SULPHUR STATUS OF MAJOR UPLANDS OF SOUTH KERALA

By

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THESIS
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DECLARATION

I hereby declare that this thesis entitled Sulphur Status of major uplands of South Kerala' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society

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CERTIFICATE

Certified that this thesis, entitled Sulphur status of major uplands of South Kerala' is a record of research work done independently by Sheeba, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her

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

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INTRODUCTION

With the intensification of agriculture and ever increasing demand for nutrients made by crops on soil and fertilizer system, the traditional boundaries between primary and secondary nutrients are becoming narrower Sulphur, often referred to as a secondary nutrient in the past is now gaining much importance in boosting food production in many soils. Crops require as much sulphur as they do phosphorus and it can therefore be rightly called the fourth major nutrient in Indian agriculture. Today this nutrient has taken a prominent position in the fertilization programme in several areas

The functions of sulphur in plant growth and metabolism are numerous and important Sulphur is best known for the synthesis of sulphur containing amino acids cystine, cysteine and methionine, which are essential components of protein. It is also needed for the synthesis of coenzyme A, biotin, thiamine and glutathion, formation of chlorophyll and metabolism of carbohydrates, proteins and oils. Sulphur lowers the HCN content of certain tuber crops, promotes nodulation in legumes, produces bold grains in oilseeds and improves the quality of sugarcane juice It occurs in volatile compounds responsible for the characteristic taste and smell of plants in mustard and onion families. Sulphur also enhances oil formation in oilseeds and improves nutritive value of forages

The importance of sulphur is equal to that of nitrogen in terms of protein synthesis and equal to that of phosphorus in terms of crop uptake In spite of these significant factors, the role played by sulphur, especially under tropical agriculture, has not been fully realised during the past mainly because of the fact that sulphur deficiency was not a serious problem then

Incidence of sulphur deficiency in India is on the rise primarily due to the increasing crop uptake and removal associated with increase in agricultural production and the phasing out of the sulphur containing straight fertilizers by non sulphur containing complex fertilizers The deficiency which was noticed many years ago only in localised areas, has engulfed much larger areas in its fold Based on the details of published and unpublished sources, Tandon (1986) reported that 90 out of the 400 districts in India have exhibited sulphur deficiency problem Considering the quantum of available information on sulphur in relation to that on other elements of importance to Indian agriculture, an overall stepping up of sulphur research and its co-ordination seems necessary Only through research we can find the overall magnitude of sulphur deficiency, its practical implication and the alleviation of its constraint through suitable technologies The studies on sulphur nutrition of soils of Kerala are meagre. Also there is a paucity of information on suitable soil test methods for assessing the sulphur status for different soils Obviously research efforts are needed to identify proper extractants giving more authenticated estimates of sulphur availability to crops for various agro-soil cropping systems. Keeping in view the aforesaid facts the present investigation was undertaken with the following objectives

(i) to make a detailed assessment of sulphur status of major upland soils of South Kerala.

(ii) to find out the most suitable extractant for the determination of available sulphur in soils

(iii) to find out the relationship of sulphur with relevant soil parameters and the relationship between various forms of sulphur

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Systematic research on sulphur in India began a little more than thirty years ago. Over these years research on sulphur in India had expanded although at a slow pace and in a scattered manner. Sulphur research has expanded to cover about 31 crops and several of the agro-climatic regions. Information about sulphur status in soils is available for both irrigated, as well as rainfed conditions Considerable emphasis has been placed on the fractionation of sulphur and determination of available sulphur by the known extractants and techniques

2 1 Forms of sulphur

The original source of soil sulphur is the sulphides of metals present in plutonic rocks During soil formation, mineral forms of sulphur are redistributed and organic sulphur compounds are synthesised and accumulated Thus in soils, sulphur is present both in organic and inorganic forms

2 1.1 Total sulphur

The total sulphur status of surface soils of India can vary 200 fold, that is form 19 ppm to 3836 ppm sulphur

(Tandon, 1986) He opined that wide variation of sulphur status can be observed in soils within a state, within a district or even within a catena Within a state, the probable area deficient in sulphur can vary from negligible in some districts to 40 per cent of the crop land in other districts as in the case of Punjab Dolui and Bandyopadhyay (1983) reported a remarkably wide range of 551-2206 ppm sulphur within a catena of Bengal

Jacob (1966) in his studies of the sulphur status of Kerala soils stated that in sandy soils of Onattukara region, the total sulphur content varied from 304 to 456 ppm in wet land and dry land respectively. According to him, the red loam soils of Vellayani contained about 304 6 ppm sulphur whereas laterite soils of Ambalavayal contained 822 3 ppm sulphur Leela (1967) reported that red loam lake soils of Vellayani contained about 1233 ppm sulphur The corresponding values of total sulphur in sandy and laterite soils of Kerala were 671 and 1037 ppm respectively. Cicy (1989) has also reported that total amount of 1026 5, 2008.6 and 4020 ppm sulphur, respectively in Karappadam, Kayal and Kari soils of Kerala

Balanagoudar and Satyanarayana (1990a) in their studies on sulphur in vertisols and Alfisols of Karnataka districts reported that the total sulphur content in soils varied from

500 to 3500 ppm with an average of 1239 ppm Ruhal and Paliwal (1978) found that the total amount of sulphur ranged as 500-3250 ppm in calcareous, fine textured soils of Rajasthan. Misra *et al* (1990) have shown that the total sulphur content of soils of Orissa ranged from 25 7 to 925 ppm. They have established that light textured red and laterite and alluvial soils with low clay content contained less total sulphur as compared with the soils of other groups. Arora and Takkar (1988) reported that total sulphur in some Entisols and Inceptisols of Ludhiana districts of Punjab ranged from 32 to 126 5 ppm Tiwari and Pandey (1990) have stated that the total sulphur status of soils varied between 62 44 and 216 63 ppm in Varanasi region of Uttar Pradesh The total sulphur contents in some typical soil profiles of West Bengal ranged from 18 7 to 333.2 ppm with an average of 130 6 ppm The soils from hill, terai and coastal saline soils contained, in general, higher amount of total sulphur than those from alluvial and laterite regions (Mukhopadhyay and Mukhopadhyay, 1980)

A 29 fold variation existed in total sulphur content in alluvial soils of India Ahmed and Jha (1969) reported the maximum 851 ppm in fine textured soils of Bihar while Arora and Sekhon (1977) reported a minimum of 26 ppm in Ustochrepts in Punjab In various soil types of India, the mean content of total sulphur was 213 ppm in red, 329 ppm in alluvial, 350 ppm in laterite, 456 ppm in hill, 530 ppm in black and 6319 ppm in saline soils (Hegde et al., 1980).

Balasubramanian and Kothandaraman (1985) reported that total sulphur content varied widely among the soil series of Tamil Nadu ranging from 190 to 5700 ppm Palaniappan et al (1978) have stated that in hill soils of Tamil Nadu a wide variation in total sulphur ranging from 89 to 2256 ppm can be observed with a mean content of 1354 ppm In a comparative study of total sulphur content in the hill soils, the tea soils of Himachal Pradesh contained lower sulphur contents (189 ppm) as compared to other hill soils of Himachal Pradesh (276 ppm), West Bengal (221 ppm) and Tamil Nadu (1323 ppm) as reported by Kanwar and Takkar (1964), Singh et al. (1976), Mukhopadhyay and Mukhopadhyay (1980) and Palaniappan et al (1978) The fine texture and high organic carbon content in the latter soils as compared to the former tea soil were the factors that led to these variations in sulphur content of soils

Vinay Singh and Sharma (1983) reported that the mean sulphur content in soils of Agra region ranged between 97 5 ppm and 187 5 ppm with a mean value of 156 ppm In soils of Ganga flats the total sulphur ranged between 129 and 167 ppm, the mean being 140 ppm as reported by Dwivedi et al. (1983).

The soils of West Bengal were relatively poor in total sulphur (74 ppm) than those from Uttar Pradesh (143 ppm) despite having the fine texture of former soil (Kanwar and Mohan, 1964 Bhan and Tripathi, 1973) Prasad et al (1983) found that red soils from Andhra Pradesh contained very high amount of sulphur (1783 ppm) Thirupathi Reddi et al (1985) reported that total sulphur in loamy soils of Andhra Pradesh varied from 235 to 329 ppm with a mean of 226 ppm while in clayey soils it ranged between 376 and 658 ppm with a mean of 476 ppm Arora et al. (1988) from their studies concluded that in some benchmark soils of Punjab, total sulphur varied from 87 to 222 ppm. In soils of Haryana total sulphur ranged between 61 7 and 331 3 ppm as reported by Karwasra et al. (1986). Sharma et al (1988) reported that humid subtropical zone in the Himalaya region contained about 100-212 ppm sulphur. The corresponding values of total sulphur in wet temperate zone ranged between 75-1250 ppm and in subtropical zone it ranged between 87-212 ppm Ganeshamurthy et al (1989) have reported very high values for total sulphur in Andaman soils In coastal planes of Andaman total sulphur ranged between 1120 and 9750 ppm while in the hill slopes it ranged from 875 to 2625 ppm

In India, the tropical soils possess less sulphur than in the temperate zone The low sulphur reserves in tropical Indian soils appears to have resulted largely from their poor organic matter (Takkar, 1988). Consolidation of available information shows that sulphur deficiencies in Indian soils are more extensive and variable than generally thought to be. Many workers have reported that soils initially well supplied with sulphur can become deficient within a few years of intensive agriculture without a sulphur input (Das and Datta, 1973 Subba Rao and Ghosh, 1981 Anandswarup and Ghosh, 1980).

2.1 2 Organic suplhur

Organosulphur compounds are the potential sources of sulphur which become available to the plant after mineralisation (Bramyan and Galstyan, 1986) It is designated as an indicator of reserve sulphur status of soil

Mukhopadhyay and Mukhopadhyay (1980) concluded that organic sulphur constituted the major part of total sulphur in soil profiles of hill, terai, alluvial and lateritic regions of West Bengal They have reported that organic sulphur accounted for 34.4 to 99 7 per cent (average 79.9 per cent) of total sulphur in soil profiles Average organic sulphur content in hill (189.6 ppm) and terai region were noticeably higher than those observed in lateritic (44 3 ppm), alluvial (57 8 ppm) and coastal saline regions (986 ppm)

Aulakh and Dev (1976) reported that except for saline sodic soils, the content of organic sulphur was highest in soil series found in Sangrur district of Punjab. Kanwar and Mohan (1964) stated that in arid regions of Punjab, organic sulphur constituted only 10 per cent of total sulphur while in prehumid to humid regions, organic sulphur accounted 72 per cent of total sulphur content Ahmed and Jha (1969) have found that in some soils of Bihar, organic sulphur constituted only 16 per cent of total sulphur. Shukla and Ghey (1971) in their studies reported that organic sulphur in some profiles of Rajasthan soils ranged between 60 and 298 ppm Vijaykumar and Maharaj Singh (1974) reported that sandy loam soils of Nainital terai region possessed above 275.5 ppm organic sulphur whereas silty clay loam contained about 668 8 ppm organic sulphur Organic sulphur content in the alluvial soils varied widely from 7 ppm in Ustochrepts in Punjab (Arora and Sekhon, 1977) to 109 ppm in the fine textured soils of Bihar (Ahmed and Jha, 1969)

Jacob (1966) reported that organic sulphur constituted about 95-98 per cent of total sulphur in Kerala soils. The mean content of organic sulphur in red loam, sandy and laterite soils were 276, 462 and 813 ppm respectively. The high percentage of organic sulphur in Kerala soils was also reported by Leela (1967) She opined that wetland soils of red loam and laterite soils carried about 162 and 979 ppm organic sulphur respectively. Cicy (1989) reported that Kari soils of Kerala have 2446 ppm (55.9 per cent of total sulphur) organic sulphur

The mean content of organic sulphur in red soils of Andhra Pradesh was reported as 1783 ppm, 189 ppm in lateritic, 143 ppm in greyish black 144 ppm in greyish black and 141 ppm in non lateritic soils of Maharashtra, 46 ppm in Bundelkhand and 34 ppm in black soils of Gujarat (Reddy and Mehta, 1970 Bhan and Tripathi, 1973 Prasad et al , 1983)

According to Joshi et al. (1973) though the red, black and desert soils of Rajasthan had higher organic sulphur (134-153 ppm), it accounted for only 39-50 per cent of total sulphur compared to 89-98 per cent in hill, terai and alluvial soils of West Bengal with similar range of sulphur content viz , 125-156 ppm. Misra et al (1990) reported that organic sulphur constituted 66 5 to 98 3 per cent of total sulphur in soil samples collected from Orissa. The coastal saline soils contained a relatively lower fraction of organic sulphur (66 57 per cent) as compared to other soils (81 44-93 97 per cent). Virmani and Kanwar (1971), in their studies on the sulphur status in N E India, reported that the content of organic sulphur with respect to total sulphur in acid soils was about 80 per cent as against 50 per cent in alkaline soils They further reported that organic sulphur varied from 192 to 228 ppm in the surface horizon of profiles from acid soils compared to 70-92 ppm in alkaline soils Ahmed and Jha (1969) had reported that in Bihar soils organic sulphur constituted 1/5 of total sulphur They had shown that the mean content of organic sulphur in alkaline, neutral and acid soils were 88 5, 100 and 99 ppm respectively. Dwivedi et al (1983) concluded that organic fraction amounted to 17 1 to 26 1 per cent total sulphur On an average, 31, 30 8, 26 5 and 31 8 ppm organic sulphur were recorded in different regions of the Ganga flat Thirupathy Reddy et al. (1985) reported that organic sulphur constituted 89 per cent total sulphur (310 ppm) in soils of Andhra Pradesh

2.1.3 Sulphate sulphur

Plants absorb sulphur in the form of sulphate ions from the soil Generally water soluble sulphate sulphur in Indian soils is within 10 per cent of the total sulphur (Tandon, 1986)

Pandey et al. (1989) reported that sulphate sulphur constituted only a small fraction of total sulphur being, 8-17 per cent in the alluvial soils of Uttar Pradesh The sulphate sulphur in these soils ranged as 6 5-37 5 ppm with a mean of 15 5 ppm The 0 15 percent $CaCl_2$ available sulphur in surface samples collected from tea soils of Himachal Pradesh varied as 0 5-25 ppm with a mean value of 7 2 ppm

(Kanwar and Takkar, 1964 Takkar, 1987) and it formed only a small percentage of total sulphur

Kanwar (1963) reported the extensive deficiency of sulphur in 75 per cent of the soil samples collected from Ludhiana, Punjab Kanwar and Mohan (1964) showed that sulphate sulphur in the soils of different agroclimatic zones of Punjab varied from 7.4 to 48 ppm and constituted a very small fraction of total sulphur. They opined that sulphate sulphur form decreased from 10.1 to 3 4 ppm as one moved from alluvial soil groups in arid and semi arid climatic zones towards hills soils in semihumid and hot, humid to subtropical and prehumid to humid climate

Dwivedi et al. (1983) reported that in some central alluvial soils of Uttar Pradesh, sulphate sulphur ranged from 14 8 to 32 ppm (mean 23 2) which constituted about 11 4-20.7 per cent of total sulphur. Bharadwaj and Pathak (1969) showed that in soils of Uttar Pradesh sulphate sulphur content in surface soils varied from 5 7 to 105 6 ppm

Ahmed and Jha (1969) had shown a widespread deficiency of sulphur in neutral, acidic and alkaline soils of Bihar Cheema and Arora (1984) showed that sulphate sulphur ranged between 0.3 and 56.3 ppm and the extent of sulphur deficiency was 75 per cent in 1983 and 82 per cent in 1984 based on the analysis of 500 surface soil samples from Ludhiana, Punjab.

The proportion of sulphate sulphur to total sulphur ranged from 2 per cent to 24 per cent in the hill soils of Punjab (Ghai, 1980). Sureshlal and Mathur (1985) found that the sulphate sulphur content in Indian soils ranged from 3 4 to 81 ppm. Red, black and desert soils of Rajasthan contained a high amount of sulphate sulphur (Joshi et al., 1973). Tiwari and Pandey (1990) reported that 57 percent of soil samples in the Varanasi region of Uttar Pradesh were low in plant available sulphur, 33.3 per cent medium and that 0 5 per cent have shown high available sulphur status. The sulphate sulphur distribution in these soils varied between 6 5 and 30 ppm.

Arora and Takkar (1988) reported that sulphate sulphur ranged from 7.4 to 20 7 ppm, the sulphate sulphur being 19 percent of total sulphur in some entisols and inceptisols of Punjab. Bansal et al (1991) found that 0 15 per cent $CaCl_2$ extractable sulphur ranged from 2 8 to 155 ppm in Kapurthala district of Punjab.

Balanagoudar and Satyanarayana (1990 a) concluded from their studies the sulphate sulphur in Vertisols and Alfisols of North Karnataka ranged from 2.8 to 250 ppm with an average of 29 3 ppm and accounted for a small fraction of total sulphur

Misra et al (1990) had shown that soluble sulphate extracted with 0.15 per cent $CaCl_2$ solution varied from traces to 64.2 ppm sulphur except for two saline soils which had very high values of 273 and 407 7 ppm sulphur. They reported taking less than 10 ppm $CaCl_2$ extractable sulphur as low (Kanwar and Takkar, 1964), most of the alluvial and black soils and 45 per cent of all the soil samples analysed were likely to be deficient in available sulphur.

Jacob (1966) reported that in upland soils of Kerala, sulphate sulphur constituted only a small fraction of total sulphur. The mean content of sulphate sulphur were 28.3, 4.9 and 322.5 ppm for red loam, sandy and Pokkali soils respectively. Cicy (1989) reported very high values for sulphate sulphur in the Kuttanad soils of Kerala. Leela (1967) reported that wetland soils of Kerala contained about 1 4-5 9 per cent of total sulphur in the form of sulphate sulphur

2.2 Distribution pattern

All forms of sulphur showed a regular decline with depth in Kerala soils (Jacob, 1966). The total sulphur content decreased from 822.3 ppm to 609.1 ppm in surface and subsurface of laterite soils and from 456 to 91 ppm in sandy soils of Kerala. Organic sulphur also showed declining trend with depth But in sandy soils of Kerala, more sulphate sulphur was seen accumulated in lower layers. These findings were also supported by Leela (1967) in Kerala soils.

Tiwari and Pandey (1990) observed that total sulphur decreased from 230 to 95 ppm in black soils, 140 to 85 ppm in alluvial soils and 150 to 80 ppm in red soils Other forms of sulphur like organic, sulphate and water soluble sulphur were also found to be decreased with depth They opined that this might be due to high organic matter content in the upper layers of the soil as most of the sulphur is present in organically bound forms Vinay Singh and Sharma (1983) also reported the decreasing trend of different forms of sulphur with depth. The total sulphur ranged between 97.5-187.5 ppm with a mean value of 156 ppm for surface soils and 142 4 ppm for subsurface soils in Agra region They found that the concentration of sulphate sulphur was 22 7 ppm in surface soils and 16 ppm in subsurface soils. The negative correlation between organic sulphur and depth was also established Aulakh and Dev (1976) in their studies of profile distribution of sulphur in soils of Sangrur district of Punjab, reported that the highest amount of sulphur was found in surface soils, which decreased slightly in the rooting zone and was least in the last horizon.

Vijaykumar and Maharaj Singh (1974) observed that the heat soluble sulphur content decreased with depth of soil, from a mean value of 24 ppm in surface soils to a mean value of 12 ppm in the subsurface soils showing an average decrease of 50 per cent in Nainital terai soils. They opined that the decrease was more than the average decrease in coarse textured soil and less than the average decrease in the fine textured soil.

Mukhopadhyay and Mukhopadhyay (1980) observed that the total sulphur content in surface soils (0-6) was higher than that of subsurface layer in soils of West Bengal. In lateritic region, the total sulphur contents were *108 7, 56 2* and 18.7 ppm in soils of depth 0-15, 15-30 and 30-45 cm respectively in Raghunathpur region. Organic sulphur also showed a declining trend with depth. In some profiles of alluvial alkaline soils poorer in organic matter content no regular decline in sulphur content was noticed as the soil sulphur was present mainly in inorganic form (Virmani and Kanwar, 1971). Misra et al. (1990) reported that in Bhubaneswar profile of Orissa both total and organic sulphur decreased with depth upto 60 or 90 cm and increased at lower depth which might be associated with the increase in clay and organic carbon content In Sambalpur profile, the total and organic sulphur increased with depth upto 60 cm and then decreased They reported that this increase in total and organic sulphur with depth upto 60 cm in this profile was probably due to the presence of sulphur rich organic matter in the increasingly anaerobic conditions of lower depth In

Karisoils of Kerala also a corresponding increase in total organic sulphur was observed due to the high accumulation of organic matter in lower layers (Leela, 1967). Ruhal and Paliwal (1978) observed that total and sulphate sulphur showed a regular increase with depth while organic form generally increased upto the fourth horizon followed by a decrease in deeper horizons in soils of Rajasthan. Somani and Saxena (1976) reported a regular decrease of organic sulphur with increase in depth in Rajasthan soils. Virmani and Kanwar (1971) revealed that the total sulphur content of the soils from N.E. India showed a decline with depth in the case of acid soils, whereas in alkaline soils no such regular decrease in sulphur content was observed They suggested that this is due to the fact that most of soil sulphur present in acid soils is primarily organic in nature while in the case of alkaline soils, the non organic forms dominate. Organic sulphur content also showed a regular decline with depth in the profiles

Ganeshamurthi et al. (1989) reported that in the hill slope soils of Andaman-Nicobar island a regular decline of organic and sulphate sulphur with depth can be observed. They stated that the higher sulphur content in surface soils was associated with higher organic matter content

2.3 Available sulphur using different extractants

Available sulphur in soil is usually determined using different extractants, viz , water, neutral solutions, dilute acids, phosphate solutions etc

2.3 1 Water soluble sulphur

Water soluble sulphur content varies widely in different soils of India The minimum value of 1.8 ppm was reported for soils of Madhya Pradesh (Bansal et al , 1979) Tanawade (1976) reported that water soluble sulphate fraction constituted about 11 3 per cent of total sulphur and ranged from 6 (laterite) to 54 ppm (clayey soil) with an average of 30 ppm in soils of Maharashtra According to Lande et al (1977) water soluble sulphur ranged as 5.1-22 ppm with an average of 10.7 ppm in surface soils of Maharashtra Rawat and Srinivas (1979) reported that the water soluble sulphur content in soils of Udaipur, Rajasthan was 184 ppm, the range being 9-32 ppm. Tiwari et al (1983) reported that alluvial soils of Uttar Pradesh contained about 14.9 ppm water soluble sulphur. Ahmed and Jha (1969) in their studies about sulphur status in Bihar soil reported that water soluble sulphur ranged between 5.7 and 36 ppm

Ruhal and Paliwal (1978) reported that cold water extracted 69 6 ppm, 22 8 ppm and 49.9 ppm in desert, grey brown and undifferentiated alluvium in soils of Rajasthan. Dwivedi et al. (1983) arrived at the conclusion that water soluble sulphur ranged between 14.1 and 36.5 ppm with a mean of 22 5 ppm in Gangaflats Karwasra et al. (1986) had shown that the soils of Haryana possessed 31.1 ppm water soluble sulphur which constituted about 21.1 per cent of total sulphur. Sharma et al. (1988) noticed that the water soluble contents of sulphur were 15.3 ppm, 14.7 ppm, and 30 6 ppm in wet temperate zone, humid subtropical zone, and subhumid subtroprical zones of W.Himalaya respectively.

Mehta et al. (1988) reported that water soluble sulphur constituted only a small percentage of total sulphur in alluvial soils The respective values of water soluble sulphur in Himachal Pradesh, Punjab and Tamil Nadu were 17, 22 and 18 ppm respectively (Palaskar and Ghosh, 1982 Ghai et al. 1984, Balasubramanian and Kothandaraman, 1985). Leela (1967) reported that water soluble sulphur constituted only a small fraction of total sulphur in Kerala soils. The respective values for water soluble sulphur in sandy, laterite and red loam soils were 18, 27, 35 ppm respectively. Cicy (1989) reported that Karappadam soils contained about 76.5 ppm sulphur while the Kayal and Kari soils contained respectively about 156 8 ppm and 139 8 ppm water soluble sulphur. Sureshlal and Mathur (1985) observed a wide range of 62-1161 ppm water soluble sulphur in Indian soils.

