ml volumetric flask to which 10 ml of ammonium molybdate was added. Diluted the contents with about 40 ml distilled water and 6 drops of stannous chloride added to it. The volume was made upto the mark. Shook the contents well and the absorbance read in a Klett Summerson Colorimeter using a red filter. From the standard curve drawn for phosphorus, the percentage of P was calculated.

(12) Exchangeable cations

(a) Potassium

To 5 g of soil contained in a conical flask 25 ml neutral N ammonium acetate was added. Shook the contents for 5 minutes and filtered. Exchangeable K in the filtrate was estimated using EEL Flame photometer.

(b) Sodium

Exchangeable sodium in the above diltrate was also determined in the same way as potassium in EEL Flame photometer using Na filter.

(c) Calcium

Iron and alumina was eliminated (as described under total calcium) in an aliquot of the ammonium acetate leachate set apart for individual cations. Exchangeable calcium was estimated in 20 ml aliquot of the solution by the versenate method described under total calcium.

(d) Magnesium

Calcium and magnesium was also estimated by the versenate method in 20 ml aliquot of the ammonium acetate leachate (after eliminating iron and alumina) as described under 'total magnesium'. By substracting the exchangeable Ca from the (Ca + Mg) value, the exchangeable Mg was obtained and expressed as milli equivalents per 100 g soil.

(e) Exchangeable iron

Exchangeable iron in ammonium acetate extract was determined by reduction to ferrous with Hydroquinone and formation of a ferrous complex of orthophenanthroline, vide procedure described in Jackson (1967) with slight modifications in the reagents used.

10 g soil was weighed into a 250 ml conical flask to which 100 ml of neutral N ammonium acetate was added. Shook for 30 seconds and filtered under suction. Leached with 3 successive 25 ml lots of ammonium acetate and the filtrate made free of ammonium acetate by evaporation. Added 10 ml aqua regia and again evaporated to dryness. The residue was dissolved in 1 ml of 1 N HCl and the volume made upto 100 ml.

2 ml of the above solution was taken in a graduated test tube to which 0.2 ml of 25 per cent sodium citrate was added to adjust the pH above 2.7 (using an aliquot of the sample as well as standard the quantity of sodium citrate required to bring the pH above 2.7 was predetermined, testing with 2,4-dinitrophenol which gives yellow colour above pH 2.7) Diluted the solution in the test tube and added 0.5 ml each of 1 per cent hydroquinone and 0.5 per cent orthophenanthroline aqueous solutions. The volume was made upto 25 ml with distilled water. The intensity of the colour was measured in Spectronic-20 at 508 mu and exchangeable Fe calculated from the standard curve prepared with iron standards in the same way.

(f) <u>Exchangeable hydrogen and aluminium</u>

Exchangeable H and Al was estimated volumetrically by the method described by Yuan (1959).

To 10 g air dry soil contained in a beaker 25 ml Normal potassium chloride was added. Stirred and kept for 30 minutes. Transferred the contents to a funnel fitted with filter paper and filtered. Leached the soil 3 times with 25 ml lots of N KCl and collected the filtrate. To the filtrate 10 drops of 0.1 per cent phenolphthalein was added and titrated against standard NaOH, with alternate stirring and standing until the pink colour persisted.

Added a drop of standard HCl to the solution until the pink colour just vanished. Added 10 ml of 4 per cent sodium fluoride. Reappearance of pink colour showed presence of aluminium. The solution was then titrated, stirring constantly, against standard HCl until the pink colour just vanished even after stirring and standing for few minutes. The milli equivalents of acid used was recorded as the exchangeable Al. Exchangeable hydrogen was obtained by substracting the sum of exchangeable cations from the cation exchange value.

(13) Micronutrients

Estimation of available Zn, Cu, Fe and Mn were done in Atomic absorption Spectrophotometer (Varian threshold A.A.120).

(a) Available Zn

The soil was extracted with a solution of 0.01 per cent dithizone in CCl_4 and neutral ammonium acetate, with soil to solution ratio of 1:10 and shaking the mixture for one hour, in a platform shaker. The extracted zinc was then converted into HCl phase with Normal HCl and the extend of absorption measured using the resonance-line 2139 A°.

(b) Available copper

The soil was extracted with neutral N ammonium acetate shaking for one hour and maintaining a soil:solution ratio of 1:2 and the extracted copper estimated using the resonance line 3247 A°.

(c) Available iron

Extraction was done by shaking with N ammonium acetate of pH 4.8 for 30 minutes maintaining a soil:solution ratio of 1:4 and iron in the extract determined using the resonance line 2483 A°.

(d) Available manganese

The soil was extracted by shaking with neutral N ammonium acetate for 10 hours and maintaining a soil: solution ratio of 1:25 and manganese in the extract determined using the resonance line 2483 A°.

RESULTS

RESULTS

A. Physical characteristics

1. Mechanical composition

The data on the mechanical composition of the soil samples are presented in table V. The texture of the soil varied from loam to sandy clay loam, silty loam to clay loam, silty loam to sandy clay loam and silty loam to clay in profiles 1 to 4 respectively. A steady trend in the distribution of the clay content was noticed only in the Rani kayal profiles (No.1 and 2) which registered decreasing and increasing values respectively with increase in profile depth. The clay content ranged between 6.8 and 22.7, 12.2 and 22.0, 5.0 and 19.05 and 15.6 and 36.5 per cent for profiles 1 to 4 respectively. The subsurface layer of R block profile (No.3) and the surface layer of Chithira kayal profile (No.4) recorded the minimum and maximum values of 5.0 and 36.5 per cent respectively.

With regard to silt content profile 2 showed a steady decreasing trend with profile depth whereas the other 3 profiles did not show a regular distribution pattern. The values ranged between 1.68 and 35.4, 23.5 and 37.5, 1.9 and 33.5 and 7.5 and 33.8 per cent for the profiles 1 to 4 respectively. The lowest and highest values were recorded in the intermediate and surface layers of profiles 1 and 2 respectively.

Fine sand showed an increasing trend with increase in depth in profile 2 whereas the other 3 profiles did not show any regular trend. The values varied from 53.04 to 75.91, 43.70 to 49.42, 53.40 to 72.78 and 41.13 to 59.86 respectively.

Coarse sand did not show a regular trend in any of the profiles studied. The values varied from 0.78 to 1.34, 0.42 to 0.78, 0.29 to 1.68 and 0.58 to 2.55 per cent respectively.

2. Single value constants

The single value constants of the soil samples studied are presented in table VI.

(a) Absolute specific gravity

A steady decrease in the absolute specific gravity was noticed in profiles 1 and 3. In the other two profiles also the trend was for a decrease with increase in depth. The values ranged between 2.03 and 2.21, 2.00 and 2.03, 1.97 and 2.31 and 1.90 and 2.18 respectively.

