SULPHUR AND BORON NUTRITION OF GROUNDNUT (*Arachis hypogaea* L) VAR TG - 3

BY

A CHANDINI B Sc (Ag)

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI TRIVANDRUM

1992

DECLARATION

I hereby declare that this thesis entitled 'Sulphur and boron nutrition of groundnut (*Arachis hypogaea* L) var TG-3" 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 any degree, diploma, associateship, fellowship or other similar title at any other University or Society

Chandini

Vellayani, (A CHANDINI)

15-6-1992.

CERTIFICATE

Certified that this thesis entitled "Sulphur and boron nutrition of groundnut (Arachis hypogaea L) var TG-3" is a record of research work done independently by Kum A. Chandini 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.

Dr (Mrs) S Chandini
Chairman
Advisory Committee
Associate Professor of Agronomy

Vellayani,

15-6-1992.

Approved by:

Chairman

Dr. (Mrs.) S. CHANDINI

Members

1. Prof. P. CHANDRASEKHARAN

2. Dr. V. MURALEEDHARAN NAIR

3. Dr. (Mrs.) P. SARASWATHY

External Examiner

31/10/82

ACKNOWLEDGEMENT

I am deeply indebted to my guide Dr.(Mrs.)S.Chandini, Associate Professor of Agronomy for the most valuable guidance, constant encouragement and tireless help throughout the conduct of the study as well as in the preparation of the thesis.

I express my sincere gratitude to Shri.K.P.Madhavan Nair Professor and Head, Department of Agronomy (retd.) for the expert advice and help rendered during the course of this study.

I am deeply obliged and grateful to Dr. G.Raghavan Pillai Professor of Agronomy for his valuable suggestions and critical evaluation of the script.

I am extremely grateful to Dr.V.Muraleedharan Nair, Professor of Agronomy for the timely suggestions and critical scrutiny of the script.

I wish to express my deep sense of gratitude to Dr.(Mrs.)P. Saraswathy, Associate Professor and Head of Agricultural Statistics for her valuable guidance in the statistical analysis of the data and interpretation of results.

My sincere thanks to Dr.V.L.Geethakumari, Associate professor of Agronomy for the helpful suggestions extended throughout the course of this investigation.

My thanks are due to Sri. C.E.Ajithkumar, Junior Programmer, Agricultural Statistic for help in the Computer analysis of the data, and Dr.N.Saifudeen, Associate Professor of Soil Science and Agricultural Chemistry for the help in the Chemical analysis.

I thank the P.G.scholars and the teaching and non-teaching staff of the Department of Agronomy, for their help during the period of study.

I also thank Sri. Nadaraj Pillai for executing the typing of the thesis.

I am also thankful to Kerala gricultural University for awarding me a fellowship for the post graduate programme.

I take this opportunity to express my indebtedness to my parents and brother for their help and encouragement throughout the course of study.

Chandini

(CHANDINI.A.)

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF TABLES (Contd)

LIST OF TABLES (Contd)

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

cm	centimetre
g	gram
kg	kilogram
t	tonne
ha	hectare
°C	degree celsius
cv	cultivar
var.	variety
Co-A	Coenzyme A
DAS	days after sowing
DBS	days before sowing
DMP	drymatter production
TDMP	total drymatter production
LAI	leaf area index
HI	harvest index
Fig.	figure
KAU	Kerala Agricultural Universi

INTRODUCTION

1 INTRODUCTION

Oilseeds and pulses have the dubious distinction of being the sick segments of Indian agriculture Till 1965, India was an exporter of oilseeds and oils, when the annual oilseed production far exceeded the domestic demand Gradually the production of oilseeds slipped and imports of oilseeds became necessary to meet the surging demand Imports kept rising year by year to reach a high of nearly two million tonnes in the leave year 1988-89 (Achaya, 1989)

In India, the daily availability of 13 g of oil is far below the minimum nutritional level of 18 g. The consumption has been limited by the inability to meet the demand and hence there is an urgent need for increasing production of oilseeds in India

Among the seven edible annual oilseed crops cultivated in India, groundnut is the most important and is well known as the 'King of oilseeds as it constitutes about 60 percent of the total oilseed production in the country. Besides being a rich source of vegetable protein, it is the main source of vegetable oil both for human consumption and industrial purposes. Moreover, groundnut cake is an excellent animal and poultry feed

