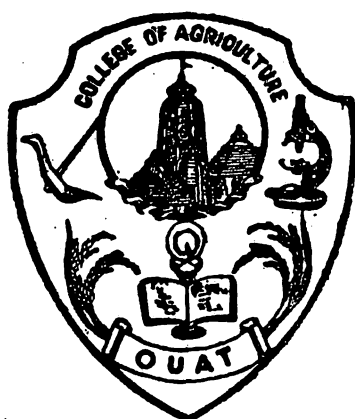


# EFFECT OF SULPHUR AND LIME APPLICATION ON SULPHUR NUTRITION OF GROUNDNUT

A THESIS PRESENTED TO  
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,  
BHUBANESWAR  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
MASTER OF SCIENCE IN AGRICULTURE  
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By

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DEPARTMENT OF SOILS AND AGRICULTURAL CHEMISTRY  
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BHUBANESWAR

1988

THESIS ADVISOR : DR. U. K. MISRA

**DEDICATED TO  
MY REVERED PARENTS**

APPROVAL SHEET

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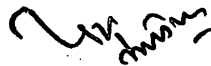
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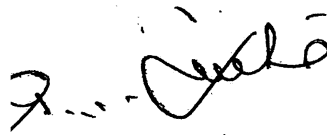
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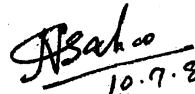
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C E R T I F I C A T E

Certified that the thesis entitled "EFFECT OF SULPHUR AND LIME APPLICATION ON SULPHUR NUTRITION OF GROUNDNUT" submitted in partial fulfilment of the requirement for the award of the degree of MASTER OF SCIENCE IN AGRICULTURE (Soil Science and Agricultural Chemistry) to Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried out by Shri Rajesh Das under my guidance and supervision during the academic year 1988. No part of this thesis has been submitted for the award of any other degree or diploma. It is further certified that all possible help and sources of information availed during the course of this investigation have been duly acknowledged by him.

Date : 15.6.89

  
( U. K. Misra )

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Date- 15.6.89

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## **CHAPTER - I**

### **INTRODUCTION**

## CHAPTER - I

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

Modernisation of agriculture has highlighted the importance of nutrient supplement through fertilisers for attaining higher levels of crop production. Mainly the importance of nutrient elements like N,P,K supplied through fertilisers is well recognised. But sulphur which is one of the essential nutrient elements for plant growth with crop requirement as high as phosphorus has been traditionally neglected.

The main reasons attributed for lack of attention given to role played by sulphur are subsistence farming, low crop yields, traditionally low sulphur responsive varieties, incidental return of sulphur to soil through FYM, conventionally used sulphur containing fertilisers and addition through rain water, irrigation water,  $SO_2$  emissions from industries, dusts and sea water etc. But the use of high analysis fertilisers like DAP, TSP, Urea and other sulphur free fertilisers, greater removal of sulphur through crops, decreased use of FYM along with regulations over industrial emission have lead to depletion of native sulphur status of the soil.

The evidence of crop response to applied S, the drastic decline in the addition of S because of continuous use of high analysis and sulphur free fertilisers and the growing need for increased food production necessitate a critical look at the sulphur fertilization problem. Of late, sulphur has been receiving the increasing attention of scientists all over the world and deficiencies of S have been reported from 72 countries including India. Tandon (1986) and Kanwar and Mudhar (1986) have reviewed the areas of sulphur deficiency in India. In Orissa only Ganjam district has been identified as the probable area of sulphur deficiency.

Sulphur research India began about 27 years ago with chlorosis of Jute and Sugarcane being attributed to S deficiency and at present S deficiency has been reported in 90 out of 400 edd districts in 16 states. Sulphur deficiency and crop response to application of S has been obtained under field condition in 31 crops. About 50% of studies on sulphur deal with oil seeds. Among oil seed crops mustard and groundnut have received more attention than others.

No information was available on the sulphur status of the soils of Orissa except a couple of reports on the response of some crops to sulphur application till a systematic survey on the S status of Orissa soil was carried out by this department during the year 1987-88. Soils were indentified as deficient based on monocalcium phosphate extractable S of 10 ppm or less.

In the present investigation an attempt was made to study the S response of groundnut grown in a S deficient acid soil. Further, the sulphate retention capacity of the soil of the field experiment site, and the effect of liming on sulphate adsorption character of the soil were studied in the laboratory. The objectives of the investigation were:

1. To evaluate gypsum as a source of sulphur for groundnut grown in a sulphur deficient acid soil under lined and unlined condition.
2. To study the effect of liming on the sulphur adsorption character of the soil.
3. To evaluate the sulphur and calcium requirement of groundnut.

- 4. To evaluate the percentage of applied sulphur utilized by the crop, retained in the surface soil (zone of application) and lost from the surface soil.

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## CHAPTER - II

# REVIEW OF LITERATURE

## REVIEW OF LITERATURE

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**2.1 Importance of sulphur**

Sulphur being one of the essential nutrients required for plant growth is in no way less important than phosphorus in its level of uptake by plant. It is required for its role in the formation of aminoacids like methionine (21% S) and cystine (27% S). Sulphur is also needed for synthesis of chlorophyll, proteins, oil content of oil seeds and nutritive quality of forages (Beaton and Fox, 1971; Blair, 1979). Plants like onion, garlic etc. owe their characteristic odour to sulphur containing glucosides.

Besides increasing crop yields, the other effects of S fertilisation on plant growth reported (Kanwar and Mudahar, 1986; Tandon 1986) are that it improves the nutritive quality of forages, quality of vegetables and sugarcane juice, both quality and quantity of proteins in pulses, cereals, oilseeds and tuber crops and lowers HCN content of some crops. The increase in crop yield due to sulphur fertilization are due to following reasons:

- a. it provides direct nutritive value.
- b. helps in correcting problems of calcareous and alkali soils.

- c. it helps in improving efficiency of uptake of other nutrients like N and P.

Tandon (1986) reported that annual removal of sulphur is quite high which comes to about  $5.7 \text{ kg ha}^{-1}$  of gross cropped area. So in order to maintain the soil fertility status sulphur needs to be replenished by external additions.

## 2.2 Sources of sulphur in soils

Sulphur is ranked as the thirteenth most abundant element in earth's crust which is having a sulphur content of 0.06 to 0.1% (Tisdale et al., 1985). Sulphur concentration in soil varies from 0 to 500 ppm (Ensminger, 1958; Starkey, 1950). It occurs in various forms such as elemental S, sulphates, sulphides and in organic combinations.

The main sulphur bearing minerals in rocks and soils are Anhydrite ( $\text{CaSO}_4 \cdot 7\text{H}_2\text{O}$ ), Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), Epsomite ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ) and pyrite etc. Silicate minerals normally have 0.01% sulphur and sedimentary rocks have 0.02-0.22% S. So they are considered to be the important source of S in soils.

Weathering of sulphur bearing rocks and minerals add sulphur to soils. There is also absorption

of sulphates by living organism or it is reduced to elemental sulphur by other organisms. Addition of sulphur to soil also occurs through irrigation water, rain water, fertilisers and pesticides.

Sulphur requirement of crop can be met through a number of sulphur containing materials like gypsum, elemental S, pyrite etc. Use of fertilisers like  $(\text{NH}_4)_2\text{SO}_4$ ,  $\text{K}_2\text{SO}_4$  and single super phosphate also contribute to sulphur pool of the soil. However gypsum whose natural deposits are found in abundance in India can be used as a source of sulphur for groundnut (Aslakh and Pasricha, 1986; Chahal and Virmani, 1973; Tandon, 1986).

#### 2.2.1 Atmospheric additions :

Gases like  $\text{H}_2\text{S}$  and  $\text{SO}_2$  generated from various sources by entering S cycle contribute to S addition to soil and plants. Plants may directly absorb  $\text{SO}_2$  from atmosphere. Sulphate addition through annual rainfall varies from 2 kg to 234 kg/ha.

#### 2.2.2 Fertilisers and pesticides :

Use of S containing fertilisers such as  $(\text{NH}_4)_2\text{SO}_4$ , SSP etc. and sulphur containing fungicides such as lime sulphur, sulphur dust add sulphur to soil. Use of

high analysis fertilizers and sulphur free pesticides may lead to sulphur deficiency.

### 2.2.3 Irrigation water :

A lot of sulphur is also added to soil through irrigation water. Tandon (1986) quoted Sahoo and Panda (TNAU, 1985) having reported addition of about 10 kg of S per hectare through irrigation water to rice crop grown in Bhubaneswar during rabi season. Cheema and Arora (1984) reported that tube-well waters of Ludhiana can add about 24 kg S per hectare.

## 2.3 Forms of sulphur

Sulphur exists both in organic as well as inorganic forms (Dev and Kumar, 1982; Kanwar and Randhawa, 1974). It occurs either as solid, liquid or gas. Its oxidation number varies from +6 in  $H_2SO_4$  to -2 in  $H_2S$ .

### 2.3.1 Inorganic sulphur:

The common inorganic forms of sulphur which occurs in soil are (1) readily soluble sulphates of Na, K, Mg and Ca (2) adsorbed sulphate on the surface of clay minerals and sesquioxides (3) insoluble sulphates of Ca, Ba, Fe and Al and (4) sulphide or reduced

forms of sulphur. Available sulphur refers to easily soluble plus adsorbed sulphate.

### 2.3.2 Organic sulphur :

Seventy to ninety per cent of the soil sulphur in humid tropics are in organic form (Kanwar and Mudahar, 1986; Das, 1987). This proportion varies with soil type and depth as most of organic sulphur is present on surface layer. Organic sulphur exists as a part of organic matter and may be in following forms.

a) Ester sulphates, which are largely organic sulphates containing ester (C-O-S) linkages. They are available to plant when the soil is dry.

b) Sulphur bound to carbon as a constituent of aminoacids viz. methionine(21% S) cystine (27% S) and cysteine. These constitute about 30% of total organic S (Freney et al., 1972).

c) Sulphur bound to carbon in forms other than aminoacids which include sulphoxides, sulphones etc.

d) Organic S, which is not reduced by either Raney nickel or hydroiodic acid. But this is of little importance to plant nutrition.

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Organic sulphur needs to be mineralised before it is available to plants. The mineralisation depends upon temperature, moisture, aeration, soil acidity, organic S content and N:S ratio of organic matter.

#### 2.4 sulphur status of soils

##### 2.4.1 Total sulphur:

The total sulphur content of surface soils of India varies between 19 ppm to 3836 ppm. Heavy textured soils have generally a higher total sulphur content than light textured soils as they retain more organic matter (Reddy et al., 1985).

Acid soils of Bihar and Punjab have higher total S than alkaline soils (Ahmed and Jha, 1969; Kanwar and Mohan, 1964). But reverse was the case in soils of Maharashtra (Patil et al., 1981 b).

In West Bengal, soils of hill, Tarai and coastal saline regions in general, have been found to contain higher amount of total S as compared to those from alluvial and lateritic regions (Mukhopadhyay and Mukhopadhyay 1980).

The total S content of soils of Orissa varied between 23.7 ppm to 925 ppm. The range of total sulphur recorded for different soil groups were, 23.7 - 468.1 ppm in mixed red and yellow soil 48-363.75 ppm in brownforest, 83.7 - 393.7 ppm in black, 39-293.75 ppm in red and laterite and 41.12 - 295.9 in alluvial soils (Das, 1987).