2.3 2 Ammonium acetate extractable sulphur

Balasubramanian and Kothandaraman (1985) reported that the available sulphur extracted by neutral normal ammonium acetate constituted about 1-33 per cent of total sulphur They noticed that sulphur extracted by ammonium acetate ranged from 54 to 130 ppm in soils of Coimbatore district of Tamil Nadu. The low proportion of neutral normal ammonium acetate soluble sulphur in Tamil Nadu soils was also reported by Ayyathurai (1969) Leela (1967) reported that ammonium acetate extractable sulphur in the lake soils of Vellayani and the laterite soils of Pattambi were 175 ppm and 87 ppm respectively, which constituted about 14.2 and 85 per cent of the total sulphur. Ganeshamurthi et al (1989) reported that ammonium acetate extract more sulphur than that of water The ammonium acetate extractable sulphur ranged from 333 to 4106 ppm in the surface soils of the coastal planes of Andaman Nicobar islands. Arora and Takkar (1988) reported that ammonium acetate extracted 11 3 ppm sulphur the range being 3.9-36 8 ppm in Ludhiana soils

2.3.3 HCl extractable sulphur

Balasubramanian and Kothandaraman (1985) reported that HCl extractable sulphur constituted 1-14 per cent of total sulphur in Tamil Nadu soils. N HCl extracted about 23-110 ppm sulphur from the soils of Tamil Nadu Sharma et al. (1988) had shown that 0.001 N HCl extracted 13 1 ppm, 14.6 ppm and 29.4 ppm sulphur respectively from wet temperate zone, humid subtropical zone and subhumid subtropical zones of W.Himalaya.

Leela (1967) reported that N HCl extracted 825 ppm and 500 ppm sulphur from red loam lake soils of Vellayani and laterite soils of Pattambi in Kerala She found that HCl extractable sulphur was more than the water soluble form. Shukla and Ghey (1971) reported that N HCl extracted more sulphur than Morgan s reagent in soils of Rajastan

2.3.4 Morgan's reagent extractable sulphur

Shinde (1988) reported that Morgan's reagent was proved to be the best suitable extractant for available sulphur as compared to other extractants like salt solutions, phosphate solutions etc. in black and alluvial soils of Madhya Pradesh Ghai et al. (1984) reported that in Punjab soil, Morgan's reagent extractable sulphur ranged from 4 2 to 52 1 ppm with an average of 17 1 ppm. Balasubramanian and Kothandaraman (1985) reported that Morgan's reagent extractable sulphur was high compared to neutral normal ammonium acetate and normal HCl extractable sulphur. They opined that the available sulphur extracted by Morgan's reagent to total sulphur was 14.94 per cent of the total sulphur The corresponding values in Uttar Pradesh, Madhya Pradesh and Delhi were 15.1, 6 2 and 101.2 ppm as reported by Tiwari et al. (1983), Bansal et al. (1979) and Palaskar and Ghosh (1982).Jethra etal (1989) reported that soils of Amer region in Rajasthan contained 37.5 ppm Morgan's reagent extractable sulphur where as Bairath region contained 45.1 ppm sulphur.

Karwasra et al (1986) reported that Morgan's reagent extracted about 11.7 per cent of total sulphur Morgan's reagent extractable sulphur ranged between 6 3 and 65 6 ppm with a mean of 16.8 ppm in Haryana soils Arora and Takkar (1988) had shown that Morgan's reagent extractable sulphur ranged 45 4-46 ppm with a mean of 16 ppm. They established that Morgan's reagent extracted more sulphur than ammonium acetate and HCl. Ganeshamurthy et al (1989) reported that Morgan's reagent extracted more sulphur than water in soils of Andaman soils. In hill slope soils of Andaman Morgan's reagent extractable sulphur ranged from 313 to 691 ppm. Biswas et al (1989) reported that Morgan's reagent extracted more sulphur than that of 0.001 N HCl in soils collected from Mangoorchards of Lucknow.

2 4 Relationship between forms of sulphur and soil properties

2.4.1 Soil texture

There exists a positive relationship between clay content and sulphur content in soils. The direct relationship between clay and total sulphur in many soils were reported by Halder and Barthakur (1976), Ruhal and Paliwal (1980b), Dolui and Nayak (1981), Patil et al (1981b) and Singh et al (1985). Arora and Takkar (1988) reported that clay and silt contents had positive relationship with total, organic and sulphate sulphur. Clay is positively correlated with sulphate (0.67) organic (0.86) and total (0 82) sulphur and silt is related with sulphate (0 85), organic (0 87) and total (0.89), sulphur They opined that the positive relation between clay and organic sulphur was due to association of organic matter with clay fraction of soils.

Fine textured soils of Bihar contained higher content of organic sulphur than coarse to medium textured soil. Silt and clay fractions were shown to be related with organic sulphur content of Hangarian series of Sangrur, Punjab (Ahmed and Jha, 1969 Aulakh and Dev, 1976). A higher organic sulphur content in fine textured soils than in coarse textured soils of Gujarat and Andhra Pradesh has been reported by Reddy and Mehta (1970), and Prasad et al. (1983) Vijaykumar and Maharaj Singh (1974) reported that organic sulphur content markedly increased with the fineness of texture. The cause of this increase in the organic sulphur content with the fineness of texture may be related to the increased organic carbon content in fine textured soils.

Aulakh and Dev (1976) reported that sulphate sulphur content was shown to be a function of silt + clay fraction and clay fraction in typic Ustipsamment of Hoshiarpur, Punjab. They observed a positive correlation of 0.307, 0 921 and 0.884 between silt + clay content and organic, sulphate and water soluble sulphur The positive correlation between different forms of sulphur and clay content were reported by Singh and Chhibba (1987), Dwivedi et al. (1983) and Shukla and Ghey (1971).

2 4.2 Soil reaction

Takkar (1988) reported that acid soils contained more sulphur than alkaline soils. He opined that acid soils have high content of free aluminium and iron oxides which have high adsorption capacity for sulphates. Tiwari and Pandey (1990) reported that a significant but negative correlation existed between pH and all forms of sulphur except for nonsulphate sulphur. They opined that the increase in pH value would result in decrease in various forms of sulphur. An intimate relationship between pH and soluble forms of sulphur in some series of Punjab was reported by Aulakh and Dev (1976). Misra et al. (1990) reported that in brown forest soils of Orissa, pH was correlated with total sulphur (0.98) and organic sulphur (0.98).

Ananthanarayana et al (1986) reported that pH showed negative correlation with available sulphur content in the soils of Karnataka. Pandey et al. (1989) also reported that significant negative correlation existed between soil reaction and all forms of sulphur in alluvial soils of Uttar Pradesh. Karle et al. (1985) found that pH and the different forms of sulphur were positively correlated in the soils of Maharashtra This finding was also supported by Patil et al. (1981b) in his studies of sulphur in Maharashtra soils.

2 4.3 Electrical conductivity

Accumulation of sulphur is generally accompanied by accumulation of sulphate Very high values of sulphur in saline soils of Canning, West Bengal (Hegde et al , 1980) and relatively high contents in coastal saline and alkaline alluvial soils have resulted from the accumulation of sulphate salts in these soils. Cheema and Arora (1984) reported that sulphate sulphur is a function of salt content in alluvial soils of Ludhiana. Singh and Chhibba (1987) reported that in typic Ustipsamment soils of Bhunga block of Hoshiarpur, the sulphate sulphur was positively correlated with salt content in the soils.

Arora and Takkar (1988) found that total sulphur, organic sulphur and sulphate sulphur were functions of electrical conductivity in the soils of some entisols and inceptisols of Ludhiana. Electrical conductivity was positively correlated with sulphate sulphur (0 79**), organic sulphur (0 87**) and total sulphur(0.88**). The relationship between soil salinity and sulphur content was also reported by Pandey et al. (1989) in alluvial soils of Uttar Pradesh Electrical conductivity was negatively correlated with total sulphur (0.80) and positively related with organic sulphur (0.81) and sulphate sulphur (0.78) Aulakh and Dev (1976) reported the positive relationship between electrical conductivity and sulphur content in soils of Punjab.

2.4 4 Calcium carbonate

Karle et al (1985) reported that in soils of Maharashtra calcium carbonate showed a positive significant relationship with total sulphur (0 63**) and water soluble sulphur (0.80**) Patil et al. (1989b) analysed forty surface soil samples from different localities of Maharashtra

State and reported that total, organic and water soluble sulphur showed positive significant correlation with free calcium carbonate. Takkar et al. (1985) and Takkar et al. (1986) have shown that the extent of sulphur deficiency decreased from 43 to 30 per cent in alluvial soils of Ludhiana as calcium carbonate content exceeds 1 per cent level in the soils.

Vinay Singh and Sharma (1983) reported a positive correlation between calcium carbonate and sulphate sulphur in citrus growing soils of Agra region Pandey et al (1989) from their studies on different forms of sulphur in alluvial soils concluded that no significant correlation existed between calcium carbonate and sulphur content in soils.

2.4.5 Organic matter and other nutrient elements

Total sulphur in most of the soils of India has been shown to be a function of soil organic matter as both are significantly and positively interrelated (Kanwar and Mohan, 1964 Kanwar and Takkar, 1963 Virmani and Kanwar, 1971). Tiwari and Pandey (1990) reported that total sulphur, organic sulphur and sulphate sulphur were positively correlated with organic matter in soils. They found that organic carbon showed positive relationship with total sulphur (0 272), organic sulphur (0.325) and sulphate sulphur (0.280) Takkar *et al*. (1984) and Takkar *et al* (1985) have further shown that soil organic matter regulated markedly the content of sulphate sulphur in alluvial soils of Ludhiana and Bhandia. As the organic carbon increased, the proportion of percent samples deficient in sulphur strikingly decreased.

Arora and Takkar (1988) had shown that in Ludhiana soils organic carbon had positive correlation with sulphate sulphur (0 73**), organic sulphur (0 97**) and total sulphur (0.97**). Misra *et al*. (1990) established that significant positive relationship exists between organic carbon and total sulphur (0.75**) in red and laterite soils of Orissa. Significant positive relationship between sulphate sulphur and organic carbon and sulphate had been shown by Bharadwaj and Pathak (1969), Kumar and Singh (1974) and Ruhal and Paliwal (1980b) in Indian soils. Balanagoudar and Satyanarayana (1990 a) reported that lower values of organic sulphur at deeper layers was attributed to organic matter content of soil Dwivedi *et al*. (1983) reported that organic carbon showed positive relationship with total sulphur (0.61), organic sulphur (0.8) and sulphate sulphur (0.82) in Ganga flat.

Virmani and Kanwar (1971) reported highly significant relationship existed between organic carbon and organic sulphur in acid soils (0.971) and alkali soils (0.356). The positive correlation between organic sulphur and organic matter has been established by many workers (Lande, <u>et</u> <u>al</u> 1977 Leela, 1967 Vijaykumar and Maharaj Singh, 1974) Since sulphur is a constituent of organic matter its content in Indian soils has been shown to be governed by the amount and nature of organic matter (Venkateswarlu <u>et</u> <u>al</u>., 1969 Dolui and Nayak, 1981 Singh and Sharma, 1983 Reddy <u>et</u> <u>al</u> , 1985).

Since sulphur is a constituent of the soil organic matter, its enrichment with sulphur generally determines the sulphur supplying capacity of the soils (Takkar, 1988). Cicy (1989) reported a narrow C S ratio 48, 20 and 14 5 for Karappadom, Kayal and Kari soils of Kerala

Joshi (1984) reported the relation between C, N, organic P and organic sulphur on the tea soils of Himachal Pradesh He found that the soils of higher altitude had better sulphur supplying capacity than those of the lower altitude, because of narrow C organic sulphur ratio (100 1.4) in the former than in the later (100 1.2) The C N P S ratios in the soil organic matter of selected Entisols, Mollisols, Vertisols and Alfisols were 100 12.5 4 6 3 6, 199 7 8 2.7 2.3, 100 11 4 8 4 7 and 100 11.9 4.8 4 3

(0.147*), organic sulphur and sulpahte sulphur (0.265**), sulphate sulphur and water soluble sulphur (0.270**), organic sulphur and water soluble sulphur (0.216) in soils of Varanasi region. The significant positive relationship among total sulphur, water soluble sulphur, Morgan's reagent extractable sulphur, HCl soluble sulphur and sulphate sulphur were emphasised by Leela (1967) in Kerala soils. Cicy (1989) also reported the positive relationship between total sulphur and water soluble sulphur (0.6899**), total sulphur and sulphate sulphur (0 8771**), total sulphur and Morgan's reagent extractable sulphur (0.8062**), and total sulphur and organic sulphur (0 9391**) in Kuttanad soils of Kerala. The highly significant positive correlation between total sulphur and organic sulphur in soils of Tamilnadu was reported by Balasubramanian et al (1989).

Balanagoudar and Satyanarayana (1990 b) had shown significant relationship between sulphate sulphur and water soluble sulphur (0.937**), total sulphur and water soluble sulphur (0.268**) and total sulphur and sulphate sulphur (0.280**). Ruhal and Paliwal (1980a) reported the positive relation between total sulphur and organic and sulphate forms in undifferentiated alluvium in Rajasthan soils. The positive relationship of water soluble sulphur, HCl soluble sulphur and Morgan's reagent soluble sulphur with total and organic sulphur in Rajasthan soils were reported by Ruhal and Paliwal (1980b).

Kanwar and Takkar (1964) also reported the intimate relationship of organic sulphur with organic P as well as with organic carbon and total nitrogen in soils of Punjab Tarafdar (1989) reported that the N/S and P/S ratio of soils belonging to some series in Assam ranged from 7 1 to 10 and 6.6 to 1.3 respectively Balanagoudar and Satyanarayana (1990 b) reported that the carbon organic sulphur ratio varied from 27 3 to 123 5 in soils of Karnataka probably due to the diverse nature of organic matter The ratio increased with depth showing higher organic sulphur in surface soils. Leela (1967) reported that in Kerala soils, N S ratio varied as 0.32-1.87 N S ratio existing in the lake soils of Vellayani, laterite soils, sandy soils and forest soils were 1.87, 0.84, 0.75 and 0 80 respectively The positive correlation between available sulphur and total nitrogen, phophorus and total bases like calcium, magnesium and potassium in soils of Chickmagalur district of Bangalore was established by Krishnappa et al (1989).

2.5 Inter relationship between different forms of sulphur

The inter relationship among different forms of sulphur has been reported by many workers Tiwari and Pandey (1990) had proved the positive relation between total sulphur and organic sulphur (0.212**), total sulphur and sulphate sulphur (0 178*), total sulphur and water soluble sulphur

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Sharma *et al*. (1988) reported that in soils of North Western Himalaya total and organic sulphur were positively correlated with Morgan's reagent extractable sulphur and water soluble sulphur. In wet temperate zones of the Himalayas total sulphur showed significant positive correlation with water soluble sulphur (0.80^{**}) and also with Morgan's reagent extractable sulphur (0.73^{**}). The significant positive relationship between water soluble sulphur and sulphate sulphur in alluvial soils of Uttar Pradesh had been established by Pandey *et al*. (1989).

Dolui and Saha (1983) in their studies of the sulphur status of some soils of West Bengal reported that both total and organic sulphur had positive and significant correlation with sulphate sulphur Shukla and Ghey (1971) reported that the sulphur extractable in water and Morgan's reagent was positively related to total and organic sulphur. They found that only water soluble sulphur was related to inorganic sulphur in the soils of Rajasthan. Vinay Singh and Sharma (1983) opined that since sulphate sulphur and total water soluble sulphur are in a dynamic equilibrium, they are related significantly with each other.

2.6 Plant uptake

Total sulphur concentration in plants vary over a tenfold, ranging between 0.05 per cent and 0 5 percent depending largely on sulphur supply (Randall, 1988). A cereal crop producing 4 tonnes of grain can remove 12-16 kg sulphur Intensive cropping sequence can remove 30-72 kg sulphur/ha/yr under Indian conditions (Mehta and Raman, 1972 Nad and Goswami, 1984 Subha Rao and Ghosh, 1981).

Arora and Takkar (1988) reported that leaf sulphur in rice plants varied from 0.11 to 0.25 per cent with an average of 0-17 per cent whereas the wheat plants contained an average of 0 29 percent. In a study of sulphur in tropical countries, a net requirement of 6 kg S/t of grain production has been reported, the requirement being in the order oilseeds > pulses > cereals > millets (Kanwar and Mudahar, 1985). Under comparable conditions, a cereal dominated crop sequence may remove 2 kg sulphur/tonne drymatter production (Tandon, 1986)

Response towards sulphur application in plantation crops, tuber crops, oilseeds, cereals and legumes was reported by many workers (Bhat and Ranganathan, 1981 Korah et al., 1990 Pillai and Singh, 1975 Dev et al.,1979 Shinde, 1988). Jain et al. (1984) reported that the average uptake of sulphur by blackgram, greengram, sunflower, mustard and sugarcane were 5.1, 6.5, 16.5, 44 9 and 16 4 ppm respectively. Among the field crops, oilseeds have the highest requirement of sulphur per unit yield (Tandon, 1988)

Increase in yield and quality of oilseeds like groundnut, mustard, sunflower, linseed, sesamum etc. have been reported from many parts of India (Patil *et al.*, 1981 a Badiger *et al.*, 1982 Ankineedu *et al.*, 1983 Hooda and Dahiya, 1986 Dixit and Shukla, 1984 Rawat and Srinivas, 1976 Aipe, 1981 Singh and Sahu 1986 and Sharma *et al.*, 1991).

MATERIALS AND METHODS

MATERIALS AND METHODS

In order to study the status, forms and availability of sulphur in the upland soils of South Kerala, fifty localities representing ten each of the five major upland soil types of South Kerala viz., sandy, redloam, laterite midland, laterite midupland and forest soils were identified in Trivandrum district. Both surface and subsurface soil samples were collected from the below mentioned localities from depths of 0-20 and 20-50 cm.

Location of sites for soil collection

SANDY (Kandiudepts)

No.	Location	Depth (cm)	Village
1.	Oolankuzhy	0-20 20-50	Kadakampally
2.	Venpalavettam	0-20 20-50	Kadakampally
3.	Kuttivilakam	0-20 20-50	Kadakampally
4.	Kazhakoottam	0-20 20-50	Kadakampally
5.	Vetturoad	0-20 20-50	Meenamkulam
6	Alummoodu	0-20 20-50	Pallippuram
7.	Pallippuram	0-20 20-50	Andoorkonam

8.	Vetturoad	0-20 20-50	Meenamkulam
9	Arattuvazhi	0-20 20-50	Meenamkulam
10.	Kariyil Kazhakoottam	0-20 20-50	Meenamkulam
REDLOAM (Kandiudults)			
11.	College of Agriculture	0-20 20-50	Nemam
12.	Poonkulam	0-20 20-50	Nemam
13.	Vandithadam	0-20 20-50	Thiruvallam
14.	Pachalloor	0-20 20-50	Thiruvallam
15.	Thiruvallam	0-20 20-50	Thiruvallam
16.	Koliyoor	0-20 20-50	Thiruvallam
17	Chavadinada	0-20 20-50	Vizhinjam
18.	Vouvamoola	0-20 20-50	Venganoor
19	Peringamala	0-20 20-50	Venganoor
20.	Coconut Research Station	0-20 20-50	Balaramapuram
LATERITE MIDLAND (Kandiudults)			
21.	Palamkonam	0-20 20-50	Manamboor
22	Kannankara	0-20 20-50	Manamboor

23	Velankonam	0-20 20-50	Attingal
24	Keraladithyapuram	0-20 20-50	Uliyazhathura
25	Aliyavoorkonam	0-20 20-50	Uliyazhathura
26.	Kuttiani	0-20 20-50	Vattappara
27.	Vattappara	0-20 20-50	Vattappara
28.	Kazhunadu	0-20 20-50	Vattappara
29.	Maruthoor	0-20 20-50	Karakulam
30.	Aruviyod	0-20 20-50	Ulloor
LATERITE MIDUPLAND (Kandiudults)			
31.	R.K Estate	0-20 20-50	Palamoodu
32	Mundani	0-20 20-50	Mundani
33	Valikode	0-20 20-50	Nedumangadu
34.	Perumala	0-20 20-50	Nedumangadu
35.	Mandakuzhy	0-20 20-50	Karakulam
36.	Azhikode	0-20 20-50	Aruvikkara
37	Valavetti	0-20 20-50	Aruvikkara
38	Ayanikad	0-20 20-50	Karakulam

39.	Karakulam	0-20 20-50	Karakulam
40.	Kachani	0-20 20-50	Karakulam
FOREST	(Tropudolls)		
41	Kanchimoodu	0-20 20-50	Paruthipalli range
42.	Moonnattumukku	0-20 20-50	Paruthipalli range
43.	Mankodi	0-20 20-50	Paruthipalli range
44.	Thakkudi	0-20 20-50	Paruthipalli range
45	Takkudi	0-20 20-50	Paruthipalli range
46.	Kappukadu	0-20 20-50	Paruthipalli range
47.	Irappupara	0-20 20-50	Paruthipalli range
48.	Field No. 5/23 Bonaccord Tea Estate	0-23 20-50	Bonaccord
49.	Field No 8/19 Bonaccord Tea Estate	0-20 20-50	Bonaccord
50.	Field No. 6/20 Bonaccord Tea Estate	0-20 20-50	Bonaccord

LABORATORY INVESTIGATIONS

3 1 **Soil Analysis**

The samples were airdried in shade and ground with a mallet. Each sample was then screened through a 2 mm sieve and screenings were collected and stored in labelled stoppered glass bottles.

The soil samples were examined for the following physico chemical characteristics using standard analytical procedures.

3 1.1 **Physico chemical characteristics of the soil**

(i) Mechanical analysis

International pipette method (Jackson, 1973) was followed for particle analysis of soil.

(ii). Soil reaction

The pH of soil water suspension (1 2.5) was determined by using Perkin Elmer pH meter (Jackson, 1973).

(iii) Electrical conductivity

Electrical conductivity of the supernatant liquid of 1 2.5 soil water suspension was read with the help of conductivity bridge (Jackson, 1973)

(iv). Organic carbon

Organic carbon content of soil was determined by Walkley and Black's rapid titration method as described by Jackson (1973).

(v) Total Nitrogen

Total nitrogen content of soil was determined by microkjeldhal method as described by Jackson (1973)

(vi). Total phosphorus

Total phosphorus in hydrochloric acid extract of soil was determined by chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1973).

(vii) Total Potassium, Calcium and Magnesium

Total potassium, calcium and magnesium in the acid extract of soil was determined by using Atomic absorption spectrophotometer (Hesse 1971) (viii). Sesquioxide content

Sesquioxide content in the soil was determined by the standard procedures as described by Hesse (1971)

3.1 2 **Forms of sulphur**

Total sulphur, organic sulphur and sulphate sulphur in soils were determined by the following methods.

I Total sulphur

Total sulphur content in the soil was determined as per the method described by FAO (1988) Weighed out 1 g of 0.15 mm sieved soil into a 100 ml conical flask and 5 ml of digestion mixture was added (The digestion mixture was prepared by dissolving 3 g potassium dichromate in 146 ml deionised water. It was then added to a mixture of 434 ml 70 per cent perchloric acid of specific gravity 1 65 and 420 ml concentrated nitric acid Added 10 ml of bromine to each liter of this mixture) The flask was then covered with a funnel and heated on a hot plate. After completion of oxidation stage, allowed the flask to simmer on the hot plate for one hour It was then cooled and the funnel was washed down with 10 ml of deionised water About 40 ml water was added so that the final volume was 50 ml. After keeping overnight, an aliquot was decanted off for the determination of sulphur

Sulphur in the aliquot was determined turbidimetrically according to the method of Chesnin and Yien (1951). To 5 or 10 ml of the aliquot taken in a 25 ml volumetric flask, added 1 g of 30-60 mesh $BaCl_2$ crystals followed by 2 ml 0.25 per cent gum acacia solution The solution was made upto the volume Turbidity readings were taken between 5 and 30 min after the precipitation in a Spectronic-20 Spectrophotometer and the sulphate was determined by reference to a standard curve.

II Organic sulphur

Organic sulphur in soil was estimated by the method of Evans and Rost (1945) 10 g soil was first leached with water, then with 1 per cent hydrochloric acid and finally with distilled water till free of chloride The soil was transferred to a beaker and oxidised with 30 per cent H_2O_2. When the oxidation was completed, it was filtered and the filtrate was then made upto 100 ml Sulphur content in an aliquot of the extract was determined turbidimetrically according to the method of Chesnin and Yien (1951)

III. Sulphate sulphur

Sulphate sulphur in the soil was extracted with 0.2 N HCl (1 5) after shaking for 30 minutes (Williams and Steinberg, 1962). The sulphur content in the extract was determined turbidimetrically according to the method of Chesnin and Yien (1951).

