SULPHUR STATUS OF KERALA SOILS

A THESIS

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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 C.I. Jacob 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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C O N T E N T S

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INTRODUCTION

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Sulphur occupies a pre-eminent place in agriculture. It is an essential element for all forms of life, for it is a common constituent of proteins. The two amino acids Methionine and Cystine, commonly found in plants contain sulphur to the extent of 21 and 27 per cent respectively. Two growth regulators thiamin and biotin, contain sulphur. The characteristic flavour of certain vegetable oils are due to volatile compounds of sulphur. Total sulphur in plants may approach or even exceed the concentrations of phosphorus.

Though the essential nature of sulphur was demonstrated a century and a half ago, this nutrient received only sporadic study at the hands of agricultural scientists. A renewed interest in sulphur as a plant nutrient has followed reports of response to sulphur from certain places. Many soils of Australia and New Zealand are reported as deficient in sulphur. In India sulphur deficiency is reported only in the tea soils of Punjab.

Sulphur is present in soils both in inorganic and organic forms. Very little information is available regarding the nature of compounds in soil and whatever information available is confined merely to total sulphur and sulphate sulphur. Plants absorb sulphur from the soil principally as sulphates. The main reservoir of available sulphur in most agricultural soils is, however, in the organic matter.

Sulphur is in an endless and recurrent cycle. Initially derived from soil minerals, sulphur is also added to the soil by rain and irrigation waters, atmosphere, fertilizers, insecticides and fungicides. It is removed from the soil by plants and partially or completely returned to it in plant residues and animal products. In the soil, sulphur undergoes certain changes which directly or indirectly affect plant growth.

Transformations of both organic and inorganic sulphur compounds within the soil are largely microbial. They are accomplished by diverse organisms and the end products that accumulate depend on the environmental conditions. The fluctuating moisture regime in most of our water-logged soils may lead to the formation of reduction products like sulphides, or oxidation products like sulphuric acid, the accumulation of both affecting plant growth.

Thus the need for precise data on the forms of sulphur in different soil types of Kerala is obvious and will be most useful in the efficient management of these soils. In view of the facts that no such data are available for the soils of Kerala, the present study is undertaken with the following objectives.

1. To assess the different forms of sulphur present in soil profiles of Kerala State.

2. To compare the distribution of various forms of sulphur in dry land soils and wet land soils.

3. To study the relationships amongst the various forms of sulphur and with organic matter in soil.

REVIEW OF LITERATURE

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Forms of Sulphur.

Sulphur is present in soils in both inorganic and organic forms. Very little information is available regarding the nature of sulphur compounds in soil and whatever information available is confined merely to total sulphur and sulphate sulphur.

Considering the reactions whereby organic and inorganic sulphur compounds were transformed by micro-organisms, Starkey (1950) observed that many sulphur compounds were produced in soils, but as they were susceptible to decomposition, they did not accumulate and were not detected. In addition to H_2S and sulphates, thiosulphates, tetrathionates, and other polythionates, and even elemental sulphur were detected. Among the organic forms of sulphur, the amino acids cystine, cysteine, methionine, taurine; ethereal sulphates, thiourea, glucosides and the vitamins thiamin and biotin have been detected.

Radio-chromatographic investigations on the cycle of sulphate and the sulphur amino acids by Scharphnseel and Krausse (1963) revealed that the sulphur amino acids potentially occuring in soils and humic acids, were mainly cysteic acids, cystenine-sulphinic acids, taurine, methionine sulphone, cystine and methionine.

Reviewing certain aspects of sulphur as a soil constituent and plant nutrient, Freney *et al* (1962) found that most of the sulphur in humid regions was in organic form. They also noted that in most agricultural soils the inorganic fraction contained only a small portion of forms other than sulphates.

Williams and Steinbergs (1962) studying the chemical nature of sulphate in some Australian soils, observed that in the surface horizons of most of the well drained acid soils, nearly all the sulphur was present in organic form. It was also established that except under anaerobic conditions, when reduced form of sulphur, particularly sulphates might predominate, most of the inorganic sulphur in soils occured as sulphates. Williams and Steinbergs (1965) also reported that sulphur occured in soils mainly in organic form or as sulphate. They concluded that important categories of sulphate in Australian soils included water-soluble sulphate, adsorbed sulphate and insoluble sulphate associated with calcium carbonate.

That organic form of sulphur constitutes the major portion of sulphur in soils is also supported by the findings of Shkonde (1957), Walker (1957), Freney (1958) Johansson (1959), Olivero (1960), Kanwar and Surinder Mohan (1962), Aidinyan (1964) and Kanwar and Takkar (1964).

Distribution of different forms of sulphur in soils.

Rost (1922) detected occurence of sulphides in samples of peat and muck from Golden Valley peat experiment fields of Minnesota. Sulphides were found at all levels in the peat, in the muck substratum and in the upper portion of the mineral sub-soil below. Expressing the sulphide content as H_2S, he found a minimum of 0.016 per cent and a maximum of 0.06 per cent for the lower most layers of peat and 0.002 and 0.013 per cent for the muck substratum immediately below.

Evans and Rost (1945) determined the amount of organic sulphur in a number of Minnesota soils. The data showed that the chernozems, black praire soils, north-eastern podsols and north-central podsols contained 73.3, 71.0, 49.5 and 45.4 per cent respectively of their total sulphur in organic form. In the sub-surface layers studied, they found that only 9-15 per cent was in organic form.

Madanov (1946) determining sulphur content of a number of chernozem and chestnut soils, found that in chernozem the organic sulphur constituted about 75 per cent and in chestnut soils about 50 per cent of the total sulphur.

Investigating the total sulphur content of a wide range of lowveld soils, Goldschmit (1951) reported a variation from 40 to 1800 lb/ac.ft. It was also observed that sandy granite soils contained much lower amounts than loams or heavy loams of fairly high organic matter.

The sulphur content of soils in the humid areas of the United States was listed by Millar (1951). The total sulphate in some soils varied from 2.8 per cent in chernozems (about 73 per cent inorganic form) to 7.9 per cent in podsols (about 45 per cent in organic form).

According to Shkonde (1957) the sulphur content of Zei-Burya soils of Russia varied from 0.10 to 0.05 per cent or less. Of these about 90 per cent of the sulphur in the ploughed layer of meadow dark-brown soil was represented by organic sulphur and stable minerals and in sod-podsolic soils these forms represented 80 per cent of the total sulphur.

From the surface horizons of red-yellow podsolic soils of south-eastern parts of United States, Jordan and Bardsley (1958) got only 3 ppm. or less of sulphur extractable by Morgan's CH_3 COONa - buffer, and it tended to accumulate 6-30 inches below the surface.

About 30 per cent of the agricultural soils of West Scotland as examined by Little (1958), had readily soluble sulphate content of less than 40 mg./100 g. soil and 7 per cent had less than 3 mg.

Reviewing the role of sulphur in soil fertility, Jordan and Ensminger (1958) established the variability of total sulphur content of soils. As estimated by Robinson (1917), the range of total sulphur content was 0.008 to 0.136 per cent for the top soil. Byers <u>et al</u> (1938) gave 0.045 per cent as the average content of sulphur in A and B horizons of 18 representative soils.

Walker and Adams (1958) determining the sulphur content of the grassland soils of New Zealand for 3 horizons, found mean values of 700, 410 and 230 lb./ac. for the A, B and C horizons respectively. Soils in strongly weathered sequence had higher sulphur content in all the three horizons studied, as reported by Walker and Adams (1959). Investigations in a chronosequence at Taupo (New Zealand) by Walker, Thapa and Adams (1959) showed the percentage of sulphur increased steadily with time. Comparing the virgin soils and 25 year old pastures in the chronosequence, they observed that the average annual increase was 14 lb. sulphur per acre.

Jordan and Baker (1959) reported that the total sulphur content of North Idaho soils varied from 0.020 to 0.039 per cent.

Estimating different forms of sulphur in the calcareous and non-calcareous soils of Italy, Olivero (1960) found that the content of organic sulphur varied from 77 to 2300 ppm.

Williams <u>et al</u> (1960) recorded occurence of insoluble sulphate associated with calcium carbonate in calcareous soils in Scotland.

In a group of 24 soils studied by Freney (1961), only about 1 per cent of the total sulphur occured in inorganic compounds less oxidized than sulphates.

The values for available sulphur in 105 different Polish soils, estimated by Nowosielski (1961), varied from 0.3 to 52 mg./100 g. in the arable layers and from traces to about 15 mg. in the deeper horizons. The values were lowest in light loamy soils and highest in peats.

Parson and Tinsley (1961) suggested that the organic compounds in the soil organic matter to which a considerable fraction of the soil sulphur is covalently bound, could be sulphated polysaccharides or sulphate esters of phenols and they showed that polysaccharides might constitute up to 30 per cent of the organic sulphur.

Kanwar and Surinder Mohan (1962) while studying the distribution of different forms of sulphur in Punjab Soils, found that organic sulphur formed 72 per cent of the total sulphur in acid soils, while it was only 19 per cent in alkaline soils.

Comparing the nutrient status of a peaty soil and a red loam laterite soil of Kerala, Money (1962) found that sulphate content of the peaty soil was 2.3 per cent while it was only in traces in the red loam soil.

Lowe and Delong (1963) observed that organic soils of Qubec contained substantially more carbon-bonded sulphur than did mineral soils. Comparing between organic soils and mineral soils in the above studies, the range for sulphur values bonded to carbon obtained, varied from 47 to 58 per cent in the former and 12.35 per cent in the latter.

Tszyun and Tszin (1963) determined microquantities of H_2S in Chinese soils by isotopic dilution using radioactive isotope S 35-. Under ordinary conditions, rice soils contained only a few mg. H_2S per 100 mg. The pH as well as the iron and manganese content of

Chinese soils suggested that H_2S poisoning would be infrequent.

Aidinyan (1964) studied the content and forms of compounds of sulphur in various soils of the U.S.S.R. In non-saline soils, the distribution of sulphur depended on the distribution of humus carbon. Sulphur accumulation was greatest in the humus accumulative horizons and decreased gradually towards the parent material. In non-saline soils 70-90 per cent of the total sulphur was bound to organic matter and sulphur occured in all the main fractions of the humus. Sulphur reserves in the soils studied, were 1-9 tons/ha. The reserves were higher in peat soils and low in sandy-loamy podzolic soils.

Jackson (1964) observed that field soils of humid temperate regions contained 50-100 ppm. water soluble sulphates and 100-1500 ppm. total sulphates. Distribution of total sulphur in the profile varied from soil to soil.

Kanwar and Takkar (1964) studied the distribution of sulphur forms in tea soils of the Punjab. The total sulphur in those soils varied from 130.2 to 298.9 ppm. with a mean value of 188.8 ppm. The organic sulphur content varied from 49 to 95 per cent of the total sulphur with a mean value of 72 per cent. They also found that the total sulphur decreased with an increase in the depth in profile.

Massoumi and Cornfield (1964) analysing 58 samples of mineral soils, reported that total sulphur varied from 112 to 1775 ppm. They also found that calcareous soils were richer, with average values of 858 ppm., than non-calcareous soils with values of 485 ppm. in total sulphur.

Naik and Das (1964) tested samples representative of the main soil types of India for the available sulphur by Aspergillus niger method. Their studies revealed that a large number of laterites, red and alluvial soils contained less than 10 ppm. available sulphur. Black and coastal alluvial soils were richer. Saline and alkaline soils gave high values with a mean of 1074 ppm.

Nelson (1964) observed that organic sulphur content of 12 Mississippi soils ranged from 57 to 353 pounds per acre. Nikolov (1964) studied 17 soils types of Bungaria and found that the sulphur content was 14.9 to 37.2 mg./100 g. in the top horizon, and 9.1 to 20.4 mg. in the C horizon. He also observed that the sulphur content depended mainly on the organic matter content. Chernozem-smonitzas and chernozems had highest proportion of sulphur, cinnamon forest contained the lowest, while grey forest contained intermediate properties.

Work of Davidesco and Palovski (1965) on soils of Rumania showed that the sulphur content in the arable layers varied from 16 mg. per 100 g. in the reddish brown forest soil to 44 mg. per 100 g. ~~in the reddish brown forest soil to 44 mg.~~ in leached chernozems. In the reddish brown forest soil the fulvic acid fraction of the humus contained more sulphur (10-12 mg./100 g.) than did humic acid fraction (6-8 mg./100 g.)

<u>Sulphur transformations</u>

Verner and Orlovsky (1948) detected sulphate reducing bacteria in saline soils and particularly in peaty and bog solonchaks, where anaerobic conditions prevailed. Their activity was demonstrated by a decrease in the quantity of sulphates and increase in the quantity of sulphide and bicarbonate in the culture solution inoculated with the soils.

Hughes (1949) found that though saw-dust improved the physical condition of soil, decomposition of some hardwood saw-dust led to the formation of sulphides toxic to plant life.

Accordingly to Starkey (1950) micro-organisms that transform sulphur and its compounds are present in soils. The transformation of any one organism is masked by the reaction of others and the material that accumulate is either the completely oxidised product, sulphate - under aerobic conditions - or the reduced product, sulphide - under anaerobic conditions.

Bromfield (1953) noticed that after treatment with volatile antiseptics, some soils evolved H_2S when moistened with sucrose and ammonium sulphate and incubated aerobically. He identified the bacterium producing H_2S as Bacillus megatherium.

Koyama and Sugarwasa (1953) observed that all submerged situations are not reducing. Several lake muds contained more of their inorganic sulphur as sulphate than as sulphide.

Satyanarayana and Datta (1953) noted sulphate reducing organisms in all the profiles in the soils of Rann area of Cutch. Their activity varied throughout the profile independently of the horizon. The organism was a rod-shaped motile spore-former.

Starkey et al (1953) showed that end products of the decomposition of cystine by micro-organisms isolated from soil may be sulphate, sulphide, or polythionates depending on the experimental conditions.

Picci (1954) reported that the rate of sulphur oxidation was highest at 15 to 20 per cent moisture content and in samples with a sand clay ratio of 3:1. Addition of peptone and glucose increased sulphur oxidations more than mineral nitrogen and complex carbohydrates.

Hesse (1956) studying the sulphur metabolism in soils and muds, found that the organic sulphur in the mud was slowly oxidised to sulphate but a reduction to sulphide occured under predominantly water-logged conditions.

According to Frederick et al (1957) sulphate was the major product when cystine was added to the soil. Their study on the degradation of methionine in soil showed that sulphur of methionine was released as methyl mercaptan, part of which was oxidised to dimethyl disulphide. These workers observed no sulphate in the end products of methionine.

Hesse (1957) noticed that biological oxidation of organic sulphur was extremely slow compared with that of carbon and nitrogen. Incubation with sulphur containing amino acids or $CaSO_4$ increased the rate of oxidation of soil sulphur.

Barrow (1958) investigated the effect of nitrogen and sulphur content of organic matter on the production of ammonium and sulphate. When the C/S ratio was reduced to 50/1, SO_4 production occured; when N in the organic matter was reduced, SO_4 production was enhanced.

