MORPHOLOGICAL AND PHYSICO-CHEMICAL PROPERTIES OF *KARAPADOM* SOILS OF THE KUTTANAD REGION OF KERALA STATE

BY

G. SANTHAKUMARI B. Sc. (Ag.)

COLLEGE OF HORTICULTURE
VELLANIKKARA

THESIS SUBMITTED TO
THE FACULTY OF AGRICULTURE, KERALA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL CHEMISTRY)

DIVISION OF AGRICULTURAL CHEMISTRY,
COLLEGE OF AGRICULTURE, VELLAYANI
TRIVANDRUM.

1975

CERTIFICATE

Certified that this thesis is a record of research work done independently by Smt. G. Santhakumari under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

(Dr. R.S. Aiyer)

Chairman, Advisory Committee
Junior Professor,
Division of Agricultural
Chemistry

College of Agriculture,
Vellayani, Trivandrum

17th July, 1975

APPROVED BY:

Chairman:

(Dr. R.S. Aiyer) 12/9/75

Members:

(T. Pankajakshy Amma) 12/9/1975

(P.R. Ramasubramonian) 12-9-75

(P. Balakrishna Pillai) .9.75

ACKNOWLEDGEMENT

The author wishes to place on record her deep sense of gratitude and indebtedness to:

Dr. R.S.Aiyer, Junior Professor of Agricultural Chemistry and Chairman of the Advisory Committee, for suggesting the problem, and for his sustained and inspiring guidance and valuable suggestions at every stage of this investigation and in the preparation of this thesis,

Dr. N.S.Money, Dean, Faculty of Agriculture, Kerala Agricultural University for providing necessary facilities,

The members of the Advisory Committee, Smt. T.Pankajakshy Amma, Junior Professor of Agricultural Chemistry, Shri. P.R. Ramasubramonian, Junior Professor of Agricultural Chemistry and Dr. P. Balakrishna Pillai, Assistant Professor in Agronomy (College of Horticulture) for the keen interest and encouragement evinced by them during the course of this investigation,

Dr. M.M. Koshy, Additional Professor of Agricultural Chemistry for his valuable suggestions,

Shri. C.K. Rajagopal, Associate Professor, Division of Agricultural Chemistry and Soil Science, Agricultural College, Coimbatore and his staff for their help in analysing the soil samples for the micronutrient contents,

All members of the staff in the Agricultural Chemistry Division and her colleagues for their valuable help during the course of this investigation and

Kerala Agricultural University for deputing her to undergo the post-graduate course.

G.SANTHA KUMARI

CONTENTS

INTRODUCTION

INTRODUCTION

Kuttanad comprising an area of approximately 875 sq.km in the two districts of Alleppey and Kottayam is a unique agricultural region. The origin of the soils of this area is not yet clearly known. According to Velu Pillai (1940), the entire area of Kuttanad was a bay in the geological past. Large quantities of sediments were deposited in this bay by the rivers, year after year, during the monsoons. Sand embankments were slowly formed and the nearest areas were linked together and the bay was then converted into a lagoon. This lagoon was gradually silted up and eventually transformed into the paddy lands and coconut gardens of Kuttanad.

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. Being situated at a depth 1 to 2.5 metres below the sea level, it is submerged under water for a major part of the year. It is also periodically inundated by the saline water from the adjoining Vembanad lake. During the South-West (June-August) and North-East (October-December) monsoon periods fresh water from rivers enter the area and as North-East monsoon recedes sea water again enters and the whole area become saline again. Kuttanad area is therefore faced with some peculiar problems and cultivation is rather uncertain and hazardous.

The rice soils of *Kuttanad* fall under 3 categories namely *kari*, *kayal* and *karapadom*. The investigation proposed to be taken up is confined to the *karapadom* soils. These soils occur along the inland water ways and rivers and are spread over a large part of the upper *Kuttanad*, covering an area of about 41,000 hectares. They are river borne alluvial soils. The fields lie at about 1 - 2 m below the sea level. The soils are characterised by high acidity, high salt content and a fair amount of decomposing organic matter. They are generally poor in available plant nutrients particularly so in phosphorus. They are also highly deficient in lime. Low fertility status is the most significant aspect of these soils. Further, these soils were the one subjected to cultivation since the earliest days.

The reclamation of these soils to enhance their productivity is of utmost importance to the economy of the State. Not much is known regarding the profile characteristics of these soils. Further the available micronutrient status of these soils are also unknown. The present investigation is therefore undertaken with the object of studying the morphological and physico-chemical properties of the *karapadom* soils. The result obtained would certainly contribute towards further knowledge regarding the nature and origin of these soils.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Physical properties

Keen and Racksskowski (1925) observed that pore space and clay content were positively correlated. The correlation between specific gravity and clay content was found to be negative. Volume expansion was found to be directly correlated to percentage of clay.

Marchand (1924) reported that specific gravity, pore space, water holding capacity and volume expansion of soils determined by the Keen Rackszkowski method could be roughly correlated with clay content of the soils.

Coults (1929) obtained a positive correlation between volume expansion and clay content of Natal soils.

Wilcox (1939) found that the sand content of soil was negatively correlated with the maximum water-holding capacity.

Joachims and Kandiah (1947) reported that a high correlation existed between clay content and water-holding capacity in soils of Ceylon.

Lesstak and Darab (1964) noted that peaty, boggy and meadow soils of the Hansang region possess high water-holding capacity, but low permeability due to compact mineral horizon at about 30 cm.

Janardhanan Nair et al (1965) reported that free specific gravity and apparent specific gravity appear to be a function of the coarse particles of the soil while water holding capacity, pore space, volume expansion and organic carbon are related to the finer particles of the soil both in quantity and quality.

Miller (1966) observed that the soil moisture content at the time of sampling to be positively correlated with volume change and negatively correlated with variation in bulk density. Although the volume changes were negligible in A horizons, the average volume changes in B_2, B_3 and C horizons were 11, 13 and 17 per cent respectively.

Horn et al (1967) in their studies on poorly drained coastal alluvial soils of The Republic of Guinea affected by salt-water intrusion found that in some soils the electrical conductivities were as high as 50 m mhos/cm.

Sturges (1968) reported that surface peat had the lowest bulk density, 0.160 g/cc; bulk density at 13 - 25 and 36 - 48 cm depths were 0.208 and 0.216 g/cc respectively. Bulk density and water retention were related to the degree of decomposition and thus to pore size distribution.

Reppo and Bergert (1969) reported that the high correlation between the bulk density on one hand and the content of organic matter, moisture regime and means of land utilisation on the other, makes possible the use of derived regression equations for calculation of mean densities. The dependence of bulk density on texture, depth of occurrence and the reaction of soils in most cases was statistically significant.

Venugopal (1969) found that the kari soils had the minimum value for apparent density among the different soil types of Kerala State.

Elgabaly and Elghamry (1970) noted that air permeability of the soil decreases with decreasing particle diameter and with increasing bulk density.

Gupta and Narin (1971) in their studies on alluvial soils of Uttar Pradesh concluded that the prediction of hydraulic conductivity, volume of non-capillary pores and available moisture capacity of the soils from the values of silt and clay can serve as a good diagnostic technique for soil conservation, planning and management.

Koshy and Thomas Varghese (1971) reported that the peaty and kari soils are characterised by a deep black colour, heavy texture, poor drainage, extremely high content of organic matter and strong acidity.

Velayutham and Raj (1971) suggested that influence of clay was more than that of organic carbon on water holding capacity.

Ghosh et al (1973) found that kari soils from Thottappally, N. Parur and Kattampally of Kerala State are clay loam in texture and rich in organic matter. The bulk density and particle density varied from 1.24 to 1.40 and 2.50 to 2.65 g/cc respectively. The hydraulic conductivities were quite low in Thottappally soil and high in Kattampally soil.

Subramoney and Gopalaswamy (1973) in their studies with acid sulphate alluvial soils of Kerala State, reported that the colour varies from greyish to black olive brown to very dark brown with distinct mottlings in the upper horizons. The alluvial materials are mainly clayey, sometimes loamy and occassionally sandy. Medium texture sediments are also common and the soils are rich in organic matter.

SOIL REACTION

Stephenson (1921) stated that highly organic soils and clays exhibited a high degree of buffering while coarse sand showed little of this capacity and liming is essential when the amount of exchangeable hydrogen exceeds the amount of exchangeable Ca in the soil.

Albrecht and Smith (1952) stated that soil acidity is only a condition of nutrient deficiency, predominantly calcium.

Grist (1953) stated that good paddy soils are almost invariably acid in reaction.

Ponnamperuma (1955) reported that pH of the soil and of the percolates increases on water-logging and this may be because of formation of ammonia in the soil.

Subramoney (1960) found that the high acidity of <u>kari</u> soils was due to the production of sulphuric acid by the sulphur oxidising bacteria.

Moorman (1962) reported that acid soils with considerably high content of sulphate showed extreme variability in soil reaction. Seasonal variation in these soils especially when subjected to frequent inundation were remarkably high. On inundation, pH value gradually increased up to neutral point and decreased rapidly to extreme acid range on drying.

Nhung and Ponnamperuma (1965) stated that acid sulphate soils are extremely acidic and unproductive. The acidity of the aerobic soils has been attributed to the presence of aluminium and ferric sulphates and sometimes free sulphuric acid.

According to Ponnamperuma et al (1966) the pH values of acid soils increased to a fairly stable value of 6.7 to 7.2, 12 weeks after flooding. At this time the solution pH values were 6.5 to 7.0. The increase in soil solution pH of the acid soil was quantitatively related to the potential of $Fe(OH)_3$-Fe^{++} system.

Horn et al (1967) in their studies on poorly drained coastal alluvial soils of The Republic of Guinea affected by salt water intrusion stated that acid sulphate soils occur with pH values ranging from 2.6 to 4.0.

Alexander and Durairaj (1968) reported that loss on ignition, organic carbon, total nitrogen and cation exchange capacity of acid soils were negatively correlated with soil pH in Kerala Soils.

Mahapatra (1968) reported that due to water-logging soil pH tended to be neutral and the water soluble Ca^{++}, Fe^{++}, Fe^{+++}, Al^{+++} ions increase, the last three ions being absent in the water extract of non-flooded soil samples.

Grant (1969) observed that development of acidity on drying appeared to be related to FeS rather than FeS_2 content.

Win et al (1969) in their study of changes of pH values of Gyogon paddy growing soils showed a steady rise of pH from 4.26 to 4.98 and 5.45 to 6.26. pH values increased with duration of submergence; it reached peak values at 120 days and declined on non-submergence.

Cervantes et al (1970) reported that pH decreased with increasing Al content. This effect of Al on pH was independent of organic matter content.

Davies and Brian (1971) determined the pH values of British soils both by equilibration with water and 0.01 M $CaCl_2$ solution. Values from the two determination were linearly related with a highly significant positive correlation. A pH of 6.5 is conveniently regarded as neutrality when soil reaction is determined with $CaCl_2$ solution.

Dev and Sharma (1971) found that on submerging paddy soils for 15 days pH values increased in all soils except those which were calcareous in nature. No further change in pH was noticed by prolonged period of 30 days submergence. Increase in pH has been ascribed to the increased content of reducible Mn, and not so much to reducible ferrous.

Schächtschabel (1971) reported that soil pH below 5 was governed by release of protons into the soil solution. High pH values are attributed to biological production of CO_2.

Allam *et al* (1972) stated that two most important factor regulating H_2S accumulation in Louisiana rice fields were soil pH and oxidisable carbon.

Svant and Kibe (1972) suggested that on 0 - day submergenc~~y~~e, the addition of increasing quantities of $Ca(OH)_2$ increased soil pH, but with time it converged in the neutral range of pH 6.5 to 7.1. The progressive neutralisation curves of soils treated with $Ca(OH)_2$ submerged for 30 days and dried thereafter showed that pH dependant acidity and exchangeable acidity were concurrently neutralized.

Ghosh *et al* (1973) found that *kari* soils of Kerala are very low in, pH (3.2 to 3.8).

Kurup and Aiyer (1973) reported that in Kuttanad soils the maximum and minimum values of soil pH and the minimum and maximum values of electrical conductivity in 1:2 soil water extracts when sampled during periods of October to November and March to April respectively. pH varied most, in *kari* soils while electrical and conductivity fluctuated to a maximum extent in *kayal* soils.

Subramoney and Gopalaswamy (1973) in their studies on acid sulphate soils suitable for growing paddy found that there is considerable difference in pH between fresh and dried soils and between upper and lower horizons of the profiles. The undisturbed soils are neutral to strongly acid.

CHEMICAL PROPERTIES

Nitrogen

Pearsall (1950) stated that the reducing conditions prevailing in water-logged soils accelerate ammonification and loss of ammonia by volatilisation, while oxidation of carbonaceous material is a minimum thus the C/N ratio in soil widens on water-logging.

Donskikh (1966) noted that the total nitrogen content of the top 120 cm layer of upper peat was 5.45 tons/ha and of lower peat 36.85 tons/ha. Organic nitrogen in the surface horizon of upper peat was 47.69 per cent of the total nitrogen. In upper peat most of the N is mobile and soluble in 0.2 N NaOH, and in lower peat more of N is immobile, but hydrolysable with boiling H_2SO_4.

James et al (1966) showed that soil nitrogen was significantly related to the mean annual precipitation at the site of soil formation for A_1 and B_1 soils, but with increase in precipitation, B_1 soils because of higher amounts of clay, are richer in nitrogen than A_1 soils.

Availability of nitrogen was related in a linear fashion to soil nitrogen.

Taha et al (1967) in their studies on microbiological and chemical properties of paddy soils found that:-

(1) Organic matter and total nitrogen fluctuated throughout the experimental period.

(2) Ammoniacal nitrogen showed a marked increase as a result of water-logging.

(3) NO3-N decrease initially on water-logging and this decrease was more pronounced than that recorded for ammoniacal nitrogen showing thereby that the latter form of soluble nitrogen was held more tightly in the clay minerals of the soil.

(4) Drying of the soil increased ammoniacal nitrogen and NO3-N due to aeration that favoured ammonification and nitrification processes.

Yuan et al (1968) in pot culture experiments on silty loam and loam soils found that ammonium concentration of the soil solution was a better index of nitrogen supplying power of flooded soils in the early stage of submergence than organic matter or total nitrogen content.

Verstraeten et al (1970) concluded that vegetation and soil texture exert their influence on the nitrogen index.

According to Avenimelech (1971) nitrates accumulate in peat as one of the end products of organic matter decomposition. Nitrate production is affected by moisture content of the peat reaching an optimum at about the field capacity.

Bhattacharyya (1971) observed that water-logging of rice soils causes expansion of crystal lattices of clay minerals when a part of the fixed ammoniacal nitrogen came out and were held as an exchangeable complex outside the crystal lattice. The increase of exchangeable ammoniacal nitrogen during short periods of water-logging was not due to microbial activity.

Yoram Avnimelech (1971) found that nitrates are accumulated in the peat as one of the end products of decomposition of organic matter. Nitrate production is affected by the moisture content of the peat reaching an optimum at about field capacity.

Varghese (1972) in his studies on acid soils of Kerala recorded 0.49 to 0.55 per cent of N in <u>kari</u> soils 0.13 to 0.19 for <u>karapadom</u> soils and 0.14 to 0.17 for <u>kayal</u> soils.

<u>Phosphorus</u>

Raman (1911) observed that the distribution of phosphate in successive horizontal soil layers was not governed by a universal rule.

Iyer (1928) noted that kari soils are very deficient in phosphate and lime but abnormally high in soluble salts.

Davis (1935) stated that hydrogen ion concentration is largely responsible for phosphate fixation in soils, and he also observed that phosphate availability is maximum in a pH range of 6 to 6.5.

Chandler (1941) observed that acidity coupled with higher content of sesquioxides will favour maximum P fixation. Raychoudhari and Mukherjee (1941) recorded the same result.

Shapiro (1958) reported that the increase of A value after flooding is higher in acid soil than in neutral soil presumably because the acid soil is more abundant in iron phosphate.

Chang (1965) found that the availability of Al-P, Fe-P and organic P decreased while that of Ca-P, tended to increase with decrease in soil pH. Occluded P was unavailable.

Koshy and Brito-mutunayagam (1965) obtained 0.024 to 0.256 per cent total P in ten typical soil profiles of the major soil groups of Kerala. In their study on fixation of P, it was found that acid soils with high sesquioxide content have high capacity for fixation. The downward movement of P in Kuttanad soil was very low.

De Datta et al (1966) reported that 8 to 27 per cent of the total P was derived from applied P for paddy plant. Phosphorus remaining in solution was lowest in acid latosolic soils containing kaolin type minerals, high in soil containing mainly montmorillionite and unaltered in calcareous soil.

Padmanabhan 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. All the experiments directly and indirectly show that iron phosphate is the predominant form of phosphate in the soils studied and it is this form that is plant available.

