

**PHYSICO-CHEMICAL AND MICROBIOLOGICAL STUDIES  
ON SOME 'KARI' SOILS OF KERALA**

BY

**V. SUKUMARA PILLAI, B. Sc. (AGRI.)**

**THESIS**

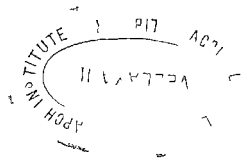
**SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
MASTER OF SCIENCE IN AGRICULTURE  
(AGRICULTURAL CHEMISTRY)  
OF THE UNIVERSITY OF KERALA**

**DIVISION OF AGRICULTURAL CHEMISTRY**

**AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE**

**VELLAYANI**

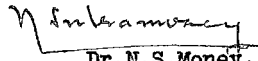
**1964**



C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Sri.V.Sukumara Pillay under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

  
Principal

  
Dr. N.S. Money,  
Additional Professor of  
Agricultural Chemistry.

Agricultural College &  
Research Institute,  
Vellayani, Trivandrum,  
25..7..1964.

## A C K N O W L E D G E M E N T S

I am deeply indebted to Dr. N.S. Money, Additional Professor of Agricultural Chemistry, for suggesting and planning the present investigation and for his able guidance in the execution of this work.

My sincere thanks are due to Prof. E.J. Verghese, Head of the Division of Agricultural Chemistry and Prof. A.P.A. Brito Mutunayagam, University Grants Commission Scheme, for the keen interest evinced by them in this investigation.

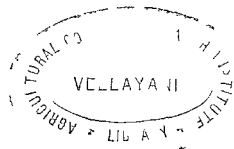
I wish to acknowledge my deep gratitude to Dr. M.M. Koshy and Dr. R. Subramonia Aiyer, Junior Professors, for their valuable suggestions and creative criticisms in the course of the work and for perusing the manuscript.

I express my sincere thanks to Dr. C.K.N. Nair, Principal, Agricultural College and Research Institute, Vellayani, for the facilities provided for my work and other courtesies extended.

My thanks are also due to the members of the staff of the Agricultural Chemistry Division for their kind co-operation and for the generous help rendered.

I am grateful to the Government of Kerala for deputing me for this course of study which enabled me to undertake this investigation.

V. Sukumara Pillay.



C O N T E N T S

	Page No.
1. Introduction . . . . .	1
2. Review of Literature . . . . .	7
3. Materials and Methods . . . . .	29
4. Results . . . . .	46
5. Discussion . . . . .	65
6. Summary and Conclusions . . . . .	77
7. References	



# INTRODUCTION

## I N T R O D U C T I O N

Conspicuous among the physical features of Kerala are the backwater areas adjoining the sea. Kuttanad, the rice bowl of Kerala, forms a major economically important part of these backwater tracts.

A most fascinating--at the same time not as yet proved--theory regarding the origin of Kuttanad area was put forward by Velu Pillay (1940) in his Travancore State Manual. His view is that the area must have been a bay in the geological ages. Into this bay were being discharged the waters of Periyar and other rivers draining Central Travancore. One of the effects of the discharge of these waters laden with sediments, was the formation of a sand bank linking up the nearest points of land. Thus the bay became a lagoon, which gradually silted up and gave rise to the wet paddy lands and coconut gardens which now characterise the backwater tract. The not yet fully silted up portions of the lagoon form the present day lakes of these areas. This theory owes its origin to some evidence furnished by Pillay (1924).

In different parts of this backwater tract large areas of Kari or peaty marsh soils occur. The name Kari is derived from the intense black colour of the soils, 'Kari' in Malayalam meaning charcoal. These soil formations comprise irregularly shaped areas and are scattered about

in different regions in the coastal planes alongside the backwater areas and adjoining the sea. There are about 10,000 acres of these lands in and around Porakad in Ambalapuzha Taluk, 10,000 acres in Vaikom Taluk, 5,000 acres in Kunnathunad and about 5,000 acres in Sbertallai Taluk.

The origin of these soils is still shrouded in mystery, but it is popularly believed that there were huge forests in these tracts which, due to disturbances in bygone times, might have been destroyed and got submerged under the sea. Later on the sea might have slowly receded, thereby partly exposing these soils. But the exact period of their origin and the probable causes that led to it, while of intense interest to the geologist, will not form the subject matter of the present study.

The presence of large quantities of organic matter which have resisted decomposition for a long period of time, the high acidity in spite of the presence of a large proportion of calcareous shells and their being periodically submerged under saline water from the adjoining backwaters are all unique features of the Kari soils. But it is quite probable that there are marked differences in the physical, chemical and other properties of the Kari soils of different tracts.

The Kari area like the rest of Kerala has a uniform climate. The South West Monsoon (June to September) and the

North East Monsoon (October to December) together bring an annual precipitation of about 275 cm. The temperature varies between 75°-85°F. January and February are the coolest and driest months.

The topography of the area is level and the fields are situated at or below the sea level. In the summer months from February to May the land is submerged under saline water. With the onset of the South West Monsoon in June the flood waters flowing into the area dilutes and pushes out the salt water into the sea. With the cessation of the South West Monsoon in September, the area is dewatered and paddy is grown. The crop is harvested in next February, after which salt water is once again allowed to get into the fields. This practice is followed to keep an anaerobic reduced condition in the soil so as to prevent the biological oxidation of sulphur compounds in the soil to free sulphuric acid, the resultant acidity being considered responsible for subsequent crop failures. (Subramoney, 1948).

Large logs of wood, partly altered due to natural agencies of destruction are encountered almost everywhere below the surface of the soils.

A large quantity of lime shells is found in the fields adjoining the lake and in areas that have been reclaimed from the lake by putting up permanent stonewalls. The source of these shells is the adjoining Vembanad lake



where molluscos and similar marine fauna grow in abundance.

Marsh vegetation, especially, the weed 'Kathira' (Eleocharis palustris), and other aquatic grasses are noticed prominently.

Based on topography, the position of drainage channels and rivers and the soil type the area is divided into a number of Padasekharams, each 50-250 hectares in extent. All agricultural operations in one padasekharam are carried out at the same time.

Paddy is the only crop that is being cultivated in these fields. The cultural operations start towards the end of the first rainy season in September and the crop (90 to 115 days' duration) is harvested in next February. Prior to sowing, mud walls are made around the fields and the water is drained out by pumping. Outside the mudwalls, in the channels, water stands to a height of about 4-6 feet above the field level. The seeds used are mostly local varieties. Crop failures due to flood hazards, and of late, due to blast disease of paddy, are not infrequent.

Past works on the Kari soils are few in number. Pillay (1924) has analysed a few soil samples from one of the Kari lands round about Porakad in Ambalapuzha Taluk, and furnished some data on their chemical composition. Iyer (1928) working with soils collected from different Kari areas deter-

mined their lime requirement, phosphoric acid content and the amount of watersoluble salts, based on which he suggested some reclamation practices. Pillay and Subramoniam (1931) investigated the origin and nature of these peaty soils. Nair (1945) conducted physicochemical analysis of surface soils from five representative tracts of Kari and studied the agricultural aspects of the soils. Subramoney (1947, 1958) studied the microbiological properties of Kari soils, and Gopulaswamy (1958) conducted studies on their fertility status .

An acute dearth of cultivable land in this State has forced the farmers to take up the risky cultivation of these problem lands. The specific problems encountered in the cultivation of these lands, such as, salinity, high acidity and the resultant unavailability of certain nutrients, are to be tackled and solved for the best returns from these inherently fertile lands.

An understanding of the physical, chemical and other properties of the soil is a very essential prerequisite for any improvement programme. It is with this end in view that the present work is taken up. In this work it is proposed to study the Kari soils of only one tract (Vaikom Taluk) and the location of the profiles collected is so selected as to be representative of the soils of the tract under study. A profile study is more informative than a study of the top soils alone, as it throws

some light on the behaviour of the sub-soils too. Moreover no profile studies of these soils has been conducted so far. So instead of collecting and analysing a large number of top soils, four representative profiles are studied in this work.

Some microbiological properties of the soils, too, are studied besides the physical and chemical determinations.

It is hoped that this work will be a prelude to similar studies in other tracts of Kari land areas, so that in due course enough scientific data will accumulate, based on which lime and fertiliser recommendations and suggestions for suitable management practices can be made with a view to increasing the productivity of these soils.

REVIEW OF LITERATURE

## REVIEW OF LITERATURE

### 1. Origin, formation and nomenclature of organic soils

Dachnowsky (1930) suggested that various layers of a peat deposit would reflect stages in the history of the peat and could not be considered as a profile in the same sense as applied to a mineral soil.

A picture of the origin and nature of the soils of erstwhile Travancore State has been presented by Pillay and Subramoniam (1931). No reliable record on the early history of Kari soils is available. In different parts of the Kari tracts partially decomposed wood as well as huge stumps of forest trees are still found. A popular suggestion is that the peaty tract of Kerala was once more elevated, and afterwards, perhaps, due to an upheaval became depressed below sea level.

Anderson et al. (1933) stated that peat formation takes place in low spots in poorly drained lands, that are submerged most of the time, or in shallow ponds and marshes. In very humid and cool regions it may be formed on steep slopes too. Organic matter decomposes very slowly under water. Then the remains of vegetation growing in water or falling into it tend to accumulate more rapidly than they decompose until the accumulation is exposed to air at the surface during dry periods.

Teakle and Southern (1937) stated that peat soil is composed mainly of considerably decomposed organic matter with highly fibrous plant remains. They considered that waterlogging, restricted drainage and aeration and an abundance of vegetable matter are conditions conducive to peat formation.

According to Lyon et al. (1947) the submerged condition of marshes, bogs and swamps shut out the air, prohibits rapid oxidation, and thus acts as a partial preservative. As the process of anaerobic decomposition proceeds the organic mass becomes brown or even black in colour. When the decomposition proceeds far enough, this mass acquires profile characteristics to justify its designation as a true organic soil.

Pearsal (1950) studying the microbiological characteristics of organic soils showed that in lake muds, they are marked by the gradual accumulation of organic matter. By the time 20 per cent of organic matter has accumulated microbiological activity is extreme and the muds become typically black and reducing with an abundance of exchangeable bases. The black colour is associated with the presence of ferrous sulphide and a luxuriant flora. Such a soil continued to lose minerals freely by leaching, apparently owing to accumulation of ammonia and further base exchange.

Robinson (1951) categorised peats as soils having higher proportions of organic matter comprising the residues of natural vegetation in highly humified form. According to him 15 per cent of organic matter is enough to give a peaty character to a light sand. He gave a comparatively vivid account of the process of peat formation. Peat is mostly developed under cool humid climates. He differentiated various types of peats in connection with the process of peat formation and their subsequent development. For example, basin peat is formed under lacustrine conditions and the fen or low moor peat is formed when the mixture of littoral residues and mineral matter is deposited as a sediment under anaerobic conditions. The climatic moor or mountain peat occurs in mountainous regions formed along the slopes down which water is percolating continuously. The nature of the percolating water determines the character of peat.

Lawton (1955) defined an organic soil as one containing 20 per cent or more of organic matter and one foot or more in depth which was formed under waterlogged conditions or under cool and wet conditions.

Russel (1956) described the role of impaired drainage and ground water in the formation of peat. Such conditions decrease the rate of decomposition of organic matter, as a result of which peat formation takes place.

Edelman et al. (1958) stated that the organic soils of the United States are sometimes flooded with salt or brackish water. Consequently some sulphur compounds are trapped in these organic deposits giving a certain potential acidity to them.

Moorman and Panaboke (1960) described bog and half-bog soils as having an organic surface layer at least 12 inches thick and containing a minimum of 25-30 per cent organic matter. The bog and half-bog soils of Ceylon are mainly composed of acid peats which rest on marine alluvial fill. Peat formation takes place in wet depressional sites and is therefore restricted to wet zones.

Thenabadu (1960) working on ill-drained paddy soils of Bombuwela, Ceylon, found that the water table has a marked influence on the profile characteristics. The high water table and the consequent lack of aeration retard the biochemical processes that effect decomposition of buried plants and plant residues. The prevailing anaerobic conditions restrict the oxidative processes of the microorganisms. The result is an accumulation of organic matter. The soils are not highly acidic in spite of the high organic matter content.

## 2. Physical properties of organic soils

According to McCool and Weidemann (1924) the physical condition of organic soils has a great influence on the rate



at which they take up water. There is very close relationship between the heat of wetting and the unfree waterholding capacity of an organic soil.

Veenenbos (1950) observed that infiltration in drained peat soils is possible on the surface with ditches and trenches and in the sub-soil with the moletrack and drain tubes.

Croegaert et al. (1954) found that the fine particles and loam fractions were effective in increasing the maximum waterholding capacity and widening the range of available water respectively. An organic soil showed a waterholding capacity of 82-92 per cent and a very wide range of available water.

Oloffson (1954) found that slightly humified soils were more permeable than highly humified ones.

According to Lyon et al. (1955) the colour of a typical peat soil is dark brown or intensely black when it is wet. The light weight of a representative peat soil or similar soils, when dry, is the second outstanding characteristic. The volume weight compared with mineral surface soil is surprisingly low, 0.2 or 0.3 being a fair estimate. The third important property of a peat soil is its high waterholding capacity. In peat soils, the amount of unavailable water is proportionately higher than that of mineral soils. The

outstanding characteristic of a typical woody or fibrous peat is its invariably good physical condition. The cohesion and plasticity capacities of colloids of such soils are very low. A peat soil of good quality is therefore porous, open and easy to cultivate.

Grebenshchikova (1957) found that moss and grass moss peats when saturated has moisture contents of 5-35 per cent, wooded peats 35-60 per cent, grass peats 24-45 per cent and sphagnum peats 90-93.5 per cent.

Gopalaaswamy (1958) studying the fertility status of some peaty marshy and swampy soils of India, concluded that the soil profiles of Kuttanad area differ considerably in their content of textural separates in the various layers, indicating thereby the prominent role played by transportation and sedimentation processes in the assemblage of these soils. He found that these soils generally do not show any distinct correlation between waterholding capacity and clay contents as in other soils, probably due to the subjection of these soils to the influence of water which have hampered such relationships.

### 3. Chemical properties of organic soils

According to Harcourt (1905) the availability of nitrogen to plants in organic soils is not satisfactory. Only a portion of the organic matter is humus. As to the

amount of inorganic matter contained in swamp soils, it is altogether a very variable quality, depending upon how much sand and clay have got mixed with the surface accumulation of decayed vegetable matter.

Robinson (1911) concluded that a considerable portion of nitrogen in peat is present in the form of a protein compound or a mixture of such compounds which can be broken down on treatment with acids in the same manner as casein, egg albumin etc.

According to Alway (1914) peat soils, in their supply of potassium, phosphoric acid and nitrogen differ markedly from mineral soils. The amount of potash is usually very low while the proportion of phosphoric acid is high, but is largely unavailable, being combined with organic matter in such a form that it can be used by plants only after it has been set free by the destruction of organic matter either by thorough decay or burning. The content of lime is variable. All peats are very rich in nitrogen, containing from 1.3 to 4.0 per cent of this element. The proportion of lime in a peat soil controls the supply of both calcium and nitrogen as the nitrogen transformations are greatly affected by pH.