Clay content, silt content and organic matter content were found to be positively correlated with total S and sand per cent and pH were negatively correlated with total S in soil (Ruhel and Paliwal, 1978).

#### 2.4.2 Organic sulphur:

Studies in the soils of West Bengal and Andhra Pradesh revealed that organic S content of soil was positively correlated with organic carbon and total S content of soils (Mukhopadhyay and Mukhopadhyay, 1980; Reddy et al. 1985).

Sulphur mineralisation has been reported to range from 1 to 10 % per year (Sanchez, 1976) and from 2 - 2.3 % per year in Nigerian soils (Bremfield et al., 1982). Many factors govern the mineralisation of organic S. The optimum temperature for mineralisation is around 35<sup>0</sup>C (Williams, 1975). Optimum mineralisation occurs at 60% of the water holding capacity. Stewart, Porter and Viets (1966) have shown that S mineralisation occurs only

when the S content of straw is above 0.15%. Further mineralisation of organic S is enhanced in the presence of plant than in absence probably because of greater number of microscopic organisms in rhizosphere. Karwasra, as reported by Dev and Kumar (1982) observed that mineralisation of native S was greater in soils having wider C:S ratio. The soil pH and  $\text{CaCO}_3$  content affect mineralisation of native and added S. In Sirsa soil of Haryana a rise in pH from 7.4 to 8.2 increased organic sulphur mineralisation from 5.6% to 7.7%. Addition of calcium carbonate enhanced the mineralisation of added S. Immobilisation of sulphur is observed in soils with C:S ratio greater than 200 and material containing less than 0.15% S.

McClung et al. (1959) recorded a decrease in organic S of virginia soils of Brazil after soils were cropped for 20 - 30 years. Similar observations were made by Bremfield (1972) in Nigeria.

#### 2.4.3 Available sulphur in soil (soluble and adsorbed sulphur):

Soluble plus adsorbed sulfate are the fractions of total S in soil which are important for plant nutrition. In general this can be termed as readily available sulphur to plant which can be extracted by monocalcium phosphate solution.

Sulphate S content of the Indian soils have been found to vary from 2 - 46 ppm in alluvial, 3.-40 ppm in red and lateritic, 10 -25 ppm in arid and 10-169 ppm in black soils (Singh et al., 1988).

Content of soluble sulphate in surface soils of Rajasthan varied from 12 ppm in yellow brown soils to 205 ppm in desert soils (Joshi et al., 1973).

Parvathamana et al. (1986) studying the response of S to groundnut in a pot culture experiment using coastal sandy soils of Andhra Pradesh have reported good correlation between available sulphur with pod yield. Similar study conducted in Punjab to investigate about available sulphur in groundnut growing areas showed that in 82% of samples available S was below critical level and it correlated positively with organic carbon and negatively with pH (Arora and Cheema, 1984).

Sulphate sulphur content of soils vary from 1.4 to 4.1 ppm in different climatic zones of Punjab, Haryana and Himachal Pradesh (Kanwar and Mohan, 1964). In Orissa the mean content of MCP extractable S of red and laterite soil was 18.64 ppm, mixed red and yellow soil was 24.3 ppm, brown forest soil was 20.64 ppm, alluvial soil was 14.47 ppm

and black soil was 10 ppm (Das, 1986).

The critical level of available S for different crops varies between 5 ppm to 30 ppm depending upon soil properties, extraction technique, crop types and its genotype.

The critical level of calcium phosphate extractable sulphate (ppm S) established for different crops are 10 ppm for rice (Tiwari et al., 1983 a) and maize (Palaskar and Ghosh, 1985) 9.3 ppm for lucerne (Bansal et al., 1979). Critical level of heat soluble S suggested for groundnut and wheat is 10 ppm (Patel and Narsonia, 1981) 20 ppm for onion, garlic, alfalfa and oil seeds (Dangarwala and Vakharia, 1983).

Though critical level of available sulphur varies depending on crop type and extraction procedure still then since early 60's, 10 ppm S continues to be the most frequently used critical level of available S (Tandon, 1986).

### 2.5 Yield response of groundnut

A survey conducted in the groundnut growing areas of Punjab showed that 50 % of plant samples were deficient in S considering 0.2 % S in plant as the critical level of S (Cheema and Arora, 1984). Kanwar (1963) reported that

75% of groundnut growing areas Punjab were deficient in S.

Rahal in Rajasthan reported that highest yield of groundnut was obtained by applying fertilisers containing S (Dev and Kumer, 1982). Anilakh et al. (1977) observed that 32 kg S/ha was enough for obtaining optimum yield in groundnut.

A pot culture experiment in S and Zn deficient soils with groundnut grown in Kharif showed that maximum pod yield was obtained with 10 kg Zn/ha combined with 15 kg S/ha (Talukder and Islam, 1982). In uncultivated red earth and Krasnozem S deficiency symptoms appeared after 12 weeks and 15 weeks respectively when groundnut was grown. Although vine yield was reduced by S omission neither pod yield nor pod quality was affected (Sulphur Abstract, 1983).

Groundnut cultivar TMV.2 grown during 1979 and 1980 in an Alfisol showed that highest pod yield was obtained by application of 100 kg gypsum/ha at earthing up with or without  $ZnSO_4$  at sowing. Pod yield with 1000 kg/ha rate of gypsum was significantly higher than with 500 kg rate (De et al., 1982). Groundnut grown in Kharif season on a red sandy loam soil gave higher pod yield with 250 kg gypsum/ha than with 500 kg gypsum/ha. In rabi season groundnut yield obtained from residual effect of 500 kg gypsum/ha was higher than that obtained from 250 kg gypsum/ha (Rao et al., 1984)

Heavy S application to groundnut grown in Taiwan on a calcareous soil to reduce pH<sub>c</sub> gave a dramatic increase in yield at one site in addition to relieving chlorotic symptoms. But, its effect at other sites were much less marked. (Houng, 1984).

In a 2 year field study of groundnut grown in Tolewal Loamy sand of Punjab the yield of groundnut increased with application of 15 kg S/ha as ZnSO<sub>4</sub> (Bahl et al., 1986).

Field trials in 27 farmers field revealed that addition of about 75 kg S/ha as gypsum produced 1.0 q/ha of extra pod yield over normal recommended doses of N and P (Aulakh et al., 1987). In low fertility soils of Haryana application of S produced significantly higher dry matter yield and kernel yield of groundnut but 20 ppm S was sufficient in medium to high fertility soils (Rathee and Chahal, 1977). However on a coarse textured soil response was upto 100 ppm S (Singh and Singh, 1977).

In Rajasthan, the optimum sulphur dose required for groundnut yield was 120 kg S/ha (Ruhel, 1975). Singh and Kalra (1983) observed that a significant increase in groundnut yield was observed upto 40 kg S/ha and optimum level of S was worked out to be 16.28 kg /ha.

Depending upon soil condition variable responses of groundnut grown under field and green house conditions to S application have been obtained (Bahl et al., 1986; Dhillon et al., 1983; Rathee and Chahal, 1977; Singh et al., 1970 ). Tandon (1986) concluded from review of many research findings that yield of groundnut increased from 0.8 to 4.8 q/ha by S application. Highest increase of 7.9 q/ha of groundnut kernels with 100 kg S/ha applied as elemental S has been reported.

### 2.6 Influence of sulphur on quality of groundnut

Sulphur influences not only the yield of groundnut but also its quality. Sulphur is involved in oil synthesis, and oil storage organs in this crop are also proteinous in nature which are rich in S. Sulphur application has been reported to increase the oil content upto 5% in groundnut (Chopra and Kanwar, 1966; Singh et al., 1970). Sulphur being constituent part of S containing essential aminoacids such as methionine, cystine and cysteine its application causes substantial increase in protein and amino-acids (Chopra and Kanwar, 1966; Singh et al., 1970; Aulakh et al., 1987).

Applied S has been reported to increase 6.2% oil, 6.0 - 8.4% protein and 21.1% aminoacids in groundnut kernel (Aulaha and Paericha 1986).

Gypsum application was unlikely to alleviate the problems of groundnut peg development and pod filling under moisture stress condition of soil (Balasubramaniam and Yayock, 1982). Application of gypsum to groundnut also helps in escaping drought effects due to increased early pod development (Proceedings of international symposium, 1985). Sulphur application also increases root dry matter of groundnut grown in black calcareous soils (Anonymous, 1985). Sulphur deficiency leads to a reduction of 80-88% in legumin synthesis. Level of legumin mRNA in polysomal and total RNA preparations were reduced by 90% (Chandler et al., 1983).

## 2.7 Effect of calcium on yield and quality of groundnut

In Brazil groundnut cultivar Tatui grown with or without dolomitic lime stone (CaO 26.3%) in an acid soil responded to application of lime in two out of 10 sites (Neptune et al., 1982). Ossenl (1986) reported that groundnut grew better in soils above pH 5.

Bell (1985) reported that groundnut cultivar virginia bunch grown with graded doses of lime i.e. 0, 250, 500, 1000 and 1500 kg of crushed lime stone/ha applied before sowing with or without 500 kg gypsum as top dressing showed a maximum yield of 1 tonne with lime stone (360 kg ca/ha). Top dressing of gypsum at flowering did not produce any additional yield. The seed Ca content was significantly correlated with extractable soil Ca content

before sowing and with percentage germination in field. Allison (1987) reported that Ca application increased Ca uptake and germination of groundnut.

An increased output of seed was reported in groundnut when 40 kg Ca along with 80 kg K was applied to it. Oil content and oil yield were also reported to be highest with this combination (Rajan et al., 1984).

## 2.8 Interaction of sulphur and calcium on yield and quality attributes of groundnut

A two year experiment with "Tatu" peanut cultivars on a red latosol with graded doses of dolomitic lime stone and gypsum either broadcasted before planting or applied at top of row just after emergence showed that response to lime and gypsum was low due to relative tolerance of cultivar to acidity. Gypsum applied to plots receiving lower rates of lime caused leaching of bases the severity of loss being of Mg and K. The green house experiment with lime and gypsum revealed that yield of groundnut increased with a combination of lime and gypsum but performance of gypsum alone was superior to lime alone supported by increased shelling % (Neptune et al., 1982). In pot trials with groundnut grown on a variety of soils high pod yields were obtained by application of S and Ca. Shelling percentage was also increased by Ca and sulphur but oil content was not affected by Ca or S (Ramanathan and Ramanathan, 1982).

## **2.9 Performance of different sources of sulphur on yield of groundnut**

Dalal, Kenwar and Saini (1963) observed that yield of groundnut was increased over control by 34% with  $(\text{NH}_4)_2 \text{SO}_4$ , 46% with SSP and by 41% with gypsum (Aulakh and Pasricha, 1986).

In another study, groundnut grown in red sandy loam soils and fertilised with different sources of sulphur like gypsum, factomphos,  $(\text{NH}_4)_2 \text{SO}_4$  showed greater response in terms of kernel yield, protein yield and oil content incase of gypsum (Badiger and Shivaraj, 1986).

In a field study to determine phosphorus requirement of groundnut conducted over a period of six years, SSP gave maximum yield over DAP and TSP. It has been observed that groundnut response to P was of low magnitude (Pasricha et al., 1980 a). The main effect of SSP on yield was due to its S content. But when S content of SSP was compensated in DAP and TSP with gypsum there was no difference between three sources.