In India, groundnut is cultivated in an area of 7.7 million ha with an annual production of 6.6 million tonnes In Kerala, the area under groundnut is very limited, only 12665 ha, with an annual production of 13,288 tonnes The importance of the crop can be judged from the fact that India stands first among groundnut growing countries both in area and production. However, with regard to productivity India stands 11th out of the 13 major groundnut producing countries of the world

In order to boost up the productivity, attempts have been directed towards the use of high yielding varieties, which are highly fertilizer responsive. TG-3, a mutant of Spanish Improved has been recommended for cultivation by KAU, in the uplands and coconut gardens in the red loam soils of Kerala. Since TG-3 is a high yielding and exhaustive crop, it naturally requires high amount of nutrients Nowadays, farmers have started using nitrogenous and phosphatic fertilizers in near optimum quantity to oilseed crops. However, the nutrient 'sulphur' which plays multi-role in plant nutrition and is found to increase oil yields is still neglected Along with nitrogen and phosphorus sulphur plays an important role in the formation of proteins and is involved in the metabolic and enzymic processes of all living cells. Since the key role of sulphur is in increasing the oil content of oilseeds, it can play a very important role in augmenting the production and productivity of oilseeds. Woefully, the present usage of sulphur in oilseed crop is much lower

Compared to its uptake.

The increase in the consumption of fertilizers along with intensive cropping has enormously increased the importance of micronutrients in oilseeds. It is quite evident that the full benefit of application of major nutrients cannot be obtained in the absence of available micronutrients in the soil In Kerala boron deficiency may be one of the causes for low yields in groundnut, as it plays a vital role in the physiological processes of the plant such as cell maturation, tissue hydration, pollen germination, formation of reproductive organs etc.

Significant response of ground nut to the application of sulphur and boron have been reported from red sandy loams in Karnataka, Tamilnadu and Gujarat Such responses to the application of sulphur and boron in groundnut could be obtained in Kerala also and hence the present study was undertaken with the following objectives

1 To determine suitable doses of sulphur and boron, for the groundnut variety TG-3 in the red loam soils of Kerala

2 To find out the best time of application of sulphur and boron to the crop.

3 To study the effect of sulphur and boron application on crop quality and nutrient uptake.

4 To work out the economics of cultivation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The results of the experiments conducted in India and elsewhere, on the growth, yield and quality of groundnut and related crops as influenced by sulphur and boron fertilization are reviewed here

2.1 SULPHUR

2.1.1 Effect of sulphur on growth of groundnut and related crops

In pot culture studies with groundnut, Yadav and Singh (1970) found that the drymatter production was increasing when sulphur was applied at the rate of 56 to 112 kg S. ha^{-1} as gypsum. A similar finding was recorded by Pasricha and Randhawa (1973) in mustard, wherein the drymatter production showed a progressive and significant increase upto 50 ppm sulphur, after which it declined slightly.

Nankumba and Edji (1974) reported that dusting of sulphur @ 39 kg S. ha^{-1} at 2 and 4 weeks after seedling emergence in groundnut plants, increased the height and width of canopy, leaf area index and drymatter accumulation.

In a pot culture study by Karle and Ghonsikar (1980) good interaction effects were noticed between phosphorus and sulphur in increasing the biomass of groundnut at various stages of growth. A significant P x S interaction in increasing the biomass production in groundnut was also reported by Karle (1982).

In trials by Balasubramaniyan and Yayock (1981) it was observed that 46 kg Ca. ha^{-1} as gypsum had no significant effect on vegetative growth or yield of groundnut cv. Spanish 205. Similar finding has been reported by Aipe (1981) wherein applied sulphur @ 30 kg ha^{-1} failed to influence the growth of sesamum at any of the stages of growth.

In sunflower cv. Kernel, Hocking et al. (1987) reported that sulphur deficiency (6 ppm in soil) reduced the plant height and leaf area.

Singh and Saran (1987) reported that application of sulphur @ 30 or 60 kg S. ha^{-1} along with 30 kg ha^{-1} of nitrogen, increased the height of plants in Indian rape.

In an alluvial sandy loam soil given 0, 25, 50 or 75 kg S. ha^{-1}, increasing levels of sulphur increased the plant height, number of leaves and drymatter production in soybean cv. Gaurav (Fazal and Sisodia, 1989).