According to Whitson et al. (1919) acid marshy soils of a sandy nature have practically no lime in the sub-soil.

Lipman and Wank (1924) found that peats are relatively of high nitrogen content ranging from 1-3 per cent. But the nitrogen is only very slowly available to plants.

Pillay (1924) studied a few soil samples from one of the Kari lands in Porakad and reported that the infertility of these soils was due to their low content of the plant food elements.

Hissink (1926) studied the relation between the values of pH, volume and soil humus of some organic soils. He emphasised that the humus fraction possesses a far greater power of base adsorption than the clay fraction.

Iyer (1928) working with soils collected from different Kari areas concluded that the soils are deficient in phosphoric acid and lime and contained toxic concentrations of water soluble salts. He suggested heavy applications of lime and phosphates along with adequate drainage for the successful reclamation of these soils.

The harmful effects of high acidity on the rice roots has been demonstrated by Mitra and Phukan (1929).

Gans (1913), Bradfield (1923) and Troug (1930) have established that actual acids are involved in soil acidity. Solubility of iron and aluminium depends on the

degree of acidity. The soils being highly acidic contain large amounts of iron and aluminium in solution.

The reaction of a soil exerts a direct influence on plant growth. Hoagland (1919) and Troughton (1930) have indicated that a direct toxic effect due to excess of hydrogen ions on root tissues manifest only at very low pH values.

Robinson (1930) studied the effect of submergence on a number of widely different soils and found that reducing conditions may develop within eight days. Toxicity in submerged soil is due largely to soluble iron, soluble manganese and hydrogen sulphide or to a general reducing condition, which in itself is the main and most toxic agent.

Pillay and Subramoniam (1930) observed that by the continuous cultivation of the Kari soils the organic matter content may get reduced by decomposition. The available phosphoric acid and potash contents of these soils were found to be extremely low. They also noticed a very poor microbiological activity and an almost complete absence of mineralised forms of nitrogen in these soils. According to them the Kari soils contained large quantities of iron and aluminium salts and sulphur compounds, principally mineral sulphates. The possibility of utilising the free sulphuric acid formed in the soil for rendering insoluble phosphates

available for plant nutrition are discussed.

In his conclusions on the factors affecting the qualities of humus-containing layer of natural soils, Aarnio (1928, 1933) stated that even if inorganic electrolytes play a certain part in the precipitation of sesquioxides one is justified in concluding that in the humid regions the reaction of humic substances is more important in the soil-forming processes.

A close correlation between the total base exchange capacity and the carbon content of soils was found by McGeorge (1931, 1934). An increase of 35 milliequivalents for each 10 g. of carbon was noted in the soil. By oxidising the humus of the soil with hydrogen peroxide he showed that the loss in exchange capacity approximate a linear function of the organic matter destroyed.

Wilson and Staker (1932) found that peat soils are low in mineral matter and high in organic carbon. Phosphorus, Potassium and Magnesium are present in small amounts. Most soils are found to contain large amounts of nitrogen and calcium. Calcium carbonate, however, is not present in the soil to any considerable extent. With very few exceptions the soils are acid in nature. The surface soils and the corresponding sub-soils are similar in chemical composition. Surface soils usually contain a high percentage

of ash and consequently a smaller percentage of organic matter.

Nair (1945) found that the difference between the various Kari soils was primarily in the quantity of organic matter. The organic matter content, exchangeable hydrogen, pH and the C/N ratio seemed to be inter-related and correspond to the observed fertility of the soils. Fertility and salt concentrations were shown to have no correlation to each other. The effect of organic matter of the soils on the growth of paddy was illustrated by pot experiments.

Subramoney (1947) considered the acidity in Kuttanad soils to be responsible for the frequent crop failures in these areas. It was also reported that free sulphuric acid in high toxic concentrations is produced in these soils by biological oxidation of sulphur compounds present in them. A type of clay rich in iron sulphide is found in the sub-soil which is considered to be harmful to crops. The increase in acidity due to exposure to air is a property peculiar to these soils.

Pearsal (1950) attributed the high carbon : nitrogen ratio in waterlogged acid soils to loss of nitrogen from these soils. Owing to the reducing conditions prevailing in them, ammonification and denitrification proceed rapidly and the nitrogen thus transformed to ammoniacal form or gaseous nitrogen is lost immediately. The oxidation of

carbon, on the other hand, is hindered and this element is therefore conserved. As a result such soils have high carbon : nitrogen ratios. The losses of nitrogen induced in this way are serious and are often accompanied by toxic effects due to nitrites, but they are often balanced by the activities of the nitrogen-fixing organisms particularly in soils that are slightly acid.

According to Polak (1950) there are stable lignoproteins in the soil and hence a marked deficiency of nitrogen.

Vanwijk (1951) suggested that the chemical composition of the swamp soils is related to the organic matter content. The very humus upper layers are rich in nitrogen and have a very high content of phosphoric acid soluble in 25 percent hydrochloric acid. The potash content also shows a distinct correlation with the level of organic matter. The mineral sub-soil is usually deficient in phosphoric acid and the percentage of potash is also low.

Lytle and Driskell (1954) concluded that marsh peats are subject to greater shrinkage and subsidence and contain more water-soluble salts than muck soils. Swamp clays have a higher pH and contain more sesquioxides than peats and their carbon : nitrogen ratios increase with increasing organic matter. Marsh peats contain considerable amounts of sulphates and chlorides.



Kaila (1956) stated that a large part of phosphorus in peats of different vegetational types occurred in the organic form which amounted to 50-60 per cent of the total phosphorus in undecomposed plant material. Low levels of organic phosphorus indicated that there was rapid mineralisation of phosphorus in these soils. The concentration and solubility of inorganic phosphorus was greatly decreased with depth and there was a tendency for total phosphorus to increase with depth in low quality peat and to decrease in high quality peats.

Subramoney (1958) found that crop failure in Kuttanad is generally due to insufficient drainage. Due to large amounts of organic matter there is shrinkage and drying resulting in an uneven surface in the peat areas. Deep ploughing would set free the sulphides and sulphates present in the sub-soil. As in the case of lignite deposits the sub-soils in these regions contain embedded in them iron sulphides and marcacites which on exposure to air and moisture give rise to sulphuric acid and ferrous sulphate.

Kaila (1958) stated that the extent of availability of inorganic phosphorus in peat seemed to depend more on the degree of humification, depth of the peat layer and the sesquioxide content than on the type of peat. The water-soluble phosphorus was a satisfactory index of phosphorus availability in acid peats, 0.5 N acetic acid generally

extracting too little, 1 per cent citric acid and 0.1 N sulphuric acid extracting relatively too much.

Kivekas (1958) found that the increase in pH after one month's incubation was greater in limed than in unlimed samples, irrespective of the peat type. A decrease in pH occurred after three months, but the levels remained higher than the initial.

Frercks and Puffe (1958) found that strongly decomposed peats compared with less decomposed ones showed markedly narrower total C/N and humic C/N ratios. The field capacity of organic matter was higher in peats of more advanced decomposition. Increasing rates of liming increased the cation exchange capacity of organic matter, promoted decomposition, decreased maximum field capacity and increased the danger of an irreversible drying of the organic soils.

Kanno et al. (1958) found that the clay separates of organic soils consisted mainly of halloysite, illite and hydrated halloysite with small amounts of chloritic minerals, quartz and feldspars. Kaolin minerals predominated in the A horizon and illite in the B horizon.

Gopalaswamy (1958) reported that the high salt content of the Kuttanad soils was due to marine and river influences. He concluded that these soils contained montmorillonite and illite types of clay, as they were

having a fairly high cation exchange capacity, low exchangeable calcium and magnesium and high content of nonexchangeable potassium. The molar ratios of clay fractions confirmed this finding. The variable distribution of sesquioxides and variation in molar ratios suggested that the soils were alluvial in nature. The presence of a mixture of clay minerals was suggested.

Stevenson (1959) found that from 3.5 to 7.9 per cent of the nitrogen of surface soils of nine profiles representing several great soil groups occurred as fixed ammonium. The relative proportion increased with depth due largely to the decrease in organic nitrogen. Narrowing of the carbon : nitrogen ratio with depth was due to (a) the increase in relative amount of nitrogen fixed as ammonium and (b) the presence of a relatively higher amount of nitrogen-rich compounds in the organic matter of sub-soil as compared with surface soil.

Mandal (1961) studying the iron and manganese transformations in waterlogged rice soils reported that in the presence of organic matter the reduction process of iron was more intense and carbon dioxide production greater.

Lucas and Davis (1961) found that organic soils with low pH values have C/N ratios between 30 and 60. The unfavourable C/N ratio and low nitrogen content reduce the

availability of nitrogen. Available phosphorus in soils well supplied with calcium was more. Availability of potash, too, was very low in these soils.

Burgess and Broadbent (1961) found that in a series of organic soils ranging in carbon content from 14-43 per cent ammonium fixation was linearly correlated with carbon content. Tracer experiments indicated that the fixed ammonia slowly became available to plants.

#### 4. Microbiological properties of organic soils

##### (a) Total count:

Waksman (1923) found that peat soils contained over six million bacteria per g. even at a pH as low as 5.9.

Harszewska and Zimiecka (1949) found that soils derived from low moor peats and manifesting reduced fertility had a low bacterial flora with a predominance of antagonistic organisms, mainly actinomycetes.

Burges and Co-workers (1953) concluded that the ability of fungi to live deep in the soil is not a consequence as is commonly supposed, of their ability to do without oxygen but of their ability to withstand high concentrations of carbon dioxide.

Tchan and Whitehouse (1953) have shown that algae

are confined to the top few millimeters in wet soils.

Blue, Eno and Westgate (1955) found that the total microbial count was highest in the top six inches of the soil. Very few microorganisms were found in the A<sub>2</sub> horizon (9-12 inches) below which there was a deficiency of the nutrients. The number was more between 12 and 30 inches below the surface. The number in this horizon was found to increase by dressings of potassium and of nitrates.

Garbosky (1956) reported that Azotobacter was found at depths down to two metres in Argente soils and that it was more abundant between 50 and 100 centimeters below than at the surface.

The distribution of fungal species at different levels in sandy Podzol profiles was studied by Jeffreys et al. (1956) who found that plate counts decreased usually with depth but showed a secondary maximum in the B horizon, noticeable for the preponderance of mucor at this level.

Guillenat et al. (1956) observed in plots from long term experiments that different species of fungi occurred at different depths.

Pochon (1956) found that acid peats (pH 3.6 to 4.6) showed low activity and population of soil microorganisms and very low ratio of bacteria to fungi. This seemed to be due to the combined effects of high acidity,

high organic matter content and wide C/N ratio.

In the sandy dunes of Deliblato Milosevic (1958) found no decrease in the total microbial population with depth, but observed a seasonal fluctuation in their numbers.

Frercks and Puffe (1960) observed that increasing levels of liming so as to raise the pH from 3.2 to 7.0 increased the counts of bacteria and decreased those of fungi in moor and sandy soils. The change in microflora brought about by differential liming was reflected in the trends in cellulose decomposition and organic matter decomposition. Addition of nitrogen too was found to increase cellulose decomposition.

(b) Nitrogen transformations in soils:

Muntz et al. (1893) showed that protein decomposition in the soils result in the formation of ammonia. They observed abundant formation of ammonia by fungi and attributed the ammonia production in soils (particularly in acid soils) chiefly to the action of fungi.

Warrington (1891) and Winogradsky and Omeliansky (1899) showed that nitrate production is inhibited by the presence of ammonia. Winogradsky maintained that organic matter initiated nitrification.

Beckwith (1914) found a definite correlation

between total bacterial count and ammonia formation.

Gainy (1919) investigated the conditions which retard ammonia formation and showed that presence of certain toxic substances, such as, high concentrations of salts as well as high acidity inhibit bacterial activity.

Meek and Lipman (1922) found that pH tolerance of the nitrifying bacteria varied with the pH of the soil from which they were isolated. They observed that nitrification was possible over the pH range 5.0 to 13.0.

Olsen (1928) proved that ammonifiers can function in the pH range 3.7 to 9.0.

Meyerhoff (1917) and Winogradsky (1938) found that the optimum pH for nitrification was between 7.0 and 9.0. Winogradsky was the first to isolate nitrifying and nitrite oxidising bacteria.

Paul and Shariff (1954) found that a soil at pH 3.5 had a very low nitrifying power and that partial reduction on nitrates to ammonia occurred in such soils.

Acharya and Jain (1954) showed that organic and other soils with C/N ratio wider than 10, nitrified more slowly than soils with narrower C/N ratios.

Subramoney (1958) observed that nitrifiers were completely absent in the Kari soils of Kuttanad. He con-

cluded that the Kari soils contained some toxic substances which completely destroyed nitrifying bacteria and also inhibited the activity of ammonifiers.

(c) Nonsymbiotic nitrogen fixation and the organisms concerned:

Winogradsky (1893) demonstrated that the property of nitrogen fixation is limited to certain bacteria. The first nonsymbiotic organism was isolated by him.

Beijerinck (1901) isolated the aerobic nitrogen fixers Azotobacter chroococum and Azotobacter agile.

Gainy (1919) found that Azotobacter is abundant in soils having a pH below 5.9, the optimum reaction for the development of these organisms being between pH 7.0 and 7.8. A species of Azotobacter which grows and fixes nitrogen in very acid media was isolated by Starkey and De (1938). This species was isolated from Indian soils having a pH 4.9 to 5.2 and was named Azotobacter indicum. The unusual tolerance of this organism to acidity made the authors claim it as a new species. This organism differs in several respects from the other well known species of the genus.

According to Tchan (1953) the species so far known as Azotobacter indicum and Azotobacter lacticogenes belong to an entirely new genus altogether, which he named Beijerinckia. In a study of the distribution of these



bacteria he found that they are present only in tropical soils. According to him Atson (1936) was the first to detect Beijerinckia in the acid soils of Malaya. Later in Indian soils it was found by Starkey and De (1939); in Indonesia and Pacific islands by Derx et al. (1950); in South America by Derx (1952) and in Africa by Kauffman (1953) and Jensen (1955).

Derx (loc. cit.) observed sufficient prominent differences in the characteristics of these organisms from those of Azotobacter to include the former into a new genus Beijerinckia.

Meiklejohn (1954, 1955) has stressed the importance of these organisms resembling Azotobacter sp. and having almost similar efficiency of nitrogen fixation in the nitrogen economy of tropical soils.

Subramoney (1958) isolated an organism from the Kari soils of Kerala capable of fixing 10 to 14 milligrams of nitrogen per gram of energy material and occurring as diplococci or yeast-like cells. He found that this organism has a few characters similar to those of Azotobacter, but there are a number of other characters in which they differ. So he considered it as a new species of Azotobacter and named it as Azotobacter Keralum.