(b) Apparent density

Apparent density also showed a decreasing trend

MECHANICAL COMPOSITION OF SOIL AS A FUNCTION OF DEPTH

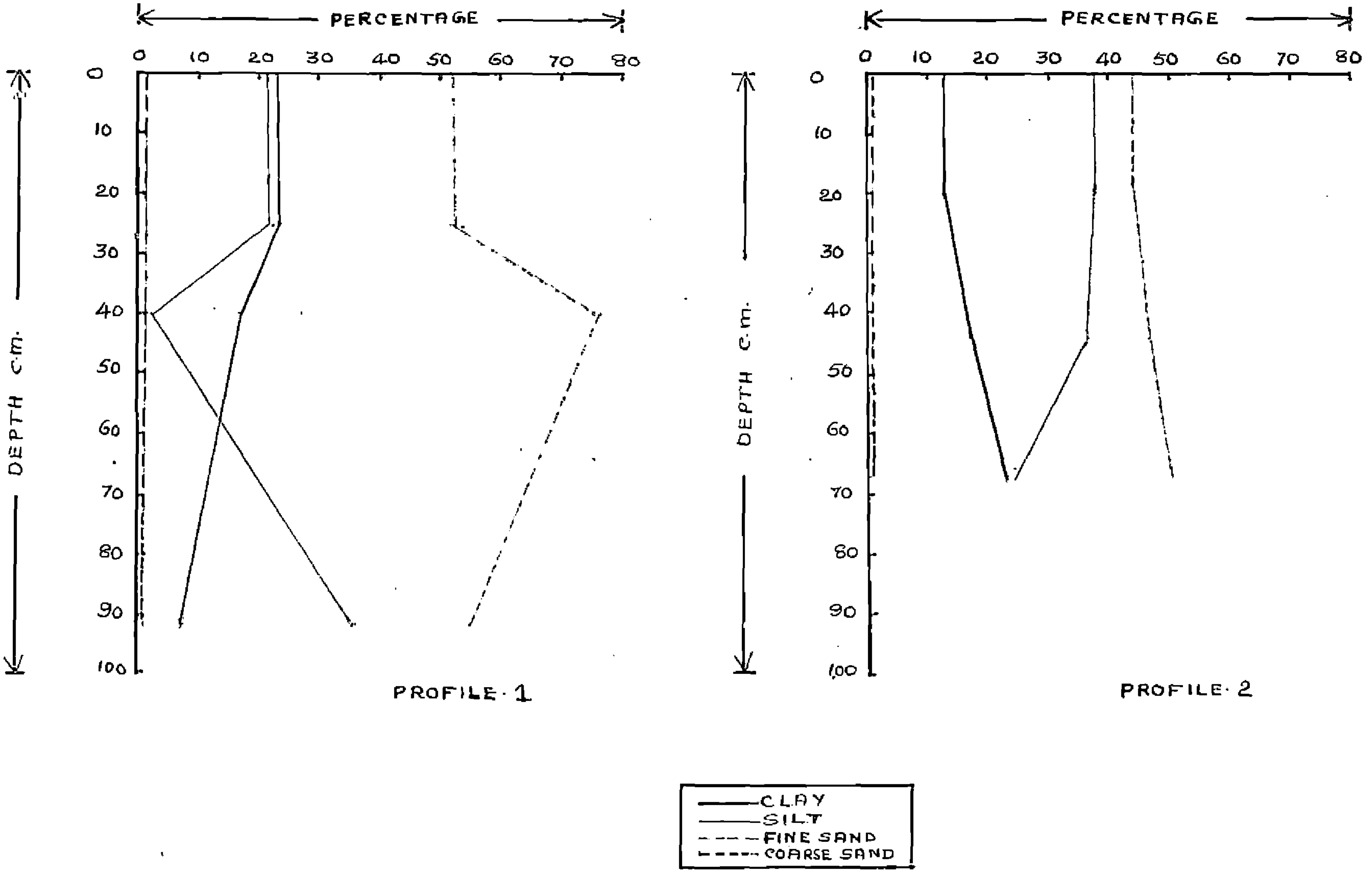


FIG. 1a

MECHANICAL COMPOSITION OF SOIL AS A FUNCTION OF DEPTH

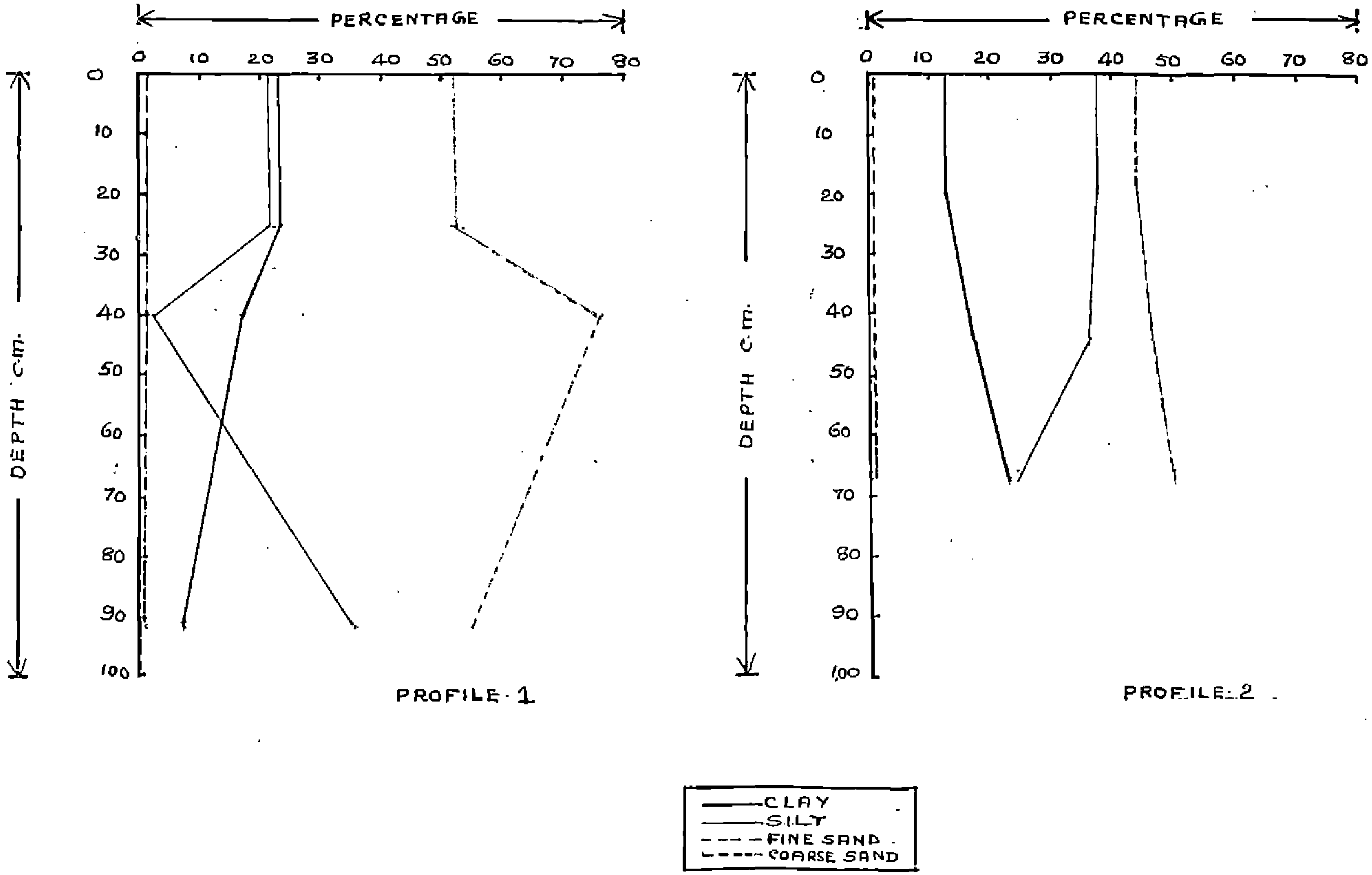
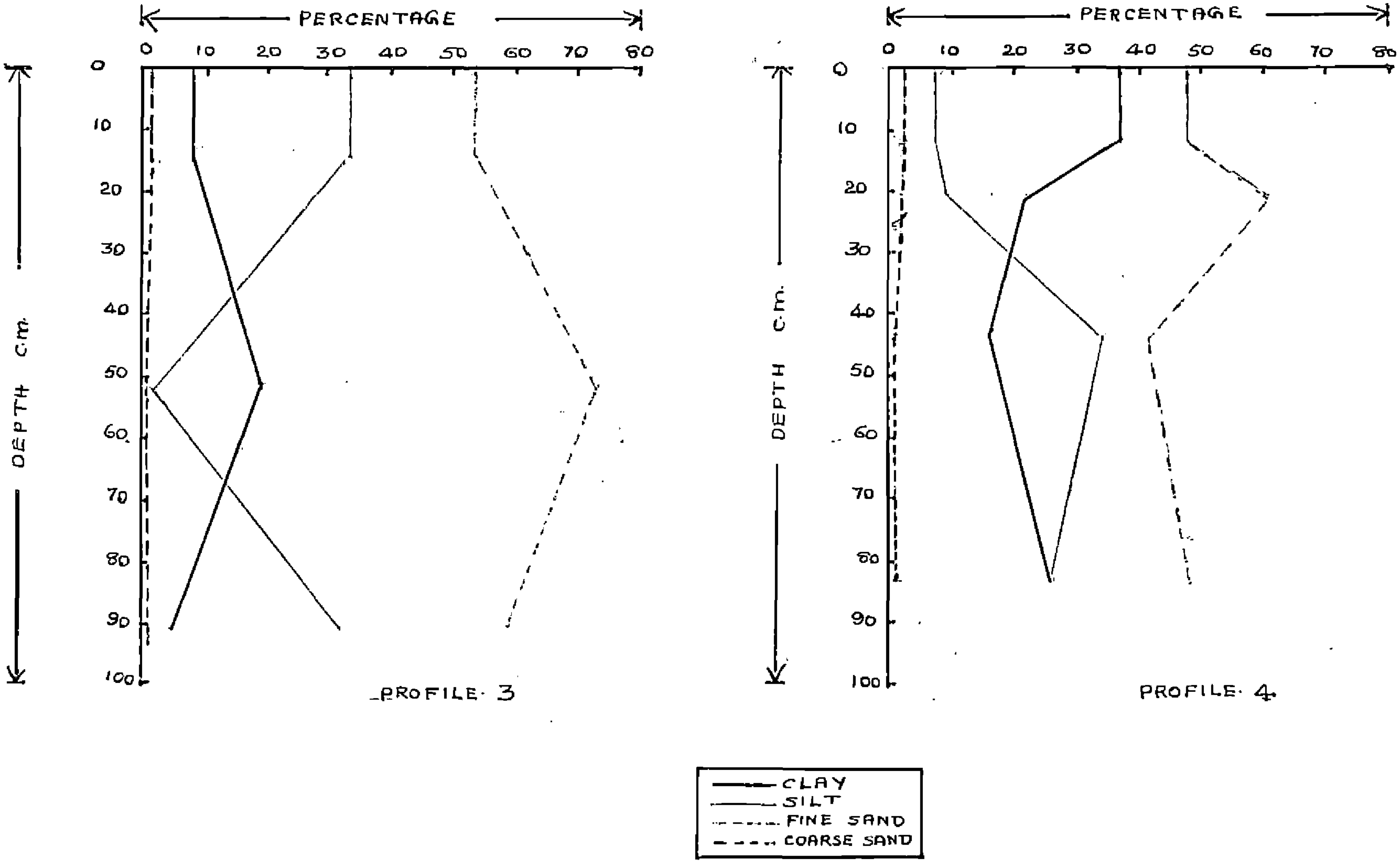


FIG. 1a

MECHANICAL COMPOSITION OF SOIL AS A FUNCTION OF DEPTH



PROFILE 3

PROFILE 4

FIG 1b

with increase in depth with values varying from 0.96 to 1.12, 0.90 to 1.00, 0.94 to 1.30 and 0.91 to 1.15 respectively for the 4 profiles.

(c) Pore space

Pore space increased with increase in profile depth in the 2nd profile. The other 3 profiles did not show a steady increase with depth though an increasing trend was observed. The values varied from 53.99 to 58.30, 55.10 to 59.07, 47.30 to 58.12 and 50.51 to 57.02 respectively.

(d) Maximum water holding capacity

With increase in profile depth an increase in maximum water holding capacity was recorded in profile 3 only. The values for the 4 profiles ranged between 51.94 and 68.27, 56.62 and 66.37, 36.79 and 66.1 and 48.14 and 68.14 respectively.

(e) Volume expansion

The values for volume expansion varied from 9.81 to 13.08, 10.61 to 13.34, 5.98 to 11.79 and 7.52 to 11.92 for profiles 1 to 4 respectively. It increased with increase in depth in profile 2 while no steady trend was noticed in the other 3 profiles.

3. Moisture

The moisture percentage of each sample expressed

TABLE VI

SINGLE VALUE CONSTANTS AND MOISTURE (Oven dry basis)

Sample No.	Location	Profile No.	Depth cm	Absolute specific gravity	Apparent density	Pore space %	Maximum water holding capacity %	Volume expansion %	Moisture %
1.	Rani kayal Plot, D	1	0-25	2.21	1.12	53.99	51.94	10.14	5.19
2.	,,		25-40	2.05	0.96	58.30	68.27	13.08	7.52
3.	,,		40-92	2.03	0.96	57.39	63.73	9.81	7.08
4.	Rani kayal Plot, G	2	0-20	2.02	1.00	55.10	62.35	10.61	6.51
5.	,,		20-44	2.03	1.00	58.64	56.62	10.84	8.38
6.	,,		44-67	2.00	0.90	59.07	66.37	13.34	7.96
7.	R Block kayal	3	0-15	2.31	1.30	47.30	36.79	5.98	3.83
8.	,,		15-22	2.09	1.00	58.12	61.84	11.79	5.94
9.	,,		22 and below	1.97	0.94	55.58	66.10	10.36	6.16
10.	Chithira kayal	4	0-12	2.08	1.07	51.65	52.04	7.52	4.77
11.	,,		12-20	2.18	1.15	50.51	48.14	7.93	3.42
12.	,,		20-44	1.90	0.98	54.96	59.09	11.92	1.93
13.	,,		44 and below	1.92	0.91	57.02	68.14	10.65	7.79

on oven dry basis are given in table VI. The values varied from 5.19 to 7.52, 6.51 to 8.38, 3.83 to 6.16 and 1.93 to 7.79 per cent respectively.

B. Chemical constituents

The chemical characteristics of the soil samples are presented in tables VII to XIV.

1. Soil reaction

The data pertaining to pH of fresh and air dry soil samples in water as well as 0.01 M $CaCl_2$ are presented in table VII.

Fresh sample in 1:2.5 soil water suspension registered a pH varying from 5.1 to 5.7, 5.0 to 6.3, 5.3 to 6.6 and 3.7 to 7.2 for the 4 profiles. There was a decrease in pH with increase in depth in profiles 2, 3 and 4 whereas profile 1 showed a reverse trend. On air drying, a decrease in pH was noticed only in the case of subsurface samples whereas the surface samples showed an increase. The pH values for dry soil varied from 3.7 to 6.8, 3.4 to 6.6, 2.9 to 6.7 and 2.9 to 6.7 respectively. In 0.01 M $CaCl_2$ the samples did not show a decrease in pH, the values varying from 3.8 to 6.9, 3.6 to 6.2, 3.2 to 6.5 and 3.1 to 6.3 for profiles 1 to 4 respectively. In all cases the general trend is for the pH to decrease with increase in depth.

TABLE VII

SOIL REACTION AND CONDUCTIVITY

Sample No.	Location	Profile No.	Depth cm	pH			Conductivity m.mhos/cm
				Wet soil 1:2.5 soil-water	Dry soil 1:2.5 soil-water	Dry soil 1:2.5 soil-$CaCl_2$	
1.	Rani kayal Plot, D	1	0-25	5.1	6.8	6.9	1.7
2.	,,		25-40	5.6	6.3	6.8	1.8
3.	,,		40-92	5.7	3.7	3.9	3.0
4.	,, Plot, G	2	0-20	6.3	6.6	6.2	1.2
5.	,,		20-44	5.0	3.4	3.6	2.9
6.	,,		44-67	5.0	4.8	4.9	3.2
7.	R. Block kayal	3	0-15	6.6	6.7	6.2	0.7
8.	,,		15-52	6.5	6.5	6.5	1.2
9.	,,		52 and below	5.3	2.9	3.2	1.5
10.	Chithira kayal	4	0-12	5.9	5.3	4.9	0.65
11.	,,		12-20	7.2	6.7	6.3	0.66
12.	,,		20-44	3.9	3.9	4.3	1.60
13.	,,		44 and below	3.7	2.9	3.1	3.95

2. Conductivity

The values of electrical conductivity in, 1:2 soil water suspension showed a steady increase with profile depth. The values varied from 1.7 to 3.0, 1.2 to 3.2, 0.7 to 1.5 and 0.65 to 3.95 for the 4 profiles. The data are presented in table VII.