So it can be concluded that gypsum whose natural deposits are found in abundance in India (Tandon, 1986) can be used as an effective source for S for groundnut (Chahal and Virmani 1973; Aulakh and Pasricha, 1986).

## 2.10 Effect of pH on sulphate adsorption

Sulfate when added to soil much of it is adsorbed. The common site for adsorption is on positively charged surfaces of iron and aluminium oxides and clay minerals. The sulphate adsorption capacity is governed by following factors.

1. Adsorption decreases with increasing pH (Ensminger, 1954; Kamprath et al., 1956).
2. Adsorption increases with increasing clay content (Neller, 1959; Chao et al., 1962).
3. Adsorption decreases with removal of iron and aluminium oxides (Chao, et al., 1962).
4. Adsorption decreases with phosphate application (Metson and Blackmore, 1978).
5. Decreases with organic matter content in the soil (Kamprath, et al., 1956, Chao, et al., 1962).

According to Couto, Lathwell and Bouldin (1979), sulphate sorption by Oxisol and Alfisol of tropics was dependent on the pH of equilibrium solution, the amount sorbed decreased as the pH increased in each soil. Soils having low adsorption capacity for sulphate show a tendency

of sulphur deficiency as added sulphate is not retained and moves away with leachates (Metson and Blackmore, 1978).

Balan et al. (1986) reported that depending on pH sulphate is adsorbed only when the surface potential is positive. A small change in solution pH have large effect as sulphate adsorption characteristics of mineral soils. The ability of soil to remove sulphate from solution increased as pH of solution decreases. The sulphate removal by a soil from solution depends upon the ability of soil to partition sulfate between soil and solution phases and the amount of reactive native sulphate that is present in soil (Nedvin et al., 1986).

Groundnut growing areas represented by coarse texture slightly alkaline soils show a poor sulphate adsorption leading to sulphur deficiency. Even complete saturation with  $\text{Ca}^{2+}$  does not help much in sulphur adsorption (Bahl and Paricha, 1984).

Application of lime to groundnut growing areas accelerate leaching losses of sulphate in coarse textured soils. But soils with acid reaction have capacity to retain sulphate sulphur (Ahmed and Jha, 1964; Kanwar, 1976). So liming of acidic soil is expected to decrease sulphur adsorption capacity of the soil.

The review of literature reveals that sulphate adsorption by acid soils is likely to decrease by liming and application of lime increase the groundnut yield. Also positive response of groundnut to sulphur application is indicated. Significant yield increase due to Ca-S interaction in some cases and no response in others have been observed.

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## **CHAPTER - III**

# **MATERIALS AND METHODS**

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

3.1 Field Experiment

To investigate the response of groundnut to application of sulphur under limed and unlimed condition a field experiment was conducted in an aric haplaquet soil in the Central Farm of Bhubaneswar. The experiment was laid in randomised block design (factorial). Groundnut (Var. AK 12-24) was grown as the test crop during Kharif, 1988.

Fifty per cent of the lime requirement as determined by Woodruff's buffer method was applied to the field 7 days before seeding in form of paper mill sludge having a neutralising value of 70%. Seeds were sown on 27.88 with a spacing of 25 x 10 cm.

The treatments consisted of two levels of lime i.e. no lime and 0.5 L.R. and 5 doses of sulphur 0(S<sub>0</sub>), 10(S<sub>10</sub>), 20(S<sub>20</sub>), 30(S<sub>30</sub>) and 40(S<sub>40</sub>) kg sulphur per hectare applied as gypsum (14.25% S and 17% Ca). The treatments (10) were replicated thrice. The size of each plot was 5 m x 3 m.

Fertiliser at the rates of 20 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O per hectare were applied to the plots once at the time of sowing in the form of IFFCO N, P, K,

10:26:26 and urea. The crop was harvested on 13.11.88 and the vine and pod yields for each plot were recorded after sun drying. Also shelling percentage was determined.

### 3.1.1 Collection of soil samples

Surface soil samples (0-15 cm) were collected from the field at three stages of crop growth using a soil auger. The soil samples were collected after one month two months and four months (after harvest of the crop) of sowing. The samples of each treatment were composited by mixing equal volume of soil taken from each replication. The composite samples were air dried and ground to pass through a 2 mm sieve and stored in sample bags for further analysis. In addition, a composite surface soil sample of the experimental site was collected for analysis.

### 3.1.2 Collection of plant sample

Composite plant samples of each treatment was collected from the field, after one month of sowing the crop. The samples were washed with tap water followed by distilled water, dried in a air circulating hot air oven at 70<sup>o</sup>F for 36 hours. After complete drying, the samples were ground in a Wiley mill and stored for future analysis. Similar procedures of cleaning and

storing of plant samples were followed for the samples collected from each replication separately after harvest.

### 3.2 Adsorption study

In order to study the adsorption of sulphate by the surface soil of the experimental site under limed and unlimed conditions, the bulk surface soil sample of the experimental site was used. About 1 kg of the soil was incubated with paper mill sludge (added @ of 0.5 L.R.) at room temperature for a period of 1 month. During the incubation soil moisture was brought to 50% of the field capacity and the soil was allowed to dry at room temperature. The process of alternate wetting and drying was continued till the end of the period of incubation.

Adsorption of sulphate in unlimed and limed soils was studied following the method described by Barrow (1967).

To 10 gms of soil samples taken in a conical flask, 50 ml of 0.5, 10, 15, 20 and 25 ppm of sulfur as  $K_2SO_4$  in 0.01M NaCl were added. The samples were equilibrated for 24 hours on a reciprocating shaker with intermittent shaking for 4 hours at a time and then filtered through a Whatman number 42 filter paper.

pH of the equilibrium extract was measured and the sulphur in the extract was determined following the turbidimetric procedures of Mass-cumi and Cornfield (1963) as described by Heeft. et al. (1973).

### 3.3 Analysis of soil

To characterise the soil of the experimental site, the bulk sample was analysed for pH, organic carbon textural class (hydrometer method), E.C., CEC, available P (Olsen's) and K (Ammonium acetate extractable) following the standard methods of analysis.

Available sulphur content of the soil was determined by extracting 10 grams of soil with 25 c.c of monocalcium phosphate solution containing 500 ppm of P. The soil was shaken with the extracting solution for a period of 30 minutes on a mechanical shaker, filtered, and sulfur in the extract was determined following the turbidimetric method as described below. The soil samples from each treatment collected at different time were analysed for pH and monocalcium phosphate extractable S.

#### 3.3.1 Turbidimetric procedure

To 10 ml of the extract taken in a conical flask, 10 ml. of 6.25%  $\text{HNO}_3$  and 5 ml. of 8.7 N acetic

acid solution containing 0.5% gum acacia were added. Then 0.3 g of 20 to 30 mesh  $\text{BaCl}_2$  crystals were added to it. The flask was swirled thoroughly for 1 minute. After allowing 10 minutes for developing turbidity the optical density was measured at a wavelength of 410 m $\mu$  using a Bausch and Lomb spectrophotometer. In case of samples containing low sulfur, 5 c.c. of 6.25%  $\text{HNO}_3$  containing 50 ppm S as  $\text{K}_2\text{SO}_4$  (seed solution) was added alongwith 5 c.c. of 6.25%  $\text{HNO}_3$  so that in the final volume of 25 c.c. a S concentration of more than 10 ppm S was maintained instead of more than 2.2 ppm as described by Massoumi and Cornfield (1963).

The S content in the test solution was determined by comparing with a standard curve for sulfur in the range of 4-20 ppm S.

### 3.4 Analysis of plant samples

#### 3.4.1 Oil content

Oil content of the kernel was determined following the cold percolation method of Kartha and Sethi (1957).

#### 3.4.2 Sulphur

Sulphur content of vine, kernel and shell was determined after digesting the samples with diacid

mixture. To 0.5g of dried plant sample taken in a conical flask 10 ml. of concentrated  $\text{HNO}_3$  was added and the flask was kept over night. The digestion of sample in the flask was carried out by moderate heating on a hot plate till all the brown fumes came out, after which 5 ml. diacid mixture (perchloric acid:  $\text{HNO}_3$  2:3) was added to the flask. Heating was continued until white fumes started condensing in the flask. Then the flask was taken out and 1 c.c of 6N HCl was added to it followed by warm distilled water. The content of the flask was transferred to a 50 ml. volumetric flask and the flask was washed 2-3 times with 5 ml. of distilled water and the volume was made upto 50 c.c. with distilled water. Then it was filtered through a Whatman No.42 filter paper and the sulfur in the filtrate was determined using the turbidimetric method of analysis described earlier.

#### 3.4.3 Calcium

Calcium in the digestion extract was determined following the modified flame photometric method as described by Wells and Corey (1960). To 10 ml. of digestion extract taken in a 50 ml. volumetric flask 2.5 ml. of 1%  $\text{FeCl}_3$  solution and 2.5 ml. of 1000 ppm K as KCl were added. The final K concentration was

maintained at 50 ppm. It was titrated against 1:5  $\text{NH}_4\text{OH}$  solution using a drop of methyl red indicator till the colour changed from red to yellow. Then 0.1N HCl was added dropwise till the red colour just reappeared. Then it was titrated against 1:20  $\text{NH}_4\text{OH}$  slowly to make the colour just light pink (pH 5.6). Then the volume was made upto 50 c.c and filtered using a Whatman filter paper No. 41. Concentration of Ca in the filtrate was determined flame photometrically using an Elico flame photometer.

Calcium solutions of 20,40,60 and 80 ppm were used for preparing the standard curve.

### 3.5 Statistical analysis

The yield data of vine and pod, S uptake and Ca uptake oil content and oil yield were analysed statistically for analysis of variance and linear regression.

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## CHAPTER - IV

# RESULTS AND DISCUSSION

## **CHAPTER - IV**

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## RESULTS AND DISCUSSIONS

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To investigate the response of Kharif groundnut grown in an aeric haplaquept under limed and unlimed condition to application of gypsum a field experiment was conducted in the Central Farm of Orissa University of Agriculture and Technology, Bhubaneswar during Kharif 1988. Some of the physico-chemical properties of the experimental site has been recorded in Table 1. It was an acidic loamy and soil with 0.62 % organic carbon. Available (Monocalcium phosphate extractable) Sulphur content of the soil was low (6 ppm). The site was chosen for its low sulphur content where the response of S to groundnut is more likely.

The lime requirement of the soil and determined by "new Woodruff buffer method" described by Brown and Cisco (1984) was  $2 \text{ t ha}^{-1}$ . Addition of the paper mill sludge ( $\text{CaCO}_3$  equivalent = 70 %) equivalent to 50% of the lime requirement of the soil could raise the pH to about 6.2 .