Ahmad (1967) reported that submergence increased Al-PO4, alkali-extracted Fe-PO4 and Ca-PO4 and decreased reductant soluble P in rice soils. FePO4 constituted the bulk of the inorganic P, Ca-PO4 was particularly low.

Kurup (1967) found that the phosphorus is substantially increased in the limed than in the unlimed samples of

Kuttanad soils.

Pirkl et al (1967) reported that with lower pH values, a major part of the phosphoric ions is bound by ferric ions; with a rising pH, the percentage of the proportion of P bound by Al-ions increases.

Holmen (1968) found that peat soils are often deficient in phosphorus, potassium and sometimes nitrogen.

Mahapatra (1968) reported that water-logging resulted in an increase of water soluble phosphate. Similar observations were made by Nair and Aiyer (1966) for the Kuttanad soils.

Srivastava and Pathak (1968) noted that the Olsen and Bray methods belong to one group whose determined value of available P is highly correlated with Al-PO4 and Fe-PO4 and Bray-2 and Truog methods belong to another group whose determined value of available P is highly correlated with Ca-PO4. Except Bray-2, all extractants were negatively correlated with clay content.

Watts (1968) observed that the decrease in pH on drying causes inorganic P to become occluded. By prolonged water-logging, the occluded P may be converted to more available form due to Fe reducing bacteria and the immobilized P_2O_5 may be reversed to some extend.

Kabeerathumma (1969) reported that lime application enhances the availability of phosphorus in kari and karapadom soils.

Islam (1970) reported that levels of soil P first increased and then decreased with lime of submergence under rice cropping. Increase in soluble P in acid soils was due to a decrease in Ca, Fe and reductant soluble P concentrations; in near neutral soil P increased with decrease in Fe-P and Al-P.

Rovira and Stace (1970) observed that grinding a sample to a smaller particle size increased the amount of phosphorus extracted.

According to Satyanarayana et al (1970) in flooded soils containing Fe, available P levels were higher at all depths than in soils containing calcium.

Savant et al (1970) found that drying increased the available P at re-submergence in clay loam and sandy loam acid lateritic soils.

Cholitkul and Tyner (1971) observed that surface bounded Fe-P, reductant soluble P, Al-P and Ca-P comprised 35 per cent, 19 per cent, 5 per cent and 5 per cent respectively of the mean total P which was about 400 ppm in the soil.

According to Khanna and Mahajan (1971) in acid soils, added phosphorus was transformed mainly into Al-P and Fe-P.

Mehta et al (1971) in their studies on vertical distribution of P in the soils of Western Rajasthan reported that:-

(1) The total P and organic, inorganic and available P were found to increase with the depth of the soil.

(2) Organic P was positively correlated with organic carbon and clay.

(3) Inorganic P was nearly 53.3 to 90.7 per cent of the total P.

(4) Calcium phosphate was predominant.

(5) The available P was negatively correlated with pH and $CaCO_3$ content.

(6) Positive correlation was obtained between available P and Al-P and Fe-P and available P.

Pathak et al (1972) observed positive correlation between available soil P and Mn and negative correlation between P and Fe and also between Mn and Fe.

Varghese (1972) reported that acid soils of Kerala have low P_2O_5 content.

Chibba and Sekhon (1973) observed that available P did not show any definite trend of increase or decrease with depth, although it was high in the surface soils in two profiles. It varied from 3.9 to 85.1 kg P/ha. Fixation of P due to increased activity of Al and Fe in acid soils leads to low levels of available P.

Ghosh *et al* (1973) reported that *kari* soils of Kerala have low phosphorus content.

Potassium

Chang (1960) reported that under flooded condition, the plant uses more non-exchangeable K relative to exchangeable K than under upland conditions.

Chang and Feng (1960) in their studies on exchangeable and non-exchangeable K in the main agricultural soils of Taiwan found that exchangeable potassium varies slightly and non-exchangeable potassium varies greatly among flooded soils belonging to different groups.

Tseng and Wang (1963) reported that rice growth depends more and more on non-exchangeable potassium in alluvial soils.

Kanwar and Grewar (1966) found that potassium content showed significant negative correlation with particle size.

Welte et al (1968) observed that 'C' horizon fix more potassium than 'A' horizon.

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

Kuntze and Leisen (1970) reported that levels of HCl soluble potassium increased with increasing clay content.

Nemete et al (1970) found that at a given amount of exchangeable potassium with an increase in clay and silt content, the proportion of potassium, adsorbed to P-positions decreases, which results in a low potassium concentration under equilibrium conditions.

Wild (1971) reported that exchangeable potassium content was low in soils containing kaolinitic clay.

Kadrekar (1973) observed that the contents of exchangeable, available and water soluble forms of potassium in acid soils decline with the depth of profile.

Mithyantha et al (1973) found that exchangeable potassium percentage have a positive correlation with pH and base saturation but it varied with clay content.

Sreedevi Amma 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 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 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 waters.

Cations and cation exchange capacity: Alway (1914) reported that the content of lime is variable in peat soils and the proportion of lime in a peat soil controls the supply of both Ca and Nitrogen.

According to Mitchell and Muir (1937) the cation exchange capacity of a soil depends mainly on the clay content and its composition.

Nambiar (1947) observed that Ca was the principal replaceable base followed by Mg, Na and potassium in paddy soils of Kerala. Exchangeable Ca was low on the surface layers.

According to Bear and Toth (1948) for an ideal soil 65 per cent of the exchange complex should be occupied by Ca, 10 per cent by Mg and 5 per cent by K and 20 per cent by hydrogen.

Milton and Wadleigh (1951) reported that there is a positive correlation between sodium and pH and the exchangeable sodium can be predicted from pH values.

Albrecht and Smith (1952) suggested that soil acidity is only a condition of nutrient deficiency predominantly calcium.

Aslander (1952) found that calcium supply is seldom, if ever the limiting factor in crop production in acid soils.

Musierowicz and Konecka-Betley (1956) suggested that the exchangeable calcium content increase with increase in the content of clay and humus.

According to Menon and Sankaranarayanan (1957) cation exchange capacity increased with depth of soil. Of the different exchangeable cations, 80 per cent was Ca.

Donahue (1958) reported that cation exchange capacity is a single index of fertility.

Gopalaswamy (1961) observed a high cation exchange capacity for <u>kari</u> soils of Kerala and attributed this to a high content of organic matter and the probable presence of illitic and montmorilloritic clay in them.

According to Jaskowski (1964) significant positive correlation existed between available magnesium and soil particles 0.02 mm on the one hand and pH on the other; available magnesium showed a significant negative correlation with hydrolytic acidity.

Lefebvre-Drouet (1966) observed that pH of the extractant solution did not affect exchange capacity or the sum of $Ca^{++} + Mg^{++} + Na^{+} + K^{+}$. Exchange capacity was related to the type and amount of clay and organic matter. Amount of aluminium extracted varied with pH of the extractant.

Nhung Mai Thimy and Ponnamperuma (1966) reported that the acidity of the aerobic soils can be attributed to the presence of aluminium and ferric sulphates and sometimes free sulphuric acid.

Brauner and Catani (1967) suggested that the addition of calcium carbonate decreased both exchangeable aluminium and the exchangeable acidity content. Exchangeable aluminium does not constitute the only source of soil acidity.

Pionke and Corey (1967) found that KCl exchangeable aluminium was related to pH whereas non-exchangeable acidic aluminium was found to be related to organic matter.

Alexander and Durairaj (1968) reported that cation exchange capacity in acid soils was negatively correlated to pH.

According to Kawaguchi and Kawachi (1969) during flooding and drying of the soil, corresponding movements of Fe^{++} into and away from the soil exchange complex occurred; some of the cations previously desorbed from the original soils, then returned to the exchange sites, the remainder were occupied by Al^{+++} and H^{+}.

Lavti <u>et al</u> (1969) reported that cation exchange capacity of soils are significantly correlated with clay, silt and organic matter content. Equation (CEC. 0.51 clay + 4.12 O.M) relating clay and organic matter with the CEC was found more suitable than that including the silt factor and can be used to predict the CEC of soils.

Sanchez (1969) found that the effect of organic matter on cation exchange capacity was greater than that of the mineral fraction in acid soils.

According to Thakur et al (1969) very small fractions of the total aluminium was found to be present in available form which increased with the increasing soil acidity. The various forms of aluminium were found as water soluble > exchangeable > mobile > extractable > total in sedentary and alluvial soils. There was highly significant correlation observed between mobile and extractable forms.

Kamprath (1970) observed that below pH 5.4, the buffer capacity of the soils was primarily due to exchangeable aluminium.

Martinez (1970) reported that values for extractable Al ranged from 0.8 to 100 ppm and that of soluble Al ranged from 0 - 36 ppm. There was no correlation between soluble and extractable aluminium or between soluble Al and soluble Fe. Exchangeable Al was significantly correlated with pH.

Nemeta et al (1970) suggested that the calcium and magnesium concentration increased with increasing quantities of exchangeable calcium and magnesium regardless of the soil texture.

Saini (1970) found that in salt affected coastal alluvial soils, sodium chloride releases aluminium which may cause the phosphorus deficiency symptoms.

Tandon (1970) reported that fluoride extractable aluminium is proposed as an index of phosphorus retention characteristic of soils.

According to Vintila (1970) exchangeable aluminium content of the soil varies according to pH and clay content. In surface horizons, in all oligobasic soils and in those with pH $\leq$ 5.0 potentially toxic amount of aluminium occur (78 mg al/100 g soil).

Janik (1971) reported that EDTA extracted magnesium was more highly correlated with pH, $CaCO_3$, content, exchangeable calcium and organic matter content than $CaCl_2$ extracted magnesium.

Singh (1971) suggested that the total exchange capacity increased with the proportion of silt and clay.

Dixit and Lal (1972) reported that an increase in exchangeable sodium percentage was accompanied by a marked decrease in hydraulic conductivity.

Nemeth and Grimme (1972) found that the cation exchange capacity of clay fraction of B horizons of soils low in organic matter content decreased with decreasing pH of the soils.

Wright and Foss (1972) suggested that correlation coefficients of clay and organic matter with cation exchange capacity for coastal plain Ap horizon were 0.90 and 0.76 respectively and 88 per cent of the variability in cation exchange capacity could be attributed to these components.

Ananthanarayana <u>et al</u> (1973) reported that calcium is found to have a positive significant correlation with electrical conductivity while magnesium has a positive relationship with pH and organic carbon.

Ghosh <u>et al</u> (1973) found that the <u>kari</u> soils of Kerala have low amount of calcium and magnesium.

Krishnamoorthy <u>et al</u> (1973) reported that the acid soils of Tamil Nadu are found to be poor in bases especially calcium, magnesium and potassium.

Sreedevi Amma and Aiyer (1974) reported that kari soils had the highest cation exchange capacity among the different acid rice soil types of Kerala and the content of exchangeable potassium was fairly high in kari, karapadom and kayal soils of Kuttanad.

Organic carbon and C/N ratio

Nair (1945) found that the important feature of the kari soils of Kerala was their high content of organic matter. According to him, the organic matter, exchangeable hydrogen, pH and C/N ratio are interrelated and have a direct bearing on their low fertility status.

Pearsall (1950) observed that the reducing conditions prevailing in water-logged soils accelerate ammonification as a result of which nitrogen escapes from the soil and the oxidation of carbonaceous materials is at a very low pace and thus the C/N ratio of the soil widens.

According to Lucas and Davis (1961) the C/N ratio of very acid organic soil is 60 to 1 and medium acid organic soil is 30 to 1.

Premanathan and Durairaj (1966) reported that there was a close relationship between organic carbon and loss on ignition.

Dolman and Buol (1967) found that organic soils have extremely low pH and high C/N ratios.

Koshy (1970) reported that the ratio of C to N in 4 typical Kerala soils ranged from 12.17 per cent in a submerged rice soil to 23.67 per cent in _kari_ soil.

Chibba and Sekhon (1973) reported that organic carbon was positively related with the content of N, K, Fe, Mn, Zn and Cu.

Ghosh _et al_ (1973) found a high percentage of organic carbon (2.28 to 7.1 per cent organic carbon) in Thottappally _kari_ soils and Kattampally swamp soils.

Micronutrients

Hosoda (1942) showed that the addition of 100 ppm Fe did not show any toxicity.

Ishizuka _et al_ (1961) noticed that 0.1 ppm Fe in the culture solution increased the yield, up to 10 ppm Fe had no influence and concentrations above 10 ppm reduced the yield of paddy.

Jaffery (1961) reported that when "healthy reducing conditions" are established in flooded top soil, part of ferric, manganic and other compounds is mobilized and may accumulate in layers under the reduced puddled top soil.

Mandal (1961) observed that the presence of organic matter accelerated reduction of Fe in water-logged soils.

Nhung Wai Thimy and Ponnamperuma (1966) suggested that active Fe and total S are ecologically important constituents of acid sulphate soils. Toxicity of flooded acid sulphate soil to rice was due to excess of Al and Fe.

Muresana et al (1968) found that Fe content is greater in the deep strata than in the surface strata of some genetic types of soil from Banat.

Breemen (1969) reported that the equilibria between ferric and ferrous iron are governed largely by ill-defined ferric oxides.

Motomura (1969) suggested that ferrous iron in flooded soil condition occur in various forms, water soluble, exchangeable, active, inactive and non-extractable form. He concluded that the adsorption of Fe^{++} produced under reduced condition changes the colloidal structure of the soil and results in decreased porosity and permeability.

Motomura and Yokoi (1969) reported that the addition of organic matter increased the amount of water soluble, exchangeable, active, inactive and non-extractable Fe^{++}.

According to Anderson and Jenne (1970) free iron oxides are associated with clay minerals.

Collins and Buol (1970) reported that under acid or slightly acid conditions the oxidation of both Fe^{++} and Mn^{++} was slow.

Martinez (1970) found that values for extractable Fe was 2.0 to 16.8 ppm and values for soluble Fe was 2.0 to 28.0 ppm in Argentinian soils. There was no correlation between soluble Al and soluble Fe.

Gangwar et al (1971) reported that in loam, sandy loam and fine sandy loam developed from silty alluvium and loamy alluvium the available Fe was about 18 ppm and decreased with increasing coarseness of texture except in the poorly drained coarse sands of the lower horizons which had the highest available Fe contents.

According to Chibba and Sekhon (1973) available Fe tended to decrease with depth.

Ghosh et al (1973) reported that in kari soils of Kerala Fe and Zn were present in fairly high amount.

Takkar et al (1973) found that Fe contributes 2.6 to 9.0 per cent of the total acidity.

Zinc

Schroo (1959) suggested that Zn deficiency in acid soils are generally associated with low soil Zn content. Lucas and Davis (1961) and Jackson et al (1967) reported the same.

Afusoaie and Murasu (1967) found that liming increased Zn mobility to a certain level.

Bandyopadhya and Adhikari (1968) reported that the total Zn is about 26 times the average value of extractable Zn in soil. A positive correlation existed between extractable Zn and total Zn.

Follett and Lindsay (1970) reported that there was a high correlation between organic matter and available zinc.

Navrot and Gal (1971) suggested that Zn is more strongly bound to montmorillionite type of clay.

According to Lindsay (1972) high levels of organic matter in the upper horizon of soil are believed to be important in keeping Zn more available in the surface horizon of soils. He reported that EDTA extractable Zn decreased sharply with depth in the profile. He also stated that Zn^{++} activity decreases 100 fold for each unit increase in pH.

Matt (1972) reported that the total and extractable Zn in soil were increased with increased acidity, finer texture and higher organic matter content.

According to Balakrishna Rao <u>et al</u> (1973) compared to neutral or alkaline soils, the acid soils fixed less amount of Zn and the availability of this ~~natural~~ nutrient is considered to be high.

Chibba and Sekhon (1973) reported that available Zn is maximum in surface soil.

<u>Copper</u>

Peech (1941) reported that the decrease in acidity for any given level of Cu reduced the availability, when measured either chemically or by total Cu absorbed by plants. Piper (1942) recorded the same data.

Harmer (1946) suggested that the soils of high organic matter such as peat soils, the increase in acidity, the greater will be the relative response to Cu.

Frank (1952) found that copper is more soluble in acid conditions and total Cu in a soil does not indicate the Cu available to plants.

Afusoaie and Muraru (1967) suggested that liming decreased copper mobility.

According to Bandhyopadhya and Adhikari (1968) total copper was about 70 times the average value of extractable Cu. They also found that exchangeable Cu varied from 0.25 to 0.53 ppm in rice soils of West Bengal.

Muresanu et al (1968) reported that the Cu contents were higher at arable layer.

Badhe et al found that there was a significant negative correlation between pH and available copper and a significant positive correlation between organic carbon and available Cu.

Chhibba and Sekhon (1973) reported that available Cu is maximum in surface soil.