3.1.3 Available sulphur using different extractants

The different extractants used were

i) water
ii) neutral normal ammonium acetate solution
iii) normal hydrochloric acid
iv) Morgan's reagent

(i) Water soluble sulphur

The method of Frency (1958) was adopted for the determination of water soluble sulphur Soil was extracted with distilled water in the ratio 1 5 by shaking for 1 hour The suspension was then filtered and sulphate content in the solution was determined turbidimetrically as per the method of Chesnin and Yien (1951).

(ii). Neutral normal ammonium acetate extractable sulphur.

Soil was extracted with neutral normal ammonium acetate solution in the ratio 1 5 by shaking for 30 minutes The suspension was filtered and sulphur content in the aliquot was determined turbidimertically as described by Chesnin and Yien (1951).

(iii). 1N HCl extractable sulphur

Soil was shaken with IN HCl in the ratio 1 5 for 30 minutes. The sulphur content in the aliquot was determined turbimetrically according to the method of Chesnin and Yien (1951).

(iv). Morgan's reagent extractable sulphur

The method of Chesnin and Yien (1951) was followed for the determination of Morgan's reagent extractable sulphur. Soil and Morgan's reagent (100 g sodium acetate and 30 ml 99 5 per cent acetic acid dissolved in 500 ml water and the volume made upto 1 litre) in the ratio 1 5 were shaken for half an hour and suspension was filtered and sulphur content in the aliquot of the extract was determined turbidimetrically To overcome the problem of residual colour of soil extract 1 g activated charcoal was added to the soil mixture before shaking.

3.2 UPTAKE STUDIES.

(i) Neubauer technique

The different forms of sulphur and the available sulphur in the soil, determined using different extractants were correlated with the actual plant available sulphur as determined by modified Neubauer's technique for the six surface samples each of the five different types of soils.

100 g soil was mixed with 50 g of acid washed quartz sand, washed repeatedly with triple distilled water and placed in plastic dishes of 12 cm diameter and 8 cm height. Hundred seeds of rice of good quality (germination 100 percent) variety Jaya were uniformly sown in each dish. The sprouted seeds were irrigated periodically with triple distilled water The dishes were kept in the sun for five hours daily. The experiment was replicated twice Hundred seeds sown in 50 g of the sand represented the control Seventeen days after sowing the plants were uprooted. The harvested material was washed in 0.1 N HCl, dried, weighed, powdered and kept for chemical analysis in serially numbered clean plastic bottles

(ii) Plant Analysis

Plant samples were analysed by the method as outlined by A.O.A.C. (1960). 1 g sample was taken into a large porcelain crucible 7.5 ml magnesium nitrate solution was added so that all material came in contact with solution. Sample was heated on electric hotplate at 180°c until no further action occurs. The crucible was transferred while hot to electric muffle and kept it remain at low heat until charge is thoroughly oxidised. Crucible was removed from muffle and let cool Added water and then hydrochloric acid in excess, brought the solution to boil, filtered and washed thoroughly. Sulphur content in the solution was determined turbidimetrically according to the method of Chesnin and Yien (1951).

RESULTS

RESULTS

The results obtained in the present study are detailed here under

4 1 Physico-chemical properties of the soils

4 1 1 Mechanical composition

The Mechanical composition of the hundred soil samples included in the study are presented in Table 1 and the range and mean values of the different soil seperates in the various soil types are given in Table 2

The results clearly indicate that except for sandy soils, there was appreciable uniformity in the texture of the soils of different types The texture of the four types viz redloam, laterite midland, laterite midupland and forest soils were sandy clay loam where as in sandy soils, it varied from sand to loamy sand

In the surface layers of sandy soils, coarse sand varied from 64 8 to 70 2 %, fine sand from 12 0 to 15 2 %, silt from 5 0 to 7 0 %, and clay from 9 0 to 13.9 %, the mean values being 67 3, 14 0, 5 8 and 10 3 % respectively In subsurface layers the coarse sand, fine sand, silt and clay ranged between 62 8 and 65 9%, 14 1 and 18 2 %, 6 8 to 7.5 % and 8 0 and 11 8 % with mean values 64 2, 17 1, 7 2 and 8.5 % respectively.

In the surface of redloam soils, the coarse sand, fine sand, silt and clay varied from 45 0 to 49 5 %, 23.9 to 26.1%, 7 1 to 12 5 % and 16 9 to 19.0 % where as in sub surface layers these fractions varied from 43.1 to 49 5 % 21.0 to 24 2 %, 9 0 to 12 9 % and 17 4 to 22.0 % The respective average values of soil seperates were 46 7, 25.1, 9.3 and 18.2 % for surface samples and 45 5, 23 0, 10 7 and 20 2 % for subsurface samples.

In the laterate midland soils the range values of coarse sand varied between 48.6 and 54 0 % (mean 50.6 %), fine sand 14 0 and 16 1 % (mean 15 3 %) silt between 8 1 and 13.0 % (mean 10 4 %) and clay between 21 8 and 25.3 % (mean 24 0 %) for surface layers In subsurface layers, the values ranged from 47 1 to 53 0 % (mean 48 7 %), 13 4 to 14.9 % (mean 14 1 %), 9.1 to 13.5 (mean 11 9 %) and 24 0 to 26 4 % (mean 24.9 %) for the different textural fractions such as coarse sand, fine sand, silt and clay respectively

In surface layers of laterite midland soils, coarse sand, fine sand, silt and clay varied from 46 7to52 5 % 13 0to 15.3 %, 9 6 to 13 5 % and 21.9 to 24 1 % and in sub surface

Table - 1

MECHANICAL COMPOSITION OF SOILS

Sample No	Depth cm	Mechanical composition (percentage) Coarse sand	Fine sand	Silt	Clay	Textural class
1	2	3	4	5	6	7
SANDY SOILS						
1	0-20	68.0	13.1	6.0	12 0	Loamy sand
	20-50	65 9	16.2	7.0	10.1	Loamy sand
2	0-20	64 8	12.9	6 1	13.9	Loamy sand
	20-50	63 0	14.1	6.8	10.5	Loamy sand
3	0-20	69 0	12 0	5.5	11.5	Loamy sand
	20-50	63.1	18 0	7.1	10.3	Loamy sand
4	0-20	65 1	15.0	7.0	12.0	Loamy sand
	20-50	64.0	18.0	7.0	10.1	Loamy sand
5	0-20	67.0	14 0	6.0	12.0	Loamy sand
	20-50	65.1	18.2	7 0	8.1	Sandy
6	0-20	68.0	16 0	5.0	10.1	Sandy
	20-50	65.1	17.0	7 0	9 0	Sandy
7	0-20	68.1	12 9	5 7	12.7	Loamy sand
	20-50	63.0	16 9	6.9	10 5	Loamy sand
8	0-20	70.2	14.0	5.0	9.0	Sandy
	20-50	64.9	18.0	7 0	8.0	Sandy
9	0-20	68 0	15.0	5 6	10.1	Loamy sand
	20-50	65.0	17 4	7 5	8.1	Sandy
10	0-20	64 9	15 2	6 0	12.9	Loamy sand
	20-50	62 8	17.4	7 2	11.8	Loamy sand

1	2	3	4	5	6	7
RED LOAM						
11	0-20	49.1	15 4	7 1	17 6	Sandy clay loam
	20-50	46.0	23.5	9.9	19.4	Sandy clay loam
12	0-20	49.0	24.9	8 4	18.2	Sandy clay loam
	20-50	47.9	22.7	9.0	20.1	Sandy clay loam
13	0-20	45.9	25 6	9.4	18.7	Sandy clay loam
	20-50	44 1	24.1	11 0	20 0	Sandy clay loam
14	0-20	46.7	24.9	9 1	18.9	Sandy clay loam
	20-50	43 1	23.9	10.9	20 1	Sandy clay loam
15	0-20	46.9	26.1	8 7	18.1	Sandy clay loam
	20-50	44.7	24.0	10.9	20 1	Sandy clay loam
16	0-20	44 0	25 7	12.5	16 9	Sandy clay loam
	20-50	44 1	24.2	12 9	17 4	Sandy clay loam
17	0-20	45 0	24.8	11 7	18.2	Sandy clay loam
	20-50	45 0	22 0	12.1	20.1	Sandy clay loam
18	0-20	48.2	23.9	9.0	17.9	Sandy clay loam
	20-50	49 5	21 0	10 0	19.5	Sandy clay loam
19	0-20	47.0	24.7	9 2	18.5	Sandy clay loam
	20-50	44.0	23.3	10 7	21 9	Sandy clay loam
20	0-20	45.0	25.4	10 1	19.0	Sandy clay loam
	20-50	44 0	22 4	11 5	21.4	Sandy clay loam
LATERITE MIDLAND						
21	0-20	54.0	15.2	8.1	22 1	Sandy clay loam
	20-50	53 0	14 6	9 0	24.0	Sandy clay loam

1	2	3	4	5	6	7
34	0-20	49.2	15.1	12.5	22.7	Sandy clay loam
	20-50	50.8	13.7	9.6	24.9	Sandy clay loam
35	0-20	49.0	14.9	11.9	23.4	Sandy clay loam
	20-50	48.0	14.0	12.0	25.4	Sandy clay loam
36	0-20	49.5	13.9	13.5	22.1	Sandy clay loam
	20-50	49.0	13.5	12.2	24.2	Sandy clay loam
37	0-20	52.5	14.5	10.4	21.9	Sandy clay loam
	20-50	51.7	13.0	11.2	23.2	Sandy clay loam
38	0-20	50.0	15.1	10.9	22.9	Sandy clay loam
	20-50	44.7	14.4	12.0	27.5	Sandy clay loam
39	0-20	48.0	15.3	12.2	23.9	Sandy clay loam
	20-50	46.0	13.9	13.0	26.2	Sandy clay loam
40	0-20	46.7	14.7	13.1	24.0	Sandy clay loam
	20-50	46.0	13.2	13.7	25.9	Sandy clay loam
FOREST						
41	0-20	46.5	11.1	11.5	30.1	Sandy clay loam
	20-50	41.8	10.2	12.3	35.0	Sandy clay loam
42	0-20	44.0	13.2	10.6	31.2	Sandy clay loam
	20-50	40.2	12.1	12.1	34.9	Sandy clay loam
43	0-20	43.1	12.9	11.1	32.2	Sandy clay loam
	20-50	38.9	11.8	14.1	34.9	Sandy clay loam
44	0-20	43.8	14.2	10.7	30.5	Sandy clay loam
	20-50	37.9	12.1	12.5	35.0	Sandy clay loam
45	0-20	43.2	13.9	10.5	32.1	Sandy clay loam
	20-50	43.5	10.9	12.1	33.0	Sandy clay loam

1	2	3	4	5	6	7
22	0-20	53.9	15 1	8.9	21.9	Sandy clay loam
	20-50	50 2	14.2	10.9	24.1	Sandy clay loam
23	0-20	51.1	15 0	9 0	24.2	Sandy clay loam
	20-50	47 4	14.5	10.5	26.4	Sandy clay loam
24	0-20	50.0	14 0	10 2	25.3	Sandy clay loam
	20-50	48.4	13.5	11.5	26.9	Sandy clay loam
25	0-20	50.2	15.5	10.0	23.4	Sandy clay loam
	20-50	49 5	13 7	11 7	25.2	Sandy clay loam
26	0-20	49 6	16.0	9.8	24.1	Sandy clay loam
	20-50	49.0	14.9	12 4	24.3	Sandy clay loam
27	0-20	48 9	15.1	12.0	23 2	Sandy clay loam
	20-50	47 1	14.3	13 4	24.4	Sandy clay loam
28	0-20	50 4	16 1	10.7	22.1	Sandy clay loam
	20-50	48 4	14.0	12.0	25 0	Sandy clay loam
29	0-20	48.6	15 7	12.2	23.2	Sandy clay loam
	20-50	47.4	13 4	13.5	24.9	Sandy clay loam
30	0-20	49 3	14 9	13 0	21 8	Sandy clay loam
	20-50	42 2	14.0	14 0	24.1	Sandy clay loam
LATERITE MID UPLAND						
31	0-20	51.1	14.5	9 1	24.1	Sandy clay loam
	20-50	49 1	13.6	10.2	26.2	Sandy clay loam
32	0-20	50.5	15.2	10.7	22 7	Sandy clay loam
	20-50	48.1	13.4	12 2	25.4	Sandy clay loam
33	0-20	50 5	14 8	11 1	23 1	Sandy clay loam
	20-50	48 7	14 0	11.8	25.0	Sandy clay loam

1	2	3	4	5	6	7
34	0-20	49.2	15.1	12 5	22.7	Sandy clay loam
	20-50	50.8	13.7	9 6	24.9	Sandy clay loam
35	0-20	49 0	14 9	11.9	23.4	Sandy clay loam
	20-50	48 0	14 0	12.0	25.4	Sandy clay loam
36	0-20	49.5	13 9	13.5	22.1	Sandy clay loam
	20-50	49.0	13.5	12.2	24.2	Sandy clay loam
37	0-20	52.5	14.5	10.4	21 9	Sandy clay loam
	20-50	51.7	13.0	11.2	23.2	Sandy clay loam
38	0-20	50.0	15.1	10.9	22.9	Sandy clay loam
	20-50	44.7	14.4	12.0	27.5	Sandy clay loam
39	0-20	48.0	15.3	12.2	23.9	Sandy clay loam
	20-50	46.0	13.9	13 0	26.2	Sandy clay loam
40	0-20	46.7	14 7	13.1	24.0	Sandy clay loam
	20-50	46 0	13.2	13.7	25.9	Sandy clay loam
FOREST						
41	0-20	46 5	11.1	11.5	30.1	Sandy clay loam
	20-50	41 8	10.2	12.3	35.0	Sandy clay loam
42	0-20	44.0	13.2	10.6	31.2	Sandy clay loam
	20-50	40.2	12.1	12.1	34.9	Sandy clay loam
43	0-20	43.1	12.9	11 1	32.2	Sandy clay loam
	20-50	38.9	11.8	14.1	34.9	Sandy clay loam
44	0-20	43 8	14 2	10 7	30 5	Sandy clay loam
	20-50	37.9	12.1	12 5	35.0	Sandy clay loam
45	0-20	43.2	13 9	10 5	32 1	Sandy clay loam
	20-50	43.5	10 9	12.1	33.0	Sandy clay loam

1	2	3	4	5	6	7
46	0-20	43 0	13 8	12.6	30 0	Sandy clay loam
	20-50	40.4	11 5	14 1	34.1	Sandy clay loam
47	0-20	42.7	12.9	11 7	32.0	Sandy clay loam
	20-50	43 0	11.6	11 1	34 0	Sandy clay loam
48	0-20	42 9	14.1	12.7	30.1	Sandy clay loam
	20-50	41 0	13.0	11 3	34.2	Sandy clay loam
49	0-20	43.0	13 9	12.0	30 5	Sandy clay loam
	20-50	39 5	12.1	12.1	35.7	Sandy clay loam
50	0-20	43.2	13.1	13 5	29.4	Sandy clay loam
	20-50	40 0	11.0	14.2	34.1	Sandy clay loam

Table - 2

MEAN AND RANGES OF MECHANICAL COMPOSITION OF SOILS

Soil Type	Depth cm	Coarse and %	Fine sand %	Silt %	Clay %
Sandy	0-20	67 3 (64 8-70 2)	14.0 (12.0-15.2)	5 8 (5 0-7 0)	10 3 (9.0-13.9)
	20-50	64.2 (62 8-65.9)	17 1 (14 1-18 2)	7.2 (6 8-7.5)	8 5 (8 0-11.8)
Redloam	0-20	46 7 (45 0-49 5)	25.1 (23 9-26 1)	9 32 (7.1-12 5)	18 2 (16 9-19 0)
	20-50	45.5 (43.1-49.5)	23.0 (21.0-24.2)	10.7 (9.0-12.9)	20.2 (17 4-22.0)
Laterite midland	0-20	50 6 (48 6-54 0)	15 3 (14.0-16 1)	10.4 (8.1-13 0)	24.0 (21.8-25.3)
	20-50	48.7 (47.1-53 0)	14 1 (13.4-14.9)	11 9 (9.1-13 5)	24 9 (24 9-26.4)
Laterite midupland	0-20	49 7 (46.7-52.5)	14.8 (13.0-15.3)	11 3 (9.6-13.5)	23 1 (21 9-24.1)
	20-50	48 0 (44.7-51.7)	13.6 (13.0-14.4)	12 1 (9.6-13.7)	25 4 (23 2-27.5)
Forest soil	0-20	43.5 (42.0-46.5)	13.1 (11 1-14.2)	12 0 (10.5-13.5)	30 8 (29.4-32.2)
	20-50	40.7 (38.9-43.5)	11 8 (10.2-13.0)	12.2 (11 1-14.2)	34 2 (33.0-35.7)

Figures in paranthesis are the range values

layers these fractions varied from 44.7to51 7%, 13 0 to 14 4 % 9 6 to 13 7 %, 23 2 to 27.5% respectively. The corresponding mean values of these fractions were 49 7, 14 8 11 3 and 23 1 % in surface layers and 48 0, 13 6, 12 1 and 25.4%in subsurface layers

In the surface layers of forest soils, coarse sand varied from 42.0 to 46 5 %, fine sand 11 1 to 14.2 % silt 10 5 to 13 5 % and clay 29 4 to 32.2 %, the mean being 43.5, 13 1, 12 0 and 30 8 % respectively In the subsurface layers the coarse sand, fine sand, silt and clay ranged from 38 9 to 43 5 %, 10 2 to 13 0 %, 11 1 to 14.2 %, 33 0 to 35 7 % with mean values 40.7, 11 8, 12.2 and 34.2 % respectively

Chemical properties

Chemical properties of the soils under study are given in Tables 3 and 4.

4 1 2 Soil reaction

Generally, all the soils under the present study were acidic in reaction In surface layers acidity of the soils increased in the order Sandy < redloam < laterite midland < laterite midupland < forest soils pH of the surface samples varied from 4.9 to 6 0, 4 6 to 5 7, 4 7 to 5 5, 4.5 to 5.3 and 4 6 to 5 1, the mean value being 5.2, 5 1, 5 0, 4.8 and 4 7 respectively in sandy, redloam, laterite midland, laterite midupland and forest soils In subsurface layers of the respective soil types, pH ranged from 4.7 - 5 7, 4 5 to 5.7, 4 4 to 5 3, 4 2 to 4.8 and 4.2 to 5.1 with mean values of 5.0, 5 1, 4 8, 4.5 and 4 6 showing increasing trend in acidity with depth

4 1 3 Electrical conductivity

All the soil samples recorded low values of electrical conductivity proving the low salt content in the soils In surface layers elect rical conductivity ranged from 0 027 to 0.057 dS/m, 0 045 to 0 120 dS/m, 0 042 to 0.195 dS/m, 0 086 to 0.234 dS/m and 0 048 to 0.102 dS/m the mean value being 0.043, 0.073, 0 089, 0 146 and 0 075 dS/m respectively in sandy, redloam, laterite midland, laterite midupland and forest soils Electrical conductivity in subsurface layers of the corresponding soil types ranged from 0 027 to 0 048 dS/m, 0.042 to 0 087 dS/m, 0 030 to 0 168 dS/m, 0 084 to 0 270 dS/m and 0 048 to 0 132 dS/m with mean values 0.037, 0 058, 0 102, 0 161 and 0 074 dS/m

4 1 4 Organic carbon

Organic carbon ranged from 0 15 to 0.42 % in surface samples of the sandy soils and in the redloams it has varied from 0 15 to 0 67 %, the mean being 0 25 and 0.33 % respectively. The subsurface layers contained 0 12 to 0 39 % organic carbon in sandy soils and 0.06 to 0.6 % in redloams. the mean values of organic carbon in subsurface layers of sandy soils and redloams were 0 19 and 0.30 % respectively In the laterite midland and midupland soils, the organic carbon content ranged from 0 45 to 0 96 % and 0 90 to 1 38% in surface layers where as in subsurface layers it ranged from 0 33 to 0.80 % and 0.45 to 0.87 % The respective average values of organic carbon were 0.72 and 0.94 % in surface layers and 0 57 and 0 76 % in subsurface layers of laterite midland and laterite midupland soils In all these soils organic carbon tended to decrease with depth The surface layers of forest soils possessed an average amount of 1 66 % organic carbon, the range being 1.02 to 2 70 %, showing a comparatively higher content than in the other groups In subsurface layers, organic carbon ranged from 0 72 to 2 64 % with a mean value of 1 39 % Here also organic carbon tended to show a decreasing value with depth

4 1 5 Total nitrogen

Total nitrogen contents of the soil samples were found to be poor except for the forest soils The surface layers of the four soil types viz sandy, redloam, laterite midland and laterite midupland soils contained an average amount of 0 030, 0 080, 0 064 and 0 070 % while the range values being 0.029 to 0 034 %, 0 078 to 0 084 %, 0.059 to 0 075% and 0 067 to 0 075 % respectively Comparatively the higher content of nitrogen was observed in forest soils with a range value of 0.134 to 0 170 %

In the subsurface layers, the total nitrogen contents ranged between 0 026 and 0 030 %, 0 071 and 0 079 %, 0 050 and 0.071 %, 0 060 and 0 071 % and 0 120 and 0 162 % with corresponding mean values of 0 029 0 075, 0 063, 0 070 and 0.146 % in sandy, redloam, laterite midland, laterite midupland and forest soils In all the soil types, the total nitrogen was found to decrease with depth

4.1 6 Total phosphorus

Total phosphorus in surface samples ranged from 0 009 to 0 012 % in sandy soils (mean 0 010 %) and in redloams it varied from 0 012 to 0 019% (mean 0 014%) The corresponding range values in laterite midland, laterite midupland and forest soils were 0 011 to 0.017 %, 0.014 to 0.019 % and 0 026 to 0 037 %, and the mean values were 0 012, 0 017 and 0 031 % respectively The total phosphorus varied from 0 008 to 0 010 %, 0 010 to 0 017 %, 0 010 to 0 016 %, 0 010 to 0.014 % and 0.014 to 0 031 % in subsurface layers of sandy, redloam, laterite midland, laterite midupland and forest soils with mean values of 0.010, 0 012, 0.012, 0 011 and 0 024 % respectively

4 1 7 Total potassium

Total potassium ranged from 0 076 to 0 090 % in surface layers of sandy soils, the mean value being 0 079 % The potassium contents in the surface layers of redloam, laterite midland, laterite midupland and forest soils were 0 103, 0 128, 0.130 and 0.208 %, the range value being 0 090 to 0 140%, 0 112 to 0 143 %, 0 120 to 0.137 % and 0.190 to 0 262% respectively The range value of total potassium in subsurface layers were 0.059 to 0 086 %, 0 085 to 0.120 %, 0 110 to 0 137 %, 0 114 to 0 131 % and 0.185 to 0 126 % in sandy, redloam, laterite midland, laterite midupland and forest soils These soils contained an average amount of 0 104, 0 114, 0 119 and 0 199 % potassium respectively showing a decreasing trend with depth

4 1 8 Total calcium

Total calcium ranged from 0 056 to 0 075 % (mean 0.066%) in surface layers of sandy soils, 0 104 to 0 109 % (mean 0 105 %) in redloams, 0 105 to 0.126 % (mean 0 118 %) in laterite midland soils and 0 101 to 0.130 % (mean 0 116%) in laterite midupland soils

In forest soils, the range value of calcium was recorded as 0 132 to 0.157 % In the subsurface layers of sandy, redloam, laterite midland, laterite midupland and forest soils the total calcium varied from 0 041 to 0.071%, 0 090 to 0 103 %, 0 092 to 0 119 %, 0 100 to 0 128 % and 0 118 to 0 114 % with mean values of 0 056, 0.100, 0 118, 0.116 and 0 144 % respectively.