Bhattacharya (1956) found that more than 50 per cent

of the rice soils collected from different parts of Bengal contained no Azotobacter, though the majority of soils had favourable pH values. The number of Azotobacter in the remaining soils was rather small and a rapid disappearance occurred when added to some of the rice soils. The growth of Azotobacter appeared to be stopped, especially in the sub-soil, by waterlogged conditions.

Barrooah and Sen (1959) found that out of the 50 soils examined from various parts of the country 40 per cent contained Beijerinckia. The presence of this organism in soils could not be attributed to the occurrence of any soil constituent in excess or to any particular vegetation. The nitrogen fixing capacity of the strains of Beijerinckia varied from 5.97 to 11.57 milligrams per gram of glucose during the period of one month.

Becking (1959) found that eleven out of twenty soils yielded Beijerinckia. The organism occurred in soils within the pH range 4.3 to 7.0 in the wide range of soil types examined.

## M A T E R I A L S   A N D   M E T H O D S

## M A T E R I A L S   A N D   M E T H O D S

For the purpose of the present study four representative 'padasekharams' were selected, which in general features, represent the Kari lands of Vaikom Taluk. One profile was taken from each padasekharam.

The profiles were taken on 13.8.1962. At that time the fields were under water (2 to 2½ feet deep) and hence the ordinary method of taking a profile was not possible. Therefore, a special technique was adopted for this purpose. Bamboo tubes, about six feet in length, were prepared by knocking off the internodes with an iron rod. One end of this was sharpened and the tube was driven five feet deep into the soil. This procedure was quite easy since the soil under water was soft and plastic. The tube was then withdrawn slowly, retaining a column of soil inside. The soil column was drained by keeping it aside for a few days. The bamboo tubes were then split open longitudinally keeping the soil column intact. The profile characteristics, such as, colour, texture etc. were noted. Samples from each horizon were then collected in separate bags, labelled and taken to the laboratory for analysis.

No distinct horizon differentiation could be made out by colour or other outward appearance, especially when the soil was wet. The whole column looked like a dark

sticky rod, the colour gradually and slightly lightening as depth increased. Each profile was differentiated into three arbitrary horizons at the following depths based mainly on textural differences.

First horizon	..	0 to 24 cm.
Second horizon	..	24 to 75 cm.
Third horizon	..	Below 75 cm.

## Description of the profiles

Profile I

Location	Koithuruthu padasekharam, Vechoor village, Vaikom Taluk, Kottayam District.
Topography	Flat and level.
Vegetation	Originally marsh and aquatic grasses, now under rice.
Special features	Waterlogged for most part of the year.

<u>Sample No.</u>	<u>Depth in cm.</u>	<u>Description.</u>
1	0 - 24	Black, 7.5 YR. 2/0; clay loam; soft sticky and plastic when wet; poorly drained; undecomposed plant residues abundant; plant roots present; horizon differentiation difficult.
2	24 - 75	Very dark grey, 7.5 YR. 3/0; sandy clay loam; not very sticky and plastic; poorly drained; undecomposed plant residues and roots few; horizon differentiation difficult; carbonates present.
3	Below 75	Dark grey, 7.5 YR. 4/0; clay; very sticky and plastic; poorly drained; few plant roots; undecomposed plant residues absent; horizon differentiation difficult; supplied with carbonates.

Profile II

Location	Oorikari padasekharam, Thalayazham village, Vaikom Taluk, Kottayam District.
Topography	Flat and level.
Vegetation	Aquatic and marsh grasses, rice cultivated.
Special features	Waterlogged for most part of the year.

<u>Sample No.</u>	<u>Depth in cm.</u>	<u>Description.</u>
4	0 - 24	Black, 5 YR. 2/1; clay loam; sticky and plastic when wet; poorly drained; undecomposed organic residues and plant roots abundant; horizon differentiation difficult.
5	24 - 75	Very dark grey, 5 YR. 3/1; clay loam; not so sticky and plastic when wet; poorly drained; undecomposed plant residues and roots absent; horizon differentiation difficult.
6	Below 75	Dark grey, 5 YR. 4/1; clay; very sticky and plastic when wet; very poorly drained; plant roots and undecomposed organic matter absent; horizon differentiation difficult; carbonates present.

Profile III

Location	Elurkalam padasekharam, Vechoor village, Vaikom Taluk, Kottayam District.
Topography	Flat and level.
Vegetation	Originally aquatic and marsh grasses now reclaimed for rice cultivation.
Special features	Waterlogged for most part of the year.

<u>Sample No.</u>	<u>Depth in cm.</u>	<u>Description.</u>
7	0 - 24	Black, 2.5 YR. 2/0; clay; sticky and plastic when wet; poorly drained; undecomposed plant residues and roots abundant; horizon differentiation difficult.
8	24 - 75	Very dark grey, 2.5 YR. 3/0; clay loam; not very sticky and plastic when wet; undecomposed organic residues and plant roots only few; poorly drained; horizon differentiation difficult.
9	Below 75	Dark grey, 2.5 YR. 4/0; clay; highly sticky and plastic when wet; drainage very poor, undecomposed plant residues and plant roots absent; differentiation from other horizons difficult; carbonates present.



Profile IV

Location	Kochukottakari padasekharam, Kallara village, Vaikom Taluk, Kottayam District.
Topography	Flat and level.
Vegetation	Marsh weeds and aquatic grasses, rice cultivated.
Special features	Waterlogged for most part of the year.

<u>Sample No.</u>	<u>Depth in cm.</u>	<u>Description.</u>
10	0 - 24	Reddish black, 10 R. 2/1; sandy clay loam; somewhat sticky and plastic when wet; drainage very poor; undecomposed organic matter and plant roots found in plenty; horizon differentiation difficult.
11	24 - 75	Dark Reddish grey, 10 R. 3/1; sandy clay loam; not very sticky and plastic when wet; ill-drained; undecomposed plant residues and plant roots very few; horizon differentiation difficult.
12	Below 75	Dark reddish grey, 10 R. 4/1; clay loam; very sticky and plastic when wet, plant roots absent; very poorly drained; horizon differen- tiation difficult; carbonates present.

## Methods of analysis

The collection and preparation of the samples and their analysis were carried out by standard methods (Piper, 1950; Jackson, 1960).

### Preparation of soil samples

Air-dried soil samples were ground in a porcelain mortar with a wooden pestle, passed through a 2 mm. sieve with round holes and stored in labelled and stoppered bottles.

#### (a) Physical determinations

1. Moisture: A known weight of the air-dried soil was dried in an air-oven at 100-105°C for eight hours and the loss in weight noted. This was expressed as per cent of the moisture-free weight of the soil.

2. Loss on ignition: A known weight of the moisture-free soil was ignited at 600-800°C for about eight hours until all the organic matter was oxidised. The loss in weight was noted and expressed as per cent of the moisture-free weight of the soil.

3. Keen-Raczkowski box measurements: Waterholding capacity, apparent density, total porespace, volume of expansion and true specific gravity were determined using Keen-Raczkowski boxes (Keen-Raczkowski, 1952).

4. Mechanical analysis: The mechanical analysis of the samples was carried out by the international pipette method.

(b) Chemical Analysis

1. pH: The pH of the fresh soils, as well as the air-dried samples, were determined in soil-water suspension and in 0.01 M. calcium chloride solution with a Beckman pH meter using a 1:2.5 soil : solvent ratio.

2. Organic carbon: Organic carbon was determined by Walkley and Black's quick titration method.

3. Organic matter: The organic matter content was calculated from the organic carbon content of the soil by multiplying it with the factor 1.7.

4. Total nitrogen: Total nitrogen was estimated by the Kjeldal method using sulphuric-salicylic acid mixture.

5. Hydrochloric acid extract: The hydrochloric acid extract was prepared as follows:

20 g. of oven-dry soil was digested with 1:1 hydrochloric acid on a sand bath for six hours, filtered, washed and made upto 500 ml. The following estimations were done using this extract.

1. Total  $P_2O_5$ : Total  $P_2O_5$  was determined by

precipitating the phosphorus in an aliquot of the hydrochloric acid extract as phosphoammonium molybdate and estimating volumetrically.

ii. Total  $K_2O$ : Potassium was precipitated in an aliquot of hydrochloric acid extract as potassium sodium cobaltinitrite in acetic acid medium and estimated gravimetrically.

iii. Total sesquioxides: The sesquioxides were estimated by precipitating in an aliquot of the hydrochloric acid extract using ammonium chloride and ammonium hydroxide. The precipitate was filtered, washed, dried, ignited and weighed as total sesquioxides.

iv. Total  $Fe_2O_3$ : Iron was estimated volumetrically by titration with potassium permanganate after reducing the ferric iron to the ferrous state by granulated zinc and sulphuric acid.

v. Total  $Al_2O_3$ : The alumina content was obtained by subtracting the value of iron oxide from that of total sesquioxides.

vi. Total  $CaO$ : Calcium was precipitated in the filtrate left after the separation of the sesquioxides as calcium oxalate and estimated volumetrically by titration with standard potassium permanganate.

vii. Total MgO: Magnesium was precipitated as magnesium ammonium phosphate in the filtrate from calcium estimation. The precipitate was filtered, washed, ignited and estimated as magnesium pyrophosphate.

viii. Sulphur: Sulphur was estimated gravimetrically as sulphates in an aliquot of the hydrochloric acid extract.

6. Available nitrogen: Available nitrogen was determined by the alkaline permanganate method.

7. Available P<sub>2</sub>O<sub>5</sub>: Available phosphorus was extracted with Bray's Reagent No.1 (0.03 N Ammonium fluoride in 0.025 N hydrochloric acid) and estimated colorimetrically using a Klett-Summerson colorimeter.

8. Available K<sub>2</sub>O: Morgan's Reagent (Sodium acetate and glacial acetic acid) was used as the extractant for available K<sub>2</sub>O. In the extract K<sub>2</sub>O was determined turbidimetrically using a Klett-Summerson colorimeter after developing turbidity by the addition of sodium cobaltinitrite in a medium of equal quantities of isopropyl and methyl alcohols.

9. Carbonates: A weighed sample of the soil was treated with a known excess of standard hydrochloric acid. When the reaction was completed, the excess acid was titrated against standard alkali. From the volume of acid consumed, the carbonates were calculated and reported as calcium carbonate.

10. Analysis of the water extract: A 1:5 water extract was prepared by keeping the soil and water in the proportion 1:5 overnight after thorough shaking for half an hour in an end over end shaking machine. The extract was filtered and stored in bottles. The following estimations were carried out using this extract:

i. Conductivity: The electrical conductivity of the extract was measured using a conductivity bridge.

ii. Total soluble salts: Total soluble salts were determined by evaporating to dryness an aliquot of the water extract and weighing.

iii. Chlorides: Chlorides were estimated volumetrically in an aliquot of the water extract by titration with standard silver nitrate.

iv. Sulphates: In an aliquot of the water extract the sulphates were precipitated as Barium sulphate and estimated gravimetrically.

v. Water soluble CaO: In the water extract calcium was estimated volumetrically after precipitation as calcium oxalate.

vi. Water soluble MgO: Water-soluble MgO was determined gravimetrically by the magnesium pyrophosphate method.

11. Cation exchange capacity: The cation exchange capacity of the soils was determined by the neutral normal ammonium acetate method.

(c) Separation and analysis of the clay fraction:

The clay fraction from the soil was separated by Puri's ammonium carbonate method and examined as follows:

1. Moisture: The loss in weight of the sample of clay dried to constant weight in an air oven at 105°C was expressed as percentage of moisture on oven-dry basis.

2. Loss on ignition: 2 g. of clay was heated in a muffle furnace at 900°C for one hour and the loss in weight was calculated on moisture-free basis and reported as loss on ignition.

3. Preparation of clay fusion extract: The sodium carbonate fusion method was followed.

4. Silica: The fusion extract dissolved in hydrochloric acid was evaporated to dryness and dehydrated in an air oven at 150°C for about 6 hours. The dehydrated residue was treated with dilute hydrochloric acid, filtered, washed, ignited and weighed. The weight was reported as  $SiO_2$  on oven dry basis.

5. Sesquioxides: The filtrate from silica estimation was made up to 500 ml. and in an aliquot of the solution, the

sesquioxides were estimated gravimetrically.

6. Iron oxide: In an aliquot of the fusion extract the iron was reduced to the ferrous state with sulphuric acid and granulated zinc and estimated volumetrically by titration with potassium permanganate.

7. Aluminium oxide: Alumina content was obtained by subtracting the value of iron oxide from the value of sesquioxides.

8. Cation exchange capacity: The cation exchange capacity of the clay was determined by the neutral normal ammonium acetate method.

(d) Microbiological studies:

1. Total count: Thornton's standardised agar medium was used for determining the total count. The medium had the following composition:

Dipotassium <sup>hydrogen</sup> phosphate	( $K_2HPO_4$ )	1.00 g.
Magnesium sulphate	( $MgSO_4 \cdot 7H_2O$ )	0.20 g.
Calcium chloride	( $CaCl_2 \cdot 2H_2O$ )	0.10 g.
Sodium chloride	(NaCl)	0.10 g.
Ferric chloride	( $FeCl_3 \cdot 7H_2O$ )	0.002g.
Potassium nitrate	( $KNO_3$ )	0.50 g.
Asparagin		0.50 g.
Mannitol		1.00 g.
Agar		15.00 g.
Distilled water		1 litre.



The pH was adjusted to 7.4 and the medium sterilised at 15 pounds pressure for 30 minutes.

The soils were plated in the medium at 1:10,000 dilution in four replications. The plates were incubated for four days at 30°C and the number of colonies developing in each plate was counted.

2. Ammonifying power: Remy's medium with the following composition was used for the determination of ammonifying power.

Peptone	10.0 g.
Sodium chloride (NaCl)	5.0 g.
Distilled water	1 litre.

25 ml. lots of the medium were dispensed into 150 ml. Erlenmeyer flasks and sterilised. One g. of the soil sample was added to each flask under sterile conditions. Control flasks were also kept. After 10 days' incubation at room temperature the nitrogen was distilled with freshly ignited magnesia and estimated. Four replications were maintained.

3. Nitrogen-fixing power of soils: Jensen's medium (1952) with the following composition was used.

Sucrose		20.00 g.
Dipotassium phosphate	( $K_2HPO_4$ )	1.00 g.
Magnesium sulphate	( $MgSO_4 \cdot 7H_2O$ )	0.50 g.
Sodium chloride	(NaCl)	0.50 g.
Ferrous sulphate	( $Fe_2SO_4$ )	0.50 g.
Sodium molybdate	( $Na_2MoO_4 \cdot 2H_2O$ )	0.005g.
Calcium carbonate	( $CaCO_3$ )	2.00 g.
Distilled water		1 litre.

25 ml. lots of the medium were dispensed into 150 ml. Erlenmeyer flasks, sterilised and inoculated with 0.1 g. of the soil. The flasks were incubated for 30 days at 30°C, at the end of which the amount of nitrogen fixed was estimated by the modified Kjeldal method (Allen, 1953). One control and four replications were maintained for each sample.