Freney (1958 followed the aerobic transformation of cysteine to sulphate in soil and established a sequence in the following order.

Cysteine → cystine → cystine disulphoxide → cysteine sulphinic acid → sulphate.

Studying the fixation of sulphur in the muck of Lake Victoria, Hesse (1958) pointed out that in the presence of large amount of organic sulphur, sulphates were present more than sulphides.

Sperber (1958) suggested that production of H_2S by several strains of <u>Bacillus megatherium</u> might transform ferric phosphate to black forms of sulphide with release of available phosphate. Hart (1959) concluded that sulphide accumulation was fairly common under strongly reducing condition such as at depth in tidal swamps or in poorly drained sub-soils.

Subramoney (1960) studied the sulphur bacterial cycle and the probable mechanism of toxicity in acid soils of Kerala and worked out the sulphur microbial cycle in the following reversible sequence.

Sulphuric acid $\rightleftharpoons$ Sulphates $\rightleftharpoons$ Sulphides $\rightleftharpoons$ organic and elemental sulphur $\rightleftharpoons$ sulphuric acid.

According to Stevenson (1964) the sulphur cycle in soil is divided into four distinct phases, viz., mineralization, immobilisation, oxidation and reduction.

Results obtained by Ogata and Bower (1965) indicated that appreciable reduction of the sulphate did not occur in poorly drained saline soils, unless undecomposed plant residue was present or the soil organic matter was greater than 5 per cent.

Factors influencing the retention and mobilization of sulphates in soil

Tikhova (1953a) observed the absorption of sulphate to be greatest in soils of the moist sub-tropics, less in sod-podzolic soils and least in chernozem, chestnut and solonetz. Studying the conditions of absorption of the anions by soils from solutions, Tikhova (1953 b) found that maximum absorption was at a concentration of 0.02N, a soil solution ratio of 1.25 and time of interaction of 24 hours.

Ensminger (1954) studying the factors affecting the adsorption of sulphate by Alabama soil showed that sulphate was retained to a certain extent in moist soils. The sub-surface layers absorbed more sulphate than the surface layers. Aluminum oxides had a high capacity to adsorb sulphate. He also suggested that the sulphate leached from the top soil might be retained further down in the profile by a clay layer.

Kamprath et al (1956) investigated the effect of pH, sulphate and phosphate concentrations on the adsorption of sulphates by soils and found that soils containing relatively large amounts of 1:1 type of clay mineral adsorbed more SO_4 from $CaSO_4$ solutions than did soil in which 2:1 type clay minerals predominated. Sulphate adsorption decreased as pH increased from 4 to 6 and was directly related to SO_4 concentration. Increasing the PO_4 content of the solution reduced SO_4 adsorption.

Lysimeter studies reported by Hington (1959) showed that sulphate might be readily leached from light textured soils. Investigations of McClug et al (1959) suggested the downward movement of sulphur under cropping. Neller (1959) noticed that sulphate leached from the surface was retained by clay layer further down.

Schell and Jordan (1959) postulated three machanisms of adsorption of sulphate by clay minerals, viz., adsorption at the exchange sites, occlusion between the lattice and substitution for aluminum and silicon in the lattice.

McKell and Williams (1960) pointed out that 18 inches of percolates removed 77 per cent of the sulphur contained in 100 lb. gypsum applied to a sandy soil.

The studies of Liu and Thomas (1961) explained the increase in sulphate retention with increasing concentration and decreasing pH. He found that in acid red soils the sulphate ion exchanged with some of the hydroxyl ions on the hydroxy-aluminum (or iron) polymers.

Tikhova (1962) studied the mobilization of sulphate in a leached chernozem and reported mobilization of SO_4 originating from organic sulphur in humic substances, increased with increasing moisture content. Mobilization was decreased by Ca and promoted by K and Na. Highest mobilization of SO_4 occured on decreasing pH from 6 to 1.52 or increasing it from 7 to 9.35.

Chang and Thomas (1963) suggested a mechanism for sulphate adsorption by soils, which was in agreement with the views presented by these authors earlier (1961).

Chao (1964) reported the effect of 26 inorganic and organic anions on the SO_4 adsorption by soil suspension. Of the anions, 18 were observed to decrease SO_4 adsorption.

According to Odelien (1965) leaching of sulphate was closely related with the amount of readily soluble SO_4 in the soil and the intensity of leaching.

Chao et al (1965) studied the exchange reactions between OH and SO_4 ions in soils and obtained corroborative evidence to the effect that the retention of SO_4 involved an anion - exchange reaction with OH groups in soils.

MATERIALS AND METHODS

MATERIALS AND METHODS

The material for the present study consisted of 20 profiles which included 14 wet lands and 6 dry lands representing different soil types of Kerala. In addition to these, 5 surface samples from typical paddy lands were also included.

Soil sampling and preparation of samples

Each of the profile was marked into three horizons and described in this thesis as 'surface soil', 'subsurface soil' and 'subsoil' as per the depths given below.

a. 0 - 20 cm. Surface soil.

b. 20 - 40 cm. Subsurface soil.

c. 40 - 60 cm. Subsoil.

Composite samples of each horizon were thoroughly mixed and a portion of 500 g. was transferred into a polythene bag. This was then treated with 10 per cent zinc acetate solution to prevent the loss of sulphides. Duplicate samples of untreated samples were also stored in airtight polythene bags. About 500 g. of the untreated samples were air-dried, gently crushed and passed through a 2 mm. sieve and stored in properly labelled glass bottles.

About 15 g. of these air-dried samples were ground in a porcelain mortar and these were stored in paper packets along with the dried samples.

Analytical procedures

The samples were analysed for diffeent forms of sulphur and organic matter content. The pH values were also determined.

Total sulphur: The total sulphur in the soil was determined by fusion with Na_2CO_3 and $NaNO_3$ according to Robinson's method as described by Jackson (1958). Versenate method of Jackson was followed for the estimation of sulphates in the water extract.

1 g. of finely ground soil sample was fused in a platinum crucible with five times the weight of Na_2CO_3 and 0.2 to 0.3 g. of $NaNO_3$ in an electric furnace. After the fusion, the melt was thoroughly disintegrated in water on a steam bath. The solution was then filtered and the volume made up to 100 ml. in a volumetric flask. Sulphates in an aliquot of the solution were precipitated by the addition of an excess quantity of standard $BaCl_2$ solution and the excess Ba remaining after the precipitation of $BaSO_4$ was determined by titration with versenate.

Water soluble sulphate sulphur: 30 g. fresh soil and 150 ml. distilled water were shaken for 30 minutes. The suspension was filtered through Whatman's No.42 filter paper. The sulphate content of the extract was determined by versenate method. The total volume of the soil extract was calculated by adding up the moisture content of the fresh soil and the water added to the soil.

<u>Total sulphate sulphur:</u> Total sulphates were extracted in two stages, first with 0.2 N HCl and then with water (Ravshevskaya, 1959 and Williams and Steinberg, 1962)

30 g. fresh soil was shaken with 100 ml. 0.2N HCl for 30 minutes. The suspension was filtered through Whatman's No.42 filter paper. The soil was transferred back to the shaking bottle and 50 ml. distilled water added to it. Small quantities of $CaCO_3$ were added till the suspension was neutral to litmus paper. The suspension was again shaken for 30 minutes and filtered through Whatman's No.42 filter paper. The soil was repeatedly washed with distilled water, till a total quantity of about 200 ml. filterate was collected. The iron and aluminum from the solution were removed by NH4OH separation as described by Jackson (1958). The volume of the solution with the sesquioxide precipitates was then made up to 250 ml. and the suspension was filtered through a dry filter paper. Sulphate content of the filtrate in aliquots of 40 ml. was determined by versenate method.

Sulphide sulphur: The sulphide sulphur was determined iodometrically by the Kuzretsov's method as described by Kader (1963). For the collection and estimation of the H_2S liberated from the soil, the procedure recommended by the American Public Health Association (1960) was adopted as a modification to the above method.

The apparatus used comprised of a reaction vessel with a dropping funnel for HCl, an inlet for CO_2 and an outlet for the H_2S. To the outlet were connected two 150 ml. Erlenmeyer flasks each containing about 5 ml. 2N zinc acetate solution diluted to 100 ml. and suitable connections to pass the gas through them in series. To ensure complete absorption of the H_2S from the reaction vessel, the outlet of the second absorption vessel was connected to an aspirator adjusted to drain water at a very slow rate.

Soil samples preserved by the treatment with zinc acetate solution was used to estimate the sulphides. A weighed quantity of about 50 g. soil was taken in the reaction vessel and 20 ml. conc. HCl was added to it through the dropping funnel. CO_2 gas (produced by the reaction of $CaCO_3$ and HCl) was allowed to pass through the apparatus. After one hour, standard iodine solution, well in excess of the amount necessary to react with the collected sulphides (judged by the turbidity in the zinc acetate solution) was added to the solution in the absorption vessels. This was then acidified with 5 ml. conc. HCl, stoppered, shaken and set aside for 5 minutes. The solutions from both the vessels were then transferred quantitatively into a larger flask and the excess iodine was back titrated against standard sodium thiosulphate solution using starch as indicator.

For every set of estimations carried out each day, a blank was also run with the reagents. Sulphide content of the soil was calculated on oven-dry basis. The moisture percentage of the zinc acetate treated soils were determined separately.

Organic sulphur: The values for the organic sulphur were obtained by subtracting the sum of sulphate and sulphide sulphur from the total sulphur.

Organic carbon: Organic carbon was estimated by Walkley-Black method with the modifications of Smith and Weldon (1941) as described by Jackson (1958).

Depending on the organic matter content of the soil, 0.1 to 1.5 g. finely ground air-dried soil was treated with 10 ml. normal potassium dichromate solution and 20 ml. concentrated sulphuric acid and kept for half an hour. An excess of N/2 ferrous solution was added to the chromic acid remaining after digestion.

The excess ferrous solution was back titrated against standard potassium permanganate solution.

<u>pH</u> : pH was measured in a 1:2.5 soil water suspension using a glass electrode pH meter.

<u>Moisture:</u> 10 g. fresh soil was dried in an air oven at 100 - 105°C to constant weight and the loss in weight was expressed as percentage on oven-dry basis.

MORPHOLOGICAL DESCRIPTIONS OF THE SOIL PROFILES

P R O F I L E 1

Location	Agricultural College and Research Institute, Vellayani, Trivandrum District.
Soil type	Red loam lateritic region, Kayal area.
Special features	The site recently reclaimed and brought under paddy cultivation, subject to flooding.

Samples collected:

1a. Surface soil (0 - 20 cm.)	10 YR 6/2 light brownish grey, 5/3 moist; sandy loam; non-sticky and non-plastic when wet, loose and friable when dry.
1b. Subsurface soil (20 - 40 cm.)	10 YR 6/3 pale brown, 5/3 moist; silt loam; slightly sticky and non-plastic when wet and soft when dry.
1c. Subsoil (40 - 60 cm.)	10 YR 4/3 dark brown, 4/2 moist; peaty in nature with high content of partially decomposed organic matter.

P R O F I L E   2

Location	Agricultural College and Research Institute, Vellayani, Trivandrum District
Soil type	Red loam lateritic region; wet, double-crop paddy lands.
Special features.	Subject to flooding, remain submerged for three to four months a year.

Samples collected:

2a. Surface soil (0 - 20 cm.)	10 YR 6/8 brownish yellow, 5/8 moist; sandy clay; sticky and slightly plastic when wet, firm and hard when dry.
2b. Subsurface soil (20 - 40 cm.)	7.5 YR 6/8 reddish yellow, 5/8 moist; sandy clay; sticky and plastic when wet, firm and hard when dry.
2c. Subsoil (40 - 60 cm.)	7.5 YR 6/6 reddish yellow, 5/6 moist; silt clay; sticky and plastic when wet, firm and hard when dry.

P R O F I L E 3

Location.	Agricultural College and Research Institute, Vellayani, Trivandrum District.
Soil type	Red loam lateritic region; dry lands.
Special feature.	Normal relief, well drained, vegetation mainly coconut.
Samples collected:	
3a. Surface soil (0 - 20 cm.)	7.5 YR 5/8 strong brown, 5/7 moist; sandy loam; slightly sticky and non-plastic when wet, loose and friable when dry.
3b. Subsurface soil (20 - 40 cm.)	7.5 YR 6/6 reddish yellow, 6/6 moist; fine sandy loam; slightly sticky and non-plastic when wet, friable and soft when dry.
3c. Subsoil (40 - 60 cm.)	5 YR 6/8 reddish yellow, 6/8 moist; sandy clay loam; slightly sticky and non-plastic when wet, firm and slightly hard when dry.

PROFILE 4

Location	Rice Research Station, Kottarakara, Quilon District.
Soil type	Laterite region; wet, double-crop paddy lands.
Special features	Narrow strip of terraced lands in the valleys of hills, moderately well drained.

Samples collected:

4a. Surface soil (0 - 20 cm.)	10 YR 5/6 yellowish brown, 3/3 moist; clay loam, sticky and plastic when wet, firm and hard when dry.
4b. Subsurface soil (20 - 40 cm.)	10 YR 5/4 yellowish brown, 3/3 moist; sandy clay; sticky and plastic when wet, firm and hard when dry.
4c. Subsoil (40 - 60 cm.)	10 YR 5/8 yellowish brown, 4/4 moist; sandy clay; sticky and plastic when wet, firm and hard when dry.

PROFILE 5

Location	Rice Research Station, Kayamkulam, Alleppey District.
Soil type	Sandy soil tract; wet, double-crop paddy lands.
Special features	Nearly flat lands

Samples collected:

5a. Surface soil (0 - 20 cm.)	10 YR 6/2 light brownish grey, 4/3 moist; sandy loam; non-sticky and non-plastic when wet, loose when dry.
5b. Subsurface soil (20 - 40 cm.)	10 YR 5/6 yellowish brown, 5/4 moist; sandy loam; non-sticky and non-plastic when wet, very friable and loose when dry.
5c. Subsoil (40 - 60 cm.)	10 YR 6/6 brownish yellow, 6/6 moist; sandy loam; slightly sticky and non-plastic when wet, friable and soft when dry.

PROFILE 6

Location	Rice Research Station Kayamkulam, Alleppey District.
Soil type	Sandy soil tract, dry lands.
Special features.	Nearly flat lands, somewhat excessively drained, vegetation mainly coconut palms.

Samples collected:

6a. Surface soil (0-20 cm.)	10 YR 5/2 greyish brown, 3/2 moist; loamy sand; loose and friable.
6b. Subsurface soil (20 - 40 cm.)	10 YR 5/2 greyish brown, 3/2 moist; loamy sand; loose and very friable.
6c. Subsoil (40 - 60 cm.)	10 YR 6/2 pale brown, 4/2 moist; sandy loam; loose and friable.

PROFILE 7

Location	'R' Block Kayal Alleppey.
Soil type	Lake bed soils; wet, paddy lands.
Special features	Lands below sea level, very poorly drained, paddy crop taken after dewatering operations.