3. Organic carbon

An increase in organic carbon was noticed with increase in depth in all the profiles. The values varied from 1.43 to 3.09, 1.9 to 3.98, 1.14 to 3.84 and 0.86 to 3.58 in profiles 1 to 4 respectively.

4. Total nitrogen

Not much variation was noticed in the total nitrogen content between profiles and between layers in the same profile. An increase in the nitrogen content with increase in depth was noticed in profiles 2 and 4 whereas profile 3 showed a decreasing trend. The values ranged between 0.19 and 0.24, 0.21 and 0.26, 0.17 and 0.20 and 0.11 and 0.25 per cent for the 4 profiles.

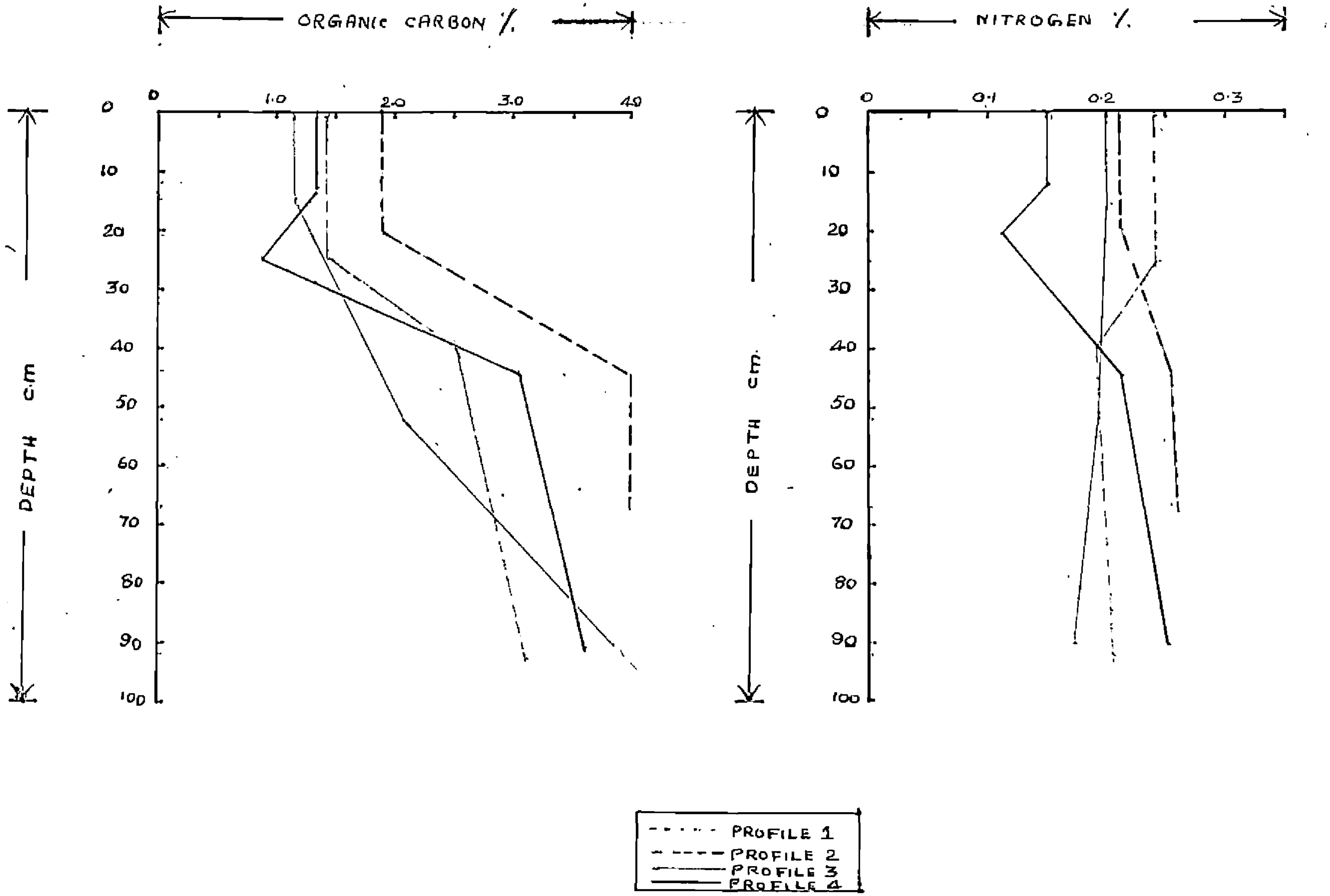
5. C/N ratio

There was a steady increase in the C/N ratio with increase in depth in all the profiles. A maximum value of 22.59 was noticed in the subsurface layer of the R block

TABLE VIII

ORGANIC CARBON, TOTAL NITROGEN AND C/N RATIO
(Oven dry basis)

Sample No.	Location	Profile No.	Depth cm	Organic carbon %	Total nitrogen %	C/N ratio	Organic matter %
1.	Rani kayal Plot, D	1	0-25	1.43	0.24	5.96	2.46
2.	,,		25-40	2.52	0.19	13.26	4.34
3.	,,		40-92	3.09	0.22	14.04	5.33
4.	Rani kayal Plot, G	2	0-20	1.90	0.21	9.05	3.27
5.	,,		20-44	3.98	0.25	15.92	6.86
6.	,,		44-67	3.98	0.26	15.92	6.86
7.	R. Block kayal	3	0-15	1.14	0.20	5.70	1.96
8.	,,		15-52	2.07	0.19	10.89	3.57
9.	,,		52 and below	3.84	0.17	22.59	6.62
10.	Chithira kayal	4	0-12	1.35	0.15	9.00	2.33
11.	,,		12-20	0.86	0.11	7.82	1.48
12.	,,		20-44	3.04	0.21	14.48	5.24
13.	,,		44 and below	3.58	0.25	14.32	6.17



VARIATION IN ORGANIC CARBON AND NITROGEN AS A FUNCTION OF DEPTH

FIG. 2

profile (profile 3). The values ranged between 22.59 and 5.7. The wide range of variations in the C/N ratio was more due to the difference in organic carbon rather than in nitrogen.

6. <u>Total phosphorus</u>

Total phosphorus showed a decreasing trend with increase in depth. The values varied from 0.04 - 0.08 per cent P on oven dry basis.

7. <u>Total potassium</u>

An increase in potassium was noticed with increase in depth, the values ranging between 0.11 and 0.38 per cent K.

8. <u>Total calcium</u>

The behaviour of calcium was erratic except in the 4th profile where it showed an increasing trend with increase in depth. The intermediate layers of the profiles 1 and 3 recorded comparatively higher values of 2.21 and 2.22 respectively for calcium probably due to the presence of high content of lime shells (53.7 and 58.3 per cent). The calcium content in the profiles ranged between 0.28 and 2.22 per cent Ca.

9. <u>Total magnesium</u>

Magnesium in general showed an increasing trend with increase in depth. The values ranged between 0.11 and 0.44 per cent Mg.

10. Available phosphorus

When the total phosphorus showed a decreasing trend with increase in depth, available phosphorus did not show any regular distribution pattern. Intermediate layers showed comparatively less phosphorus content. The values varied from 34.0 to 44.0, 60.0 to 80.0, 54.0 to 74.0 and 44.0 to 88.0 kg P/ha.

11. Sesquioxides

The surface layer of the R block profile (profile 3) recorded the highest sesquioxide value of 22.74 per cent and the subsurface layer (3rd layer) of the Chithira kayal profile recorded the lowest sesquioxide content with 3.82 per cent. The sesquioxide per cent for the different profiles ranged between 12.73 and 21.6, 16.21 and 16.45, 17.22 and 22.74 and 3.82 and 21.76 per cent respectively for the profiles 1 to 4.

12. Iron oxide

Fe_2O_3 content in the different horizons varied from 1.09 in the subsurface horizon (3rd layer) of the Chithira kayal profile to 10.84 per cent in the surface horizon of the R block profile. The values for the various horizons ranged between 2.53 and 6.98, 7.57 and 9.94, 5.4 and 10.84 and 1.09 and 9.31 for the profiles 1 to 4 respectively.

TABLE IX

AVAILABLE AND TOTAL P, TOTAL K, Ca AND Mg

Sample No.	Location	Profile No.	Depth cm	Available phosphorus as P in kg/ha	Total nutrients % on oven dry basis			
					P	K	Ca	Mg
1.	Rani kayal Plot,D	1	0-25	44.0	0.06	0.24	0.56	0.07
2.	,,		25-40	34.0	0.05	0.29	2.21	0.07
3.	,,		40-92	40.0	0.04	0.38	0.75	0.31
4.	Rani kayal Plot,G	2	0-20	76.0	0.06	0.28	0.95	0.11
5.	,,		20-44	60.0	0.06	0.34	0.99	0.23
6.	,,		44-67	80.0	0.06	0.36	0.58	0.37
7.	R Block kayal	3	0-15	74.0	0.07	0.11	0.28	0.05
8.	,,		15-52	54.0	0.05	0.21	2.22	0.06
9.	,,		52 and below	56.0	0.04	0.29	0.83	0.28
10.	Chithira kayal	4	0-12	88.0	0.03	0.19	0.28	0.08
11.	,,		12-20	44.0	0.04	0.12	0.37	0.17
12.	,,		20-44	62.0	0.07	0.21	0.41	0.22
13.	,,		44 and below	81.0	0.06	0.36	0.48	0.44

13. Aluminium oxide

The intermediate horizon of Rani kayal profile (No.1) recorded the maximum of 14.62 per cent and the subsurface layer (3rd horizon) of the Chithira kayal profile recorded the minimum of 2.73 per cent of Al_2O_3. The range of values for the various profiles are 10.2 to 14.62, 6.51 to 8.64, 10.45 to 13.15 and 2.73 to 12.45 respectively.

14. Cation exchange capacity and exchangeable cations

Data on the cation exchange capacity (C.E.C.) and exchangeable cations are presented in table XI. The relative proportion of individual exchangeable bases to total exchangeable bases are given in table XII.

(a) Cation exchange capacity

The C.E.C. of the samples varied from a minimum value of 9.92 me/100 g soil for clay loam to 19.3 me/100 g soil in the case of silty loam. C.E.C. was found to be influenced more by the organic matter content rather than by the mechanical composition of the soil. The values for C.E.C. did not show any trend either to decrease or increase with profile depth.