In groundnut cv. J-11, soil application of sulphur @ 20 kg S. ha^{-1}, increased the plant height and haulm yield significantly (Singh et al., 1991).

Available literature on the effect of sulphur on growth characters of groundnut show that the studies are limited with respect to this nutrient element. In most of the investigations application of sulphur, has resulted in increased plant height and drymatter production. In certain studies applied sulphur showed no significant influence on the growth of the crops.

2.1.2 Effect of sulphur on yield and yield attributes of groundnut and related crops

Several studies have been reported on the significant influence of sulphur on pod yield of groundnut.

Dalal et al. (1963) observed that the yield of groundnut increased by 41 percent by the application of gypsum at 25 kg S. ha^{-1}.

Chopra and Kanwar (1966) reported that application of NPK and S @ 224 kg ha^{-1} resulted in 50 per cent increase in groundnut yields. Similarly sandy soils given nutrient solutions and 22.4-44.8 kg S. ha^{-1} as ammonium sulphate, significantly increased the yield of unshelled nuts of groundnut (Singh et al., 1970).

Increase in shelling percentage of groundnut was reported by Verma et al. (1973) by the application of sulphur as ammonium sulphate, elemental sulphur or gypsum in combination with NPK. With 20 kg S. ha^{-1} the shelling percentage was 70.22 percent as against 66.58 percent in the control.

Dungarwal *et al*. (1974) obtained 0.62 t ha^{-1} of unshelled nuts in plots given no sulphur, while yield with 500 kg elemental sulphur applied 21 DBS was 1.75 t ha^{-1}. The yield obtained with 2 sprays of 0.1 percent sulphuric acid (at 4-5 leaf stage and 20 days later) was 1.47 t ha^{-1}.

Dusting 39 kg S. ha^{-1} at 2 and 4 weeks after seedling emergence in groundnut increased the shelled nut yields to 1.90 t ha^{-1}, while it was 1.61 t ha^{-1} in the untreated plots (Nankumba and Edji, 1974).

Satyarajan *et al*. (1975) reported reduction in groundnut yield with gypsum levels beyond 3 t ha^{-1}.

Laurence *et al*. (1976) observed that application of 30 kg S. ha^{-1} as soil treatment increased groundnut kernel yields in sulphur deficient soils.

The average yield of dry pods by sulphur application @ 62 kg ha^{-1} using elemental sulphur reported a 7 percent increase over the control in another trial conducted by Dongale and Zende (1976).

In an alluvial soil testing 14 ppm available sulphur and 57 ppm magnesium, the highest yield of mustard was obtained with 50 kg S. ha^{-1} applied along with 40 kg Mg. ha^{-1} (Singh and Singh, 1978).

Gaur (1980) reported that application of 100 kg S. ha^{-1} along with recommended dose of NPK, increased the seed yield of sesamum from 1.4 q ha^{-1} to 5.1 q ha^{-1}.

Application of 20 kg S. ha^{-1} increased the seed yield of sunflower by 30 percent in Karnataka (Channel and Rao, 1981).

Natarajan (1981) observed no response for either calcium or sulphur on yield, drymatter and oil content of groundnut.

In a pot culture study Talukder and Islam (1982) obtained maximum pod yield of 127.7 g pot^{-1} with 15 kg S. + 10 kg Zn. ha^{-1} for the groundnut cv. Dacca-1. In a similar trial by Ramanathan and Ramanathan (1982) in red sandy loam soil maximum shelling percentage was recorded with the application of 100 kg Ca and 40-80 kg S. ha^{-1}.

In another trial with groundnut on a sandy loam soil, Badiger et al. (1982) observed significant effects for the application of 5 ppm potassium and 10 ppm sulphur on pod (18 percent increase) and haulm yields and shelling percentage of groundnut.

Ankineedu et al. (1983) reported 42 percent increase in groundnut yields by the application of 22 kg S. ha^{-1} as gypsum in a red soil in Tamilnadu.

Optimum level of sulphur for obtaining maximum yield (2.69 t ha^{-1}) from groundnut cv. M-13, was worked out to be 16.28 kg ha^{-1} by Singh and Kalra (1983).