Manganese

According to Motomura (1964) microbial action seems to be an important mechanism for the occurrence of manganese sediments in paddy soils.

AfusouiE and Muraru (1967) reported that liming decreased Mn mobility.

Bandhyopadhya and Adhikari (1968) found that the average value of total Mn was 10 times the average value of extractable Mn and a positive correlation exist between total and extractable manganese.

Muresanu et al (1968) suggested that Mn contents are greater in the arable layer.

According to Collins and Buol (1970) under acid or slightly acid conditions the oxidation of Mn^{++} was slow.

EL-Sherif et al (1970) reported that content of Mn was higher in alluvial than in saline-alkali soils. All forms of Mn were positively correlated with clay content and negatively correlated with exchangeable sodium and total soluble salts. They also reported that the distribution of various forms of Mn followed a general trend of decrease downward throughout the profiles of marine alluvial origin.

Mithyantha and Perur (1970) found that with few exceptions the ratio of Fe to Mn in surface soil samples is 1.5 indicating a probable Fe deficiency and Mn toxicity.

Badhe et al (1971) reported that there exist a significant negative correlation between pH and available manganese.

Singh (1971) found that in submerged paddy soils with pH ranging from 6.0 to 8.6, available form of manganese increased with decreasing pH. Mn availability increased by application of sulphates, $FeSO_4$ and sucrose.

Gotoh and Patrick (1972) suggested that between pH 6 and 8, conversion of insoluble soil Mn to the water-soluble and exchangeable form increased with decreases in Eh and pH.

Lakshmanan et al (1972) reported that correlations were found between water soluble and exchangeable Mn and organic carbon and clay content.

Mahapatra and Kibe (1972) suggested that rainfall was the most important factor affecting available Mn which also decreased with increasing pH and C.E.C.

Chhibba and Sekhon (1973) reported that available Mn tended to decrease with depth.

MATERIALS AND METHODS

MATERIALS AND METHODS

The soils used in the investigation were collected from the fields of 3 cultivators. Totally 3 profiles were collected, from Vettikaripadom, Mathurpadom and Mathurvadakke padom in 3 different locations. Profiles were dug and horizons marked and examined for morphological features according to the F.A.O.System. The description and morphological features are presented in Table No.I to III. Composite soil samples from each horizon were collected, using a chromium plated steel sampling implement thoroughly mixed and put separately in polythene 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. The clods in the dried samples were broken with a wooden mallet, sieved through a 2 m.m plastic sieve and stored in 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 was again recorded one week after, maintaining the water level. 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. Electrical conductivity

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

3. Cation-exchange capacity

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 percent 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 Piper (1950) with the difference that ferrous ammonium sulphate was used instead of ferrous sulphate.

0.5 g of the soil passed through 80 m.m 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%) 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 (1958) 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 ($CuSO_4.5H_2O$) 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 - 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 has 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. <u>Analysis of Hydrochloric acid extract</u>

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, 1962.

(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 paper 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) Total magnesium

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) Total iron

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% aqueous solution
(4) Conc. sulphuric acid

Evaporated 20 ml of the HCl extract in a porcelain basin. Added 10 ml of conc. 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 a 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 ml of 0.1 N $KMnO_4$ = 0.008 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, 1962 using Bray No.2 as the extractant instead of Bray No.1.

Reagents

1. Bray No.2: 0.03 Normal NH_4F in 0.1 normal HCl.

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

3. Stannous chloride: 10 g $SnCl_2 \cdot 2H_2O$ 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 up to 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 filtrate 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 (1962) 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 up to 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 were estimated volumetrically by the method described by Yuan (1959).

To 10 g air dry soil contained in a beaker 25 ml 1 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 HCl 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.

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^o.

(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°.

TABLE I

SOIL DESCRIPTION

I. Information on the site

(a) Profile number : I S.K.Panicker

(b) Soil name : Kuttanad soil (Karapadom)

(c) Higher category classification : Entisol

(d) Date of examination : 16-3-1974

(e) Author : G. Santhakumari

(f) Location : Punnapra village - Vettikkaripadam, Near coast 2½ ~~metres~~ miles east of sea

(g) Elevation : 1 to 3 feet below sea level

(h) Land form

- (i) Physiographic position : Waterlogged area
- (ii) Surrounding land form : Vembanad lake
- (iii) Microtopography : Flat

(i) Slope : Level

(j) Vegetation : Paddy. Puncha crop from september to March. II crop being taken as a trial.

TABLE I

(continued....)

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

Rainfall : 2700 mm

II. <u>General information on the soil</u>

(a) Parent material : Mixed silty alluvium

(b) Drainage : Poorly drained

(c) Moisture condition in profile : Wet

(d) Depth of ground water : 77 cm

(e) Presence of surface stones rock out crops : 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. <u>Brief description of the profile</u>

Karapadom soil containing fairly good amount of organic matter especially in deeper layers. Colour ranging from dark brown to black. Acidic in reaction. Increased salinity due to salt water inundation during certain parts of the year. Texture ranges from clay to loamy sand.

TABLE I

(continued.....)

IV. Profile description

	1	2	3
(a) Depth in cm	0-15	15-49	49 and below
(b) Colour			
(i) Moist	10 YR 2/1 black	10 YR 3/1 Very dark grey	10 YR 2/1 Black
(ii) Dry	2.5 Y 3/2 Very dark greyish brown	10 YR 3/2 Very dark greyish brown	2.5 Y 3/2 Very dark greyish brown
(c) Mottlings	Nil	Nil	Nil
(d) Texture	Clay	Loamy sand	Loamy sand
(e) Structure	Structureless	Structureless	Structureless
(f) Consistence			
(i) Wet	Slightly sticky	Non-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 cemented
(i) Pores	Discontinuous	Discontinuous	Discontinuous
(j) Content of rocks & mineral fragments	Nil	Nil	Nil

TABLE I

(continued...)

(k) Content of mineral nodules	Nil	Nil	Nil
(l) Pans	Nil	Nil	Nil
(m) Carbonates/ salts	Nil	Nil	Nil
(n) Roots	Abundant	None	None
(o) Boundary	Wavy not clear		
(p) pH	5.3 Acid	4.5 Strongly acid	3.2 Very strongly acid

TABLE II

SOIL DESCRIPTION

I. Information on the site

(a)	Profile number	:	II. M.S.N.Panicker
(b)	Soil name	:	Kuttanad soil (Karapadom)
(c)	Higher category classification	:	Entisol
(d)	Date of examination	:	16-3-1974
(e)	Author	:	G. Santhakumari
(f)	Location	:	Nedumudi Village, Mathurpadom
(g)	Elevation	:	1 to 3 feet below sea level
(h)	Land form		
	(i) Physiographic position	:	Waterlogged area
	(ii) Surrounding land form	:	Vembanad lake
	(iii) Microtopography	:	Flat
(i)	Slope	:	Nil
(j)	Vegetation	:	Paddy
(k)	Climate	:	Tropical humid climate with wet and dry periods
	Rainfall	:	2700 mm

TABLE II

(Continued..)

II. <u>General information on the soil</u>

(a)	Parent material	:	Mixed silty alluvium
(b)	Drainage	:	Poorly drained
(c)	Moisture condition in profile	:	Wet
(d)	Depth of ground water	:	80 cm
(e)	Presence of surface stones rock out crops	:	Nil
(f)	Evidence of erosion	:	Nil
(g)	Presence of salt and alkali	:	Moderate with seasonal fluctuations.
(h)	Human influence	:	Cultivated area

III. <u>Brief description of the profile</u>

Karapadom soils containing fairly good amount of organic matter especially in deeper layers. Colour ranging from dark brown to black. Acidic in reaction. Increased salinity due to salt water inundation during certain parts of the year. Texture ranges from clay to silt.

TABLE II

(continued...)

IV. Profile description

	1	2	3
(a) Depth in cm	0-15	15-58	58-75
(b) Colour			
(i) Moist	10 YR 2/2 Very dark brown	10 YR 2/2 Very dark brown	10 YR 2/1 Black
(ii) Dry	10 YR 4/3 Dark brown	2.5 Y 4/4 Olive brown	10 YR 3/2 Very dark greyish brown
(c) Mottlings	Yellow mottlings present in all layers		
(d) Texture	Silt	Clay	Clay
(e) Structure	Structureless	Structureless	Structureless
(f) Consistence			
(i) Wet	Slightly sticky	Non 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 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	Nil	Nil	Nil
(n)	Roots	Abundant	None	None
(o)	Boundary	Waxy not clear		
(p)	pH	4.9 Strongly acid	3.5 Very strongly acid	2.9 Very strongly acid

TABLE III

SOIL DESCRIPTION

I. Information on the site

(a)	Profile number	:	III. M.Govinda Panicker
(b)	Soil name	:	Kuttanad soil (Karapadom)
(c)	Higher category classification	:	Entisol
(d)	Date of examination	:	16-3-1974
(e)	Author	:	G.Santhakumari
(f)	Location	:	Mathurvadakke padom
(g)	Elevation	:	1 to 3 feet below sea level
(h)	Land form		
(i)	Physiographic position	:	Waterlogged area
(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

TABLE III

(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 : 60 cm

(e) Presence of surface stones and rocks Outcrops : No stones and rocks

(f) Evidence of erosion : Nil

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

(h) Human influence : Cultivated area

III. Brief description of the profile

Karapadom soil containing fairly good amount of organic matter especially in deeper layers. Colour ranging from dark brown to black. Acidic in reaction. Increased salinity due to salt water inundation during certain parts of the year. Texture ranges from loam to silty loam.

TABLE III

(continued....)

IV. Profile description

		1	2	3
(a)	Depth in cm	0-16	15-36	36-57
(b)	Colour			
	(i) Moist	10 YR 3/1 Very dark grey	2.5 Y 3/0 Very dark grey	10 YR 2/1 Black
	(ii) Dry	10 YR 4/3 Dark brown	10 YR 3/2 Very dark greyish brown	10 YR 3/2 Very dark Greyish brown
(c)	Texture	Loam	Silty loam	Silty loam
(d)	Structure	Structureless	Structureless	Structureless
(e)	Consistence			
	(i) Wet	Slightly sticky	Non sticky	Non sticky
	(ii) Moist	Firm	Friable	Friable
	(iii) Dry	Hard	Hard	Hard
(f)	Cutans	Nil	Nil	Nil
(g)	Cementation	Weakly cemented	Weakly cemented	Weakly cemented
(h)	Pores	Discontinuous	Discontinuous	Discontinuous
(i)	Content of rocks and mineral fragments	Nil	Nil	Nil

TABLE III

(Continued...)

(j)	Content of mineral nodules	Nil	Nil	Nil
(k)	Pans	Nil	Nil	Nil
(l)	Carbonates/ salts	Nil	Nil	Nil
(m)	Roots	Abundant	None	None
(n)	Boundary	Wavy not clear		
(o)	pH	3.2 Strongly acid	3.2 Strongly acid	3.8 Strongly acid

RESULTS

RESULTS

I. Physical properties

1. Mechanical composition

The results of the mechanical analysis of the soil samples are presented in Table IV.

From the data obtained, it can be seen that the texture of the soils are clay, loamy sand, silt and silty loam. Maximum percentage of coarse sand (59.3 and 59.2 per cent) was recorded in the middle and lowest layer of Vettikaripadom profile (Profile I). In Mathurpadom profile (Profile II) the percentage of coarse sand was very low and it ranges from 2.8 to 3 per cent. In Mathurvadakke padom profile (Profile III) a maximum percentage (20.8 per cent) of coarse sand was observed in the top layer and the minimum percentage (5.0 per cent) was noticed in the lowest layer.

The percentage of fine sand varies from 19.0 to per cent, 33.4 to 49.5 per cent and 47.5 to 50.6 per cent for Vettikaripadom, Mathurpadom and Mathurvadakke padom profiles respectively. Maximum value of fine sand (50.6 per cent) was recorded for the middle layer of Mathurvadakke padom profile and minimum value (19.0 per cent) was recorded for the top layer of Vettikaripadom profile.

Table IV Mechanical composition of soil

Sample No	Location	Profile No.	Depth cm	Percentage on oven dry basis			
				Coarse sand	Fine sand	Silt	Clay
1.	Vettikaripadom	I	0-15	34.4	19.0	5.5	39.0
2.	,,		15-49	59.2	23.6	8.0	6.0
3.	,,		49 and below	59.3	24.1	9.0	7.5
4.	Mathurpadom	II	0-15	2.8	33.4	47.5	11.0
5.	,,		16-58	3.0	49.5	7.2	36.7
6.	,,		58-75	2.9	39.3	12.0	41.5
7.	Mathurvadakke padom	III	0-16	20.9	47.5	13.0	13.5
8.	,,		16-36	9.2	50.6	21.0	16.5
9.	,,		36-57	5.0	48.7	37.0	3.5

MECHANICAL COMPOSITION OF SOIL AS A FUNCTION OF DEPTH

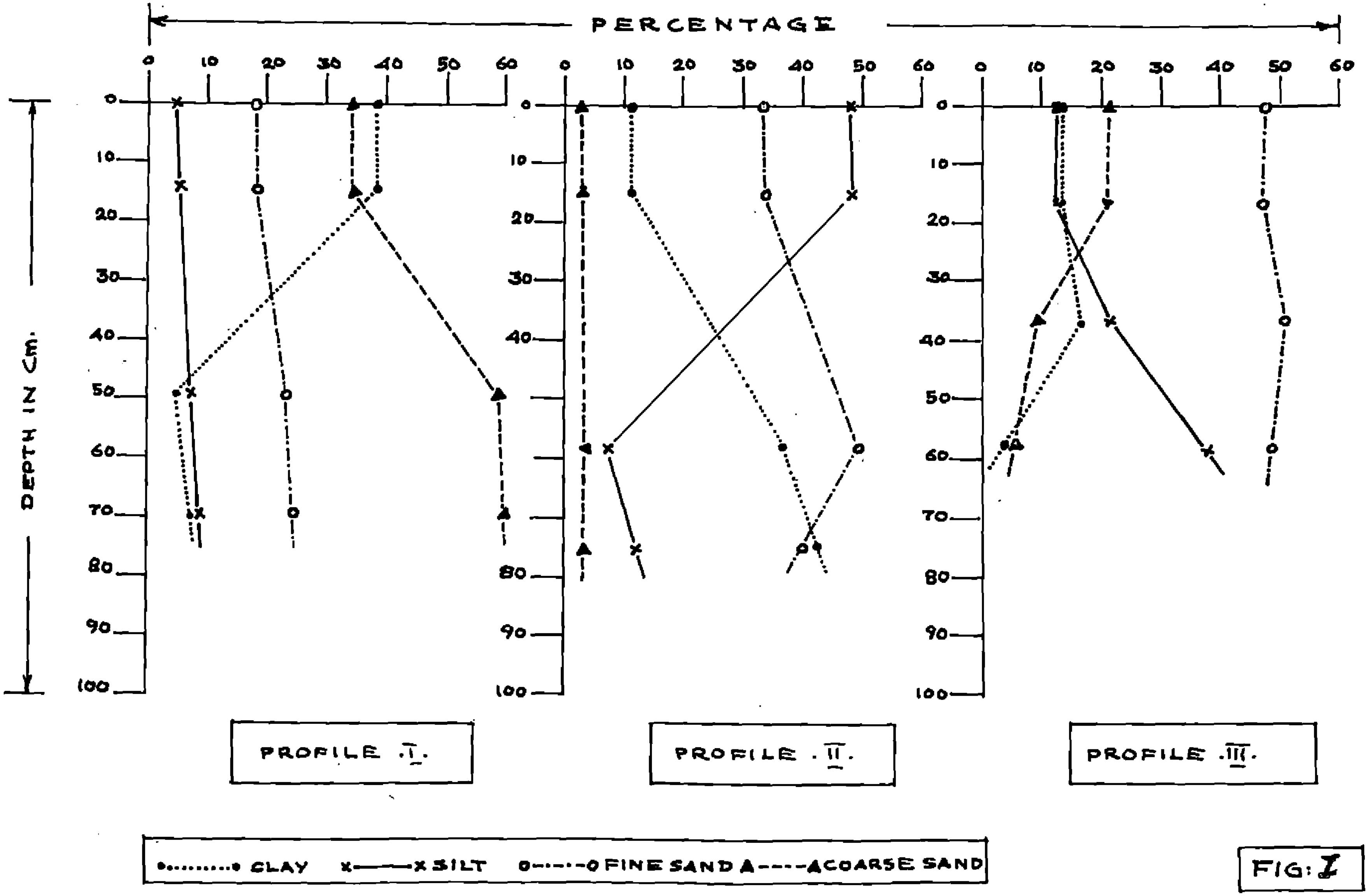


FIG: I

The range of variation for silt was from 5.5 to 47.5 per cent, the minimum being recorded in the surface layer of Vettikaripadom and maximum for the surface layer of Mathurpadom.