Samples collected:

7a. Surface soil (0 - 20 cm.)	2.5 Y 4/1 dark greyish brown, 3/1 moist; clay; very sticky and very plastic when wet, very firm when moist, extremely hard when dry.
7b. Subsurface soil (20 - 40 cm.)	2.5 Y 3/2 very dark greyish brown, 2/0 moist; clay; consistency as of surface soil; heavy deposits of shells (about 13 per cent by weight)
7c. Subsoil (40 - 60 cm.)	2.5 Y 3/1 veey dark greyish brown 3/0 moist; clay; consistency as of surface soil, very heavy deposits of shells (about 18 per cent by weight)

PROFILE 8

Location	Rice Research Station, Monkompu, Alleppey District.
Soil type	Alluvial soils; wet, single-crop paddy lands.
Special features	Nearly flat lands, poorly drained.

Samples collected:

8a. Surface soil (0 - 20 cm.)	10 YR 4/2 dark greyish brown, 3/1 moist; clay; very sticky and very plastic when wet, very firm when moist and extremely hard when dry.
8b. Subsurface soil (20 - 40 cm.)	10 YR 5/4 yellowish brown, 3/2 moist; clay; consistency as of surface soil.
8c. Subsoil (40 - 60 cm.)	10 YR 5/8 yellowish brown, 4/4 moist, clay; consistency as of surface soil.

P R O F I L E 9

Location	Mundar, Vaikom Taluk, Kottayam District.
Soil type	Kari soils; wet, single-crop paddy lands.
Special features	Flat lands, very poorly drained, waterlogged for about eight months, subject to salt-water inundation.

Samples collected.

9a. Surface soil (0 - 20 cm.)	10 YR 3/2 very dark greyish brown, 2/1 moist; clay; sticky and plastic when wet, very hard when dry; yellow motlings present.
9b. Subsurface soil (20 - 40 cm.)	10 YR 3/1 very dark grey, 2/1 moist; clay, peaty; slightly sticky and slightly plastic when wet, very hard when dry.
9c. Subsoil (40 - 60 cm.)	10 YR 3/1 very dark grey, 2/1 moist; peaty; non-sticky and non-plastic when wet, very hard when dry.

PROFILE 10

Location	Rice Research Station, Vytilla, Ernakulam District.
Soil type	Saline soils; wet, single-crop "Pokkali" paddy lands.
Special features	Flat lands, very poorly drained, subject to periodical inundation with sea water.

Samples collected:

10a. Surface soil (0 - 20 cm.)	10 YR 5/4 yellowish brown, 3/3 moist; clay; very sticky and very plastic when wet, very firm when moist, extremely hard when dry.
10b. Subsurface soil (20 - 40 cm.)	10 YR 6/3 pale brown, 3/3 moist; clay; consistency as of surface soil.
10c. Subsoil (40 - 60 cm.)	10 YR 5/4 yellowish brown, 3/3 moist; clay; consistency as of surface soil.

P R O F I L E 11

Location	Rice Research Station, Mannuthy, Trichur District.
Soil type	Laterite region; wet, double-crop paddy lands.
Special features	Normal relief, well drained, fields remain dry from December to May.
Samples collected:	
11a. Surface soil (0 - 20 cm.)	10 YR 6/6 brownish yellow, 5/6 moist; sandy clay; non-sticky and non-plastic when wet, friable when moist, hard when dry.
11b. Subsurface soil (20 - 40 cm.)	7.5 R 6/6 brownish yellow, 5/6 moist; sandy clay loam; non-sticky and slightly plastic when wet, friable when moist, hard when dry.
11c. Subsoil (40 - 60 cm.)	7.5 R 5/6 yellowish brown, 5/6 moist; sandy clay loam; non-sticky and slightly plastic when wet, friable when moist, hard when dry.

PROFILE 12

Location	Integrated Seed Development Farm, Eruthampathy (Chittoor) Palghat District.
Soil type	Mixed black and red soil tract; wet, double-crop paddy lands.
Special features	Flat lands at the foot of the hills, very poorly drained.

Samples collected:

12a. Surface soil (0 - 20 cm.)	10 YR 5/2 greyish brown, 3/2 moist; silty clay; sticky and very plastic when wet, very firm when moist, very hard when dry.
12b. Subsurface soil (20 - 40 cm.)	10 YR 5/2 greyish brown, 3/2 moist; silty clay; consistency as of surface soil.
12c. Subsoil (40 - 60 cm.)	10 YR 4/2 dark greyish brown, 3/2 moist; silty clay; consistency as of surface soils.

PROFILE 13

Location	Integrated Seed Development Farm, Eruthampathy (Chittoor) Palghat District.
Soil type	Mixed black and red soil tract; dry, red loam soils.
Special features	Normal relief; soil permeability moderately rapid; dry land crops like ground-nut, sesamum, castor grown.

Samples collected:

13a. Surface soil (0 - 20 cm.)	5 YR 5/8 yellowish red, 4/6 moist; very fine sandy loam; non-sticky and non-plastic when wet, friable when moist, slightly hard when dry.
13b. Subsurface soil (20 - 40 cm.)	2.5 YR 3/6 dark red, 3/4 moist; loam; consistency as of surface soil.
13c. Subsoil (40 - 60 cm.)	2.5 YR 4/6 red, 3/6 moist; loam; non-sticky and non-plastic when wet, friable when moist, very hard when dry.

PROFILE 14

Location	Integrated Seed Development Farm Eruthampathy (Chittoor) Palghat District.
Soil type	Mixed black and red soil tract; dry, black soils.
Special features	Normal relief, soil permeability moderately slow, crops like cotton, sugarcane grown.

Samples collected:

14a. Surface soil (0 - 20 cm.)	10 YR 3/2 very dark greyish brown, 2/1 moist; sandy clay; very sticky and plastic when wet, firm when moist, slightly hard when dry.
14b. Subsurface soil (20 - 40 cm.)	10 YR 3/2 very dark greyish brown, 2/1 moist; sandy clay; consistency as of surface soil.
14c. Subsoil (40 - 60 cm.)	10 YR 3/2 very dark greyish brown, 2/1 moist; sandy clay; consistency as of surface soil.

PROFILE 15

Location	Central Rice Research Station, (Block V) Pattambi, Palghat District.
Soil type	Laterite region, wet, three crop paddy lands.
Special features	Nearly flat, plots wet throughout the year, somewhat poorly drained.
Samples collected:	
15a. Surface soil (0 - 20 cm.)	10 YR 5/6 yellowish brown, 4/4 moist; sandy loam; slightly sticky and non-plastic when wet, friable and soft when dry.
15b. Subsurface soil (20 - 40 cm.)	10 YR 5/6 yellowish brown, 4/4 moist; loamy sand; gravelly, very compact; nonsticky and non-plastic when wet, friable and soft when dry.
15c. Subsoil (40 - 60 cm.)	10 YR 6/6 brownish yellow, 5/4 moist; loamy sand; more gravelly and compact; non-sticky and non-plastic when wet, friable and soft when dry.

P R O F I L E 16

Location	Central Rice Research Station, Pattambi, Palghat District.
Soil type	Laterite region; wet, double-crop paddy lands, coarse textured.
Special features	Terraced plots at the foot of the hills, usually a sown first crop and a transplanted second crop, well drained, plots remain dry from December to May.

Samples collected:

16a. Surface soil (0 - 20 cm.)	10 YR 6/6 brownish yellow, 5/6 moist; sandy loam; non-sticky and non-plastic when wet, friable and loose when dry.
16b. Subsurface soil (20 - 40 cm.)	10 YR 7/8 yellow, 6/8 moist; loamy sand; non-sticky and non-plastic when wet, friable and soft when dry.
16c. Subsoil (40 - 60 cm.)	10 YR 6/8 brownish yellow, 5/8 moist; sandy loam; slightly sticky and slightly plastic when wet, firm when moist, slightly hard when dry.

P R O F I L E 17

Location	Central Rice Research Station, Pattambi, Palghat District.
Soil type	Laterite region; wet, double-crop paddy lands; fine textured.
Special features	Nearly level topography, first and second crops transplanted, moderately well drained, plots remain dry from January to May.

Samples collected:

17a. Surface soil (0 - 20 cm.)	10 YR 6/8 brownish yellow, 6/6 moist; sandy clay loam, slightly sticky when wet, firm and slightly hard when dry.
17b. Subsurface soil (20 - 40 cm.)	10 YR 7/8 yellow, 6/6 moist; sandy loam; non-sticky when wet, friable and soft when dry.
17c. Subsoil (40 - 60 cm.)	10 YR 6/6 brownish yellow, 5/6 moist; sandy loam; non-sticky when wet, firm when moist, slightly hard when dry.

PROFILE 18

Location	Central Rice Research Station, Pattambi, Palghat District.
Soil type	Laterite region; wet, single-crop paddy land ('Palliyal')
Special features	Terraced plots on the slopes, somewhat excessively drained, plots remain dry from September to June.
Samples collected.	
18a. Surface soil (0 - 20 cm.)	10 YR 7/8 yellow, 6/6 moist; sandy loam; gravelly, non-sticky and non-plastic when wet, friable and soft when dry.
18 b. Subsurface soil (20 - 40 cm.)	10 YR 7/8 yellow, 6/6 moist; sandy loam; gravelly; slightly sticky and non-plastic when wet, friable and soft when dry.
18c. Subsoil (40 - 60 cm.)	7.5 YR 7/8 reddish yellow, 6/8 moist; hard compact lateritic bed.

P R O F I L E 19

Location	Central Rice Research Station, Pattambi, Palghat District.
Soil type	Laterite region; dryland ('Modan')
Special features	Normal relief; well drained; dryland crops like tapioca, gingelly grown.

Samples collected:

19a. Surface soil (0 - 20 cm.)	7.5 YR 5/6 strong brown, 4/4 moist; gravelly, sandy clay loam; friable and loose.
19b. Subsurface soil (20 - 40 cm.)	7.5 YR 5/6 strong brown, 4/4 moist; gravelly clay loam; slightly sticky and slightly plastic when wet, slightly hard when dry.
19c. Subsoil (40 - 60 cm.)	7.5 YR 5/6 strong brown, 4/4 moist; gravelly clay loam; slightly sticky and slightly plastic when wet, slightly hard when dry.

P R O F I L E 20

Location	Agricultural Research Station Ambalawayal, Kozhikode District.
Soil type	Laterite, hilly tract, dry land soil.
Special features	Crops like oranges, lime, pineapple grown.
Samples collected:	
20a. Surface soil (0 - 20 cm.)	7.5 YR 5/7 strong brown, 4/5 moist; sandy clay loam; slightly sticky and non-plastic when wet, friable when dry.
20b. Subsurface soil (20-40 cm.)	7.5 YR 5/6 strong brown, 5/5 moist; clay loam; slightly sticky and slightly plastic when wet, slightly hard when dry.
20c. Subsoil (40 - 60 cm.)	7.5 YR 6/6 reddish yellow, 5/6 moist; clay loam; slightly sticky and slightly plastic when wet, slightly hard when dry.

SURFACE SAMPLES

Sample No.21	
Location	Karamana, Trivandrum District.
Soil type	Laterite region; wet, double corp paddy land.
Surface soil (0 - 20 cm.)	10 YR 7/8 dark greyish brown, 6/6 moist; sandy clay loam
Sample No.22	
Location	Neelamperoor, Kottayam District.
Soil type	Karapadam soil.
Surface soil (0 - 20 cm.)	10 YR 5/2 greyish brown, 3/1 moist; clay.
Sample No.23	
Location	Varkala, Trivandrum District.
Soil type	Laterite region; wet,double-crop paddy lands.
Surface soil (0 - 20 cm.)	10 YR 5/6 yellowish brown, 4/4 moist; sandy clay loam.
Sample No.24	
Location	Ambalawayal, Kozhikode District.
Soil type	Laterite; hilly tract; wet, double-crop paddy lands.
Surface soil (0 - 20 cm.)	10 YR 5/6 yellowish brown, 4/4 moist; sandy clay loam.
Sample No.25	
Location	Chithirapuram kayal, Alleppey District.
Soil type	Lake bed soils, wet, paddy lands.
Surface soil (0 - 20 cm.)	2.5 Y 4/3 dark greyish brown, 3/2 moist; clay.

RESULTS

RESULTS

The results obtained are presented in Tables I to IV.

Data relating to moisture content, pH and organic carbon of all the soil samples are given in Table I.

Moisture content of the samples at the time of collection varies widely from place to place.

Most of the soils are acidic in reaction. Soils collected from Eruthampathy are slightly alkaline with pH values ranging from 7.1 to 7.8. A pH value of 7.1 is recorded in the lower layers of 'R' Block kayal. In all other cases the pH ranges for 3.5 to 6.5.

The values for organic carbon vary widely with different profiles. The Kari soils have values above 19.0 per cent. More than 4.0 per cent organic carbon is present in Karapadam soils (22a) and in the subsoils of the recently reclaimed areas of Vellayani Kayal (1a).

For all other samples the values are below 2.5 per cent. Subsoils of Palliyal lands of Pattambi (18c) record the value of 0.09 per cent.

The distribution of different forms of sulphur in various soils groups are presented in Tables II to VI.

T A B L E 1

MOISTURE CONTENT, pH AND ORGANIC CARBON (WALKLEY-BLACK) CONTENT OF THE SOIL SAMPLES

Sample No. 1	Soil type 2		Depth of sampling in cm. 3	Moisture content % on over-dry basis 4	pH (1:2.5) 5	Organic carbon % 6
1	Vellayani, Kayal lands					
		(a)	0-20	28.76	5.0	0.9644
		(b)	20-40	32.74	4.5	1.0226
		(c)	40-60	50.00	4.1	4.8399
2	Vellayani, Wet lands					
		(a)	0-20	39.23	5.0	0.8731
		(b)	20-40	27.61	4.5	0.6279
		(c)	40-60	28.10	4.5	0.4218
3	Vellayani, Dry lands					
		(a)	0-20	7.31	5.3	0.4611
		(b)	20-40	12.42	5.5	0.3864
		(c)	40-60	14.16	5.5	0.2304
4	Kottarakara, Wet lands					
		(a)	0-20	15.31	5.5	2.4142
		(b)	20-40	35.30	5.5	1.7936
		(c)	40-60	40.32	5.7	0.8290

contd...

Table 1 contd.

Sample No.	Soil type		Depth of samp-ling in cm.	Moisture content % on oven-dry basis	pH (1:2:5)	Organic carbon %
1	2		3	4	5	6
5.	Kayamkulam, Wet lands	(a)	0-20	16.62	5.4	0.2534
		(b)	20-40	14.32	5.7	0.3625
		(c)	40-60	17.42	5.7	0.2388
6.	Kayamkulam, Dry lands	(a)	0-20	3.12	5.5	0.5406
		(b)	20-40	6.50	5.5	0.3032
		(c)	40-60	10.75	6.0	0.1741
7.	Alleppey (R. Block) Kayal lands	(a)	0-20	42.45	6.5	1.7695
		(b)	20-40	30.54	7.1	1.0177
		(c)	40-60	65.58	7.1	2.3822
8.	Mancompu, Punja lands	(a)	0-20	35.24	5.4	1.9503
		(b)	20-40	44.32	4.8	1.7750
		(c)	40-60	70.68	4.8	1.1250

contd......