#### 4.1 Sulphate adsorption character of the soil

The results of sulphate adsorption study carried out using both limed and unlimed soils are recorded in

Table 1. Some Physico-chemical properties of the soil

Soil properties

1.	pH	5.3
2.	E.C. ( $\text{dSm}^{-2}$ )	0.13
3.	C.E.C ( $\text{c mol (p}^+) \text{ kg}^{-1}$ )	3.82
4.	Mechanical composition	
	(a) Sand (%)	80.3
	(b) silt (%)	10.3
	(c) Clay (%)	9.4
	Textural class	Sandy loam
5.	Available P ( $\text{kg ha}^{-1}$ ) (Olsen's method)	9
6.	Available K ( $\text{kg ha}^{-1}$ ) (Ammonium acetate method)	70
7.	Available N ( $\text{kg ha}^{-1}$ ) (Alkaline Permanganate method)	210
8.	Available S ( $\text{kg ha}^{-1}$ ) (Mancalcium phosphate extractable)	12

Table 2 and the amounts of S adsorbed have been plotted against equilibrium concentration of S in Fig. 1. More sulphate was adsorbed by unlimed soil than by the limed soil. The sulphate adsorption capacity of soil has been shown to decrease with increasing pH (Ensminger, 1954; Kamprath et al., 1956). The adsorption of sulphate is depended on the amount of change on the surface and hence on the pH value. The soil of the experimental field is known to be dominated by variable charge minerals like Keolinite and oxides of iron and aluminum and the soil has a permanent negative charge of  $0.59 \text{ cmol (p}^+) \text{ kg}^{-1}$  at  $\text{pH}_0$  (Misra et al., 1989). By liming such soils the variable negative charge increased and hence adsorption of sulphate decreased. The highest amount of 66 ppm S was adsorbed by unlimed soil against a value of 41.1 ppm for limed soil at same equilibrium S concentration of 11.8 ppm.

These results suggest that liming an acid soil will increase the readily available sulphur in soil and unless it is immediately utilised by the crop, leaching of sulphate from the limed zone by heavy rains may cause loss of S.

#### 4.2 Yield response of groundnut to application of sulphur and lime

The data on yields of pod, vine shelling percentage and per cent oil content have been statistically

Table 2. Sulphate adsorption character of soil as effected by liming

Concentration of S in equilibrating solution (ppm)	Equilibrium Ccn. of S (ppm)	Amount of S adsorbed ( $\mu\text{g.g}^{-1}$ )
	<u>Un-limed</u>	
0	0.32	-1.6
5	2.6	12
10	4.06	29.7
15	6.03	44.9
20	8.7	56.5
25	11.8	66.0
	<u>Limed</u>	
0	2.56	-12.8
5	4	5
10	6.5	17.8
15	9.6	27.0
20	11.8	41.1

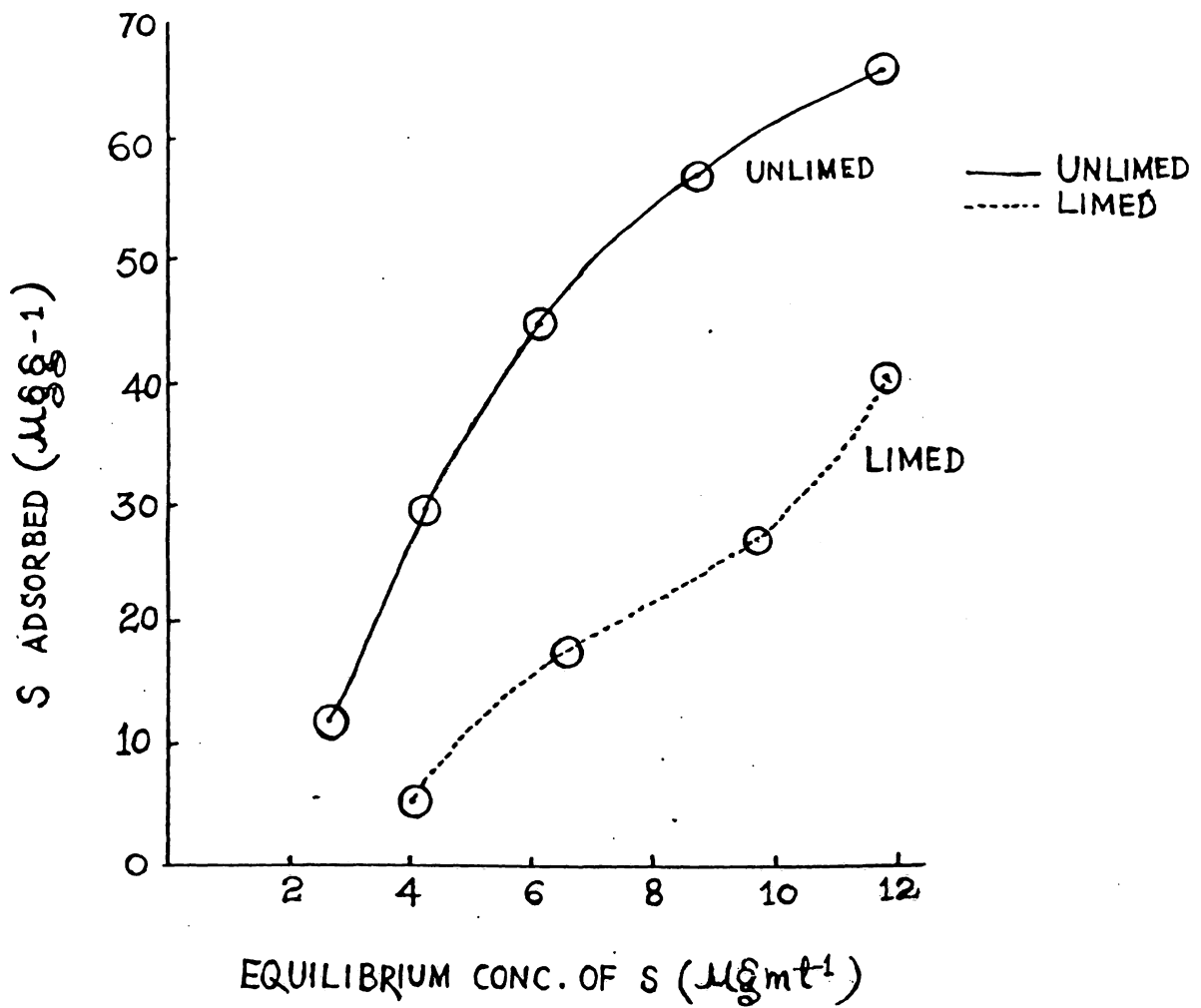


FIG:- 1. SULPHATE ADSORPTION CHARACTER OF THE SOIL OF EXPERIMENTAL SITE AS AFFECTED BY DOSES OF S AND LIME.

analysed and presented in Table 3.

#### 4.2.1 Pod yield:

The yield of pod recorded for various treatments (Table 3a) shows that both under limed and unlimed condition application of graded dose of S increased the yield. Under unlimed condition the yield increased from 5.32 q ha<sup>-1</sup> in control to 7.56 q ha<sup>-1</sup> at 30 kg level of sulphur application was at par with the yield obtained at 40 kg level (7.54 q ha<sup>-1</sup>) and at 20 kg level (6.88 q ha<sup>-1</sup>).

Due to liming the yield of control plot increased from 5.32 to 6.72 q ha<sup>-1</sup>. Response to application of S has also increased in limed soil registering the highest yield of 10.85 q ha<sup>-1</sup> at 40 kg level of S which was statistically at par with 20 kg S. Statistical analysis of the pod yield have shown that both S as gypsum and lime applied to groundnut significantly increased the yield, but the interaction was not significant. Therefore, the effect of gypsum and lime are additive only. Such effect has also been observed by Ramanathan and Ramanathan (1982).

#### 4.2.2 Vine yield:

The yield of vine recorded in Table 3b shows similar trend as discussed for pod yield. A significant positive correlation ( $r = 0.77$ ) was obtained between vine and pod yield.

**Table 3. Effect of sulphur and Lime application on pod yield, vine yield, shelling percentage and per cent oil content of Kharif groundnut**

**(a) Pod yield**

Doses of sulphur (kg ha <sup>-1</sup> )	Pod yield (g ha <sup>-1</sup> )		Mean
	Unlimed	Limed	
0	5.32	6.72	6.02
10	6.13	7.28	6.70
20	6.88	9.5	8.20
30	7.56	10.32	8.94
40	7.54	10.85	9.19
Mean	6.68	8.94	
<u>Source</u>	<u>SE(m)<sub>t</sub></u>	<u>C.D.(0.05)</u>	
Sulphur	0.38	1.13	
Lime	0.24	0.71	
S x L	0.54	NS*	

(b) Vine yield

<u>Doses of sulfur (kg ha<sup>-1</sup>)</u>	<u>Vine yield (g ha<sup>-1</sup>)</u>		<u>Mean</u>
	<u>Unlined</u>	<u>Lined</u>	
0	16.13	19.57	17.85
10	17.99	20.10	19.04
20	20.63	22.48	21.56
30	21.42	24.34	22.88
40	21.42	22.48	21.95
Mean	19.52	21.79	

<u>Source</u>	<u>SE(m)<sub>±</sub></u>	<u>C.D. (0.05)</u>
Sulfur	0.43	1.27
Line	0.27	0.81
S x L	0.61	NS <sup>†</sup>

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#### 4.2.3 Shelling percentage:

The variation of shelling percentage (Table 3c) of groundnut grown with varying doses of S in unlimed soil was between 50.7 to 60.3 per cent and in limed soil the variation was between 61.4 to 67.3 per cent. The highest shelling percentage was recorded at S dose of 30 kg ha<sup>-1</sup>, both under limed (67.3%) and unlimed (60.3%) conditions. There was a significant reduction in oil content of groundnut, both at higher and lower doses of S application as compared to 30 kg level (Fig.2). The effect of sulphur, lime and their interactions were significant. The highest shelling percentage of 67.3 was recorded for 30 kg ha<sup>-1</sup> sulphur application under limed condition. These results suggest that calcium helps in improving the shelling percentage in groundnut. The work of Ramanathan and Ramanathan (1982) on groundnut grown in an acid soil have also shown highest shelling percentage when treated with 40 kg S per hectare along with calcium.

#### 4.2.4 Oil percentage:

No significant increase in oil content of groundnut kernel was observed due to application of lime (Table 3d). But, oil percentage increased with increasing level of sulphur application attaining the maximum of 41.95% at 30 kg level which decreased to 37.8% at 40 kg

#### 4.2.3 Shelling percentages:

The variation of shelling percentage (Table 3c) of groundnut grown with varying doses of S in unlimed soil was between 50.7 to 60.3 per cent and in limed soil the variation was between 61.4 to 67.3 per cent. The highest shelling percentage was recorded at S dose of 30 kg ha<sup>-1</sup>, both under limed (67.3%) and unlimed (60.3%) conditions. There was a significant reduction in oil content of groundnut, both at higher and lower doses of S application as compared to 30 kg level (Fig.2). The effect of sulphur, lime and their interactions were significant. The highest shelling percentage of 67.3 was recorded for 30 kg ha<sup>-1</sup> sulphur application under limed condition. These results suggest that calcium helps in improving the shelling percentage in groundnut. The work of Ramanathan and Ramanathan (1982) on groundnut grown in an acid soil have also shown highest shelling percentage when treated with 40 kg S per hectare along with calcium.