(b) Exchangeable cations

1. Sodium

A fairly high value for exchangeable sodium was

TABLE X

SESQUIOXIDES, Fe_2O_3 AND Al_2O_3

(Oven dry basis)

Sample No.	Location	Profile No.	Depth cm	Sesquioxide %	Fe_2O_3 %	Al_2O_3 %
1.	Rani kayal Plot, D	1	0-25	12.73	2.53	10.20
2.	,,		25-40	21.60	6.98	14.62
3.	,,		40-92	18.63	5.85	12.78
4.	Rani kayal Plot, G	2	0-20	16.45	9.94	6.51
5.	,,		20-44	16.21	7.57	8.64
6.	,,		44-67	16.35	7.93	8.42
7.	R Block kayal	3	0-15	22.74	10.84	11.90
8.	,,		15-52	17.22	6.77	10.45
9.	,,		52 and below	18.55	5.40	13.15
10.	Chithira kayal	4	0-12	11.29	4.76	6.53
11.	,,		12-20	21.76	9.31	12.45
12.	,,		20-44	3.82	1.09	2.73
13.	,,		44 and below	15.39	6.28	9.11

recorded in all the profiles. When profile 1 showed an increasing trend with increase in depth reverse was the case for profile 4. Profiles 2 and 3 did not show a steady trend with depth of profile. The range of variation for exchangeable Na in the different horizons of the 4 profiles are 1.96 to 4.98, 0.74 to 1.44, 0.15 to 1.44 and 0.13 to 1.65 with a mean of 3.11, 1.2, 0.87 and 0.68 me/100 g soil. The relative proportion of exchangeable Na to total exchangeable bases (Na + Ca + Mg + K) varied from 14.3 to 32.2 per cent, 4.4 to 9.8 per cent, 1.3 to 11.9 per cent and 0.9 to 16.4 per cent with a mean value of 22.4, 7.7, 7.4 and 6.7 per cent respectively for the p 4 profiles.

2. Potassium

The exchangeable potassium content in the profiles are generally low ranging between 0.06 and 1.06, 0.4 and 0.90, 0.04 and 0.43 and 0.07 and 1.02 with a mean value of 0.67, 0.68, 0.28 and 0.59 me/100 g soil for the 4 profiles. In profile 2 the exchangeable potassium showed a decreasing trend with increase in depth whereas in the other 3 profiles no relation with depth was noticed. Profile 1 showed an accumulation in the intermediate layer. The relative proportion of exchangeable K to total exchangeable bases varied from 0.4 to 9.2, 2.8 to 5.7, 0.4 to 3.6 and 0.4 to 9.5 per cent with a mean of 5.36, 4.3, 2.39 and 5.68 per cent respectively for profiles 1 to 4.

3. Calcium

The exchangeable calcium varied from 5.6 to 6.81, 6.23 to 10.23, 8.91 to 9.12 and 6.71 to 7.23 with a mean of 6.48, 8.86, 9.01 and 6.99 me/100 g soil for the 4 profiles. Of all the cations, calcium occupied major portion of the exchange complex, the proportion of exchangeable Ca to total exchangeable bases ranging between 36.2 and 61.2, 43.1 and 64.0, 75.4 and 80.3 and 45.2 and 75.2 with a mean of 49.1, 55.7, 78.4 and 62.9 per cent respectively for the 4 profiles. The distribution was more or less uniform in all the layers of profiles 1, 3 and 4. Profile 2 showed a decreasing trend with increase in depth.

4. Magnesium

Exchangeable magnesium showed an increasing trend with increase in depth in profiles 2, 3 and 4. The range of variation in the different profiles are 1.01 to 4.81, 3.42 to 6.41, 0.92 to 2.01 and 0.92 to 8.41 with a mean of 3.27, 5.04, 1.34 and 3.26 me/100 g soil respectively for the 4 profiles. The relative proportion of exchangeble Mg to total exchangeable bases varied between 8.8 and 31.1, 21.4 and 44.3, 8.2 and 17.9 and 9.1 and 53.4 per cent with a mean of 23.1, 32.4, 11.7 and 24.6 per cent respectively.

5. Hydrogen

The exchangeable hydrogen varied from 0.4 to 1.26, 0.33 to 2.51, 0.4 to 2.09 and 0.03 to 3.2 with a mean of 0.79, 1.47, 0.97 and 1.46 me/100 g soil for the profiles 1 to 4 respectively. A regular trend in the distribution of exchangeable hydrogen was noticed in all the profiles. While the values increased with increase in depth in profiles 2, 3 and 4 the reverse was the case in profile 1.

6. Aluminium

Exchangeable aluminium was present only in the subsurface layers of the profiles. The values ranged between 0.12 and 0.73 me/100 g soil.

7. Iron

The values for exchangeable iron varied from 0.02to 1.21 me/100 g soil. No steady increase or decrease with profile depth was noticed in any of the 4 profiles studied.

8. Total exchangeable bases

Exchangeable K, Ca and Mg expressed as percentage of total K, Ca and Mg are given in table XII.

Total K in the soil varied from 6.15 to 9.74, 7.18 to 9.23, 2.82 to 7.43 and 3.08 to 9.23 me/100 g soil in profiles 1 to 4 with mean values of 7.77, 8.38, 5.26 and 5.68 me/100 g soil respectively. It is seen that the percentage

TABLE XI

CATION EXCHANGE CAPACITY (C.E.C.) AND EXCHANGEABLE CATIONS (Oven dry basis)

Sample No.	Location	Profile No.	Depth cm	Exchangeable cations - me/100 g							Total exchangeable metal cations determined (me/100 g)	C.E.C me/100 g
				Na	K	Ca	Mg	Fe	Al	H (by difference)		
1.	Rani kayal Plot, D	1	0-25	1.96	0.89	6.81	4.00	0.30	--	1.26	14.23	15.22
2.	,,		25-40	2.38	1.06	7.02	1.01	0.72	--	0.72	12.81	12.91
3.	,,		40-92	4.98	0.06	5.60	4.81	0.55	0.43	0.40	16.53	16.83
4.	Rani kayal Plot, G	2	0-20	1.44	0.90	10.23	3.42	0.10	--	0.35	16.03	16.42
5.	,,		20-44	0.74	0.73	10.11	5.30	0.34	0.52	1.56	17.90	19.30
6.	,,		44-67	1.42	0.40	6.23	6.41	0.02	0.13	2.51	15.10	17.12
7.	R Block kayal	3	0-15	1.02	0.36	8.91	0.92	0.13	--	0.40	12.13	11.74
8.	,,		15-52	1.44	0.43	9.12	1.10	0.29	--	0.43	13.10	12.81
9.	,,		52 and below	0.15	0.04	9.00	2.01	1.21	0.73	2.09	12.81	15.23
10.	Chithira kayal	4	0-12	1.65	0.79	6.71	0.92	0.21	--	0.03	10.94	10.31
11.	,,		12-20	0.80	0.48	7.23	1.11	0.06	--	0.24	10.21	9.92
12.	,,		20-44	0.13	1.02	6.91	2.61	0.05	0.12	2.36	11.34	13.20
13.	,,		44 and below	0.14	0.07	7.12	8.41	0.08	0.21	3.20	16.82	19.23

of exchangeable K to total K ranged between 0.62 and 14.3, 4.3 and 12.5, 0.5 and 12.8 and 0.8 and 18.4 with mean values of 5.41, 8.4, 7.05 and 12.75 per cent respectively.

Total Ca varied from 28.0 to 110.5, 29.0 to 49.5, 14.0 to 111.0 and 14.0 to 24.0 me/100 g soil in profiles 1 to 4 with a mean of 58.7, 42.0, 55.5 and 19.2 respectively. The percentage of exchangeable Ca to total Ca ranged between 6.3 and 24.3, 20.4 and 21.5, 8.2 and 63.6 and 4.8 and 39.1 per cent with mean values of 15.2, 21.1, 31.2 and 26.8 per cent respectively.

Total Mg varied from 5.76 to 25.5, 9.05 to 30.43, 4.11 to 23.03 and 6.58 to 36.18 me/100 g soil for profiles 1 to 4, with a mean of 12.74, 19.46, 10.69, 18.71 respectively. Exchangeable Mg constituted 17.5 to 69.4, 21.1 to 37.8, 8.7 to 22.4 and 7.9 to 23.2 per cent of total Mg with mean values of 35.3, 29.00, 17.8 and 14.8 per cent respectively.

9. Percentage saturation of bases and other cations

The percentage base saturation and the percentage saturation of individual cations are given in table XIII. Percentage base saturation varied from 73.5 to 97.7 per cent. The percentage saturation of Na ranged from 0.3 to 29.6, K from 0.3 to 8.2, Ca from 33.3 to 75.9, Mg from 7.8 to 43.7 Fe from 0.4 to 7.9, Al from 0.8 to 4.8 and H from 0.3 to 17.9 per cent.

TABLE XIII

PERCENTAGE SATURATION OF BASES AND OTHER CATIONS

Sample No.	Location	Profile No.	Depth cm	Total exchangeable bases (Na,K, Ca,Mg) me/100 g soil (a)	C.E.C. me/100 g soil (b)	Percentage base saturation a/b x 100	Percentage saturation of individual cations							
							Na	K	Ca	Mg	Fe	Al	H	pH
1.	Rani kayal Plot, D	1	0-25	13.66	15.22	89.7	12.9	5.8	44.7	26.3	2.0		8.3	5.1
2.	,,		25-40	11.47	12.91	88.8	18.4	8.2	54.4	7.8	5.6	-	5.6	5.6
3.	,,		40-92	15.45	16.83	91.8	29.6	0.4	33.3	28.6	3.3	2.5	2.4	5.7
4.	Rani kayal Plot, G	2	0-20	15.99	16.42	97.3	8.8	5.4	62.3	20.8	0.6	-	2.0	6.3
5.	,,		20-44	16.88	19.30	87.5	3.8	3.8	52.4	27.5	1.8	2.7	8.1	5.0
6.	,,		44-67	14.46	17.12	84.5	2.3	2.3	36.4	37.4	0.1	0.8	14.7	5.0
7.	R Block kayal	3	0-15	11.21	11.74	95.5	3.1	3.1	75.9	7.8	1.1	-	3.4	6.6
8.	,,		15-52	12.09	12.81	94.4	3.4	3.4	71.2	8.6	2.1	-	3.3	6.5
9.	,,		52 and below	11.20	15.23	73.5	0.3	0.3	59.1	13.2	7.9	4.8	13.7	5.3
10.	Chithira kayal	4	0-12	10.07	10.31	97.7	7.7	7.7	65.1	8.9	2.0	-	0.3	5.9
11.	,,		12-20	9.62	9.92	97.0	4.8	4.8	72.9	11.2	0.6	-	2.4	7.2
12.	,,		20-44	10.67	13.20	80.8	7.7	7.7	52.3	19.8	0.4	0.9	17.9	3.9
13.	,,		44 and below	15.74	19.23	81.9	0.4	0.4	37.0	43.7	0.4	1.1	16.6	3.7

Micronutrients (Available Zn, Cu, Fe and Mn)

In general the availability of Zn, Fe, Cu and Mn was more in the lower layers of the profiles. Available copper did not show as much variation between horizons and profiles as in the case of Zn, Fe and Mn. The data are presented in table XIV.

Zinc

Availability of zinc was more in the lower most layer, the values ranging between 0.0 and 6.2, 0.0 and 5.5, 0.3 and 9.0 and 0.2 and 7.2 ppm for profiles 1 to 4 with mean values of 2.2, 3.5, 3.4 and 2.0 ppm respectively. There was a general increase for available zinc with increase in profile depth.

Copper

Available copper varied from 0.16 to 0.26, 0.2 to 0.4, 0.14 to 0.26 and 0.12 to 0.16 ppm with a mean of 0.19, 0.31, 0.21 and 0.15 ppm respectively for profiles 1 to 4. There was more or less a uniform distribution of copper in all the profiles in the different layers.

Iron

Available iron ranged between 8.0 and 520.0, 12.0 and 704.0, 6.0 and 210.0 and 2.0 and 162.0 ppm with a mean of 180.7, 293.3, 76.7 and 70.3 ppm in profiles 1 to 4.

