STUDIES ON THE SEASONAL VARIATIONS IN pH, WATER SOLUBLE SALTS AND BACTERIAL POPULATION IN THE KARI SOILS OF KERALA

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CERTIFICATE

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

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INTRODUCTION

INTRODUCTION.

Kuttanad, the rice bowl of Kerala, comprising an area of approximately 350 square miles is an unique agricultural region in the world. Practically the whole of this area is situated at a depth of three to four feet below sea-level and, for the major part of the year, remains submerged under water.

Paddy is the most important crop in this region. The agricultural operations commence at the close of the rainy season, with the strengthening of the mud embankments round the fields. The water within the embankments is then pumped out and sprouted paddy seeds are sown. During the growth period of the crop water stands at a depth of five to seven feet outside the embankments, the waves lashing out against the bunds, and threatening to inundate the entire area and destroy the crop. For this reason, paddy cultivation in this area should be considered the most uncertain and hazardous agricultural operation ever undertaken in any part of the world.

The harvest season in Kuttanad generally falls in February. After the harvest, the sea water is allowed to get into the fields. Though this leads to a deterioration in soil structure, the practice has its own advantage,

in that it prevents the accumulation of toxic salts on the surface soil.

A very fascinating theory regarding the origin of Kuttanad area is the one put forward by Velu Pillay (1940) in his Travancore State Manual. According to him, the area was once a bay. The waters of Periyar and other rivers laden with sediments were discharged into this bay resulting in the formation of a sand bank linking up the nearest points of the land. The bay, thus eventually became a lagoon which gradually silted up and gave rise to the present wet paddy lands and coconut gardens.

A sizeable portion of the Kuttanad area is known as Kari lands. The name 'Kari' is probably derived from the intense black colour of the soils. This soil formation lies scattered in different regions in the coastal planes alongside the back water areas. There are about 10,000 acres of these lands in and around Porakad in Ambalapuzha Taluk, 5000 acres in Kunnathunad, 5000 acres in Shertallai Taluk and 10,000 acres in Vaikom Taluk.

In Kari areas there occur large amounts of partially decomposed woody matter, at various stages of decomposition. Similar peat soils have always posed numerous problems for agriculturists all over the world. However the Kari soils differ in many respects from the usual peats. The conditions under which Kari soils exist suggest that they belong to the class of saline peats.

The Kari area has a uniform climate like the rest of Kerala. There is high humidity and the variations in temperature are small. The South West monsoon from June to August and the North East monsoon from October to December together contribute to the annual rainfall. The average annual rainfall in the area is 279.40 cm. The temperature varies from 75°F. to 85°F.

These soils are extremely acidic.The high acidity often results in crop failures, especially in the years of short rainfall and low water level in the lakes. The general condition of the soil keeps changing with the season. Although the intricate problems connected with these lands are not yet solved, a considerable volume of data regarding the physico-chemical and biological characteristics of these soils are now available from the investigations carried out by previous workers. However, the need for sufficient data regarding the seasonal variations in soil properties that lead to frequent crop failures, is keenly felt. The present investigation is a modest attempt to correlate the soil properties, both chemical and biological with seasonal changes, and to study the effects of seasonal variations in soil properties on the standing crop. For this study, Kari soils of one tract, namely Vaikom Taluk are selected. Although the soils differ in physical, chemical and biological properties

with different tracts, it is hoped that the present work may contribute some useful information regarding the behaviour of these soils which pose many a baffling problem to the cultivators. A proper understanding of these problems and their solution will go a long way in surmounting the uncertainty and risks involved in the paddy cultivation of this area.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Variations in pH and water soluble salts

Seasonal variations in pH and water soluble salts in soils have been studied by many workers.

Rost and Fieger (1923) observed that the hydrogen ion concentration of the soil was increased by air drying. Krickman (1925) found that sun drying enhanced soil acidity and that drying at higher temperatures increased the acidity still further. Gans (1913), Bradfield (1923) and Troug (1930) established that actual acids were involved in soil acidity.

According to Iyer (1928) the infertility of Kari soils was due to the enormous amounts of water soluble salts in them. Pillay and Subramoniyam (1931) recognised that the low pH of these soils was primarily responsible for the inhibition of plant growth.

Nair (1945) showed that fertility and salt concentration have no correlation to each other and that the organic matter content, exchangeable hydrogen, pH and

C/N ratio seemed to be interrelated and correspond to the observed fertility of those soils.

Molfino (1945), in his observations of pH variations in flax soils over a period of seven years, concluded that high temperature and low rainfall were conducive to alkalinity while the reverse conditions to acidity, thus establishing a correlation between climatic variations and pH changes.

According to Subramoney (1947) free sulphuric acid in high toxic concentrations is produced in the Kari soils of Kerala by the biological oxidation of sulphur compounds present in them and solubilises the iron and aluminium thereby resulting in toxicity to plants.

The influence of nitrification on the seasonal variations in the pH of the soil was investigated by Lehr (1950). He found that pH was highest in the plots cropped with oats and lowest in plots left bare fallow but dressed with nitrogen as ammonium nitrate. A general rise in the pH during autumn was attributed by him to a decline of biological activity and leaching of nitrate by rain. A high correlation was observed between pH values and nitrate content of soils. He suggested that plants absorb part of their nitrogen as nitric acid, thereby

reducing the concentration of hydrogen ions in the soil.

Raupach (1951) in his studies on the pH and total soluble salts of different Australian red loam earths suggested that the variation in pH was due to soluble salts and that there were spatial variations for organic carbon, nitrogen, clay and exchangeable cations over small areas. It was suggested that the change in pH with time over a small area consisted of a recognition of all the factors contributing to hydrogen ion concentration.

Pearsal (1952) found that the pH of natural soils was related to base status, water content, soil metabolism and vegetation.

Tomlinson (1957), from his monthly determination of pH of some rice soils of Sierra Leone for a period of 32 months, suggested that increase of pH values during wet season and decrease during dry season were the result of translocation of water soluble acidic compounds to and from the soil surface.

Gopalaswamy (1958) reported that the high salt content of the Kuttanad soils was due to marine and river influences.

According to Bowser and Leat (1958) the variations of pH from neutral to strong acidity during the period from May to November were related to changes in soil moisture possibly due to microbial activity.

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.

Yu et al (1959) working on the acid and neutral soils of Central China found that the conductivity of the ploughed layer was, by and large, closely correlated with soil fertility. Conductivity of different soils became less conspicuous during plant growth, suggesting the adsorption of nutrient ions by the roots. This was also indicated by the low conductivity of the rhizosphere compared with the bulk of the soil. The increase in electrical conductivity after water-logging showed considerable difference between fertile and infertile soils of the same type and could be a reliable index of fertility.

Moormann (1962) observed that the pH values in acid sulphate soils were extremely variable. Seasonal variations of pH were very pronounced, especially in periodically

inundated lands, such as, rice fields. During inundation pH values increased gradually, eventually coming close to neutral, whereas during the following dry period they dropped quickly.

2. Toxic factors in organic soils

Clayton and Rost (1922) considered iron sulphide as the toxic factor in Minnesota peat.

Gans (1913), Bradfield (1923) and Troug (1930) established that actual acids were involved in soil acidity. Solubility of iron and aluminium depended on the degree of acidity. The soils being highly acidic contained large amounts of iron and aluminium in solution.

Hoagland (1919) and Troug (1930) indicated that a direct toxic effect due to excess of hydrogen ions on root tissues manifested only at very low pH values.

According to Robinson (1930) toxicity in submerged soils was due largely to soluble iron, soluble manganese and hydrogen sulphide or to a general reducing condition, which in itself was the main and most toxic agent.

Pillay and Subramoniam (1930) suggested that Kari soils contained large quantities of iron and aluminium salts and sulphur compounds.

Auriol et al (1934) stated that aluminium toxicity of acid sulphate soils was the most predominent characteristic under the conditions prevailing in Viet Nam. According to him aluminium concentrations of 300 ppm. or more in the soil seriously affected the production of rice.

According to Subramoney (1947) sulphides were the sources of toxicity. He found that the quantities of the ferrous salts and sulphuric acid largely depend on the nature of aeration, drainage etc. and that alternate wetting and drying facilitate the removal of these harmful substances. The yellow crusts formed on the surface of these soils during drying consists mainly of iron sulphate.

Van der Speck (1950) used the term cat-clay for acid soil material in its oxidised form, showing straw-yellow motlings and streaks of basic ferric sulphate; while Chenery (1954) proposed the term acid sulphate soils for the soils in which such straw-yellow motlings occurred. He also found that oxidation of iron sulphides by the oxygen of the air results in the formation of ferric sulphate and sulphuric acid. This ferric sulphate on hydrolysis by a series of steps results in the formation of straw-yellow basic ferric sulphate and more sulphuric acid.

Tomlinson (1957) suggested that an aluminium level higher than 250 ppm. was harmful for rice in Sierra Leone. He expected that a level of 1000 ppm. of iron or more would be harmful to this crop.

Moormann (1963) stated that in cat-clay, the iron sulphide containing horizons show yellow motling and streaks of basic ferric sulphate. Such horizons may occur anywhere in the profile. The pH values in the acid sulphate soils are extremely variable. Values for pH of approximately 1 to 2 have occasionally been observed in cat-clay horizons.

3. Variations in microbial population

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

Webley et al (1952) concluded that bacterial and fungal populations increased steadily with the development of vegetation.

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_2 horizon below which there was a deficiency of the nutrients. The

number was more between 12 and 30 inches below the surface.

Pochon (1956) found that the acid peats (pH 3.6 to 4.6) showed low activity and population of soil micro-organisms 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.

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 with depth but showed a secondary maximum in the B horizon.

Eno (1957) stated that most microbial activities were satisfactory in the optimum pH range of most crops, viz., pH 5.5 - 6.5.

In the study of seasonal variations in the composition of the bacterial soil flora in relation to plant development, Gyllenberg (1957) found that at the beginning of growth the composition of the soil bacterial population differed from that of the rhizosphere. But it changed gradually and by the end of the season the two populations became similar. This change occurred first in the surface soil and then in the deeper soil layers and was due to root development and the migration of bacteria from the rhizosphere into the soil.

Khudyakov et al (1956) found a large variation in the number of microorganisms in a short time under constant external conditions.

According to Fedorov et al (1958) an increase in dry matter production by the plant was accompanied by an increase in the rhizosphere bacteria.

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.

Katznelson et al (1959) suggested that in light soils the total number reached a maximum in spring and sometimes in autumn also. Azotobacter was absent from virgin and slightly cultivated soils, but small numbers of nitrifiers occurred in the top horizon in summer. In virgin soils cellulose was decomposed by moulds but in peat-bog soils decomposition was by bacteria. Cultivation increased the total number of microorganisms and the numbers of nitrifying, denitrifying and sporeforming bacteria and of actinomycetes.

Moureaux (1959) reported experimental data on seasonal variations and the activities of soil microorganisms in lateritic soils, red and brown colluvial soils,

hydromorphic soils, rice soils and peaty-bog soils. He found close relationship between microbial activity and soil fertility.

Frercks and Puffe (1960) observed that increasing the pH from 3.2 to 7.0 increased the counts of bacteria. The change in microflora brought about by differential liming was reflected in the trends in cellulose and organic matter decomposition. Addition of nitrogen also increased cellulose decomposition.

Nepomiluev (1960) found that the number of rhizosphere bacteria in podzolic soil varied throughout the vegetative period.

4. Nonsymbiotic nitrogen fixation and the organisms concerned

Winogradsky (1893) isolated the first nonsymbiotic organism from the soil. He found that certain bacteria have the ability to fix nitrogen.

Beijerinck (1901) isolated two aerobic nitrogen fixers namely *Azotobacter chroococcum* and *Azotobacter agile*.

Fred (1918) observed that the major factor controlling the presence of *Azotobacter* in a soil is the H^+ion

concentration and noted lack of growth of this organism at pH 6.4—6.8.

Gainy (1919) observed that Azotobacter is abundant in soils having an optimum pH between 7.0 and 7.8.

Meek and Lipman (1922) found that the pH tolerance of the nitrifying organisms varied with the pH of the soil from which they were isolated.

Starkey and De (1938) isolated a species of Azotobacter from Indian soils, which fixed nitrogen in very acid media. This organism differed from the other species of the genus and was named Azotobacter indicum.

Attson was the first to detect Beijerinckia in the acid soils of Malaya. Later in Indian soils it was found by Starkey and De (1939). Derx et al (1950) isolated this organism from soils of Indonesia and observed that there were sufficient prominent differences in the characteristics of this organism from those of Azotobacter.

Subramoney (1958) isolated a new organism from the Kari soils of Kerala. According to him it was able to fix 10-14 mg. of nitrogen per gram of energy material. He considered it as a new species of Azotobacter and named it as Azotobacter Keralam.

According to Bhatacharya (1958) more than 50 per cent of the rice soils in Bengal contained no Azotobacter, especially in the water-logged condition.

Becking (1959) found that Beijerinckia occurred in soils within the pH range 4.3 to 7.0.

Berrooah and Sen (1959) found that the nitrogen fixing capacity of the strains of Beijerinckia, isolated from soils examined from various part of India varied from 5.97 to 11.57 mg. per gram of glucose during a period of one month.

Pillay (1964) isolated a species of nitrogen fixing organism from the Kari soils of Kerala. According to him this organism resembled both Azotobacter and Beijerinckia.

MATERIALS AND METHODS

MATERIALS AND METHODS

To study the seasonal variations in pH, water soluble salts and bacterial population in Kari soil two suitable locations about one furlong apart were selected in Vechoor village, Vaikom Taluk. Five samplings were made and during every sampling one profile was taken from each of the locations.