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#### 4.2.3 Shelling percentages:

The variation of shelling percentage (Table 3e) of groundnut grown with varying doses of S in unlimed soil was between 50.7 to 60.3 per cent and in limed soil the variation was between 61.4 to 67.3 per cent. The highest shelling percentage was recorded at S dose of  $30 \text{ kg ha}^{-1}$ , both under limed (67.3%) and unlimed (60.3%) conditions. There was a significant reduction in oil content of groundnut, both at higher and lower doses of S application as compared to 30 kg level (Fig.2). The effect of sulphur, lime and their interactions were significant. The highest shelling percentage of 67.3 was recorded for  $30 \text{ kg ha}^{-1}$  sulphur application under limed condition. These results suggest that calcium helps in improving the shelling percentage in groundnut. The work of Ramanathan and Ramanathan (1982) on groundnut grown in an acid soil have also shown highest shelling percentage when treated with 40 kg S per hectare along with calcium.

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No significant increase in oil content of groundnut kernel was observed due to application of lime (Table 3d). But, oil percentage increased with increasing level of sulphur application attaining the maximum of 41.95% at 30 kg level which decreased to 37.8% at 40 kg

**(c) Shelling percentage**

Doses of sulphur (kg ha <sup>-1</sup> )	<u>Shelling percentage</u>		Mean
	unlimed	limed	
0	50.7	65.9	58.3
10	57.4	63.8	60.6
20	56.5	64.7	60.6
30	60.3	67.3	63.8
40	58.4	61.4	59.9
Mean	56.7	64.3	
<u>Source</u>	<u>SE (m)+</u>	<u>C.D. (0.05)</u>	
Sulphur	0.87	2.56	
Lime	0.55	1.62	
Sulphur x lime	1.22	3.64	

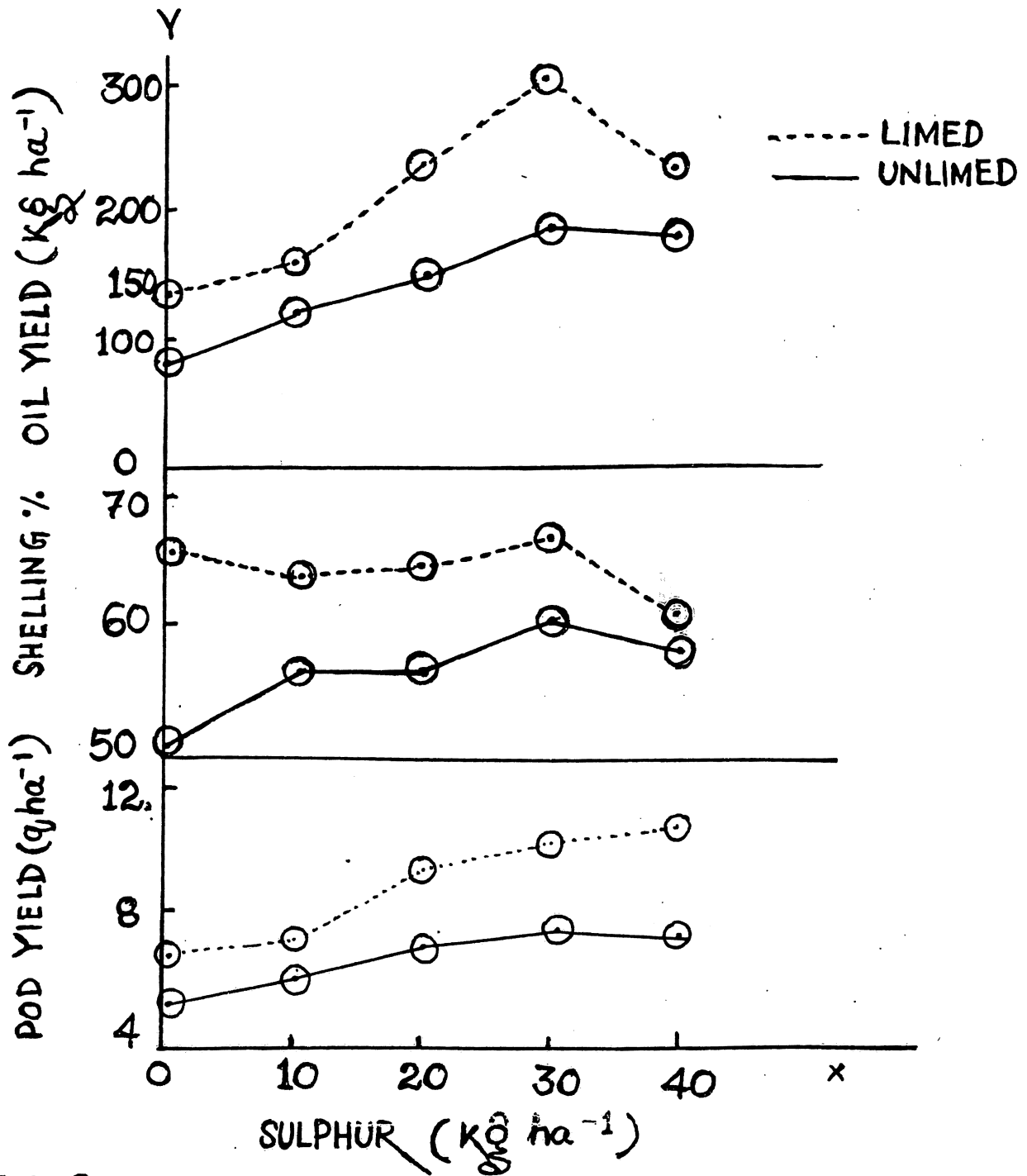


FIG: 2

POD YIELD, SHELLING PERCENTAGE AND OIL YIELD AS AFFECTED BY LIME AND SULPHUR APPLICATION.

(d) Percentage Oil

Doses of Sulphur (kg/ha <sup>-1</sup> )	<u>Oil content (%)</u>		Mean
	Unlined	Lined	
0	30	30.3	30.15
10	31.6	34.7	33.15
20	39.0	38.6	38.8
30	40.6	43.3	41.95
40	41.6	34.0	37.80
Mean	36.56	36.18	
<u>Source</u>	<u>SE(m)<sub>±</sub></u>	<u>C.D. (0.05)</u>	
Sulphur	0.45	1.34	
Lime	0.29	NS*	
Sulphur x lime	0.64	1.90	

level. When no sulphur was applied, the oil content was 30.15 %. Such increase in oil content due to sulphur application under unlimed condition has been reported earlier (Chopra and Kanwar, 1986; Singh et al., 1970). Although lime alone did not help to increase the oil content, the interaction of lime and sulphur was significant. The highest percentage oil (43.3) was recorded at 30 kg level of S applied to limed soil.

#### 4.2.5 Oil yield:

Although there was no significant difference in yield at S dose beyond 20 kg ha<sup>-1</sup>, the highest shelling percentage and oil content were observed at 30 kg ha<sup>-1</sup> sulphur application to limed soil (Fig.2). Therefore, the highest oil yield of 300.6 kg per hectare was obtained in limed soil treated with 30 kg S per hectare (Table 4, Fig. 2) which may be used as recommendation for growing groundnut in acid soil.

Table 4. Oil yield as affected by sulphur application

Doses of sulphur (kg ha <sup>-1</sup> )	Yield of oil (kg ha <sup>-1</sup> )	
	Unlimed	Limed
0	80.7	133.8
10	112.0	161.2
20	150.9	236.4
30	185.5	300.6
40	184.2	226.6

### 4.3 Sulphur uptake by plant

#### 4.3.1 Concentration of S in plants:

The concentrations of sulphur in plant at one month of growth and at harvest are shown in Table 5. Percentage of S in vine collected at one month varied between 0.18 to 0.24 per cent in unlimed condition and between 0.17 to 0.27 per cent in limed condition. In limed soil S concentration in vine decreased slightly as compared to unlimed soil for S treatment levels up to 20 kg ha<sup>-1</sup>. But at higher dose of S application the concentration was slightly higher under limed condition. At harvest there was a decrease in concentration S in vine as compared to S content at one month. Percentage S in vine varied between 0.10 to 0.14 % and in kernel it varied between 0.11 and 0.15%. The lowest concentrations ranging between 0.05 to 0.08 was observed in case of the shell.

#### 4.3.2 Sulphur removal by crop:

The total amount of S taken up by the crop and their distribution in vine, shell and kernel has been recorded in Table 6. The highest amount of S has been removed by vine followed by kernel. Considering all the levels of S applied, the per cent distribution of the total S taken by the crop is given in Table 7.

**Table 5. Concentration of S in plant at different growth stages**

Doses of S (kg ha <sup>-1</sup> )	Concn. of S in vine at one month(%)	Concn. of S at harvest (%)		
		<u>Vine</u>	<u>shell</u>	<u>kernel</u>
	<u>Unlimed</u>			
0	0.18	0.10	0.06	0.13
10	0.21	0.12	0.07	0.15
20	0.21	0.13	0.07	0.13
30	0.23	0.14	0.08	0.12
40	0.24	0.13	0.06	0.14
	<u>Limed</u>			
0	0.17	0.10	0.06	0.12
10	0.17	0.11	0.08	0.12
20	0.20	0.11	0.05	0.11
30	0.25	0.13	0.07	0.15
40	0.27	0.13	0.06	0.11

**Table 6. Uptake of S by groundnut as affected by application of lime and sulphur**

Dose of S (kg ha <sup>-1</sup> )	<u>Sulphur uptake (kg ha<sup>-1</sup>)</u>			
	Vine	Shell	Kernel	Total
	<u>Unlimed</u>			
0	1.67	0.14	0.35	2.16
10	2.23	0.17	0.51	2.91
20	2.73	0.21	0.51	3.45
30	3.02	0.23	0.53	3.78
40	2.69	0.19	0.59	3.47
	<u>Lined</u>			
0	1.67	0.14	0.52	2.53
10	2.14	0.19	0.54	2.87
20	2.21	0.17	0.70	3.08
30	3.20	0.23	1.01	4.44
40	3.00	0.24	0.69	3.93

**Table 7. Relative distribution of total S taken up by the crop in different plant parts**

Plant part	% of total S uptake	
	Unlimed	Limed
Vine	78.1	73.7
Shell	6.0	5.8
Kernel	15.9	20.5

A greater percentage of total S taken up by the crop receiving lime appeared in kernel as compared to the crop grown without lime. Correspondingly there was a decrease in % of total S taken up by vine and shell under limed condition. The increase in % of total S taken up by kernel and decrease in total S taken up by vine and shell under limed condition corresponds to 4.6 %. It appears that application of lime and sulphur helps in increasing the kernel yield so that a greater percentage of S appears in kernel.

When the total sulphur uptake data were statistically analysed (Table 8), the effect of sulphur was significant but not the effect of lime or lime and sulphur interaction. The highest mean total S removed by the crop at 30 kg S per hectare application was

Table 3. Sulphur uptake by plant as affected by application of lime and sulphur

Doses of S (kg ha <sup>-1</sup> )	Uptake of sulphur (kg ha <sup>-1</sup> )		Mean
	<u>Unlined</u>	<u>Lined</u>	
0	2.16	2.53	2.35
10	2.91	2.87	2.89
20	3.45	3.08	3.27
30	3.78	4.44	4.11
40	3.47	3.93	3.70
Mean	3.15	3.37	
<u>Source</u>	<u>SE(m)<sub>±</sub></u>	<u>C.D. (0.05)</u>	
Sulphur	0.21	0.62	
Lime	0.13	NS*	
Sulphur X Lime	0.29	NS*	

4.11 kg ha<sup>-1</sup>. The highest oil yield was also recorded at this level of S application under limed condition corresponding to total S removal of 4.44 kg ha<sup>-1</sup>.