The content of clay ranged from 6.0 to 39.0 per cent, 11.0 to 41.5 per cent and 3.5 to 16.5 per cent for the soil samples of Vettikaripadom, Mathurpadom and Mathurvadakke padom profiles respectively. Minimum percentage (3.5 per cent) was obtained for the lowest layer of Mathurvadakke padom profile and the maximum percentage (41.5 per cent) was obtained for the lowest layer of Mathurpadom profile.

The content of coarse sand, fine sand and silt increased with increase in depth for the Vettikaripadom profile. The percentage of coarse sand decreased with increase in depth and the percentage of silt increased with increase in depth in the Mathurvadakke padom profile. However, in the Mathurpadom profile, the percentage of clay increased as depth increased. There is no definite pattern in distribution of clay in the various horizons in Vettikaripadom and Mathurvadakke padom profile.

II. Single value constants

The data obtained for single value constants are presented in Table V.

Table V Physical properties of soil

Sample No.	Location	Profile No.	Depth cm	Absolute specific gravity	Apparent density	Pore space %	Maximum water holding capacity %	Volume expansion %	Moisture % on oven dry basis
1.	Vettikaripadom	I	0-15	3.19	1.09	49.23	47.52	6.66	4.21
2.	,,		15-49	2.82	1.36	37.66	28.02	2.93	1.11
3.	,,		49 and below	2.94	1.32	40.60	31.38	3.43	1.38
4.	Mathurpadom	II	0-15	3.31	0.98	53.08	56.14	4.50	5.49
5.	,,		15-58	3.45	1.06	49.28	49.07	4.68	4.47
6.	,,		58-75	3.68	0.99	55.25	64.20	14.06	7.67
7.	Mathurvadakkepadom	III	0-16	2.99	1.12	45.94	42.33	3.66	2.26
8.	,,		16-36	3.55	1.08	53.07	52.69	7.84	4.99
9.	,,		36-57	3.93	1.00	57.10	66.24	17.44	9.10

1. Absolute specific gravity

The value for absolute specific gravity increased with increase in depth for the Mathurpadom and Mathurvadakke padom profiles. The middle layer of Vettikaripadom had the minimum value (2.82) and the sub surface layer of Mathur vadakke padom had the maximum value (3.93).

2. Apparent density

Minimum value (0.98) for apparent density was recorded by the surface layer of Mathurpadom profile and maximum value (1.36) was recorded by the middle layer of Vettikaripadom profile. In Mathurvadakke padom profile, apparent density decreased with increase in depth, but for the other two profiles, there is no definite trend of its distribution.

3. Pore space

The pore space for different layers lies within the limits of 37.66 and 57.10 per cent and the minimum value was recorded by the middle layer of Vettikaripadom and the maximum value was recorded by the lowest layer of Mathurvadakke padom profile and in this profile the percentage of pore space increased with increase in depth and there is no definite pattern of increase or decrease as the depth increases in other two profiles.

4. Maximum water holding capacity

The values for maximum water holding capacity ranged from 28.02 to 47.52 per cent, 49.07 to 64.20 per cent and 42.33 to 66.24 per cent for Vettikaripadom, Mathurpadom and Mathurvadakke padom profiles respectively. The percentage of maximum water holding capacity increased with increase in depth in Mathurvadakke padom profile.

5. Volume expansion

Values for volume expansion ranged from 2.93 to 6.66 per cent, 4.50 to 14.06 per cent and 3.66 to 17.44 per cent for Vettikaripadom, Mathurpadom and Mathurvadakke padom respectively. The percentage of volume expansion increased with increase in depth for Mathurpadom and Mathur vadakke padom. Minimum values (2.93 per cent) was recorded for the middle layer of Vettikaripadom and maximum value (17.44 per cent) was recorded for the lowest layer of Mathurvadakke padom.

6. Moisture

Maximum percentage (9.10 per cent) of moisture was observed in the lowest layer of Mathurvadakke padom profile and minimum percentage (1.11 per cent) was observed in the middle layer of Vettikaripadom profile.

III. Chemical properties

The chemical properties of the soils are presented in Tables VI to IX.

1. Soil reaction

pH of the wet soil varied from 5.2 to 5.9, 2.9 to 4.9 and 3.2 to 3.8 for Vettikaripadom, Mathurpadom and Mathurvadakke padom respectively. In Mathurpadom profile, as the depth increases, the pH decreases. pH of dried soils varied from 2.3 to 4.9 in soil:water system (1:2.5) and 2.6 to 4.0 in soil:0.01 M $CaCl_2$ solution (1:2.5). In both cases the pH increased as depth increased in Vettikaripadom profile as the pH decreased as the depth increased in Mathur padom profile.

2. Conductivity

Conductivity values ranged from 0.70 to 3.90, the minimum value was recorded for the top layer of Mathurpadom and the maximum value was recorded for the lowest layer of Mathurvadakke padom.

3. Organic carbon

In Vettikaripadom profile, the content of organic carbon decreased as the depth increased while the reverse was the case in the Mathurvadakke padom profile. Organic carbon values ranged from 0.79 per cent, recorded for the

Table VI Soil reaction

Sample No.	Location	Proffile No.	Depth cm	Wet soil in 1:2.5 soil water suspension		Dry soil in 1:2.5 soil water suspension	In 0.01 M $CaCl_2$	Conductivity m.mhos/cm
				fresh	week after			
1.	Vettikari padom	I	0-15	5.3	4.5	3.2	3.4	0.85
2.	,,		15-49	5.2	3.2	3.5	3.7	1.60
3.	,,		49 and below	5.9	4.6	4.9	3.9	1.10
4.	Mathurpadom	II	0-15	4.9	4.6	4.0	4.0	0.70
5.	,,		15-58	3.5	3.8	3.6	3.6	0.80
6.	,,		58-75	2.9	2.9	2.4	2.7	1.50
7.	Mathurvadakke padom	III	0-16	3.2	3.4	2.9	3.0	1.30
8.	,,		16-36	3.2	2.9	2.3	2.6	3.00
9.	,,		36-57	3.8	3.5	2.6	2.8	3.90

middle layer of Mathurpadom profile to 4.09 per cent recorded for the top layer of Vettikaripadom profile.

4. Total nitrogen

Values for nitrogen percentage varied from 0.12 to 0.30, 0.12 to 0.23 and 0.11 to 0.17 for Vettikaripadom, Mathurpadom and Mathurvadakke padom respectively. In Vettikaripadom and Mathurpadom profile, surface layer contains higher percentage of nitrogen, whereas in Mathur vadakke padom profile, the lowest layer contains higher percentage of nitrogen.

5. C/N ratio

Maximum value of 18.33 for C/N ratio was recorded for the middle layer of Vettikaripadom profile and the minimum value of 6.58 was recorded for the middle layer of Mathurpadom profile. In Mathurvadakke padom profile the value of C/N ratio increases as the depth increases.

6. Organic matter

The percentage of organic matter varied from 1.36 to 7.05, the minimum was recorded for the middle layer of Mathurpadom and maximum was recorded for the top layer of Vettikaripadom profile.

7. Available phosphorus

Maximum value of 162.8 kg/ha for available P was

Table VII Organic carbon, nitrogen, C/N ratio and organic matter

Sample No.	Location	Profile No.	Depth cm	Organic carbon %	Nitrogen %	C/N ratio	Organic matter %
1.	Vettikari padom	I	0-15	4.09	0.30	13.63	7.05
2.	,,		15-49	2.21	0.12	18.33	3.81
3.	,,		49 and below	1.96	0.13	15.07	3.38
4.	Mathurpadom	II	0-15	2.49	0.23	10.82	4.29
5.	,,		15-58	0.79	0.12	6.58	1.36
6.	,,		58-75	2.04	0.13	15.69	3.52
7.	Mathurvadakke padom	III	0-16	1.33	0.14	9.50	2.29
8.	,,		16-36	1.83	0.11	16.63	3.15
9.	,,		36-57	3.01	0.17	17.70	5.19

VARIATION OF ORGANIC CARBON AND NITROGEN AS A FUNCTION OF DEPTH

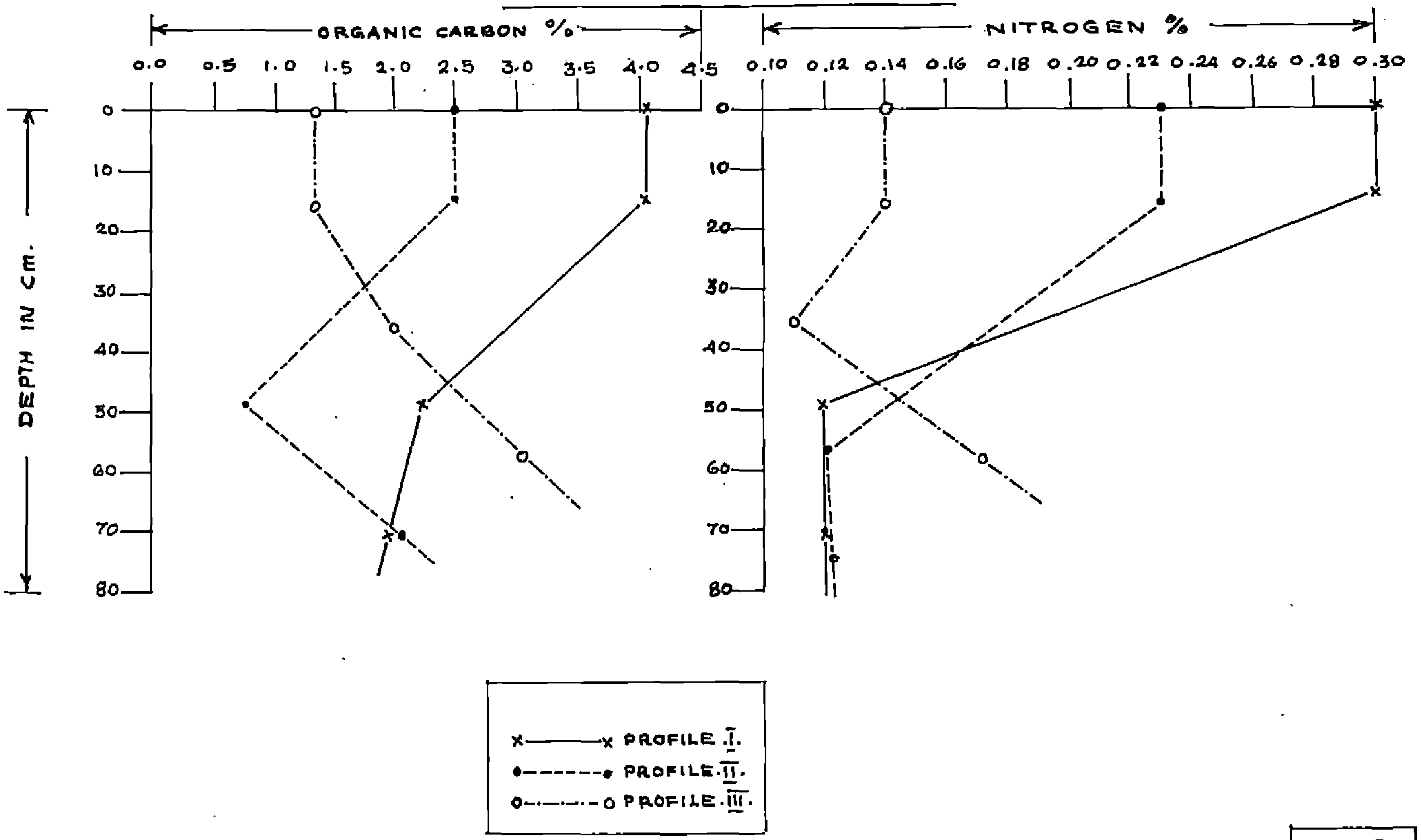


FIG: 2

recorded by the lowest layer of Mathurvadakke padom profile and the minimum value of 8.0 kg/ha was recorded by the middle layer of Vettikaripadom profile.

8. Total phosphorus

The range of total phosphorus percentage in the profiles studied ranged from 0.008 to 0.053, the minimum value was recorded for the middle layer of Vettikaripadom profile and the maximum value was recorded for the middle layer of Mathurvadakke padom profile. Mathurpadom profile has equal values in all the 3 layers for total phosphorus percentage.

9. Total potassium

Percentage of potassium varied from 0.030 to 0.146; 0.095 to 0.335 and 0.071 to 0.407 for Vettikaripadom, Mathurpadom and Mathurvadakke padom profiles respectively. In Mathurpadom and Mathurvadakke padom profiles, the percentage of potassium increases with increase in depth, whereas in the Vettikaripadom profile, potassium content decrease as the depth increases.

10. Total calcium

Maximum percentage (0.396 per cent) of calcium was recorded by the lowest layer of Mathurvadakke padom profile and minimum percentage (0.182 per cent) was recorded

Table VIII Available and total P, total K, Ca and Mg
(On oven dry basis)

Sample No.	Location	Profile No.	Depth cm	Available P kg/ha	Total P %	Total K %	Total Ca %	Total Mg %
1.	Vettikari padom	I	0-15	64.4	0.052	0.146	0.229	0.083
2.	,,		15-49	8.0	0.008	0.051	0.222	0.030
3.	,,		49 and below	18.1	0.020	0.030	0.182	trace
4.	Mathur padom	II	0-15	17.4	0.011	0.095	0.233	0.032
5.	,,		15-58	21.0	0.011	0.158	0.231	0.032
6.	,,		58-75	17.8	0.011	0.335	0.194	0.227
7.	Mathur vadakke padom	III	0-16	11.2	0.010	0.071	0.224	0.031
8.	,,		16-36	80.8	0.053	0.189	0.284	0.315
9.	,,		36-57	162.8	0.033	0.407	0.396	0.946

by the lowest layer of Vettikaripadom profile. The calcium content of the Vettikaripadom and Mathurpadom profile decreased with increase in depth and it increased as depth increases in Mathurvadakke padom profile.

11. Total magnesium

The percentage of magnesium showed variation from trace to 0.946 the minimum (trace) was recorded for the lowest layer of Vettikaripadom profile and maximum (0.946 per cent) was recorded for the lowest layer of Mathurvadakke padom profile. In Vettikaripadom and Mathur padom profiles, the content of magnesium decreased as depth increased whereas in Mathurvadakke padom profiles, it increased as the depth increased.

12. Iron oxide

Fe_2O_3 content in the different horizon showed a range of 1.94 per cent in the middle and lowest layer of Vettikaripadom to 6.79 per cent in the lowest layer of Mathurvadakke padom profile.

13. Aluminium oxide

Maximum percentage (16.55 per cent) and minimum percentage (1.86 per cent) for aluminium oxide were recorded for the top layer and lowest layer of Mathurpadom respectively. The A1203 content increased with increase

Table IX Fe_2O_3, $Al2O_3$ and Sesquioxides

Sample No.	Location	Profile No.	Depth cm	Fe_2O_3 %	$Al2O_3$ %	Sesquioxides %
1.	Vettikaripadom	I	0-15	4.04	5.96	10.00
2.	,,		15-49	1.94	3.56	5.50
3.	,,		49 and below	1.94	4.31	6.25
4.	Mathurpadom	II	0-15	4.20	16.55	20.75
5.	,,		15-58	5.01	9.49	14.50
6.	,,		58-75	3.14	1.86	5.00
7.	Mathurvadakke padom	III	0-16	3.55	4.70	8.25
8.	,,		16-36	5.01	11.99	17.00
9.	,,		36-57	6.79	12.21	19.00

in depth for the Mathurvadakke padom profile and it decreased with increase in depth for Mathurpadom profile.

14. Sesquioxides

The percentage of sesquioxides ranged from 5.5 to 10.0, 5.00 to 20.75 and 8.25 to 19.0 for Vettikaripadom, Kathurpadom and Mathurvadakke padom profiles respectively. In Mathurpadom profile, the percentage of sesquioxide decreased as depth of the profile increased, while in Mathurvadakke padom profile, it increased as depth increased.

IV. Cation exchange capacity and exchangeable cation

The values for cation exchange capacity and exchangeable cations are presented in Table X.

1. Exchangeable sodium

The exchangeable sodium content of the different horizons ranged from 0.07 to 2.57 meq./100 g, the minimum was recorded by the top layer of Mathurpadom profile and the maximum percentage was recorded by the lowest layer of Mathurvadakke padom profile. In Mathurvadakke padom profile the percentage of exchangeable sodium increased as the depth increased.