4 1 9 Total magnesium

The maximum value of total magnesium was recorded in surface layers of forest soils the range value being 0 195 to 0.213 % and minimum in sandy soils, the range being 0 095 to 0 112 %. The surface layers of redloam, laterite midland and laterite midupland soils contained 0 104 to 0 127 %, 0 120 to 0 134 % and 0 109 to 0 137 % respectively Range value of total magnesium were 0 041 to 0 109 %, 0 097 to 0.116%, 0 100 to 0 118 %, 0 100 to 0 118 and 0 146 to 0 202 % respectively ın subsurface layers of sandy, redloam, laterıte mıdland, laterıte mıdupland and forest soıls. The correspondıng mean values were 0.106, 0.114, 0 126, 0 129 and 0 202 % ın surface layers and 0 092, 0 102, 0 108, 0 107 and 0 175 % ın subsurface layers

4 1.10 Total sequıoxıdes

Sequıoxıdes ranged from 1 1 to 2 2 % wıth a mean value of 1.8 % ın surface layers of sandy soıls and ın the redloams ıt varıed from 5 4 to 6 5 %, the mean value beıng 5 8 % In both the soıls, sequıoxıdes ıncreased wıth depth The range values of sesquıoxıdes were 1 2 to 2 7 % and 5 7 to 7 2 % (mean 6 2 %) ın subsurface layers of sandy soıls and redloams respectıvely In laterıte mıdland and mıdupland soıls sesquıoxıdes ranged from 14.2 to 18.1 % and 16 1 to 20 3 % ın surface layers where as ın subsurface layers ıt varıed from 18 1 to 20.5 % and 18.3 to 22 3 % respectıvely The correspondıng mean values were 16.4 and 18.5 % ın surface layers and 19 4, 19 9 % ın subsurface layers In surface layers of forest soıls, the range value of sequıoxıdes was from 12.1 to 15.2%(mean 13 3 %) showıng a comparatıvely hıgher content than ın other types In subsurface layers the sesquıoxıdes ranged from 13 1 to 16 0 %, the mean value beıng 15 2 % In all the soıl types, sesquıoxıde content was hıgher ın the subsurface layers than ın the surface layers.

Table - 3

Chemical properties of soils

Sample No.	Depth cm	pH	EC dS/m	Organic carbon %	Total Nitrogen %	Total Phosphorus %	Total Potassium %	Total Calcium %	Total Magnesium %	Sesqui-Oxides %
1	2	3	4	5	6	7	8	9	10	11
SANDY SOIL										
1	0-20	4 90	0.057	0.19	0 033	0 009	0.081	0.067	0 107	1.8
	20-50	5.00	0.036	0.19	0 029	0.008	0.074	0 051	0.100	2.0
2	0-20	5.30	0 036	0.15	0.031	0 010	0.076	0.061	0.102	2 0
	20-50	5 00	0 033	0.14	0.028	0.009	0.062	0 047	0.109	2.2
3	0-20	5 10	0 033	0 42	0 030	1 011	0.084	0.071	0 097	2.0
	20-50	5 00	0 027	0.12	0.029	0 008	0.081	0 052	0 091	1 3
4	0-20	5.41	0.045	0.24	0 032	0.010	0.076	0.067	0.110	2.2
	20-50	5 30	0 031	0.20	0.028	0.010	0.069	0.062	0.109	2.7
5	0-20	5 10	0 033	0 30	0.029	0 009	0.085	0.071	0 095	2 0
	20-50	4.80	0.048	0.19	0 026	0 008	0.062	0 072	0 041	2 2
6	0-20	6 00	0 057	0.27	0.031	0 009	0.082	0 067	0.107	2.0
	20-50	5.70	0 039	0.18	0.027	0 008	0.086	0.059	0 100	1.3
7	0-20	4 90	0.048	0 18	0 029	0 012	0 075	0.075	0.097	2.2
	20-50	4 80	0 030	0 15	0.026	0 012	0.062	0.071	0.090	2.3
8	0-20	4 90	0 045	0.27	0 034	0 009	0.820	0.056	0.109	2.0
	20-50	4 70	0.027	0.27	0 030	0 009	0 059	0 050	0.104	2.2
9	0-20	5 40	0 027	0 39	0 031	0 012	0 082	0.061	0.116	1.1
	20-50	4.90	0 030	0 18	0.027	0.010	0 081	0.041	0.101	2.1

1	2	3	4	5	6	7	8	9	10	11
10	0-20	5.00	0 027	0.12	0 032	0.007	0.061	0.064	0.076	1 2
	20-50	5 10	0.020	0.09	0.027	0.005	0.058	0 069	0 061	1 4
RED LOAM										
11	0-20	5.1	0 195	0 32	0 078	0 019	0.093	0 104	0.115	5 4
	20-50	5 1	0.078	0.30	0 071	0.017	0 085	0 103	0.103	6.7
12	0-20	5.7	0 045	0.60	0 081	0 012	0.140	0 104	0 105	6.2
	20-50	5.7	0 054	0.30	0 072	0 111	0.120	0 103	0 100	7 2
13	0-20	5 2	0 075	0 24	0.081	0 012	0 100	0 104	0 109	6 2
	20-50	5 2	0.054	0.15	0 079	0.012	0 098	0 103	0 100	7 2
14	0-20	5 6	0 069	0 67	0 076	0 012	0 090	0 105	0 109	6 3
	20-50	6 0	0 054	0 61	0 073	0 012	0 081	0 103	0 100	7 0
15	0-20	5 1	0 120	0 61	0.075	0.012	0 085	0 105	0 112	5 5
	20-50	5 1	0 087	0 51	0 071	0 012	0 123	0 101	0 097	6 5
16	0-20	4 9	0.069	0 30	0 079	0 012	0 104	0 106	0 123	5 6
	20-50	4 5	0 048	0 30	0 075	0 013	0 115	0 101	0 116	6 6
17	0-20	4 8	0 066	0 15	0 081	0 012	0 105	0 107	0 118	6 5
	20-50	4 8	0.042	0.06	0.076	0.013	0 097	0.101	0 100	7 0
18	0-20	5 5	0 072	0 30	0 084	0.016	0 100	0 107	0 104	5 4
	20-50	5 6	0 051	0.30	0 079	0.013	0 104	0.101	0.100	6 4
19	0-20	4 6	0 069	0.29	0.082	0.013	0 090	0 109	0 114	5 7
	20-50	4.6	0 048	0.24	0.078	0.010	0.089	0 091	0 107	6 2
20	0-20	4 8	0 045	0.30	0 081	0.014	0.135	0 098	0 127	5 1
	20-50	4 7	0 048	0.30	0.075	0.010	0.121	0 090	0 100	5 9
LATERITE MIDLAND										
21	0-20	5 0	0 195	0 96	0 068	0 012	0 113	0 119	0 131	14 6
	20-50	4 5	0 141	0 69	0 061	0.011	0 110	0 108	0 110	20 5

1	2	3	4	5	6	7	8	9	10	11
22	0-20	4 7	0.042	0.91	0.059	0.012	0.117	0 126	0.134	16.8
	20-50	4 6	0 030	0.75	0.050	0.011	0.110	0 107	0.108	18.2
23	0-20	5 0	0 072	0.63	0 072	0.012	0.122	0 118	0.129	17.5
	20-50	5.0	0 072	0.63	0.072	0.012	0.122	0 118	0.129	17.5
24	0-20	5.3	0 063	0.66	0 069	0.012	0.130	0.123	0.131	15.3
	20-50	4.7	0.060	0.57	0.061	0.012	0.104	0.103	0 118	19.3
25	0-20	5 4	0 066	0 75	0 072	0 012	0 120	0.118	0 129	18.1
	20-50	5.3	0.030	0.48	0.060	0.011	0.107	0 102	0 105	20.2
26	0-20	5 0	0 078	0.69	0 065	0.012	0.131	0 120	0 134	15.8
	20-50	4.4	0 162	0 60	0.061	0.011	0.121	0 100	0 103	19.6
27	0-20	5 1	0.102	0.90	0.072	0.013	0.142	0.109	0 120	17.1
	20-50	5 0	0 123	0 80	0 061	0.012	0 137	0.096	0.115	20.5
28	0-20	4.7	0 138	0 72	0.071	0.013	0.143	0.128	0 134	17.3
	20-50	4.4	0.168	0.55	0.070	0 011	0 126	0.105	0.103	18.1
29	0-20	5 5	0 084	0 57	0 068	0 017	0 127	0.105	0.123	17.4
	20-50	5.3	0.087	0 48	0 065	0.016	0 110	0.092	0.110	19.1
30	0-20	4 9	0 048	0.45	0.075	0 011	0.137	0.120	0 120	14.2
	20-50	4.5	0.090	0.45	0.071	0.010	0.121	0.119	0.105	18 2
LATERITE MID UPLAND										
31	0-20	4.4	0.099	0 96	0.074	0 014	0.132	0 130	0.128	47.9
	20-50	4.3	0 177	0 45	0 065	0.012	0.131	0.128	0.107	19.3
32	0-20	4.3	0.150	1.38	0.070	0.015	0.133	0.120	0.137	18.3
	20-50	4 2	0.102	0 78	0.067	0.010	0 121	0.100	0 111	19.9
33	0-20	4.6	0.096	0.84	0.064	0.019	0 127	0.110	0.120	19.7
	20-50	4 3	0.168	0.78	0 070	0.011	0.120	0.107	0.107	20.[illegible]

1	2	3	4	5	6	7	8	9	10	11
34	0-20	4 6	0.144	0 93	0.061	0 015	0.137	0.110	0.117	16.1
	20-50	4.3	0.186	0.66	0.072	0 012	0.117	0.101	0.101	18.3
35	0-20	5 3	0 108	1 05	0 069	0.016	0.124	0 110	0.117	20.6
	20-50	4.7	0.126	0 72	0 073	0 010	0 117	0 107	0.114	20.1
36	0-20	5 0	0 177	1.00	0.070	0 017	0.120	0 117	0 127	19.5
	20-50	4.8	0 099	0 80	0.073	0.010	0114	0 100	0.107	21 5
37	0-20	5 3	0 156	1.08	0.071	0.018	0 132	0.122	0 120	20.3
	20-50	4 6	0.270	0.78	0 069	0.010	0 121	0 101	0 104	22.3
38	0-20	4 9	0 111	0 90	0 060	0.018	0 134	0 117	0 109	18 7
	20-50	4.7	0 192	0.69	0 069	0.013	0.116	0.100	0 100	19 8
39	0-20	4 5	0 185	0.90	0 062	0 019	0.129	0.101	0.123	17.9
	20-50	4.4	0.160	0.75	0.075	0.013	0.114	0.099	0 118	19.0
40	0-20	4 8	0.234	1.20	0.071	0.014	0.134	0.123	0.120	16.3
	20-50	4 7	0.084	0 89	-	0 014	0 120	0.118	0 103	19 1
FOREST										
41	0-20	4.9	0.081	1.47	0.149	0.031	0 190	0.157	0 201	13 8
	20-50	4 8	0 087	1 44	0.120	0 029	0.185	0 134	0.101	14.6
42	0-20	4 6	0.102	1 83	0 156	0.030	0 231	0.148	0.213	13.2
	20-50	4.5	0 066	1.83	0 143	0 027	0.216	0.137	0.202	14.7
43	0-20	4.8	0.072	2 70	0.162	0 032	0 207	0.144	0.200	13.1
	20-50	4.7	0.108	2.64	0.120	0.027	0.201	0.128	0.187	14.4
44	0-20	4.6	0 048	1.05	0 140	0.037	0.199	0.138	0.208	14.1
	20-50	4.5	0 051	0 72	0.136	0.021	0.188	0.119	0.191	16 0
45	0-20	4 7	0 072	1 98	0 134	0 031	0 232	0.137	0 200	13.8
	20-50	4 2	0 132	1.28	0.129	0 020	0.210	0 118	0.146	15.7

1	2	3	4	5	6	7	8	9	10	11
46	0-20	4 6	0 048	1.20	0.152	0 032	0 262	0.147	0 196	14 3
	20-50	4 5	0 048	1 00	0 147	0 019	0 202	0 119	0.172	16 7
47	0-20	4.7	0.057	2.28	0 160	0 035	0.199	0.132	0 197	13.3
	20-50	4 5	0.070	1 89	0.151	0.031	0.190	0 119	0 167	15.5
48	0-20	5 1	0 054	1 35	0.157	0 026	0.209	0 150	0 204	13 6
	20-50	4 1	0 072	1 14	0 139	0 017	0 198	0 137	0 175	15 1
49	0-20	4 6	0.090	1 02	0.169	0 026	0 212	0 147	0 206	13 5
	20-50	4 6	0 048	1 00	0.157	0 014	0 200	0 144	0 174	15 2
50	0-20	4 8	0 108	1 77	0 170	0 632	0 224	0 146	0 199	12 1
	20-50	4 6	0 060	1 00	0 162	0 030	0 196	0 120	0 146	14 4

Table - 4

Mean and ranges of chemical properties of soils

Soil type	Depth cm	pH dS/m	EC %	Organic carbon %	Total N %
	1	2	3	4	5
Sandy	0-20	5.2 (4.9-6 0)	0.043 (0.027-0 057)	0.25 (0.15-0.42)	0.030 (0.029-0 034)
	20-50	5 0 (4.7-5.7)	0 037 (0 027-0.048)	0 19 (0.12-0.39)	0 029 (0 026-0 030)
Redloam	0-20	5 1 (4 6-5 7)	0.073 (0 045-0.120)	0.33 (0.15-0.67)	0 080 (0 078-0 084)
	20-50	5 1 (4 5-5.7)	0 058 (0.042-0.087)	0.30 (0.06-0.60)	0.075 (0 071-0.079)
Laterite midland	0-20	5.0 (4 7-5.5)	0.089 (0.042-0.195)	0 72 (0 45-0 96)	0 064 (0.059-0.075)
	20-50	4 7 (4 4-5 3)	0.102 (0 030-0 168)	0.57 (0.33-0.80)	0.063 (0 050-0.071)
Laterite midupland	0-20	4 8 (4.5-5.3)	0 146 (0 086-0.234)	0 94 (0 90-1.38)	0 070 (0.067-0.075)
	20-50	4.[illegible] (4 2-4.8)	0.161 (0 084-0.270)	0 76 (0 45-0.87)	0.066 (0.060-0 071)
Forest	0-20	4 7 (4 6-5.1)	0 075 (0 048-0.102)	1.66 (1.02-2.70)	0.148 (0 134-0.170)
	20-50	4.6 (4 2-5.1)	0 074 (0 048-0.132)	1 39 (0 72-2 64)	0.146 (0 120-0 162)

Figures in paranthesis are the range values

Soil type	Depth cm	Total P %	Total K %	Total Ca %	Total Mg %	Sesquioxide
		6	7	8	9	10
Sandy	0-20	0 010 (0 009-0.012)	0 079 (0 076-0 090)	0.066 (0 056-0 075)	0.105 (0 095-0 112)	1.84 (1.1-2.2)
	20-50	0 010 (0 008-0 010)	0.069 (0.059-0 086)	0 056 (0 041-0 071)	0 092 (0 041-0 109)	1 95 (1 2-2 7)
Redloam	0-20	0.014 (0 012-0.019)	0 103 (0 090-0 140)	0 105 (0 104-0.109)	0.114 (0 104-0 127)	5 76 (5.4-6.5)
	20-50	0.012 (0 010-0 017)	0.104 (0 085-0 120)	0.099 (0 080-0.103)	0 102 (0 097-0 116)	6 62 (5.7-7 2)
Laterite midland	0-20	0 011 (0 011-0 017)	0 128 (0 112-0.143)	0.118 (0 105-0.126)	0.129 (0.120-0 134)	16 40 (14 2-18 1)
	20-50	0 01 (0 010-0.016)	0 114 (0.110-0 137)	0 102 (0 092-0 118)	0 108 (0 100-0 118)	19 40 (18 1-20 5)
Laterite midupland	0-20	0 016 (0 014-0 019)	0 130 (0 120-0.137)	0.116 (0 101-0 130)	0 112 (0 109-0 137)	18 50 (16 1-20 3)
	20-50	0 012 (0 010-0 014)	0.119 (0 114-0 131)	0 104 (0 100-0 128)	0 107 (0 100-0 118)	19 90 (18 3-22.3)
Forest	0-20	0 031 (0 026-0 037)	0 208 (0 190-0 262)	0.144 (0 132-0 157)	0.202 (0 195-0 213)	13 30 (12.1-15.2)
	20-50	0 024 (0 014-0 031)	0.199 (0 185-0.216)	0 127 (0 118-0 144)	0 175 (0 146-0 202)	15 20 (13 1-16.0)

SULPHUR STUDIES

4.2 Forms of sulphur

The results of the studies on the forms of sulphur in the upland soils are presented in Tables 5 and 6 The data reveal that there was considerable variation in the content of the various forms of sulphur in the different types of soils.

4.2.1 Total Sulphur

The total sulphur content ranged from a mean value of 199.1 ppm in subsurface layers of the sandy soils to 875.0 ppm in surface layers of the forest soil. Of the five types of soils, the forest soil exhibited the maximum and the sandy soils the minimum content of total sulphur The total sulphur in the surface samples of the sandy soil ranged between 280.3 and 317 0ppm, the mean being 298 ppm, while the subsurface samples possessed a total amount ranging between 185.0 and 218 7ppm with a mean value of 199 4 ppm In redloam soils, the sulphur content ranged between 297.0 and 397.0ppm with a mean of 349 0ppm Total sulphur status of laterite region was higher than that of sandy soils and redloamsoils.

Total sulphur content in surface samples of laterite midland ranged between 499.0 and 599.0ppm, the mean being 525 0ppm. In laterite midupland soils, total sulphur ranged between 545 1 and 645 2ppm, the mean being 586.5ppm, while in the forest soil a range of 840.0 to 892 4ppm was observed with a mean value of 868 3ppm Forest soil possessed a fairly good amount of total sulphur in the surface and subsurface layers. The subsurface samples of redloam, laterite midland, laterite midupland and forest soils possessed average amounts of 214.7, 402.0, 404 0 and 706 5ppm of sulphur respectively. Total sulphur ranged from 185.0 to 218.7ppm, 189 0 to 260 0ppm, 370 2 to 478 0ppm, 370.4 to 459 0ppm and 650 0 to 775.0ppm in sandy, redloam, laterite midland, laterite midupland and forest soils.

Total sulphur in these soils increased in the order sandy < redloam < laterite midland < laterite midupland < forest. It is obvious that significant variation in sulphur content existed between different soil types of South Kerala.

4.2 2 Organic Sulphur

While comparing the soil types, it was evident that forest soils contained more organic sulphur Organic sulphur content in the forest soils ranged between 800 0 and

856 0ppm, the mean being 828 2ppm. It constituted about 95.4% of total sulphur in the forest soils while in the snady, redloam, laterite midland and laterite midupland soils it came to about 94 2, 94.7, 95 5 and 95 5 percent respectively The organic sulphur content in surface samples of sandy soils ranged between 262 0 and 296.0ppm, the mean being 280.6ppm. It ranged from 280 0 to 380.0ppm, 475.0 to 572 5ppm and 519 0 to 615.0ppm with mean values of 330 0, 501.5 and 560.0ppm respectively in the surface samples of redloam, laterite midland, and laterite midupland soils respectively In all the five soil types, surface soils were richer in organic sulphur than the subsurface soils Subsurface samples of sandy, redloam, laterite midland, laterite midupland and forest soils possessed average amount of 181 0, 198.2, 377 9, 380 9 and 671 6ppm organic sulphur respectively. It constituted about 90.8, 92.3, 94 3, 94.2 and 95.0 percent of total sulphur respectively in the subsurface layers of the sandy, redloam, laterite midland, laterite midupland and forest soils Like total sulphur, organic sulphur content in the soils also decreased in the order forest > laterite midupland > laterite midland > redloam > sandy soils.

4 2 3 Sulphate Sulphur

Of the five soil types, forest soils exhibited the highest and sandy soils the lowest content of sulphate sulphur In the surface samples of sandy soils, sulphate sulphur ranged between 11.4 and 21.2ppm, the mean being 17.1ppm It constituted about 5 7 percent of total sulphur in surface soils. In the redloams, the range was between 11.5 and 22.8ppm, in laterite midland soils between 17.1 and 27.0ppm, in laterite midupland soils between 23.0 and 28 0ppm and in forest soils between 33.2 and 44.0ppm, the corresponding mean being 18.3, 23.0, 25.4 and 39 5ppm respectively. It constituted about 5.2, 4 4, 4.4 and 4.5 percent of total sulphur in these soils. All the five types of soils were significantly different in their sulphate content.

The subsurface soils possessed less of sulphate sulphur than the surface soils. In subsurface soils, sulphate sulphur ranged between 12 9 and 21 5ppm, 11 0 and 17.6ppm, 16 0 and 24.9ppm, 20.0 and 26 0ppm and between 28.1 and 40.0ppm with mean values of 18.3, 15.0, 21 0, 22 9 and 33 8ppm respectively for sandy, redloam, laterite midland, laterite midupland and forest soils Sulphate sulphur

Table - 5

Forms of Sulphur in soils

No.	Depth cm	Total S ppm	Organic S ppm	Sulphate S ppm
1	2	3	4	5
SANDY SOIL				
1	0-20	298 6	279 1	19 0
	20-50	201 8	181 6	19.9
2	0-20	306.0	284 1	21.2
	20-50	199.2	177.5	21.5
3	0 20	280.3	262.0	18.1
	20-50	185.0	164.9	20 0
4	0-20	295.2	279.0	16.0
	20 50	218 7	201 4	17 2
5	0-20	296.6	279 1	19.3
	20-50	193 7	175.6	18.2
6	0-20	282.4	264.0	18.0
	20-50	189.0	160.0	19.9
7	0-20	317 0	296.0	19 0
	20-50	196 4	176.0	20 1
8	0-20	304 0	290.0	14 0
	20-50	199 0	182 6	16.2
9	0-20	292 7	281.0	11.4
	20-50	202.0	189.1	12.7
10	0-20	311 1	296 0	19.0
	20-50	209.0	191.5	17 4
REDLOAM				
11	0-20	350.2	329 0	20 7
	20-50	254.1	236 1	17.4
12	0-20	297 3	280 2	17.0
	20-50	201 2	187.0	13.4

1	2	3	4	5
13	0-20	330.0	306.1	22.8
	20-50	186.0	169.0	16.5
14	0-20	296.0	280.0	16.0
	20-50	225.4	209.4	14.9
15	0-20	341.1	320.0	20.0
	20-50	224.2	206.1	17.6
16	0-20	346.0	334.0	11 5
	20-50	200.0	189.0	11.0
17	0-20	380.2	375.1	14.9
	20-50	260.0	235.0	14.1
18	0-20	361.0	341.0	19.5
	20-50	200 0	186.0	14.0
19	0-20	351.0	329.0	20.9
	20-50	189.2	176.0	12.8
20	0-20	391.4	371.0	20.2
	20-50	207.4	189.0	17.1
LATERITE MIDLAND				
21	0-20	501.4	475.0	26.0
	20-50	380.0	357.5	22.2
22	0-20	500.7	480.1	20.0
	20-50	370.2	350.1	19.3
23	0-20	520.4	499.0	21.0
	20-50	400.0	280.0	19.4
24	0-50	500.0	482.1	17.1
	20-50	390.0	371.9	16.9
25	0-20	598.4	572.0	26.0
	20-50	478.0	452.0	25.1
26	0-20	499.0	479.0	20.0
	20-50	435.2	419.0	16.0
27	0-20	550.0	522.1	27.0
	20-50	390.0	375.1	24.1

1	2	3	4	5
28	0-50	586 3	559 0	26 1
	20-50	374 9	300.0	24.9
29	0-20	509 4	487 0	22.1
	20-50	404.7	383 1	21.0
30	0-20	550.4	425.0	25 0
	20-50	373.3	351 0	22 0
LATERITE MIDUPLAND				
31	0-20	545 4	519 0	26.0
	20-50	396.0	371.0	23.9
32	0-20	564.1	537.2	26.1
	20-50	390.2	369 0	21.0
33	0-20	560.6	532.0	27.1
	20-50	370.0	344.0	26.0
34	0-20	575.0	549.1	25 2
	20-50	406 2	381.6	24.0
35	0-20	644 1	615.0	27 3
	20-50	420 6	394.3	25 6
36	0-20	584 2	561 0	23 0
	20-50	404 0	381 9	20.9
37	0-20	625 5	594.0	26.0
	20-50	459 0	439.0	20.0
38	0-20	645.0	620.0	25.0
	20-50	398.3	374 1	23.6
39	0-50	548 9	524 0	24 7
	20-50	400 0	375.0	24.2
40	0-20	578 0	549.0	28.0
	20-50	399.3	379 0	20 0
FOREST				
41	0-20	843.4	800 0	43 0
	20-50	689.3	655 9	33 1

1	2	3	4	5
42	0-20	880.5	845.0	35.0
	20-50	700.0	664.0	34.7
43	0-20	845.0	800.1	44.0
	20-50	690.1	650.0	40.0
44	0-20	880.5	839.0	41.1
	20-50	691.0	660.2	30.2
45	0-20	840.0	801.0	38.5
	20-50	700.6	656.0	34.0
46	0-20	860.9	840.1	40.0
	20-50	775.0	737.0	37.0
47	0-20	860.4	820.1	40.0
	20-50	700.7	661.0	34.2
48	0-20	890.0	856.0	33.2
	20-50	760.2	730.0	30.0
49	0-20	892.0	850.2	41.0
	20-50	650.0	612.1	37.1
50	0-20	870.2	830.4	40.1
	20-50	708.5	680.0	28.1

constituted about 7.6, 6 9, 5 2, 5 6 and 4.8 percent of total sulphur in the subsurface samples of sandy, redloam, laterite midland, laterite midupland and forest soils.