The percentage recovery of applied S was calculated based on the following formula

$$\% \text{ recovery} = \frac{\text{Sum of the total S uptake by S treated plots} - (\text{S uptake by control} \times \text{number of S treatments})}{\text{Sum of all S doses}} \times 100$$

The recovery of applied sulphur was 4.9% in unlimed soil and 4.2% in limed soil. Although Subbiah and Singh (1970) obtained a recovery of 10.3 to 13.6% when the rate of application was 10 to 20 kg S as gypsum per hectare, in the present study the recovery was about 4.2 to 4.9 % only.

#### 4.4 Calcium uptake by crop

As gypsum containing 17 % Ca and lime as paper mill sludge were applied to field it was necessary to study the uptake of Ca by plant. The concentration of Ca in plant at harvest (Table 9) was highest in vine followed by shell and kernel. Invariably the concentration of calcium in plants grown with lime was higher than the plants grown without lime. The percentage of Ca in vine for all S treatments varied between 0.50 to 0.59 in unlimed soil and between 0.60 to 0.66 in limed soil.

**Table 9. Concentration of calcium in different plant parts at harvest**

Doses of sulphur (kg/ha <sup>-1</sup> )	Concentration of calcium (%)		
	Vine	Shell	Kernel
		<u>Unlimed</u>	
0	0.50	0.24	0.19
10	0.54	0.25	0.16
20	0.54	0.19	0.14
30	0.57	0.28	0.20
40	0.59	0.22	0.16
		<u>Limed</u>	
0	0.66	0.30	0.22
10	0.60	0.37	0.15
20	0.62	0.28	0.16
30	0.64	0.30	0.22
40	0.60	0.27	0.15

The corresponding variation for shell was 0.19 to 0.28 and 0.27 to 0.30 and for kernel it was 0.14 to 0.20 and 0.15 to 0.22, respectively.

From the data on concentration of S and Ca already presented it may be seen that as compared to unlimed soil the Ca percentage in vine and shell and S in kernel groundnut grown in limed soil were higher. Such condition appears to favour higher production of pod, and oil yield.

The total amount of Ca removed by vine, shell and kernel of groundnut is recorded in Table 10. The total amount of Ca removed from unlimed control treatment was  $10.9 \text{ kg ha}^{-1}$  which increased with increasing dose gypsum of  $14.1 \text{ kg ha}^{-1}$  at 40 kg level of S application. For equal level of S application, removal of Ca from limed soil was always higher ( $14.5 \text{ kg ha}^{-1}$  in control and  $18.13 \text{ kg ha}^{-1}$  in 30 kg  $\text{ha}^{-1}$  S treatment). Statistical analysis of these data (Table 11) shows that the effect of gypsum and lime in increasing Ca uptake by the crop was significant where as their interaction was not. The highest amount of Ca taken up by the crop was  $18.2 \text{ kg ha}^{-1}$  from treatment receiving 30 kg S and lime. The same treatment also showed the highest S uptake and highest oil yield. Therefore, it may be concluded that to obtain

**Table 10. Uptake of calcium by different plant parts as affected by application of lime and gypsum**

Doses of sulphur (kg ha <sup>-1</sup> )	Calcium uptake (kg ha <sup>-1</sup> )			Total (kg ha <sup>-1</sup> )
	Vine	Shell	Kernel	
		<u>Unlimed</u>		
0	8.96	0.59	0.50	10.52
10	10.15	0.69	0.60	11.44
20	11.20	0.55	0.52	12.27
30	12.13	0.85	1.02	14.00
40	12.70	0.74	0.74	14.18
		<u>Limed</u>		
0	12.80	0.71	0.94	14.45
10	11.90	0.97	0.77	13.64
20	14.09	0.93	0.96	15.98
30	15.60	1.02	1.51	18.13
40	13.50	1.13	0.99	15.62

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Table 11. Calcium uptake by plant as effected by lime and gypsum application

Doses of S ( kg ha <sup>-1</sup> )	Calcium uptake (kg ha <sup>-1</sup> )		Mean
	<u>Unlimed</u>	<u>Limed</u>	
0	10.52	14.45	12.50
10	11.44	13.64	12.54
20	12.27	15.98	14.13
30	14.0	18.13	16.06
40	14.18	15.62	14.90
Mean	12.48	15.56	
<u>Source</u>	<u>SE(m)±</u>	<u>C.D (0.05)</u>	
Sulphur	0.38	1.13	
Lime	0.24	0.72	
Sulphur x lime	0.53	NS*	

higher yield of groundnut oil, the crop may be grown in limed acid soil with  $30 \text{ kg ha}^{-1}$  sulphur applied as gypsum to the crop.

#### 4.5 Change in pH and available soil S

##### 4.5.1 pH:

The pH and available sulphur (monocalcium phosphate extractable) content of different treatments monitored at one month, two months and four months (at harvest) of application of lime and sulphur are recorded in Table 12. The pH in unlimed plots varied between 5.2 to 5.9 and in limed plot it varied from 6.0 to 6.3. There was a continuous rise in soil pH in limed treatments, probably due to slow dissolution of gypsum releasing Ca in addition to Ca supplied by paper mill sludge. But, in unlimed soil all the treatments receiving gypsum showed a small decrease in pH at 2 months which again increased attaining the same or slightly higher pH value recorded at one month.

##### 4.5.2 Available sulphur:

The available S content of the bulk sample of the experimental site was 6 ppm which increased with cropping attaining a value of 6.81 ppm at one month and 9.4 ppm at four months of crop growth. On liming although

Table 12. Change in pH and available sulphur content of soil following application of lime and sulphur

Doses of sulphur (kg ha <sup>-1</sup> )	Soil pH				Available S (ppm) in soil			
	months after application				months after application			
	1 month	2 months	4 months	6 months	1 month	2 months	4 months	6 months
0	5.4	5.3	<u>Unlimed</u> 5.3		6.8	7.8	9.4	
10	5.5	5.5	5.5		10.4	14.2	14.0	
20	5.5	5.3	5.9		13.8	16.1	16.1	
30	5.5	5.3	5.6		15.5	16.1	20.6	
40	5.5	5.2	5.8		17.5	18.3	20.6	
			<u>Limed</u>					
0	6.0	6.1	6.2		6.8	9.4	12.0	
10	5.7	5.8	6.0		11.2	14.1	16.0	
20	5.7	5.8	6.0		15.5	18.3	18.3	
30	5.8	6.0	6.3		17.5	20.6	22.5	53
40	5.9	6.0	6.3		13.8	14.1	18.3	

the value at one month was similar to unlimed soil it increased to 12 ppm at four months.

As the experiment was laid in a virgin field, the mineralization of organic S was increased due to increased microbial activity thereby registering an increase in available soil S. Besides, on liming the available S further increased due to increased soil pH favouring mineralization. Further the moisture content of the soil was around 60% of field capacity for some time since the crop was grown during Kharif and the temperature of around 35°C maintained during the growth period are favourable for S mineralization. Choudhury and Cornifield (1967) have observed increased mineralization of S at 60% of field capacity and Williams (1975) have reported optimum temperature of around 35°C or higher for mineralization of S. Therefore these factors which are favourable during the growth of the crop might have increased the available S through mineralization.

Addition of S as gypsum has increased the available S in all the treatments, the increase being higher in unlimed soil than in limed soil.

#### 4.6 Relationship between available sulphur, sulphur uptake and yield

The concentration (%) of sulphur in plant at

one month of growth correlated well ( $r = 0.80$ ) with available S content of soil at one month (Fig 3). Also a significant correlation ( $r = 0.91$ ) between available S determined after harvest of the crop and total S uptake was obtained (Fig 4). These results show that monocalcium phosphate extractable sulphur in soil is a good indicator of sulphur available for crop growth. Further it has been shown that although soil may be deficient in available sulphur before cropping during crop growth the availability to crop may be more due to mineralization.

With increase in available S content of soil, pod yield also increased, the relationship between the two being significant at 1% level ( $r = 0.72$ , Fig 5). Removal of S by groundnut kernel was positively related with total S uptake by plant ( $r = 0.77$ , Fig 6) and the oil content (%) of kernel was positively related to sulphur concentration in kernel ( $r = 0.57$ , Fig 7). With the increase in amount of S in kernel the oil yield increased significantly, the correlation coefficient between the two being 0.94 (Fig 8).

These findings are in agreement with the findings of Chopra and Kamwar (1966) and Singh et al., (1970).

#### 4.7 Sulphur balance

Considering the increase in available sulphur content of the soil and increased uptake from soil treated

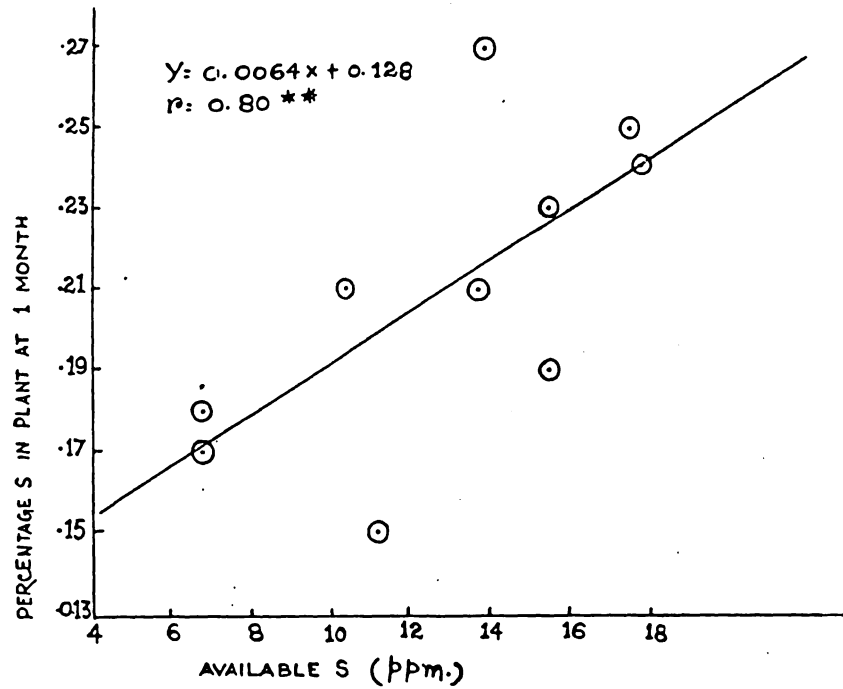


FIG: 3 RELATIONSHIP BETWEEN AVAILABLE S IN SOIL AT 1 MONTH OF CROP GROWTH AND S CONC. IN VINE.