The dates of samplings are given below:

First sampling	-	24th August	1964
Second sampling	-	12th October	1964
Third sampling	-	1st November	1964
Fourth sampling	-	1st January	1965
Fifth sampling	-	12th February	1965

Method of sampling

As the area is waterlogged for most part of the year, ordinary sampling methods could not be adopted in this case. So the following procedure was adopted for this purpose. Bamboo poles of about six feet in length were selected and were cut longitudinally into two halves. The internodes were removed and the two halves were tied

tightly with iron wires so that it formed a hollow cylinder of six feet in length. One end of the tube was sharpened and the tube was driven five feet deep into the soil. The soil entered the tube and the tube was then withdrawn slowly, thereby retaining the soil as a column inside the tube. The tube was drained by keeping it aside for a few hours. The bamboo tubes were packed safely and transported to the laboratory. Thereafter the tubes were split open keeping the soil column intact as shown in Plate I. The profile characteristics were studied and samples from each horizon were collected for analysis.

Horizon differentiation based on any morphological characters was found rather difficult. So each profile was differentiated into three arbitrary horizons based mainly on textural differences, at the following depths.

First horizon	:	0 to 30 cm.
Second horizon	:	30 to 70 cm.
Third horizon	:	Below 70 cm.

Description of the profiles

Profile I Series

Location — Valiyavelicham padasekharam, Vechoor village, Vaikom Taluk, Kottayam District.

Profile II Series

Location — Arikupuram padasekharam, Vechoor village, Vaikom Taluk, Kottayam District.

The First Sampling

The first sampling was done on 24th August, 1964 when the water depth was about 1 metre. Total rainfall during the month was 539.30 mm.

Profile I (i)

Depth (cm.)	Description
0 – 30	Very dark greyish brown, 10YR 3/2; clay; plastic and sticky when wet; undecomposed organic matter abundant; no horizon differentiation.

Depth (cm.)	Description
30 - 70	Very dark greyish brown, 10YR 3/2; clay; not very plastic and sticky; a few undecomposed plant residues; horizon differentiation difficult; traces of carbonates.
Below 70	Dark grey, 10YR 4/1; clay loam; not very sticky and plastic; undecomposed organic matter less abundant; no horizon differentiation; carbonates present.

Profile II (1)

Depth (cm.)	Description
0 - 30	Very dark grey, 10YR 3/1; clay loam; undecomposed organic matter abundant; no horizon differentiation.
30 - 70	Very dark greyish brown, 10YR 3/2; sandy clay loam; not very sticky and plastic; no clear trace of horizon differentiation.

Depth (cm.)	Description
Below 70	Very dark greyish brown, 10YR 3/2; sandy clay loam; not very sticky and plastic; undecomposed organic matter less abundant; no horizon differentiation.

The Second Sampling

The second sampling was done on 12th October, 1964 two days after sowing. The field was then in a puddled condition. Total precipitation during the month was 315.8 mm.

Profile I (ii)

Depth (cm.)	Description
0 - 30	Very dark greyish brown, 10YR 3/2; clay; streaks of yellow deposit; plastic and sticky when wet; undecomposed organic matter in fairly large amount; no clear horizon differentiation.
30 - 70	Very dark greyish brown, 10YR 3/2; clay; plastic and sticky when wet; undecomposed organic residues less abundant;

Depth (cm.)	Description
	streakes of yellow deposit; no clear horizon differentiation.
Below 70	Very dark greyish brown, 10YR 3/2; clay loam; not very sticky and plastic; no horizon differentiation.

Profile II (ii)

0 - 30	Very dark grey, 10YR 3/1; clay loam; plastic and sticky when wet; undecomposed organic matter abundant; no horizon differentiation.
30 - 70	Dark grey, 10YR 4/1; sandy clay loam; not very sticky; undecomposed plant roots less abundant; horizon differentiation difficult.
Below 70	Dark grey, 10YR 4/1; sandy clay loam; undecomposed plant roots absent; no trace of horizon differentiation; carbonates present.

The Third Sampling

The third sampling was done on 1st November, 1964. During sampling the seedlings were of height about 50 cm. Water depth was about 15 cm. and the total rainfall during November was 220.2 mm.

Profile I (iii)

Depth (cm.)	Description
0 - 30	Very dark grey, 10YR 3/1; clay; streaks of yellow deposit; plastic and sticky when wet; undecomposed plant roots abundant; horizon differentiation difficult.
30 - 70	Very dark grey, 10YR 3/1; clay; streaks of yellow deposit less marked; undecomposed organic matter less abundant; horizon differentiation difficult.
Below 70	Dark grey, 10YR 4/1; clay loam; no streaks of yellow deposit; undecomposed organic matter very little; difficult to trace horizons.

Profile II (iii)

Depth (cm.)	Description
0 - 30	Very dark grey; 10YR 3/1; clay loam; sticky and plastic when wet; undecomposed plant roots abundant; difficult to mark the horizons.
30 - 70	Dark grey, 10YR 4/1; sandy clay loam; not very sticky and plastic when wet; no clear horizon differentiation.
Below 70	Greyish brown, 10YR 4/1; sandy clay loam; not very sticky and plastic; undecomposed organic matter less abundant; no horizon differentiation; carbonates present.

The Fourth Sampling

The fourth sampling was done on 1st January 1965. Water was only about 15 cm. in depth and the crop was at grain formation stage. Rainfall during the month of January was only 3 mm.

Profile I (iv)

Depth (cm.)	Description
0 - 30	Very dark greyish brown, 10YR 3/2; clay; streaks of yellow deposit; plastic and sticky when wet; horizon differentiation difficult.
30 -70	Very dark greyish brown, 10YR 3/2; clay; plastic and sticky; undecomposed organic matter less; no clear sign of horizon differentiation.
Below 70	Dark grey; 10YR 4/1; clay loam; no streaks of yellow deposit; no significant amount of undecomposed organic matter; horizon differentiation difficult.

Profile II (iv)

0 - 30	Black, 10YR 2/1; clay loam; not very sticky and plastic; undecomposed organic matter abundant; no clear horizon differentiation.
30 - 70	Black, 10YR 2/1; sandy clay loam; not very sticky and plastic; organic matter less abundant; horizon differentiation difficult.

Depth (cm.)	Description
Below 70	Very dark greyish brown; 10YR 3/2; sandy clay loam; not plastic and sticky; undecomposed organic matter less; horizon differentiation difficult; carbonates present.

The Fifth Sampling

The fifth sampling was done on 12th February 1965, one week after the harvest. There was no rainfall during this month.

Profile I (v)

0 - 30	Very dark greyish brown, 10YR 3/2; clay; patches of yellow deposit; plastic and sticky when wet; undecomposed organic matter present in small amounts; no horizon differentiation.
30 - 70	Very dark greyish brown, 10YR 3/2; clay; less amount of yellow deposit; undecomposed organic matter less abundant; horizon differentiation difficult.

Depth (cm.)	Description
Below 70	Very dark greyish brown, 10YR 3/2; clay loam; not very sticky and plastic; no yellow deposit; no horizon differentiation.

Profile II (v)

0 - 30	Very dark grey, 10YR 3/1; clay loam; sticky and plastic when wet; undecomposed organic matter abundant; difficult to trace horizons.
30 - 70	Very dark grey, 10YR 3/1; sandy clay loam; not very sticky or plastic; undecomposed organic matter less abundant; horizon differentiation difficult.
Below 70	Dark grey, 10YR 4/1; sandy clay loam; not very sticky and plastic; undecomposed organic matter not significant; no horizon differentiation.

Methods of analysis

As soon as the samples were received in the laboratory they were divided into two halves. One half was used for analysis in the fresh condition. The other half was air dried and then analysed.

Preparation of soil samples

The soils in the fresh condition from each horizon were mixed separately and samples stored moist in glass bottles for analysis.

Portion of soil samples were also air dried and ground in a porcelain mortar with a wooden pestle, and passed through 2 mm. sieve and stored in labelled sample bottles.

Loss of moisture on air drying the fresh soil was determined.

Chemical analysis.

1) pH: pH of the fresh soils as well as the air dried samples was determined in soil water suspension using 1:2.5 soil:water ratio. pH of the air dried soils

was also found in 1 N KCl using 1:2.5 soil:solvent ratio and also in 0.01 M $CaCl_2$ solution using 1:2 soil: solvent ratio (Jackson, 1960).

2) Water soluble salts: Water extracts of the fresh and air dry soils were prepared as follows.

Hundred gram of air dry soil was shaken with 200 ml. of water in an end-over-end shaking machine for half an hour and then kept overnight. The supernatent liquid was filtered through a Buchner funnel and the filtrate was collected.

In the case of fresh soil, sufficient amount of the fresh soil equivalent to 100 g. of air dry soil was weighed out and the calculated quantity of water added, taking into account the moisture content of the fresh soil, to give 1:2 soil water ratio. This was shaken with water as in the case of air dry soil and the water extract collected.

The following estimations were made using the water extracts.

(a) Chloride: An aliquot of the water extract was titrated against standard silver nitrate and the chloride estimated by Mohr's method (Piper, 1950).

(b) Sulphate: Sulphate was precipitated in the aliquot as barium sulphate and estimated gravimetrically.

(c) Calcium: An aliquot of the extract was treated with 10% sodium hydroxide and titrated against 0.02 N EDTA using murexide powder as indicator and the milliequivalents of calcium per litre of water extract was calculated.

(d) Magnesium: An aliquot of the extract was adjusted to pH 10 by adding ammonium chloride-ammonium hydroxide buffer and titrated against standard 0.02 N EDTA using Eriochrome Black T indicator. From the milliequivalents of calcium and magnesium so obtained, the milliequivalents of calcium was substracted to get the milliequivalents of magnesium.

(e) Conductivity: Electrical conductivity was measured using 1:2 soil water suspension. In measuring the conductivity of the fresh sample, the quantity of water added was adjusted, taking into account the moisture content of the fresh sample, to give a 1:2 soil-water suspension.

3) Analysis of scrapings: The yellow motlings formed on the surface of the soil on air drying were

scraped. Hydrochloric acid extract of the scrapings was prepared and iron and aluminium estimated in the extract by standard methods (Piper, 1950).

In the experiments to find out the toxic factors in these soils fresh samples were stored in open boxes and allowed to dry and the changes studied.

This soil was filled in pots and water was added every day. The thick deposits that are formed on the outer surface were scraped and analysed.

The paddy seedlings were planted after the soluble salts were leached out. The growth of the plants was observed and the physiological changes of the leaves noted.

Microbiological studies

(i) Total count: Thornton's standard agar medium and Soil extract agar medium were used for determining t total count. Thornton's medium had the following composition.

Dipotassium phosphate	-	1.00 g.
Potassium nitrate	-	0.50 g.
Magnesium sulphate	-	0.20 g.

Calcium chloride	-	0.10 g.
Sodium chloride	-	0.10 g.
Ferric chloride	-	trace
Asparagin	-	0.50 g.
Mannitol	-	1.00 g.
Agar	-	15.00 g.
Water	-	1000.00 ml.

Soil extract agar medium had the following composition.

Agar	-	12.50 g.
Glucose	-	1.00 g.
Dipotassium phosphate	-	0.50 g.
Soil extract (stock)	-	100.00 ml.
Water	-	900.00 ml.

Preparation of stock solution

This was prepared by heating 1000 g. of garden soil with 1000 ml. of tap water in the autoclave for 30 minutes. A small amount of calcium carbonate was added and the whole was filtered through a double paper filter. 100 ml. of the clear extract was taken for the preparation of medium.

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

The soils were plated in the medium at 1:10,000 dilution in four replications and incubated for 7 days at 30°C. The number of colonies developing in each plate was counted.

(ii) Isolation and study of nitrogen fixing organisms

Ashby's mannitol phosphate agar medium was used for this purpose. The medium had the following composition.

Magnesium sulphate	-	0.20 g.
Monopotassium phosphate	-	0.20 g.
Sodium chloride	-	0.20 g.
Calcium sulphate	-	0.10 g.
Calcium carbonate	-	5.00 g.
Mannitol	-	10.00 g.
Distilled water	-	1000.00 ml.

The soils were plated in the medium at 1:10,000 dilution, in four replications and incubated for 7 days at 30°C as above. The cultures were purified by repeated

plating and selecting well growing good colonies until pure cultures were obtained.

(iii) Morphological features

The morphological features of the isolated strains were studied by standard methods.

(iv) Nitrogen fixing capacity

The nitrogen fixing capacity of the isolated strains was determined in Ashby's mannitol phosphate medium (liquid).

25 ml. of the sterile media was inoculated with a loopful of the growth and incubated at $30^{o}C$ for 21 days with four replications including the control. The nitrogen content of the liquid media after incubation was determined by the Kjeldahl's method.

RESULTS

RESULTS

Variation in soil reaction at different periods

The pH of the soil samples collected at different periods during the course of the present investigation are given in Tables I and II. It will be seen from the results that the soils from the different horizons of the same profile show marked variation in their pH values. Also the two profiles differ widely as regards the pH of the soils.

The pH of the surface soils of profile I series when determined on the fresh sample varies from 3.7 to 6.9 depending on the time of collection. On air drying the pH values decrease considerably, the values ranging from 3.0-5.8. The soils of the lower layers are generally neutral in reaction, and there is considerable reduction in their pH values on air drying. However, the fall in pH of the soils of the lower horizon due to air drying is not as sharp as that observed in the case of the surface soil samples.