Table 1 contd.

Sample No. 1	Soil type 2		Depth of samp-ling in cm. 3	Moisture content % on over-dry basis 4	pH (1:2.5) 5	Organic carbon % 6
9.	Mundar, Kari lands					
		(a)	0-20	64.31	4.0	19.2730
		(b)	20-40	136.70	3.8	21.2254
		(c)	40-60	224.00	3.5	19.2378
10.	Vytilla, Pokkali lands					
		(a)	0-20	41.59	5.3	1.4838
		(b)	20-40	37.87	5.1	1.4439
		(c)	40-60	50.60	5.1	2.1691
11.	Mannuthy Wet lands					
		(a)	0-20	13.63	5.4	0.4435
		(b)	20-40	13.12	5.7	0.1659
		(c)	40-60	13.52	5.7	0.1002
12.	Eruthampathy, Wet lands					
		(a)	0-20	17.12	7.2	1.0131
		(b)	20-40	24.96	7.5	0.8726
		(c)	40-60	21.71	7.8	0.6131

contd.....

Table 1 contd.

Sample No. 1	Soil type 2	Depth of sampling in cm. 3	Moisture content % on oven dry basis 4	pH (1:2.5) 5	Organic carbon % 6
13.	Eruthampathy, Dry lands, red soil				
	(a)	0-20	1.87	7.1	0.4316
	(b)	20-40	8.94	7.1	0.3222
	(c)	40-60	14.56	7.2	0.2561
14.	Eruthampathy, Dry lands, black soil				
	(a)	0-20	5.52	7.5	0.7726
	(b)	20-40	14.81	7.5	0.6866
	(c)	40-60	13.17	7.2	0.6256
15.	Pattambi, Wet lands, Punja area				
	(a)	0-20	43.17	4.6	1.7329
	(b)	20-40	24.92	5.2	1.0619
	(c)	40-60	23.86	5.2	0.7727
16.	Pattambi, Wet lands, sandy loam				
	(a)	0-20	14.25	5.6	0.6389
	(b)	20-40	10.08	5.6	0.1373
	(c)	40-60	7.03	5.8	0.1123

contd.....

Table 1 contd.

Sample No. 1	Soil type 2		Depth of sampling in cm. 3	Moisture content % on oven dry basis 4	pH (1: 2.5) 5	Organic carbon % 6
17.	Pattambi, Wet lands, sandy clay loam	(a)	0-20	7.89	6.8	1.2981
		(b)	20-40	16.28	5.8	0.4846
		(c)	40-60	15.92	5.8	0.2342
18.	Pattamby, Wet lands, Palliyal	(a)	0-20	3.83	6.1	0.9351
		(b)	20-40	2.81	5.8	0.4491
		(c)	40-60	2.63	5.8	0.0884
19.	Pattambi, Dry lands Moden	(a)	0-20	4.06	6.1	0.7099
		(b)	20-40	5.05	6.1	0.4010
		(c)	40-60	7.78	6.1	0.3676
20.	Ambalawayal, Dry lands	(a)	0-20	6.58	5.8	1.3334
		(b)	20-40	11.81	6.0	0.9227
		(c)	40-60	15.31	6.0	0.7795

contd.....

Table 1 contd.

Sample No. 1	Soil type 2		Depth of samp- ling in cm. 3	Moisture content % on oven dry basis 4	pH (1:2.5) 5	Organic carbon % 6
21.	Karamana, Wet lands	(a)	0-20	26.31	5.5	1.5108
22.	Neelamperoor, Karapadam lands	(a)	0-20	88.24	3.8	4.0102
23.	Varkala, Wet lands	(a)	0-20	29.58	5.5	2.1672
24.	Ambalawayal, Wet lands	(a)	0-20	28.30	5.4	1.2036
25.	Chithirapuram, Kayal lands	(a)	0-20	40-70	6.5	2.1197

TABLE II

DISTRIBUTION OF SULPHUR IN SOILS OF LATERITE BELT REGION

Soil samples 1	Sulphur ppm. Water soluble sulphate 2	Total sul-phate 3	Sul-phide 4	Organic 5	Total 6
4 Kottarakara, Wet lands					
a. 0-20 cm.	47.8	53.7	2.7	1771.1	1827.5
b. 20-40 cm.	18.7	24.2	1.2	918.8	944.2
c. 40-60 cm.	7.1	11.3	1.1	596.7	609.1
11 Mannuthy, Wet lands					
a. 0-20 cm.	23.7	25.2	0.2	888.3	913.7
b. 20-40 cm.	8.8	12.3	Tr.	292.2	304.6
c. 40-60 cm.	9.3	12.3	0.3	193.7	152.3
15 Pattambi, Wet lands Punja area					
a. 0-20 cm.	31.7	35.2	10.7	1537.9	1583.8
b. 20-40 cm.	20.8	21.9	9.6	882.2	913.7
c. 40-60 cm.	20.8	23.4	1.3	584.4	609.1
16. Pattambi, Wet lands sandy loam					
a. 0-20 cm.	9.8	9.7	0.3	660.0	670.0
b. 20-40 cm.	13.7	15.1	0.9	440.9	456.8
c. 40-60 cm.	9.6	13.8	1.0	61.3	76.1

contd...

Table II contd.

Soil samples 1	Sulphur ppm. Water soluble sulphate 2	Total sulphate 3	Sulphide 4	Organic 5	Total 6
17 Pattambi, Wet lands sandy clay loam					
a. 0-20 cm.	3.6	12.1	1.1	1509.7	1522.9
b. 20-40 cm.	4.1	9.4	0.9	827.2	837.5
c. 40-60 cm.	Tr.	7.1	Tr.	145.2	152.3
18 Pattambi, Wet lands Palliyal					
a. 0-20 cm.	5.1	5.3	Tr.	1060.7	1066.0
b. 20-40 cm.	Tr.	5.1	Tr.	116.7	121.8
c. 40-60 cm.	Tr.	4.8	Tr.	10.4	15.2
19 Pattambi, Dry lands Modan					
a. 0-20 cm.	8.9	8.7	Tr.	570.0	578.7
b. 20-40 cm.	9.3	9.8	Tr.	20.7	30.5
c. 40-60 cm.	14.6	15.2	Tr.	15.3	30.5
20 Ambalawayal, Dryland					
a. 0-20 cm.	5.4	8.3	0.3	813.7	822.3
b. 20-40 cm.	25.3	25.6	0.3	583.2	609.1
c. 40-60 cm.	2.3	6.3	0.8	368.4	375.5
23 Varkala Wet lands					
a. 0-20 cm.	10.0	15.8	4.3	1655.1	1675.2
24 Ambalawayal, Wet lands					
a. 0-20 cm.	36.8	35.9	9.9	867.9	913.7

TABLE II A

FORMS OF SULPHUR IN SOILS OF LATERITE BELT REGION
EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soil samples	Water soluble sulphate sulphur %	Total sulphate sulphur %	Sulphide sulphur %	Organic sulphur %
1	2	3	4	5
Kottarakara				
4 a	2.62	2.94	0.14	96.92
4 b	1.98	2.56	0.13	97.31
4 c	1.17	1.86	0.18	97.96
Mannuthy				
11 a	2.60	2.76	0.02	97.22
11 b	2.89	4.04	Tr.	95.96
11 c	6.11	8.08	0.20	91.72
Pattambi				
15 a	2.00	2.22	0.68	97.10
15 b	2.28	2.40	0.11	97.49
15 c	3.41	3.84	0.21	95.95
16 a	1.45	1.45	0.04	98.51
16 b	3.00	3.31	0.20	96.49
16 c	12.63	18.13	1.31	80.56

CONTD...

Table II - A contd.

Soil samples 1	Water soluble sulphate sulphur % 2	Total sulphate sulphur % 3	Sulphide sulphur % 4	Organic sulphur % 5
Pattambi				
17 a	0.24	0.79	0.01	99.20
17 b	0.49	1.12	0.01	98.87
17 c	Tr.	4.66	Tr.	95.34
18 a	0.48	0.50	Tr.	99.50
18 b	Tr.	4.19	Tr.	95.81
18 c	Tr.	31.58	Tr.	68.42
19 a	1.50	1.50	Tr.	98.50
19 b	30.51	32.13	Tr.	67.87
19 c	47.87	49.83	Tr.	50.17
Ambalawayal				
20 a	0.66	0.01	0.04	98.95
20 b	4.10	4.15	0.05	95.80
20 c	0.61	1.68	0.21	98.11
Varkala				
23 a	0.59	0.94	0.26	98.80
Ambalawayal				
24 a	3.93	3.93	1.08	94.99

T A B L E III

DISTRIBUTION OF SULPHUR IN THE SOILS OF RED LOAM LATERITIC REGION

Soil samples	Sulphur ppm.				
	Water soluble sulphate	Total sulphate	Sulphide	Organic	Total
1	2	3	4	5	6
3 Vellayani, Dry lands					
a. 0-20 cm.	24.5	28.3	Tr.	276.3	304.6
b. 20-40 cm.	5.4	8.2	Tr.	144.1	152.3
c. 40-60 cm.	Tr.	5.1	Tr.	55.8	60.9
2 Vellayani, Wet lands					
a. 0-20 cm.	54.4	60.8	21.7	831.2	913.7
b 20-40 cm.	4.6	12.7	3.2	441.0	456.9
c 40-60 cm.	2.1	3.2	2.4	177.2	182.8
1 Vellayani, Kayal lands					
a. 0-20 cm.	119.6	132.3	13.4	712.3	857.0
b. 20-40 cm.	86.1	114.5	1.0	855.5	971.0
c. 40-60 cm.	314.9	320.3	3.2	1655.5	1979.0
21 Karamana, Wet lands					
a. 0-20 cm.	25.3	29.8	19.4	864.5	913.7

T A B L E III A

FORMS OF SULPHUR IN SOILS OF RED LOAN LATERITIC REGION EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soil samples 1	Water soluble sulphate sulphur % 2	Total sulphate sulphur % 3	Sulphide sulphur % 4	Organic sulphur % 5
Vellayani				
3 a	6.96	8.04	Tr.	91.96
3 b	3.54	5.38	Tr.	94.62
3 c	8.37	8.37	Tr.	91.63
2 a	5.95	6.65	2.37	90.98
2 b	1.01	2.78	0.70	96.52
2 c	1.15	1.75	1.31	96.94
1 a	13.95	15.43	1.56	83.01
1 b	8.86	11.79	0.01	88.20
1 c	8.05	8.38	0.08	91.54
Karamana				
21 a	2.77	3.26	2.12	94.62

TABLE IV

DISTRIBUTION OF SULPHUR IN SOILS OF RED AND BLACK MIXED SOIL TRACT OF CHITTUR TALUK

Soil samples	Sulphur ppm.				
	Water soluble sulphate	Total sul-phate	Sul-phide	Organic	Total
1	2	3	4	5	6
13 Eruthampathy, Dry lands, red					
a. 0-20 cm.	Tr.	3.8	Tr.	361.7	365.5
b. 20-40 cm.	Tr.	5.2	Tr.	32.8	38.0
c. 40-60 cm.	Tr.	5.8	Tr.	32.2	38.0
14 Eruthampathy, Dry lands, black					
a. 0-20 cm.	24.4	27.2	Tr.	581.9	609.1
b. 20-40 cm.	13.5	21.2	Tr.	222.5	243.7
c. 40-60 cm.	4.4	19.3	Tr.	163.5	182.8
12 Eruthampathy, Wet lands					
a. 0-20 cm.	73.8	91.7	2.3	1337.5	1431.5
b. 20-40 cm.	59.4	78.3	1.3	590.4	670.0
c. 40-60 cm.	47.7	84.5	2.1	523.5	609.0

T A B L E IV A

FORMS OF SULPHUR IN SOILS OF RED AND BLACK MIXED SOIL TRACT OF CHITTUR TALUK EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soil samples	Water soluble sulphate sulphur %	Total sulphate sulphur %	Sulphide sulphur %	Organic sulphur %
1	2	3	4	5
Eruthampathy				
13 a	Tr.	1.04	Tr.	98.96
13 b	Tr.	13.68	Tr.	86.32
13 c	Tr.	15.26	Tr.	84.74
14 a	4.01	4.47	Tr.	95.53
14 b	5.54	8.70	Tr.	91.30
14 c	2.41	10.56	Tr.	89.44
12 a	5.16	6.41	0.16	93.43
12 b	8.87	11.69	0.19	88.12
12 c	7.83	13.88	0.34	85.78

T A B L E V

DISTRIBUTION OF SULPHUR IN SOILS OF ONATTUKARA

SANDY SOIL TRACT

Soil samples	Sulphur ppm.				
	Water soluble sulphate	Total Sulphate	Sulphide	Organic	Total
1	2	3	4	5	6
5 Kayamkulam, Dry lands					
a. 0-20 cm.	Tr.	4.9	Tr.	452.0	456.9
b. 20-40 cm.	Tr.	5.3	Tr.	86.1	91.4
c. 40-60 cm.	Tr.	5.3	Tr.	70.8	76.1
6 Kayamkulam, Wet lands					
a. 0-20 cm.	13.8	15.2	1.4	288.0	304.6
b. 20-40 cm.	4.5	7.9	0.7	219.8	228.4
c. 40-60 cm.	4.6	6.7	0.6	114.5	121.8

T A B L E V A

FORMS OF SULPHUR IN SOILS OF
ONATTUKARA SANDY SOIL TRACT
EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soil samples	Water soluble sulphate sulphur %	Total sulphate sulphur %	Sulphide sulphur %	Organic sulphur %
1	2	3	4	5
Kayamkulam				
5 a	Tr.	1.07	Tr.	98.93
5 b	Tr.	5.80	Tr.	94.20
5 c	Tr.	6.96	Tr.	93.04
6 a	4.53	4.99	0.46	94.55
6 b	1.97	3.46	0.31	96.23
6 c	3.78	5.50	0.49	94.01

T A B L E VI

DISTRIBUTION OF SULPHUR IN SOILS OF KUTTANAD AND POKKALI AREAS

Soil Samples.	Sulphur ppm.				
	Water soluble sulphate	Total sulphate	Sulphide	Organic	Total
1	2	3	4	5	6
7 'R' Block Kayal lands					
a. 0-20 cm.	131.7	162.8	73.0	4585.3	4821.1
b. 20-40 cm.	71.6	220.6	26.2	2961.4	3208.2
c. 40-60 cm.	279.9	364.3	3.2	2526.1	2893.6
8 Moncompu, Punja lands					
a. 0-20 cm.	114.5	156.4	2.3	4105.7	4264.2
b. 20-40 cm.	175.8	285.1	1.0	3064.4	3350.5
c. 40-60 cm.	254.6	298.4	2.1	2442.8	2741.3
9 Mundar, Kari lands					
a. 0-20 cm.	1261.0	1612.4	102.3	13818.9	15533.6
b. 20-40 cm.	2524.0	2613.1	4.9	15961.6	18579.6
c. 40-60 cm.	670.0	724.5	3.0	18147.4	18874.4
10 Vytilla, Pokkali lands					
a. 0-20 cm.	284.7	322.5	227.5	424.1	974.6
b. 20-40 cm.	231.6	378.4	19.9	302.2	700.5
c. 40-60 cm.	296.3	343.1	5.0	352.2	700.5
22 Neelamperoor, Karapadam lands					
a. 0-20 cm.	2074.0	2334.0	3.0	4061.4	6398.4
25 Chithirapuram, Kayal lands					
a. 0-20 cm.	154.8	208.2	42.0	4623.2	4873.4