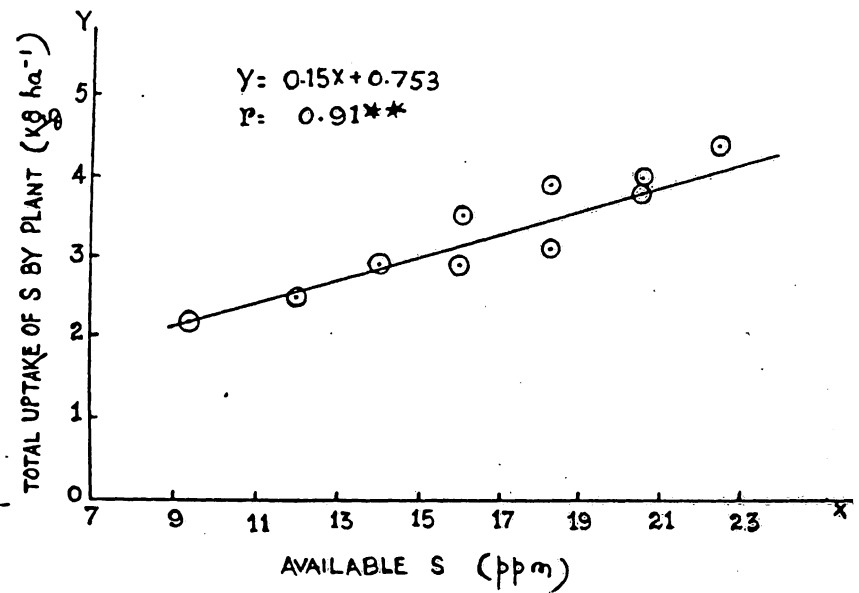


FIG:- 4 RELATIONSHIP BETWEEN AVAILABLE SULPHUR AFTER HARVEST AND TOTAL UPTAKE OF SULPHUR BY PLANT.

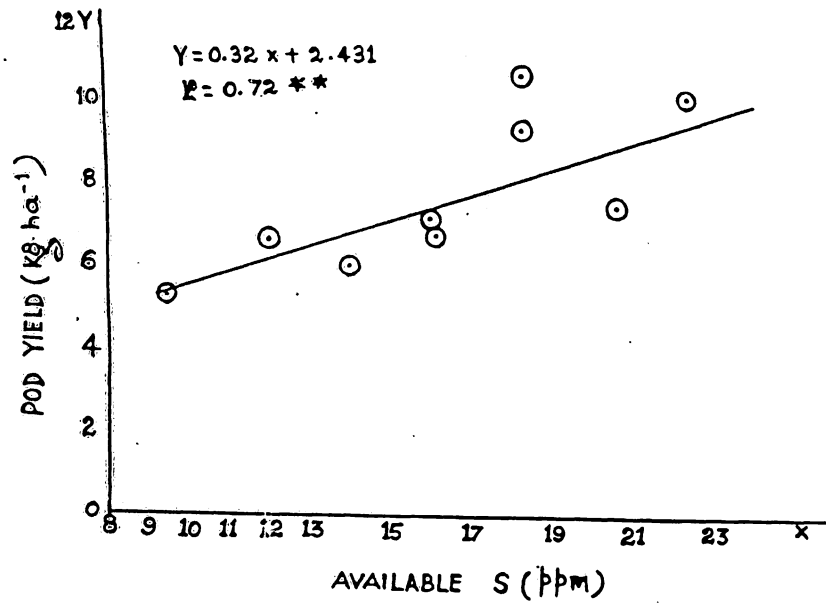


FIG: 5 RELATIONSHIP BETWEEN AVAILABLE SULPHUR AFTER HARVEST AND POD YIELD.

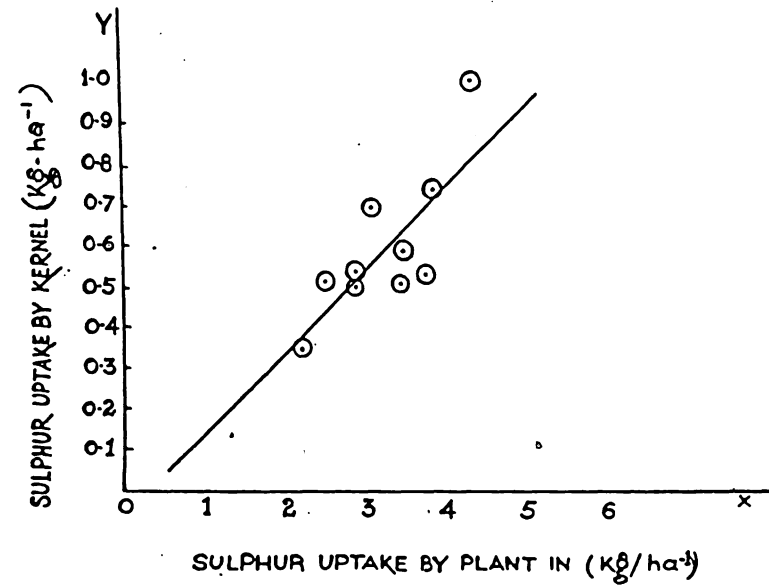


FIG:-6 RELATIONSHIP BETWEEN SULPHUR UPTAKE BY PLANT AND SULPHUR REMOVED BY KERNEL.

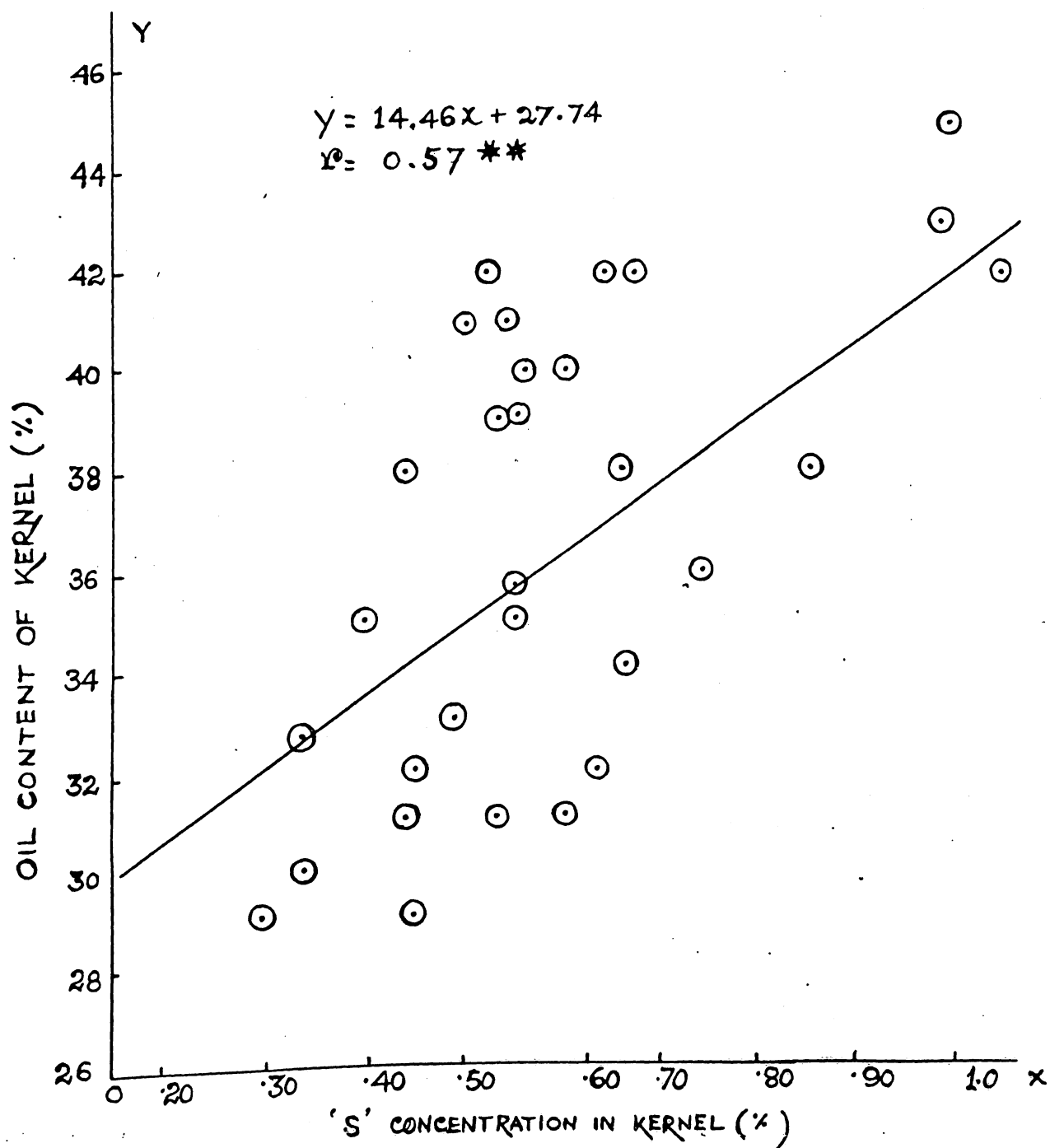


FIG: 7

RELATIONSHIP BETWEEN SULPHUR CONCENTRATION IN KERNEL AND OIL CONTENT OF KERNEL.