The soils of profile II series have generally a higher pH value. For surface soils in the fresh condition

TABLE I

pH of soil samples at different periods

Profile I series

Date of Collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	5.9	5.0	6.1	5.5	4.8	5.9
12th October	5.7	5.9	6.5	5.3	5.7	6.4
1st November	6.9	6.9	6.9	3.0	3.7	6.0
1st January	3.7	5.0	6.5	3.6	4.1	5.0
12th February	3.7	5.2	6.6	3.2	4.9	6.0

TABLE II

pH of soil samples at different periods

Profile II series

Date of Collection	Fresh samples			Air dry samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	5.8	6.5	7.1	5.0	5.5	6.0
12th October	6.7	6.7	7.0	5.8	6.4	6.8
1st November	7.1	7.0	7.2	3.3	5.9	6.1
1st January	6.2	6.0	7.7	5.8	5.7	7.0
12th February	5.2	7.6	8.0	4.8	7.0	7.1

the pH varies from 5.2 to 7.1. Air drying causes the pH values to decrease and vary from 3.3 to 5.8. Thus, in the case of both the profiles, the pH values of the air dried surface soils are identical. In profile II series the soils are slightly alkaline in reaction at the bottom. The profile collected during the month of February records a pH of 8.0 for the bottom layer.

The results recorded in Tables I and II show that the fresh soil samples collected during the month of November are neutral in reaction, But these samples have very low pH values on air drying. Thus, it is observed that the soil samples having very high pH values in the field condition, record a very sharp decrease in pH when air dried. The soils of the different horizons in a profile show marked differences in pH. This difference in pH between different horizons is very clearly manifested on air drying the soil.

The pH of the soil samples determined in 0.1 N KCl and in 0.01 M $CaCl_2$ are given in Tables III and IV. The pH values determined in salt solution and those determined in soil water suspension do not differ widely for most of the soil samples.

TABLE III

pH of soil samples at different periods

(pH - determined in salt solutions)

Profile I series

Date of Collection	pH in 0.1 N HCl			pH in 0.01 M $CaCl_2$		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	5.3	4.8	5.3	4.0	4.3	5.3
12th October	4.2	5.2	6.0	3.5	5.2	5.9
1st November	3.0	3.6	5.9	3.0	3.5	5.7
1st January	3.4	3.5	4.7	3.3	3.4	4.4
12th February	3.2	4.8	5.8	3.2	4.7	5.9

TABLE IV

pH of soil samples at different periods

(pH - determined in salt solutions)

Profile II series

Date of Collection	pH in 0.1 N KCl			pH in 0.01 M $CaCl_2$		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	4.9	5.2	5.8	4.5	4.8	5.4
12th October	5.3	6.3	6.5	5.3	6.0	6.1
1st November	3.0	5.4	6.0	3.1	5.5	5.9
1st January	5.2	5.5	7.0	5.0	5.4	6.8
12th February	4.6	6.9	6.8	4.5	6.7	6.8

2. Variation in water soluble salts at different periods

The variation in the conductivity of the soil samples collected at different periods are given in Tables V and VI. The conductivity values are found to depend on the soil, the season and the horizon. The conductivity of the water extracts of the soil shows that the soils are slightly saline in nature. The soluble salt content of the soils is comparatively high.

The profiles collected during the month of November record minimum conductivity values for all the three horizons when they are fresh. The conductivity values of the samples collected during other periods are almost identical.

When the soil samples are air dried, the samples collected during the month of November give the highest conductivity values. The samples collected at different periods differ widely in their total soluble salts, when the samples are air dried. The conductivity values of air dried samples vary from 8.5 to 15.0 m.mhos./cm.

Water soluble calcium content was determined on both fresh and air dry samples and the results are given in Tables VII and VIII. The calcium

TABLE V

Conductivity of soil samples at different periods

Profile I series

Date of Collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	4.2	4.5	4.6	9.5	12.0	15.0
12th October	4.0	4.5	4.0	9.5	12.0	12.0
1st November	2.6	3.6	3.2	14.0	15.0	11.0
1st January	4.0	5.5	5.5	8.5	13.0	12.0
12th February	5.0	4.5	4.0	9.0	12.0	12.0

TABLE VI

Conductivity of soil samples at different periods

Profile II series

Date of Collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	4.5	4.2	4.0	12.0	12.0	11.0
12th October	2.6	2.6	2.6	5.8	6.4	6.8
1st November	2.8	2.4	2.5	15.0	14.0	13.0
1st January	4.0	3.6	3.2	6.5	9.0	8.0
12th February	4.5	4.5	4.5	9.0	10.0	10.0

TABLE VII

Water soluble Calcium content of soil samples at different periods

(meq./litre of water extract)

Profile I series

Date of Collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	5.32	18.51	17.31	5.91	19.63	17.23
12th October	9.21	10.70	18.99	9.14	10.92	19.09
1st November	13.89	15.24	9.51	13.88	15.26	9.46
1st January	3.50	14.00	15.80	3.59	13.90	15.70
12th February	6.54	12.75	12.83	6.56	12.85	12.85

TABLE VIII

Water soluble calcium content of soil samples at different periods

(meq./litre of water extract)

Profile II series

Date of Collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	14.61	27.56	18.20	14.77	27.50	18.18
12th October	9.57	9.21	9.31	9.55	9.33	9.14
1st November	15.11	8.51	6.26	15.03	8.33	6.25
1st January	1.81	5.23	3.07	1.74	5.16	3.14
12th February	4.40	5.87	6.51	4.39	5.78	6.47

content fluctuates widely and does not follow any definite pattern of variation. The calcium content of the soils in the second horizon is higher than that of the soils from the other two horizons in most cases.

In Tables IX and X are given the water soluble magnesium content of the fresh and air dry samples. Magnesium content of the soils is higher than the calcium content. As in the case of the calcium content the magnesium content of the samples also varies widely and no definite trend is noticed in its seasonal variation. The magnesium content is more in the lower horizons than in the surface layers.

A fairly good amount of chloride is present in all the profiles collected at different seasons. Tables XI and XII give the data regarding the chloride content of the fresh and air dry soils, collected at different seasons. The lower horizons are comparatively rich in chlorides. It is also observed that the chloride content does not appreciably vary as a result of air drying.

The water soluble sulphate content fluctuates from season to season. The sulphate content is invariably higher than the chloride content in the case of air dry soil. On air drying, the water soluble sulphate of the

TABLE IX

Water soluble magnesium content of soil samples at different periods

(meq./litre of water extract)

Profile I series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	15.35	26.52	26.91	15.45	26.79	26.80
12th October	4.61	10.20	8.90	4.54	10.00	8.85
1st November	30.00	36.52	15.37	30.06	36.73	15.49
1st January	13.51	25.49	38.97	13.43	25.29	39.08
12th February	21.30	13.63	34.86	21.28	13.52	34.75

TABLE X

Water soluble magnesium content of soil samples at different periods

(meq./litre of water extract)

Profile II series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	25.78	26.91	29.21	25.90	26.89	29.51
12th October	4.52	23.00	16.23	4.77	22.73	15.78
1st November	36.01	18.92	15.31	36.62	19.19	15.42
1st January	8.23	20.00	3.98	8.47	20.04	4.13
12th February	17.89	13.58	16.21	17.95	13.81	15.96

TABLE XI

Chloride content of soil samples at different periods

(meq./litre of water extract)

Profile I series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	26.03	38.51	28.11	26.13	38.64	28.41
12th October	51.20	68.13	82.72	51.13	68.17	82.97
1st November	34.60	56.65	50.00	34.68	56.65	49.72
1st January	49.21	82.31	72.31	49.33	82.79	72.78
12th February	53.45	75.71	73.50	53.44	75.68	73.48

TABLE XII

Chloride content of soil samples at different periods

(meq./litre of water extract)

Profile II series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	35.92	44.50	50.97	36.36	44.32	51.13
12th October	19.91	67.53	52.89	19.86	67.13	53.16
1st November	43.00	49.21	21.42	43.05	49.77	21.53
1st January	37.00	39.11	51.00	36.90	39.13	51.05
12th February	46.81	66.89	66.91	46.78	67.00	67.00

soil considerably increases as seen from Tables XIII and XIV. It may be noted that the samples collected during the month of November are very rich in sulphur compounds as evident from the sulphate content of the air dry samples. This phenomenon is more marked in the case of surface soil samples.

Tables XV and XVI give the relation between the pH values and sulphate contents of soil samples collected at different periods. It is observed that the samples rich in sulphate show high acidity. It is particularly evident in the samples collected during November.

3. Toxic factors in organic soils

It is a common observation that when the fields in this region get dried, a yellowish white incrustation is formed on the surface (Plate II). The surface soils of all the profiles on air drying are also covered with a similar incrustation. When these acid soils were kept in pots and watered every day, the dissolved salts get leached out through the pores and get deposited on the outer surface of the pots. Plate III shows the deposit so formed on the outer surface of a pot containing the soil. The composition of the material deposited on the

TABLE XIII

Water soluble sulphate content of soil samples at different periods

(meq./litre of water extract)

Profile I series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	2.60	54.45	59.16	12.42	111.90	174.60
12th October	42.80	77.09	42.81	102.00	157.00	43.81
1st November	23.07	10.71	14.00	137.70	129.70	83.81
1st January	43.63	34.83	14.86	95.06	100.70	98.17
12th February	10.02	23.77	20.65	38.19	91.62	95.94

TABLE XIV

Water soluble sulphate content of soil samples at different periods

(meq./litre of water extract)

Profile II series

Date of collection	Fresh samples			Air dried samples		
	0-30 cm.	30-70 cm.	Below 70 cm.	0-30 cm.	30-70 cm.	Below 70 cm.
24th August	40.09	14.66	9.04	118.60	102.00	63.28
12th October	37.05	28.51	27.13	120.50	62.81	34.04
1st November	14.84	11.53	11.53	139.90	49.50	40.09
1st January	13.52	23.60	10.01	58.61	88.62	46.57
12th February	13.01	19.32	29.96	57.94	59.95	88.92

TABLE XV

Relation between pH and sulphate content of soil samples at different periods

Profile I series

Date of collection	0 - 30 cm.				30 - 70 cm.				Below 70 cm.			
	pH of fresh soils	Sulphate content in fresh soils	pH of air dried soils	Sulphate content in air dried soils	pH of fresh soils	Sulphate content in fresh soils	pH of air dried soils	Sulphate content in air dried soils	pH of fresh soils	Sulphate content in fresh soils	pH of air dried soils	Sulphate content in air dried soils
24th August	5.9	2.60	5.5	12.42	5.0	54.45	4.8	111.90	6.1	59.16	5.9	174.60
12th October	5.7	42.80	5.3	102.00	5.9	77.09	5.7	157.00	6.5	42.81	6.4	43.81
1st November	6.9	23.07	3.0	137.70	6.9	10.71	3.7	129.70	6.9	14.00	6.0	83.81
1st January	3.7	43.63	3.6	95.66	5.0	34.83	4.1	100.70	6.5	14.86	5.0	98.17
12th February	3.7	10.02	3.2	48.19	5.2	23.77	4.9	91.62	6.6	20.65	6.0	95.94

TABLE XVI

Relation between pH and sulphate content of soil samples at different periods

Profile II series

Date of collection	0 - 30 cm.				30 - 70 cm.				Below 70 cm.			
	pH of fresh soils	Sulphate content in fresh soils	pH of air dried soils	Sulphate content in air dried soils	pH of fresh soils	Sulphate content in fresh soils	pH of air dried soils	Sulphate content in air dried soils	pH of fresh soils	Sulphate content 1 in fresh soils	pH of air dried soils	Sulphate content in air dried soils
24th August	5.8	40.09	5.0	118.60	6.5	14.66	5.5	102.00	7.1	9.04	6.0	63.28
12th October	6.7	37.05	5.8	120.50	6.7	28.51	6.4	62.81	7.0	27.13	6.8	34.04
1st November	7.1	14.84	3.3	139.90	7.0	11.53	5.9	49.50	7.2	11.53	6.1	40.09
1st January	6.2	13.52	5.8	58.61	6.0	23.60	5.7	88.62	7.7	10.01	7.0	46.57
12th February	5.2	13.01	4.8	57.94	7.6	19.32	7.0	89.95	8.0	29.96	7.1	88.92

TABLE XVII

Analysis of surface deposits

	From field	From pot
Total sulphate	36.60%	38.41%
Fe_2O_3	18.96%	15.89%
Al_2O_3	11.84%	13.17%

outer surface of the pot was studied and it is found that it is identical with that of the incrustation formed on the surface in the field. The analysis of this material is given in Table XVII. It will be seen that the sulphate content is very high and that iron and aluminium are present in amounts sufficient to cause acute toxicity to plant growth. After the soils in the pots are thoroughly leached, it was observed that paddy seedlings grow very well in them, whereas in unleached soils they gradually wilt and ultimately die.

4. Variation in the total bacterial count at different periods

The total bacterial count of the different samples are given in Tables XVIII and XIX.

The total count of microorganisms in the soils is rather low especially when there is no crop and the land is under water. Thus the samples collected in the month of August are very poor in microbial activity. But the total count increases gradually. The samples collected during the month of November and January have a high bacterial count.