TABLE XIV

MICRONUTRIENTS (AVAILABLE Zn, Cu, Fe and Mn)

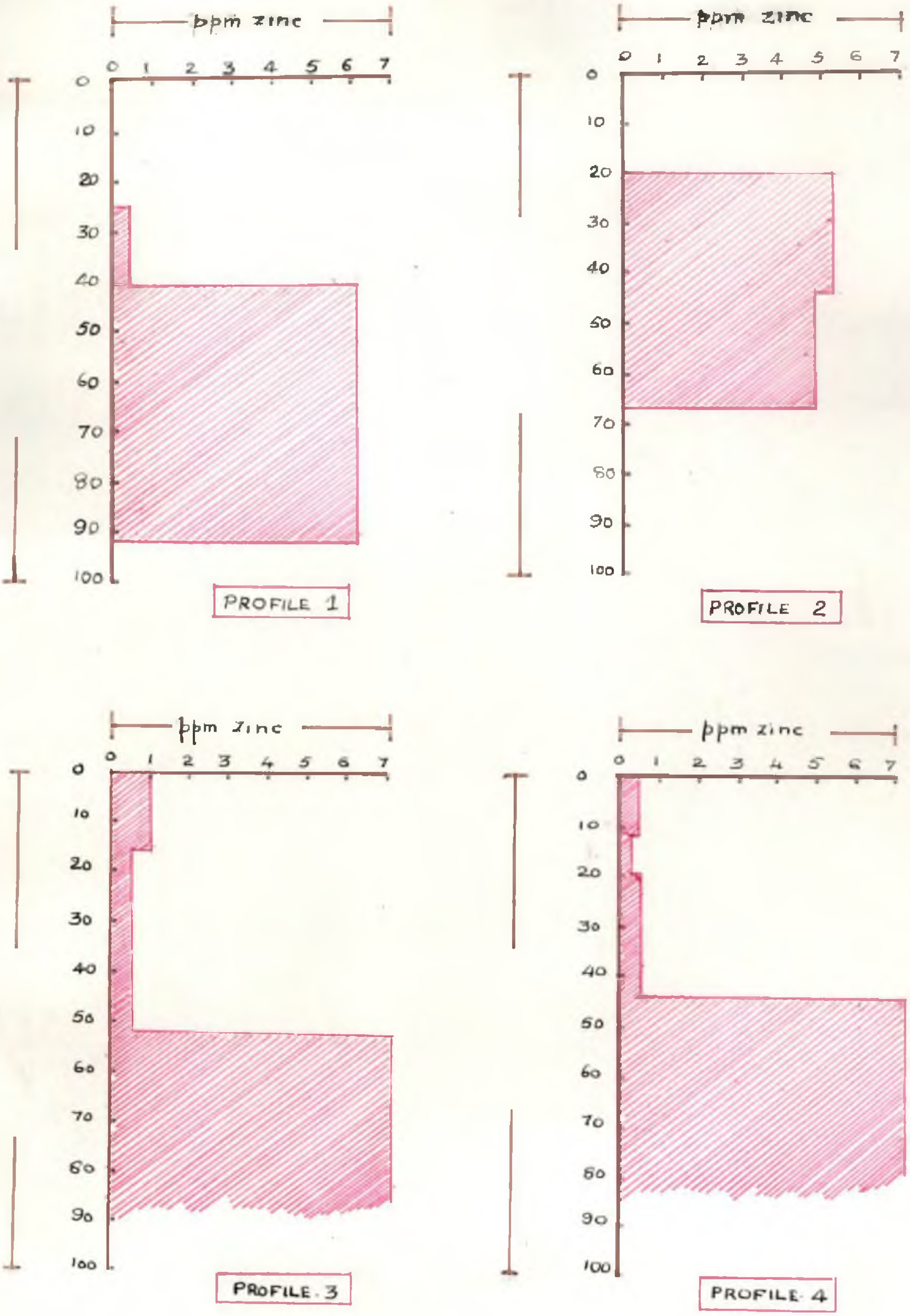
Sample No.	Location	Profile No.	Depth cm	Zn ppm	Cu ppm	Fe ppm	Mn ppm
1.	Rani kayal Plot, D	1	0-25	0.0	0.16	14.0	7.0
2.	,,		25-40	0.3	0.16	8.0	20.0
3.	,,		40-92	6.2	0.26	520.0	110.0
4.	Rani kayal Plot, (	2	0-20	0.0	0.20	12.0	7.5
5.	,,		20-44	5.5	0.40	164.0	80.0
6.	,,		44-67	5.0	0.32	704.0	105.0
7.	R Block kayal	3	0-15	1.0	0.26	6.0	5.0
8.	,,		15-52	0.3	0.14	14.0	20.0
9.	,,		52 and below	9.0	0.22	210.0	108.0
10.	Chithira kayal	4	0-12	0.3	0.16	6.0	10.0
11.	,,		12-20	0.2	0.16	2.0	11.0
12.	,,		20-44	0.4	0.12	111.3	21.0
13.	,,		44 and below	7.2	0.16	162.0	100.0

High accumulation of available Fe was noticed in the lower layers of all the profiles.

Manganese

Available Mn varied from 7.0 to 110.0, 7.5 to 105.0, 5.0 to 108.0 and 10.0 to 100.0 ppm with a mean of 45.7, 64.2, 44.3 and 35.5 ppm for profiles 1 to 4 respectively. As in the case of iron, available Mn was also found to accumulate more in the lower layers of all the profiles.

PROFILE DISTRIBUTION OF AVAILABLE ZINC



PROFILE 1

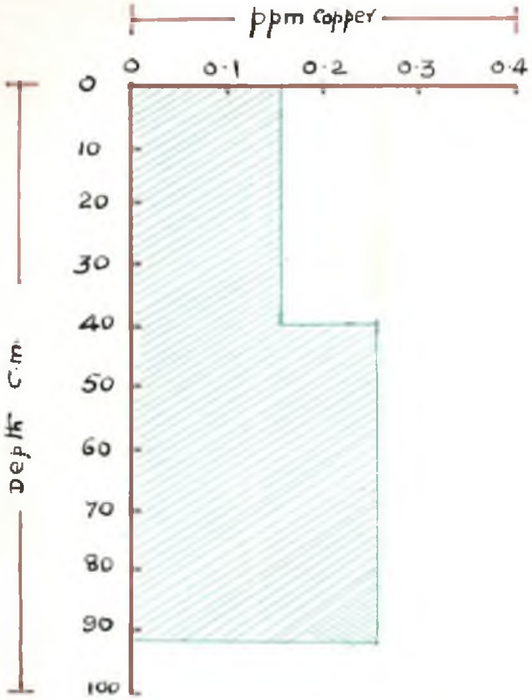
PROFILE 2

PROFILE 3

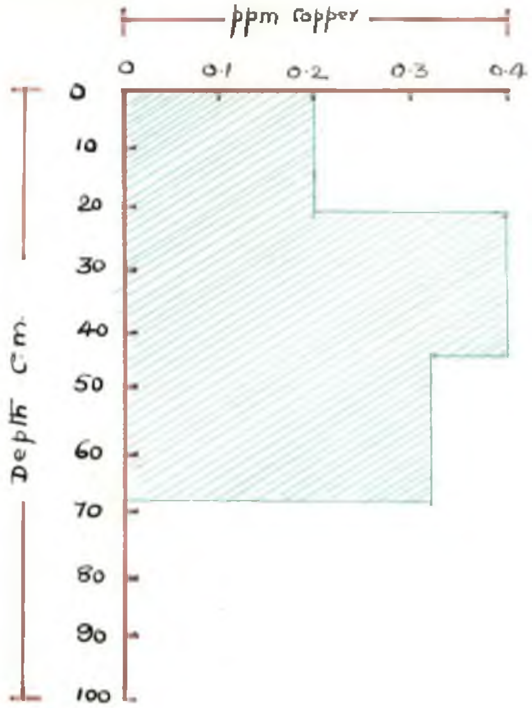
PROFILE 4

FIG. 3

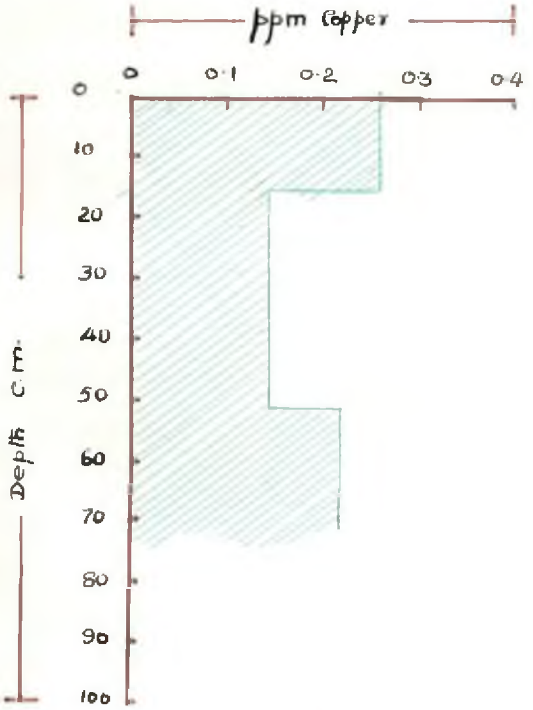
PROFILE DISTRIBUTION OF AVAILABLE COPPER