#### 4. Isolation and study of the nitrogen fixing

organism: Five ml. of the following medium (Ashby's mannitol phosphate agar) were poured into a petridish and spread all over the dish.

Dipotassium phosphate	( $K_2HPO_4$ )	0.20 g.
Magnesium sulphate	( $MgSO_4 \cdot 7H_2O$ )	0.20 g.
Ammonium sulphate	( $NH_4$ ) <sub>2</sub> SO <sub>4</sub>	0.20 g.
Sodium chloride	(NaCl)	0.20 g.
Calcium sulphate	( $CaSO_4 \cdot 2H_2O$ )	0.10 g.
Calcium carbonate	( $CaCO_3$ )	5.00 g.
Mannitol		10.00 g.
Agar		20.00 g.
Distilled water		1 litre.

When the medium was cool, but still liquid, about 0.5 g. of the soils sample was spread over the liquid in the dish. After incubating for about a week at 30°C, the medium was examined for characteristic raised colonies with a glistening appearance. A loopful of the growth was taken and streaked on fresh solid medium and incubated. The cultures were purified by repeated plating and selecting solitary and well-growing colonies until a pure culture was obtained.

#### Study of growth characters

Organisms from all the three horizons were isolated and the growth characters studied. Microscopical study of the morphology of the organism too was undertaken. The organism was inoculated on four different media viz. Thornton's agar, Ashby's mannitol phosphate agar, Derx and Jensen's media and the growth characters studied. Derx medium with the pH varying from 4.0 to 8.0, were inoculated with the organism and the growth habits noted.

#### Nitrogen-fixing capacity

The nitrogen fixing capacity of the isolates was determined in two media viz. Jensen's (Liquid) medium described earlier and Derx medium with the following composition.

Sucrose		20.00 g.
Monopotassium phosphate ( $\text{KH}_2\text{PO}_4$ )		0.80 g.
Dipotassium phosphate ( $\text{K}_2\text{HPO}_4$ )		0.20 g.
Magnesium sulphate ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ )		0.50 g.
Ferric chloride ( $\text{FeCl}_3 \cdot 7\text{H}_2\text{O}$ )		0.10 g.
Sodium molybdate ( $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ )		0.05 g.
Calcium chloride ( $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ )		0.05 g.
Distilled water		1 litre.
(pH adjusted to 6.6)		

25 ml. of the sterile media were inoculated with a loopful of the growth and incubated for a month at 30°C. The nitrogen content of the liquid after incubation was determined by Kjeldal method as described earlier. One control and four replications were maintained.

## RESULTS

## R E S U L T S

### 1. Mechanical composition

The mechanical composition of the soils is presented in Table I.

i. Loss on ignition: The loss on ignition as seen from the data is generally high. It steadily decreases with depth and reaches a minimum in the lowest layer. The values vary from 5.35 to 17.41 per cent.

ii. Soil separates: In general the percentage of the coarse sand fraction is low in the different horizons of the various profiles.

The fine sand content of the first and second layers of the profiles is usually high, whereas the lowest horizons are less sandy in all the profiles. Generally the second horizon is the most sandy containing the maximum percentage of coarse and fine sand fractions while the lowest horizons are the least sandy. The coarse sand content varies from 0.89 to 12.17 per cent and fine sand from 2.19 to 33.17 per cent.

The distribution of clay in the various horizons is similar to that of silt. The different layers are fairly high in their clay content, the maximum being in the lowest horizon and the minimum in the second layer. Clay content

T A B L E I

MECHANICAL COMPOSITION OF KARI SOILS

Sample No.	Depth in cm.	Moisture	Loss on ignition	Textural separates				Textural class	Clay ratio ( <u>Sand + silt</u> ) clay
				Coarse sand	Fine sand	Silt	Clay		
Percent on oven-dry basis									
Profile I. Koithuruthu									
1	0 - 24	8.85	17.41	1.93	21.24	22.47	36.09	Clay loam	1.27
2	24 - 75	9.95	15.50	7.69	33.17	18.70	26.47	Sandy clay loam	2.28
3	Below 75	7.05	14.56	0.89	2.19	38.61	45.18	Clay	0.92
Profile II. Oozikari									
4	0 - 24	10.89	10.71	1.34	17.87	31.30	37.45	Clay loam	1.39
5	24 - 75	9.45	7.90	3.67	26.08	23.71	37.90	Clay loam	1.41
6	Below 75	5.20	5.35	0.94	3.08	39.43	43.50	Clay	0.99
Profile III. Elurkalam									
7	0 - 24	8.23	12.27	1.36	9.39	34.12	44.20	Clay	1.01
8	24 - 75	10.85	10.40	2.09	14.48	33.65	38.87	Clay loam	1.32
9	Below 75	4.95	10.17	1.78	3.94	39.00	47.38	Clay	0.94
Profile IV. Kochukottakari									
10	0 - 24	10.65	12.06	4.98	27.11	21.54	34.21	Sandy clay loam	1.57
11	24 - 75	11.33	7.72	12.17	29.44	19.70	30.33	Sandy clay loam	2.02
12	Below 75	6.16	9.30	1.88	17.56	33.76	40.45	Clay loam	1.31

varies from 26.46 to 47.38 per cent. The clay ratio is highest in the second horizon and lowest in the third in all the profiles.

The mechanical composition indicates that the soils of the various horizons in the different profiles are either clays or clay loams.

## 2. Physical properties and soil moisture constants

The important physical properties and soil moisture constants of the samples are presented in Table II.

The apparent density of the soils in the various horizons shows significant variation. The soils of the second layers have the minimum apparent density, while the maximum is observed in the lowest horizons in all the profiles. The absolute specific gravity, too, shows some variation. While the apparent density is maximum in the lowest layer, the absolute specific gravity is highest in the middle layer. The minimum and the maximum values of apparent density observed are 0.94 and 1.32 respectively. The absolute specific gravity varies from 2.05 to 2.29.

The waterholding capacity and porosity of the soils differ considerably, the maximum in both cases being in the middle horizons. These properties have apparently no relation to the clay content of these soils as is generally found in other soil types. Waterholding capacity varies



T A B L E II  
 SINGLE VALUE CONSTANTS OF KARI SOILS  
 (Percent on oven-dry basis)

Sample No.	Depth in cm.	Apparent density	Absolute specific gravity	Maximum water holding capacity %	Percentage of porespace	Volume expansion of 100 ml. soil
Profile I. Koithuruthu						
1	0 - 24	1.11	2.12	46.90	55.50	10.31
2	24 - 75	0.94	2.29	65.40	63.90	7.16
3	Below 75	1.14	2.11	56.30	60.70	21.81
Profile II. Oorikari						
4	0 - 24	1.18	2.07	52.30	60.30	12.07
5	24 - 75	1.18	2.18	52.00	61.90	11.32
6	Below 75	1.32	2.16	53.90	60.00	19.99
Profile III. Elurkalam						
7	0 - 24	1.16	2.20	47.20	53.10	14.80
8	24 - 75	0.98	2.19	70.10	60.10	11.76
9	Below 75	1.18	2.23	54.10	55.30	24.41
Profile IV. Kochukottakari						
10	0 - 24	1.10	2.05	47.10	56.20	9.33
11	24 - 75	1.09	2.24	55.50	58.60	6.52
12	Below 75	1.20	2.12	59.70	62.10	19.14

from 46.90 to 70.10 per cent and porosity from 55.50 to 61.90 per cent.

Volume expansion is highest in the lowest horizon and lowest in the second layer. The maximum observed value of volume expansion is 24.41 and the minimum 6.52 ml. per 100 ml. of soil.

### 3. Chemical properties

The important chemical properties of the soils are given in Table III, IV, V and VI.

1. pH: The pH values of the soils and the carbon : nitrogen relationships are presented in Table III.

It may be seen from the table that the pH of the fresh samples does not vary much in the profile. They are all nearly neutral in reaction, but on air-drying there is considerable reduction in the pH, especially in the upper layers. The pH values of the lowest horizons are not much affected by drying. The pH of the air-dry soil increases with depth in all the profiles. Among the different profiles, there is very little variation in the pH values. The pH of the soils determined in 0.01 M. calcium chloride solution is not much different from that determined in soil-water suspension. The pH of the different air-dry soils varies from 2.7 to 7.2. In the second profile (Oorikari) it rises from 3.6 in the upper layer to 7.2 in the lowest layer. All the

T A B L E III

CARBON NITROGEN RELATIONSHIP OF KARI SOILS

Sample No.	Depth in cm.	pH			Organic matter (as CaCO <sub>3</sub> )	Organic carbon	Total Nitrogen	Carbon/nitrogen ratio	
		Fresh soil	Air dry soil	In 0.01 M CaCl <sub>2</sub> solution					
Profile I. Koithuruthu									
1	0 - 24	6.8	3.7	3.5	17.01	..	10.01	0.618	16.19
2	24 - 75	7.1	6.7	6.4	14.19	2.12	8.35	0.401	20.82
3	Below 75	7.1	7.1	7.2	12.58	6.72	7.40	0.291	25.43
Profile II. Oorikari									
4	0 - 24	6.5	3.6	3.5	9.95	..	5.85	0.217	26.99
5	24 - 75	6.8	5.6	5.6	7.77	..	4.57	0.183	24.98
6	Below 75	7.9	7.2	7.2	2.75	6.89	1.62	0.126	16.89
Profile III. Elurkalam									
7	0 - 24	6.1	3.7	3.4	11.59	..	6.82	0.218	31.29
8	24 - 75	6.2	2.7	2.6	9.94	..	5.85	0.210	27.85
9	Below 75	7.3	6.9	6.7	8.89	5.94	5.23	0.140	37.36
Profile IV. Kochukottakari									
10	0 - 24	6.3	4.2	4.1	11.54	..	6.73	0.178	37.87
11	24 - 75	6.5	3.9	3.7	8.41	..	4.95	0.152	32.56
12	Below 75	6.8	6.7	6.8	7.66	5.56	4.81	0.144	31.32

17.01  
14.19  
12.58  
8.35  
7.40  
5.85  
4.57  
1.62  
6.82  
5.85  
5.23  
6.73  
4.95  
4.81

other profiles show similar variations, but to lesser extents.

ii. Organic matter: As in the case of loss on ignition, the organic matter content of the soils decreases with depth and varies from 2.75 to 17.01 per cent.

iii. Carbonates: Carbonates (2.12 to 6.89 per cent  $\text{CaCO}_3$ ) are found to occur in the lowest layers of all the profiles. In the case of the first profile (Koithuruthu padasekharam) appreciable amounts are observed in the second horizon also.

iv. Carbon, nitrogen and C/N ratio: The organic carbon and nitrogen contents of the soils decrease with depth in all the profiles. The soils are rich in both these elements (1.62 to 10.01 per cent carbon and 0.126 to 0.618 per cent nitrogen). The C/N ratios of the soils are relatively high (16.19 to 37.87).

v. Sesquioxides: As can be seen from Table IV, the soils are fairly high in the sesquioxides, the percentage increasing with depth in most cases. In the second profile (Oorikari padasekharam) the sesquioxides tend to accumulate in the middle horizon. The soils contain 15.85 to 25.53 per cent sesquioxides.

vi.  $\text{P}_2\text{O}_5$  and  $\text{K}_2\text{O}$ : The soils are rich in their total phosphoric acid and potash contents. Both nutrients are relatively more in the lowest horizon. The observed maximum

T A B L E IV  
CHEMICAL CHARACTERISTICS OF KARI SOILS

Sample No.	Depth in cm.	Sesqui-oxides	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	CaO	MgO	Sulphur as SO <sub>4</sub>
P e r c e n t   o n   o v e n - d r y   b a s i s									
Profile I. Koilthuruthu									
1	0 - 24	16.15	6.29	9.89	0.185	0.233	0.63	0.314	1.852
2	24 - 75	15.85	5.98	9.87	0.148	0.192	1.33	0.607	2.674
3	Below 75	22.68	7.43	15.25	0.258	0.349	3.41	0.432	4.320
Profile II. Oorikari									
4	0 - 24	19.25	7.11	12.14	0.149	0.251	0.52	0.411	1.440
5	24 - 75	21.78	7.97	13.81	0.227	0.368	1.05	0.661	2.880
6	Below 75	15.75	5.31	10.44	0.187	0.405	3.73	0.534	3.497
Profile III. Elurkalam									
7	0 - 24	19.53	6.65	12.88	0.139	1.213	0.61	0.322	1.661
8	24 - 75	20.00	6.87	13.13	0.138	0.323	0.53	0.406	2.934
9	Below 75	21.50	7.42	14.18	0.253	0.337	2.50	0.398	3.701
Profile IV. Kochukottakari									
10	0 - 24	21.88	8.01	13.87	0.136	0.233	2.55	0.216	1.214
11	24 - 75	21.78	8.12	13.66	0.205	0.322	0.63	0.362	2.376
12	Below 75	25.53	9.14	16.39	0.270	0.401	1.87	0.543	3.185

value for  $P_2O_5$  is 0.270 per cent and that for  $K_2O$  is 0.405 per cent.

vii. Calcium and Magnesium: The calcium and magnesium status of the soils is fairly high. There is an accumulation of these elements in the lowest horizons, their maximum values being 3.73 per cent  $CaO$  and 0.661 per cent  $MgO$ .

viii. Sulphur: The sulphur content of the soils increases with depth and reaches a maximum of 4.32 per cent in the lowest layer of the first profile (Koithuruthu padasekharam).

ix. Conductivity and soluble salts: The results of analysis of the water extract of the soils are tabulated in Table V.

The conductivity of the extracts (2.7 to 6.0 mmhos per cm.) shows that the soils are slightly saline in nature. The soluble salt content of the soils is comparatively high (0.58 to 2.60 per cent). -The sulphate content of the soils is more than the chloride content. The levels of soluble calcium and magnesium are low. Potassium and sodium are the predominant cations. The salt content is more in the second horizon than in the other two.

x. Available nutrients and cation exchange capacity: Data on the available nutrients and the cation exchange capacity of the soils are presented in Table VI.

T A B L E V  
COMPOSITION OF WATER EXTRACT OF KARI SOILS

Sample No.	Depth in cm.	Conductivity mmhos/cm.	Total soluble salts					
			Chlorides	Sulphates	CaO	MgO	K + Na	
P e r c e n t   o n   o v e n - d r y   b a s i s								
Profile I. Koithuruthu								
1	0 - 24	4.5	1.51	0.170	0.75	0.082	0.162	0.346
2	24 - 75	6.0	2.60	0.262	1.36	0.216	0.181	0.581
3	Below 75	5.0	1.56	0.332	0.66	0.073	0.064	0.431
Profile II. Oorikari								
4	0 - 24	3.8	1.29	0.167	0.65	0.078	0.013	0.382
5	24 - 75	4.0	1.20	0.212	0.49	0.096	0.021	0.381
6	Below 75	2.8	0.93	0.191	0.38	0.073	0.014	0.272
Profile III. Elurkalam								
7	0 - 24	3.0	0.51	0.158	0.26	0.027	0.012	0.053
8	24 - 75	5.0	1.98	0.194	1.07	0.089	0.019	0.608
9	Below 75	4.0	0.84	0.232	0.44	0.132	0.013	0.023
Profile IV. Kochukottakari								
10	0 - 24	2.7	0.55	0.173	0.31	0.036	0.010	0.121
11	24 - 75	4.0	0.98	0.167	0.65	0.107	0.013	0.043
12	Below 75	3.6	0.85	0.282	0.41	0.064	0.011	0.083

The available nitrogen content of the soils decreases with depth in all the profiles. The available phosphoric acid status of the soils is very low. The availability of this nutrient increases with depth, the maximum being in the lowest horizons (0.0021 per cent). The available potash content of the soils, too, is very low and, like phosphoric acid, the availability of the nutrient increases with depth, the maximum observed value being 0.0187 per cent.