T A B L E VI A

FORMS OF SULPHUR IN SOILS OF KUTTANAD AND POKKALI AREAS EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soil samples 1	Water soluble sulphate sulphur % 2	Total sulphate sulphur % 3	Sulphide sulphur % 4	Organic sulphur % 5
'R' Block				
7 a	2.74	3.38	1.51	95.11
7 b	2.23	6.88	0.82	92.30
7 c	9.67	12.59	0.11	87.30
Moncompu				
8 a	2.69	3.67	0.05	96.28
8 b	5.26	8.51	0.03	91.46
8 c	9.28	10.81	0.08	89.11
Mundar				
9 a	8.12	10.38	0.66	88.96
9 b	13.58	14.06	0.03	85.91
9 c	3.54	3.83	0.02	96.15
Vytilla				
10 a	29.21	33.09	23.35	43.56
10 b	33.05	54.02	2.84	43.14
10 c	42.30	48.98	0.71	50.31
Neelamperoor				
22 a	32.42	36.48	0.05	63.47
Chithirapuram				
25 a	3.18	4.27	0.86	94.87

T A B L E VII

MEAN CONTENT OF SULPHUR COMPOUNDS IN SOIL PROFILES OF KERALA

(From Tables II to V)

Soils	Sulphur ppm.			
	Total	Organic	Sulphate	Sulphide
Dry lands				
a. Surface soils	523.0	509.1	13.5	0.4
b. Subsurface soils	194.2	181.7	12.5	Tr.
c. Subsoils	127.5	117.7	9.3	1.6
Wet lands				
a. Surface soils	1144.8	1106.1	32.7	6.0
b. Subsurface soils	548.4	525.4	20.8	2.2
c. Subsoils	280.8	260.6	18.6	1.6
Dry and Wet lands (combined)				
a. Surface soils	937.6	907.1	26.4	4.1
b. Subsurface soils	406.7	387.9	17.5	1.3
c. Subsoils	219.5	203.4	14.9	1.2

T A B L E VII A

MEAN CONTENT OF SULPHUR COMPOUNDS EXPRESSED AS PERCENTAGE OF TOTAL SULPHUR

Soils	Organic Sulphur %	Sulphate Sulphur %	Sulphide Sulphur %
Dry lands			
a. Surface soils	97.34	2.58	0.08
b. Subsurface soils	93.56	6.44	Tr.
c. Subsoils	92.31	7.30	0.39
Wet lands			
a. Surface soils	96.63	2.86	0.52
b. Subsurface soils	95.81	3.79	0.40
c. Subsoils	92.81	6.62	0.57
Dry and Wet lands (combined)			
a. Surface soils	96.74	2.82	0.44
b. Subsurface soils	95.44	4.31	0.25
c. Subsoils	92.82	6.63	0.55

Laterite Belt region

Soils collected from Kottarakara (4), Mannuthy (11), Pattambi (15, 16, 17, 18 and 19), Ambalawayal (20 and 24) and Varkala (23) are included in this group and the results of analysis for different forms of sulphur are given in Table II. Table II A show the different forms of sulphur expressed as percentages of total sulphur. Total sulphur varies from 1827.5 to 578.7 ppm. for surface soils, 944.2 to 123.8 ppm. for subsurface soils and 609.1 to 15.2 ppm. for subsoils. Sulphate sulphur accumulation is more in the surface soils of wet lands than in those of dry lands. But in most cases the percentage of the sulphate sulphur on total sulphur increases with the depth. Maximum amount of sulphide sulphur is present in profile 15 and this p fraction also decreases towards the lower layers. Soils collected under dry condition contain only very little or traces of sulphides.

Red loam lateric region

The data for the different forms of sulphur in the profiles 1, 2 and 3 and for the surface sample 21 are presented in Table III. Except for profile 1, the pattern of distribution of sulphur in these soils is similar to that of the laterite belt region. Profile 1 is from a recently reclaimed area of the Vellayani kayal area and in this profile the total sulphur and sulphates increase with depth in the profile. However, in all cases the amount of sulphate sulphur decreases with depth.

Red and black mixed soil tract

Profiles 12, 13 and 14 collected from Eruthampathy represent the wet lands, red soils and black soils of Chittur Taluk. Distribution of different forms of sulphur in these profiles are furnished in Table IV. Total sulphur and sulphate sulphur are maximum in wet lands and only very low amounts are present in red soils. Measurable quantities of sulphides are present only in wet lands. In all cases, the different forms of sulphur decrease with depth. In red soils only traces of water-soluble sulphates are present.

Sandy soil tract

The data relating to the different forms of sulphur in dry land and wet land profiles collected from Onattukara sandy soil tract are set out in Table V. In this case total and organic sulphur are higher in the surface soils of dry lands; while for lower layers, wet lands are richer in sulphur content. Dry lands are poor in sulphate sulphur and there is a slight increase in this form towards lower layers. Water-soluble forms of sulphate are only in traces in dry lands.

In wet lands maximum amount of sulphate is found in surface layers and it decreases towards the subsoil.

Estimable quantities of sulphide sulphur is present only in wet lands.

Kuttanad and Pokkali area.

Data in respect of the forms and distribution of sulphur in various soils of Kuttanad and Pokkali areas are given in Table VI. These soils vary widely in the sulphur content just as they vary in various physico-chemical characteristics . Profile 9 form Kari soil contain the maximum amount of sulphur. The surface soils of Kari lands have 15533.6 ppm. of total sulphur and it tended to increase towards lower layers. Sulphur in sulphate form also is maximum in Kari soils and in this case maximum accumulation was found in the subsurface soil. In profiles 7 and 8 the amounts of sulphate sulphur increases with depth. In Pokkali soils, which contain more than 50 per cent of its total sulphur in inorganic form, there is a uniform distribution of sulphates in the three layers. All the soils contain sulphide form of sulphur and it decreases considerably with depth. The heighest value of 227.5 ppm. for the sulphide sulphur is recorded in the surface soil of Pokkali area.

FIGURE 1

DISTRIBUTION OF TOTAL SULPHUR IN
DRY LAND SOILS

3 Vellayani

6 Kayamkulam

13 Eruthampathy (red)

14 Eruthampathy (black)

19 Pattambi

20 Ambalawayal

DISTRIBUTION OF TOTAL SULPHUR IN DRY LAND SOILS

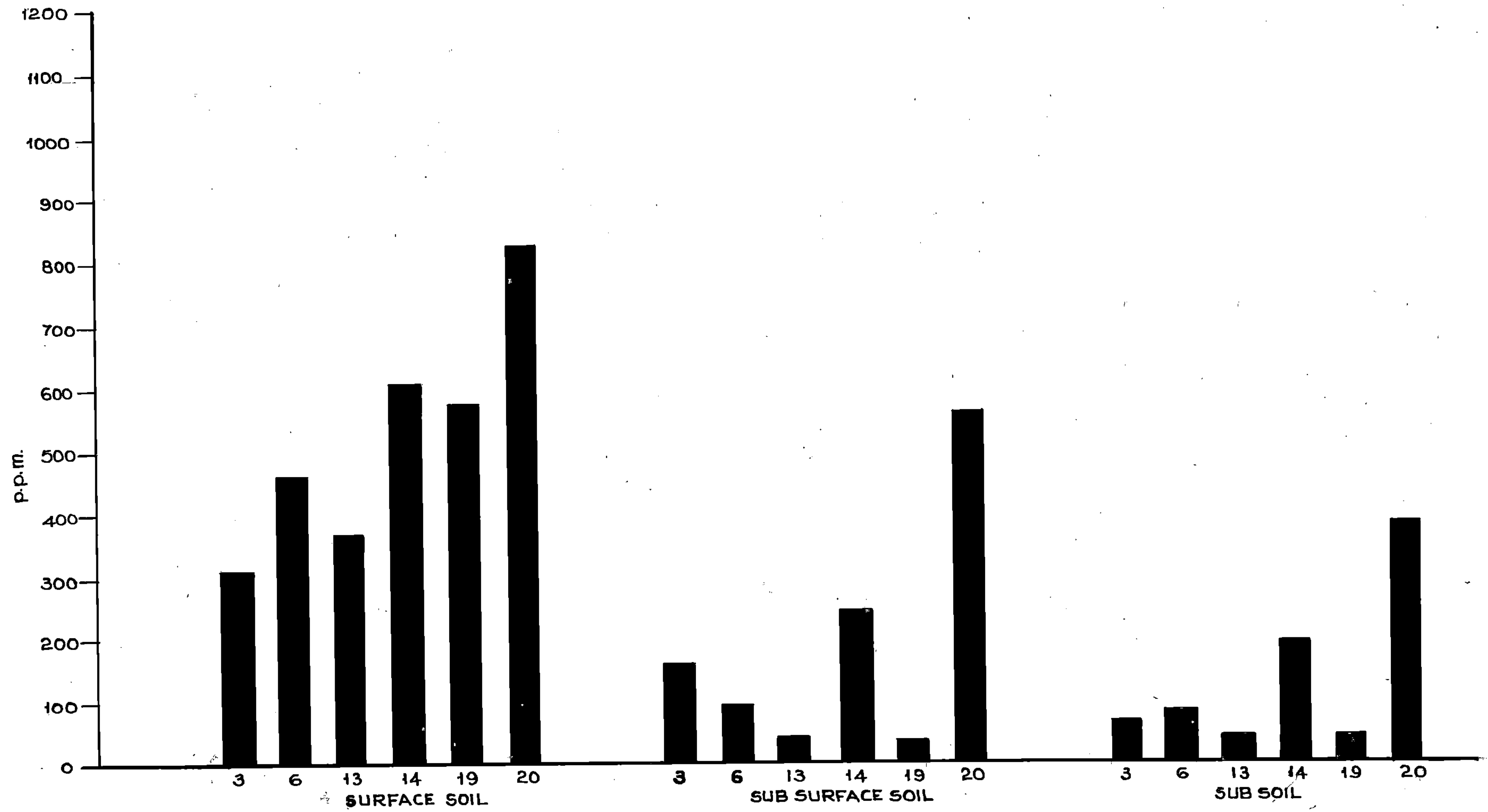

FIG. 1.

FIGURE 2

DISTRIBUTION OF TOTAL SULPHUR IN WET LAND SOILS

2 Vellayani

4 Kottarakara

5 Kayamkulam

11 Mannuthy

12 Eruthampathy

17 Pattambi

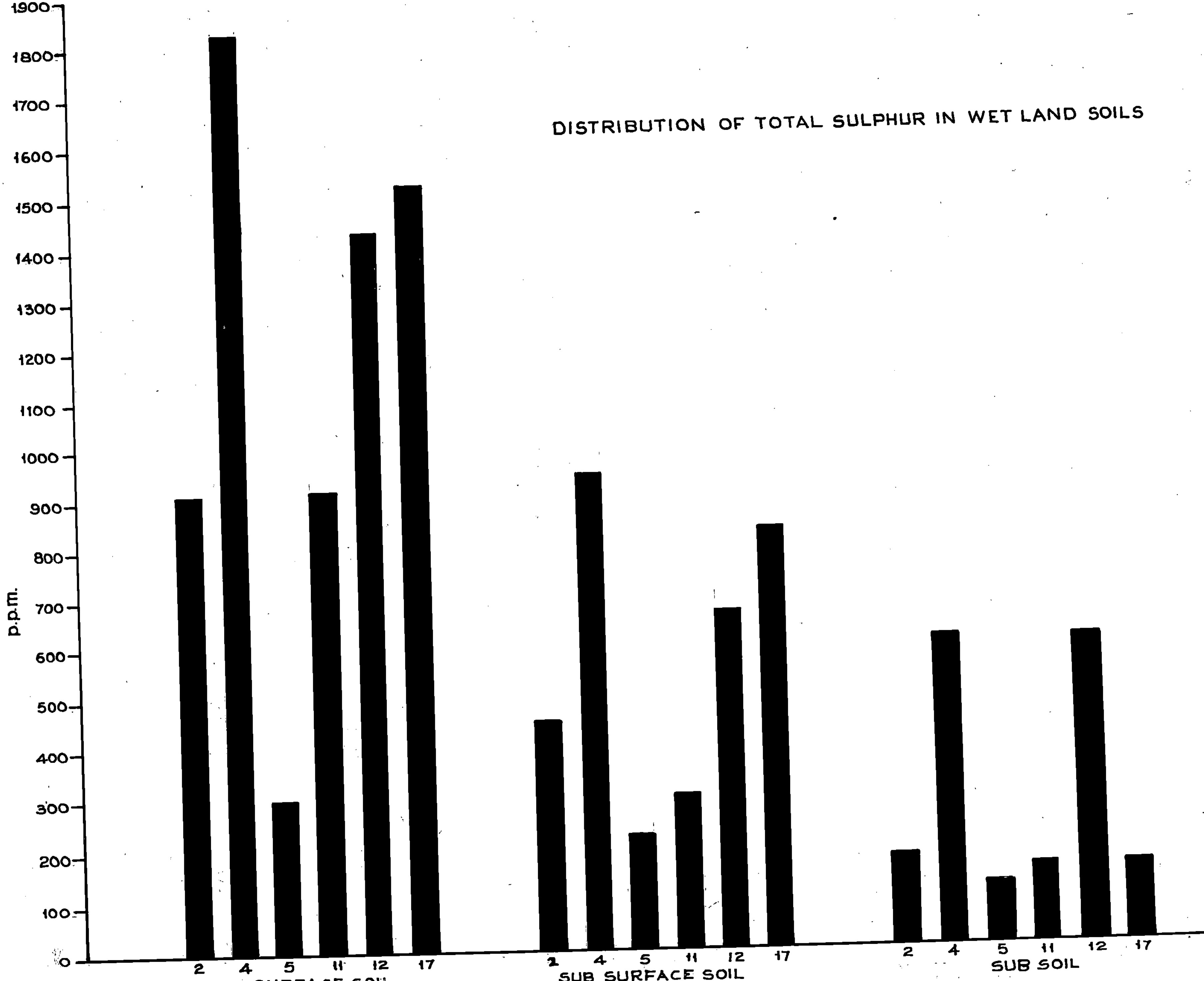
DISTRIBUTION OF TOTAL SULPHUR IN WET LAND SOILS
p.p.m.
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2 4 5 11 12 17
2 4 5 11 12 17
SUB SURFACE SOIL
2 4 5 11 12 17
SUB SOIL

FIG.2.