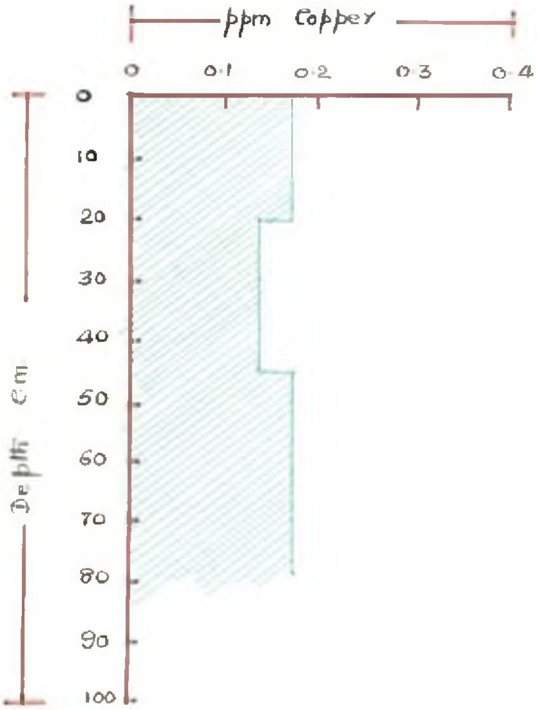
PROFILE 1



PROFILE 2



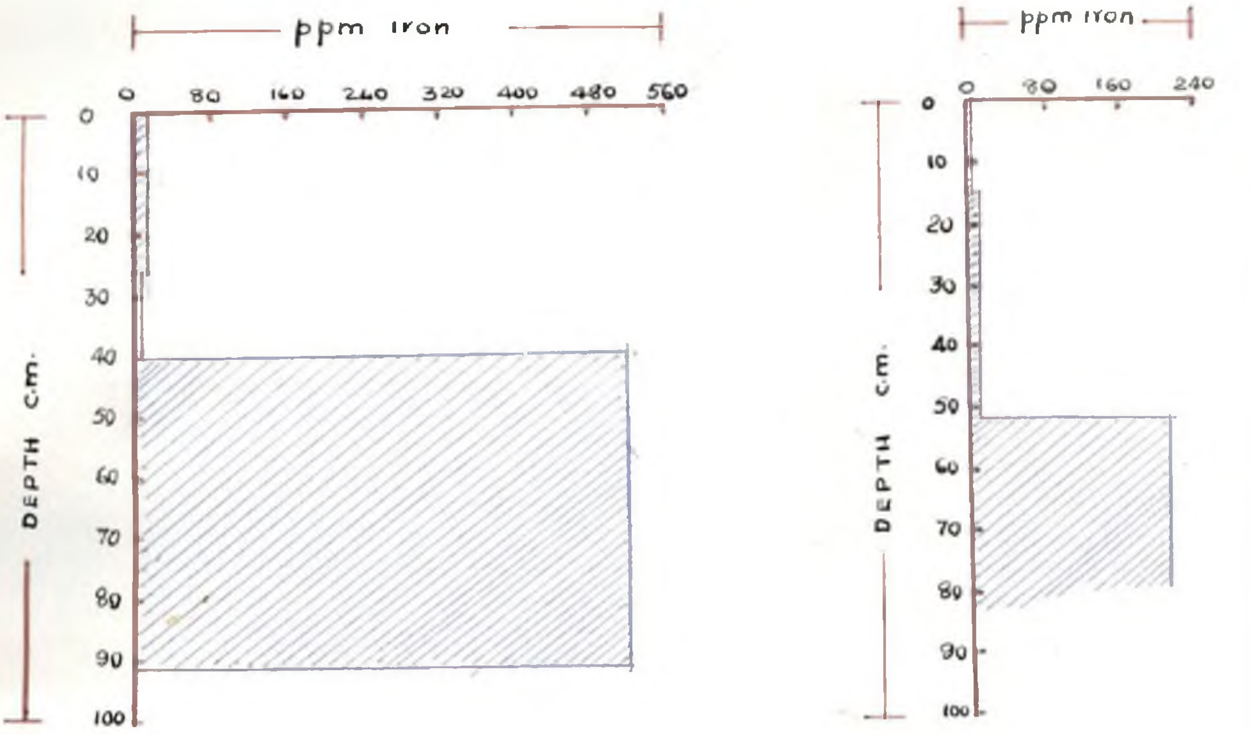
PROFILE 3



PROFILE 4

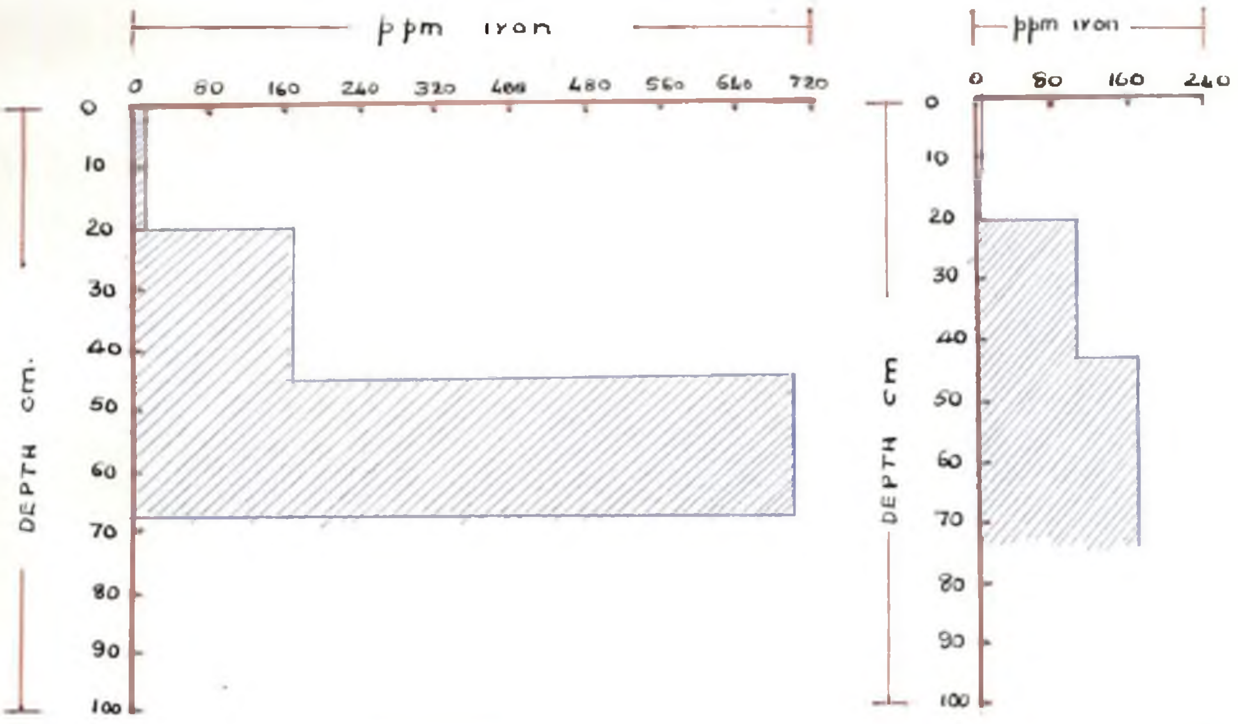
FIG. 4

PROFILE DISTRIBUTION OF AVAILABLE IRON



PROFILE 1

PROFILE. 3



PROFILE. 2

PROFILE. 4

FIG. 5

PROFILE DISTRIBUTION OF MANGANESE (AVAILABLE)

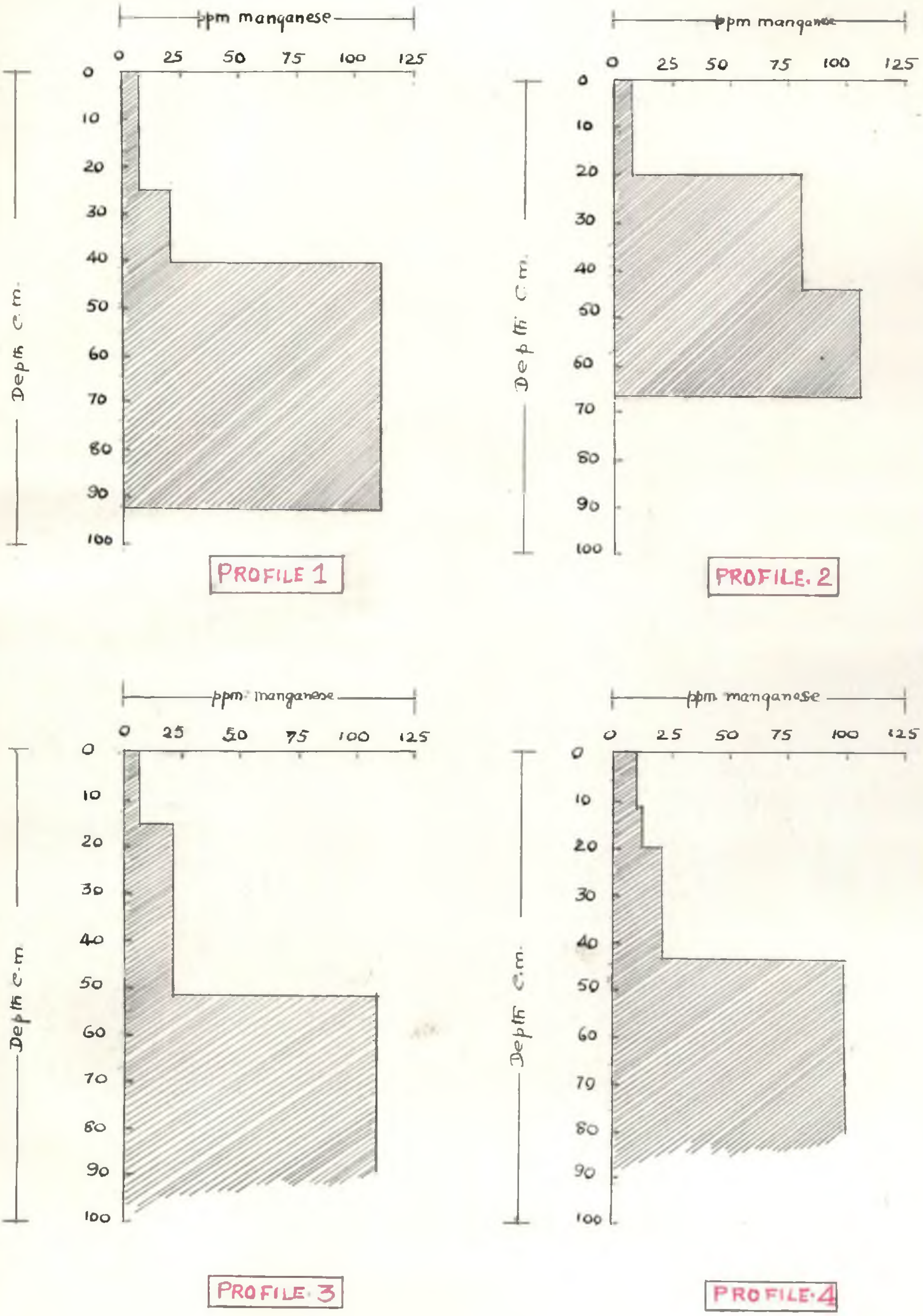


FIG. 6

DISCUSSION

DISCUSSION

Kuttanad, comprising an area of 875 sq.km, presents three major soil types namely the karapadom soils (river-borne alluvium), the kari soils (peaty soils) and the kayal soils (reclaimed lake-bed). Though the karapadom soils constitute the largest and most intensively cultivated area, the kayal soils being more recently reclaimed and having been reclaimed in contiguous areas offer high potentialities for development. They comprise an area of 8000 hectares. The problems connected with the reclaimed lake-bed soils are becoming more important in recent years in view of the extensive reclamation measures adopted. During the last few years, an area of about 500 hectares have been reclaimed in Kayamkulam kayal and an area of about 100 hectares is being currently reclaimed in Quilon district in the Paravoor kayal area. While all the above mentioned areas are reclaimed from the backwaters which are saline, there are regions like the Vellayani and Akkulam kayals in Trivandrum district which are fresh water lakes. Thus, problems of the reclaimed lake-bed soils (kayal soils) are varying in nature.

The present study is confined to the peculiar problems of the reclaimed kayal soils of the Kuttanad region. In this connection it is worthwhile to mention the existence of two major schemes for the development of reclaimed kayal lands and of the Kuttanad area in general. The first scheme is the construction of rubble ring bunds to protect the reclaimed kayal lands from salt water inundation. This work was done only in the R block kayal in Kuttanad, comprising an area of about 600 hectares in the year 1965. A profile has been taken from R block for comparison with the profiles from the adjoining unprotected blocks. The second scheme is the construction of the Vechoor-Thanneermukkam salt water barrier which has been completed this year to effectively prevent the salt water intrusion into the entire Kuttanad region to enable a second crop of paddy to be taken from the area. The profiles for the present study have been taken prior to the completion of this bund and thus it enables a comparison between an effectively reclaimed soil profile like the one from R block and the semi-permanently reclaimed areas adjoining the R block. Further, the basic data collected in the present study, it is hoped, will enable us to make an assessment of the effectiveness of the second scheme in later years.

I. Morphological characteristics of the profiles studied

The first profile collected from the Rani kayal is medium to strongly acid in reaction with a low amount of organic matter which increases towards the lower horizons.

The fourth profile from the Chithira *kayal* has a colour ranging between 2.5 Y 3/2 to 10 YR 2/1 with the texture varying from silty loam to clay. The surface horizon contains high clay content. Soil reaction is neutral to extremely acidic and the acidity is more towards the lower horizons. Lime shells are present only in the second horizon. Salinity is moderate which increases with increase in depth. Organic matter status is low which increases with depth except in the second horizon which shows a decrease in organic matter and an increase in pH.