2. Exchangeable potassium

The range of variation of exchangeable potassium was 0.01 to 0.58 meq/100 g, the minimum was recorded by

Table X Cation exchange capacity and exchangeable cations

Sample No	Location	Profile No.	Depth cm	Exchangeable cations meq/100 g							Total exchangeable ions	C.E.C
				Na	K	Ca	Mg	H	Al	Fe		
1.	Vettikari padom	I	0-15	0.32	0.16	6.10	3.00	4.98	8.12	0.12	17.82	22.80
2.	..		15-49	1.11	0.01	2.25	2.96	1.86	4.97	0.10	11.50	13.36
3.	..		49 and below	0.65	0.14	3.28	trace	0.98	3.08	0.23	7.38	8.36
4.	Mathur padom	II	0-15	0.07	0.58	5.17	3.00	0.61	7.05	0.06	15.93	16.54
5.	..		15-58	2.37	0.43	3.80	1.74	0.44	8.03	0.04	16.41	16.85
6.	..		58-75	0.30	0.05	6.00	3.30	5.53	8.40	0.50	18.55	24.08
7.	Mathurvadakke padom	III	0-16	0.40	0.02	4.49	2.48	1.36	7.41	0.04	14.84	16.20
8.	..		16-36	0.68	0.01	6.02	2.88	2.29	6.64	0.06	16.19	18.48
9.	..		36-57	2.57	0.53	6.40	2.50	2.98	5.00	0.08	17.10	20.08

the middle layer of Vettikaripadom and Mathurvadakke padom profile and the maximum was recorded by the top layer of Mathurpadum profile. In Mathurpadom profile, content of exchangeable ~~sodium~~ Potassium decreased with the increase in depth.

3. Exchangeable calcium

The content of exchangeable calcium in the different horizons examined ranged from 2.25 to 6.40 meq/100 g. The middle layer of Vettikaripadom profile recorded the minimum and the lowest layer of Mathurvadakke padom profile recorded the maximum value. Exchangeable calcium increased as the depth increased in Mathurvadakke padom profile.

4. Exchangeable magnesium

The minimum and maximum value for exchangeable Mg varied from trace to 3.30 meq/100 g, the minimum being recorded by the lowest layer of Vettikaripadom and maximum was recorded by the lowest layer of Mathurpadom profile.

5. Exchangeable hydrogen

The values for exchangeable hydrogen varied from 0.98 to 4.98, 0.44 to 5.53 and 1.36 to 2.98 meq/100 g for Vettikaripadom, Mathurpadom and Mathurvadakke padom respectively. In Mathurvadakke padom profile, there is a gradual increase in the content of exchangeable hydrogen with the increase in depth of the profile.

6. Exchangeable aluminium

The maximum and minimum values for exchangeable aluminium for the soils under study varied from 8.40 and 3.08 meq/100 g, the maximum was recorded in the lowest layer of Mathurpadom and minimum was recorded in the lowest layer of Vettikaripadom profile. In Vettikaripadom and Mathurvadakke padom profile, the content of exchangeable aluminium gradually decreased with increase in depth, whereas in Mathurpadom profile, it increased as depth increased.

7. Exchangeable iron

Maximum value (0.50 meq/100 g) for exchangeable iron was obtained for the lowest layer and minimum value (0.04 meq/100 g) was obtained for the middle layer of Mathurpadom profile. In Mathurvadakke padom profile, the content of Fe increased as depth increased.

8. Total exchangeable metal ions

In Vettikaripadom profile, maximum value (17.58 meq/100 g) was recorded for the surface layer and minimum (7.38 meq/100 g) was recorded for the lowest layer and it decreases with increase in depth. In Mathurpadom profile, value ranged from 15.93 to 18.55 meq/100 g, the minimum was recorded for the top layer and maximum was recorded for the lowest layer and it increased as depth increases. In Mathurvadakke padom profile, its value varied from 14.84 to 17.10 meq/100 g the minimum and maximum was recorded in top and lower layers respectively and it increased as depth increased.

9. Cation exchange capacity

The cation exchange capacity varied from 8.36 to 22.80, 16.54 to 24.08 and 16.20 to 20.08 meq/100 g for Vettikaripadom, Mathurpadom and Mathurvadakke padom respectively. In Vettikaripadom profile, the C.E.C. decreased as depth increased and it increased in Mathurpadom and Mathur vadakke padom profile as the depth increased.

V. Micronutrients

The data obtained for micronutrient analysis are furnished in Table XI.

1. Available zinc

In Vettikaripadom profile, Zn content varied from 0.3 to 10.5 ppm, the maximum was recorded in the top layer and minimum was recorded in the lowest layer and its content decreased with increase in depth. In Mathurpadom

Table XI Micronutrients (Available)

Sample No.	Location	Profile No.	Depth cm	Zn ppm	Cu ppm	Fe ppm	Mn ppm
1.	Vettikari padom	I	0-15	10.5	0.16	156.0	18.0
2.	,,		15-49	4.5	0.48	33.2	30.0
3.	,,		49 and below	0.3	0.16	112.0	38.0
4.	Mathurpadom	II	0-15	2.0	0.20	82.0	6.0
5.	,,		15-58	1.0	0.52	32.0	6.0
6.	,,		58-75	6.0	0.32	140.8	75.0
7.	Mathurvadakke padom	III	0-16	2.5	0.26	212.0	25.0
8.	,,		16-36	Nil	0.26	142.8	100.0
9.	,,		36-57	6.5	0.16	120.0	116.0

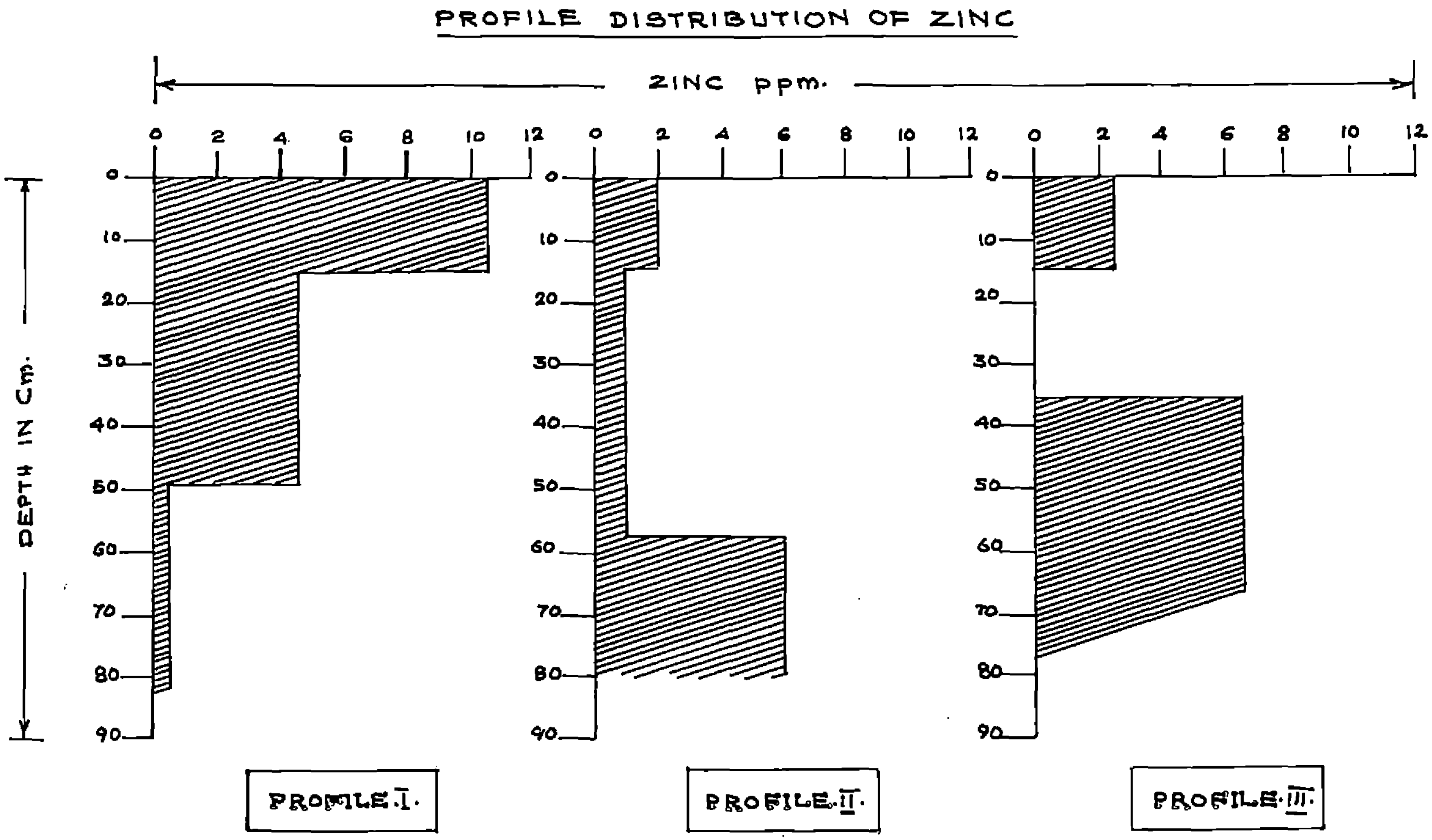
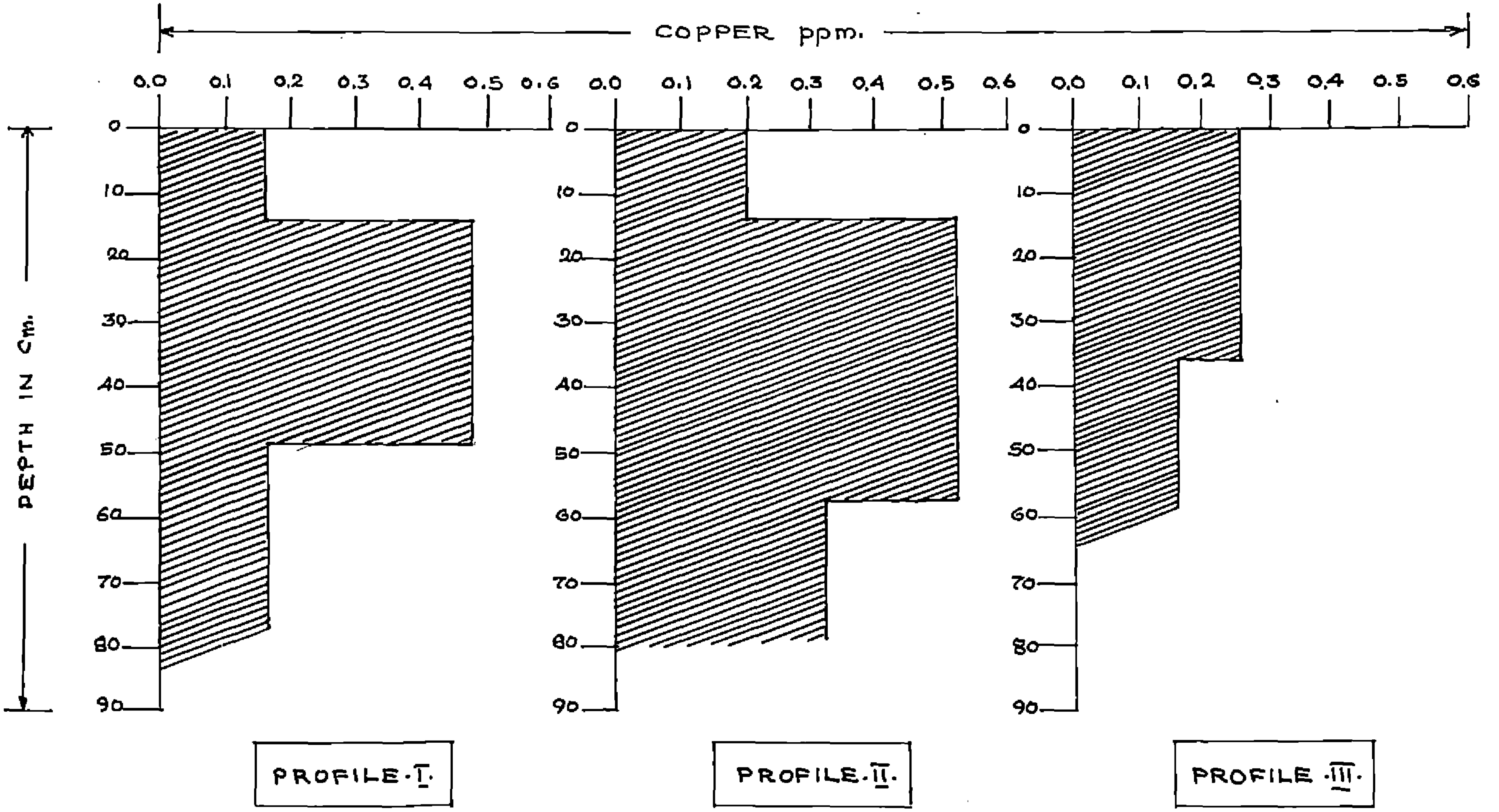

PROFILE DISTRIBUTION OF ZINC
ZINC ppm.
0
2
4
6
8
10
12
DEPTH IN Cm.
0
10
20
30
40
50
60
70
80
90
PROFILE I.
PROFILE II.
PROFILE III.