TABLE XVIII

Variation in bacterial population of soils collected at different periods

Profile I series

Date of collection	0 - 30 cm.		30 - 70 cm.		Below 70 cm.	
	pH of fresh soils	Total count (millions/g.)	pH of fresh soils	Total count (millions/g.)	pH of fresh soils	Total count (millions/g.)
24th August	5.9	0.44	5.0	0.38	6.1	1.21
12th October	5.7	0.61	5.9	0.51	6.5	3.21
1st November	6.9	3.36	6.9	4.42	6.9	4.91
1st January	3.7	1.15	5.0	2.10	6.5	8.20
12th February	3.7	0.70	5.2	0.81	6.6	1.60

TABLE XIX

Variation in bacterial population of soils collected at different periods

Profile II series

Date of collection	0 - 30 cm.		30 - 70 cm.		Below 70 cm.	
	pH of fresh soils	Total count (millions/g.)	pH of fresh soils	Total count (millions/g.)	pH of fresh soils	Total count (millions/g.)
24th August	5.8	0.23	6.5	1.53	7.1	1.71
12th October	6.7	1.26	6.7	1.24	7.0	2.00
1st November	7.1	4.81	7.0	4.67	7.2	3.98
1st January	6.2	8.40	6.0	7.80	7.7	6.80
12th February	5.2	0.80	7.6	1.90	8.0	0.90

Although the population does not vary strictly with the pH, there appears to be some correlation between pH and total count. The samples which are neutral in reaction are fairly rich in microbial activity. The total count also increases with depth. Fungi are found to predominate in the upper layers, where as bacteria predominate in the lower horizons.

5. Morphological features and nitrogen fixing capacity of isolated strains

Pigmented strain

Shape	-	Cocci
Size	-	2x2 or 3x3 μ
Motility	-	Actively motile
Gram reaction	-	Gram negative

Nonpigmented strain

Shape	-	Cocci or diplococci
Size	-	2x3 or 3x3 μ
Motility	-	Highly motile
Gram reaction	-	Gram negative

Nitrogen fixing capacity

Pigmented strain	-	11.80 mgm./g. of sucrose in 21 days in liquid media
Nonpigmented strain	-	14.21 mgm./g. of sucrose in 21 days in liquid media.

DISCUSSION

DISCUSSION

There is a common belief among cultivators in this region that crop yields are far more influenced by seasons than by application of fertilizers or methods of cultivation. Presumably, the chemical properties of the soils of this region are influenced to a very large measure by seasonal changes. It is, therefore, only appropriate to examine the extent to which seasons exert their influence on the chemical properties of the soil.

The limiting factors to crop production in acid sulphate soils, according to Moormann (1963) are soil acidity, toxicity of iron and aluminium, and poor physical soil condition. The extent to which these factors are influenced by changing seasons, as regards Kuttanad acid soils, will be evident from the results of the present study.

1. Profile characters and seasonal changes

With a view to examining how far the physical soil conditions are affected by changing seasons, two series of profiles were taken from two representative localities in the area. There appears to be no clear distinction

between the different horizons of the profile. The profiles could be divided into different horizons only on the basis of textural classification. The upper layers are deeper in colour than the lower layers which indicates that the lower layers have more decomposed organic matter whereas the upper layers are rich in undecomposed organic matter. Also, the soils of the upper layers are predominantly clayey, more plastic and sticky. The lower layers are relatively less sticky and sandy. The upper layers contain streaks of yellow deposits, the streaks becoming increasingly conspicuous when the soils are dry.

As far as the morphological characters of the profiles are concerned, it appears that these characters are practically uninfluenced by changes in season. However, the chemical characters are altered by seasonal changes. This indicates that the inorganic constituents of the soil vary with the season, while the organic portions which contribute to the morphology undergoes very little change.

2. Soil reaction

The nature of hydrogen ions in Kari soils has been studied by many workers. There appears to be some

Fig. 1

Graph showing the variation in pH of fresh soil samples at different periods

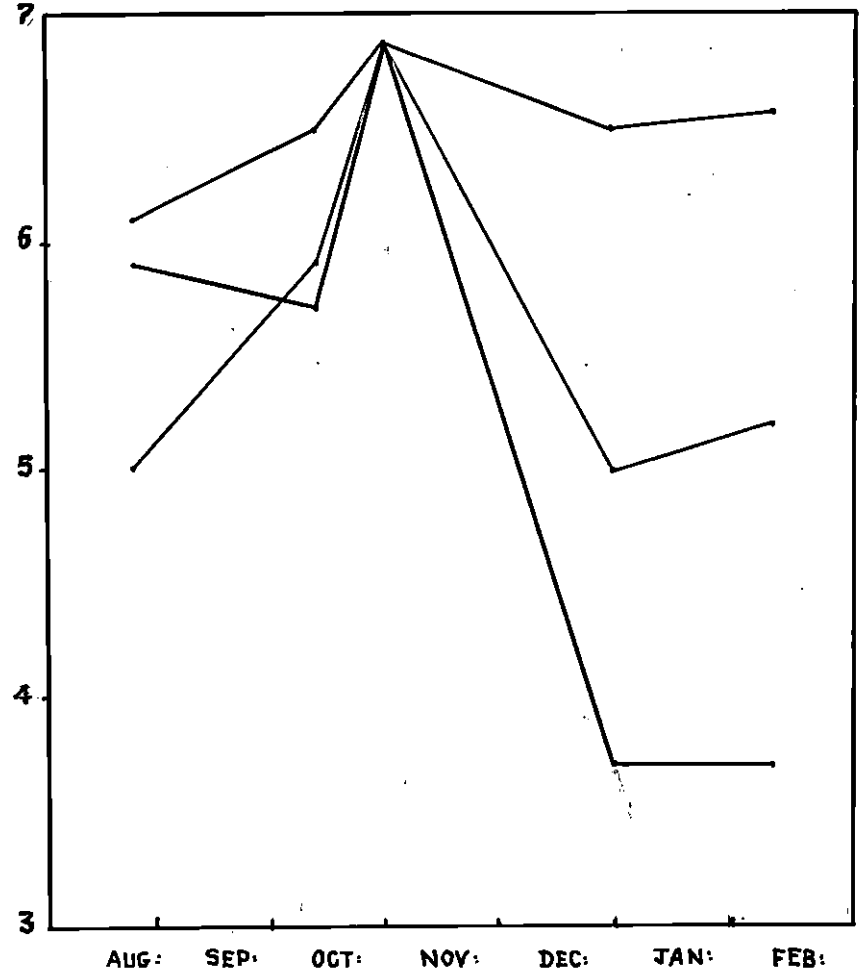
(Profile I series)

Fig. 2

Graph showing the variation in pH of fresh soil samples at different periods

(Profile II series)

Fig. 1



0-30 Cm. —— 30-70 Cm —— BELOW 70 Cm.

Fig. 2

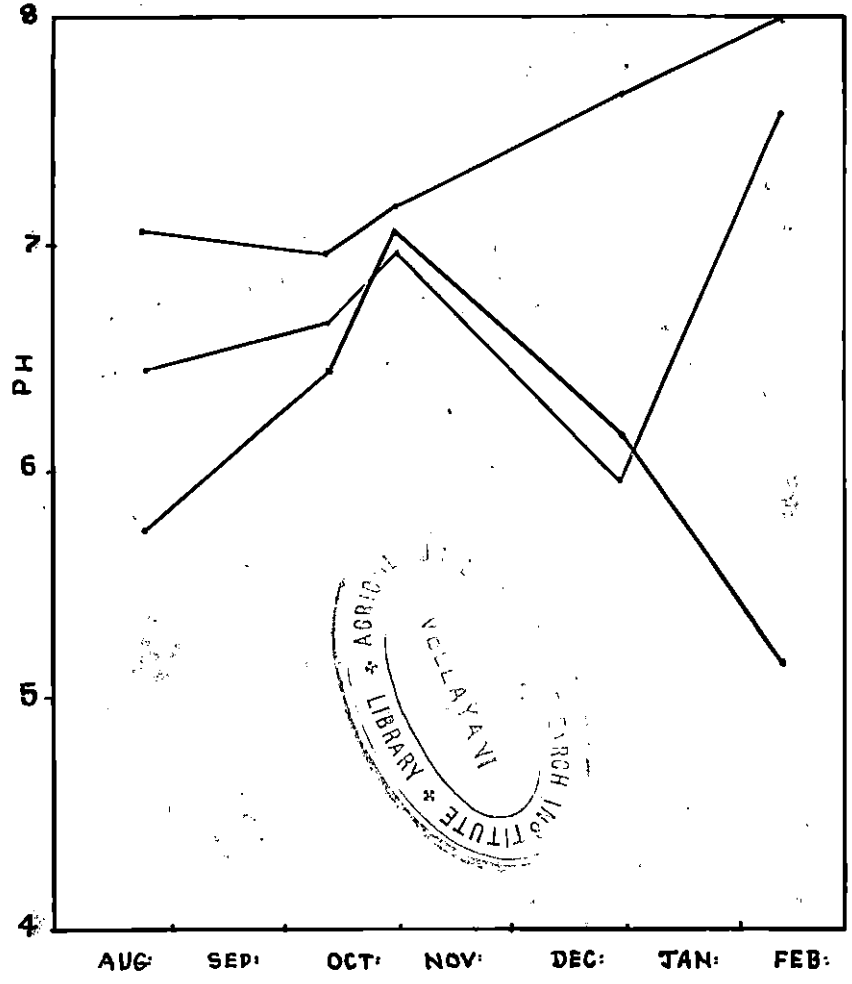


Fig. 1

Graph showing the variation in pH of fresh soil samples at different periods

(Profile I series)

Fig. 2

Graph showing the variation in pH of fresh soil samples at different periods

(Profile II series)

Fig. 1

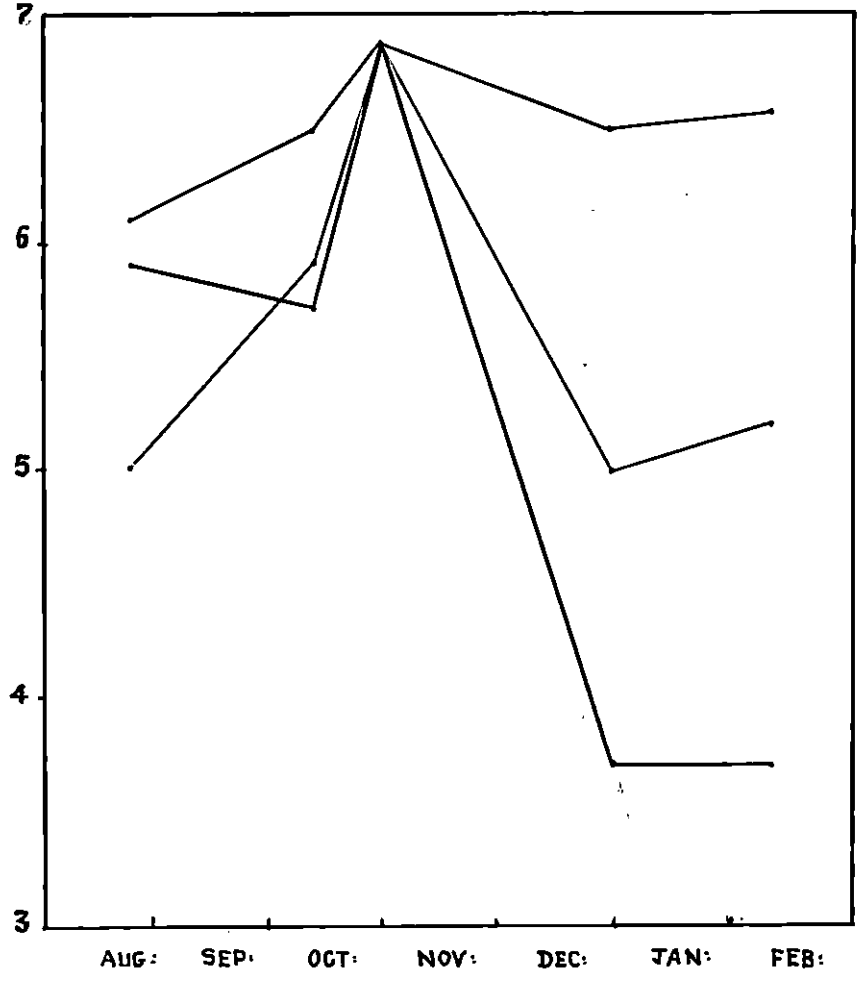


Fig. 2

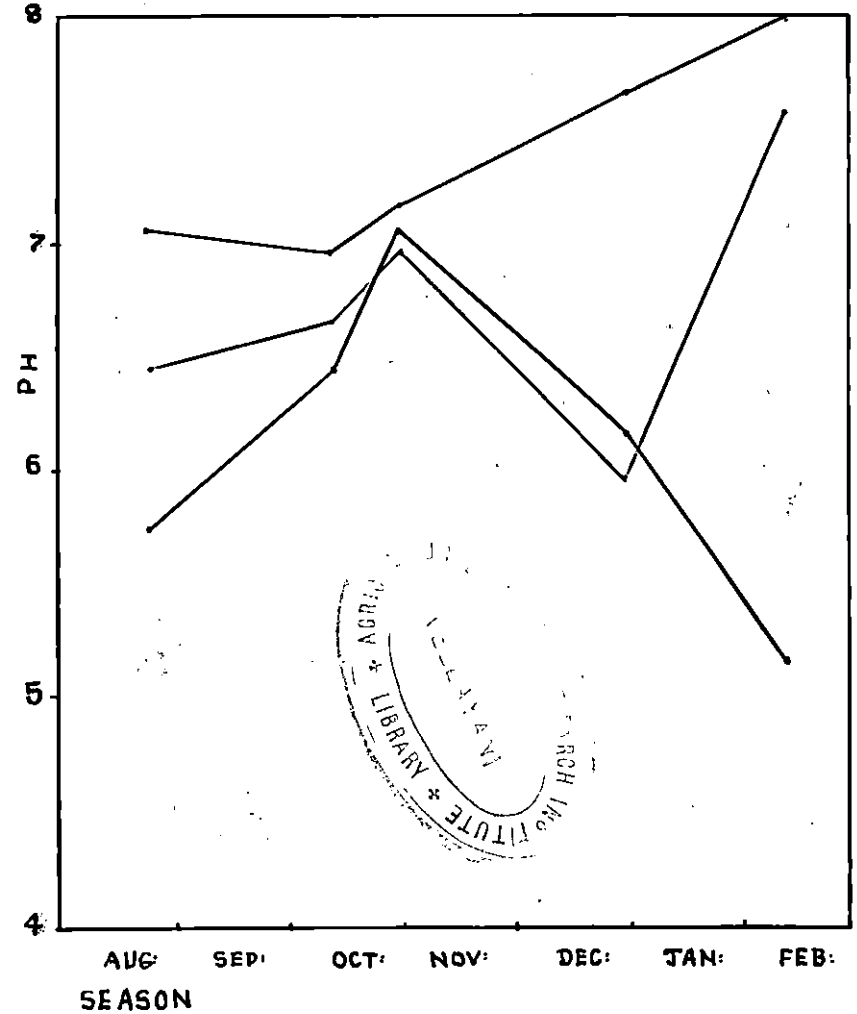


Fig. 3

Graph showing the variation in pH of
air dried soil samples at different periods
(Profile I series)