The soils have a fairly high cation exchange capacity. The exchange capacity is a maximum in the lowest layers and minimum in the upper layers in most cases. It varies between 14.7 to 25.8 milliequivalents per 100 g. of soil.

#### 4. Composition of the clay fraction

Data on the analysis of the clay fraction of the soils are given in Table VII.

The composition of the clay fraction seems to be similar throughout the profiles, as suggested by the uniformity in the values of the silica and sesquioxides contents. The silica and the sesquioxide contents of the clays do not vary to any appreciable extent among the different samples examined. The clay fraction contains a high percentage of silica (51.0 to 56.0 per cent) whereas



T A B L E VI

AVAILABLE NUTRIENTS AND CATION EXCHANGE CAPACITY OF KARI SOILS

Sample No.	Depth in cm.	Available nitrogen	Available P <sub>2</sub> O <sub>5</sub>	Available K <sub>2</sub> O	Cation exchange capacity me./100 g.
		Percent on oven-dry basis			
Profile I. Koithuruthu					
1	0 - 24	0.026	0.0009	0.0060	19.2
2	24 - 75	0.018	0.0013	0.0086	18.4
3	Below 75	0.008	0.0021	0.0137	22.3
Profile II. Oorikari					
4	0 - 24	0.014	0.0007	0.0077	17.0
5	24 - 75	0.007	0.0008	0.0068	15.6
6	Below 75	0.005	0.0011	0.0187	23.0
Profile III. Elurkalan					
7	0 - 24	0.021	0.0007	0.0053	25.8
8	24 - 75	0.011	0.0007	0.0081	21.2
9	Below 75	0.006	0.0012	0.0141	20.9
Profile IV. Kochukottakari					
10	0 - 24	0.059	0.0008	0.0064	16.6
11	24 - 75	0.024	0.0007	0.0089	14.7
12	Below 75	0.007	0.0019	0.0138	17.1

T A B L E   V I I  
ANALYSIS OF CLAY FRACTION OF KARI SOILS

Sample No.	Depth in cm.	Moisture	Loss on ignition	SiO <sub>2</sub>	R <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>
P e r c e n t   o n   o v e n - d r y   b a s i s							
Profile I. Koithuruthu							
1	0 - 24	13.15	15.45	53.43	34.26	14.00	20.26
2	24 - 75	13.07	13.34	54.17	34.88	16.10	18.78
3	Below 75	12.68	14.01	52.38	33.60	13.80	19.20
Profile II. Oorikari							
4	0 - 24	12.98	14.96	55.14	35.05	15.90	19.15
5	24 - 75	11.70	14.66	51.42	35.91	17.60	18.31
6	Below 75	12.65	14.45	54.19	36.64	14.20	22.24
Profile III. Murkalam							
7	0 - 24	11.88	15.03	53.78	34.98	13.30	21.68
8	24 - 75	12.10	14.62	53.41	36.17	19.60	16.57
9	Below 75	11.36	15.22	51.30	37.75	18.70	19.05
Profile IV. Kochukottakari							
10	0 - 24	10.11	14.99	52.66	34.08	12.40	21.68
11	24 - 75	8.89	15.67	53.78	36.21	10.90	25.31
12	Below 75	9.69	13.87	52.59	35.32	17.00	18.32

T A B L E VIII  
MOLAR RATIOS AND CATION EXCHANGE CAPACITY OF CLAY  
FRACTION IN KARI SOILS

Sample No.	Depth in cm.	SiO <sub>2</sub> /R <sub>2</sub> O <sub>3</sub> ratio	SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> ratio	Al <sub>2</sub> O <sub>3</sub> /Fe <sub>2</sub> O <sub>3</sub> ratio	Cation exchange capacity me./100 g.
Profile I. Koithuruthu					
1	0 - 24	2.69	4.50	0.444	49.3
2	24 - 75	2.27	4.90	0.543	48.7
3	Below 75	2.27	4.51	0.443	47.6
Profile II. Oorikari					
4	0 - 24	2.30	4.91	0.476	47.9
5	24 - 75	2.10	4.76	0.611	46.8
6	Below 75	2.57	4.10	0.413	46.4
Profile III. Elurkalam					
7	0 - 24	2.24	4.22	0.391	45.2
8	24 - 75	2.16	5.49	0.759	45.6
9	Below 75	1.99	4.59	0.591	44.1
Profile IV. Kochukottakari					
10	0 - 24	2.25	4.13	0.360	46.5
11	24 - 75	2.15	3.61	0.274	45.0
12	Below 75	2.12	4.86	0.588	45.2

the alumina content is comparatively low (18.0 to 22.0 per cent).

Table VIII gives the molar ratios and cation exchange capacities of the clay fractions. The silica : sesquioxide ratios are above 2.0 in all but one case and the silica : alumina ratio varies from 3.61 to 5.49. The alumina : iron oxide ratio shows an irregular variation between the profiles.

The cation exchange capacity of the clay fractions separated from all the profiles are rather high and constant, the variation being only from 44 to 50 milliequivalents per 100 g.

## 5. Microbiological properties

Some important microbiological characters of the soils are given in Table IX.

1. Total count: The total count of microorganisms in the soils is rather low, especially in the top layers where it is only of the order of a few thousands. But an increase in the microbial population is observed in the lowest layers (4.53 millions per g.). Another important finding is that most of the microorganisms in the top layers are fungi, whereas bacteria predominate in the horizons below.

T A B L E IX  
MICROBIOLOGICAL PROPERTIES OF KARI SOILS

Sample No.	Depth in cm.	pH	Total count millions/g.	Ammonifying power mg. N/g. soil	N fixing capacity mg. N/g. of sucrose
Profile I. Koithuruthu					
1	0 - 24	3.7	0.41	26.04	2.11
2	24 - 75	6.7	0.52	19.46	3.80
3	Below 75	7.1	4.53	21.42	10.20
Profile II. Oorikari					
4	0 - 24	3.6	0.44	26.17	3.67
5	24 - 75	5.6	0.23	22.54	2.48
6	Below 75	7.2	1.90	16.10	8.91
Profile III. Murkalam					
7	0 - 24	3.7	0.39	23.38	1.22
8	24 - 75	2.7	0.11	12.46	1.08
9	Below 75	6.9	1.53	11.34	9.72
Profile IV. Kochukottakari					
10	0 - 24	4.2	0.27	23.94	1.79
11	24 - 75	3.9	0.22	16.10	2.57
12	Below 75	6.7	4.51	9.38	11.46

ii. Ammonifying power: In contrast to the total count, ammonifying power is found to decrease with depth in the profiles. The soils have a fairly high ammonifying power (9.34 to 26.17 mg. of nitrogen per g. of soil).

iii. Nitrogen fixing capacity: The nitrogen-fixing capacity of the soils is found to increase with depth; the lowest layers possessing the maximum capacity. The values for nitrogen-fixing capacity varies from 2.11 to 11.46 mg. of nitrogen per g. of sugar.

#### 6. Isolation and study of a nitrogen-fixing organism

The characteristic convex, opaque to dull white, highly raised colonies of the nitrogen fixing organisms were found to develop in large numbers in plates inoculated with the soils from the lowest layers whereas the top layers gave rise to only a few such colonies. The organisms isolated from all the horizons had the same growth characters and morphological features. In all the cases the colonies developed were highly raised, large, convex, glistening and somewhat gummy in nature. The colour of the colonies varied from opaque to transparent through dull white. An abundant growth was obtained within 24 hours of inoculation.

Morphologically the organisms were cocci and diplococci with good mobility when taken from new growth.

They were found to grow readily on both nitrogenous

T A B L E X  
 NITROGEN FIXING CAPACITY OF MICROORGANISMS  
 ISOLATED FROM KARI SOILS

Sample No.	Depth in cm.	Mg. nitrogen fixed/g. of sucrose	
		Derx medium	Jensen's medium
Profile I. Koithuruthu			
1	0 - 24	12.60	12.33
2	24 - 75	10.31	11.16
3	Below 75	14.84	14.37
Profile II. Oorikari			
4	0 - 24	11.47	11.68
5	24 - 75	11.52	10.08
6	Below 75	13.17	13.65
Profile III. Elurkalam			
7	0 - 24	10.88	11.22
8	24 - 75	12.76	11.13
9	Below 75	14.26	14.14
Profile IV. K <sub>o</sub> chukottakari			
10	0 - 24	11.30	12.80
11	24 - 75	10.43	11.91
12	Below 75	14.87	13.09

and nitrogen-free media, of a wide pH range (4.0 to 8.0). In acid media the growth was not as abundant and quick as in neutral and alkaline media. The growth of the colonies did not proceed beyond a particular stage in the acid media, whereas it proceeded unhindered in neutral and alkaline media.

The nitrogen-fixing capacity of the organism was studied in two media. They were found to fix about 10-15 mg. nitrogen per g. of energy material (Table X). The organisms isolated from the different horizons did not show much variation in their nitrogen-fixing capacities.



**D I S C U S S I O N**

## DISCUSSION

The results of the present study indicate that the Kari soils of Kerala are unique in their physical, chemical and microbiological properties, and that in these properties, they differ considerably from other soil types found in the State. The following discussion will bring out some of their salient features.

### 1. Mechanical and chemical composition

The organic nature of the Kari soils is revealed by the carbon content and also the high percentage of loss on ignition, which is usually taken as a measure of the organic matter content. In the upper layers of the profiles, the values of loss on ignition can be fully accounted for by the organic matter content determined by other methods. But in the lower layers the organic matter content alone cannot fully account for the loss on ignition observed. This may be due to the carbonates present in these layers (Table III) which on heating might have given out carbon dioxide and resulted in a loss on ignition.

Though the soils contain a high percentage of organic matter, the level of this component is not sufficient to designate them as peaty soils, since typical peaty soils are those which contain more than 20 percent organic matter (Lawton, 1955; Moorman and Panaboke, 1960). The high

**Fig. 1**

**Diagrammatic representation of the  
mechanical composition of the soils.**

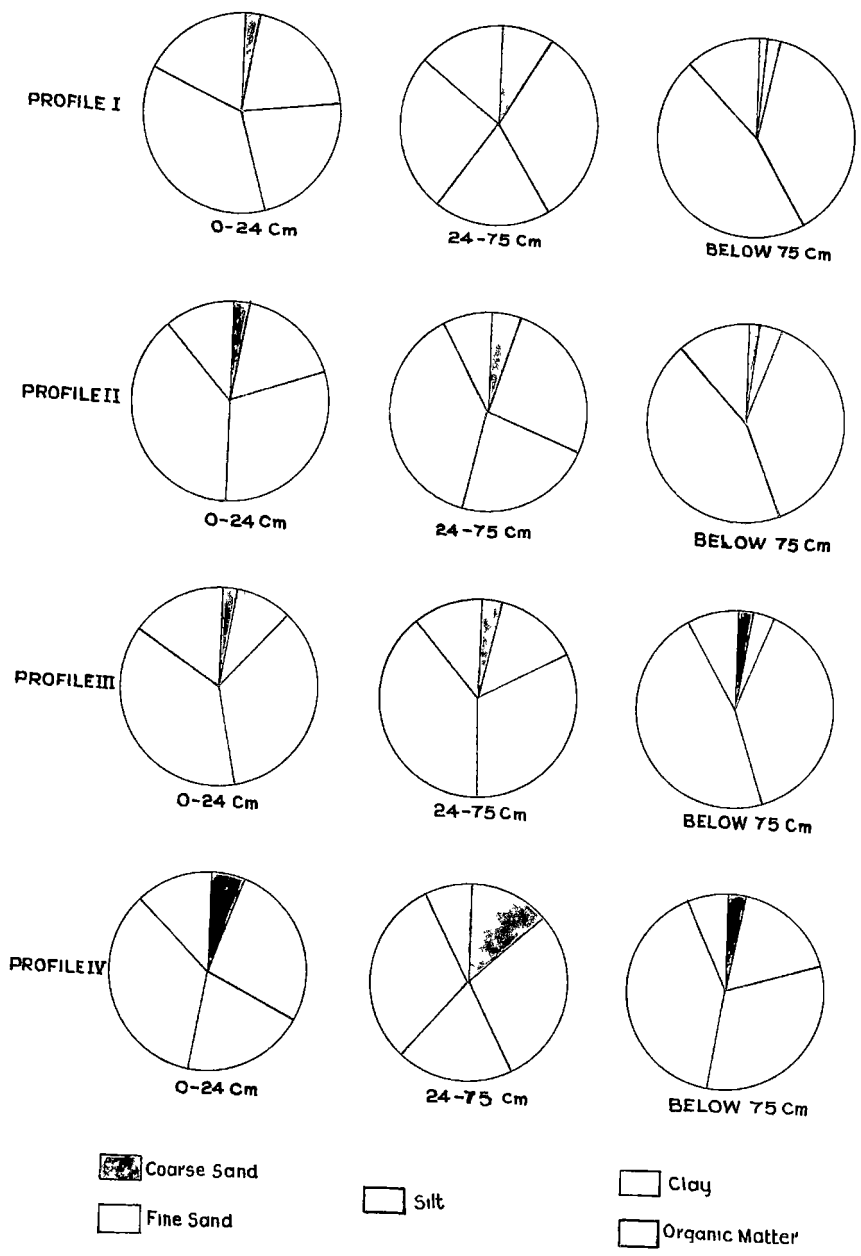


FIG.1

percentage of organic matter in the top layers and the gradual decrease in its percentage with depth suggest that the source of the organic matter in these soils might, probably, be the marshy vegetation once abundant in these areas.

By and large, most of the characteristic properties of these soils are attributable to their high organic matter content.

The soils are generally clays or clay-loams and there is an irregular distribution of the various soil separates in the profile which is diagrammatically represented in Fig. I. This irregularity in the distribution of soil separates indicates the predominant role played by transportation and sedimentation processes in the assemblage of these soils (Gopalaswamy, 1958).