FIG: 3



PROFILE DISTRIBUTION OF COPPER

FIG: 4

PROFILE DISTRIBUTION OF AVAILABLE IRON

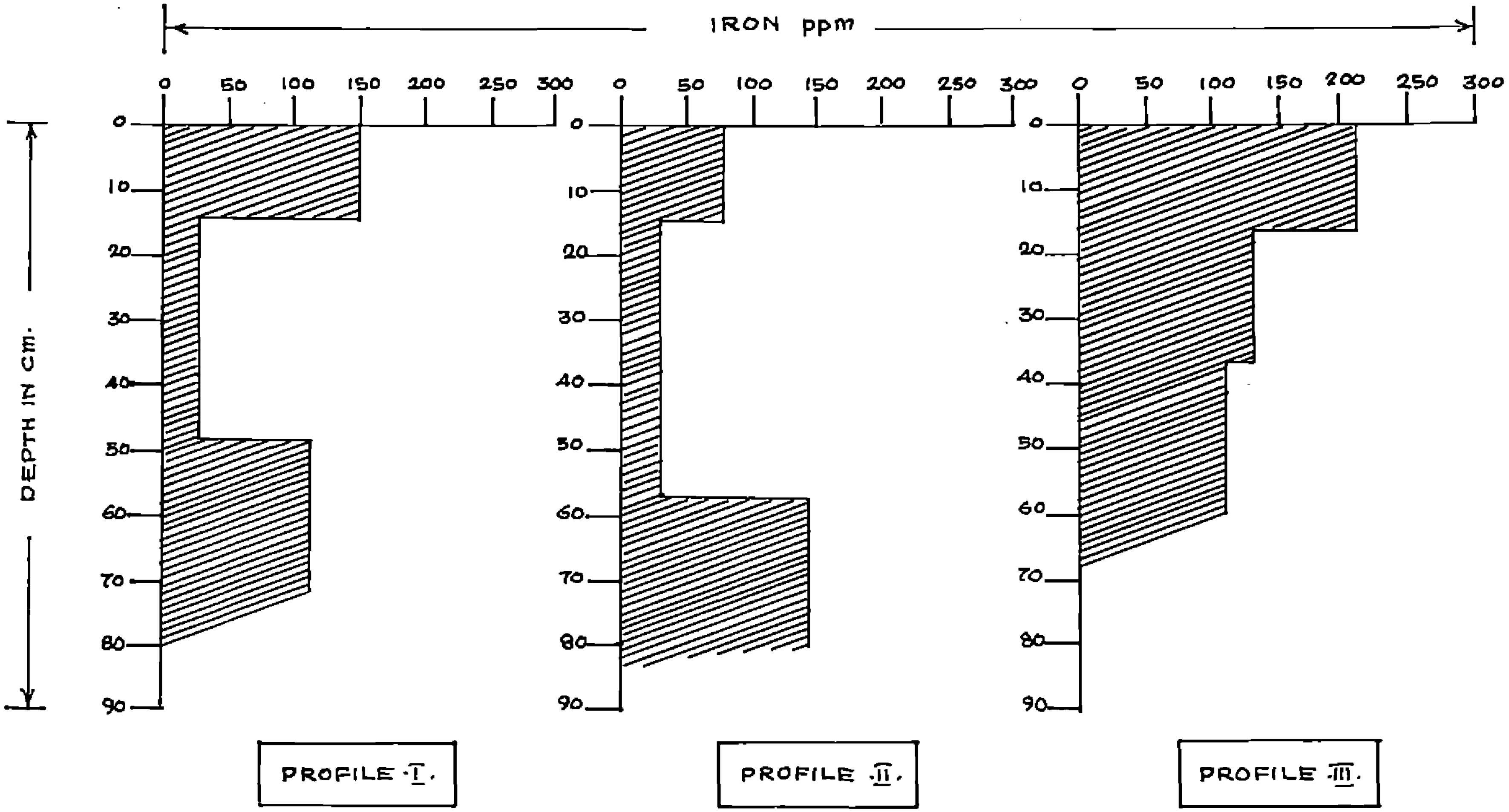


FIG: 5

PROFILE DISTRIBUTION OF AVAILABLE MANGANESE

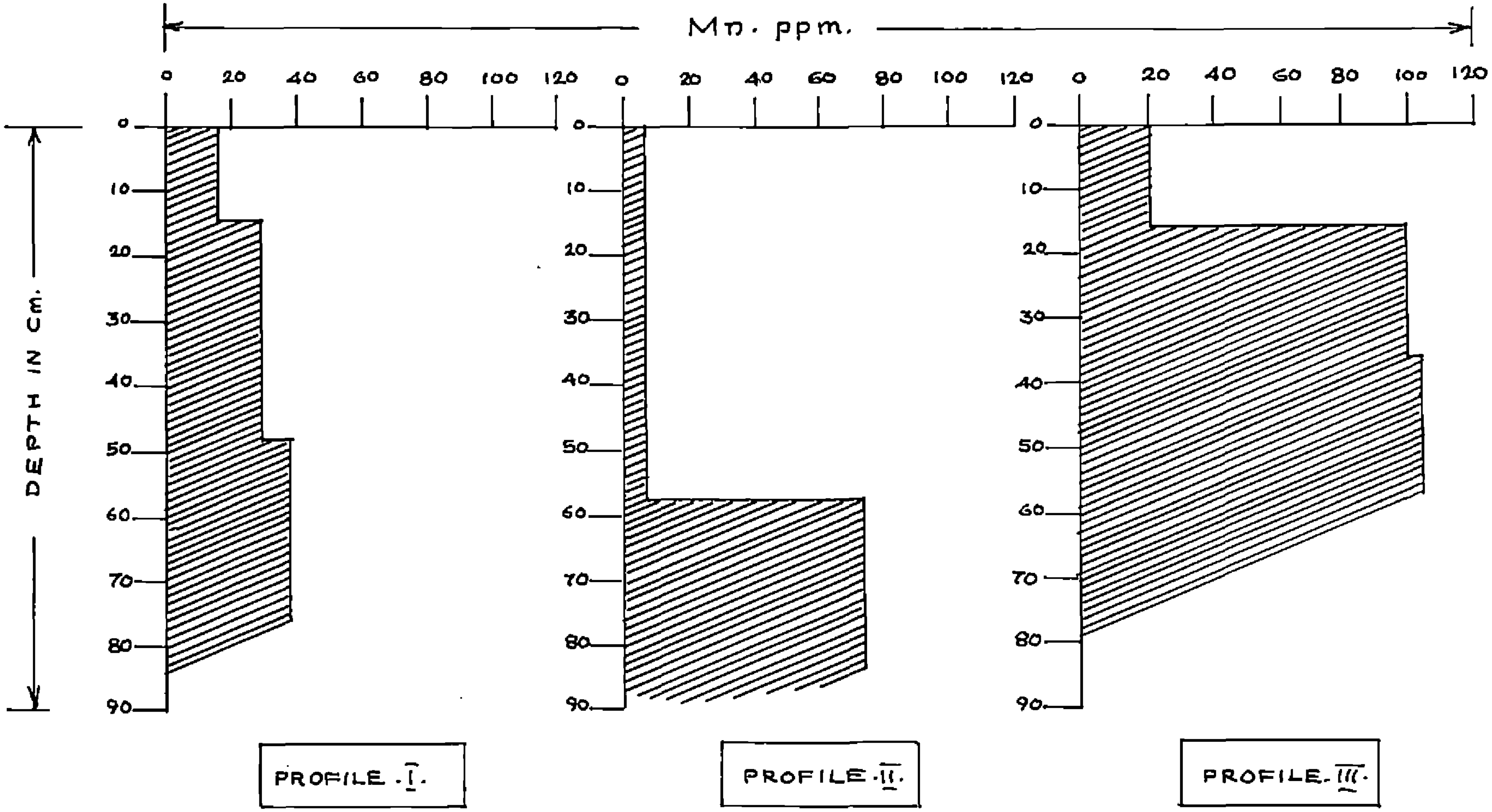


FIG: 6

profile, it varied from 1.0 to 6.0 ppm maximum and minimum was recorded in the lowest and middle layer respectively. In Mathurvadakke padom profile maximum value was recorded for the top layer and it was absent in the middle layer.

2. Available copper

Cu content of the soils under study ranged from 0.16 to 0.52 ppm, the minimum was recorded for the top and lowest layer of Vettikaripadom profile and lowest layer of Mathurvadakke padom profile and maximum value was recorded for the middle layer of Mathurpadom profile.

3. Available iron

The value for available Fe varied from 33.2 to 156.0 ppm, 32.0 to 140.8 ppm and 120.0 to 212.0 ppm for Vettikaripadom, Mathurpadom and Mathurvadakke padom profiles respectively. In Mathurvadakke padom profile, available Fe decreased as depth increases and in other two profiles, there is no general trend for its distribution.

4. Available manganese

Content of Mn varied from 6.0 to 116.0 ppm, minimum was recorded for the top and middle layer of Mathurpadom profile and maximum was recorded for the lowest layer of Mathurvadakke padom profile. In Vettikaripadom and Mathurpadom and Mathurvadakke padom, the content of Mn increased as depth increased.

DISCUSSION

DISCUSSION

In Kuttanad which comprises an area of 875 sq.km there are three major soil types namely the karapadom (river-borne alluvium) the kayal (reclaimed lake bed) and kari (peaty) soils. Of these, the karapadom soils are the most intensively cultivated since regions belonging to this soil type are comparatively more elevated in the otherwise generally low lying region. The karapadom soils constitute an area of 41,000 hectares, while the kayal soils in the lower Kuttanad region and the kari soils which were reclaimed only in recent years, constitute an area of about 8000 hectares and 20,000 hectares respectively. The three profiles studied have been selected on a west to east axis starting from the western boundary of Kuttanad region near Punnapra.

Morphological characteristics of the profiles studied

The first profile collected from near Punnapra contains fairly high amounts of organic matter, the colour varying from 10 YR 2/1 to 10 YR 3/1, acidic in reaction with acidity decreasing in lower layers and texture changing from clay to loamy sand. Moderately increased salinity in lower horizons indicate inundation with salt water.

The profile collected from the second location, east of the first location, has a colour ranging from 10 YR 2/2 to 10 YR 2/1, showing yellow mottlings, pH decreasing in lower layers and texture varying from silt to clay. The greater degree of salinity in the upper horizons and increasing salinity in lower horizons compared to the first profile may be due to the greater influence from the adjoining Vembanad lake.

The third profile from Mathurvadakke padom, which is farther to the east of the second profile has a colour variation from 10 YR 2/1 to 10 YR 3/1 and a textural variation from loam to silty loam. pH decreases and salinity increases with depth. But both salinity and pH increase and decrease respectively to a greater extent as we progress on the eastern direction from Punnapra towards the central regions of Kuttanad.

Classification of soils according to seventh approximation

These soils come under the order Entisols and they are permanently saturated with water and have dominant hues in all horizons that are around 10 Y which change on drying. Since cultivation of a crop of rice is being done during one season only, they may be considered as partially saturated with water and are artificially drained. Their textures ranged from loamy sand to clay.

Since they are recent formation formed under water and submerged during the greater part of the year, they come under the suborder Aquant. Since these soils have a mean annual temperature of more than 0°C and have at least 8 per cent clay and 3 per cent organic matter in all sub-horizons between 20 and 50 cm and have textures of loamy, very fine sand or finer textures in some horizons below the Ap, they can be placed under great group "Hydraaquants". Since subgroups are not developed, the fitting is limited to great group.

These karapadom soils are thus classified under

Order - Entisol

Suborder - Aquant

Great group - Hydraaquant

Physical properties

Data on the mechanical analysis and textural classification indicate that the surface soils are either clayey, silty or loamy. The pattern in the distribution of clay in the three profiles is interesting. It has been observed that the texture changes from a clayey to loamy sand in the first profile and in the latter two profiles, the texture changes from silt to clay and loam to silty loam with increase in depth.

The first profile, which is from a location very near to the sea, presents evidences for deposition of clayey alluvium on a sandy matrix, during the several thousands of years. It is possible that relative migration of clay with depth since initial surface deposition, has not started manifesting ~~showing~~ itself as the surface layer has still a higher content of clay than the lower layers.

In the latter two profiles a tendency for the texture to become more heavy with depth indicates possible clay migration down the profile in view of the more frequent inundation and drying up of the soils in these locations. It is interesting to note that logs of decomposed wood were dug up from the third horizon of the second and third profiles which lend support to the view that the Kuttanad area might have been originated by the submergence of a pre-historic forest by a violent landslide. The lower horizons of the latter two profiles (II and III profile) closely resemble the kari soils found in the northern end of Kuttanad region in Mundar (Vaikom taluk) and in the southern region of Kuttanad viz. in Thottappally near the coast. This suggests that while the kari soils are exposed in certain regions of Kuttanad like Ambalapuzha taluk, Vaikom and Sherthalai, it has been covered up by the deposition of river-borne alluvium carried by the four major rivers emptying into it.

The water holding capacity is higher in the first layer of the first profile and the lowest layers of the second and third profile and it is highest in the second profile. This bears a close relationship with the texture and to a lesser extend to the organic matter content which is found to decrease with depth indicating the dominance of texture in determining the water holding capacity of these soils. This agrees with the result obtained by Janardhanan Nair _et al_ (1966).

The volume expansion is highest in the third profile which is richer in organic matter.

In the soils studied, the pore space varies from 37.66 to 57.1 per cent which agrees fairly well with the reported findings for the soils of _Kuttanad_ (Kurup, 1967).

The general trend for the apparent density is to increase with depth in the first two profiles studied. The upper horizon has distinctly lower values for the first two profiles while the converse is true for the third profile. This observation is supported by the results obtained for organic matter wherein also the first horizon of the first two profiles contain a higher percentage of organic matter while higher amounts of organic matter are observed only in the lowest layer of the third profile.

Absolute specific gravity gradually decreases with depth in the first profile and it increases with depth in the second and third profile. Absolute specific gravity varies according to the type of minerals and amount of organic matter present in the horizon. The horizons that have more organic matter have less specific gravity, since the specific gravity of organic matter is 1.2 to 1.7. The high values of specific gravity in the second and third profiles may be due to the presence of higher amounts of inorganic clay.

<u>Chemical properties</u>

Results of the present investigation indicate that the top layer of the second profile recorded a pH value of 4.0, while the top layer of the third profile recorded the lowest pH value of 2.9 with the surface layer of the first profile having a pH value of 3.2. Similar low pH values have been recorded for similar acid sulphate soils by Horn et al (1967). In the second and third profile, while the pH value decreases with depth, the reverse trend is observed in the first profile. This is mainly due to the increase in organic matter and finer fractions with depth in the second and third profiles. The pH of the fresh soils are found to be higher than the pH of the air-dried soils as is to be expected for water-logged soils (Dev and Sharma, 1971). There is considerable variation in the extent of decrease of pH of the soils from the different horizons on drying. The decrease in pH on drying is most marked in the first two profiles while it is least marked in the third profile which records very low pH values of 2.3 to 2.9 units. It is, however, very interesting to note that this shift in pH on drying is exhibited to a maximum by the surface horizons which are the one's subjected to alternate drying and wetting due to frequent letting in and letting out of water and cultivation. The acidity in Kuttanad soils, has largely been attributed to the production of free sulphuric acid by the oxidation of marcasites found in them (Subramoney, 1960). That the production of free sulphuric acid in the upper horizons is greater consequent to this oxidation by drying, emphasises the need for fractional application of lime in the management of these soils.

The conductivity in 1:2 soil-water extracts ranges from 0.70 to 3.90 mmhos/cm. Conductivity in these soils is a highly fluctuating index as the soils are subject to frequent inundation with salt water. Kurup and Aiyer (1973) observed maximum electrical conductivity during the summer months in these soils. Since the present samples were collected in

March, it is evident that salinity cannot be a hazard to rice cultivation in these soils.

The soils studied have relatively medium values for organic carbon. An examination of the results of the present study for Karapadom soils with the published results for the kari and kayal soils indicate that these soils have an organic matter content intermediate to that of kari and kayal soils (Kurup, 1967).

In the first profile, while the surface soils contain nearly twice the amount of organic matter present in the sub surface layers, in the second and third profiles the lowest layer contains 50 per cent more organic matter than the surface horizon. This reverse trend in the distribution of organic matter in the second and third profiles confirm the inference made earlier, that these profiles could have developed from parent materials rich in undecomposed wood ~~waters or~~ fossils, similar to the kari soils. Since the upper horizon of the first profile contains a greater amounts of organic matter than the lower sandy horizons, suggests that this profile may be comparatively of more recent origin than the other two profiles.

The pattern of distribution of nitrogen closely parallels the distribution of organic matter in the profiles, while with respect to C/N ratio, the pattern is slightly different. In the third profile, there is a close relationship between the organic matter content and the C/N ratio, while such a relationship is not found in the first and second profile. While in the first profile, there is a decrease in the organic matter with depth, an increase in the C/N ratio from the first to the second horizon and a decrease from the second to the third horizon is observed. In the second profile on the other hand, while a decrease in organic matter from the first to the second layer and an increase to a similar degree for the second and third layer is noticed. The slight variation in the trend observed between the organic matter and the C/N ratios may partly be due to the differences in the degree of humification of the organic matter. It has been observed in the present study that undecomposed logs as is encountered in <u>kari</u> soil profiles and reported earlier (Subramoney, 1960) are also observed in the lower layers of <u>Karapadom</u> soils. Detailed investigation on the distribution pattern of humic acid and fulvic acid in the various horizons together with studies on different forms of nitrogen may throw further light on the observed variations in the C/N ratio on one hand and organic matter and nitrogen on the other.

No clear-cut pattern in the depth-wise distribution of total K is observable in the 3 profiles. The content of total K is lowest in the third horizon of the first profile and highest in the third horizon of the third profile. These variations can partly be attributed to saline water inundation and their subsequent leaching by fresh water during the monsoon season. The differences observed are also partly due to the differences in the texture of the soils. It is well known that heavy textured horizons can retain potassium to a greater extent against the leaching action of water. In this context it is noteworthy that earlier studies conducted in this laboratory (Kurup, 1967; Sreedevi Amma and Aiyer, 1974) and elsewhere (Gopalaswamy, 1961) indicate the possible existence of illitic type of clay minerals in some of these soils.

There is no clear-cut pattern in the distribution of total and available P in the various horizons of these soils. Both total and available phosphorus are extremely low in these profiles. This is in agreement with findings of Pillai and Subramoney (1967) and Nair and Aiyer (1966) and Ghosh et al (1973).

While there is a decrease in the total magnesium and total calcium of the first profile, there is an increase with depth in both total calcium and total magnesium in the third profile. However in the second profile, both calcium and magnesium do not vary much with depth. In the third profile, there is an increase in calcium with depth, with a moderate increase in magnesium. This also points to the fact that regions represented by the third profile were probably subject to a greater degree of marine influence than the other areas studied and the high amount of magnesium found in the lower horizon of the third profile can, to a large extent, be attributed to the influence of salt water from the adjoining Vembanad lake.

In the case of sesquioxides, the pattern of distribution is found to be highly varying. While in the second profile there is an initial increase in total sesquioxides, aluminium oxides and iron oxides with increase in depth followed by a slight decrease in total sesquioxides and aluminium oxides, in the third profile there is a steady increase in the concentrations of sesquioxides and aluminium oxides and iron oxide with increase in depth. In the first profile, however there is a decrease from the first to the second horizon in respect of these constituents. It increases slightly with depth in the case of sesquioxides and aluminium and remains stationary in the case of Fe_2O_3. The lack of definite pattern in the distribution of these constituents which are the major parameters to decide the nature of clay only lends support to the view that there is a considerable degree of clay migration in the profile coupled with lateral transport and deposition of clay by the flood waters.

In all the three profiles, there is a close relationship between the variation in cation exchange capacity with the variation in clay content and organic matter. The cation exchange capacity, while it decreases in the first profile with depth, is found to increase with depth in the second and third profile. The dominant exchangeable cation in all these soils are exchangeable aluminium indicating the high degree of acidity in the soils. The values for exchangeable aluminium are much higher than the values for exchangeable hydrogen indicating the high degree of potential acidity in these soils.

The exchangeable calcium and magnesium status of these soils when compared with the reported values for <u>kari</u> and <u>kayal</u> soils reveal that these soils have an intermediate status with respect to these divalent cations.

The variation in exchangeable potassium closely parallels the values for total potassium. The high content of exchangeable sodium detected in the second horizon of the second profile and third horizon of the third profile lends support to the view that the latter two profiles are subject to a greater degree of marine influence.