4.3 Available sulphur extracted by different extractants

Several extractants are employed for the extraction of sulphate sulphur which is the main source of available sulphur for plants Tables7 and 8 presents the content of available sulphur in different soils extracted by the different extractants viz water, neutral normal ammonium acetate solution, N hydrochloric acid and Morgan's reagent

4.3.1 Water soluble sulphur

The content of water soluble sulphur in the upland soils of South Kerala ranged from 7 8 to 29.7ppm. It ranged from 7 8 to 11.5ppm, 9 7 to 14.0ppm, 14.7 to 17.0ppm, 14.9 to 17.9ppm, 26 0 to 29 7ppm with mean values of 9 6, 11.7, 15.6, 16.5 and 28.2ppm in sandy, redloam, laterite midland, laterite midupland and forest soils. Except for sandy soils, all other soils showed a decreasing trend of water soluble sulphur with increasing depth.

In the subsurface samples of sandy soils, water soluble sulphur ranged from 7.3 to 11.5ppm the mean being 10.1ppm

Table - 6

Mean and Ranges of forms of sulphur ın soıls

Soıltype	Depth cm	Total sulphur ppm	Organic sulphur Content ppm	Organic sulphur Percentage to total S	Sulphate sulphur Content ppm	Sulphate sulphur Percentage to total S
Sandy	0-20	298.1	208.6	94.2	17.1	5.7
		(280 3-317.0)	(262 0-296.0)		(11.4-21.2)	
	20-50	199.4	181 0	91.7	18.3	7 6
		(185.0-218 7)	(160.0-201 4)		(12 9-21.5)	
Redloam	0-20	349.0	330.0	94.7	18.3	5.2
		(297.0-397 0)	(280 0-380.00		(11.5-22 8)	
	20-50	214 7	198 2	92 3	15.0	6 9
		(189.0-260.0)	(176.0-236 1)		(11.0-17 6)	
Laterıte mıdland	0-20	525.0	501.5	95.5	23 0	4 4
		(499 0-599 0)	(475.0-572.0)		(17.1-27.0)	
	20-50	402 0	377 9	94.3	21.0	5 2
		(370.2-478.0)	(349.2-452 0)		(16.0-24.9)	
Laterıte mıdupland	0-20	586 5	560.0	95 5	24.4	4.4
		(545.1-645 2)	(519 0-615.0)		(23.0-28.5)	
	20-50	404 0	380.9	94.2	22 9	5.6
		(370 4-459.0)	(344 0-439.0)		(20.0-26.0)	
Forest	0-20	868.3	828 2	95 4	39.5	4.5
		(840.0-592.4)	(800 0-856.0)		(33.2-44 0)	
	20-50	706 5	671 6	95.4	39 5	4.5
		(650 0-775 0)	(612.1-737.0)		(28.1-40.0)	

	Total sulphur	Organic sulphur content	Sulphate sulphur content
CD (serıes)	19.8	21 9	1.1
CD (depth)	12.5	13.8	2.5

Fıgures ın paranthesıs are the range values

It ranged from 9 1 to 12.5ppm, 13.0 to 15.1ppm, 14.0 to 16.1ppm and 22.0 to 26.1ppm with mean values of 10.3, 13.8, 15 1 and 25.0ppm in the subsurface samples of redloam, laterite midland, laterite midupland and forest soils. All the groups showed significant differences in their water soluble sulphur content. The water soluble sulphur increased in the order sandy < redloam< laterite midland < laterite midupland < forest soils In the surface samples, water soluble sulphur constituted about 3.2, 3.3, 3 0, 2 8 and 3 2 percent to total sulphur while in the subsurface sample it came to about 5.1, 4.8, 3 5, 3.7 and 3 5 percent of total sulphur in the sandy, redloam, laterite midland, laterite midupland and forest soils respectively

4 3.2 Ammonium acetate extractable sulphur

Neutral normal ammonium acetate extracted more sulphur than water It extracted about 20 2 - 32.7 percent of total sulphur in the soils studied. In the surface soils, ammonium acetate extractable sulphur ranged from 68 9 to 79.2ppm, 74 7 to 121 0ppm, 101.0 to 129.0ppm, 110.0 to 128 0ppm and 181 0 to 201.0ppm the mean being 72.7, 91 7, 110.4, 118 8 and 190 6ppm for sandy, redloam, laterite midland, laterite midupland and forest soils respectively It constituted about 24.4, 26 3, 21 0, 20.2 and 21 9 percent of total sulphur in these soils.

In all the soil groups, ammonium acetate extractable sulphur decreased with increasing depth In the subsurface soils, ammonium acetate extractable sulphur ranged from 50 1 to 69.1, 54.0 to 101.0, 85.0 to 102.0, 90.0 to 109 0 and 130.0 to 175.1ppm with mean values of 59.3, 70.2, 93.2, 97 1 and 158.9ppm respectively for the sandy, redloam, lateritemidland, laterite midupland and forest soils. All the soil types significantly differed in their sulphur content. Ammonium acetate extractable sulphur increased in the order sandy < redloam< laterite midland < laterite midupland < forest soils.

4.3.3 Hydrochloric acid extractable sulphur

1 N hydrochloric acid extracted more sulphur than water, but less than that extracted by ammonium acetate solution HCl extractable sulpur ranged between 55.1 and 185.0ppm in the surface soils of South Kerala In sandy soils, it ranged between 55.1 and 68 0ppm, the a mean being 62.3ppm This constituted about 20 9 percent of total sulphur in the soil In surface soils, HCl extractable sulphur ranged from 60.3 to 114.0ppm, 89.0 to 117.1ppm, 100 0 to 115 0ppm and 150 0 to 185 0ppm the mean being 79.6, 99.2, 107.0 and 171 5ppm for redloam, laterite midland, laterite midupland and forest soils respectively

HCl extractable sulphur showed a decreasing trend with depth. In subsurface soils, HCl extractable sulphur ranged between 43.0 and 57.3, 48.0 and 92 0, 71.0 and 94 0, 79.0 and 94.0 and between 121.0 and 157.0ppm with mean values of 49.8, 62 6, 81 2, 86.5 and 140 9ppm for sandy, redloam, laterite midland, laterite midupland and forest soils. It constituted about 20.9, 22 8, 18 9, 18 3 and 19 7 percent of total sulphur in the surface soils and 25.0, 28.8, 20.1, 21.4 and 19.9 percent of total sulphur in the subsurface soils.

4 3 4
Morgan's reagent extratable sulphur

Morgan's reagent extracted more sulphur than all other extractants. Morgan's reagent extratable sulphur ranged between 91.0 and 295.0ppm in the surface soils of Trivandrum district. Maximum amount of Morgan's extractable sulphur was present in the forest soils and the minimum in the sandy soils. This form of sulphur increased in the order sandy < redloam < laterite midland < laterite midupland < forest soils. Morgan's extractable sulphur ranged between 91 0 and 110 0ppm, 100 0 and 129.0ppm, 140 and 172 0ppm, 145.0 and 172.3ppm and 250.0 and 295.0ppm in the surface soils with mean value 102.3, 114.7, 154.7, 163 7 and 275.6ppm for the sandy, redloam, laterite midland, laterite midupland and forest soils In the subsurface soils, Morgan's reagent

Table - 7

Available sulphur in soils using different extractants

No.	Depth cm	Water ppm	Ammonium acetate ppm	HCl ppm	Morgan's reagent ppm
1	2	3	4	5	6
SANDY SOIL					
1	0-20	9.4	71.0	61.0	91.0
	20-50	9.7	54.0	48.1	68.0
2	0-20	10.4	75.0	60.0	95.0
	20-50	10.9	64.0	50.2	69.4
3	0-20	10.7	69.0	55.1	109.1
	20-50	11.0	69.0	43.0	89.0
4	0-20	11.5	76.3	62.0	104.0
	20-50	11.0	62.0	54.1	74.0
5	0-20	8.6	74.2	68.1	110.1
	20-50	10.6	58.0	57.3	68.0
6	0-20	9.7	71.0	67.0	105.1
	20-50	10.6	64.0	55.2	67.2
7	0-20	8.4	68.2	61.0	106.0
	20-50	9.2	52.0	47.0	59.1
8	0-20	9.0	72.0	64.6	100.0
	20-50	10.0	61.0	50.9	64.0
9	0-20	7.8	69.0	60.0	96.2
	20-50	7.3	50.0	47.0	60.0
10	0-20	10.8	78.0	64.0	107.0
	20-50	10 6	59.0	46.1	59.0
REDLOAM					
11	0-20	10.6	81.3	71.2	104.2
	20-50	9.1	64.1	56.1	82.1
12	0-20	10.7	75.0	69.0	100.0
	20-50	9.4	54.2	48.0	81.0

1	2	3	4	5	6
13	0-20	11.27	79.0	60.3	119.1
	20-50	10.1	64.0	51.2	97.1
14	0-20	12.0	86.1	76.4	125.0
	20-50	10.7	71.0	56.0	103.2
15	0-20	14.0	104.1	59.0	129.0
	20-50	12.5	71.1	67.1	114.0
16	0-20	13.0	74.7	69.1	105.1
	20-50	11.0	61.2	49.3	76.0
17	0-20	13.2	56.0	72.0	109.3
	20-50	10.5	49.0	56.2	89.2
18	0-20	11.8	89.1	76.1	117.1
	20-50	10.4	71.3	64.0	86.1
19	0-20	9.7	121.0	114.0	126.0
	20-50	9.2	101.0	92.0	94.0
20	0-20	11.2	120.4	99.1	107.0
	20-50	9.7	95.3	86.3	81.4
LATERITE MIDLAND					
21	0-20	15.1	104.0	91.2	140.0
	20-50	14.0	85.0	81.1	104.1
22	0-20	14.7	107.1	89.0	147.3
	20-50	13.1	89.0	72.3	100.0
23	0-20	15.2	110.3	99.1	160.2
	20-50	13.7	91.2	81.4	121.0
24	0-20	14.9	101.0	94.0	151.5
	20-50	13.0	90.1	76.5	114.4
25	0-20	16.5	119.0	114.2	164.0
	20-50	14.5	101.2	86.1	124.0
26	0-20	16.9	110.1	107.0	169.1
	20-50	14.2	102.1	89.0	140.0
27	0-20	14.7	108.4	99.0	157.2
	20-50	13.0	90.1	80.2	104.1

1	2	3	4	5	6
28	0-20	15.6	107.2	97.0	172 0
	20-50	13.4	91.3	71.0	110.1
29	0-20	17.0	129.8	117.1	146.0
	20-50	15.1	101.0	94.0	120.3
30	0-20	15.2	107.2	96.4	141.4
	20-50	14.0	91.0	80.5	102.5
LATERITE MIDUPLAND					
31	0-20	16.4	117.2	104.1	159.2
	20-50	14.7	91.1	90.3	121.1
32	0-20	16.0	110.0	107.2	164.0
	20-50	14.0	85.0	79.0	111.0
33	0-20	15.2	120.1	109.0	167.4
	20-50	14.5	90.0	81.3	104.0
34	0-20	17.5	125.2	111.1	169.0
	20-50	15.2	99.0	84.1	121.1
35	0-20	17.9	128.0	115.0	172.3
	20-50	16.1	104.1	85.4	125.0
36	0-20	14.9	111.0	100.0	164.4
	20-50	14.0	101.2	90.0	111.1
37	0-20	17.4	125.1	111.1	172.0
	20-50	16.0	107.0	94.0	114.6
38	0-20	17.0	127.0	112.2	169.0
	20-50	16 0	102.1	89.1	104.1
39	0-20	16.4	110.0	100.3	145.0
	20-50	15.4	100.3	88.0	119.0
40	0-20	16.2	114.7	100.0	156.2
	20-50	14.9	91.0	84.0	117.3
FOREST SOIL					
41	0-20	29.1	190.3	179.1	274.2
	20-50	26.1	161.1	140.2	226.1
42	0-20	27.6	181.0	166.0	266.0
	20-50	24.3	150.2	131.4	229.0

1	2	3	4	5	6
43	0-20	27.9	189.0	164.1	275.1
	20-50	24.0	159.0	133.2	230 4
44	0-20	27.6	188.1	173.0	265.1
	20-50	23 0	149.2	130.3	236.5
45	0-20	26.0	189.0	159.7	250.0
	20-50	22.0	130.0	121.0	222.0
46	0-20	28.0	190.4	179.0	282.0
	20-50	26.1	175.1	140.2	235.2
47	0-20	29.0	187.0	150.0	290.0
	20-50	26.1	151.0	140.1	239.0
48	0-20	29.0	191.2	185.0	295.0
	20-50	26.1	176.1	150.0	225.1
49	0-20	29.7	201.0	180.0	281.1
	20-50	25.4	179.0	157.0	228.0
50	0-20	28.0	199.0	179.1	278.1
	20-50	26.2	158.2	146.1	204.3

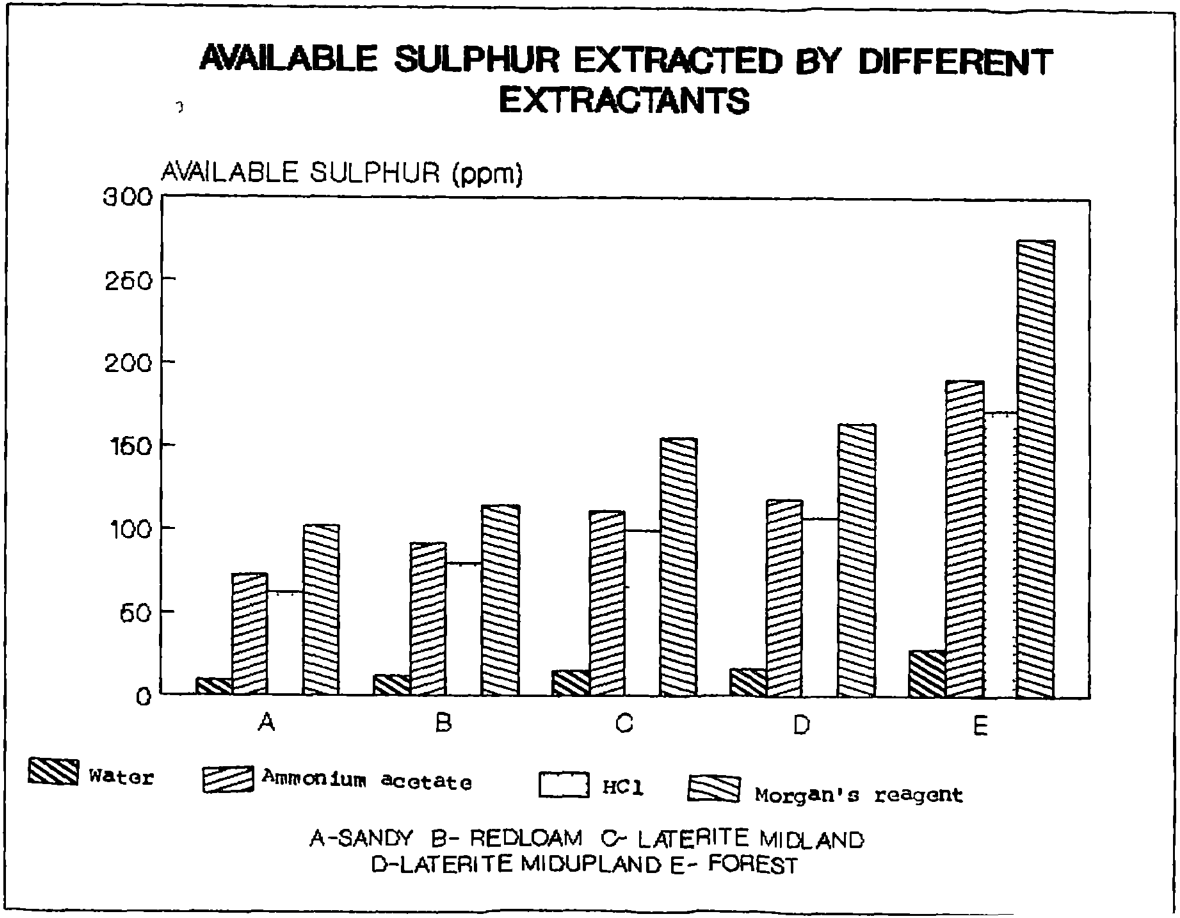
able 6

Mean and ranges of available sulphur in soil using different extractants

Type	Depth cm	Water extractable		Ammonium acetate extractable		HCl extractable		Morgan's reagent extractable	
		Content ppm	Percentage to total S	Content ppm	Percentage to total S	Content ppm	Percentage to total S	Content ppm	Percentage to total S
1	2	3	4	5	6	7	8	9	10
Sandy	0-20	9 6 (7.8-11.5)	3.2	72.1 (68.9-79.2)	24.4	62.3 (55 1-68 0)	20 9	102 3 (91 0-110.0)	34.3
	20-50	10 1 (7.3-11.5)	5.1	59.3 (50.1-69.1)	29.8	49.8 (43 0-57 3)	25 0	67.7 (59.0-89.0)	34.6
Redloam	0-20	11.7 (9 7-14.0)	3 3	91 7 (74 7-121.0)	26 3	79 6 (60 3-114.0)	22.8	114.2 (100 0-129 0)	32.9
	20-50	10 3 (9 1-12.5)	4 8	70.2 (54.0-101.0)	32.7	62.6 (48.0-92 0)	28.9	91 4 (76.0-114.0)	45.6
Laterite midland	0-20	15 6 (14 7-17.0)	3 0	110 4 (101 0-129.0)	21 0	99 2 (89 0-117.1)	18.9	154 9 (140 0-172 0)	29 5
	20-50	13 8 (13.0-15.1)	3.5	93.2 (85.0-120.0)	23.2	81 2 (71 0-94.0)	20.2	114.1 (100.0-140 0)	29.2
Laterite midupland	0-20	16.5 (14 9-17 9)	2.8	118.8 (110.0-128.0)	20.2	107 0 (100.0-115.0)	18 3	163.9 (1450.172 3)	27.9
	20-50	15 1 (14 0-16.1)	3 7	97.1 (70 0-109 0)	24 0	86.5 (79.0-94 0)	21 4	114.7 (104.0-125.0)	28.4
Forest	0-20	28.2 (26.0-29.7)	3.2	190.6 (181 0-201 0)	21.9	171 5 (150.0-185.0)	19.7	275.6 (250.0-295 0)	32.2
	20-50	25.0 (22 0-26.1)	3 5	158 9 (130 0-175 1)	22.4	140.9 (121 0-157.0)	20 2	227.6 (240.3-239.0)	32.4
CD (series)		0.68		6.94		6 47		7.61	
CD (depth)		0.43		4 39		4 08		4.81	

Figures in paranthesis are the range values

Fig. 1


AVAILABLE SULPHUR EXTRACTED BY DIFFERENT EXTRACTANTS
AVAILABLE SULPHUR (ppm)
300
250
200
150
100
50
0
A
B
C
D
E
Water
Ammonium acetate
HCl
Morgan's reagent
A-SANDY B- REDLOAM C- LATERITE MIDLAND
D-LATERITE MIDUPLAND E- FOREST

extractable sulphur tended to decrease with depth. The subsurface soils contained about 67.7, 91.4, 114 1, 114.7 and 227.6ppm sulphur, the range being respectively 59.0 to 89 0, 76.0 to 114.0, 100.0 to 140.0, 104.0 to 125.0 and 204.3 to 239.0ppm in the sandy, redloam, laterite midland, laterite midupland and forest soils In surface soils, it constituted about 34 3, 32.9, 29.5, 27 9 and 32 2 percent of total sulphur while in the subsurface soils it constituted about 34.6, 45.6, 29.2, 28.4 and 32 2 percent respectively in the aforesaid soils

4.4 Neubauer test for plant available sulphur

Table 9 presents the Neubauer values, showing the actual uptake of sulphur from 100g soil correlation between available sulphur extracted by different extractants and Neubauer test values are given in table 12

Sulphur uptake by the rice seedlings grown in 100g soil varied between mean values of 0 545mg and 1.286mg Seedlings grown in the sandy soils gave the minimum values and those in the forest soils the maximum Seedling grown in redloam laterite (midland) and laterite (midupland) gave the mean values of 0.716mg, 0 889mg and 0 993mg respectively. The values were significantly correlated with Morgan's reagent

Table - 9.

Uptake of sulphur as assessed by Neubauer technique

Soiltype	Sl.No.	Sample No.	Uptake of sulphur mg
Sandy	1.	1	0 521
	2.	2	0.591
	3.	3	0.638
	4.	4	0.582
	5.	5	0.500
	6.	6	0.435
Redloam	7.	11	0.764
	8.	12	0.718
	9.	13	0.778
	10.	14	0.700
	11.	15	0.697
	12.	16	0.641
Laterite midland	13.	21	0.844
	14.	22	0.941
	15.	23	0.977
	16.	24	0.821
	17.	25	0.888
	18.	26	0.863
Laterite midupland	19.	31	0.880
	20.	32	1.058
	21.	33	0.852
	22.	34	0.940
	23.	35	0.902
	24.	36	0.968
Forest	25.	41	1.357
	26.	42	1.316
	27.	43	1.269
	28.	44	1.260
	29.	45	1.328
	30.	46	1.187

Table - 10

Mean and ranges of neubauer values and available sulphur in respective soils

Soiltype	Neubauer values of sulphur uptake mg	Water extractable sulphur ppm	Ammonium acetate extractable ppm	HCl extractable sulphur ppm	Morgan's reagent extractable sulphur ppm
Sandy	0 545 (0 435-0 638)	10 1 (8 6-11 5)	72.8 (71 0-76 3)	62.2 (55.1-68.1)	102.3 (91 0-110 0)
Redloam	0.716 (0 641-0.778)	11.9 (10.6-14.0)	83 4 (75.0-104.1)	67.5 (60.3-76.4)	113.7 (100.0-129.0)
Laterite midland	0 889 (0 821-0.977)	15 6 (14 7-16.9)	108 5 (104.0-119 0)	97 4 (89 0-107.0)	155.4 (140.0-169 0)
Laterite midupland	0.933 (0.852-1 058)	16.3 (14.9-17-9)	118 6 (110.0-128.0)	107.7 (100 0-115.0)	166.1 (159.2-172 3)
Forest	1.286 (1 187-1 357)	27 7 (26 0-29 1)	187 9 (181.0-190.4)	170 2 (159.0-179.1)	268 4 (250 0-280 0)

Figures in paranthesis are the range values

extractable sulphur (0.9476**) ammonium acetate extractable sulphur (0.9441**) HCl extractable sulphur (0.9376**) and water soluble sulphur (0 9420**)

4.5 Inter relationship between soil properties and forms of sulphur

4.5.1 Soil texture

All the forms of sulphur were positively correlated with the clay and silt content of the soils. Clay had a significant positive correlation with total sulphur (0 7895**), organic sulphur (0.7675**), sulphate sulphur (0.7812**), water soluble sulphur (0 8269**) HCl soluble sulphur (0.8063**) and Morgan's reagent soluble sulphur (0 7801**).

Silt was also positively and significantly correlated with total sulphur (0 5621**), organic sulphur (0.5568**), sulphate sulphur (0 5192**), water soluble sulphur (0.5809**), ammonium acetate soluble sulphur (0.5590**), HCl soluble sulphur (0.5809**) and Morgan's reagent extractable sulphur (0.5048**).

4.5 2 Soil reaction

The pH exhibited significant negative correlations with total sulphur (-0.3290**), organic sulphur (0.3376**), sulphate sulphur (-0.3706**), water soluble sulphur -0.3706**), ammonium acetate soluble sulphur (-0.3402**), HCl soluble sulphur sulphur (-0.3562**) and Morgan's reagent soluble sulphur (-0.2893**).

4 5 3 Electrical conductivity

Electrical conductivity showed positive correlation with total sulphur (0 2137*), organic sulphur (0 2216*) and sulphate sulphur (0.1952*). Available sulphur extracted by different reagents did not show significant correlation with electrical conductivity.