FIGURE 3

DISTRIBUTION OF SULPHATE SULPHUR IN DRY LAND SOILS

3 Vellayani

6 Kayamkulam

13 Eruthampathy (red)

14 Eruthampathy (black)

19 Pattambi

20 Ambalawayal

DISTRIBUTION OF SULPHATE SULPHUR IN DRY LAND SOILS

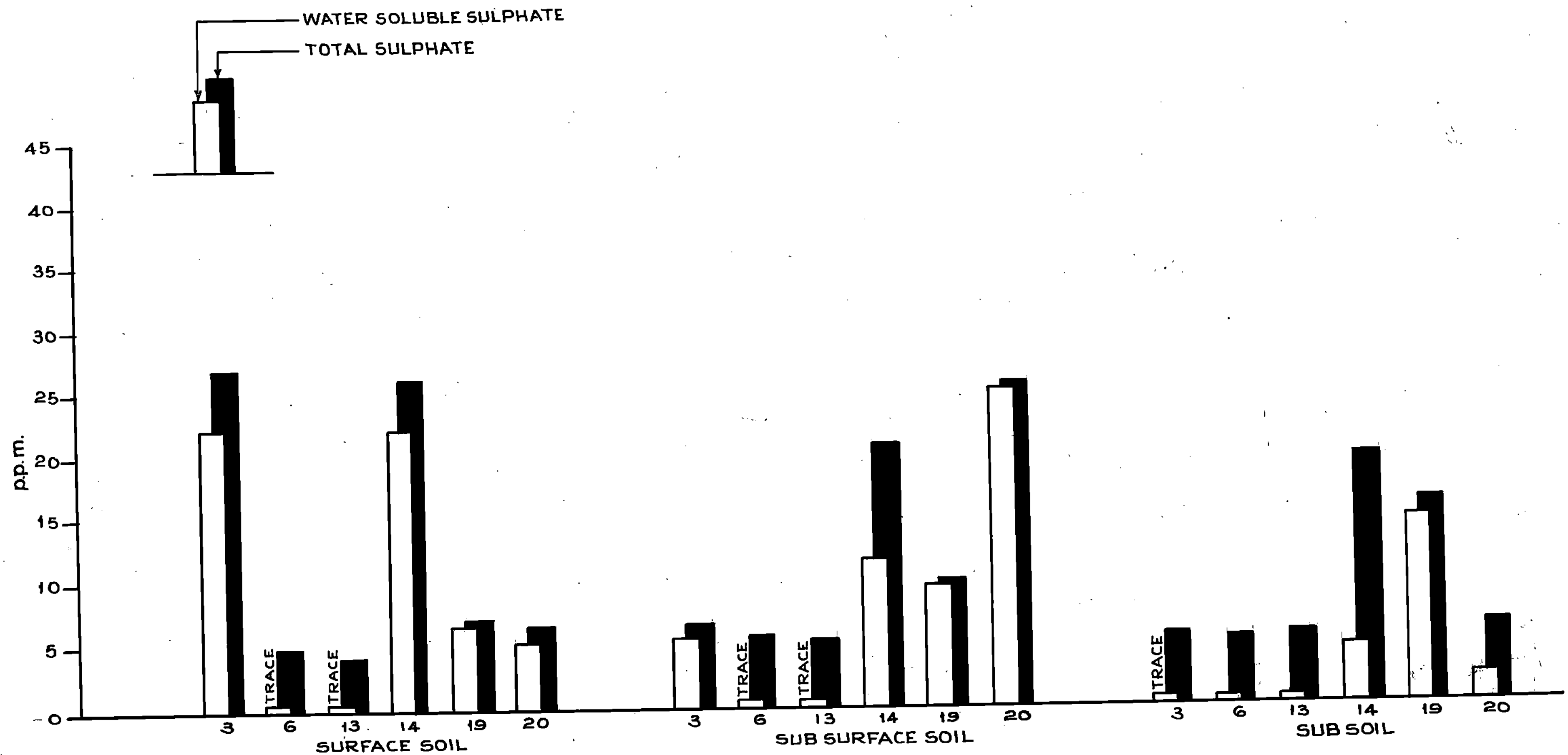

FIG. 3.

FIGURE 4

DISTRIBUTION OF SULPHATE SULPHUR
IN WET LAND SOILS

2 Vellayani

4 Kottarakara

5 Kayamkulam

11 Mannuthy

12 Eruthampathy

17 Pattambi

DISTRIBUTION OF SULPHATE SULPHUR IN WET LAND SOILS

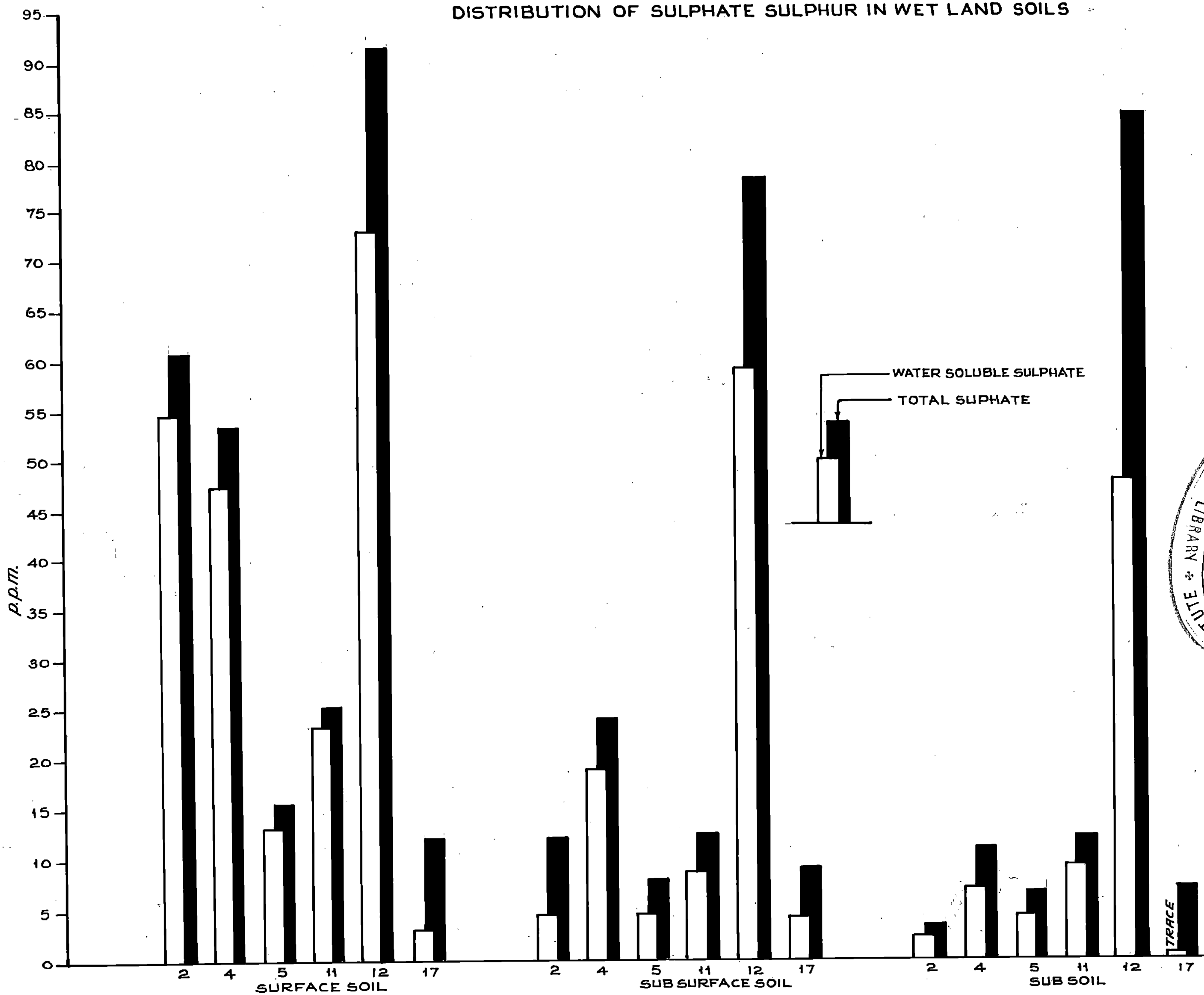

FIG.4.

FIGURE 5

DISTRIBUTION OF SULPHUR

IN THE PROFILE OF KARI LANDS (MUNDAR)

DISTRIBUTION OF SULPHUR IN THE PROFILE OF KARI SOILS
(MUNDAR)

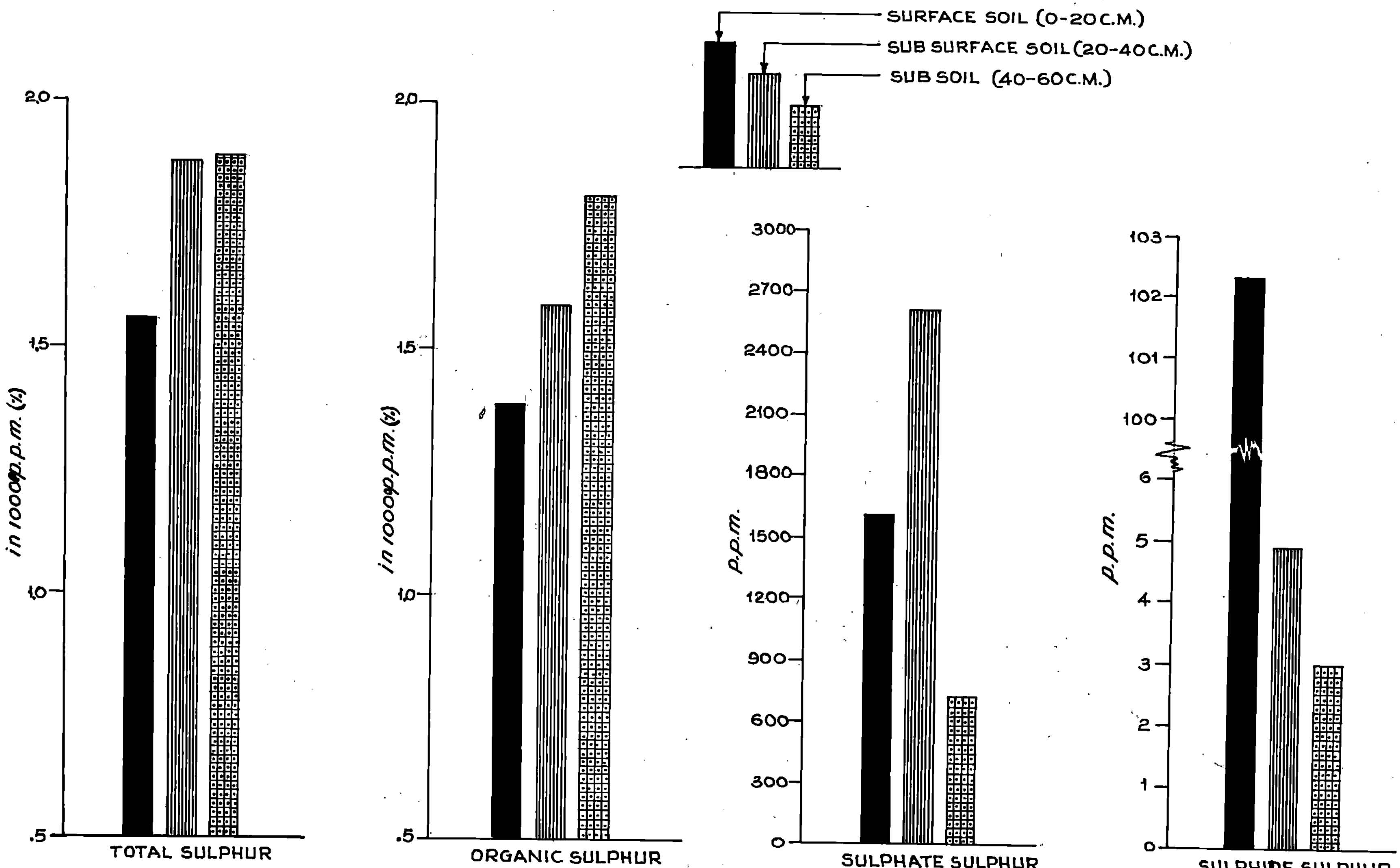

FIG. 5

DISCUSSION

D I S C U S S I O N

Results of the investigation on the status and distribution of sulphur in twenty profiles representing different soils types of Kerala are discussed in the following pages.

Total sulphur

The study reveals considerable variations in the total sulphur status of different soil types in the State. (Tables II to VI). In all the profiles except those from the Kari region and the Vellayani kayal, the surface soils contain the maximum amount of total sulphur. In the Kari and Vellayani kayal profiles, the subsurface and subsoils contain higher amounts of total sulphur than the surface soil. Since the soils of Kuttanad and Pokkali areas present quite a different pattern in the distribution of sulphur compounds, they have been excluded in the calculation of the mean contents of sulphur in the soils of Kerala (Table VII)

In all the soil profiles except the Kari and Vellayani kayal, the percentage of organic carbon is highest in the surface soils, decreasing with depth (Table I). A close relationship is observed between organic carbon content and total sulphur in the soils. In fact, both organic carbon and total sulphur decrease with increase in the depth of