Walker et al (1983) could not obtain any significant effect on yield with combined foliar application of NPK and S, while higher concentrations caused severe foliar burns.

Giri and Saran (1985) reported that application of sulphur at 0, 30 or 60 kg S. ha^{-1} at sowing recorded yields of 0.88, 1.05 and 1.41 t ha^{-1} respectively.

Application of sulphur @ 50 ppm improved the pod yield and drymatter yield of groundnut (Patel and Patel, 1985).

Sulphur application had significant role in increasing pod and kernel yields as reported by Karle and Babula (1985). The pod and kernel yields of groundnut variety JL-24, increased from 870.1 kg ha^{-1} to 1797.3 kg ha^{-1} and 584.3 kg ha^{-1} to 1190 kg ha^{-1} as the level of applied sulphur increased from 0 to 120 kg ha^{-1} of elemental sulphur. The haulm yield was also increased with increase in levels of sulphur.

Thirumalaisamy et al. (1986) reported that basal application of sulphur @ 22 kg/ha in the form of sulphur dust increased the pod yield and drymatter yield significantly in groundnut cv. TMV-2. The pod yield recorded 14.7 percent increase over control. The total drymatter production $plant^{-1}$ was increased from 46.3 to 51.2 g $plant^{-1}$, harvest index from 20.8 to 30.6, shelling percentage from 65 to 74.2 and 100 kernel weight from 38 to 41.5 g.

Chawdhary and Sharma (1986) reported significant increase in the seed yields of sesame with the application of 40 kg $S.ha^{-1}$ Nitsure and Ramteke (1987) found that application of 0, 15 and 30 kg S. ha^{-1} to 3 groundnut cultivars M-13, Kopergaon No. 1 and TG-1 gave average kernel yields of 0.69, 0.83 and 0.97 t ha^{-1} respectively.

In trials with groundnuts grown on soil containing 17 kg available S. ha^{-1}, application of 0-60 kg S. ha^{-1} as $CaSO_4$ increased pod yields from 0.75 to 1 t ha^{-1}. Sulphur at 90 kg ha^{-1} gave no further increase in yield (Naphade and Wankhade, 1988).

Nitsure _et al_. (1988) studied the effect of application of sulphur at sowing on the yield of groundnut cultivars Kopergaon No. 1, TG-1 and M-13 and observed that the number of effective pegs, pod number and weight, shelling percentage and 100 seed weight increased with increase in sulphur levels upto 30 kg S ha^{-1}.

In a trial, to study the effect of phosphorus with and without sulphur and magnesium, application of P as single superphosphate, and S as ammonium sulphate gave significantly higher (32 percent) groundnut pod yields (Maliwal and Tank, 1988).

Aulakh and Pasricha (1988) reviewed the work on response of sulphur to groundnut in India, and noted that increase in groundnut yield with applied sulphur ranged from 0.75 - 5 q ha^{-1}.

Results of an experiment conducted by Sistani and Morrill (1989) showed that gypsum application @ 672 kg ha^{-1} (124 kg S. ha^{-1}) significantly increased the yield, total kernel content (TKC) and percent sound mature kernel in spanish peanut. However increasing the gypsum rate to 1009 kg ha^{-1} (187 kg S ha^{-1}) decreased the yield and total kernel content. A similar finding has been reported by Alva et al. (1989) in experiments conducted on Lakeland sand, where application of gypsum @ 500 kg ha^{-1} (92.5 kg S. ha^{-1}) resulted in significantly higher percent sound mature kernels, compared to the control treatment.

In another experiment, Singh et al. (1989) observed that groundnut crop given NPK plus 42 kg S ha^{-1} recorded pod yields of 2.12 t ha^{-1} compared to 1.76 t ha^{-1} without sulphur.

Mandal and Chatterjee (1990) obtained 31.6 percent increase in groundnut yield by the application of 20 kg S ha^{-1} as gypsum in an alluvial soil testing 6-17 ppm available sulphur. While Misra et al. (1990) reported 53.5 percent increase in yield by the application of gypsum @ 30 kg S. ha^{-1}.

In a kharif trial on groundnut with 16 ppm available sulphur in soil, Sahu (1991) reported 43 percent increase in pod yield and 18.9 percent increase in shelling percentage, over the control by the application of 30 kg sulphur as gypsum at sowing. It was also observed that the response yardstick of groundnut to sulphur is 6.8 kg ha^{-1} at which maximum benefit cost ratio is obtained.