4.5 4 Organic carbon and other nutrient elements

Organic carbon exhibited significant positive correlation with total sulphur (0.8068**), organic sulphur (0.8066**), sulphate sulphur (0 8265**), water soluble sulphur (0.8325**), ammonium acetate soluble sulphur (0.8075**), HCl soluble sulphur (0 7789**) and Morgan's reagent soluble sulphur (0.8259**)

Total nitrogen was positively correlated with all the forms of sulphur viz. total sulphur (0 6713**), organic sulphur (0.6679**), sulphate sulphur (0 6952**), water soluble sulphur (0.7408**), ammonium acetate extractable sulphur (0.7152**), HCl extractable sulphur (0.7080**) and Morgan's reagent soluble sulphur (0.7104**).

Total phosphorus was also correlated positively and significantly with total (0.8133**), organic (0.5087**), sulphate (0.8188**), water soluble (0.8579**), ammonium acetate soluble (0.8032), HCl soluble (0 8241**) and Morgan's reagent soluble (0.8075**) forms of sulphur

Total potassium in the soils did not show any significant correlation with any form of sulphur

Total calcium in the soil exhibited significantly positive correlation with total (0.8206**), organic (0 8184**), sulphate (0 7593**), water soluble (0.7908**), ammonium acetate soluble (0.8032**), HCl soluble (0 8113**) and Morgan's reagent soluble (0.8075**) forms of sulphur

Total magnesium in the soil had significantly positive correlation with all the forms of sulphur viz. total (0 8848**), organic (0 8830**), sulphate (0 8629**), water

95

soluble (0.9090**), ammonium acetate soluble (0.4814**), HCl soluble (0.4909**) and Morgan's reagent soluble (0.9270**) sulphur.

4.6 Inter relationships between different forms of sulphur

All the forms of sulphur showed positive and highly significant correlation with each other. Total sulphur was positively and significantly correlated with organic (0.993**), sulphate (0 9101**) and available sulphur as determined by different extractants like water (0.9430**), ammonium acetate (0.9527**), hydrochloric acid (0.9547**) and Morgan's reagent (0.9662**)

Organic sulphur was positively and significantly correlated with sulphate (0 9101**), water soluble (0 9391**), ammonium acetate soluble (0.9413**), HCl soluble (0.9483**) and Morgan's reagent soluble (0.9396) sulphur.

Sulphate sulphur was correlated with all other forms of sulphur both positively and significantly. The correlation coefficient between sulphate and water soluble sulphur was 0 9254** and that of ammonium acetate soluble sulphur was 0 9371**. Sulphate sulphur was also correlated with Morgan s reagent soluble sulphur (0 9165**)

Table - 11

Coefficient of simple linear correlation between soil properties and different forms of sulphur

Y	X	r
Total Sulphur	PH	-0.3290**
	EC	0.2137
	Organic carbon	0.8065**
	Total Nitrogen	0.6713**
	Phosphorus	0.8133**
	Potassium	-0.1103
	Calcium	0.8206**
	Magnesium	0.8848**
	Sesquioxides	0.5575**
	Clay	0.7895**
	Silt	0.5621**
Organic sulphur	PH	-0.3376**
	EC	0.2216
	Organic carbon	0.8166**
	Total Nitrogen	0.6679**
	Phosphorus	0.5087**
	Potassium	-0.1059
	Calcium	0.8184**
	Magnesium	0.8830**
	Sesquioxides	0.5563**
	Clay	0.7675**
	Silt	0.5568**

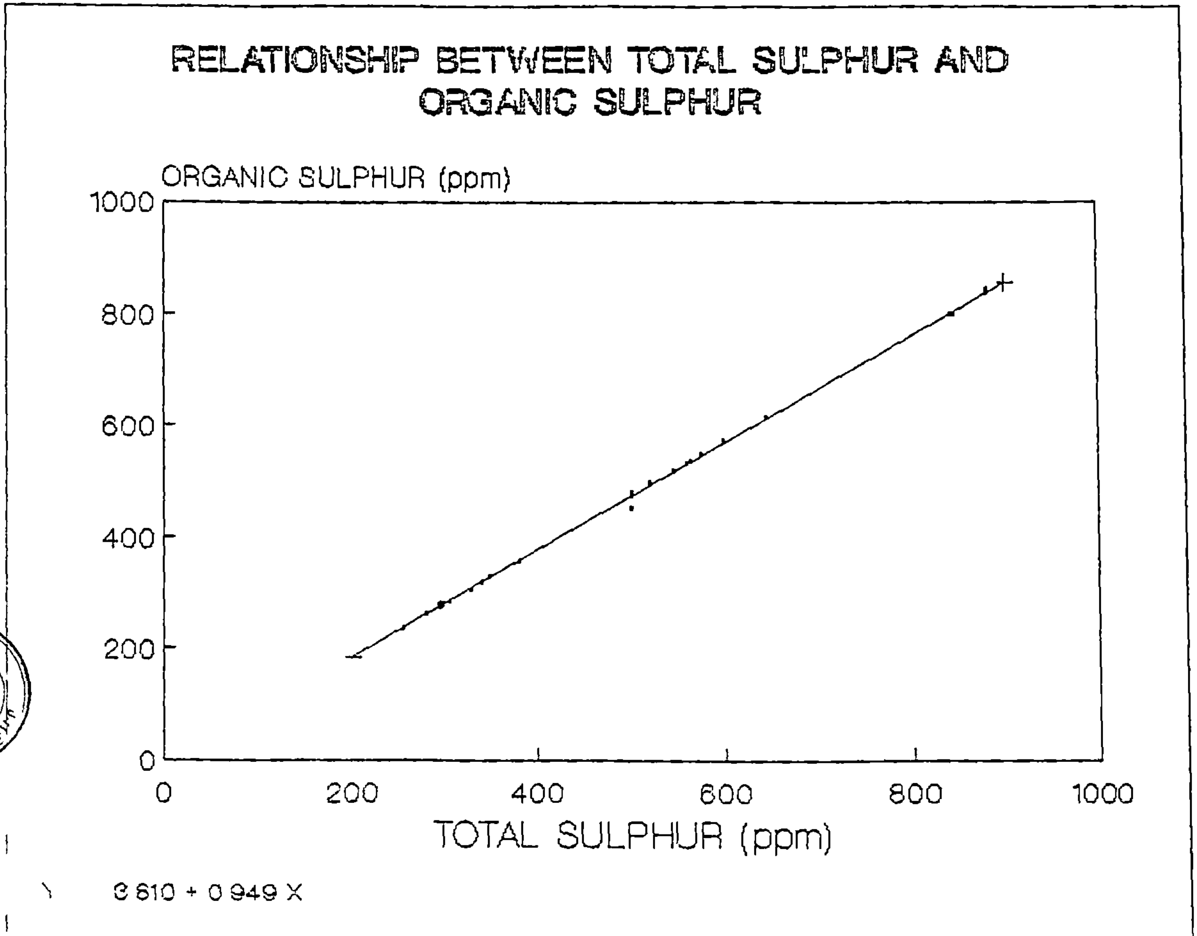
Y	X	r
Sulphate Sulphur	PH	-0 3788**
	EC	0 1952
	Organic carbon	0 8255**
	Nitrogen	0 6952**
	Phosphorus	0.8188**
	Potassius	-0 0610
	Calcium	0.7593**
	Magnesium	0 8629**
	Sesquioxides	0 4842**
	Clay	0 7812**
	Silt	0 5192**
Water soluble sulphur	PH	-0 3706
	EC	0 1522
	Organic carbon	0 8325**
	Nitrogen	0 7408**
	Phosphorus	0 8579**
	Potassium	-0 0473
	Calcium	0.7908**
	Magnesium	0 9090**
	Sesquioxides	0 4871**
	Clay	0 8269**
	Silt	0 5809**

Table - 12

Coefficient of simple linear correlations between different forms of sulphur

Y	X	r
Total sulphur	Organic sulphur	0 9933**
	Sulphate sulphur	0 9101**
	Water soluble sulphur	0.9430**
	Am. Acetate soluble sulphur	0 9527**
	HCl soluble sulphur	0.9547**
	Morgan s reagent soluble sulphur	0 9662**
Organic sulphur	Sulphate sulphur	0 9101**
	Water soluble sulphur	0 9391**
	Am. Acetate soluble sulphur	0 9463**
	HCl soluble sulphur	0.9483**
	Morgan s reagent soluble	0 9596**
	sulphur	0.9596**
Sulphate sulphur	Water soluble sulphur	0.9254**
	Am Acetate soluble sulphur	0 9371**
	HCl soluble sulphur	0.9071**
	Morgan's reagent soluble sulphur	0.9165**
Water soluble sulphur	HCl soluble sulphur	0 9471**
	Am. acetate soluble sulphur	0 9524**
	Morgan's reagent soluble sulphur	0 9568**
Ammonium acetate soluble sulphur	HCl soluble sulphur	0 9840**
	Morgan's reagent soluble	0 9578**
HCI soluble sulphur	Morgan's reagent soluble sulphur	0 9537**
Neubauer values	Water soluble sulphur	0 9420**
	Am acetate soluble sulphur	0 9441**
	HCl soluble sulphur	0.9376**
	Morgan's reagent soluble sulphur	0.9476**

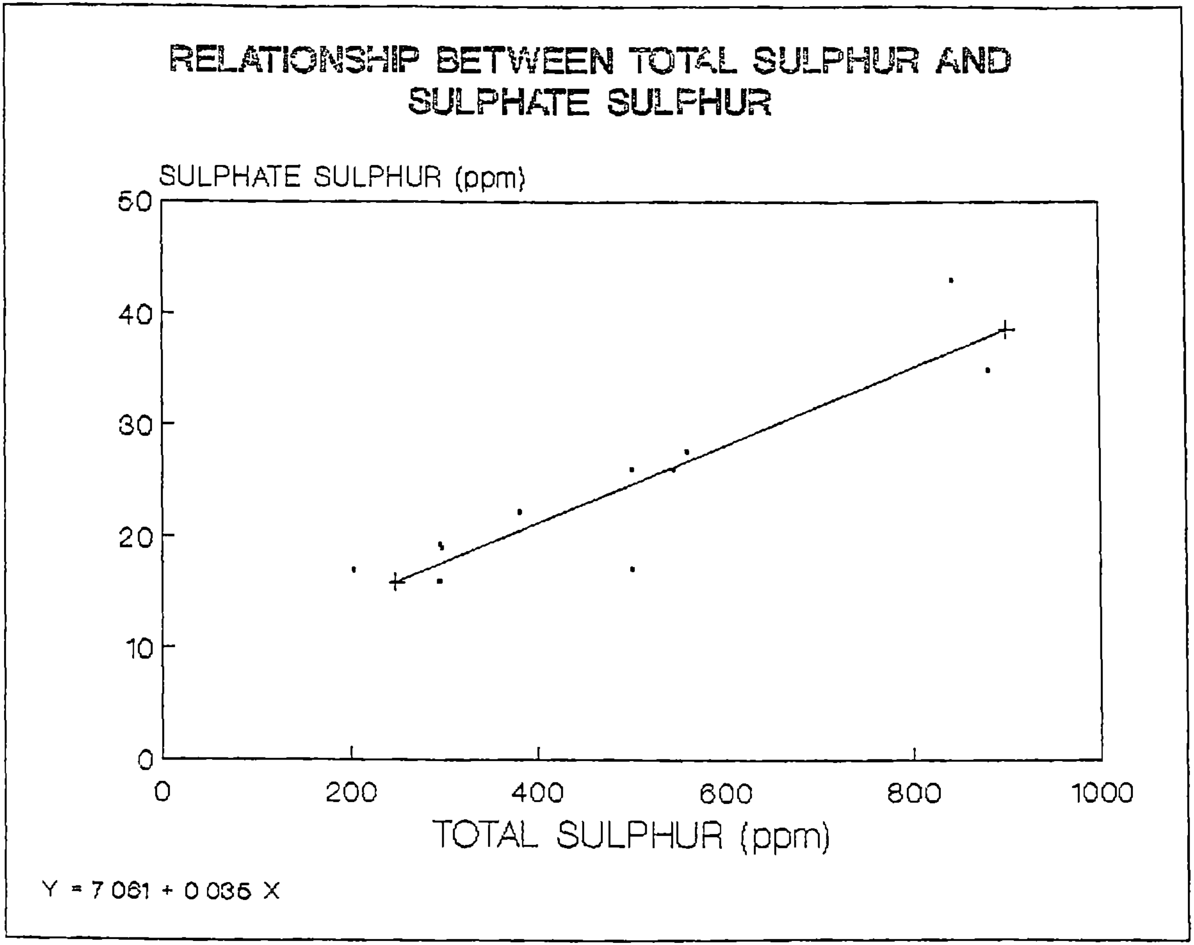
Fig 2



170299

101

Fig 3



RELATIONSHIP BETWEEN TOTAL SULPHUR AND SULPHATE SULPHUR
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
200
400
600
800
1000
TOTAL SULPHUR (ppm)
Y = 7 061 + 0 035 X

102

Fig 4

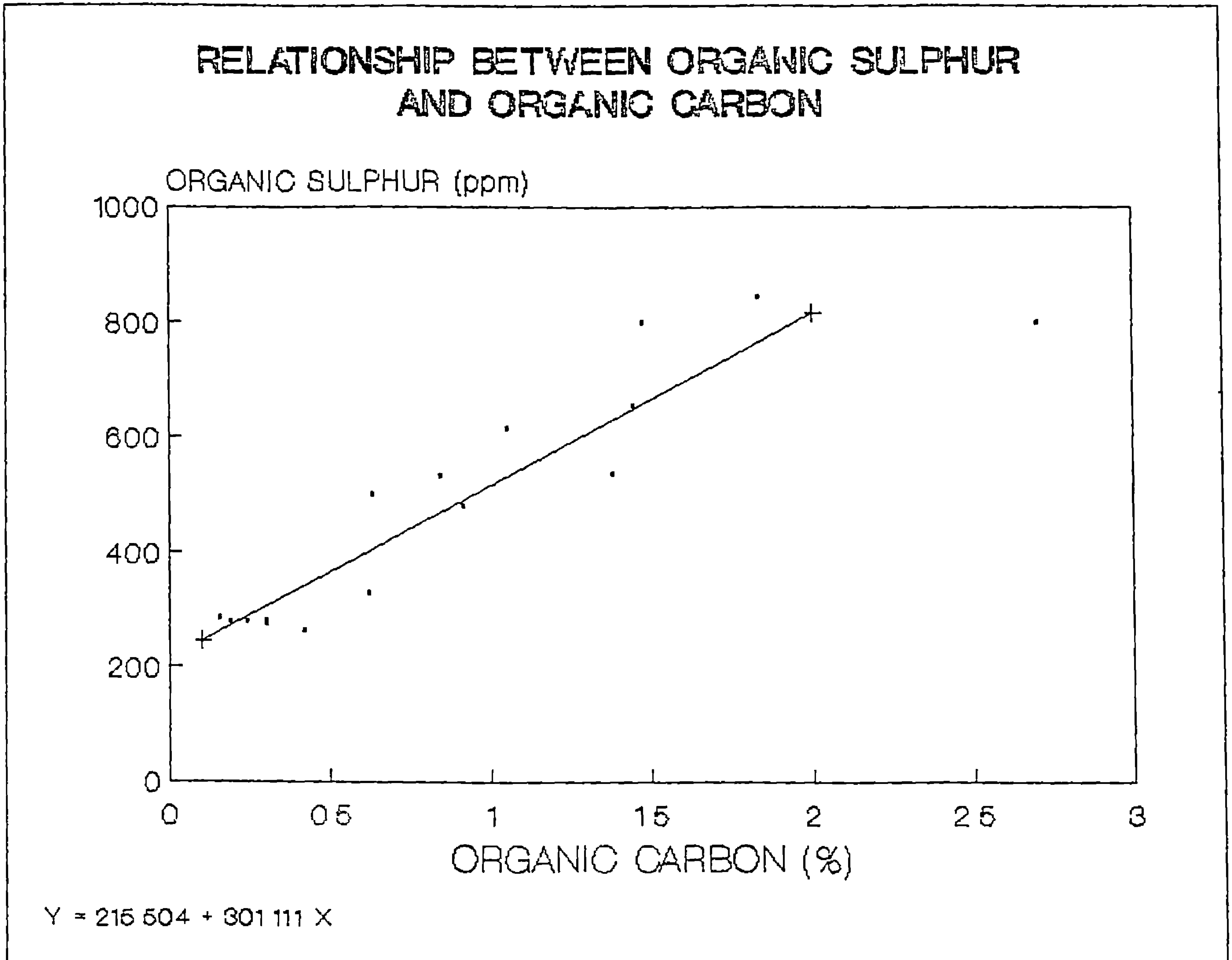
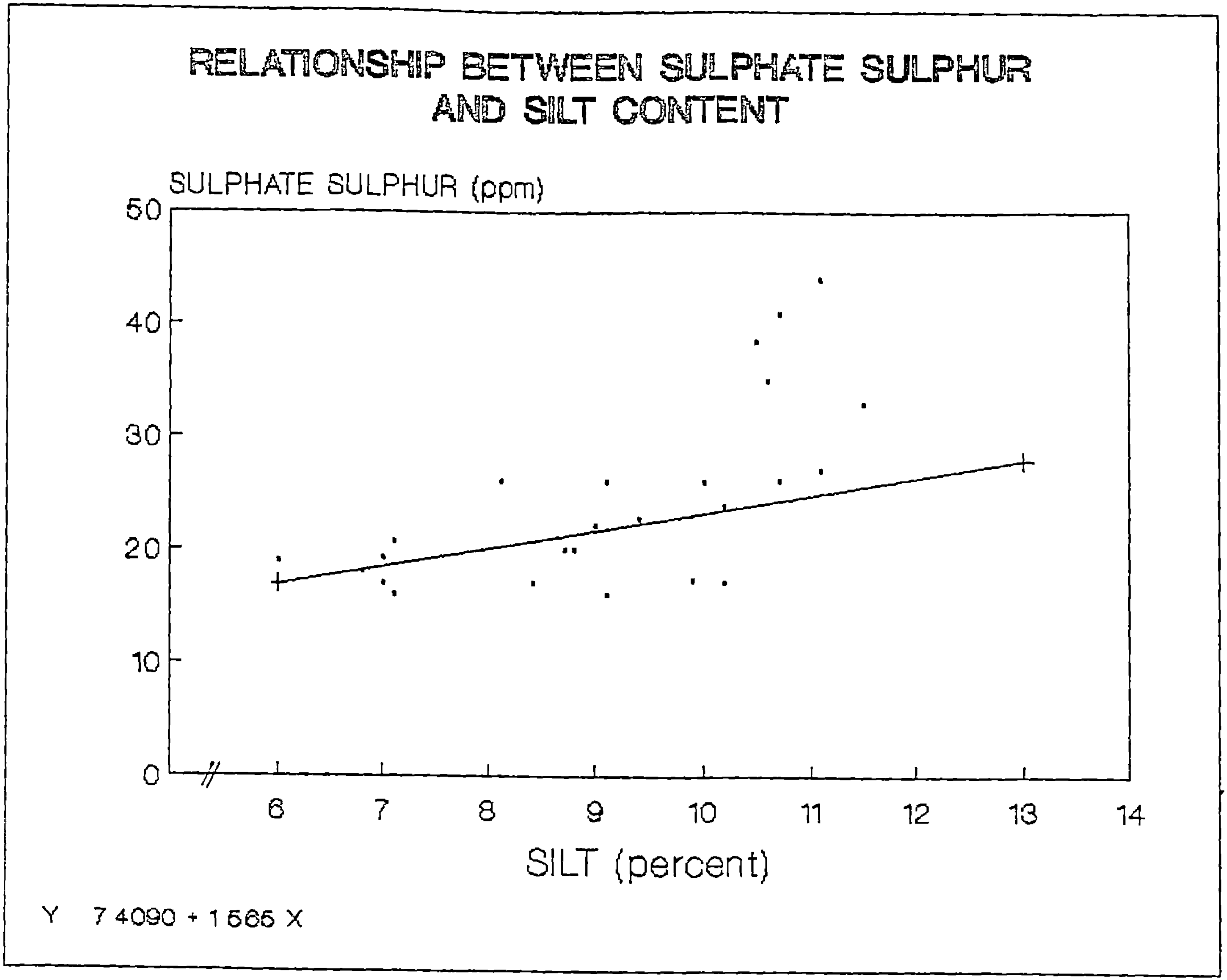

RELATIONSHIP BETWEEN ORGANIC SULPHUR
AND ORGANIC CARBON
ORGANIC SULPHUR (ppm)
1000
800
600
400
200
0
0
0 5
1
1 5
2
2 5
3
ORGANIC CARBON (%)
Y = 215 504 + 301 111 X