Interesting pattern in the distribution of zinc is observed in these profiles. In all the profiles the surface soils are adequately supplied with zinc while in the first profile, there is a decrease in available zinc with depth, in the second and third profile, there is an initial decrease followed by an increase. This agrees with the result of Chibba and Sekhon (1973). According to Lindsay (1973) high levels of organic matter in the upper horizon of soils are believed to be important in making Zn more available in the surface horizon.

In the case of available copper in the first and second profile there is a 2 to 3 fold increase from the first to the second horizon and a subsequent decrease in the third horizon. In the third profile, however, there is a tendency for available copper to decrease from the second to third horizon. The surface layers appear to be adequately supplied with copper unlike the kayal soils which are reported to be highly deficient in this micronutrient. This confirms the result obtained by Chibba and Sekhon (1973). The available copper varied from 0.16 to 0.52 ppm which almost agrees with the results obtained by Bandyopadhya and Adhikari (1968).

The trend in the variation of available iron closely parallels the pH variation of the soil; unlike the kari soils wherein available iron level reaches toxic proportion (Kurup, 1967), these soils are only just adequately supplied with this nutrient.

Exchangeable manganese levels are very high in the second and third layers of the third profile. The critical limit of exchangeable manganese is 3.0 ppm and in all the horizons the level of manganese exceeds this limit.

It will be interesting to study in greater detail the depth-wise distribution of micronutrients - total and available - in these soils and work out the interrelationships amongst them as well as their relationship to soil chemical characteristics. Such a study will enlighten us further on the influence of organic matter, parent material, saline water inundation, and clay content in determining the relative availability of various micronutrient cations. In such a study, the relative contribution of such soil factors, if critically assessed, will give us methods to manipulate the availability of micronutrients cations without recourse to soil application of these nutrients.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study was made on the morphological and physico-chemical properties of 3 profiles of the karapadom soils of the Kuttanad region. The study revealed many salient features of karapadom soils. The main conclusions drawn from the results obtained are summarised as follows:

1. The soils can be texturally classified as clay, loamy sand, silt and silty loam. Maximum percentage of clay was recorded by the top layer of Vettikaripadom, lowest layer of Mathurpadom and sub-surface layer of Mathurvadakke padom profiles.

2. In Mathurpadom and Mathurvadakke padom absolute specific gravity increased with increase in depth and thereis no general trend in the value of apparent density.

3. Mathurpadom and Mathurvadakke padom profiles are strongly acidic when compared to Vettikaripadom which is situated on the western most boundary of Kuttanad near Punnapra.

4. Electrical conductivity increased as depth of the profile increased in Mathurpadom and Mathurvadakke padom profiles.

5. In the three profiles, the organic carbon varies from 0.79 to 4.09 per cent and nitrogen varies from 0.11 to 0.3 per cent. The carbon nitrogen ratio of the profiles varies from 6.58 to 18.33.

6. Upper horizons of Vettikaripadom and Mathurpadom and middle layer of Mathurvadakke padom show a higher content of P. In Mathurpadom and Mathurvadakke padom profiles, the lowest layers and in Vettikaripadom, the top layers have recorded the higher percentage of potassium.

7. The calcium and magnesium contents are highest in the Mathurvadakke padom profile where they increase with depth down the profile. In Vettikaripadom and Mathurpadom, calcium and magnesium decreased as depth increased.

8. The sesquioxides ratios are high in the surface layer of Vettikaripadom and Mathurpadom profile and in the lowest layer of Mathurvadakke padom profile.

9. The cation exchange capacity of the three profiles are fairly high. It varies from 8.36 to 24.08 meq/100 g.

10. Total exchangeable metal ions varied from 7.38 to 18.55 meq/100 g.

11. Micronutrient analysis showed that maximum available zinc content was recorded by the surface layer of Vettikaripadom, maximum available copper was recorded by the middle layer of Mathurpadom, maximum available iron was recorded by the surface layer of Mathurvadakke padom and maximum available manganese was recorded by the lowest layer of Mathurvadakke padom.

The karapadom soils are highly acidic and liming is very necessary for improving the productivity of these soils. The soils in general are highly deficient in phosphorus and potash and hence the application in sufficient quantities at proper time will increase the crop yields. Nitrogen content of these soils are not so low, but addition of this nutrient in sufficient quantity is essential for increased production. Calcium and magnesium are present in fairly good amount. Acidity of this soil is mainly due to the presence of high amount of aluminium and hydrogen. With respect to micronutrients, iron, manganese and zinc are present in fairly good quantities, but copper content is below the critical limit for successful crop production.

REFERENCES

REFERENCES

Afusoaie, D. and Muraru, T.	1967	A study of trace element mobility (Mn, Mo, Cu, CO, Zn and B) in acid, limed soils. Biol. Abs. 51(19): 109869.
Ahamad, N.	1967	Seasonal changes and availability of P in swamp rice soils of north Trinidad. Trop. Agric. Trin. 44, 21-32. Soils and Ferti. Abs. 30(3): 223 (1621).
Albrecht, W.A. and Smith, G.E.	1952	Soil acidity as calcium (fertility) deficiency. Indian Soc.Soil Sci. Comm. II and Comm. IV Trans. 1: 119-135.
Alexander, M.T. and Durairaj, D.J.	1968	Influence of soil reaction on certain soil properties and availability of major nutrients in Kerala Soils. Agric. Res. J. Kerala 6: 15-18.
Allam, A.I., Pitts, G. and Hollis, J.P.	1972	Sulphide determination in submerged soil with an ion-selective electrode. Soil Sci. 114(6): 456-467.
Alway, F.J.	1914	Agricultural value and reclamation of Minnesota peat soils. The Univ. of Minnesota Agrl.Expt. Stn. Bull. 188.
A.O.A.C.		Official methods of analysis of the Association of official Agricultural Chemists, Washington, D.C. 9th Edn.

Ananthanarayana, R., Reddy, M.N., Mithyantha, M.S. and Perur, N.G.	1973	Status of available calcium, magnesium and sulphur in some acid soils of Mysore State. Symposium on acid sulphate and other acid soils of India held at Trivandrum in February 1973.
Anderson, B.J. and Jenne.	1970	Free-iron and manganese oxide content of reference clays. Soil Sci. **109**(3): 163-169.
Aslander, A.	1952	Standard fertilization and liming as factors in maintaining soil productivity. Soil Sci. **74**: 181-195.
Avnimelech Yoram	1971	Nitrate transformation in peat. Soil Sci. III: 113-118.
Badhe, N.N., Naphade, K.T. and Ballal, D.K.	1971	Status of available copper and manganese of soils from Bhandara district in Maharashtra. J. Indian Soc. Soil Sci. **19**(2):175-178.
Badiger, M.K. and Rao, B.V.V.	1969	Studies on fixation of potassium in soils of Mysore State. Mysore J. agric. Sci. **3**: 251-253.
Balakrishna Rao, M.S., Mithyantha Rao, and Perur, N.G.	1973	Studies on fixation of zinc in typical acid soils of Mysore State. Symposium on acid sulphate and other acid soils of India, held at Trivandrum in February 1973.
Bandyopadhya and Adhikari, M.	1968	Trace element relationships in rice soils of West Bengal. Soil Sci. **105**

Bear, F.E. and Toth, S.J. 1948 Influence of calcium on availability of other cations. Soil Sci. 65: 69-74.

Bhattacharyya, A.K. 1971 Mechanism of the formation of exchangeable ammonium nitrogen immediately after water logging of rice soils. J. Indian Soc. Soil Sci. 19(2): 209-213.

Brauner, J.L. and Catani, R.A. 1967 Variation in the amount of exchangeable aluminium in soil, influenced by lime application. AN ESC SUPER AGR LUIZ QUEIROZ UNIV SAO PAULO 24: 57-69.

Breemen, N.Van 1969 The effect of ill-defined ferric oxides on the redox characteristics of flooded soils. Neth. J. agr. Sci. 17(4): 256-260.

Cervantes, O., Leon, A. and Marin, G. 1970 Relationship between pH aluminium and organic matter in some soils of Colombia. Revta Inst. Colomb. agropec. 5, 43-64 (Soils and Ferti. Abs. 34(1) 18.

Chandler, M.V. 1941 Phosphorus absorption by five Alabama soils by reaction, base saturation and free sesquioxides. J. Amer. Soc. Agron. 31: 1-12.

Chang 1960 Effect of fertiliser treatments on the exchangeable bases of low land paddy soils. Mem. Coll. Agr. Natl. Taiwan Univ. 5(4):11-18.

Chang, C. 1965 Availability of phosphorus in paddy soils. J. Sci. Soil Manure, Tokyo, 36, 90-94 (J) Soil Sci. Pl.Nutr. 11, No.5, 37. Soils and Ferti. Abst 29(3) 237 (1538).

Chang, S.C. and Feng, M.P.	1960	Exchangeable and non-exchangeable potassium in the main agricultural soils of Taiwan. Mem. Coll. Agr. Natl. Taiwan Univ. 5(4):54-63.
Chhibba, I.M. and Sekhon, G.S.	1973	Physico-chemical characteristics and nutrient availability in some acid soils of Kangra district. Paper presented in symposium on acid sulphate and other acid soils of India held at Trivandrum during February 1973.
Cholitkul, W. and Tyner, E.H.	1971	Inorganic phosphorus fractions and their relation to some chemical indices of phosphate availability for some low land rice soils of Thailand. Proceedings, International symposium on soil fertility evaluation, New Delhi. Indian Society of Soil Science (Soils and Ferti. Abs. 35(1):12 (76).
Collins, J.F. and Buol, S.W.	1970	Patterns of iron and manganese precipitation under specified Eh-pH condition. Soil Sci. 110(3): 157-162.
Coults, J.R.H.	1929	Single value soil properties, a study of the significance of certain soil constant II. Studies in Natal Soils. J. Agric. Sci. 19: 325-341.
Davis, L.E.	1935	Sorption of phosphates by non-calcareous Hawaiian soils. Soil Sci. 40: 129-158

Davies and Brian, E.	1971	A statistical comparison of pH values of some english soils after measurement in both water and 0.01 M $CaCl_2$. Soil Sci. Soc. Amer. Proc. 35 (4) 551-552
De Datta, S.K., Moomaw, J.C., Racho, V.V. et al	1966	Phosphorus supplying capacity of low land rice soils. Proc. Soil Sci. Soc. Amer 30, 613-617.
Dev, G. and Sharma, H.C.	1971	Effect of continued submergence on soil reaction, electrical conductivity and oxidisable matter. J. Indian Soc. Soil Sci. **19**(4): 369-373.
Dixit, V.K. and Lal, R.N.	1972	Effect of exchangeable sodium on hydraulic conductivity of soils. J. Indian Soc. Soil Sci. **20**(1): 1-5.
Dolman, J.D. and Buol, S.W.	1967	A study of organic soils (Histosols) in the tide water region of North Carolina. Tech. Bull. N. C. agric. Exp. Stn. 181, pp. 52.
Donahue, R.S.	1958	An introduction to soils and plant growth, Prentice Hall Inc. New York.
Donskikh, I.N.	1966	Forms and mobility of Nitrogen in the main types of peat soils of North Western RSFSR. Zap. leninger. Sel'-Khoz Inst. **105**(1): 86-92.
Elgabaly, M.M. and Elghamry, W.M.	1970	Air permeability as related to particle size and Bulk density in sand systems. Soil Sci. **110**(1): 10-12.

El-Sherif, S., El-Leboudi, Hamdi, H. and Ismail, A.	1970	Status of manganese in some calcareous soils of the U.A.R. UAR J. Soil Sci. 10(2):235-248.
El-Sherif, S., El-Laboud , Metwally, S. et al.	1970	Status of manganese as affected by physical and chemical features of some alluvial and marine-alluvial soils in U.A.R. J. Soil Sci. Un. Arab. Repub. 10, 129-141.
F.A.O. (~~Rome~~)	1970	Guide lines for soil profile description. Soil survey and fertility branch. Rome.
Follelt, R.H. and Lindsay, W.L.	1970	Correlation between organic matter and available zinc. Colo. Agr. Exp. Sta.; Tech. Bull. 110.
Frank, A.Gilbert.	1952	Copper in the soil. Advances in Agronomy. Vol.3. 1952.
Gangwar, M.S., Mann, J.S. and Sharma, A.N.	1971	Note on the distribution of total and available iron in soil profiles of Nainital foot hills. Indian J. Agrl. Sciences. 41(12): 1120-1121.
Ghosh, S.K., Das, D.K. and Deb, D.L.	1973	Physical, chemical and minerological characterisation of kari soils from Kerala. Paper presented in the symposium of acid sulphate and other acid soils of India held at Trivandrum in February 1973.
Gopalaswamy, V.	1961	Studies on the soils of Kuttanad. Part III. The nature of clay minerals present. Agric. Res. J. Kerala. 1: 65-69.

Gotoh, S. and Patriol, W.H.(jr.)	1972	Transformation of manganese in a water logged soil as affected by Eh and pH. Soil Sci. Soc. Amer. Proc. 36(5): 738-742.
Grant, C.J.	1969	Development of acidity in acid sulphate soils. Pedologist 13: 86-95.
Grist, D.H.	1953	Rice. Longmans, London
Gupta, R.N. and Narin, B.	1971	Investigation on some physical properties of alluvial soils of Uttar Pradesh related to conservation and management. J. Indian Soc. Soil Sci. 19(1): 11-22.
Hanna, W.J.	1964	Methods for chemical analysis of soil in 'Chemistry of soils', second edition. (Edited by Firman E.Bear, Reinhold publishing corporation).
Harmer, P.M.	1946	Soil Sci. Soc. Amer. Proc. 10, 284-294.
Holmen, H.	1968	Afforestation of peat lands in Sweden, classification and site research. Proc. 3rd Inst. Peat Congr. 371-377.
Horn, M.E., Hall, V.L., Chapman, S.L. and Wiggins, M.M.	1967	Chemical properties of the coastal alluvial soils of the Republic of Guinea. Soil Sci. Soc. Amer. Proc. 31: 108-114.

Hosoda, K.	1942	Studies on improvement of soils aggregated by mine pollutions. V. Influence of copper, arsenic, zinc, lead and iron upon rice yields and the effects of improving materials against the damage. *J. Sci. Soil and manure, Japan.* **16**(11): 459-466.
Ishizuka, Y., Tanaka, A. and Fujita, O.	1961	Inorganic nutrition of rice plants. 6. Effect of iron, manganese and copper level in culture solution, on yields and chemical composition of the plant. *J. Sci. Soil and manure, Japan* **32**(3): 97-100.
Islam, A.	1970	Transformation of inorganic phosphorus in flooded soils under rice cropping. *Plant Soil* **33**(3): 533-544.
Iyer Narayana, K.R.	1928	*Depart. Agri. Travancore Bull.* 123, 126, 130.
Jackson, M.L.	1962	Soil chemical analysis, Asia Publishing House, Madras.
Jackson, T.L., Hay, J. and Moore, D.P.	1967	*Proc. of Amer. Soc. Hort. Sci.* **91**: 462-471.
James, O.Klemmedson and Hans Jenny.	1966	Nitrogen availability in California soils in relation to precipitation and parent material. *Soil Sci.* **102**(4): 215-222.
Janardhanan Nair, Y., Padmanabhan Nambiar, E. and Money, N.S.	1966	Studies on Keen-Raczkowski measurements and their relation to soil test values in cultivated soils of Kerala. *Agri. Res. J. Kerala.* **4**(1): 50-53.

Janik, V.	1971	Relationship between Mg, $CaCl_2$ and Mg EDTA values and the most important soil characteristics. Soils and Fert. Abst. 35(4) 371.
Jaskowski, Z.	1964	The correlation between available magnesium content and some properties of light textured soils. Pam Pulawski. 17, 129-140. Soils and Ferti. Abs. 29(4) 334 (2271).
Jeffery, J.W.O.	1961	Defining the state of reduction of a paddy soil. J. Soil Sci. 12(1): 172-179.
Joachims, A.W. and Kandiah, S.	1947	Studies on Ceylon soils XVII and XVIII. The physical and physico-chemical characteristics of the major soil types of Ceylon. Trop. agric. 103: 71-84.
Kabeerathumma, S.	1969	Effect of liming on exchangeable cations and availability of nutrients in acid soils of Kuttanad. M.Sc.(Ag.) Thesis, Kerala University.
Kadrekar, S.B.	1973	The study of acid soils of Maharashtra State with special reference to their potash content. Paper presented in the symposium on acid sulphate and other acid soils of India held at Trivandrum in February 1973.
Kamprath, E.J.	1970	Exchangeable aluminium as a criterian for liming leached mineral soils. Soil Sci. Soc. Amer. Proc. 34(2): 252-254.