Singh et al (1991) reported that application of 20 kg S. ha^{-1} gave 18 percent and 12.8 percent more pod yield in JL-24 and JL-11 groundnut varieties respectively.

The kernel yield of groundnut significantly increased with increasing levels of sulphur upto 50 kg ha^{-1}, and beyond 50 kg level there was no significant change in kernel yield (Mashi and Sharma, 1991).

Polaria and Patel (1991) reported 29.6 percent increase in groundnut yields by the application of 38 kg S ha^{-1} as single superphosphate.

The results of the experiment done by Singh and Tiwari (1991) showed yield increase in sesamum upto 20 kg S ha^{-1} but at 40 kg S ha^{-1} there was reduction in yield. But Patel et al. (1991) reported that irrespective of methods and levels, gypsum application produced significant effect on pod and haulm yield as well as on shelling percentage of groundnut.

The review of the works on the effect of sulphur on the yield and yield attributes of groundnut show that sulphur application has a favourable influence in increasing the yield of groundnut and related crops. In majority of the studies reviewed application of 20 to 30 kg S. ha^{-1} was found to be economical. Gypsum as source of sulphur, appeared to be the most economical one.

2.1.3 Effect of sulphur on quality of groundnut and related crops

The effect of sulphur on the quality of groundnut seeds is mainly in respect to its oil and protein contents.

Chopra and Kanwar (1966) reported significant increase in protein and oil contents of groundnut kernels by sulphur application. At 0, 50 and 100 ppm S the protein contents recorded were 29.7, 30.3 and 30.6 percent respectively, and the oil contents recorded were 46.2, 48.8 and 49.6 percent respectively. Moreover, a significant increase in the contents of cysteine and methionine by sulphur application was also reported by them.

Yadav and Singh (1970) obtained increase in oil content of groundnut when the sulphur level was increased from 56 to 112 kg S. ha^{-1} as gypsum Application of NK without S and P decreased the oil content.

Singh _et_ _al_. (1970) reported that the oil content of groundnut kernels increased by 1 percent at 10 ppm S, and when the dose of sulphur was doubled, the oil content increased by 3.73 percent. At 20 ppm sulphur as gypsum, the protein content of groundnut kernels increased by 8.4 percent.

Barhanpure (1976) studied the effect of sulphur bearing compounds on groundnut and found that the quality of groundnut with respect to protein and oil content was improved as a result of sulphur application. Addition of $CaSO_4$ @ 30 kg S. ha^{-1} increased the crude and true protein contents by 3.19 and 3.11 percent respectively.

Walker and Keisling (1978) found that gypsum application @ 22 kg S. ha^{-1}, increased the seed oil content by 4 percent, but decreased the seed nitrogen contents. A similar result was reported by Laurence et al. (1976) where sulphur application @ 30 kg S. ha^{-1} had little effect on seed protein content, but increased seed oil content.

Studies conducted by Reddy and Patel (1980) revealed that in groundnut var. Spanish Improved percentage of oil was increased by 3 percent, by gypsum application @ 20 ppm S. But Aipe (1981) found that applied sulphur @ 30 kg ha^{-1} decreased the oil content in sesamum, but had no effect on protein content. A similar result had been reported by Ramanathan and Ramanathan (1982) in POL-2 groundnut, where the oil content and composition were unaffected by sulphur

The oil content in the seeds of mustard was increased significantly with increasing levels of sulphur upto 40 ppm (Verma and Ram, 1986).

Application of 60 kg ha^{-1} of sulphur as $CaSO_4$ increased the seed protein content of groundnut from 22.31 to 28.96 percent and oil content from 48.82 to 51.97 percent (Naphade and Wankhade, 1988).

Nitsure et al. (1988) observed that oil yields by sulphur application at 30 kg S. ha^{-1} ranged from 0.30 t ha^{-1} in variety TG-1 to 0.49 t ha^{-1} in variety M-13 and protein yields from 0.15 t ha^{-1} in TG-1 to 0.27 t ha^{-1} in M-13.