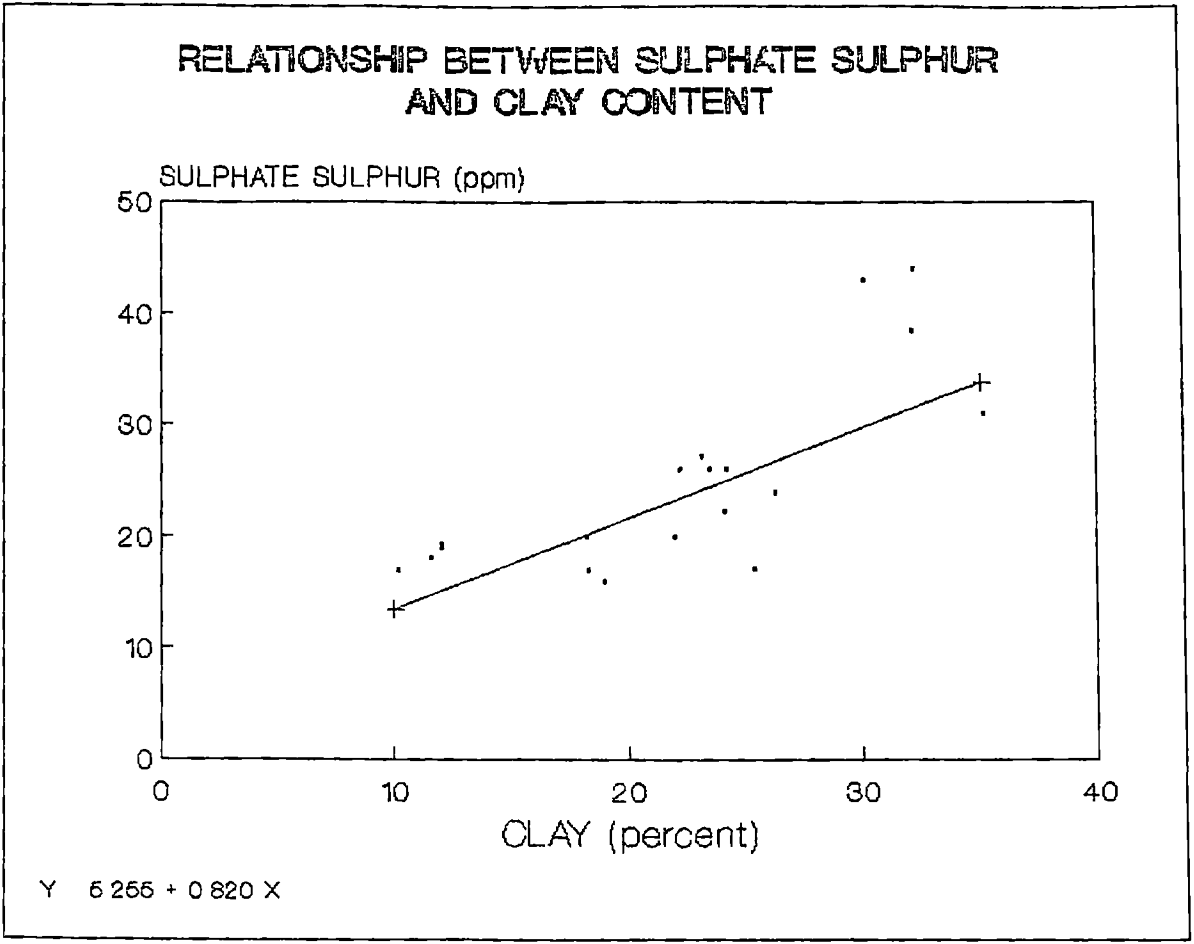
Fig 5



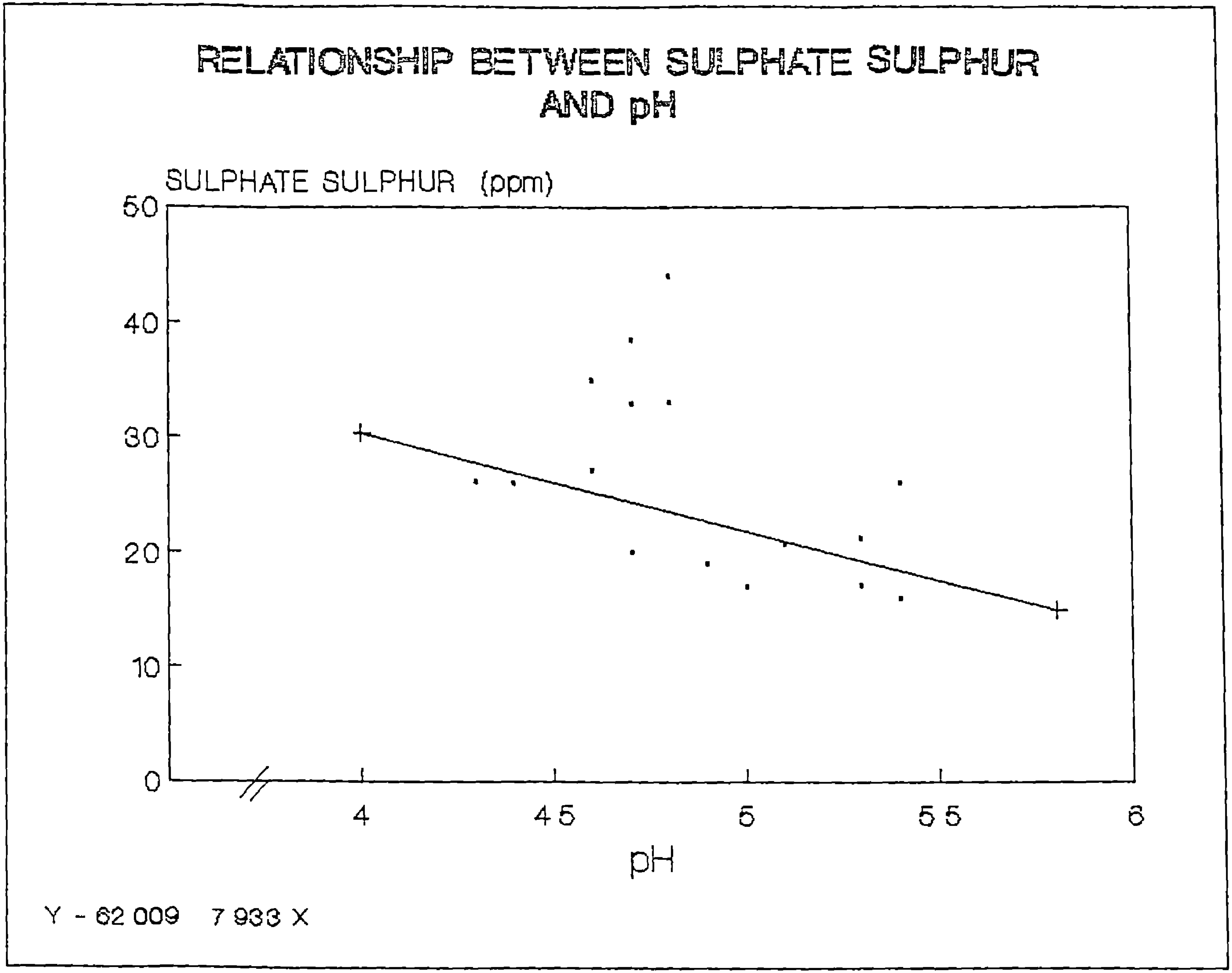
170299

104

Fig 6



RELATIONSHIP BETWEEN SULPHATE SULPHUR AND CLAY CONTENT
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
10
20
30
40
CLAY (percent)
Y 6 255 + 0 820 X



RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND pH
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
4
4 5
5
5 5
6
pH
Y - 62 009 7 933 X

Fig 8

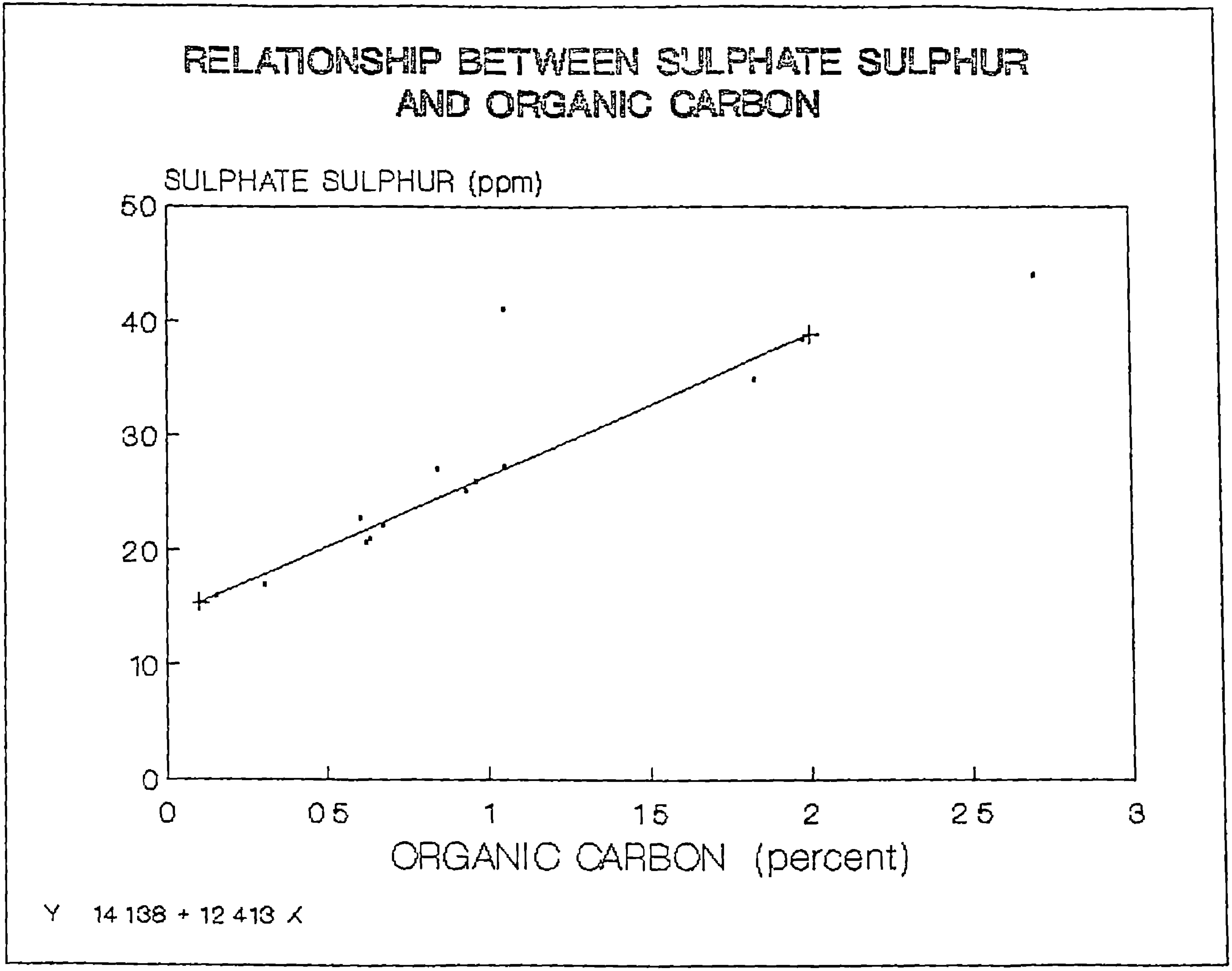
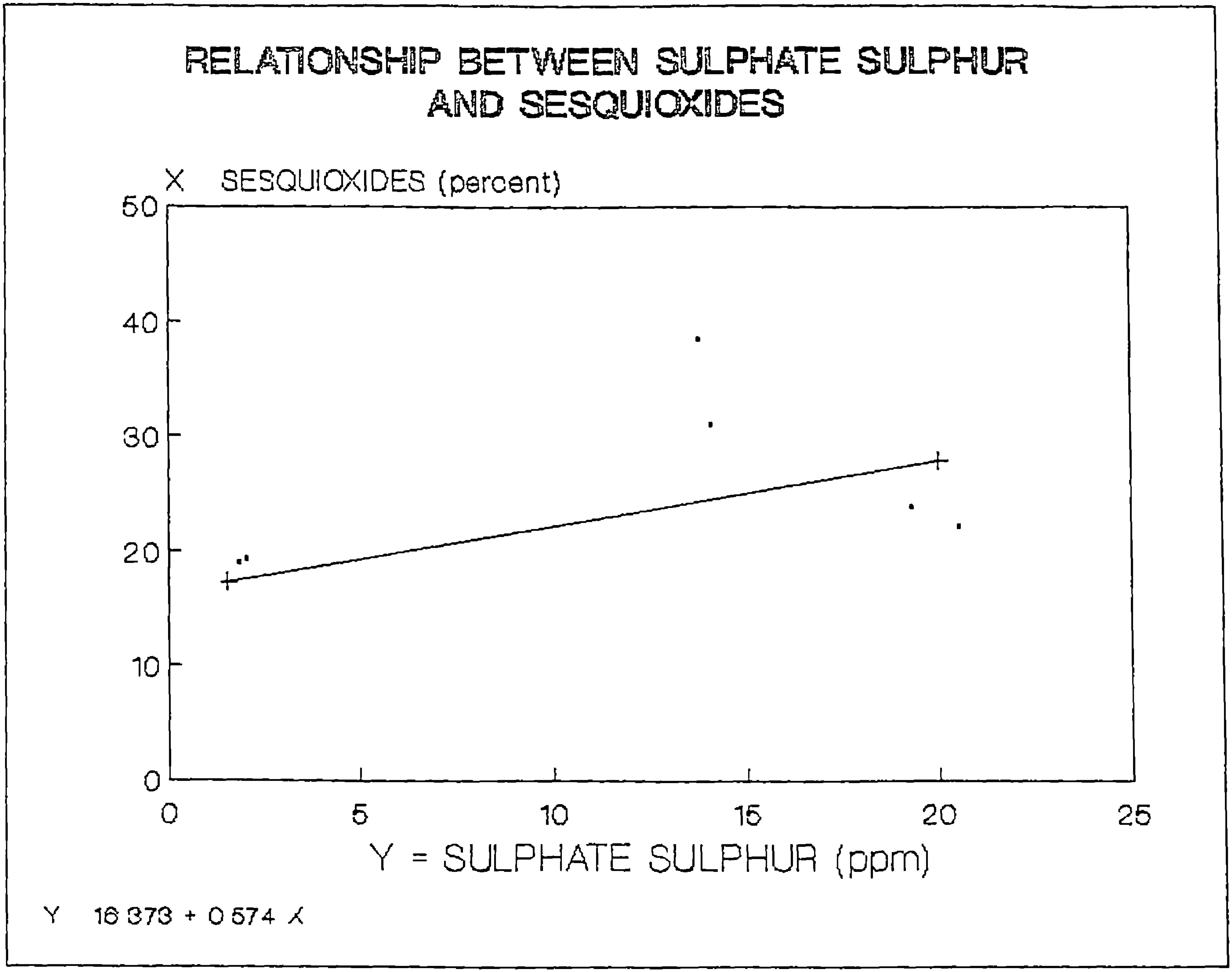

RELATIONSHIP BETWEEN SULPHATE SULPHUR AND ORGANIC CARBON
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
0 5
1
1 5
2
2 5
3
ORGANIC CARBON (percent)
Y 14 138 + 12 413 X

Fig 9


RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND SESQUIOXIDES
X SESQUIOXIDES (percent)
50
40
30
20
10
0
0
5
10
15
20
25
Y = SULPHATE SULPHUR (ppm)
Y 16 373 + 0 574 X

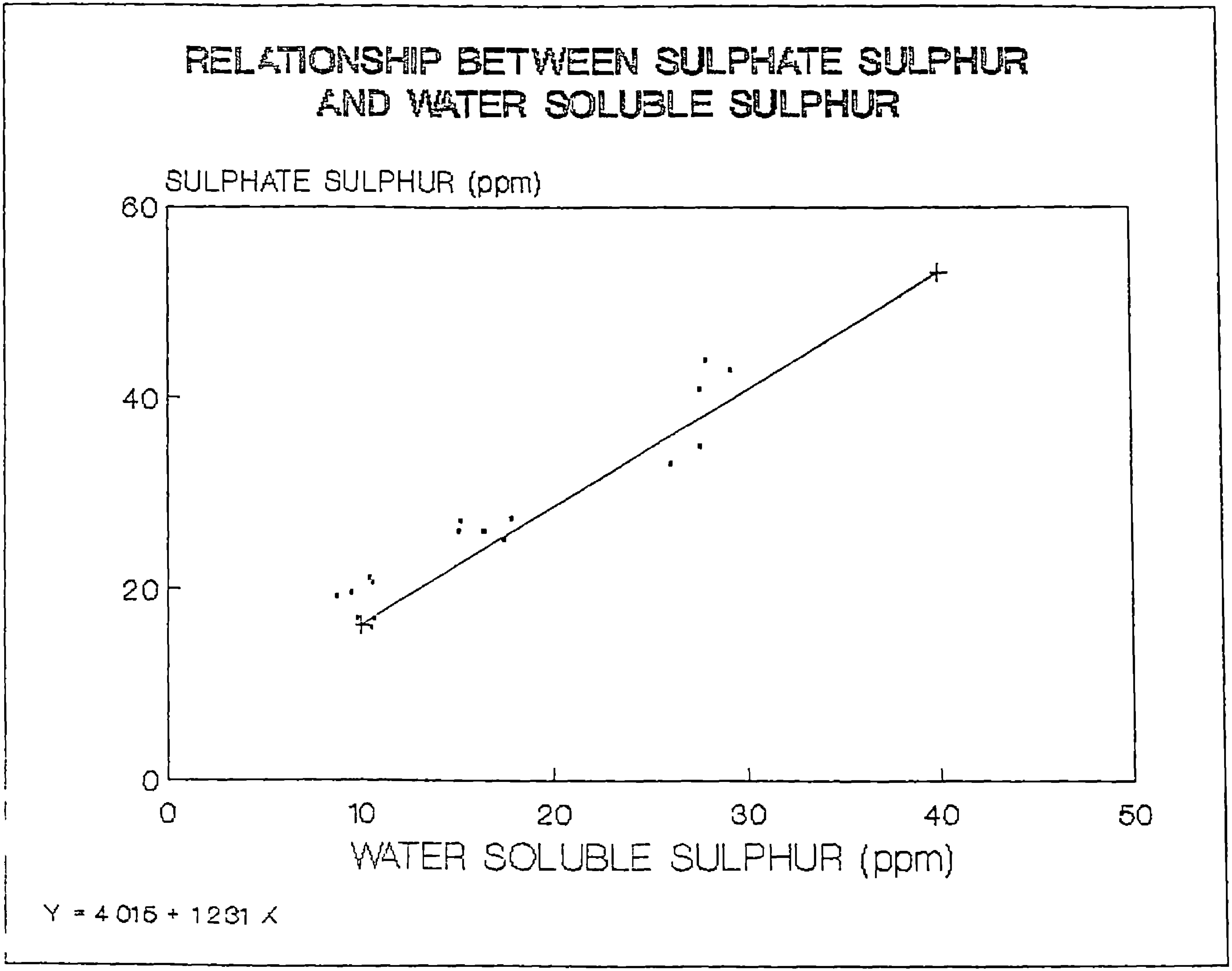
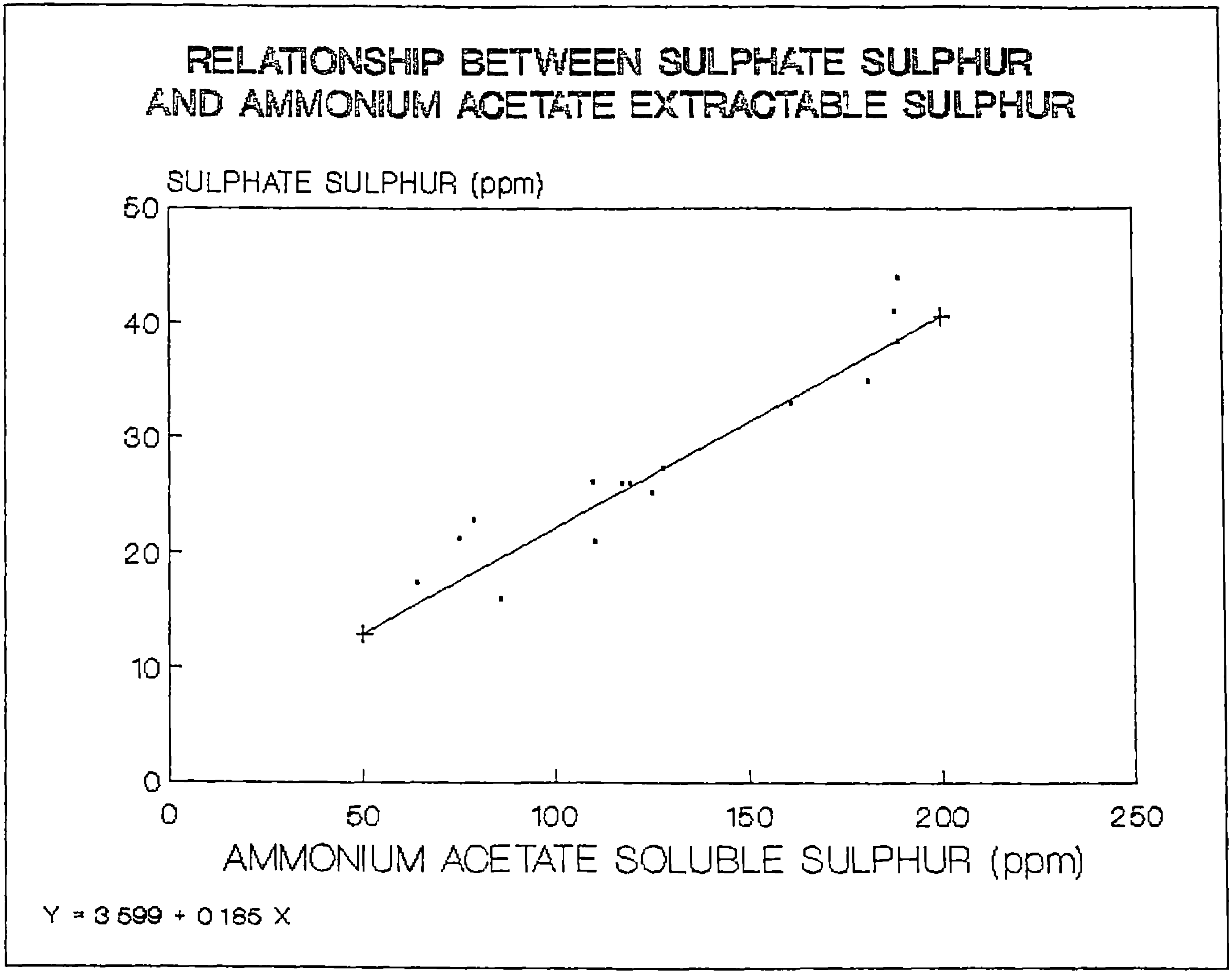

RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND WATER SOLUBLE SULPHUR
SULPHATE SULPHUR (ppm)
60
40
20
0
0
10
20
30
40
50
WATER SOLUBLE SULPHUR (ppm)
Y = 4 015 + 1231 X

Fig 11


RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND AMMONIUM ACETATE EXTRACTABLE SULPHUR
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
50
100
150
200
250
AMMONIUM ACETATE SOLUBLE SULPHUR (ppm)
Y = 3 599 + 0 185 X

110

Fig 12

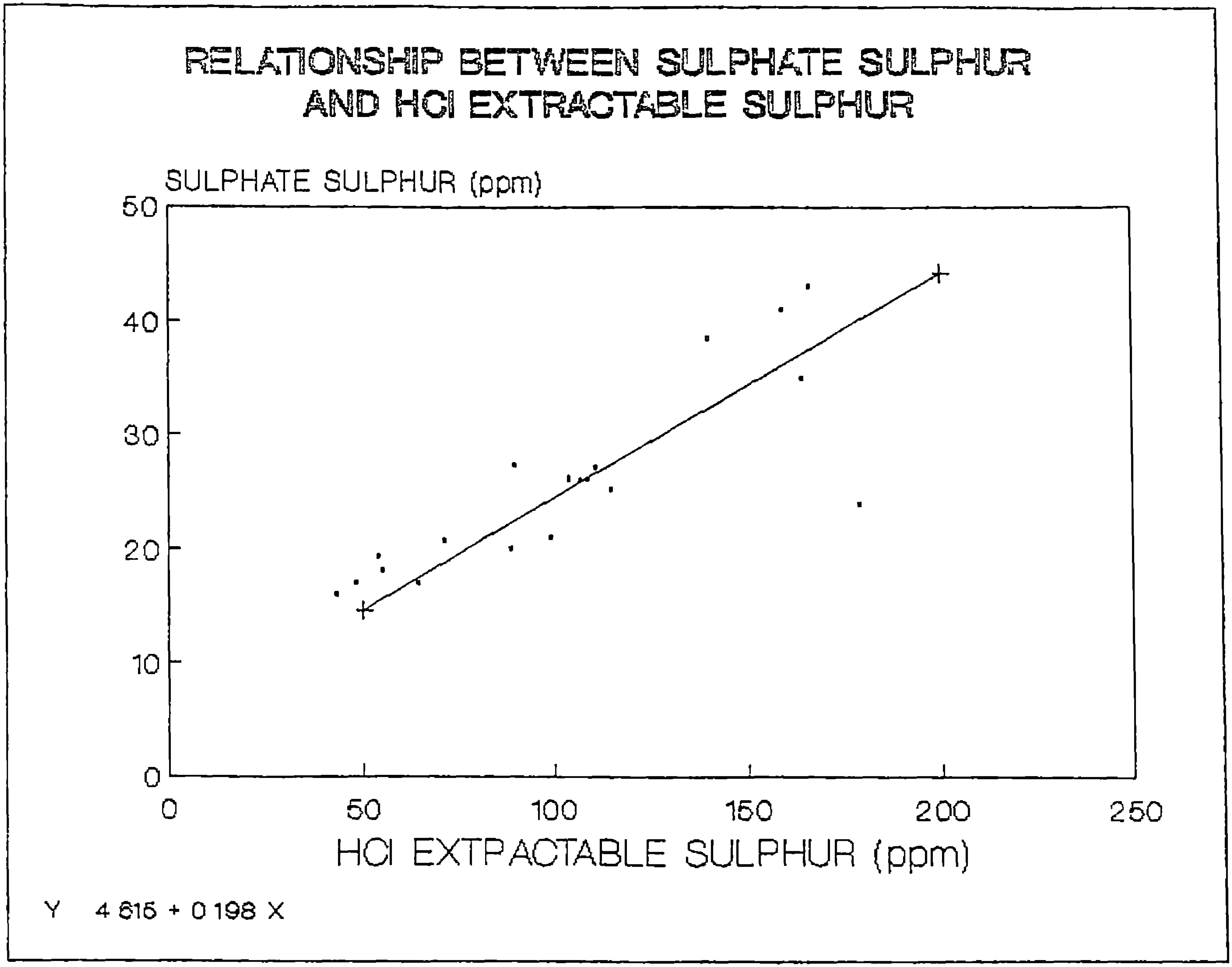
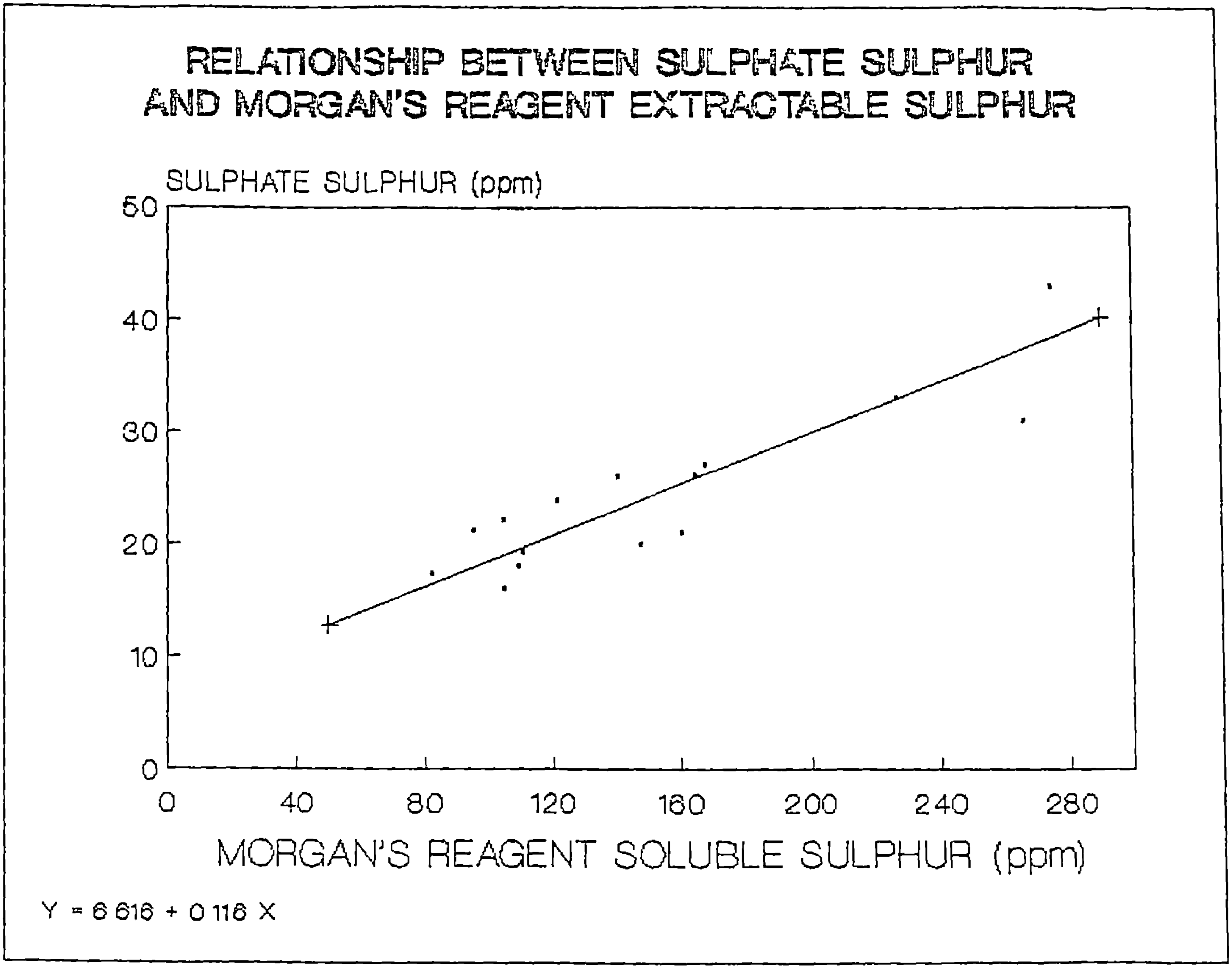

RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND HCl EXTRACTABLE SULPHUR
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
50
100
150
200
250
HCl EXTPACTABLE SULPHUR (ppm)
Y 4 615 + 0 198 X

Fig. 13


RELATIONSHIP BETWEEN SULPHATE SULPHUR
AND MORGAN'S REAGENT EXTRACTABLE SULPHUR
SULPHATE SULPHUR (ppm)
50
40
30
20
10
0
0
40
80
120
160
200
240
280
MORGAN'S REAGENT SOLUBLE SULPHUR (ppm)
Y = 6 616 + 0 116 X

Water soluble sulphur was positively and significantly correlated with available sulphur extracted by different reagents like HCl (0.9471**) ammonium acetate solution (0.9254**) and Morgan's reagent (0.9568**).