FIGURE 6

DISTRIBUTION OF SULPHUR COMPOUNDS
IN DIFFERENT LAYERS OF PADDY SOILS

DISTRIBUTION OF SULPHUR COMPOUNDS IN DIFFERENT LAYERS OF PADDY LANDS

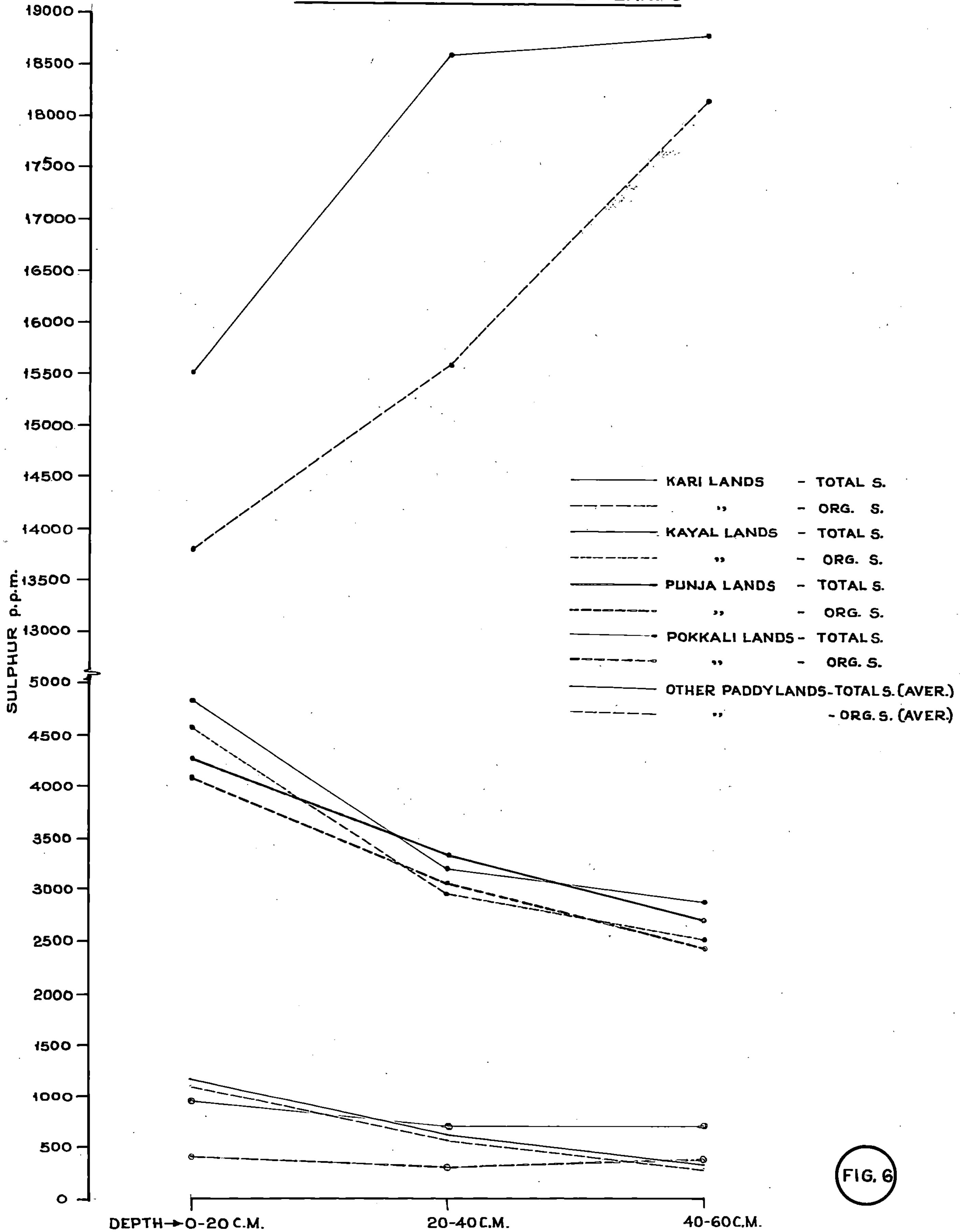

FIG. 6

the profile. The total sulphur content is significantly correlated with the organic carbon for all the layers ($r = 0.818$; Fig.8).

In general, wet land soils are richer in total sulphur than dry land soils (Table VII). The mean values for total sulphur in dry lands being 523.0, 194.2, and 125.5 ppm. for the surface, subsurface and subsoils respectively. The corresponding values for wetlands are1114.8, 548.4, and 280.8 ppm.

The pattern of variation of total sulphur content in the various profiles studied is generally in conformity with the reports of previous workers. A decrease of total sulphur with depth observed in the present study, is in good agreement with the results of Walker and Adams (1958), who reported mean values of 350,205 and 115 ppm. for the A, B and C horizons respectively, in grassland soils of New Zealand. Kanwar and Takkar (1964) also found that the total sulphur decreased with an increase in depth of the profile in the tea soils of Punjab.

The Kari soils are an exception to this general pattern. The total sulphur, instead of decreasing with depth, actually show an increase. Subramoney (1960) also recorded 19200 and 31300 ppm. total sulphur in the surface soils and subsoils respectively for Kari soils. Moreover the percentage of organic matter also shows a tendency to increase with depth of the profile (Table I). This explains the increase in total sulphur content with depth. Nair (1945) attributed the differences between various Kari soils to the quantity of organic matter present in them, obtaining values ranging from 9.48 to 38.79 per cent. Since a close relationship exists between total sulphur and organic carbon (fig.8), a wide variation in the sulphur content of Kari soils from different localities could be expected.

From the foregoing, it would appear that high values of total sulphur obtained for Kerala soils is, by and large, due to their high organic matter content. As the organic matter generally decreases with the depth of profile, the total sulphur content also decreases accordingly.

Organic sulphur

The percentage of organic sulphur to the total in Kerala soils varies from 43.14 to 99.50 per cent. However the mean values for the major soil types show that it constitut above 92 per cent of the total sulphur (Table VII A). The positive correlation between the organic carbon and the total sulphur obtained in the present study also indicates that the organic sulphur constitutes the major portion of the total sulphur. Aidinyan (1964) reported that 70 to 90 per cent of the total sulphur in non-saline soils of U.S.S.R.

is bound in the organic matter. Kanwar and Takkar (1964) found that the organic sulphur varied from 49 to 95 per cent of the total sulphur in the tea soils of Punjab.

The percentage of organic sulphur to the total sulphur is found to be low in the Pokkali soils of the State (Table VI A). This is due to the heavy accumulation of inorganic forms of sulphur by the periodic inundation of these soils by sea water.

The percentage of organic sulphur to the total sulphur is highest in the surface soils of the laterite belt of the State (Table II A). The sulphate ion is one of the most mobile ions present in the soil. The intense leaching and the consequent depletion of the inorganic sulphur makes the organic form of sulphur to be more predominant.

From Table VII - A it is evident that the percentage of organic sulphur to the total decreases with depth under both dry land and wet land conditions. This could partly be ascribed to the leaching of inorganic sulphur compounds to the lower horizons and partly to the accumulation of organic forms of sulphur in the upper horizons, due to the addition of organic matter.

Sulphate sulphur

In an aerated soil sulphate is the major inorganic form of sulphur. Among the various soil types included in the present study the maximum amount of sulphates are found in Kuttanad and pokkali soils where an increase in sulphate content with depth is observed. These soils are subjected to periodic inundation by brackish waters, especially during the summer months, which probably account for the high sulphate content. However, washing of the surface soils by the flood waters during the monsoon season reduces the sulphate content of the surface soils to some extent.

Wet lands, in general, contain more sulphates than dry land soils (Table VII). As these soils contain a relatively high amount of organic sulphur, it is quite possible that mineralisation to inorganic form has occured resulting in a higher concentration of sulphates.

When all the layers are considered together a significant linear relationship is obtained between the total sulphur and the sulphate sulphur ($r = 0.574$; Fig.9). However, no such relationship is evident between the total sulphur and sulphates when surface soils and subsurface soils are considered separately. The surface layers are susceptible to different degrees of leaching depending on the texture. Hence soluble sulphates are removed to different extents from the surface layers of different soils and as such no relationship could be expected between the total sulphur and sulphates, when surface and subsoils are considered separately.

The results presented in Table VII indicate that the mean content of sulphates decreases with an increase in depth. However this is not the case with all the profiles (Tables II and VI). In profiles 5, 13, 16, 19 and 20 the lower layers contain more sulphates than the surface soils inspite of the fact that the total sulphur content decreases with increase in depth. As these soils are light textured and well drained, it is possible that sulphates are leached down to the lower horizons, thereby enhancing the sulphate content of the lower layers.

Williams and Steinbergs (1965) found that important categories of sulphates in Australian soils included watersoluble sulphates, adsorbed sulphates and insoluble sulphates associated with calcium carbonate. Figures 3 and 4 show that in most of the soils studied the water-soluble sulphates are closely associated with the total sulphates. However, due to a very low content of total sulphates in profiles 5, 13, 17 and 18, no measurable quantities of sulphates are extracted by water from all the layers of these profiles. Sulphates not extractable by water can be considered as adsorbed sulphates. In most of the profiles, this adsorbed fraction of the sulphate sulphur increases with the depth.

FIGURE 7

DISTRIBUTION OF SULPHIDE SULPHUR IN SOME SUBMERGED PADDY SOILS

10 Vytilla - Pokkali lands

9 Mundar - Kari lands

7 'R' Block - Kayal lands

2 Vellayani - Red loam area

3 Pattambi - Laterite belt

DISTRIBUTION OF SULPHIDE SULPHUR IN SOME SUBMERGED PADDY SOILS

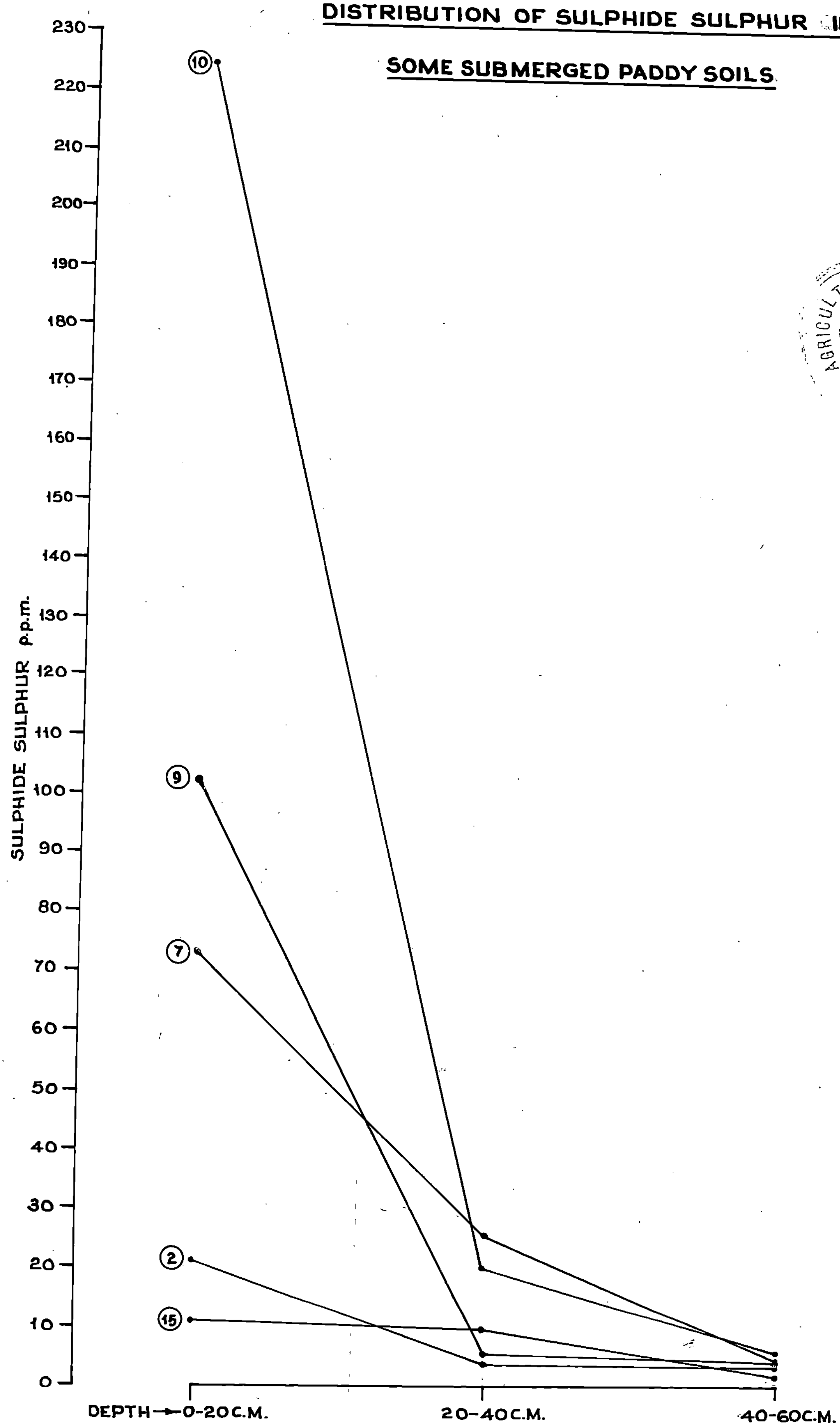

FIG. 7

Williams and Steinbergs (1962) noted that sulphates were retained in some soils by adsorption on clay collids. According to Ensminger (1954) most of the surface horizons and light textured soils had only a low capacity to adsorb sulphate, but that, appreciable adsorption was possible in the B and C horizons. Kamprath et al (1956) showed that sulphate adsorption was more in 1:1 clay minerals and under acidic conditions. Due to the predominance of 1:1 type of clay minerals and accidic nature of the soils, it would appear that most of the soils of Kerala are capable of retaining somo sulphates by adsorption.

Sulphide sulphur

It is only in the profiles of waterlogged paddy soils that sulphides are found in appreciable amounts. Data presented in Tables II to VI indicate that only very little or traces of sulphides are present when the moisture content of the soils is below 15 per cent.

The profiles 2,7,9,10 and 15, collected from water-logged paddy soils register maximum amounts of sulphides. The distribution pattern of the sulphides in these profiles is presented in Fig. 7. The lower layers contain considerably lesser amounts of total sulphides than the upper horizon. The findings of Ogata and Bower (1965) support these results. Their investigations show that the conditons necessary for the biological reduction of sulphate are an anaerobic environment, and the presence of soluble sulphates, available organic matter and sulphate reducing organisms. Starkey (1950) found that sulphate reducing organisms are widely distributed in nature and will grow wherever conditions are favourable. According to Ogata and Bower (1965) the organic matter present in the soils is a less readily assimilable source of energy material for sulphate reducing organisms than undecomposed straw. They found that the latter is about 20 times more effective for sulphate reduction than the former. In paddy soils large quantities of undecomposed plant residues are added to the surface soil and when waterlogged, all the conditions necessary for the sulphate reduction are available in the surface soils. The lower layers, however, are deficit in readily assimilable organic matter which is the dominating factor influencing the amount of sulphate reduction in poorly drained soils. This accounts for the greater amounts of sulphides in the top layers of waterlogged soils.

In drylands eventhough only small quantities of sulphides are detected, it is found that the sulphide concentration increases with increase in the depth of the profile. This is due to a more anaerobic condition in the subsoils of dry lands.