In trials at Dharwad, seed oil content of groundnuts given 0-45 kg S. ha^{-1} ranged from 47.6 percent without sulphur to 50.6 percent with 45 kg sulphur applied at peg initiation (Koti et al., 1989).

Singh et al. (1991) reported that the total oil production in groundnut increased significantly by the application of sulphur @ 20 kg ha^{-1}.

In another study soil application of sulphur at 50 kg ha^{-1}, increased the nitrogen and protein content of groundnut kernels (Mashi and Sharma, 1991). The oil and protein contents in sesamum was also found to increase significantly by the application of sulphur @ 20 kg S. ha^{-1} (Singh and Tiwari, 1991).

The review of the studies conducted to find out the effect of sulphur application on crop quality of groundnut showed that oil content in groundnut kernels was increased inevitably by sulphur fertilization, whereas in some cases the protein content of the kernels showed a decreasing trend.

2.1.4 Effect of sulphur on bacterial nodulation in the roots of groundnut and related crops

Nelson and Bear (1949) reported that poor nodule development and a low rate of nitrogen fixation is associated with sulphur deficiency in legumes.

Chopde (1964) reported that combined application of nitrogen, phosphorus and sulphur, was effective in increasing nodulation in groundnut roots

Bharadwaj and Pathak (1968) conducted studies on root nodulation of groundnut cv. T-32, by the application of sulphur and reported that the number of nodules plant^{-1} increased from 1.8 to 23.7 at 40 days, as the sulphur concentration in the nutrient solution was increased from 0 to 9 ppm, and further increase adversely affected nodulation.

Rai _et al_. (1977) reported that when soils treated with 5 t pyrites ha^{-1} (105 kg S. ha^{-1}) was incubated for 4 months, the population of nitrogen fixing and sulphur reducing bacteria increased over control.

In a trial with groundnut grown on a clayey soil, application of 25 kg sulphur along with 50 kg P_2O_5 ha^{-1}, significantly increased the number, dry weight and nitrogen content of nodules (Sagare *et al.*, 1986).

Application of sulphur has been found to influence the nodulation in all the studies reviewed above though the number of studies on this aspect is very limited.

2.1.5 Effect of sulphur on nutrient uptake by groundnut and related crops

Daftardar *et al.* (1969) studied the effect of soil application of 0-224 kg S. ha^{-1} on chemical composition of groundnut, and found that N and Ca content of the haulm showed an increase, while P content decreased with increasing dose of sulphur application.

Naphade *et al.* (1969) reported that sulphur fertilization at 112 kg ha^{-1} increased the uptake of N, P and S by pods and hay in general. The uptake of N, P and S was further increased by combining its application with phosphorus or nitrogen.

Yadav and Singh (1970) noticed significant changes in the chemical composition in groundnut plants and seeds by the application of 56 to 112 kg S. ha^{-1} as gypsum. Contents

Brar and Singh (1982) reported that application of 0-20 ppm S. and/or 0-24 ppm P_2O_5 increased the sulphur and nitrogen uptake by groundnut. Applied sulphur slightly decreased P uptake.

A synergistic influence of the combined addition of K and S on yield and nutrient uptake of groundnut was reported by Badiger et al. (1988) from the results of an experiment with groundnut cv. TMV-2 supplied with 0 to 20 kg S. ha^{-1} and 0 to 11.2 kg K_2O ha^{-1}.

Maliwal and Tank (1988) reported that the contents of P and S in pods and haulms of groundnut cv. GAUG-10 was higher when SSP + NH_4SO_4 was applied, rather than SSP + urea. Similarly Naphade and Wankhade (1988) reported increased seed and haulm contents of N, P and S with the application of 60 kg S. ha^{-1}.

Increased plant P content and uptake was noted with increasing sulphur levels upto 40 kg S ha^{-1} by Mishra and Singh (1989).

Uptake studies conducted by Mashi and Sharma (1991) showed that uptake of nitrogen and phosphorus increased upto 100 kg ha^{-1} by the application of sulphur while uptake of sulphur increased upto 150 kg ha^{-1} due to sulphur application.

The concentration and uptake of N, P, K and S by sesamum was significantly higher in plants treated with 20-40 kg S. ha^{-1}. But Patel et al (1991) reported non significant effect of application of 500 kg gypsum (92.5 kg S. ha^{-1}) on nutrient contents of pods and haulm, except N content in the haulm.