The observed single value constants of the soils suggest their intermediary position between a typical peat and a typical mineral soil. The characteristically low apparent density and high water-holding capacity of peats (Croegaert et al., 1954; Lyon et al., 1955; Grebenshchikova, 1957) are not observed in these soils. Another interesting phenomenon about these soils is that the water-holding capacity and porosity are not related to their clay content. This may either be due to the modifying effects of the comparatively high organic matter status of these soils or

due to the influence of continuous waterlogging which might have hampered such relationships (Gopalaswamy, 1958).

The lower layers of these soils are characterised by the presence of large amounts of carbonates. As these soils are generally believed to have originated from non-calcareous alluvial and organic material, the origin of these carbonates should be traced to a source other than the parent material. It will be reasonable to assume that the lime shells found in abundance in these areas might have given rise to the carbonates in the lower layers of these soils. Still, their specific occurrence exclusively in the lower horizons, remains a baffling problem, as one would naturally expect to find them in the upper layers as well. Jackson (1953) stated that the accumulation of carbonates at a particular depth in the profile indicates the depth to which percolating waters travel. But it is doubtful whether the percolating waters can be held responsible for the accumulation of carbonates in the lower layers of these soils, as their drainage conditions are extremely poor. It has to be examined whether the fluctuating water table in these soils has any role in the deposition of carbonates in the lower layers. However the available data do not warrant drawing any definite conclusion regarding the cause of the occurrence of carbonates at these depths. Further investigations will be necessary to find an explanation for this phenomenon.

Whitson et al. (1919) and Wilson and Staker (1932) found that calcium carbonate is completely absent from organic soils although they may contain calcium. The high calcium carbonate content of these soils shows that they are very much different from other organic and marshy soils.

The high sesquioxide content indicates that the inorganic component of these soils is of lateretic origin.

The cation exchange capacity of the surface soils is comparatively low in spite of their high organic matter content. On the other hand, the cation exchange capacity of the lower horizons tends to be higher, which might be attributed to the higher content of clay in them. Obviously the organic matter in the upper layers are in an unhumified state and hence makes very little contribution towards this property.

## 2. Soil acidity

It is a paradox that the soils under study have a pH as low as 2.7 in the upper layers while the pH of the lower layers remain near about 7.0. Nair (1945) has reported that the pH of the Kari soils is dependant on their organic matter content. The organic matter in the upper layers may therefore be the cause of the high acidity of these soils. Another probable reason for the neutral reaction of the lower layers is the carbonates present in them which

Fig. 2

Graph showing the pH of the soils.



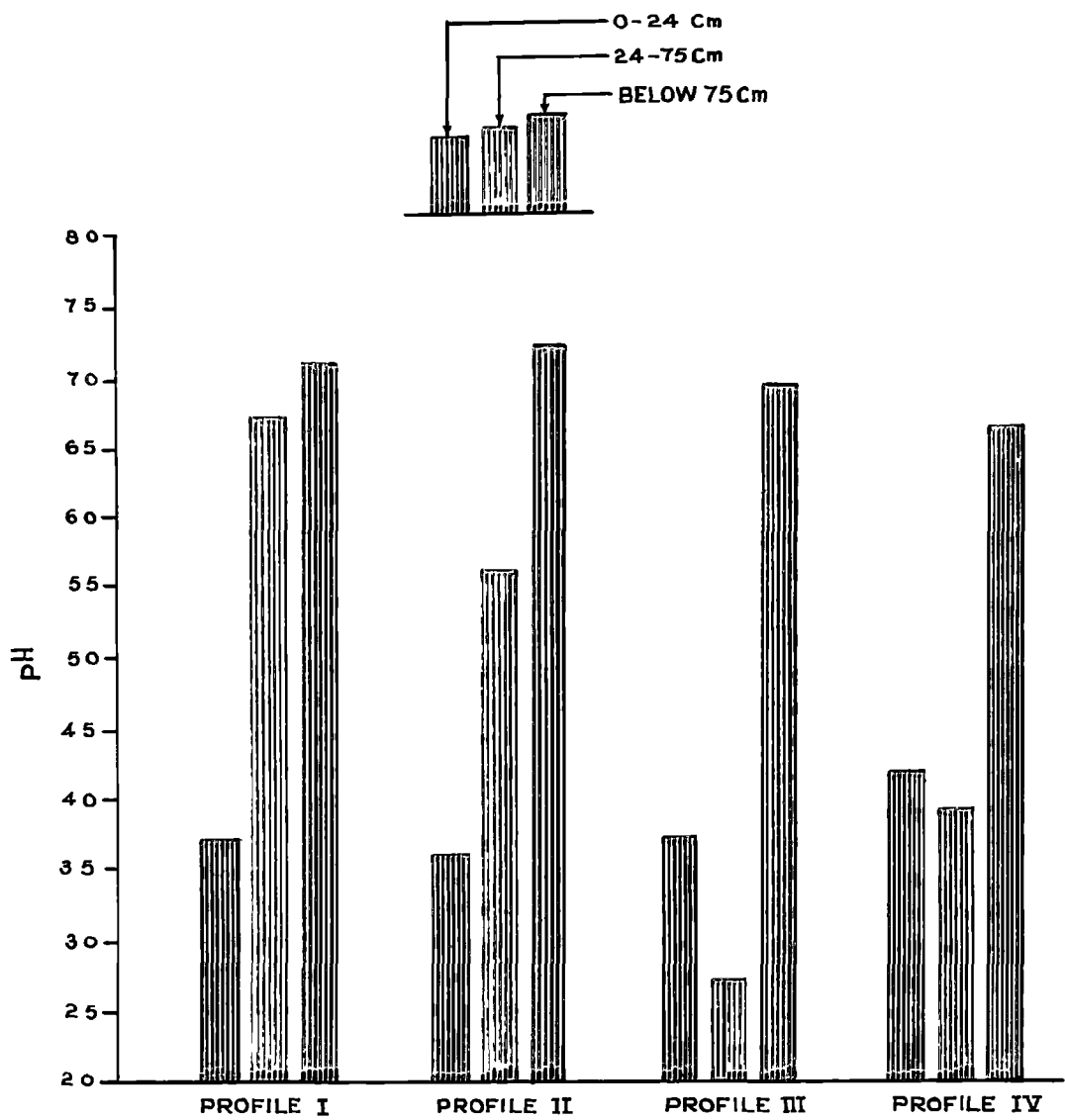


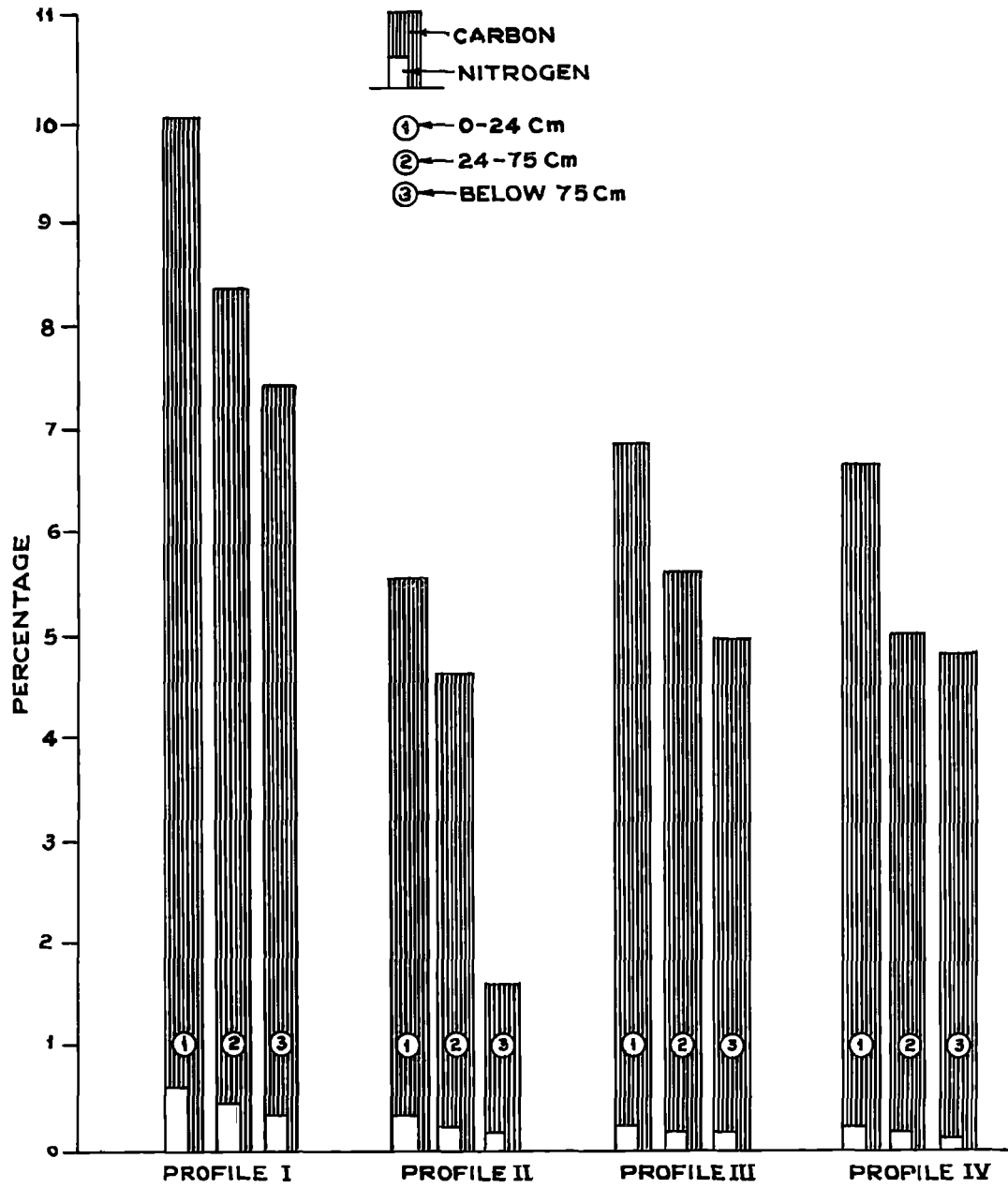
FIG 2

neutralise whatever little acidity that develops in these layers. The variation in the pH of the profiles is graphically represented in Fig. 2.

Another interesting phenomenon about the pH of these soils is that the waterlogged soils which are almost neutral in reaction becomes extremely acidic on air-drying. This may be due to the presence of substances capable of changing their degree of oxidation and reduction with consequent fall or rise in pH (Russel, 1962). Sulphides present in the soils have the property of getting alternately oxidised and reduced. The soils investigated are rich in sulphur compounds which may either have been trapped by them from the periodically inundating salt water (Edelman, 1958) or have originated from the organic matter itself. Pillai and Subramoniam (1931) have reported a high content of sulphur in the Kari soils which are present mostly in the form of sulphates. They have further shown that sulphides are formed in these soils as a result of waterlogging. Subramoney (1958), too, has reported a high sulphur content in these soils present mostly as sulphides of iron. These sulphur compounds which remains as sulphides in the waterlogged soils do not affect the pH and hence the soils are neutral. But on air drying, conditions become conducive for the oxidation of sulphides to sulphates and then to sulphuric acid which render the soils extremely acidic (Pillai and Subramoniam, 1931; Subramoney, 1958).

**Fig. 3**

**Graph showing the carbon-  
nitrogen relationship of the soils.**



**FIG 3**

The pH of the soils determined in 0.01 M calcium chloride solution did not show much difference from that determined in pure water, probably due to the naturally high salt content of the soils and due to the presence of free sulphuric acid.

### 3. Carbon nitrogen relationships

The carbon and nitrogen contents of the soils are rather high and decrease with depth, which is graphically represented in Fig.3. The high content of these elements is accompanied by a wide ratio between them. This may be due to the probable losses of nitrogen from these soils, through ammonification and denitrification, both processes being favoured by the reducing waterlogged conditions existing in them. The same reducing conditions which favour the loss of nitrogen, conserve the carbon of the soil by preventing the oxidation of the organic matter (Wills and Sturges, 1944; Pearsal, 1950). The wide C/N ratio of the marsh vegetation which gave rise to the undecomposed organic matter in these soils may also be responsible for the wide C/N ratio. (Frercks and Puffe, 1958). Lytle and Driskel (1954) have reported an increase in the C/N ratio with increase in the organic matter content. Lucas and Davis (1961), too, have reported wide C/N ratios (30-60) for organic soils with low pH. According to Hair (1945) the organic matter content, pH and C/N ratio are interrelated and are also related to the fertility status of Kari soils.

#### 4. Fertility status of the soils

The high content of nitrogen, phosphorus and potassium in these soils suggest that they are naturally fertile. A high level of nitrogen in these soils may be expected as they are rich in organic matter (Alway, 1914; Wilson and Staker, 1932; Vanwijk, 1951). But among previous workers, opinion differs regarding the phosphorus and potassium status of organic soils. The high  $P_2O_5$  content of these soils may be due to the heavy dressings of phosphatic fertilizers which they receive. The high level of  $K_2O$  can be attributed to the presence of potassium containing minerals in these soils. The soils are also rich in secondary elements such as calcium, magnesium and sulphur. As discussed earlier the source of these elements may be the lime shells which are abundant in this area and the sea water with which the soils are inundated periodically.

Though the soils are rich in total plant nutrients their availability is extremely low, probably due to unfavourable conditions in the soil. Foremost among these conditions are the acidity and the wide C/N ratio. These factors tend to reduce the availability of the plant food elements and this has been borne out by the observed low values of the available nutrients. The low availability of nitrogen in peat soils has been attributed to many factors, such as, formation of complex ligno-proteins (Robinson, 1911;

Fig. 4

Graph showing the conductivity of the soils.