II. Classification of the soil according to the Seventh Approximation

These are mineral soils having no diagnostic horizon other than an ochric or an anthropic epipedon, an albic or an agric horizon. They are saturated with water during the major part of the year and are artificially drained and they have at some depth within 50 cm, dominant moist colours in the matrix. These characters classify them under the sub-order Aquent.

These Aquent soils have a mean annual soil temperature of more than 0°C and at least 8 per cent clay and 3 per cent organic matter in all the sub-horizons between 20 and 50 cm and have textures of loamy, very fine sand in some horizon

The colour varies from 7.5 YR 3/2 to 10 YR 2/1. The texture of the soil ranges between loam and sandy clay loam, with the surface horizon containing abundant plant roots. The soil is moderate in salinity due to salt water inundation and it increases with increase in depth. Lime shells are present in all the horizons but in greater abundance in the intermediate layer.

The second profile collected from the same kayal is located towards the north eastern side of the first site. The soil is slightly to very strongly acidic in reaction and the acidity increases with depth. The texture varies from silty loam to clay loam and the colour from 10 YR 2/2 to 10 YR 2/1. Lime shells are present only in the first and third layers. Moderate salinity is observed in the case of the first profile and it increases with depth. The organic matter level is low but more than that a profile I.

The third profile from R block kayal is silty loam to sandy clay loam in texture, the colour ranging between 7.5 YR 3/2 to 10 YR 2/1. The soil is neutral to strongly acidic in reaction and the acidity increases wbth increase in depth. Lime shells are present throughout the profile with the intermediate horizon containing more. The surface horizon contains plenty of plant roots. The organic matter level is low which increases with indrease in depth.

below the Ap or 25 cm whichever is deeper. These are characteristics of Hydraquents as given by the new U.S.D.A. system of classification. Since the sub groups have not been developed (U.S.D.A. 1967) the grouping has been limited to the great group level. These *kayal* soils are thus classified under

Order - ENTISOL
Sub-order - Aquent
Great group - Hydraquent

III. Physical characteristics

Data on the mechanical composition and textural classification of the soils indicate that they are loam, silty loam, sandy clay loam or clay. The pattern of the distribution of clay in the different profiles is interesting. Among the two profiles from Rani *kayal* (Profile No.1 & 2), while the first profile showed a decrease in clay content with increase in depth a reverse trend is noticed in the second profile. In the R block profile (Profile No.3 the intermediate horizon contains the maximum amount of clay while in the Chithira *kayal* profile (Profile No.4) the maximum value for % clay is observed in the surface horizon followed by the lowest one. It is observed that the texture changes from loam to silty loam in the first profile and from silty loam to clay loam in the second profile. In the

R block profile in the texture of the first and third horizons is silty loam with a change to sandy clay loam in the intermediate horizon. In the Chithira profile the change in the variation from clay to silty clay loam takes place through the intermediate stages of clay loam to silty loam.

The first two profiles taken from the Rani kaval, comprising an area of 587 acres, themselves show considerable variation from one another. This illustrates the considerable variation in soils observed in the Kuttanad region. In the first and fourth profiles the surface horizon contains the maximum amount of clay while in the second and third profiles the maximum values are recorded in the lowermost and the middle horizons respectively. This suggests that the first and fourth profiles are from areas wherein lateral migration of clay in the form of alluvial deposition stimulated by flood waters, appears to have played a more dominant influence in deciding the profile features. In the second and third profiles, though alluvial deposition might have taken place, evidences of clay migration from the surface to sub-surface layers also exist. Further work on the nature of clay in the different horizons may throw new light on these important pedogenic processes.

It is noted that the dominant fraction in all the horizons of all the profiles is fine sand. This suggests that the finer fractions like the clay and silt have been deposited over a sandy matrix during the course of several years and the soil developed as a consequence.

The absolute and apparent specific gravities decrease with increase in depth in all the profiles, which closely parallel the variation in the organic matter in the different horizons. Organic matter content is significantly and negatively correlated with both absolute specific gravity (r = -0.65) and apparent specific gravity (r = -0.61). Similar observations have been made by Ramaswami (1966). However these single value constants are not significantly correlated with clay, probably suggesting that between clay and organic matter, the latter has a more decisive role in influencing these properties. Similar observations have been made by Sen and Deb (1961).

The pore space shows a steady increase with depth in profile 2. A trend for an increase with increase in depth is noticed in the other three profiles also. Highly significant positive correlation (r = +0.72) and a highly significant negative correlation (r = -0.67) are noticed between pore space on the one hand and organic carbon and coarse sand on the other respectively. The values for pore space range between 47.40 to 59.07.

The water holding capacity and volume expansion increase steadily with increase in depth only in the third and second profiles respectively but there is a general trend for both these properties to increase with increase in depth in the other three profiles also. Water holding capacity and volume expansion are significantly and positively correlated to organic carbon values with a correlation coefficient of +0.70 and +0.63 respectively. Coarse sand possesses a significant and negative correlation with water holding capacity ($r = -0.48$) and a positive correlation with volume expansion ($r = +0.63$) which agrees with the observations made by Ramaswamy (1966).

IV. Chemical characteristics

Investigations on soil reaction indicate a decrease in pH with increase in depth in profiles 2 to 4 while a reverse trend is noticed in the first profile. This decrease can be attributed to the steady increase in the organic matter content. In profile 1, eventhough a slight increase in the organic matter with increase in depth is noticed, the exchangeable hydrogen shows a decreasing trend. In the second layer of Chithira kayal profile also a decrease in organic matter and an increase in pH noticed. The relation between organic carbon and pH is significant and negative ($r = -0.58$) which agrees with the observations made by Alexander and Dorairaj (1968) in acid soils.

The air dry soils show a decrease in pH in profile 4 whereas in the other three profiles such a decrease is observed only in the lower horizons. The soils from the lower horizons of Chithira _kayal_ have very high acidity (Money, 1961). The high values recorded for exchangeable hydrogen are also in conformity with this trend.

Unlike _kari_ and _karapadom_ soils the _kayal_ soils do not show considerable decrease in pH on drying. In fact there has been a slight increase in pH in some of the soils on drying. This is on account of the absence of reduction products in the waterlogged soils. The reduction products encountered in the _kari_ and _karapadom_ soils are mostly ferrous sulphides (marcasites) which are known to undergo oxidation on drying liberating free sulphuric acid (Money, 1960; Moorman, 1962). Such reduction products obviously cannot exist in these soils though they may be formed on account of possible interaction with $CaCO_3$ which are found in enormous quantities as molluscan lime shells in these soils.

The conductivity in 1:2 soil water extract ranges between 0.65 and 3.95 mmhos/cm. The lower layers of the

Chithira and R block kayal profiles have the maximum and minimum values respectively for conductivity which increase steadily with increase in depth. A significant positive correlation exists between electrical conductivity and organic carbon (r = +0.73). It is interesting to note that the conductivity is considerably lower in all the layers of the R block profile than the corresponding layers in other profiles, inspite of the relatively high values for organic carbon. In this connection it may be mentioned that the R block kayal is the oldest of the Kuttanad kayals and was permanently reclaimed much earlier. The salt water intrusion into this kayal is prevented much more effectively by bunds reinforced with rubble masonry. Further, the soil samples were collected during the month of March in 1974 when the conductivity is expected to be high due to the inundation with Vembanad lake water (Kurup and Aiyer, 1973). The low values for electrical conductivity observed in the case of these soils show that if the entire area can be effectively protected from salt water intrusion salinity hazard to rice cultivation can be minimised to a great extent.

All the four profiles are relatively low in organic carbon. The values range between 0.86 per cent and 3.98 per cent which compare well with those reported for surface soils by Kurup, 1967 (0.58 to 3.3 per cent); Verghese, 1972 (2.816 to 3.038 per cent) and Money and Sukumaran, 1973 (below 4 per cent). Organic carbon increases with depth in all the profiles and bears a significant positive correlations with electrical conductivity and the single value constants like pore space, water holding capacity and volume expansion and significant negative correlations with pH and absolute and apparent specific gravities as mentioned earlier.

The values for total nitrogen do not follow the same distribution pattern as organic carbon but the C/N ratio follows the same trend with a steady increase with increase in depth. Total nitrogen shows an increasing trend with increase in depth in the second profile and vice-versa in the third, whereas in profiles 1 and 4 the nitrogen content slightly decreases in the second layer and then increases. The values for total nitrogen range between 0.11 and 0.26 per cent and that for C/N ratio vary from 5.7 to 22.59. The highest value for organic carbon is recorded in the lower horizon of profile 2 but the highest C/N ratio is observed in the lower horizon of R block profile. This difference in trend between the C/N ratio and organic carbon may partly be due to the differences in the degree of humification of organic matter. Detailed investigations on the distribution of humic and fulvic acids in the various horizons together with studies on the different forms of nitrogen may yield more conclusive results on this aspect.

Compared to <u>kari</u> and <u>karapadom</u> soils, the status of total phosphorus is low in <u>kayal</u> soils the values ranging between 0.04 and 0.08 per cent P. This compares well with the values reported by Kurup (1967) and Verghese (1972) (0.079 to 0.183 per cent and 0.09 to 0.156 per cent P_2O_5 respectively). Available phosphorus status in these soils is medium to high, unlike in the case of <u>kari</u> and <u>karapadom</u> where, though there is adequate supply of total phosphorus, the available phosphorus status is reported to be low due to the high acidity and high amounts of iron and alumina. In the <u>kayal</u> soils, however, it is seen from the results of the present study that the pH of the soil is very nearly optimum for maximum availability of phosphorus. Surface layers contain higher content of total phosphorus in all the profiles and no downward movement of phosphorus is noticed as in <u>kari</u> soils where, due to the high organic matter content, penetration of phosphorus to the lower horizons occur as reported by Koshy and Brito-mutunayagam (1965).

The soils are adequately supplied with total potassium, the values ranging between 0.11 to 0.38 per cent K. Potassium content increases steadily with increase in depth in the first three profiles while in the Chithira profile it decreases in the second layer and then increases. The general trend is for an increase in potassium content with depth which agrees with the observations made by Karim and Khan (1956). It is also interesting to note that in the R block profile the potassium content is comparatively less in all the layers than what is found in the other three profiles. This is due to the lack of penetration of salt water during the last 10 years after the construction of permanent bunds. This observation is in agreement with the findings of Sreedevi and Aiyer (1974) who reported comparatively high values for total K (and exchangeable potassium) in Kuttanad soils due to submergence of salt water and deposition of silt by flood waters.

The calcium status of the soils in all the profiles is fairly high. The intermediate horizon of the first and third profile contained high Ca (2.21 and 2.22 per cent Ca respectively). It is worth mentioning in this connection that in most of the layers, and particularly in the above two, considerable quantities of limeshells are encountered. In all the profiles a higher status of Ca is noticed in the middle layers probably due to the leaching effect by heavy rains and flood water.

The magnesium status of the soil is found to be medium in the lower horizons of all the profiles while, the surface horizons show a low level. A steady increase is found in all the profiles with increase in depth, the values ranging between 0.07 to 0.44 per cent Mg. The R block profile shows the lowest status for magnesium. In view of the high status of calcium found in these soils the crop is likely to suffer from deficiencies of magnesium.

The sesquioxide content is found to be highly varying, with the R block surfade soil containing the highest amount. In the first and fourth profiles there is an initial increase in sesquioxide content with increase in depth, followed by a decrease. In the second profile the sesquioxide content remains fairly uniform while in the third profile a slight decrease with depth is noticed. The same pattern is reflected in the constituent sesquioxides, iron and aluminium. The lack of a definite pattern with depth in these important constituents which are the major parameters helpful in deciding the nature of clay, lend support to the view that there is a considerable degree of deposition of clay by flood waters coupled with vertical migration of clay.