Ammonium acetate soluble sulphur was positively correlated with HCl soluble (0.9840**), and Morgan's reagent soluble (0.9578**). HCl soluble sulphur showed positive and significant correlation with Morgan's reagent soluble sulphur (0 9537**).

DISCUSSION

DISCUSSION

Till recently sulphur was rather a neglected element in Indian Agriculture, and it was only during the last two decades that any serious attention was paid to its occurrence and distribution in Indian soils. The plant requirement of sulphur is comparable to that of phosphorus and therefore, it can be accorded the status of the fourth major nutrient Information on sulphur status of soils is available from certain areas, but it is lacking in many others. Only some sporadic studies on soil sulphur have been carried out in Kerala, mainly from the point of view of toxicity in wetland soils and also from the point of view of its general status in various soil groups In view of these facts, the results of present study provide very useful information regarding the forms and distribution of sulphur in the upland soils of South Kerala

The soils included in the study have been characterised as sandy, redloam, laterite midland, laterite midupland and forest Fifty representative samples representing ten each of the major five soil types were identified and samples were collected from depths of 0-20 and 20-50 cm. The mean values of the physical and chemical properties are given in Table 1, 2, 3 and 4 and the results of the studies are discussed in relation to these soil parameters.

5.1 Forms of Sulphur

5.1 1 Total sulphur

The total sulphur content of the different soil types varied significantly (Table 5). It increased in the order sandy < redloam < laterite midland < laterite midupland < forest soils. It is to be noted that clay and organic matter in these soils increased steadily from the sandy soils to the forest soils through redloam, laterite midland and laterite midupland in that order. Hence the sequence of variation in the content of soil sulphur is to be expected in view of the generally increasing proportion of clay and organic matter as we pass from the sandy soils to the forest soils through the redloam, laterite midland, laterite midupland and also because this form of sulphur is significantly correlated to clay and organic matter An increase in the content of total sulphur in the soils of Kerala in the order sandy < laterite < forest reported earlier by Leela (1967) is in agreement with the present findings.

In all the soil types, the surface soils contained the maximum amount of total sulphur which decreased with increasing depth. Sulphur is an integral part of organic matter and an increase in the content of organic matter in the surface soils observed explains the increase in total sulphur in surface soil. Vinay Singh and Sharma (1983) and Tiwari and Pandey (1990) have reported the same tendancy in the distribution of total sulphur in the soils of Agra and Varanasi regions respectively.

5 1.2 Organic Sulphur

As in the case of total sulphur the organic sulphur in the different soils also varied significantly. The sequence of organic sulphur in the soils was also similar, viz sandy < redloam < laterite midland < laterite midupland < forest The comparative values of organic matter in these soils explain the variation in the content of organic sulphur The organic sulphur constituted 91 7 to 95.5 per cent of the total sulphur in the different layers of all the soils, showing a dominance over other forms of sulphur in the soils. The higher contribution of organic sulphur to total sulphur may be attributed to the leaching loss of inorganic sulphur in these humid tropical soils.

The predominance of organic sulphur in Kerala soils reported earlier by Jacob (1966) is in agreement with the results of the present study

In all the soil types the distribution pattern of organic sulphur showed a decreasing trend with increasing depth. This may be ascribed to the decreasing trend in organic matter with increasing depth and the significant correlation of orgnanic sulphur with organic matter Such a trend in the distribution of organic sulphur was reported earlier by Tiwari and Pandey (1990), Vinay Singh and Sharma (1983) and Leela (1967). The percentage of organic sulphur to total sulphur was highest in surface soils. The intense leaching and consequent depletion of inorganic sulphur in the surface soils makes the organic form of sulphur to be more prominent in surface soils.

5.1.3 Sulphate sulphur

Sulphate sulphur is formed in the soil by oxidation of organic sulphur and therefore this fraction is bound to show the same trend in distribution as total and organic sulphur It was actually found to be so in this study, the lowest quantities of sulphate sulphur being present in the sandy soils and the largest quantities in the forest soils, the redloam, laterite midland and laterite midupland coming in between The variation in the contents of sulphate sulphur in the different soils was in general statistically significant. Such a sequence of variation in the content of sulphate sulphur in sandy, laterite and forest soil of Kerala, reported earlier by Leela (1967) is in agreement with the present study. The sulphate sulphur constituted 4 4 -

7.6 per cent of total sulphur in all the layers of the different soils. The lower contribution of sulphate sulphur to the total may be attributed to the leaching loss of inorganic sulphur in humid tropical soils. The lower contribution of sulphate sulphur to total sulphur was reported earlier by Jacob (1966) and Leela (1967) in soils of Kerala.

Except for sandy soils, the distribution pattern of sulphate sulphur in all the soil types showed a decreasing trend with an increase in depth Due to the coarse textured nature sulphate sulphur get leached and accumulated in the lower layers of sandy soils and this led to a higher content of sulphate sulphur in subsurface layers of sandy soils. Similar findings was reported earlier by Jacob (1966) in soils of Kerala

5 2 Available sulphur using various extractants

Plants take up sulphur in the form of sulphate and the soil sulphur mainly comprises water soluble, adsorbed and organically bound sulphur Attempts were made to compare the quantities of sulphur extracted by the various extractants viz, water, ammonium acetate, HCl and Morgan's reagent which are shown in Table 7 and 8 and graphically presented in Fig 1

5 2.1. Water extractable sulphur

Water extracted only a small fraction of the total sulphur in the different soils The mean content of water extractable sulphur ranged from 9 6 to 28 2 ppm. Water extracted the largest amount of sulphur from the forest soil and the smallest from the sandy soil. Except for sandy soils, water extractable sulphur showed a decreasing trend with increasing depth The higher content of water extractable sulphur in the subsurface layers of sandy soils may be due to its coarse textured nature which leached sulphur from the surface layers and get accumulated in the subsurface layers. Being a weak extractant only low quantities of sulphur were understandably extracted by water from the different soils. The low efficiency of water to extract sulphur from soil as reported earlier by Leela (1967) and Mehta et al (1988) is in accordance with the present finding

5.2.2 Neutral normal ammonium acetate extractable sulphur

Mc Clung et al (1959) suggested this extractant for soil sulphur estimation.

Of the four extractants used, ammonium acetate ranked second in its ability to extract soil sulphur, showing superiority over water and HCl in all types of soils The mean content of ammonium acetate extractable sulphur varied from 59 3 to 190 6 ppm. The largest amount of sulphur extracted was from the forest soils and the smallest from the sandy soils in both the layers The amount of sulphur extracted decreased with increasing depth in all types of soils which may be attributed to the higher content of sulphur in surface layers The superiority of ammonium acetate to water exhibited in extracting more sulphur from soil is due to its capacity to extract a fraction of organic sulphur as well Such findings on the soils of Kerala reported earlier by Leela (1967) is in agreement with the results of present study.

5.2 3 Normal hydrochloric acid extractable sulphur

Available sulphur extracted by N HCl was higher than the water extractable but lesser than ammonium acetate and Morgan s reagent extractable sulphur. The mean hydrochloric acid extractable sulphur ranged from 49 8 to 171 5 ppm in the various soils The maximum quantities were extracted from the forest soils and the minimum from the sandy soils, the other soils coming in between in the order redloam < laterite midland < laterite midupland

Lowe and Delong (1963) noticed that organic soils of Quebec contained substantially more carbon bonded sulphur and the recovery of carbon bonded sulphur in acid extractable fraction was higher in proportion to the organic matter content of soil. The variation in the content of organic matter in the various soils under study understandably reflected on the content of acid extractable sulphur as well The content of acid extractable sulphur decreased with depth in accordance with the content of organic matter in the respective layers of the soils A similar finding reported earlier by Leela (1967) is in accordance with the present finding.

5.2.4 Morgan's reagent extractable sulphur

The mean values of sulphur extracted by Morgan s reagent varied from 67.7 to 275.6 ppm Among the various soils, forest soil was the highest in the release of sulphur followed by laterite midupland, laterite midland, redloam and sandy soil in the decreasing order As in the case of other extractants used, Morgan's reagent extractable sulphur also decreased with increasing depth of soils The magnitude of available sulphur extracted by Morgan's reagent was highest in comparison with the other extractants used. This may be due to its greater ability to extract the adsorbed form of sulphate ions held by clay and organic matter.

Balasubramanian and Kothandaraman (1985) in their studies on soil sulphur have reported the superiority of Morgan's reagent in extracting soil sulphur which is in agreement with the present study.

5 3 Uptake of sulphur as assessed by Neubauer technique

The Neubauer technique is based on the uptake of nutrients by a large number of plants grown on a small amount of soil The roots thoroughly penetrate the soil, exhausting the available nutrient supply within a short time.

From the data, it is evident that uptake values of sulphur were highest for plants grown in forest soils and lowest for those in sandy soils Neubauer values decreased in the order Forest > Laterite midupland > Laterite midland > Redloam > Sandy soils Correlation studies revealed that highly significant positive relation existed between uptake values and available sulpher extracted by different reagents The uptake value exhibited by the plants is evidently a reflection of the sulphur content in the soils.

5.4 Relationship of forms of sulphur with general soil properties

It was evident from the data (Table 11 and Fig 7) that a significant but negative correlation existed between pH and all the forms of sulphur viz total, organic, sulphate, water extractable, ammonium acetate extractable, HCl extractable and Morgan's reagent extractable sulphur. This indicate that an increase in soil pH would result in a corresponding decrease in the various form of soil sulphur. These results are in accordance with the finding of Tiwari and Pandey (1990) The negative relationship may be due to the replacement and substitution of OH ions by sulphate ion from aluminium hydroxide present in clay. The replaced OH ions inturn react with H^+ ions present in the soil solution Sulphate adsorption is increased as the pH is lowered because the replaced OH ions are more effectively neutralised Creation of more positive charges at the basal plain surfaces of clay minerals by the addition of H^+ ions is another reason for the increased adsorption of sulphate ions with increasing acidity.

Fine textured soils possess more sulphur than coarse textured soils. In the present study it was established that a significantly positive correlation exists between silt, clay, and all forms of sulphur (Table 11 Fig 5 and 6). The relationship of clay with sulphate sulphur shown may be ascribed to the capacity of clay to attract sulphate ions Proposed mechanisms for sulphate adsorption by clay minerals include replacement of OH^- from clay mineral surfaces especially around the flake edges and adsorption via anion exchange sites existing along the basal plane surfaces. Adsorption of sulphate usually increases with clay content of the soils Similarly the positive relation between clay and organic sulphur is due to the association of organic matter with the clay fraction of the soil Since both sulphate and organic sulphur showed a positive relation with clay, total sulphur is also understandably a function of clay content as reported by Patil et al (1981) The significant positive correlation of clay and silt with total, organic and sulphate sulphur reported by Arora and Takkar (1988) and the positive relationship between organic sulphur and clay established earlier by Vijaykumar and Maharaj Singh (1979) are in agreement with the finding of the present study.

The organic carbon content of the soils was found to be significantly and positively interrelated with all the forms of sulphur studied (Table 11, Fig 4, 8). Dwivedi et al (1985) Arora and Takkar (1988) and Tiwari and Pandey (1990) have reported that organic carbon has positive correlation with total organic and sulphate forms of sulphur which is in confirmity with the findings of the present study. Sulphur in most of the Indian soils has been a function of organic matter, (Kanwar and Takkar, 1964 Virmani and Kanwar, 1971 and Reddy et al., 1985) which explains the relationship established

Significant positive correlations were observed between the different forms of sulphur with soil nitrogen and phosphorus (Table 11). This is easily explained when we remember that both nitrogen and phosphorus are positively correlated with soil organic matter to which the different forms of sulphur are also positively correlated This would mean that soil organic matter is an important source of soil nitrogen, phosphorus and sulphur although a latter two elements may be derived from mineral sources as well The significantly positive relationship between organic sulphur and total nitrogen reported by Kanwar and Takkar (1964) and the positive correlation of available sulphur with total nitrogen and total phosphorus established by Krishnappa et al (1989) are in agreement with the present findings.

The significant positive correlation exhibited between different forms of sulphur and the bases calcium and magnesium is apparently difficult to explain in view of the negative correlation between soil sulphur and pH or the positive correlation between sulphur and acidity However, we have to remember that there are more determinative factors such as soil texture or clay content which also control and determine the distribution of the various elements in the soil Thus in the present study the different forms of sulphur are significantly and positively correlated with clay to which the soil calcium, and magnesium are also positively correlated. Naturally therefore the different forms of sulphur are significantly and positively correlated to calcium and magnesium The positive and significant correlation of available sulphur with calcium and magnesium was reported earlier by Krishnappa et al (1989)

The significant positive relationship between different forms of sulphur and sesquioxides in the soils was also established in the present study (Table 11, Fig. 9) Hydrous oxides of aluminium and iron showed marked tendencies to retain sulphates These compounds are considered to be responsible for most of the sulphate adsorption in many soils Sulphate ions exchange hydroxyl ions of Sesquioxides Hence the greater the amount of sesquioxide, the greater will be the adsorption of sulphate Sulphate ions are also retained as hydroxy-aluminium complexes by co-ordination. These explains the correlation between sulphur and sesquioxides.

5 5 Interrelations between different forms of sulphur in soils.

Various forms of sulphur showed positive and significant relation among themselves in the soils studied (Table 12). Total sulphur was positively and significantly correlated with organic and sulphate forms of sulphur present in the soils (Fig. 2 and 3) Significant positive relation between organic sulphur and sulphate sulphur was also established in the present study. These results are in accordance with the findings of Ruhal and Paliwal (1980a) and Balasubramanian and Kothandaraman (1985). The above relationship may be due to the contribution of organic sulphur towards total and sulphate sulphur.

It was also established that total, organic and sulphate sulphur were positively and significantly correlated with sulphur extracted by the different extractants used, viz water, ammonium acetate, HCl and Morgan's reagent (Fig. 10, 11, 12, 13). Within the different extractants all of them exhibited highly positive correlation with each other.

The significant relationship observed among the various forms of sulphur simplifies the study of these forms because even from the estimation of the most easily determined form all other forms can be predicted.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An investigation was carried out to study the forms and distribution of sulphur in the upland soils of South Kerala The soils included in this study have been characterised as sandy, redloam, laterite midland, laterite midupland and forest Fifty localities representing ten each of the aforesaid five major upland soil types of South Kerala were identified in Thiruvananthapuram district and soils collected from depths 0-20 and 20-50 cm were subjected to the study

The texture of the four groups of soils viz redloam, laterite midland, laterite midupland and) forest soils were sandy clay loam where as in sandy soil, it varied from sand to sandy loam Clay content in these soils increased steadily from sandy to forest soils through the redloam, laterite midland and laterite midupland in that order Though the different soil types differ in the extend of acidity, all the soils were acidic in reactions. In general, the acidity of the soils tend to increase with increasing depth. Organic carbon was highest in the forest soil followed by laterite midupland, laterite midland, redloam and sandy soils in the descending order. Organic carbon tend to decrease with increasing depth in all the soils Except for forest soils, total nitrogen contents of soils were found to be poor. Forest soil recorded the maximum content of total phosphorus, total potassium, total calcium, total magnesium and sesquiodixdes while sandy soil the minimum

The soils were analysed for different forms of sulphur and available sulphur was estimated using different extractants Neubauer test was conducted using paddy as the test crop to assess the plant available sulphur.

The data obtained were studied and analysed statistically The interrelationship of different forms of sulphur with the relevant soil parameters and among different forms of sulphur were examined The correlation coefficients were worked and tested for significance in cases where relationship was found to be close

The results of these studies led to the following conclusions.

The different soils under study viz sandy, redloam, laterite midland, laterite midupland and forest soils contained varying amounts of the different forms of sulphur The upland soils of Kerala in general were not deficient in sulphur

Total sulphur increased in the order sandy < redloam < laterite midland < laterite midupland < forest. The same sequence of variation was noticed for organic sulphur as well.

Sulphate sulphur is formed in the soil by the oxidation of organic sulphur and hence this fraction also showed the same trend as total and organic sulphur. The lowest quantities of sulphate sulphur being present in sandysoils and the largest quantities in forest soils, the redloam, laterite midland, and laterite midupland coming in between The organic sulphur constituted 94 2 - 95.5 % of total sulphur in surface and 91 7 - 94.3 % in the subsurface layers Sulphate sulphur recorded only 4 4 - 5 7 % of total sulphur in the surface and 4.8 - 7.6 % in the subsurface layers.

The proportion of total, organic and sulphate sulphur was more in the surface layers than in the subsurface layers of redloam, laterite midland, laterite midupland and forest soils In sandy soils, due to its coarse textured nature sulphate sulphur was higher in subsurface layers than the surface layers

The quantities of sulphur extracted by various reagents increased in the order water < HCl < ammonium acetate solution < Morgan's reagent The lowest quantities were extracted from sandy soils and the largest amount from the forest soils, the other soils coming in between in the order redloam < laterite midland < laterite midupland.

Except for sandy soils, in all other soil types, the proportion of sulphur extracted by all the extractants decreased with increasing depth. In sandy soils, water soluble sulphur was more in subsurface layers

Sulphur uptake as determined by Neubauer technique showed highest value in forest soils and lowest in sandy soils, laterite midupland, laterite midland and redloam coming in between in the decreasing order Neubauer values of sulphur were highly significantly correlated with the available sulphur as determined by the four extractants Neubauer values reflected the actual amount of sulphur present in the soils

It was evident from the study that the different forms of sulphur were positively and significantly correlated with parameters like acidity, clay and silt content, organic carbon nitrogen, phosphorus, calcium, magnesium and sesquioxides present in the soil The significant positive interrelationship among different forms of sulphur were also established in the present study

It is hoped that this status report will provide a consolidated and comprehensive picture about sulphur content in upland soils of South Kerala. From this study, it can be summarised that major soil types of South Kerala are generally not decifient in sulphur. But the results have shown that sandy and redloam contained very less sulphur in comparison to other types. It can be expected that continuous cultivaition using sulphur free fertilisers will gradually make the soils sulphur deficient. Frequent research should be done in order to identify such areas and fertiliser recommendation should include the application of sulphur wherever conclusive research evidence is available. Sulphur should not be treated as an extra nutrient as this attitude adds to its neglectance in fertiliser planning It should be assigned a value and put to work as a yield raising input in agriculture

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APPENDICES

APPENDIX I

ANOVA TABLE FORMS OF SULPHUR

Source	df	Mean squares						
		X1	X2	X3	X4	X5	X6	X7
Series	4	934363 50	846554 50	1389 50	884 08	35383 19	30037 17	88358 06
Depth	1	555022 00	489020 00	275 55	55 77	10830 5	8836 00	39501 50
Series x Depth	4	5031 0	6349 5	12 46	8 30	215 09	219 94	580 63
Error	90	991 98	1209 42	8 07	1 16	121 59	105 91	145 26

X1 - Total sulphur

X2 - Organic sulphur

X3 Sulphate sulphur

X4 - Water extractable sulphur

X5 Ammonium acetate extractable sulphur

X6 - HCl extractable sulphur

X7 - Morgan's reagent extractable sulphur

SULPHUR STATUS
OF MAJOR UPLANDS OF SOUTH KERALA

By

SHEEBA S

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ABSTRACT

A study has been made to determine the different forms and distribution of sulphur, and its relationship to relevant soil parameters in the major upland soils of South Kerala representing sandy, redloam, laterite midland, laterite midupland and forest soils. An attempt was made to study the plant available sulphur by conducting Neubauer technique using paddy as the test crop. Available sulphur in the soils was also estimated using different extractants. The results of the experiments were summarised and appropriate conclusions drawn.

The study revealed that the forms of sulphur varied considerably from soil to soil. The soils in general were not deficient in this element. The content of different forms of sulphur was maximum in the forest and minimum in sandy soils. Sulphur content decreased from forest to sandy soils through laterite midupland, laterite midland and redloam soils. Organic sulphur registered more than 90% while sulphate sulphur less than 10% of the total sulphur in all the soils. The leaching loss of sulphate sulphur in the humid tropical soils may be accounted for the lower contribution of sulphate sulphur to total sulphur.

In all the soil types both total and organic sulphur decreased with increasing depth. Except for sandy soils

sulphate sulphur also showed the same trend in distribution in all the soils. Accumulation of sulphate form in the subsurface layers of sandy soils may be attributed to its coarse textured nature

Of the four extractants used for the determination of available sulphur in soils, Morgan s reagent was proved to be the best extractant followed by neutral normal ammonium acetate, normal hydrochloric acid and water in the descending order in all the soils

Sulphur uptake as determined by Neubauer technique recorded the highest value in forest and lowest in sandy soil, laterite midupland, laterite midland and redloam coming in between in the descending order Neubauer values reflected the actual amount of sulphur in the soils The significant correlation between the Neubauer values and available sulphur determined by the different extractant was also established.

The different forms of sulphur were positively and significantly correlated with the soil characteristics viz silt clay organic carbon total contents of nitrogen phosphorus calcium magnesium and sesquioxides and negatively correlated with soil pH The relationship among the various forms of sulphur was also found to be significantly positive