Fig. 4

Graph showing the variation in pH of
air dried soil samples at different periods
(Profile II series)

Fig 3

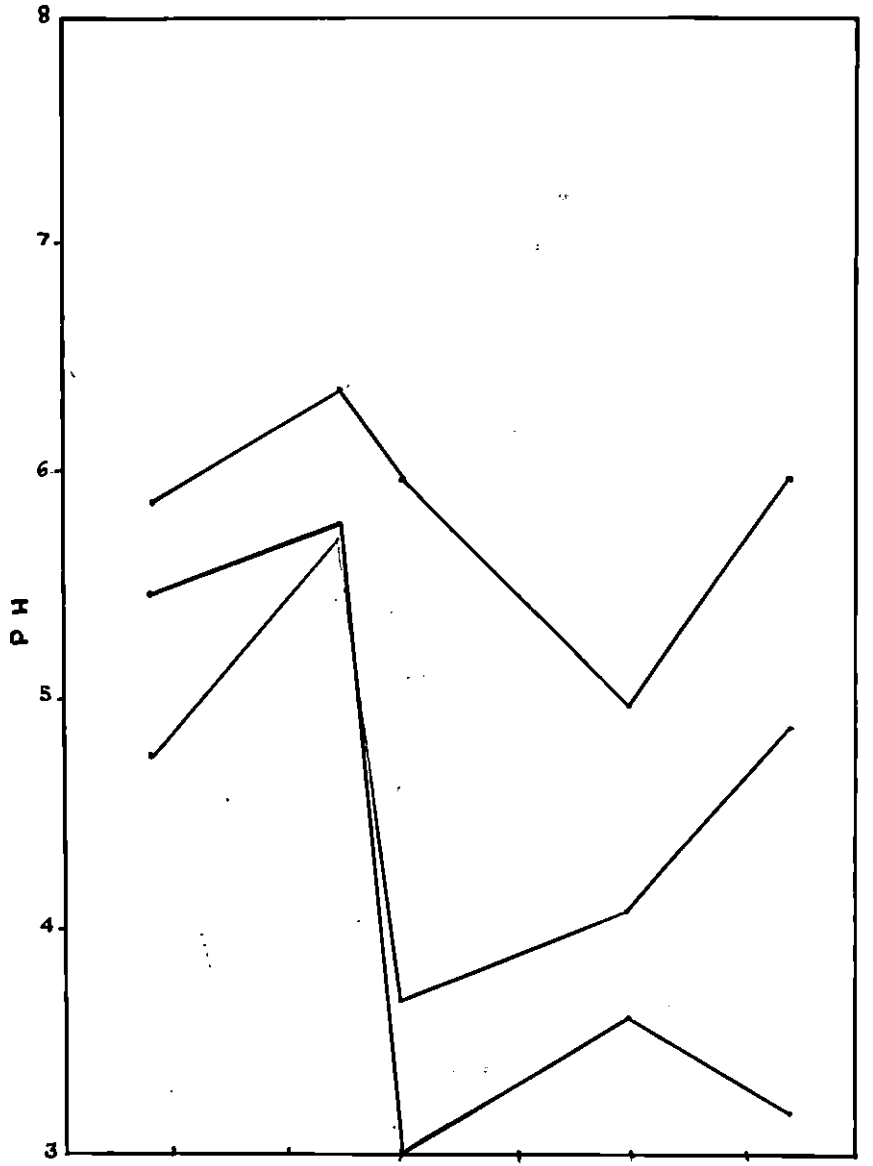
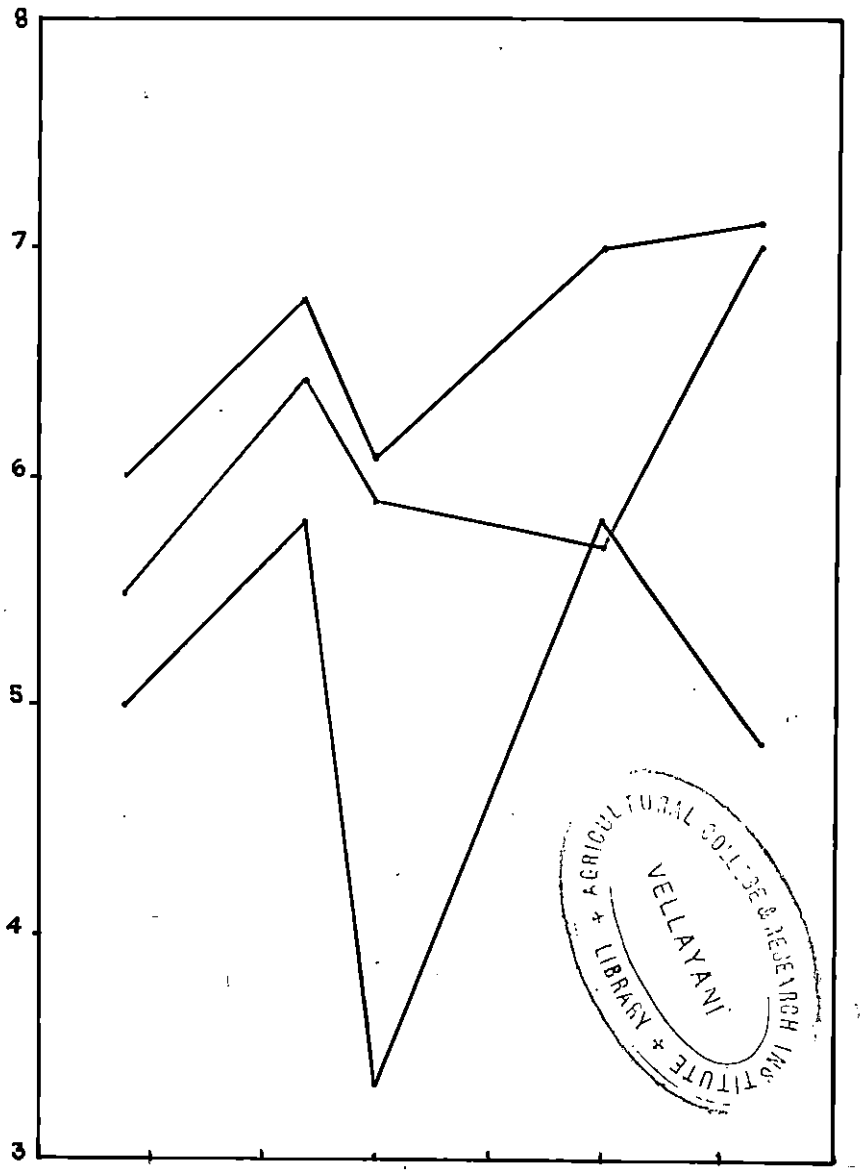


Fig 4



DATE OF SAMPLING

——— 0-30 Cm. ——— 30-70 Cm. ——— BELOW 70 Cm.

controversy regarding the nature of the acidity of these soils. Pillay and Subramoniam (1930) attributed this to the hydrolysis of salts while Iyer (1928) traced its origin to the presence of organic acids. Nair (1945) has reported that the pH of the Kari soils is dependent on their organic matter content. According to Subramoney (1947) the high acidity of these soils is the result of oxidation of sulphur compounds present in the soil.

A very peculiar feature of these soils is that the upper layers are highly acidic while the lower layers are almost neutral and in some cases slightly alkaline. The lower layers are predominantly rich in carbonates and therefore it would appear that the neutral or even alkaline reaction of the soils of the lower horizons is due to the presence of the carbonate compounds.

The fresh samples are almost neutral in reaction while on air drying there is considerable fall in pH. (Fig. 1 to 4). This appears to be in agreement with the observation of Moormann (1963) that acid sulphate soils upon drainage and aeration show a definite and severe acidification due to the oxidation of sulphides which lead to the formation of sulphuric acid.

Seasonal variations in pH are very pronounced especially in periodically inundated lands like rice fields. During inundation pH values may increase gradually, eventually reaching close to neutral whereas during the dry period which follows, they drop quickly. Thus the pH as such is not a deciding characteristic for these soils in the field. However, the difference between the pH of the dry and wet material may give a fairly satisfactory estimate of the potential acidity of these soils (Moormann, 1963).

It is evident from the results that seasons do exert considerable influence on the chemical properties of soils. It has been a common experience that when the crop is harvested during November or December the yields are good. But if the harvesting period extends to February-March, the yields are very poor.

It will be seen from Tables I and II that the surface soils from both the profiles collected during November are highly acidic in reaction when they are air dried. When these soils are fresh, their pH values indicate that they are nearly neutral. There is thus a wide difference in the pH values of fresh and air dry

soils in November. The fall in pH on air drying is not so sharp for the soils collected at other periods. In other words the difference in pH between fresh and air dry soils is greatest in November. Thereafter the soils are acidic even in the field condition. This indicates that by November the soil acidity has increased and during the following dry months, the acidity which was potential till then, manifests itself completely. The soils which were apparently neutral till November were potentially acidic, as indicated by the pH of the dry soil. Thus, after November, there is a sudden manifestation of soil acidity in the surface layers. Under an optimum soil reaction plants can grow well, but when there is a sudden fall in pH, and that too within a short interval, the plants will not be able to survive such a drastic change in soil reaction, and the result will be progressive wilting. According to Moormann (1963) a very high concentration of hydrogen ions such as can be found in the oxidised top layers of newly reclaimed and drained mud clays can cause physical damage to plants. He points out that there are several instances in which the junction of root and stem has been practically severed by the acid. In such cases, the roots may still be alive whereas the above ground parts have died.

In normal cultivation practices that are prevalent in the area, it becomes necessary to dry the soil during certain specific periods of crop growth. At the transplanting stage, for instance, the fields are allowed to dry for bringing about better aeration and rooting. Consequently, this operation leads to a considerable fall in pH. In circumstances where fresh water is available, this newly developed acidity could be leached away by thorough washing. However, such a possibility is remote, under conditions prevailing in the field; particularly where the fields are centrally situated in extensive blocks of areas varying from 300 to 700 acres and when the water has to come from rivers through the surrounding fields. Thus, at certain periods during crop growth, the acidity is bound to shoot up and cause damage to the crop. A clue to the solution of this vexed problem could be obtained from the results of the present investigation.