FIGURE 8

REGRESSION OF TOTAL SULPHUR (y)

ON ORGANIC CARBON (x)

(Kuttanad and Pokkali soils not included)

<u>Surface soils</u>

$n = 18$

$r = 0.8621^{**}$

$y = 678x + 222.58$

<u>Surface soils</u>

$n = 15$

$r = 0.7186^{**}$

$y = 538x + 84.71$

<u>Subsoils</u>

$n = 15$

$r = 0.8428^{**}$

$y = 698x - 52.43$

<u>All samples</u>

$n = 48$

$r = 0.8717^{**}$

$y = 777x - 8.6$

REGRESSION OF TOTAL SULPHUR (Y) ON ORGANIC CARBON (X)

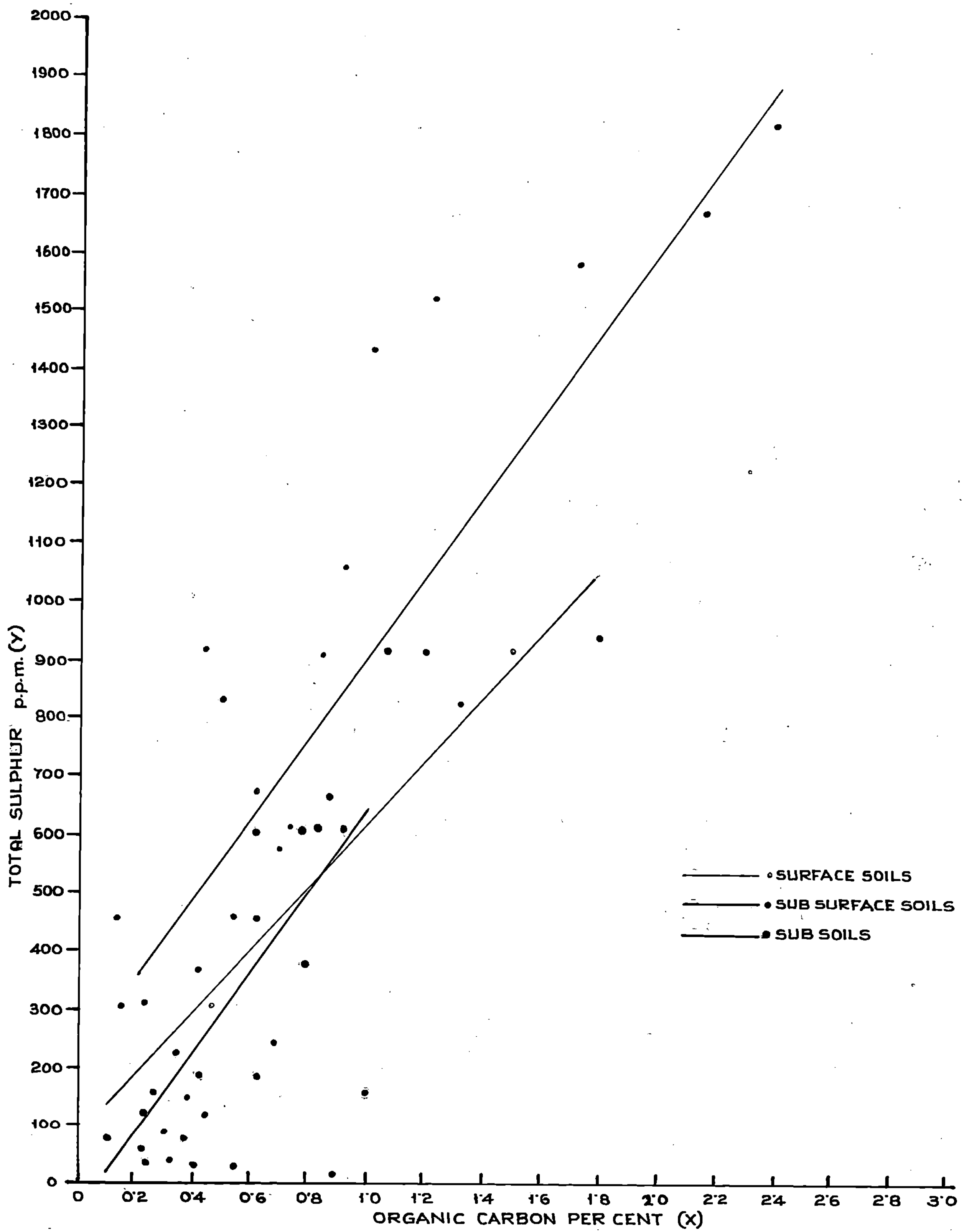

FIG. 8

FIGURE 9

REGRESSION OF SULPHATE SULPHUR (y) ON TOTAL SULPHUR (x)

(Kuttanad and Pokkali soils not included)

Surface soil

n = 18

r = (0.4379) not significant

Subsurface soil

n = 15

r = (0.4621) not significant)

Subsoil

n = 15

r = 0.5738*

y = 0.0526 x + 3.46

All samples

n = 48

r = 0.4919*

y = 0.0215 x + 8.21

REGRESSION OF SULPHATE SULPHUR (Y) ON TOTAL SULPHUR (X)

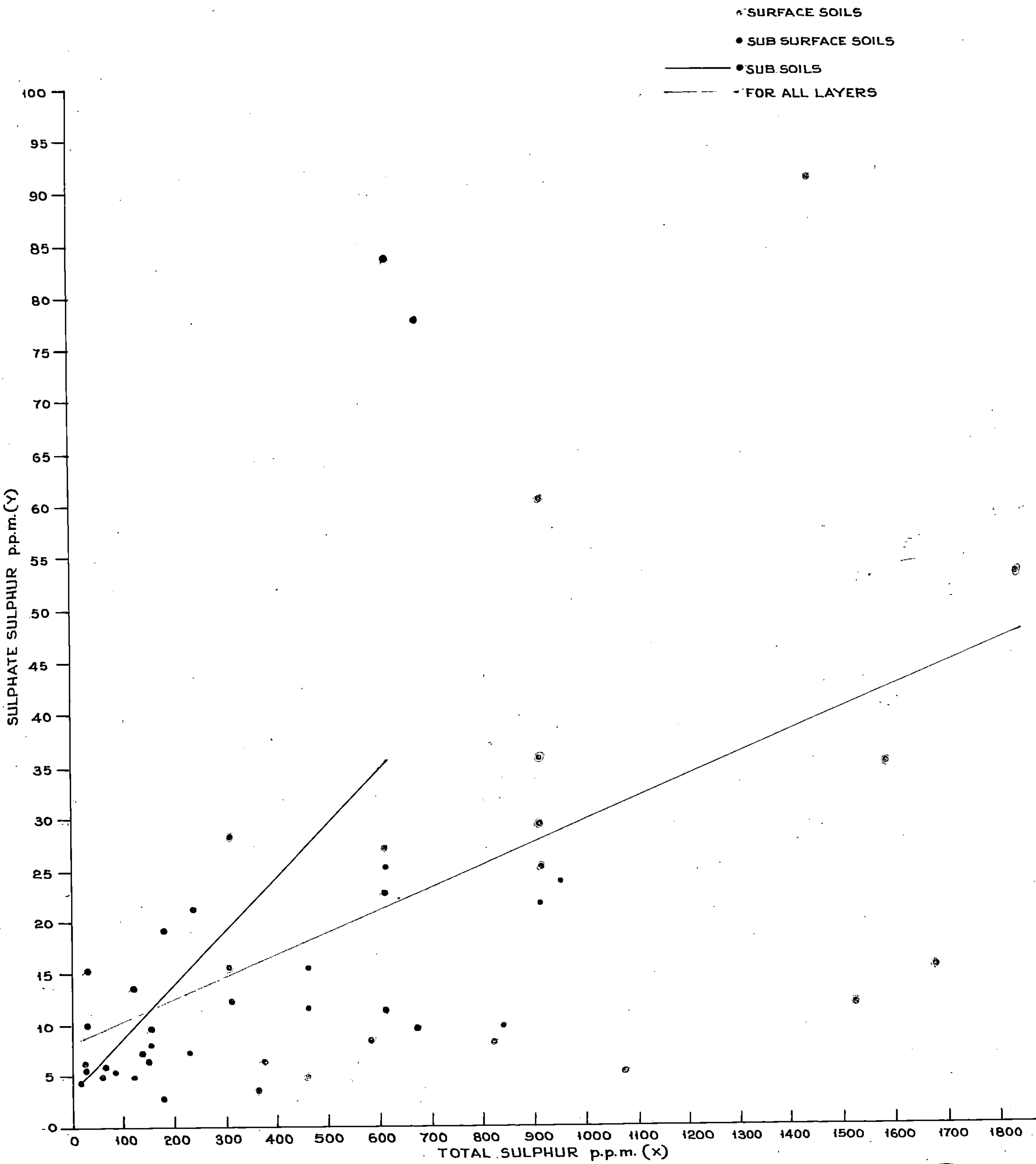

FIG. 9

Thus it would appear from the present study that Kerala soils are fairly well placed with respect to their sulphur status. The problems posed by some of these soils may be attributed more to their relatively higher content of sulphur than to their deficiency. In waterlogged soils the fluctuating environmental conditions especially the moisture regime, lead to the formation of reduction products of sulphur like sulphides or oxidation products like sulphuric acid. This is aggravated in some soils by the ingress of sulphate bearing saline waters. A detailed investigation on the factors governing the transformation of one form of sulphur to another may eventually lead to a solution of many of the problems encountered with these soils.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study was made of the forms and distribution of the sulphur in fourteen wet land and six dry land profiles. Relationship between different forms of sulphur and organic carbon was worked out. The main findings are as follows:-

1. Kerala soils in general are rich in total sulphur
2. Wet land soils contain more sulphur than dry land soils.
3. Total sulphur is significantly and positively correlated with organic carbon for all the three layers.
4. Maximum reserves of sulphur are found in the Kari soil of Kuttanad.
5. Excepting the Kari soils, in general the total sulphur decreases with an increase in the depth of the profile.
6. Organic sulphur generally constitutes the major portion of the total sulphur. The ratio of organic sulphur to total sulphur decreases with an increase in the depth.
7. In well aerated soil sulphate-sulphur accounts for the major portion of inorganic sulphur.
8. All the sulphates in soils are not extractable with water and most of the soils can retain some sulphates by adsorption.
9. Sulphate-sulphur is positively correlated with the total sulphur, when all the layers are considered together.

10. In light-textured soils the sulphates accumulate in the lower horizons only.

11. Appreciable quantities of sulphides are found only in paddy soils.

12. In well-drained soils sulphides accumulate in the lower horizons while in waterlogged soils maximum amounts are found in the surface soils. The conditions favourable for biological reduction of sulphates are present in the surface soils of poorly drained paddy soils.

The study has revealed that contents of different forms of sulphur keeps varying from soil to soil and from horizon to horizon. The problems posed by some of these soils may be attributed more to their relatively higher content of sulphur than to their deficiency. In waterlogged soils the fluctuating environmental conditions especially the moisture regime, lead to the formation of reduction products of sulphur like sulphides or oxidation products like sulphuric acid. This is aggravated in some soils by the ingress or sulphate bearing saline waters. A detailed investigation on the factors governing the transformation of one form of sulphur to another may eventually lead to a solution of many of the problems encountered with these soils.

FIGURE 10

SOIL MAP OF KERALA SHOWING THE

LOCATIONS OF SAMPLES COLLECTED

1, 2 & 3	Vellayani
4	Kottarakara
5 & 6	Kayamkulam
7	Alleppey, 'R' Block kayal
8	Moncompu
9	Mundar
10	Vytilla
11	Mannuthy
12,13 & 14	Eruthampathy (Chittur)
15 to 19	Pattambi
20 & 24	Ambalawayal
21	Karamana
22	Neelamperoor
23	Varkala
25	Chithirapuram kayal

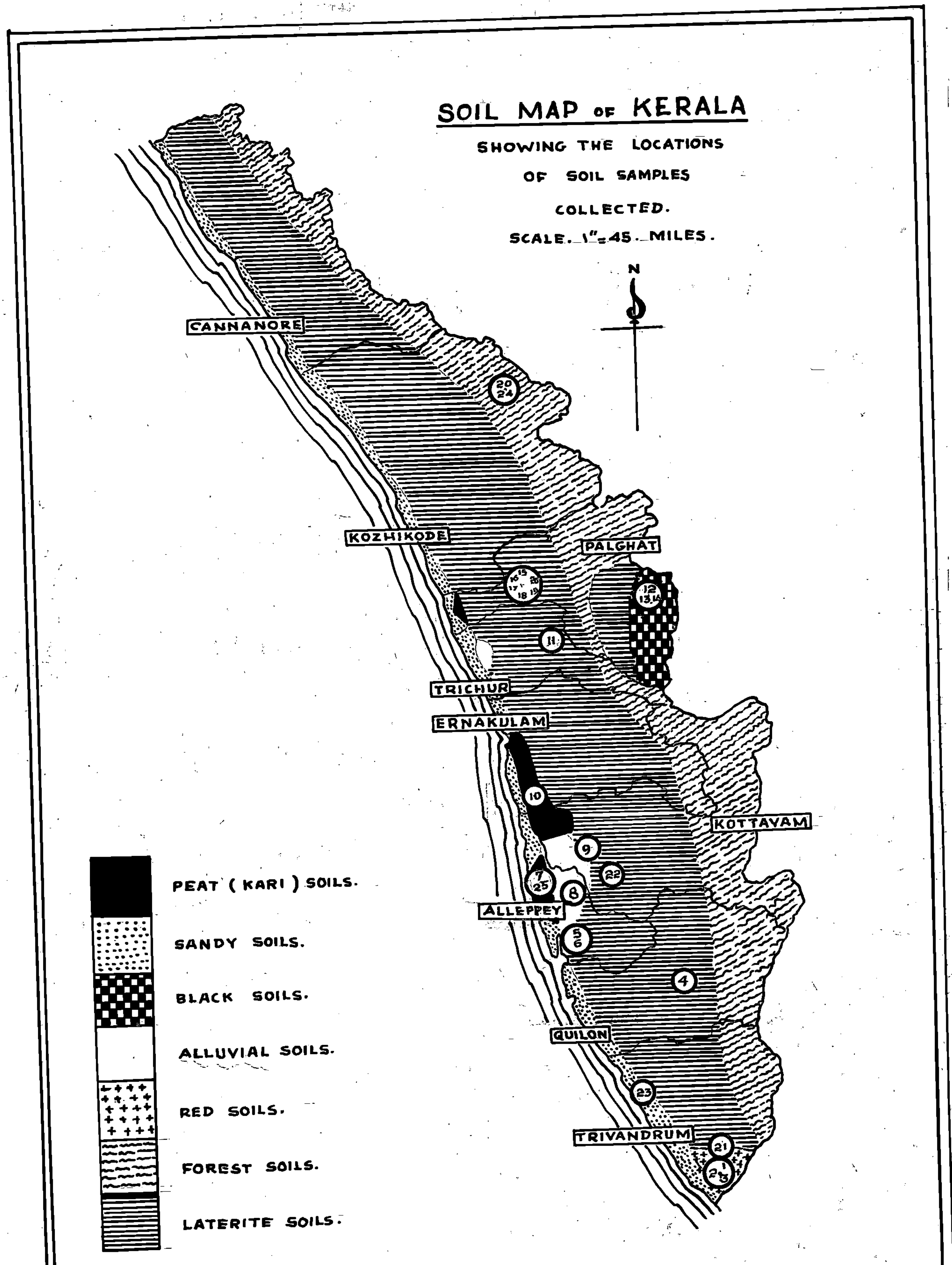
SOIL MAP OF KERALA
SHOWING THE LOCATIONS
OF SOIL SAMPLES
COLLECTED.
SCALE. 1"=45 MILES.
N
CANNANORE
KOZHIKODE
PALGHAT
TRICHUR
ERNAKULAM
KOTTAYAM
ALLEPPEY
QUILON
TRIVANDRUM
PEAT (KARI) SOILS.
SANDY SOILS.
BLACK SOILS.
ALLUVIAL SOILS.
RED SOILS.
FOREST SOILS.
LATERITE SOILS.

FIG.10.

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