Kanwar, J.S. and Grewal, J.S.	1966	Relationship between forms of soil potassium and particle size. J. Indian Soc. Soil Sci. 14, 221-225.
Kawaguchi, K. and Kawachi, T.	1969	Changes in the exchangeable cations in the course of drying of preliminary submerged soils. J. Sci. Soil manure Tokyo 40, 177-183 (J) Soils and Ferti. Abst. 34(5) 474 (3538).
Keen, A. and Rackzkowski.	1921	The relationship between clay content and certain physical properties of soils. J. agric. Sci. 11: 441-449.
Khanna, S.S. and Mahajan, K.K.	1971	A study of the behaviour of added phosphates in soils of variable physico-chemical properties. Proceedings on the International symposium on soil fertility evaluation. Indian Soc. Soil Sci. (1971). 725-736.
Koshy, M.M. and Brito-mutunayagam, A.P.A.	1965	The mechanism of phosphate fixation in soils and the nature of retained phosphate. Agric. Res. J. Kerala, 3(1):32-39.
Koshy, M.M.	1970	The chemical nature of organic complexes in Kerala Soils. Curr. Sci. 39: 353-354.
Koshy, M.M. and Thomas Varghese.	1971	Soils of Kerala. Fert. News. 16(11): 51-57.

Krishnamurthy, K.K., Mahalingam, P.K. and Kothandaraman, G.V.	1973	Physico-chemical properties of acid soils of Tamil Nadu. Paper presented in the symposium on acid Sulphat and other acid soils of India held at Trivandrum in February 1973.
Kuntze, H. and Leisen, E.	1970	Dynamics of potassium in loose low catena. *Soudesh gandev. Forsch.* **251**: 128-140.
Kurup, T.K.B.	1967	Fertility investigations on rice soils of Kuttanad, Kerala. M.Sc.(Ag.) Thesis, Kerala University.
Kurup, T.K.B. and Aiyer, R.S.	1973	Seasonal variations in soil reaction and soluble salt content of Kuttanad rice soils, Kerala State. *Agri. Res. J. Kerala.*
Lakshmanan, A.R., Bhavani Sankaran, N. Rajendran, G. *et al.*	1972	Preliminary studies on the available manganese content of alluvial soils of Thanjavur District. *Madras agric. J.* **59**(4): 224-230.
Lavti, D.L., Gandhi, A.P. and Paliwal, K.V.	1969	Contribution of clay and organic matter in the cation exchange capacity of Rajasthan soils. *J. Indian Soc. Soil Sci.* **17**(1): 71-74.
Lefebvre-Drouet, E.	1966	Exchangeable cations in various acid soils. *Annals. agron.* 17, 533-570. *Soils and Ferti. Abs.* **30**(3): 217 (1578).

Lesztak, V. and Darab, K.	1964	Soils of the Hansang region and their physical properties. Agrokem. Talajt. 13: 19-28.
Lindsay, W.L.	1972	Zinc in soils and plant nutrition. Advances in Agronomy, 24, 1972. 147-181.
Lucas, R.E. and Davis, J.E.	1961	Relationship of pH values of organic soils and availabilities of twelve plant nutrients. Soil Sci. 92: 177-182.
Mahapatra, I.C.	1968	Effect of flooding on soil reactions and mobilisation of various nutrients. J. Indian Soc. Soil Sci. 16(2): 149-153.
Mahapatra, A.R. and Kibe, M.M.	1972	Studies on the distribution and availability of micronutrients in Maharashtra soils. (1) Manganese. J. Indian Soc. Soil Sci. 20(1): 67-77.
Mandal, L.M.	1961	Transformation of iron and manganese in water logged rice soils. Soil Sci. 91: 121-126,
Martinez, M.E.C.	1970	Content of soluble and extractable iron and aluminium in some Argentinian soils and its relationship with pH. Revista de la Facultad de Agronomia J. Veterinaria 18: 85-90. Soils and Ferti. Abst 35(3): 247.
Matt K.John	1972	Influence of soil properties and extractable zinc on zinc availability. Soil Sci. 113(3): 222-227.

Mehta, P.C., Puntamkar, S.S. and Seth, S.P.	1971	Vertical distribution of phosphorus in the soils of Western Rajasthan. J. Indian Soc. Soil Sci. 19(4): 389-394.
Menon, P.K.R. and Sankaranarayanan, N.P.	1957	General characteristics of Indian black soils. Black soils of Finnis district. Ind. J. Agric. Sci. 27: 259-265.
Merchand, B.D.	1924	Some physiological properties of Transwaal soils. J. Agric. Sci. 14: 151-169.
Miller, F.	1966	Volume changes in Bulk density samples. Soil Sci. 102(5): 300-304.
Milton Fireman and Wadleigh, C.H.	1951	A statistical study of relationship between pH and exchangeable sodium percentage of Western soils. Soil Sci. 71: 251-260.
Mitchell, R.L. and Muir, A.	1937	Base exchange capacity and clay content of soils. Nature, London. 139: 552.
Mithyantha, M.S. and Perur, N.G.	1970	Iron-manganese relationship in Some soil profiles of Bangalore district. Mysore J. agric. Sci. 4: 113-116.
Mithyantha, M.S., Balakrishna Rao and Perur, N.G.	1973	Available potassium status and its relationship with other soil properties in some acid soils of Mysore State. Paper presented in symposium on acid sulphate and other acid soils of India held at Trivandrum in February 1973.

Moorman, F.R. 1962 Acid sulphate soils (cat clays) of tropics. Soil Sci. 95(4): 62-65.

Motomura, S. 1964 Oxidative sediments in paddy soils. 1. Occurrence of Mn sediments in paddy soils. J. Sci. Soil Manure, Tokyo 33, 41 (J) Soils and Ferti. Abst 29(1) 28 (63).

Motomura, S. 1969 Dynamic behaviour of ferrous iron in paddy soils. Bull. natn. Inst. agric. Sci. Tokyo B 21, 1-114. Soils and Ferti. Abst 33(5): 458 (3452).

Motomura, S. and Yokoi, H. 1969 Characteristics of ferrous iron forms in paddy soil with reference to development of the soil profile. Soil Sci. Pl. Nutr. 15: 38-46.

Muresanu, P.L., Lazar, M. and Lazar, I. 1968 Contributions to the determination of micro element content - iron, manganese, copper of some genetic types of soil from Banat, spectrally dosed. INST AGRON TIMISOARA LUCR STIINT SER AGRON 11: 133-137.

Musierowicz, A. and Konecka-Betley, K. 1956 Studies on sorption complex and exchangeable cation content of the more important soil of Warsaw Roczn. Nauk. rol. 71 A: 493-508.

Nair, C.K.N. 1945 Studieso on the kari soils of Travancore. M.Sc. Thesis, University of Travancore.

Wild, A.	1971	The potassium status of soils in the Savanna zone of Nigeria. *Expt. agric.* **7**: 257-270.
Win, Khin, Tinkyi and Trillion Hmun	1969	Changes of pH in Gyogon paddy soils under water logged condition. *Union Burma J. Life Sci.* **2**(1): 11-15.
Wright, W.R. and Foss, J.E.	1972	Contributions of clay and organic matter to tho cation exchange capacity of Maryland soils. *Soil Sci. Soc. Amer. Proc.* **36**: 115-118.
Yoram Avnimelech	1971	Nitrate transformation in peat. *Soil Sci.* **111**(2): 113-118.
Yuan, T.L.	1959	Determination of exchangeable H in soils by titration method. *Soil Sci.* **88**(3): 164-168.
Yuan, W.L., Wu, C.S., Chi, C.L. *et al*	1968	Studies on nitrogen of flooded soils. I. The evaluation of nitrogen-supplying power of the flooded soils. *Soils Fertil. Taiwan* 62. *Soils and Ferti. Abst* **33**(5): 451 (3399).

Narayanan Nambiar, P.S. 1947 Base exchange studies in Travancore rice soils and utilization of bye-products from salt factories of Travancore. M.Sc. Thesis, University of Travancore.

Navrot and Gal, M. 1971 Effect of soil clay type on the availability of zinc in some mediterranean rendzina soils. J. Soil Sci. 22(1): 1-4.

Nemeta, K., Mengel, K. and Grimme, H. 1970 The concentration of potassium, calcium and magnesium in the saturation extract in relation to exchangeable potassium, calcium and magnesium. Soil Sci. 109(3): 179-184.

Nemeth, K. and Grimme, H. 1972 Effect of soil pH on the relationship between K concentration in the saturation extract and K saturation of soils. Soil Sci. 114(5): 349-354.

Nhung Nai-Thi My and Ponnamperuma, F.W. 1965 Effects of calcium carbonate, manganese dioxide, ferric hydroxide and prolonged flooding on chemical and electrochemical changes and growth of rice in a flooded acid sulphate soil. Soil Sci. 102: 29-41.

Padmanabhan Nair and Aiyer, R.S. 1966 Studies on the factors governing the available phosphorus status of the acid soils of Kerala State. Agric. Res. J. Kerala 4(2): 61-67.

Pathak, A.N., Shri Krishna and Tiwari, K.N. 1972 Correlations between phosphorus, iron and manganese availability in water logged soils at different fertility levels. J. Indian Soc. Soil Sci. 20(4): 385-389.

Pearsall, W.H.	1950	The investigation of wet soils and its agricultural implications. Emp. Journ. Expt. Agri. 18(72): 289-298.
Peech, H.	1941	Copper in nutrition. Soil Sci. 51: 473-484.
Pionke, H.B. and Corey, R.B.	1967	Relationships between acidic aluminium and soil pH, clay and organic matter. Soil Sci. Soc. Amer. Proc. 31: 749-752.
Piper, C.S.	1950	Soil and plant analysis, Universit of Adelaide, Australia.
Pirkl, Jiri and No Novosamsky	1967	The relation between the distribution of soil phosphorus fractions and soil pH. Biol. Abs. 51(7) 40099
Ponnamperuma	1955	The chemistry of submerged soils in relation to the growth and yield of rice. Ph.D. Thesis, Cornell University, Ithaca, N.Y. 208 p.
Ponnamperuma, F.N., Estrella martinez and Teresita Loy	1966	Influence of Redox potential and partial presence of CO_2 on pH values and the suspension effect of flooded soils. Soil Sci. 101(6): 421-431.
Premanathan, S. and Durairaj, D.	1966	A study of the alluvial soils of Madras State. Madras agri. J. (2): 49-59.
Raman	1911	Quoted by Das, S. in vertical distribution of phosphate in calcareous soils. Ind. J. Agric. Sci. 16: 164-168.

Reppo, E. and Bergert, L.	1969	The bulk density of soil on the main types of farm lands in Estonia. Biol. Abs. 53(6): 34502.
Richards, L.A.	1954	Diagnosis and improvement of saline and alkali soils. U.S. dep. Agric. Handl. 60.
Rovira, A.D. and Stace, H.C.T.	1970	Effect of particle size on bicarbonate extractable phosphate in a sandy soil. J. aust. Inst. agric. Sci. 36, 292-293. Soils Ferti. Abs. 34(4): 359.
Saini, G.R.	1970	Aluminium in salt affected coastal alluvial soils. Pl. Soil 32: 538-539.
Sanchez, B.	1969	Contribution of silt, clay and organic matter to the cation exchange capacity of acid soils. An. Edagol. Agrobiol. 28, 14-23.
Sankaram, A.	1962	Laboratory manual for Agricultural Chemistry, Asia Publishing House, Bombay.
Satyanarayana, T., Shivamurthy, S.C. and Hadimani, A.S.	1970	Influence of texture and soil moisture regimes on phosphate mobility. Mysore J. agric. Sci. 4, 247-252.
Savant, N.K. and Kibe, M.M.	1972	Influence of added $Ca(OH)_2$ on acidity in submerged and subsequently dried laterite rice soils. Soil Sci. Soc. Amer. Proc. 36: 529-531.

Savant, N.K., Kene, D.R. and Kibe, M.M.	1970	Influence of alternate submergence and drying of rice soils prior to resubmergence on available phosphorus. *Plant* and *Soil* 32, 521-525.
Schachtschabel, P.	1971	Causes and nature of soil acidity. *Soils* and *Ferti.* **35**(2): 116.
Schroo, H.	1959	*Neth.* *J.* *Agr.* *Sci.* 7, 309-316.
Shapiro, R.E.	1958	Effect of flooding on availability of phosphorus and nitrogen. *Soil* *Sci.* **85**(4): 190-197.
Singh, G.	1971	A study on the relationship of texture and total exchange capacity in some of the soil profiles at different elevations of Chamba district in Himachal Pradesh. *Ind.* *J.* *Agric.* *Chem.* **4**(1): 29-41.
Singh, M.	1971	Availability of manganese in submerged paddy soils as affected by pH, anions, iron and organic matter. *Riso* 2, 165-170.
Sreedevi Amma, S and Aiyer, R.S.	1973	Potassium status of the acid rice soils of Kerala State. *J.* *Indian* *Soc.* *Soil* *Sci.* **22**(4): 321-328.
Srivastava, O.P. and Pathak, A.N.	1968	Available phosphorus in relation to forms of soil phosphorus. *J.* *Indian* *Soc.* *Soil* *Sci.* **16**(2): 103-109.
Stephenson, R.E.	1921	The effect of organic matter in soil reaction II. *Soil* *Sci.* **12**: 145-162.

Sturges, D.	1968	Hydrologic properties of peat from a Wyoming mountain bog. Soil Sci. **106**(4): 262-264.
Subramoney, N.	1960	Sulphur bacterial cycle-probable mechanism of toxicity in acid soils of Kerala. Sci. and Cult. **2**: 637-638.
Subramoney, N. and Gopalaswamy, V.	1973	The acid sulphate soils of Kerala growing paddy. Paper presented in the symposium on acid sulphate and other acid soils of India held at Trivandrum in February 1973.
Taha, S.M., Mahmoud, S.A.Z. and Ibrahim, A.N.	1967	Microbiological and chemical properties of paddy soil. Plant and Soil **26**(1)
Takkar, P.N., Arora, B.R. and Bhumbla, D.R.	1973	Iron, a contribution of factor to soil acidity. Paper presented in symposium on acid sulphate and other acid soils of India at Trivandrum in February 1973.
Tandon, H.L.S.	1970	Fluoride-extractable aluminium in soils:2. as an index of phosphate retention by soils. Soil Sci. **109**(1): 13-18.
Thakur, M.S., Sinha, H. and Mandal, S.C.	1969	Aluminium in acid soils of two different origins. J. Indian Soc. Soil Sci. **17**(4): 501-505.
Tseng, H.D. and Wang, C.H.	1963	Soil test for paddy. Rice News letter, Taiwan Society of Soil Scientists and Fertiliser Technologists, 151: 635-638.

Varghese, M.P. 1972 Studies on the lime potential and aluminium hydroxide potential of acid soils of Kerala State. M.Sc.(Ag.) Thesis, University of Kerala.

Velayutham, M. and Raj, D. 1971 Interrelationship between soil separates and properties of the soils of Tamil Nadu. *J. Indian Soc. Soil Sci.* **19**(4): 353-361.

Venugopal, V.K. 1969 Cation exchange studies in Kerala soils. M.Sc.(Ag.) Thesis, University of Kerala.

Verstraeten, L.M.J., Vlassak, K. and Livens, J. 1970 Factors affecting the determination of available soil nitrogen by chemical methods: 1.Comparison of extractable with mineralized nitrogen. *Soil Sci.* **110**(5): 299-305.

Vintila, I. 1970 Exchangeable aluminium distribution in acid soils of Romania. *Studii Technico Economice, Seria*.c. 18, 401-413.

Watts, J.C.D. 1968 Phosphate relationships in acid sulphate soils from the Modacca area. *Malaya. agric. J.* 46, 252-269.

Welte, E.E., Niederbudde, E.A. and Todorcic, B. 1968 The potassium status and potassium behaviour in typical soils of eastern Slavonia and Baranja. II. *Bodenkulter* **18**: 99-112.

Wilcox 1939 Soil moisture studies.I.Some factors affecting the moisture holding capacity and its determination. *Sci. Agric.* **20**: 140-149.

Wild, A.	1971	The potassium status of soils in the Savanna zone of Nigeria. *Expt. agric.* **7**: 257-270.
Win, Khin, Tinkyi and Trillion Hmun	1969	Changes of pH in Gyogon paddy soils under water logged condition. *Union Burma J. Life Sci.* **2**(1): 11-15.
Wright, W.R. and Foss, J.E.	1972	Contributions of clay and organic matter to the cation exchange capacity of Maryland soils. *Soil Sci. Soc. Amer. Proc.* **36**: 115-118.
Yoram Avnimelech	1971	Nitrate transformation in peat. *Soil Sci.* **111**(2): 113-118.
Yuan, T.L.	1959	Determination of exchangeable H in soils by titration method. *Soil Sci.* **88**(3): 164-168.
Yuan, W.L., Wu, C.S., Chi, C.L. *et al*	1968	Studies on nitrogen of flooded soils. I. The evaluation of nitrogen-supplying power of the flooded soils. *Soils Fertil. Taiwan* 62. *Soils and Ferti. Abst* **32**(5): 451 (3399).