As has already been pointed out, the difference between pH of the fresh and air dry soils is maximum in November and at other periods the difference is comparatively very small. It would, therefore, appear that the soil is potentially very acidic in November even though

Fig. 5

Graph showing the variation in pH of
air dried soil samples as determined in different media

(Profile I series)

Fig. 5

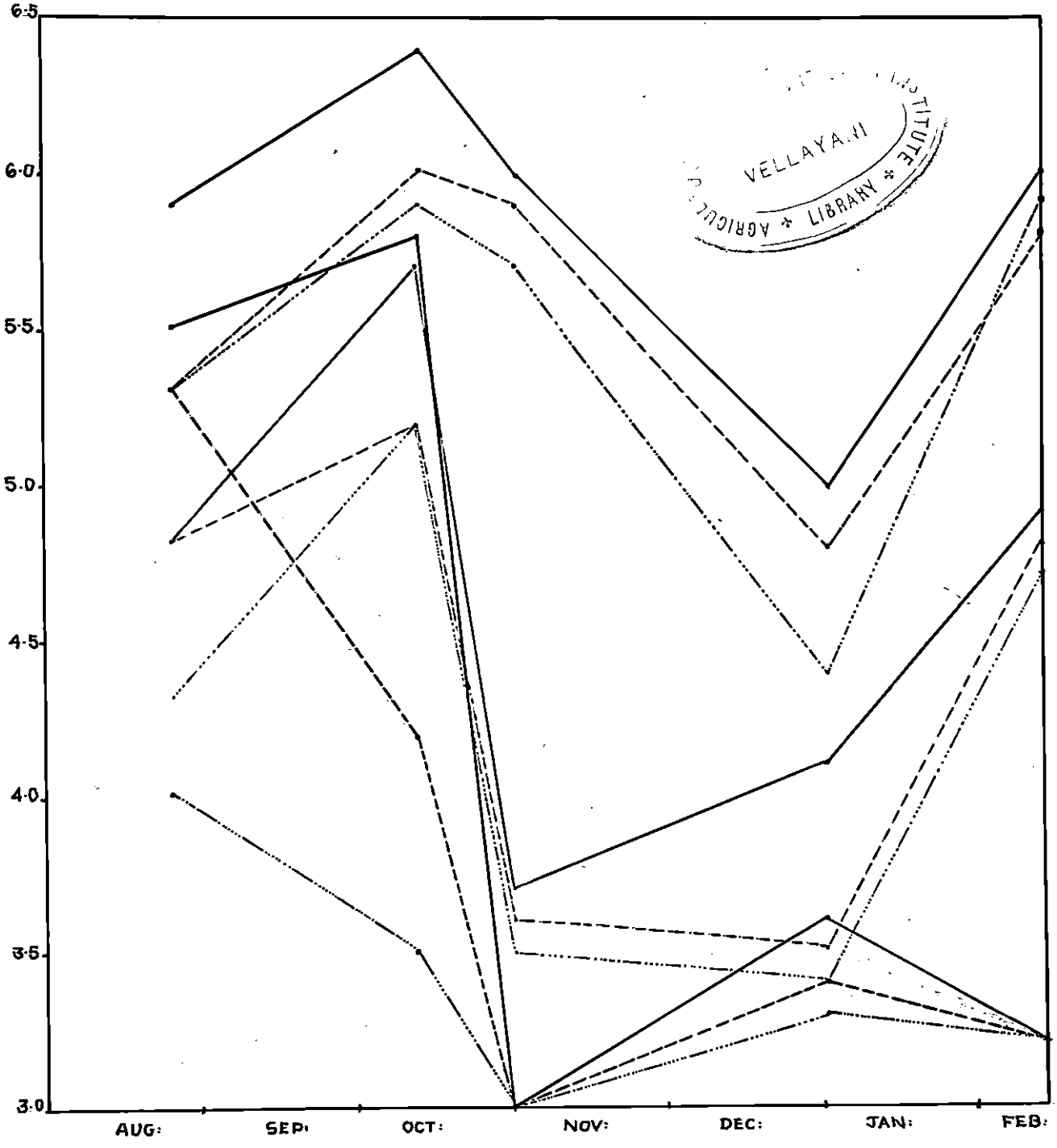
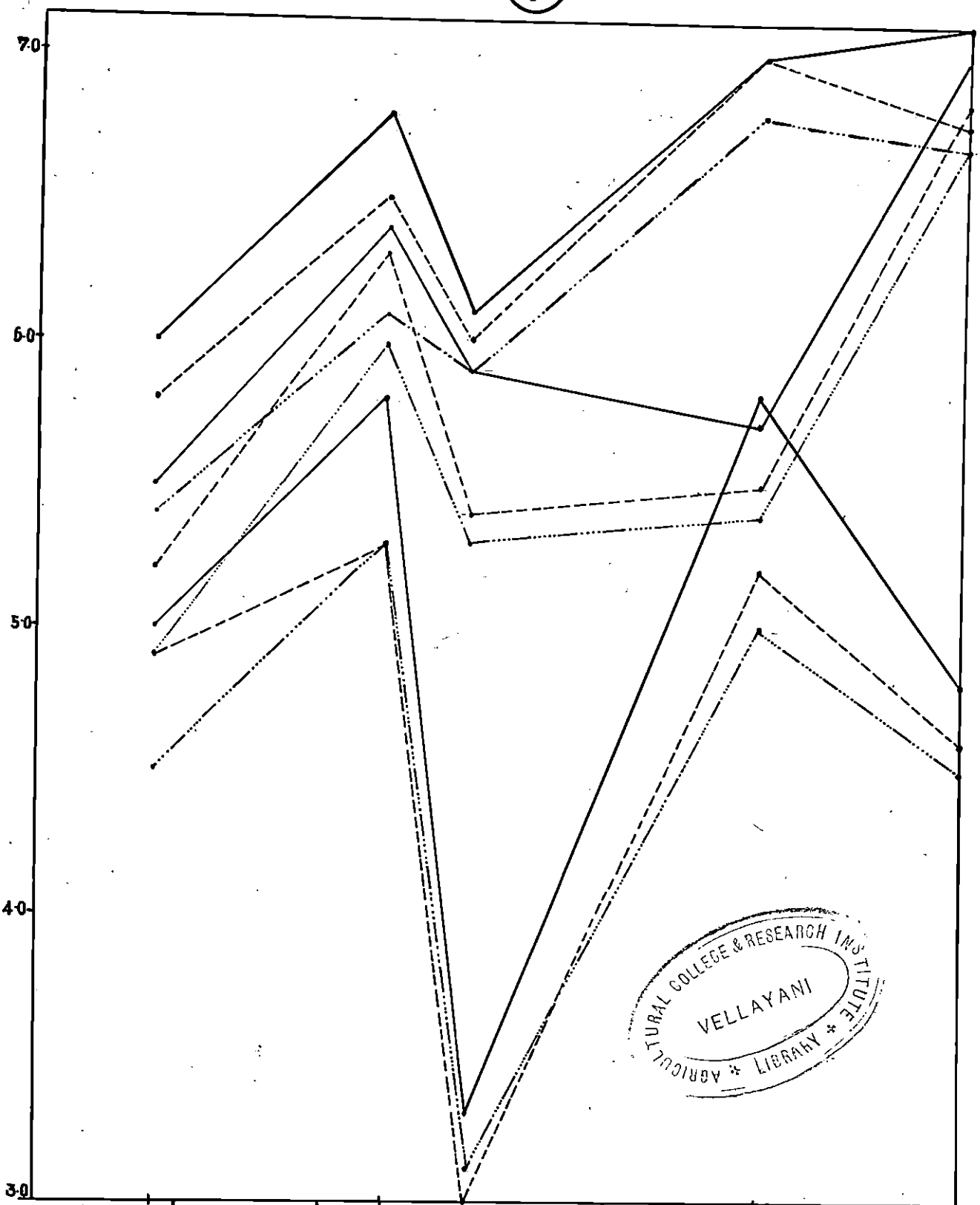


Fig. 6

Graph showing the variation in pH of
air dried soil samples as determined in different media

(Profile II series)

Fig. 6



the pH of the fresh soil indicates it to be nearly neutral. This potential acidity is, therefore, bound to reveal itself completely during dry seasons following November and this is found to be so, as judged from the experimental results. Therefore, it would appear to be safe to adjust the planting time in such a way as to complete the harvest by November-December. If the plants do not mature before November, the chances of wilting will be very great, as the potential acidity will be released during the dry season following November. Thus, if the harvest period comes during February-March, the chances are that the plants would already have been subjected to the harmful effects of high acidity and consequently the yield will be poor. This conclusion arrived at on the basis of the data obtained from the present study is in complete agreement with the cultivators' experience that if the harvesting period is in February-March, the yield is poor, whereas, if it is in November-December, the yield is good.

It will be seen from the results in Tables XV and XVI that the pH and sulphate content are negatively correlated. When the pH is low, the sulphate content is found to be high. This should be so because the acidity

is the result of oxidation of sulphur compounds present in the soil. The oxidation of sulphur compounds leads to the production of sulphuric acid and consequent increase in the sulphate content.

The pH of the air dried samples as determined in soil water suspension and in soil-salt solution systems do not differ significantly (Fig. 5 and 6). Generally in most soils these two values differ appreciably. However, in the present study such a phenomenon is less noticed.

3. Total soluble salts

In a study of the tidal influences in the area, Vaidyanathan (1958) found that there is an ebb-tide during the month of November. The sea rises and consequently there is a pressure exerted in the entire Kuttanad area which might eventually lead to the capillary rise of the subsoil salts to the surface. The plants are quite susceptible to this change in total soluble salts if they are at their tender age or at the flowering stage.

Fig. 7

Graph showing the variation in conductivity of fresh soil samples at different periods

(Profile I series)

Fig. 8

Graph showing the variation in conductivity of fresh soil samples at different periods

(Profile II series)

Fig. 7

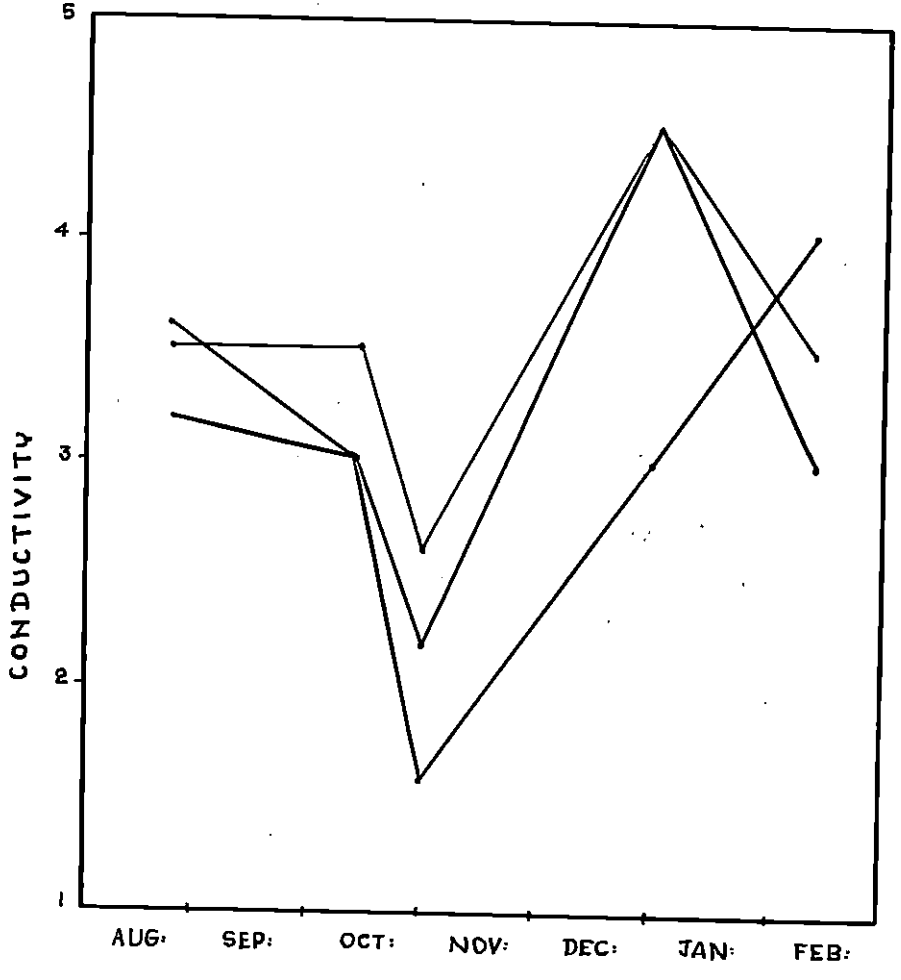
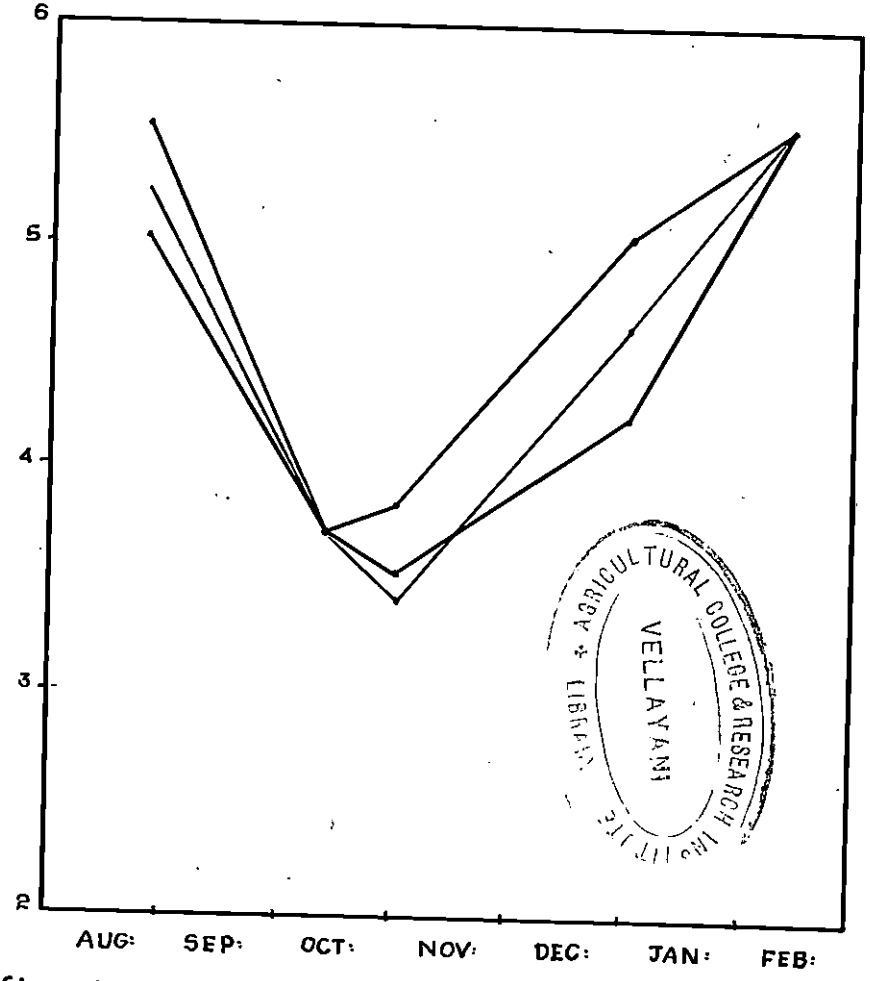