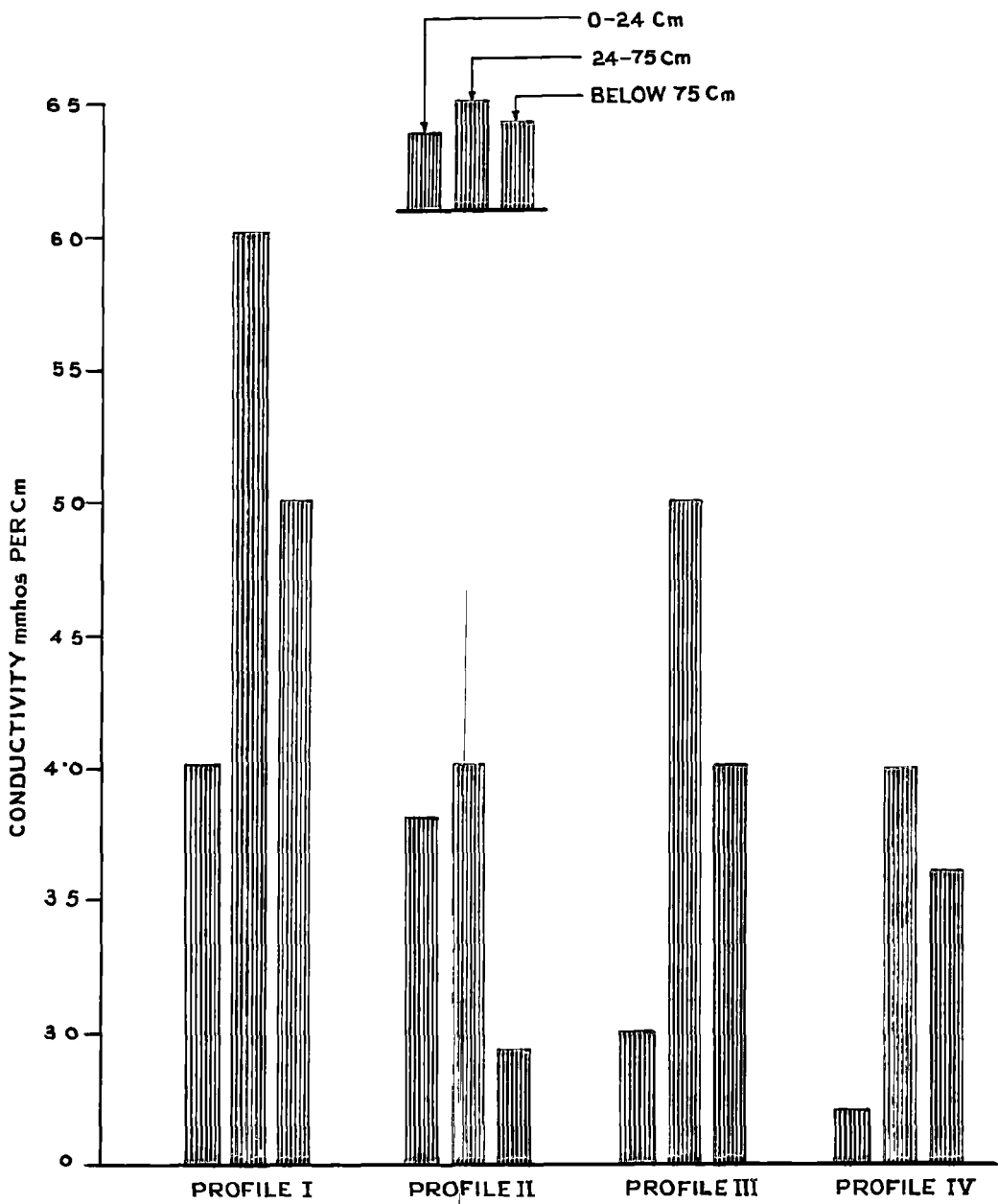


FIG. 4



Polak, 1950), low pH and poor lime content (Alway, 1914; Pearsal, 1950) and fixation of ammoniacal nitrogen in the soils (Burgess and Broadbent, 1961). Probably all these factors are together controlling the availability of nitrogen in these soils.

The pH of the soils seems to be largely responsible for the low availability of phosphorus (Alway, 1914; Davis, 1961). The theory of Kaila (1956, 1958) that the unavailability of phosphorus in peats is due to its existence in the organic form too seems to be applicable in this context.

The low values of available potassium in these soils is indicative of the fixation of this element in unavailable forms.

The conductivity and soluble salt estimations suggest that the soils can be called saline (Fig. 4). Nair (1945) found that the fertility status of these soils had no relation to their salt content.

#### 5. Composition of the clay fraction

The high silica : sesquioxide (above 2.0) and silica : alumina (3.5 to 6.0) ratios and the high cation exchange capacity (44-50 m.e. per 100 g.) suggest that there is a good proportion of montmorillonitic clays associated

Fig. 5

Graph showing the total microbial count of the soils.

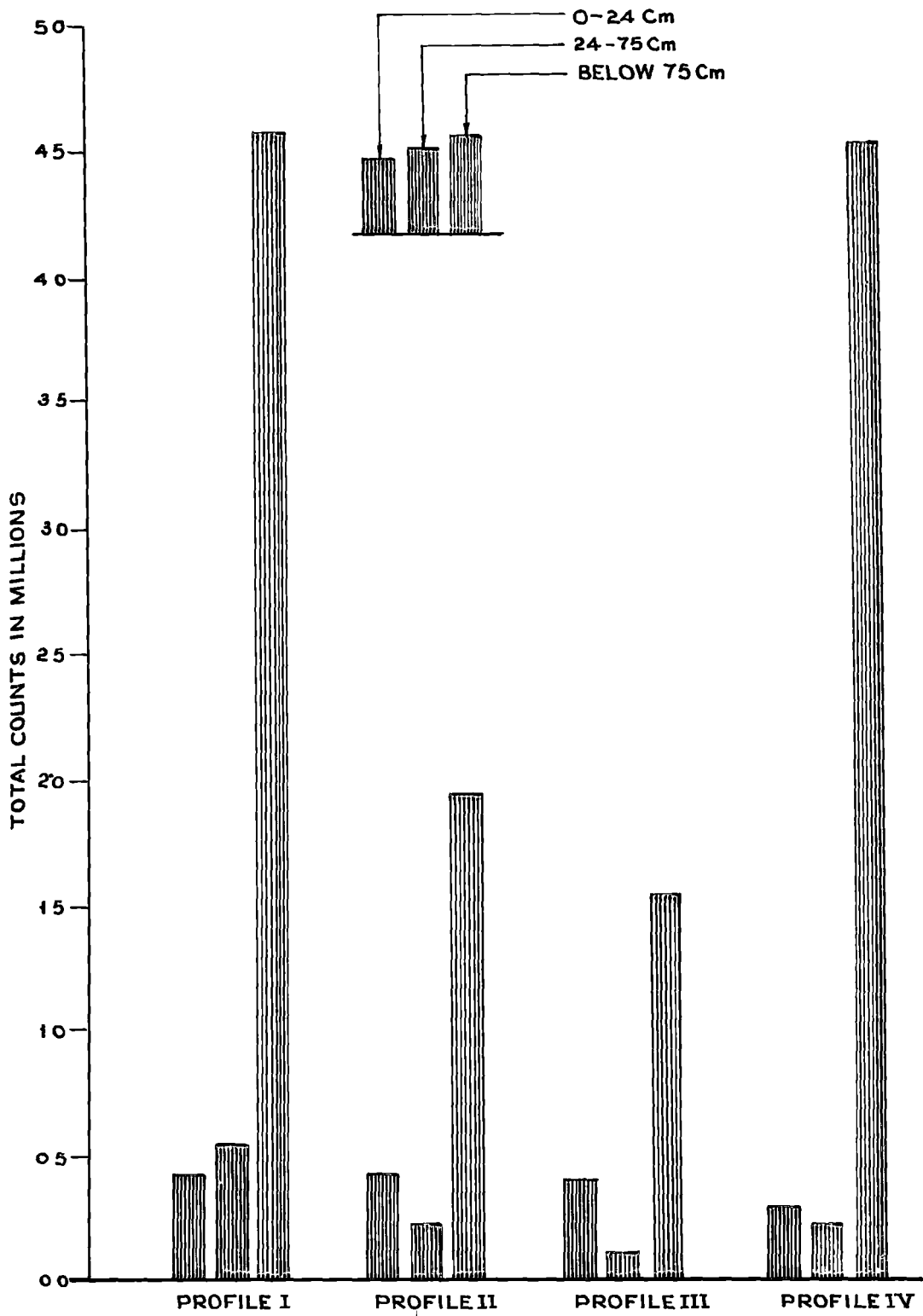


FIG.5

with some illitic materials (as indicated by the high proportion of potassium) in these soils.

Kanno et al. (1958) found that the clay separates in peats consist mainly of halloysite, illite and hydrated halloysite, with some amounts of chloritic minerals. Gopaldaswamy (1958) suggested that the Kuttanad soils contain a mixture of montmorillonite and illite types of clays.

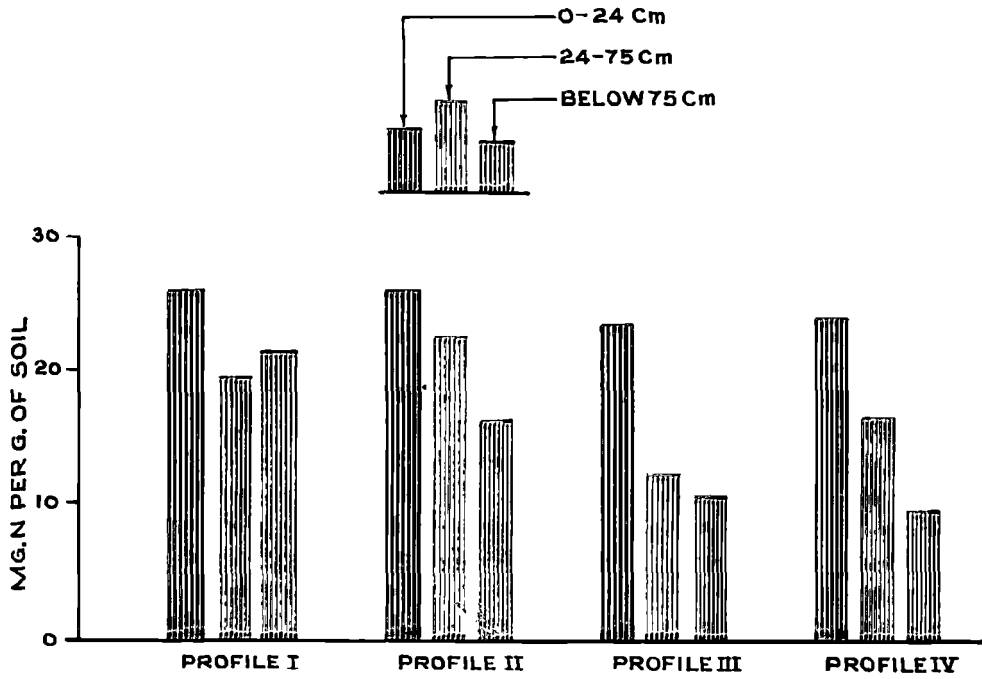
#### 6. Microbiological properties

A low microbial count which increases with depth and predominance of fungi over bacteria are characteristic of the microbial population in these soils (Fig.5). Waksman (1925) observed low microbial counts in acid peat soils. The low microbial population in the soil which increases with depth seems to be a consequence of the higher acidity in the upper layers which decreases with depth in the profile. The generally poor microbial inhabitation of these soils can be attributed to the anaerobic conditions prevailing in them for the greater part of the year, the high salt concentration and the wide C/N ratio. The preponderance of fungi over bacteria in the surface soils may be due to the better ability of the fungi to withstand the high acidity of these soils. Pochon (1956) attributes the low activity and population of microorganisms and the low bacteria to fungi ratio in organic soils to the combined effects of high acidity, high organic matter content and wide C/N ratio.

Fig. 6

Graph showing the ammonifying power  
and nitrogen-fixing capacity of the soils.

### AMONIFYING POWER OF THE SOILS



### NITROGEN FIXING POWER OF THE SOILS

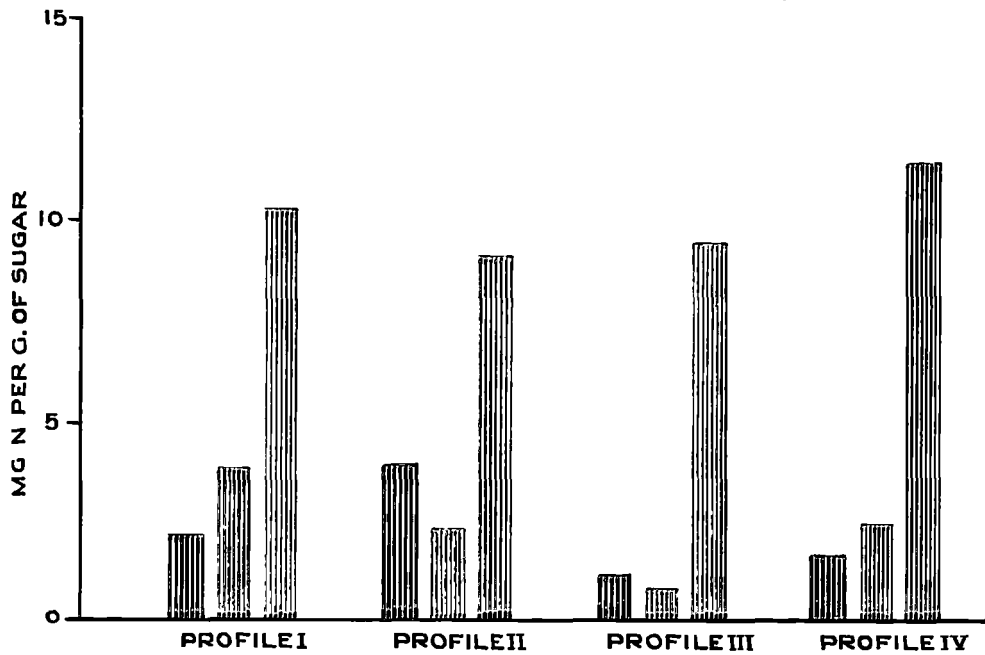


FIG 6

Jeffreys et al. (1956) have made similar observations in other soils. Frercks and Puffe (1960) observed that increased levels of liming so as to raise the pH from 3.2 to 7.0 increased the number of bacteria and decreased that of fungi. An increasing level of lime and a corresponding increase in pH with depth in the profiles may be the cause of the characteristic variation in the number of the bacteria and fungi observed in these soils.

The ammonifying capacity of the soils which is more in the upper layers (Fig. 6) should be attributed to the predominance of fungi in these layers, as fungi are known to be the chief ammonifiers, especially in acid soils. (Muntz et al., 1993). The pH of the soils does not appear to be directly concerned with the ammonifying power since it has been reported that ammonifying organisms can function in the pH range 3.7 to 9.0 (Olsen, 1928). Still, pH affects ammonification through its definite role in determining the type of microflora in the soil. The low ammonification in the lower layers may also be the result of the calcium carbonate present in them which is unfavourable for the growth and functioning of ammonifiers.

The comparatively high nitrogen-fixing capacity of the soils in the lower layers may be due to the presence of lime and a neutral pH. It is interesting to note that the number of nitrogen fixing organisms were more in the

lower layers, probably due to the same reason. Garbosky (1956) has reported an abundance of Azotobacter at a depth of 50 to 100 cm. in the profile as compared to the top layers.

#### 7. Isolation and study of the nitrogen-fixing organism

The similarity in the growth and morphological characters and the nitrogen fixing capacity of the organisms isolated from the different horizons suggest that they are all of the same species.

The environmental conditions under which these bacteria occur indicate that the organism does not belong to the Azotobacter species. The high acidity, waterlogging and low calcium content are factors which are unfavourable and even detrimental to the growth of Azotobacter. The work of Starkey and De (1939), Tehan (1952), Derx (1955), Bhattacharya (1958), Barooah and Sen (1959) and Becking (1959) suggest that these organisms might belong to the genus Beijerinckia. But some typical characteristics of Beijerinckia such as gum formation are not observed for these organisms while the acid tolerance shown by them is typical of Beijerinckia. They fix as much nitrogen as Beijerinckia or Azotobacter.