Cation exchange capacity and exchangeable cations

In all the profiles the cation exchange capacity (C.E.C.) of the soils closely follow the organic matter and clay content. A positive relation for both these factors are found with C.E.C. When the organic matter is significantly and positively correlated with C.E.C. (r = +0.82) the relation between clay and C.E.C. is positive but not significant.

A significant negative correlation is also found between pH and C.E.C. (r = -0.59). A similar relation for C.E.C. with organic matter and pH was reported by Yuan et al (1967), Alexander and Durairaj (1968), Lavti et al (1969) and Wright and Foss (1972). The C.E.C. values range between 9.92 and 19.30 me/100 g soil. Kurup (1967) reported that for Kuttanad soils C.E.C. values range between 10.6 and 17.20 which compare well with the results obtained in the present study. The fact that a significant and negative correlation exists between the C.E.C. and the pH indicate the possibility of greater contribution by pH dependent charges in determining the C.E.C. of the soils. The pH dependent charges are largelly contributed by the -COOH groups and phenolic OH groups of the organic matter and Si-OH groups of the clay. The high degree of correlation with pH suggests, the absence or presence only in small quantities of clay minerals with large permanent negative charges which are known to be pH independent.

Compared to the earlier work on kari and karapadom soils (Kurup, 1967) the amount of exchangeable aluminium and hydrogen is low in these soils. Aluminium is practically nil in the surface layers and exchangeable hydrogen low in all the layers. However with an increase in depth there is a steady increase in the amount of exchangeable hydrogen and in the lower horisons of all the profiles small amounts of exchangeable aluminium has been detected. Problems of toxicity due to iron and aluminium frequently encountered in kari and karapadom soils cannot be met with in these soils because of the high content of calcium and magnesium and the consequent favourable pH of about 5.5 in these soils.

The soil is well saturated with bases, the percentage of base saturation ranging between 73.5 and 97.7. Calcium and magnesium are the dominant exchangeable cations in these soils followed by Na and K. The proportion of exchangeable calcium to total exchangeable bases ranges between 36.2 and 80.3 and that of exchangeable magnesium ranges between 8.8 and 53.4. These results show that the management of these soils is much more easy than that of the kari and karapadom. Continuous waterlogging can lead to production of H_2S due to favourable pH conditions for SO_4 reducing organisms. In such soils it will be safer to avoid fertilisers containing SO_4 radical.

Exchangeable sodium ranging between 0.15 and 4.98 me/100 g soil contributes 1.3 to 32.2 per cent of the total exchangeable bases in the various horizons. The third layer of the first profile contains the highest quantity of exchangeable sodium. The R block profile, into which saline water intrusion has been cut off for the last 10 years and which has been flushed with rain water, though it contains only smaller amounts of exchangeable sodium cannot by any means be considered to have been desalinised. The presence of exceedingly high amounts of exchangeable sodium in the first profile and in the surface layer of the fourth profile will be injurious to proper crop growth unless its concentration is decreased by continuous washing with fresh water or application of suitable soil amendments. Exchangeable potassium ranges between 0.04 to 1.06 me/100 g and contributes 0.36 to 9.5 per cent of the total exchangeable bases. Compared to profiles 1, 2 and 4 the exchangeable potassium content in R block profile (profile 3) is less which again shows that the intrusion of salt water into these areas is considerably prevented by the construction of permanent bunds all around. Salinity, which is probably the major problem in the management of these soils can be overcome by the construction of granite ringbunds around the kayal blocks.

Micronutrients

Among the four micronutrients studied available zinc, iron and manganese decrease with increase in depth while in the case of available copper such a trend is not noticed. Taking the critical limit of available zinc as 0.5 ppm, the surface layers of both the profiles from Rani kayal and the Chithira kayal profile (1, 2 and 4) are found to be deficient in this nutrient but towards the deeper layers this nutrient increases considerably. The accumulation in the lower layers may be due to their mobilisation from upper horizons by percolating water and subsequent deposition in the lower horizons. The marginal levels of zinc in the above profiles point to the need for zinc application in these soils, especially when high yielding varieties are cultivated with high levels of phosphatic fertilisers. The surface layer of R block profile is adequately supplied with available zinc. Available zinc has a significant and positive correlation with organic carbon (r = +0.58) and non-significant negative correlation with pH. This suggests the possibility of soluble chelated complexes of zinc contributing to greater zinc availability. A similar trend for available Zn with organic content and pH has been reported by Rai et al (1972), Gupta and Singh (1972) and Balasubramaniam et al (1972).

Considering the critical limit of copper as 0.5 ppm., all the profiles are found deficient in available copper. The distribution of available copper in the profiles is more uniform than zinc which shows that unlike in the case of zinc, copper is not penetrated down the profile by the rainwater. A similar observation has been made by Jones and Belling (1967) who found that copper remained near the surface after all the fertilizer treatments and several years of rainfall. A significant negative correlation has been noticed between available copper and pH (r = -0.9) which agrees with the observation made by Mehta et al (1964), Bade et al (1971), Gopinath (1971) and Valsaji (1972).

The distribution of available iron and manganese follows the same pattern as that of available zinc but in all the profiles their levels are found to be much above the critical limits fixed for them (critical limit for iron and manganese being 2 and 3 ppm respectively). With increase in depth a steady increase in concentration of both iron and manganese is observed, which reaches very near toxic concentrations. Such high concentrations of available Fe and Mn are found to be related to high organic matter content and low pH values. Available manganese in the present study is found to be significantly and positively correlated with organic carbon (r = +0.56) and negatively correlated with pH (r = -0.48). This is in agreement with the findings of Yadav and Kalra (1964), Sharma and Motiramani (1964), Sharma and Shinde (1968), Grewal et al (1969), Rai et al (1970), Badhe et al (1971), Mishra and Tripathi (1972) and Patel et al (1972).

TABLE XV

CORRELATION VALUES

	Organic carbon	pH	Organic matter	Electrical conductivity	Single value constants				
					Ab.Sp. gravity	App.Sp. gravity	Pore space	Water holding capacity	Volume expansion
Available zinc	+0.58**	N.S.	-	-	-	-	-	-	-
Available copper	N.S.	-0.90***	-	-	-	-	-	-	-
Available iron	N.S.	N.S.	-	-	-	-	-	-	-
Available manganese	+0.56**	-0.48*	-	-	-	-	-	-	-
C.E.C.	-	-0.59**	+0.82***	-	-	-	-	-	-
Organic carbon	-	-0.58**	-	+0.73***	-0.65**	-0.61**	+0.72***	+0.70***	+0.63**
Coarse sand	-	-	-	-	-	-	-0.67***	-0.48*	+0.63**

N.S. - Non significant
*** - Significant at 1%
** - ,, at 5%
* - ,, at 10%

SUMMARY AND CONCLUSIONS

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A study made on the morphological and physico-chemical characteristics of the kayal profiles of the Kuttanad region of Kerala revealed the following salient features.

(1) These soils are classified under the order - ENTISOL, Sub order - Aquent and great group - Hydraquent according to the Seventh Approximation.

(2) Texturally they are classified mostly as silty loam or sandy clay loam, fine sand being the dominanting fraction in all the profiles and layers. Only the surface soil of the Chithira kayal profile is clayey in texture with a maximum of 36.5 per cent clay.

(3) The physical characteristics of the two profiles from the Rani kayal vary widely. While the profile 1 shows a decrease in clay content with increase in depth, the second profile shows a reverse trend for clay as well as fine sand. Fine sand is maximum in the middle layer of profile 1.

(4) The absolute and apparent specific gravities, in general, show a decreasing trend with increase in depth in all the profiles. A significant negative correlation is noted between the above constants and organic carbon.

(5) Pore space, water holding capacity and volume

expansion show an increasing trend, in general, with increase in depth. A significant positive and negative relation is noticed for pore space with organic carbon and coarse sand respectively. Water holding capacity has a significant positiv correlation with organic carbon and volume expansion has a significant positive relation with both organic carbon and coarse sand.

(6) The profiles studied are acidic to neutral in reaction and the general trend for the pH is to decrease with increase in depth except in the first profile of Rani kayal where a reverse trend is noticed. The lower layer of the Chithira kayal profile shows high degree of acidity. Comparatively higher content of exchangeable aluminium and hydrogen is also detected in these layers.

(7) The values for electrical conductivity steadily increase with increase in depth. The R block profile which is a permanently reclaimed area with rubble ring bunds show the minimum values due to prevention of salt water intrusion.

(8) Organic carbon status is poor in all the profiles the values ranging from 0.89 to 3.98 per cent. Both organic carbon and C/N ratio increase with increase in depth. A significant negative relationship exist between organic carbon and pH while a significant positive relation exist

between organic carbon and electrical conductivity.

(9) The general level of total nitrogen is low in all the profiles, the values ranging between 0.11 and 0.26 per cent.

(10) The soils are adequately supplied with total potassium, the values varying from 0.11 to 0.38 per cent K. The general trend is for an increase with increase in depth. In R block profile where salt water intrusion is less the potassium status is comparatively low.

(11) The level of total phosphorus is low ranging between 0.04 and 0.08 per cent but the available phosphorus status is medium to high, probably due to the favourable pH that exist in these soils. The profile distribution of total phosphorus shows that it is more in the surface layers.

(12) The calcium status of all the profiles is fairly high. The intermediate layer of Rani kayal profile (Profile 1) and R block profile show high calcium content due to the presence of lime shells in fairly large quantity.

(13) The magnesium status is low to medium showing an increase with increase in depth. The values range between 0.07 and 0.44 per cent.

(14) The cation exchange capacity (C.E.C.) of the

soil is low ranging between 9.92 and 19.3 me/100 g. A significant positive correlation exist between C.E.C. and organic matter while C.E.C. shows a significant negative relation with pH.

(15) Exchangeable aluminium and hydrogen are low in these soils. Aluminium exists mostly in the lower layers and exchangeable hydrogen shows an increase with depth.

(16) All these soils are well saturated with bases, the percentage base saturation varying from 73.5 to 97.7. Surface layers are comparatively richer in bases. Calcium and magnesium are the dominant cations in the exchange complex followed by Na and K.

(17) The first profile of Rani *kayal* and the surface layer of Chithira *kayal* contain high levels of exchangeable sodium.

(18) The surface soils of both the profiles of Rani *kayal* and the Chithira profile are deficient in available zinc which, however, increases with depth. A significant positive relation exists between organic carbon and available zinc.

(19) All the four profiles are deficient in available copper which shows a more uniform distribution and less susceptibility to mobilisation by the percolating water. A significant negative relation exists between available copper

and pH.

(20) Available iron and manganese follow more or less the same pattern as that of zinc, increasing with increase in depth. All the profiles are adequately supplied with available iron and manganese. Towards the lower layers the concentration of both assume toxic proportions. A positive and negative relation exist for manganese with organic carbon and pH respectively.

The above observations point to the need for providing strong permanent bunds in reclaiming these soils as has been done in the case of the R block, especially for preventing the intrusion of salt water. The low status of organic carbon necessitates the incorporation of more organic matter into the soil which will improve the structure and the exchange capacity of the soil and thereby its productivity. Due to the high calcium status, deficiency of magnesium is possible especially when the sea water intrusion is permanently checked. The high level of exchangeable sodium noticed in Rani kayal can also be minimised by preventing the intrusion of salt water with strong bunds. Application of zinc and copper along with major nutrients is necessary especially when high yielding varieties are cultivated since, the higher levels of nitrogen boost vegetative growth enhancing the demand for these elements. The Thanneermukkam - Vechoor bund is expected to solve the salinity problem in these areas and further studies of the soil samples collected from these areas will throw more light on the changes and the effectiveness of the reclamation work.

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* Original not seen