Fig. 8



——— 0-30 Cm. ——— 30-70 Cm ——— BELOW 70 Cm

Fig. 9

Graph showing the variation in conductivity of air dried soil samples at different periods

(Profile I series)

Fig. 10

Graph showing the variation in conductivity of air dried soil samples at different periods

(Profile II series)

Fig. 9

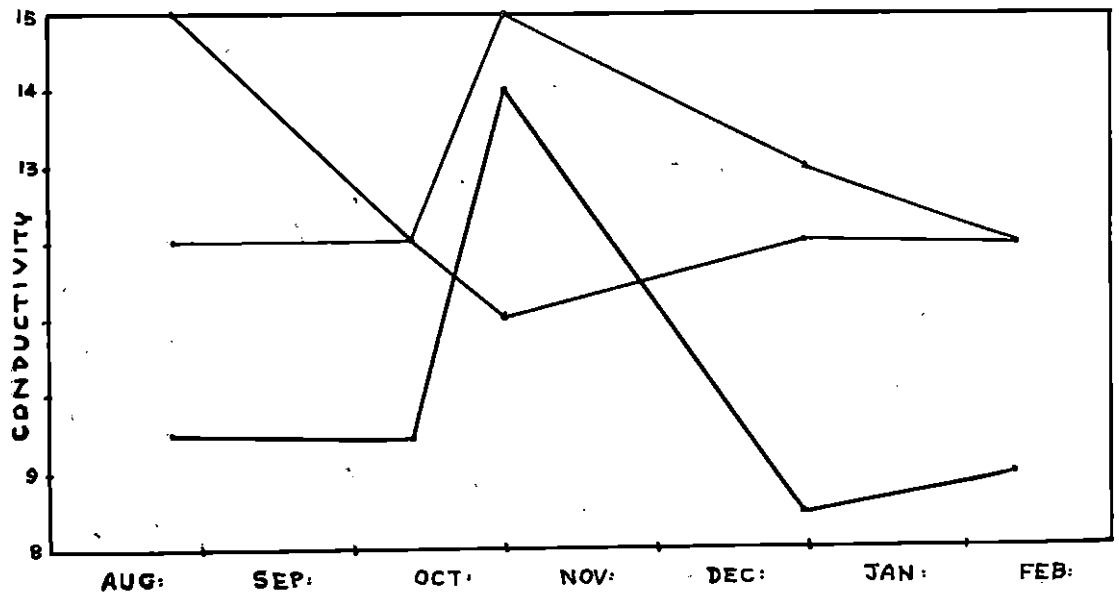
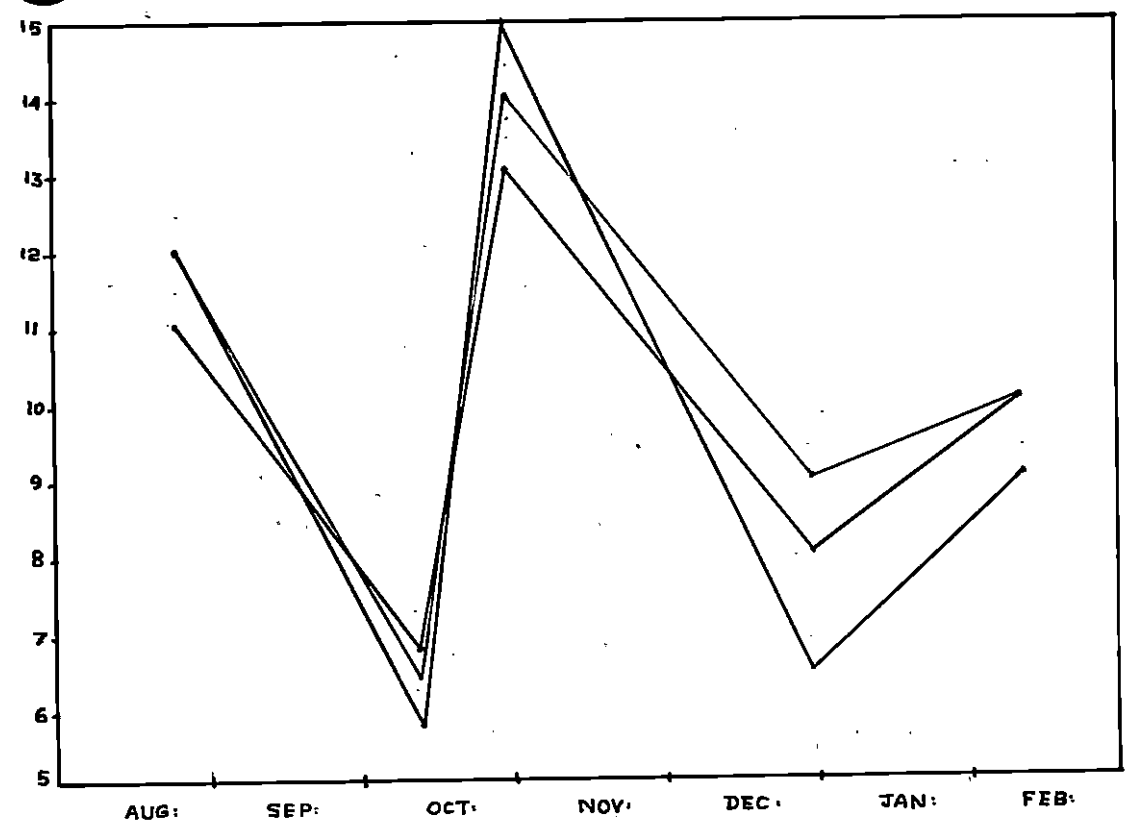


Fig. 10



The results of this study are in agreement with the experience of the cultivators that the planting or flowering stage should not be during the month of November.

On a comparison of the chloride and sulphate contents it will be seen that the chloride content is practically unaffected on air drying the soil, whereas the sulphate content increases considerably. From the results of this investigation (Fig. 6 to 10) it can be seen that the conductivity increases on air drying. It would thus appear that the increase in conductivity on air drying the soil might possibly be due to the increase in sulphate content. The increase in sulphate content according to Subramoney (1958) is the result of oxidation of sulphur compounds present in the soil when it is air dried.

As regards the variation in the water soluble calcium content, the results obtained show that the surface soils of both the series of profiles contain the maximum amount of calcium in the month of November. However, no definite pattern regarding the seasonal variations in the calcium content emerges from the results obtained. In both the profiles, the calcium content is greater in the lower horizons.

The variations in the magnesium content of the soils are generally similar to those observed in the case of calcium. The magnesium content is always found to be higher than the calcium content.

Results given in Tables XI and XII show that all the soils contain very large amounts of chloride. This might possibly be the result of frequent inundation of the lands with sea water. It is also seen that the chloride content is greatest in the middle horizon of the profiles. The values of conductivity and total soluble salts would suggest that these soils be better termed acid saline soils. According to Nair (1945) the fertility status of these soils has no relation to their salt content.

4. Toxic factor

The degree of acidity depends on various conditions. On drying the field the plants wilt completely in certain areas of the field. This wilting occurs in patches. According to Subramoney (1947) such patches in certain fields is more than 25% of the total area.

Round about the wilted plants on the air dried exposed area, an yellowish white incrustation can be seen.

These incrustations are the concentrates of the toxic material that are formed in the soil during drying. The analysis of the scrapings are given in Table XVII. There is a high content of sulphate, iron and alumina all being toxic to plant life in high concentrations.

Aluminium concentrations of 800 ppm. or more in the soil seriously affect the production of rice (Tomlinson, 1957). In Sierra Leone an aluminium level greater than 250 ppm. and iron level greater than 1000 ppm. has been found to be harmful for rice.

The term cat-clay (Van Wyk, 1951) has been used for acid soil material in its oxidised form showing straw-yellow motlings and streaks of basic ferrice sulphate. Chenery (1954) suggested the term acid sulphate soils for the soils in Central Africa in which such materials occur.

Subramoney (1958) gives an explanation regarding the possible formation of such patches in Kari lands. During summer when lands get dried this incrustation is found on the surface of the soil. According to him due to some subsoil reaction, presumably of a biological character, the matter which encrusts on the exposed soil is pushed up.

The occurrence of these incrustations on the surface soil suggests that the toxic salts are produced as a result of aeration and the products might have been formed as a result of aerobic condition. The predominence of sulphate in this substance indicates its formation from the lower horizons because lower horizons do not show high acidity when freshly collected, but gets acidic on exposure to air.

The occurrence of sulphur and sulphur compounds has been reported by Subramoney (1947). In the same work evidence has been given to show the existence of a sulphur bacterial cycle.

The formation of sulphuric acid accounts for the high contents of iron and aluminium. Evidently sulphuric acid must have dissolved out iron and aluminium from the soil. The free sulphuric acid and the consequent fall in pH are themselves factors contributing to toxicity.

Van der Spek (1950) proposed a scheme for the accumulation of sulphides under anaerobic conditions and their subsequent oxidation leading to the production of free sulphuric acid.

Fig. 11

Bar diagram showing the total microbial count of the soils

(Profile I series)

Fig. 11

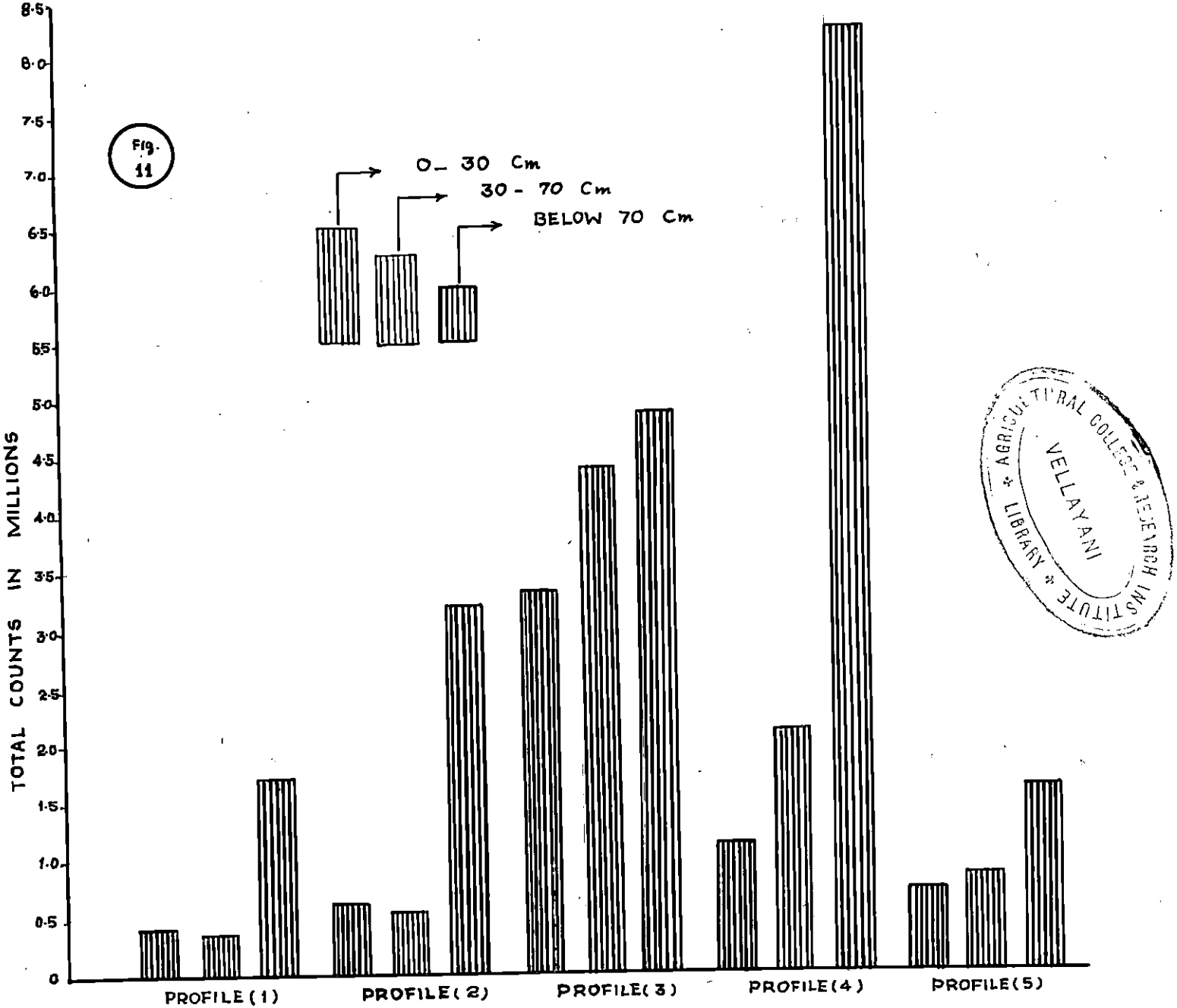
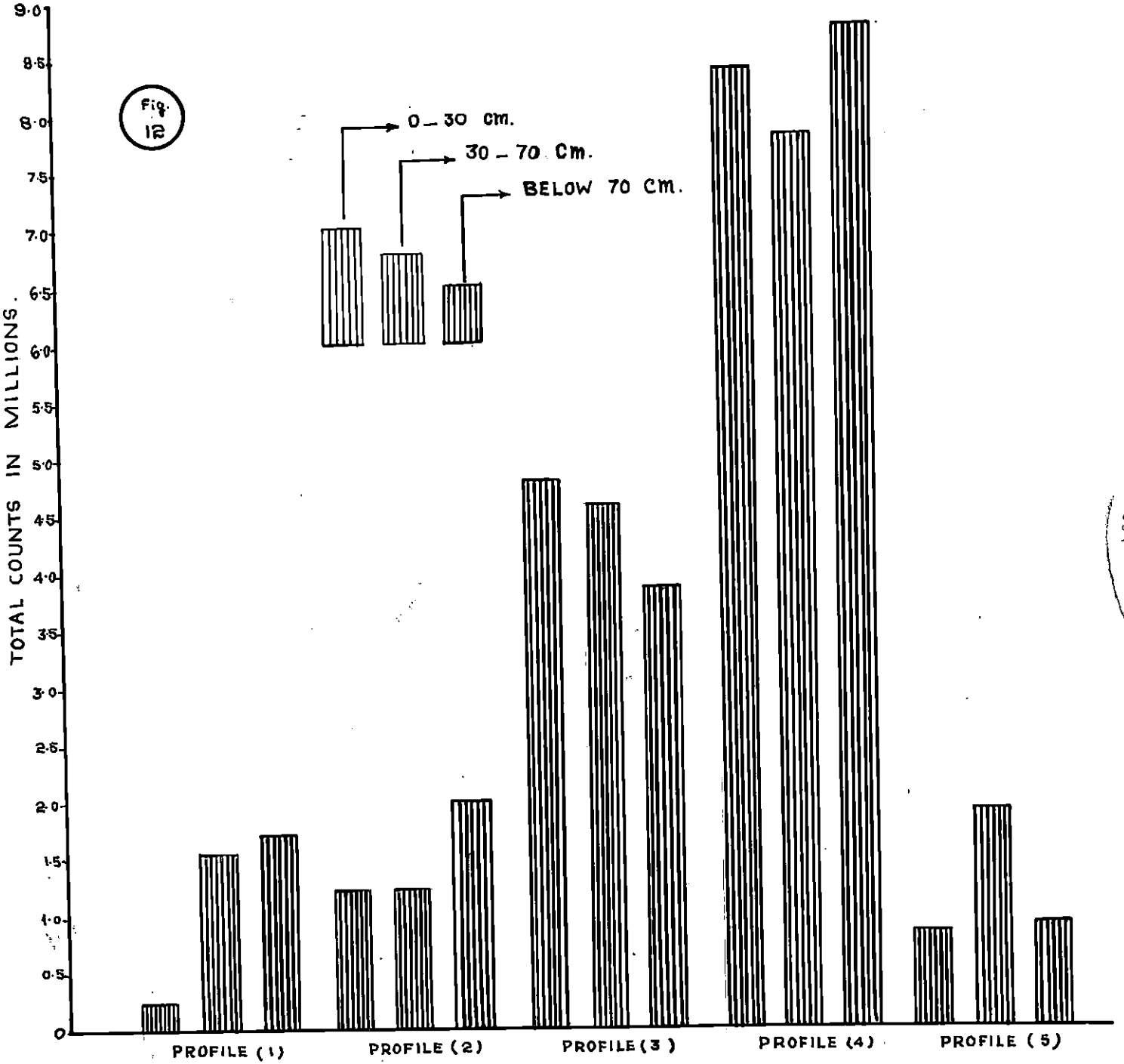