Subramoney (1958) isolated a nitrogen-fixing organism from the acid soils of Kuttanad, which fixes about



10-14 mg. of nitrogen per g. of energy material and which, in its morphological features, resembles the organism under study. He concluded that this organism is a species of Azotobacter.

Azotobacter is usually found in neutral soils while Beijerinckia has been reported in most tropical soils. But the occurrence of nitrogen-fixing organisms with characters similar to those of Azotobacter, as well as, Beijerinckia poses a new problem. The variation in pH in the profile has not in any appreciable manner affected the morphology of the organism. Moreover their occurrence in soils with high lime content also is not typical of Beijerinckia. These characters which are neither representative of Azotobacter nor of Beijerinckia reveal the scope for further work in this line.

SUMMARY AND CONCLUSIONS

## S U M M A R Y   A N D   C O N C L U S I O N S

A study has been made of the morphological, physicochemical and microbiological properties of four typical profiles from the Kari areas of Vaikom Taluk.

The soils are black to dark grey in colour, and can be texturally classed as clays or clay-loams. There is an irregular distribution of the soil separates in the profile, suggesting their formation by deposition and sedimentation.

The soils are rich in organic matter, present mostly in an unhumified form, but they do not contain enough organic matter to designate them as typical peats. The lower layers of the soils contain a high percentage of calcium carbonate which might have originated from lime shells found abundantly in these areas. Their specific occurrence exclusively in the lower layers remains unexplained and requires further investigation.

The high cation exchange capacity of the soils as well as the clay fraction and the high silica sesquioxide ratios observed in the clay separates, suggest the presence of 2:1 lattice type of minerals.

The waterlogged soils which are near neutral in reaction becomes extremely acidic on air drying, probably

due to the oxidation of sulphur compounds present in them to sulphuric acid. The pH of the air-dry soils increases with depth of the profile. The top layers are extremely acidic, while the lower layers are neutral or slightly alkaline, probably due to the differences in their content of organic matter and carbonates.

The wide C/N ratios of the soils can be attributed to the losses of nitrogen and conservation of carbon, both processes being favoured by the waterlogged reducing conditions existing in these soils.

Though the soils contain a high percentage of the major and secondary plant nutrients, the availability of these elements is surprisingly low, which can be attributed to the low pH, wide C/N ratio and anaerobic conditions in these soils. The soils contain toxic concentrations of salts to impair their productivity.

The soils have a low microbial count, which increases with depth in the profile. The ammonifying power of the soils is more in the top layers, probably due to the predominance of fungi in these layers. The nitrogen-fixing capacity is more in the lower layers, which is attributed to the neutral pH and presence of calcium carbonate in these horizons.

The nitrogen-fixing organism isolated resembles

both Azotobacter and Beijerinckia in its characters.

Further work is required to elucidate its nature and for its identification.

• .

REFERENCES

R E F E R E N C E S

- Acharya, G.N. and Jain, S.P. 1954 Nitrifiability of soil organic matter. Jour. Ind. Soc. Soil Sci. 2-1: 43-48.
- Alway, F.J. 1914 Agricultural value and reclamation of Minnesota peat soils. The Univ. of Minnesota Agr. Expt. Sta; Bull. - 188.
- Allen, O.W. 1953 Experiments in Soil Bacteriology Burgess Publishing Co., Minnesota, U.S.A.
- Anderson, M.S. and Byer, H.G. 1933 Character and behaviour of organic soil colloids. U.S. Dent, Agr; Tech. Bull. 377.
- \*Arnio, B. 1933 " Sur le de' gagement des oxydes de fer et alumine les sol". Pedology. 17 (2), 1-50.
- Barooah, P.P. and Sen, A. 1959 Studies on Beijerinckia from some acid soils in India. Indian Jour. of Agric. Sci., 29:4.
- Becking, J.H. 1959 Nitrogen fixing bacteria of the genus Beijerinckia in South African soils. Plant and Soil. 11, 193-206.
- Beckwith, T.D., Vass, A.F. and Robinson, R.H. 1914 Ont. Agr. Expt. Sta. Bull. 118.
- \*Beijerinck, M.W. 1901 Z. Bakt. II. 7:561-582 & 36-61.
- Bhattacharya, R. 1958 Growth of Azotobacter in rice soils. Indian Jour. of Agric. sci. 28: 13-80.
- Blue, W.G., Eno, G.F., and Westgate, P.J. 1955 Soil Sci. 80: 303-308.

- Bradfield, R. 1923 Colloid symposium monograph-I.  
369-391. Madison, W.S.
- Burges, A. and 1953 Brit. Mycol. Soc. Trans. 36:  
Fenton, E. 104-108.
- Burgess, F.S. and 1961 Soil Sci. 6: 449-462.  
Broadbent, R.
- Croegaert, J., 1954 The moisture economy of some  
Kuczarow, W., and Congo Soils. Proc. Second  
Ganef, J.M. Inter. Afr. Soils Conf. 1,  
315-382.
- Dachnowsky, A.P. and 1930 Report to the Sub-commission for  
Stokes, A.P. peat soils of the Int. Soc. of  
Soil Sci. Proc. 2nd Inter. Cong.  
of Soil Sci VI.
- \*Derx, H.J. 1950 Beijerinckia, a new genus of  
nitrogen fixing bacteria occurring  
in tropical soils. Proc. K.  
Nederl. Acad. Wetensch. 53: 140.
- Edelman, C.H., and 1958 Marsh soils in the United States  
Van Staveren, J.M. and on the Netherlands. Jour.  
of Soil and water conservation.  
13-1.
- \*Frercks, W., Puffe, D. 1958 Additional investigations on the  
analysis of chemical-compound  
groups in moor soils and sandy  
moor soils receiving differential  
liming. 2. PflErnahr. Dung. 83,  
42-54.
- Gainy, P.L. 1919 Soil Sci. 3: 399-416.
- \*Gainy, P.L. 1919 Soil Centralbe. f. Bakt. II  
39: 584-595.
- \*Gans, R. 1913 Internatt. Mitt. Bodenk. 3:  
529-171.
- Garbosky, A.J. 1956 Report, 6th Inter. Congr. Soil  
Sci. Paris B, 453-360.



- Gopalaswamy, V. 1958 Studies on the fertility status of some peaty, marshy and swampy soils. M.Sc. Thesis, Indian Agrl. Res. Inst.
- \*Grebenshchikova, A.A. 1957 The water capacity of peats. Pochvovedenie, 9: 102 (Soils & Fert. XX-2. No.427).
- Guillenat, J. and Montegart, J. 1956 Report, 6th Intern. Congr. Soil Sci. Paris. C:371-380.
- Harcourt, R. 1956 Swamp soils. Ann. Report Ontario Agrl. Coll. and Expt. Farm; 31: 82-86.
- Hissink, D.J. 1926 The relation between the values of pH, N and S (humus) of some humus soils. Trans. Intern. Soc. Soil Sci. 2nd Comm. A 72-93 K.
- Hoagland, D.R. 1919 Jour. Agri. Res. 18: 73-117.
- Iyer, Narayana, K.R. 1928 Dept. Agr. Travancore. Bull. 125, 126, 130.
- Jackson, M.L. and Sherman, D.D. 1953 Chemical weathering of Minerals in soils. Advance in Agronomy, V: 221-309.
- Jackson, M.L. 1960 'Soil Chemical Analysis' Prentice Hall, Inc.-N.J. U.S.A.
- Jeffreys, E.G., Brian, P.W., Heming, H.G. and Lowe, D. 1956 Journ. Gen. Microbiology, 9: 314-341.
- \*Kaila, A. 1956 Phosphorus in various depths of virgin peat land. Chemical Absts. 51-5(a): 3895.
- \*Kaila, A. 1958 Availability for plants of phosphorus in some virgin peat samples. Maataloust. Aikak. 30, 133-142.

- \*Kanno, I., Honjo, Y., 1958 Clay minerals of paddy soils in Kyushu. J. Soil Sci. Tokyo 29: 197-199 (Soils and Fert. XXII-6: 2614.)
- Kirk Lawton 1955 Chemical composition of soils. Chemistry of Soils, Edited by F.E. Bear, Reinhold Publishing Corpn. 73-74.
- \*Kivekas, J. 1958 The effect of incubation on the acidity of peat samples. Sud. 9, 72-75.
- \*Kvaratskheliya, N.T. 1959 The physical properties of meadow bog soils of the Kolkhid low lands. Pochvovedenie 2 52-58.
- Lipman, C.B. and Wank, N.E. 1924 The availability of nitrogen in peat. Soil Sci. 12.
- Lucas, P.E. and Davis, J.E. 1961 Relationships between pH values of organic soils and availability of 12 plant nutrients. Soil Sci. 92-33: 177-182.
- Lyon, T.L., Buckman, H.O. and Brady, N.C. 1947 'Nature and properties of soils' & The Macmillan Co., New York. 1955
- Lytle, S.A. and Driskell, B.M. 1954. Physical and chemical characteristics of the peats, mucks and clays of the coastal marsh area of St. Mary Parish; Louisiana. La. Agric. Expt. Sta. Bull. 484:37.
- Mandal, L.M. 1961 Transformations of iron and manganese in waterlogged rice soils. Soil sci. 91-2: 121-126.
- Narszewska-Zimiecka, J., and Golebiowska, J. 1949 The microbiological characteristics of drained peaty soils. Proc. Fourth Internat. Cong. Microbiol. 1947, 495-497.

- McCool, M.M., and Wiedemann, A.G. 1924 A study of several organic profiles. Soil Sci. 18: 117-127.
- McGeorge, W.F. 1934 Organic soils associated with base exchange reactions of soils. Arz. Agr. Expt. Sta. Tech. Bull. 31.
- Meek, C.S. and Lipman, C.B. 1922 J. Phy. 5: 195-204.
- Meiklejohn, J. 1954 Notes on nitrogen fixing bacteria from East African Soils. Trans. 5th Intern. Congr. Soil Sci. 2: 123-125.
- \*Meyerhoff. 1917 Pflug Arch. Ges. Physiol. 164: 353-427.
- \*Milosevic, R. 1958 Microbiological analysis of the sandy soils of Deliblato. Zemlj. Bilj. 7, 259-265.
- Mitra, S.K. and Phukan, L.N. 1929 The Agric. Journ. of India; 24.
- Moorman, F.R. and Panaboke, C.A. 1960 Soils of Ceylon. Tropical Agriculturist. CXVII-1:1-71.
- \*Muntz, A. and Coudon, H. 1893 Compt. Rend. Acad. Sci. 84: 301-303.
- Nair, C.K.N. 1945 Studies on the Kari Soils of Travancore. M.Sc. Thesis, University of Travancore.
- \*Oloffson, S. 1954. Ground water level and mobility of water in peat soils of Gothland; Betenvallar Mossar 4: 136-138 (S.W.) (Soils and Fert. VIII-176).
- \*Olsen, G. 1928 Compt. Rend. Acad. Sci. 116: 395-398.

- Paul, H. and Shariff, M.A.A. 1954 The rates of nitrifications of peat soils in British Guiana. Journ. of Agric. Sci. 44: 377-382.
- Pearsal, W.H. 1950 The investigation of wet soils and its agricultural implications. Emp. Journ. Expt. Agri. 18 (72).
- Pillay, K.P. 1924 Dept. Agr. Travancore Bull. 9.
- Pillay, T.R.N. and Subramoniam, V. 1930 Journ. of Ind. Inst. Sci. 13.A.1.
- Pillay, T.R.N. and Subramoniam, V. 1931 The origin and nature of the peaty soils of Travancore. Jour. Ind. Inst. Sci. 14.A, 99.
- Pillay, T.K.V. 1940 'Travancore State Manual' Vol. I pp.88. Vol. III pp.285.
- Piper, C.S. 1950 'Soil and Plant Analysis'. The University of Adelaide, Adelaide.
- \*Pochon, J. 1956 Microbiological relationship between forest mors and acid peats. Ann. Inst. Pasteur. 90. 352-354.
- Polak, B. 1950 Occurrence and fertility of tropical peat soils in Indonesia. Trans. Fourth Intern. Congr. Soil Sci. 2:183-185.
- Robinson, C.S. 1911 Organic nitrogenous compounds in peat soils. Mich. Agr. Coll. Expt. Sta. Bull. 1.
- Robinson, W.O. 1930 Some chemical phases of submerged soil conditions. Soil Sci. 30: 197-217.
- Robinson, G.W. 1951 'Soils, their origin, constitution and classification'. Thomas Murby and Co., London.

- Russel, L.W. 1956 'Soil Conditions and Plant Growth'.  
& Longman's Green and Co., London.  
1962
- Starkey, R.L. and 1938 A new species of Azotobacter.  
De, P.K. Soil Sci. 47: 329-343.
- Stevenson, F.J. 1959 Carbon nitrogen relationships  
in soils. Soil Sci. 88: 201-208.
- Subramoney, N. 1947 Fertility investigations on the  
& acid peats of Travancore. Bull.  
1951 Central Research Inst; Univ. of  
Travancore, Trivandrum II-1:  
Series A: 1-16.
- Subramoney, N. 1958 Chemical and microbiological  
studies on the acid peats of  
Kerala. Ph.D. Thesis, Univ.  
of Travancore.
- Tchan, Y.T. 1953 Studies on nitrogen fixing  
bacteria III. Proc. Lin.  
Soc. New-South Wales. LXXVIII.
- Tchan, Y.T. and 1953 Proc. Lin. Soc. New-South Wales -  
Whitehouse, J.A. 78: 160-170.
- Teakle, L.J.H. and 1937 The peat soils and related soils  
Southern, B.L. of Western Australia. Jour.  
Dept. of Agri. West Australia  
14: 2nd series.
- Thenabadu and 1960 Characteristics of an ill-drained  
Merwyn, W. rice soil profile in Bombuwela.  
Tropical Agriculturist. LXVI:  
267-271.
- Troug, E. 1930 Amer. Nat. 64: 300-313.
- Vanwijk, C.L. 1951 Soil survey of the tidal swamps  
of South Borneo. Contributions  
of the general Agri. Res. Sta.  
Bogor. Indonesia. 123.

- Veenenbos, J.S. 1950 Infiltration in peat soils. Trans. Fourth Intern. Congr. Soil Sci. 2: 199-203.
- Waksman, S.A. and Starkey, R.L. 1923 Soil Sci. 16: 137-157.
- Warrington, S. 1891 Ann. Inst. Past. 5: 92-100.
- Whitson, A.R. and Ullsperger, H.W. 1919 'Marsh Soils' Bull. 309. Expt. Sta. Univ. of Wisconsin, Madison.
- Wilson, E.D. and Staker, E.V. 1932 The chemical composition of the muck soils of New York. Cornell Univ. Agri. Expt. Sta: Bull. 527.
- \*Winogradsky, S. 1893 Compt. Rend. Acad. Sci. 116: 1385-1388.
- \*Winogradsky, S. and Omeliansky, W.L. 1899 Centrbl. Bakt. 115: 473-490.
- \*Winogradsky, S. 1938 Ann. Inst. Past. 60: 351-400.

\* Originals not seen.