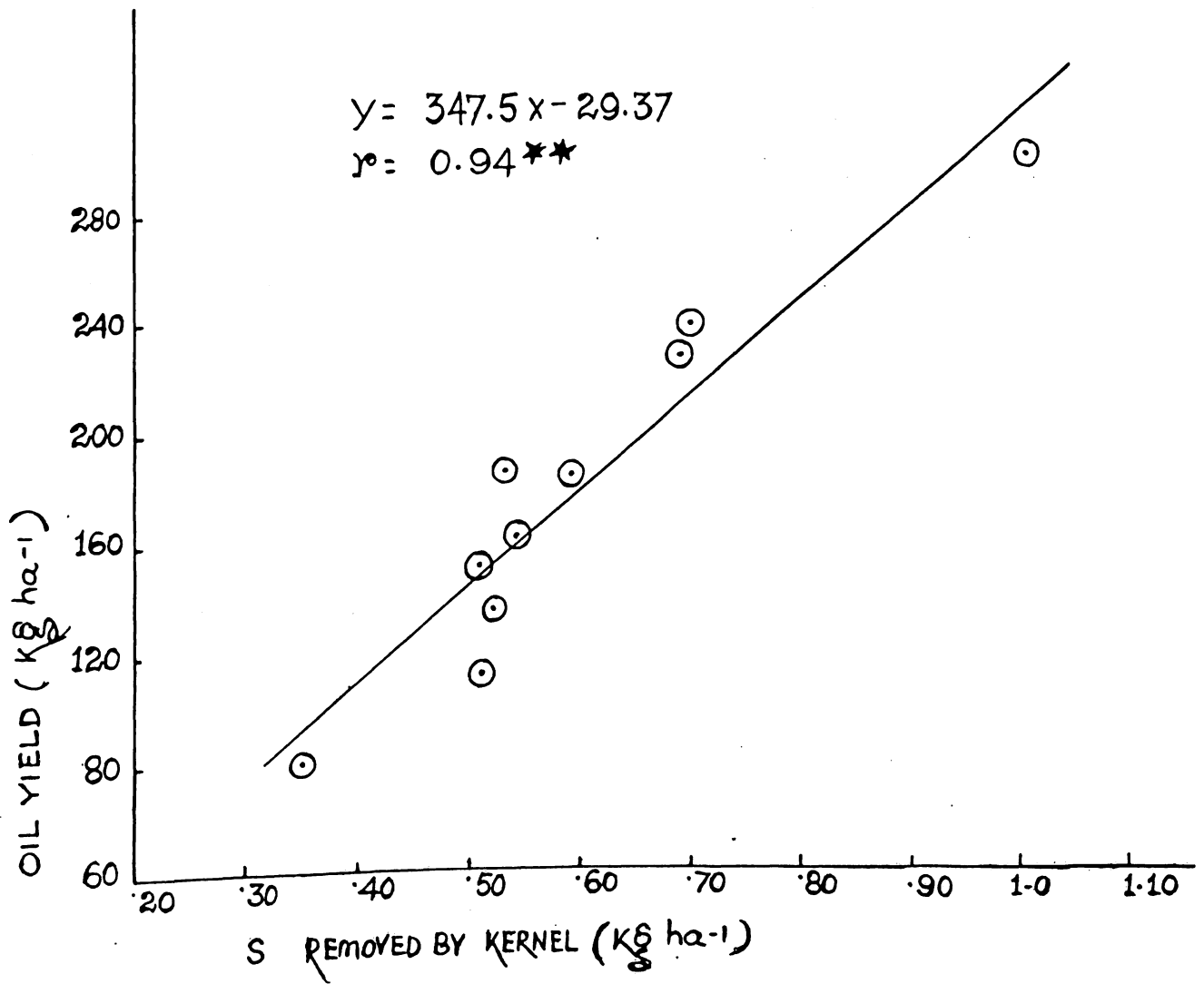


FIG: 8

RELATIONSHIP BETWEEN SULPHUR REMOVED BY KERNEL AND OIL YIELD

Table 13 ~~Table~~ Sulphur balance sheet

Sulphur applied (kg ha <sup>-1</sup> )	Available S in soil (kg ha <sup>-1</sup> )	Increase in available S over control after 4 months of S application (kg ha <sup>-1</sup> )	Uptake by crop (kg ha <sup>-1</sup> )	Increased S uptake due to S application over control (kg ha <sup>-1</sup> )	Applied S not accounted for in the surface layer (kg ha <sup>-1</sup> )
<u>Unlined</u>					
0	18.8	-	2.2	-	-
10	28.0	9.2	2.9	0.7	0.1
20	32.2	13.4	3.5	1.3	5.3
30	41.2	22.4	3.8	1.6	6.0
40	41.2	22.4	3.5	1.3	16.3
<u>Lined</u>					
0	24.0	-	2.5	-	-
10	32.0	8.0	2.8	0.3	1.7
20	36.6	12.6	3.1	0.6	6.8
30	45.0	21.0	4.4	1.9	7.1
40	36.6	12.6	3.9	1.4	26.0

with sulphur over no sulphur treatment, sulphur balance of the 0-15 cm layer of the soil to which gypsum and lime were applied has been worked out and presented in Table 13. It may be seen that the amount of applied sulphur unaccounted in the surface layer was higher in limed soil than in unlimed soil, which increases with increasing dose of S application. This unaccounted S might have been lost to the lower layer of the profile due to leaching. The loss from the surface layer of unlimed soil varied between  $0.1 \text{ kg ha}^{-1}$  in no sulphur treatment to  $16.3 \text{ kg ha}^{-1}$  in  $40 \text{ kg S}$  treated plot. In limed soil a substantially higher amount of S corresponding to  $1.7 \text{ kg ha}^{-1}$  from no sulphur treated plot and  $26 \text{ kg ha}^{-1}$  from  $40 \text{ kg S}$  treated plot has been leached to the lower layer. Assuming that the S nutrition of the crop was mainly drawn from the surface soil (0-15 cm layer), the average distribution of added sulphur in limed and unlimed soils have been calculated and reported in Table 14.

Table 14. Distribution of sulphur added to soil

Source	Percentage of added S	
	Unlimed soil	Limed soil
Crop recovery	4.9	4.2
Increase in available S in 0-15 cm layer	66.4	54.2
Loss from 0-15 cm layer	28.7	41.6

It may be noted that although crop recovery in unlimed soil was slightly higher than limed soil, 41.6 % of the added S was lost from limed soil as against 28.7 % from unlimed soil. The increase in soil pH leads to lower retention of sulphate by soil (Kamparath et al., 1956; Bahl and Pasricha, 1964; Ahmed and Jha, 1969 and Kanwar, 1976) as a result a relatively large portion of sulphur was lost through leaching.

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## **CHAPTER - V**

### **SUMMARY AND CONCLUSION**

## SUMMARY AND CONCLUSION

**5.1 Summary**

To study the effect of gypsum as a source of sulphur for groundnut grown in an Aeric Haplaquept, a field experiment in RBD design with three replication was laid in the Central Farm of Orissa University of Agriculture and Technology, Bhubaneswar during Kharif, 1988. The experiment consisted of five levels of sulphur i.e. 0, 10, 20, 30 and 40 Kg ha<sup>-1</sup> and two levels of lime i.e. 0 and 0.5 L.R. The lime requirement of the soil was 2 t ha<sup>-1</sup> as determined by Woodruff's buffer method. Gypsum supplied by Rajasthan State Mines containing 14.25 % S and 24.7 % CaO was used as source of sulphur. Paper mill sludge from Chowdwar having neutralising value of 70 % was used as liming material. Groundnut cultivar AK-12-24 was grown with 20 kg N, 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O per hectare applied as NPK 10:26:26 and urea.

Plant samples from the field were collected at 1 month of growth and at harvest. Yield of pod, vine and shelling percentage after drying were recorded. Vine, pod and kernel samples were analysed separately for sulphur and Ca content. Oil content of groundnut was also determined.

Surface soil samples from each plot were collected at 1 month, 2 months and 4 months (at harvest) of crop growth and composited for each treatment. Samples were analysed for pH and available sulphur.

Limed soil was prepared in the laboratory by incubating about 1 kg of soil to which paper mill sludge equivalent to 50 % of the lime requirement was added and allowed to equilibrate with alternate wetting and drying. Sulphate adsorption study was carried out in limed and unlimed soil by equilibrating 10 g of soil with 50 c.c of 0.01 M solution of NaCl containing varying amounts of S ( 0 to 25 ppm ).

The adsorption study showed that more sulphate was adsorbed in unlimed soil than in limed soil. At equilibrium S concentration of 11.8 ppm unlimed soil adsorbed 66 ppm of S as compared to 41.1 ppm of S in limed soil. This indicated that a large fraction of the added S will be lost from the limed soil by leaching.

Application of S as gypsum and lime as paper mill sludge, both increased the pod yield significantly but the effect was additive. The average yield of pod recorded in unlimed soil was  $6.68 \text{ q ha}^{-1}$  which increased to  $8.91 \text{ q ha}^{-1}$  by liming registering an increase of 34 per cent. Comparison of mean effect of S showed that,

the yield recorded at 20 kg ha<sup>-1</sup> level of S application was 8.2 q ha<sup>-1</sup> which was at par with 30 and 40 kg level of S application and the mean yield for no S treatment was 6.07 q ha<sup>-1</sup> only. It shows that S application increased the yield by 36 %. At a S dose of 20 kg ha<sup>-1</sup> applied to limed soil highest pod yield of 9.5 q ha<sup>-1</sup> was obtained. But treatment receiving S at 30 kg ha<sup>-1</sup> showed the highest shelling percentage of 67.3 % in limed soil as compared to 50.7 % in unlimed and 65.9 % no sulphur treated limed soil. Calcium, both from gypsum and lime helped in increasing the shelling percentage.

Sulphur application significantly increased oil content. Although the effect of lime application in increasing percentage oil was not significant the interaction of lime and sulphur was significant. The mean oil content of groundnut was 30.15 % in no sulphur treatment which increased to 41.95% in 30 kg ha<sup>-1</sup> S treatment. The highest oil percentage of 49.3 % and oil yield of 300 kg ha<sup>-1</sup> was recorded in 30 kg ha<sup>-1</sup> sulphur treated and limed soil, which may be used as a recommendation for growing groundnut in acid soil.

The amounts of S and Ca removed by crop from different treatments varied between 2.16 to 4.44 kg of S per hectare and 10.5 to 18.2 kg of Ca per hectare.

The highest S removal of  $4.44 \text{ kg ha}^{-1}$  and Ca removal of  $18.2 \text{ kg ha}^{-1}$  was associated with a pod yield of  $10.32 \text{ q ha}^{-1}$ .

Assuming that the S nutrition of groundnut is largely met from surface (0-15cm) soil, a sulphur balance sheet has been worked out. In unlimed soil 4.9 % of applied S was recovered by crop, 66.4 % appeared as available soil S and 28.7 % was not accounted for in 0-15 cm layer suggesting loss of lower layer by leaching. The corresponding percentages for limed soil were, 4.2, 54.2 and 41.6. More of applied S was lost from limed soil than unlimed soil.

The pH of unlimed plots varied between 5.2 to 5.9 and the variation was between 6.0 to 6.3 for limed plots. The available S content of the bulk sample of the experimental site was 6 ppm. In no sulphur no lime (control) plot available S increased to 6.81 ppm at 1 month and 9.4 ppm at 4 months of cropping. On liming although the value at one month was similar to unlimed soil, it increased to 12 ppm at 4 months. The increase in available S has been attributed to increased mineralisation of organic S due to increased microbial activity, increased pH, favourable soil moisture and temperature of about  $35^{\circ}\text{C}$  during crop growth.

The concentration of S in plant at 1 month of growth correlated well ( $r = 0.80$ ) with available S content of soil at that time. Significant positive correlation between available S content of soil at harvest and pod yield ( $r=0.72$ ) and total S uptake by crop ( $r = 0.91$ ) have been observed. With increased total uptake of S by crop, S uptake by kernel also increased ( $r=0.77$ ) and with the increase in S concentration in kernel both oil percentage in kernel and oil yield increased, the coefficients of correlation being 0.57 and 0.94 respectively.

From the results of the investigation as discussed and summarised above the following conclusions may be drawn.

## 5.2 Conclusions

1. The sulphate adsorption capacity of the soil decreased with increasing pH. At equilibrium S concentration of 11.8 ppm unlimed soil (pH 5.3) adsorbed 66 ppm S and limed soil (pH 6.2) adsorbed 41.1 ppm S only.
2. Application of lime and S as gypsum, both increased the yield of groundnut. In unlimed soil the average pod yield recorded was  $6.68 \text{ q ha}^{-1}$  which could be raised by 34 per cent on liming. The mean yield of  $6.02 \text{ q ha}^{-1}$  recorded for no sulphur treatment was increased by 36% due to S application at  $20 \text{ kg ha}^{-1}$ .

3. Calcium application increased the shelling percentage and sulphur increased the percentage of oil in groundnut. Groundnut grown in soil treated with lime and 30 kg S ha<sup>-1</sup> produced highest oil yield of 300 kg ha<sup>-1</sup>, highest shelling percentage (67.3%) and highest oil percentage (43.3%) which may be used as a recommendation.
4. The highest amount of Ca and S removed by crop was 18.2 kg ha<sup>-1</sup> and 4.44 kg ha<sup>-1</sup> corresponding to a yield of 10.32 q ha<sup>-1</sup>.
5. In unlimed soil, 4.9% of applied S was recovered by crop, 66.4% appeared as available S in soil and 28.7% was lost to lower layer from 0 - 15 cm layer by leaching. The corresponding percentage for limed soil were 4.2, 54.2 and 41.6.
6. Monocalcium phosphate extractable S was a good indicator of S availability to groundnut crop.



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