Fig. 12

Bar diagram showing the total microbial count of the soils

(Profile II series)



Thus we get in the soil the triple effect of low pH, soluble alumina and soluble iron (Tomlinson, 1957).

The cultivators hold the view that if the plant comes to flowering during November-December, the crop is bound to fail and they call it as 'Makarakal'.

From the results obtained in the study it can be suggested that the soils should receive good leaching during the month of November-December. However this has to be confirmed by further studies.

5. Microbiological properties

(1) Variations in the total bacterial count at different periods

A low microbial count which increases with depth and a predominance of fungi over bacteria are characteristic of the microbial population in the Kari soils. (Fig. 11 and 12). Pochon (1956) attributes the low activity and population of microorganisms and the low ratio of bacteria to fungi in organic soils, to the combined effects of high acidity, high organic matter content and wide C/N ratio.

The variation in the total microbial count, as influenced by season, is found to be very pronounced by many workers. Khudyakov et al (1958) found a large variation in the number of microorganisms even under constant external conditions.

The samples collected during November and January record a comparatively high microbial population. During this period there was standing crop in the field. It would therefore appear that the high microbial population is caused by Rhizosphere effect. It is now well recognised that plant roots and soil microorganisms form an inseparable physiological and ecological complex. Webley et al (1952) suggested that bacterial and fungal population increases steadily with the development of vegetation.

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 results of this investigation are in good agreement with the common observation that the bacterial population is strongly influenced by the soil reaction and that the root development exerts a

much greater influence in deciding the total bacterial count.

The bacterial population gradually increases and reaches a maximum during the period November to January. After the harvest, a sudden fall of microbial population is noticed.

(ii) Morphological features and nitrogen fixing capacity of isolated strains

The morphological features of the two typical isolated strains namely pigmented and nonpigmented (dull white) are studied and recorded.

Subramoney (1958) isolated a nitrogen fixing organism from Kuttanad soils, which fixes about 10-14 mg. of nitrogen per gram of energy material, and which in its morphological features resembles the pigmented organism under study. (Plate IV). The growth characters reported by him are identical with those observed for this pigmented organism. According to him this organism belong to the genus Azotobacter.

The organisms isolated from the different horizons suggests that they are all of the same species. They are similar in the growth and morphological characters.

The high acidity and waterlogging are detrimental to the growth of Azotobacter. The condition prevailing in these soils suggests that the organism does not belong to the Azotobacter species.

Gainy (1919) suggested 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. According to Starkey and De (1939), Tchan (1952) and Derx (1955) organisms found in waterlogged soils of high acidity having characters similar to those of Azotobacter, belong to the genus Beijerinckia.

Beijerinckia has been reported to be present in most tropical soils. The nitrogen fixing organism isolated from Kari soils of Kerala resemble both Azotobacter and Beijerinckia. This poses a new problem.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study was carried out on the seasonal variations in pH, water soluble salts and bacterial population in the Kari soils of Kerala. Ten profiles collected at five different periods from two locations in Vechoor village, Vaikom Taluk, were examined. The morphological characters of the profiles were also recorded.

The results are summarised below:

(i) The soil samples collected during the month of November registered the maximum pH in the fresh condition, while on air drying they became extremely acidic.

(ii) The pH of the air dried samples determined in soil-salt solution system did not differ widely from that in soil-water suspension.

(iii) The soils collected during the month of November recorded the minimum conductivity values in the fresh condition. But on air drying these samples gave the maximum conductivity values.

(iv) The water soluble calcium, magnesium and chloride contents fluctuated widely, but did not follow any definite pattern of variation. The figures were similar for the fresh and air dired samples.

(v) Water soluble sulphate was present in large amounts. Sulphate content varied from season to season and a sudden increase was observed in air dried samples.

(vi) Negative correlation was obtained between soil pH and sulphate content of air dried samples.

(vii) The composition of the yellow crust collected from the field and those found on the outer surface of the pots used in the laboratory studies were identical.

(viii) The stage of growth of the crop had a definite influence on the bacterial count of the soils.

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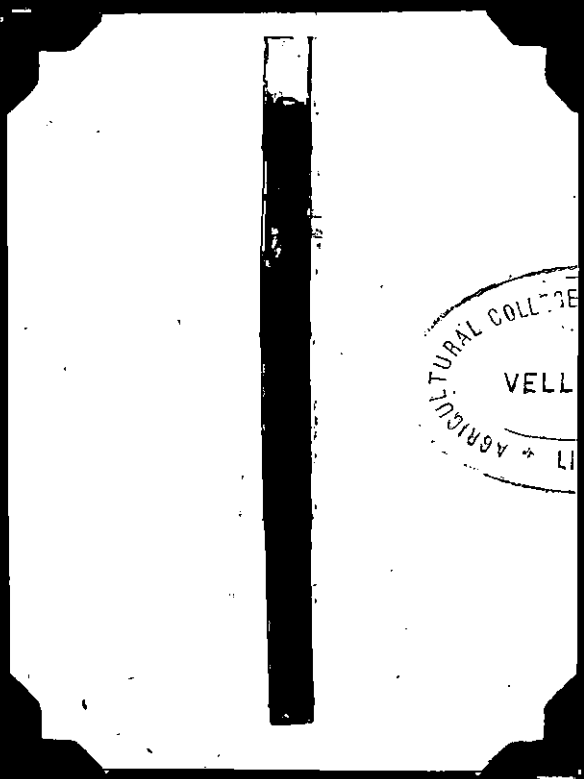
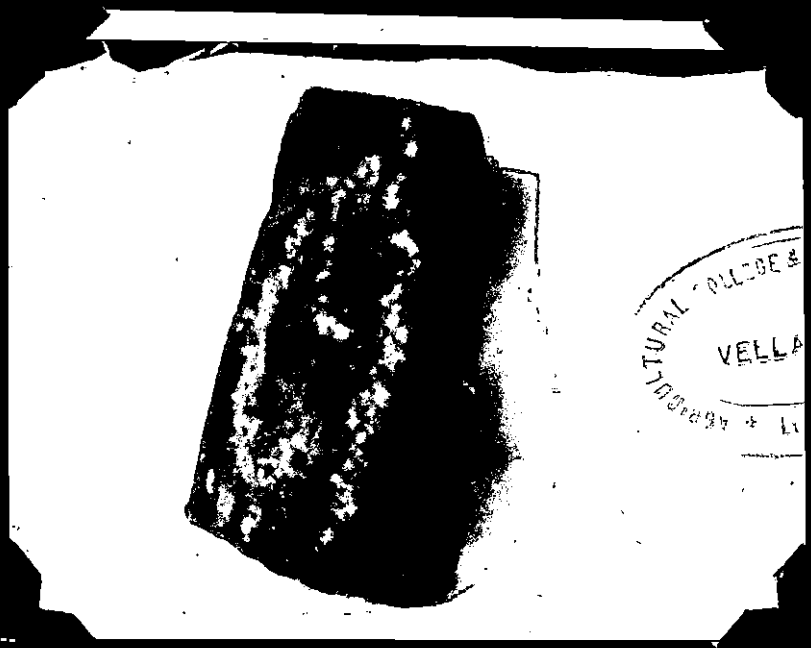
Plate I

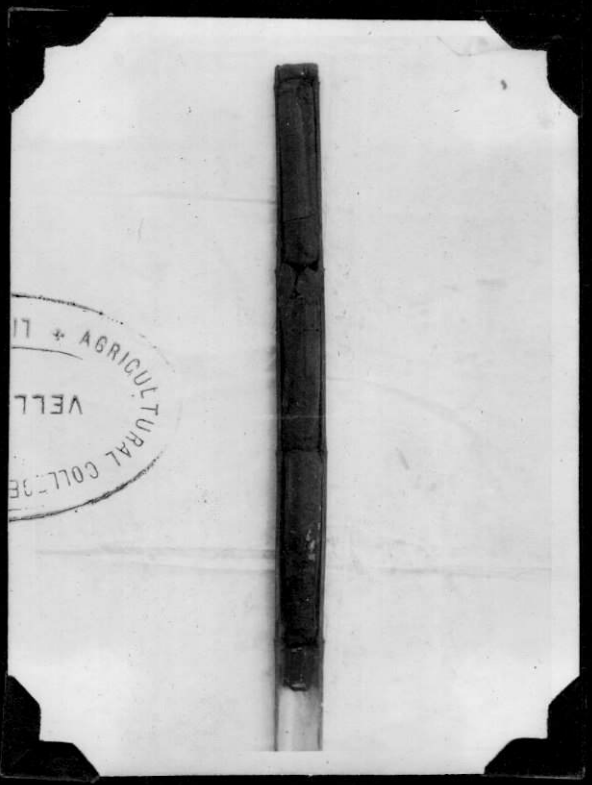
Section of the bamboo pole
showing the Kari profile

Plate II

The yellow crusts formed on the surface
of the Kari soil in the field







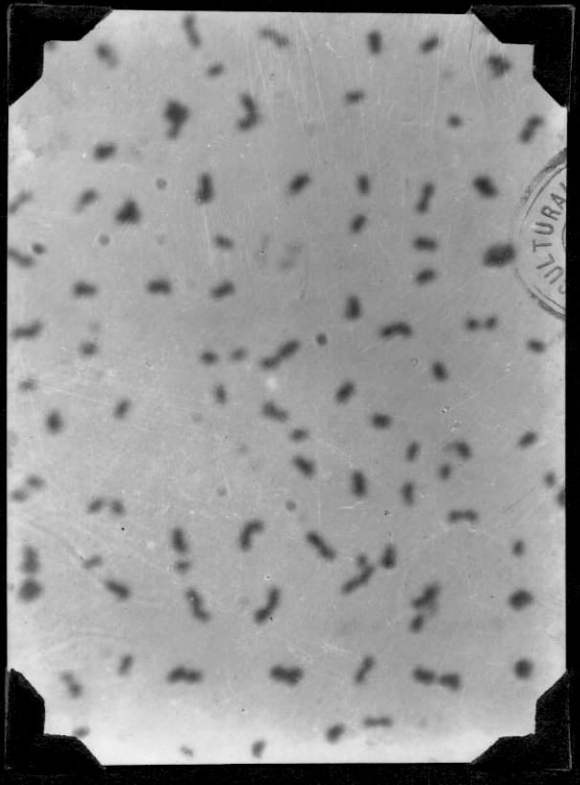


Plate III

The yellow crusts formed on the outer surface of the pot containing the waterlogged Kari soils

Plate IV

The nitrogen fixing pigmented organism x 750