The review of the works on the effect of sulphur application on nutrient uptake by the groundnut and related crops show that sulphur fertilization resulted in increased uptake of NPK and S by the plant (increased macronutrient uptake).

2.1.6 Effect of time of application of sulphur on growth, yield and quality of groundnut

In order to get increased yieldsof unshelled nuts in groundnut, Omar et al. (1970) suggested application of gypsum @ 133.2 kg S. ha^{-1} in the fruiting zone of the plant at early flowering stage.

Chahal and Virmani (1973) reported highest yield in groundnut when 75 percent of the total dose of sulphur was applied at sowing and 25 percent at flowering.

Ferreria et al. (1979) showed that highest seed yield of groundnut cv. Tatu V-53 (1.4 t ha^{-1}) was obtained when 500 kg gypsum (92 5 kg S. ha^{-1}) was applied at flowering stage, although application 30 days later produced similar yields.

In a greenhouse experiment with groundnut cv. Tatu, Sichmann et al. (1982) reported that application of 10 g gypsum pot^{-1} (1.85 g S pot^{-1}) at flowering or 12 g lime pot^{-1} at sowing + 10 g gypsum (1.85 g S. pot^{-1}) at flowering increased the pod yield significantly.

Dwivedi (1981) suggested that 25 percent of the total dose of sulphur may be applied as basal, 25 percent at flowering and 50 percent at peg initiation stage, to get high yields. Whereas Ankineedu et al (1983) advocated to band place the sulphur containing fertilizer near the pegging zone at the early flowering stage.

In a sandy loam soil, top dressing of 500 kg ha^{-1} of gypsum (92.5 kg S. ha^{-1}) 30 DAS over a basal dressing of the recommended dose of NP, significantly increased the test weight of pods and kernels, shelling outturn and pod yield of spanish groundnut cultivars JL-24 and TCG-1704. The response of JL-24 and TCG-1704 per unit of gypsum was 6.95 and 6.53 kg of pods respectively. The highest additional net returns was with NP and 92.5 kg S. ha^{-1} topdressed at flower appearance (Sridhar et al., 1985).

In experiments carried out for 2 consecutive seasons, Hago and Salama (1987) reported that flower number plant^{-1}, total and mature pod number $plant^{-1}$ and seed weight were significantly increased by the application of sulphur upto 50 kg S. ha^{-1} at the time of sowing. Sulphur applied at flowering had no effect on these attributes.

In trials, conducted at Dharwad with kharif season groundnuts, pod yield was not significantly affected by time or rate of sulphur applied @ 0-45 kg S. ha^{-1} (Koti et al., 1989).

In an experiment by Singh et al. (1991) application of 46.25 kg S. ha^{-1} in the soil at the time of pegging produced 20.5 percent more pod and 15.1 percent more fodder yields in Ginar-1 groundnut variety.

A study by Patel et al. (1991) indicated that the higher demand of sulphur and calcium by groundnut, can be met by the application of gypsum @ 500 kg ha^{-1} (92 5 kg S ha^{-1}) either by broadcasting over the soil surface just before sowing or dusting over the fruiting zone at 40 and 60 DAS.

The studies on the effect of time of application of sulphur on the growth and yield of groundnut reveal that the fertilizer responsive stages of groundnut crop are sowing, flowering and peg initiation

Blamey (1976) opined that boron plays a major role during the reproductive phase rather than in vegetative phase. Application of boron at 0-3 kg B. ha^{-1} had no beneficial effect on the vegetative growth of the crop. (Blamey et al., 1981).

Sureshkumar (1985) in a trial in the red loam lateritic soils of Vellayani, using different carriers of Ca and Mg with K and B (0 and 10 kg ha^{-1} as borax) showed that boron had a depressing effect on height and number of branches, but had no effect on the dry weight of haulms.

Foliar application of 10 ppm boron at the mid or late flowering stage in rapeseed favoured the plant dry weight (Zajonc et al., 1985). But in sunflower Kadar and Shalaby (1985) reported that application of 20 ppm B reduced the shoot yield by 89 percent. In another trial by Aboushoba et al. (1985) in sunflower, a decrease in plant height from 154 cm to 96 cm was noticed due to the application of 0 to 1 percent boric acid.

Kulkarni et al. (1989) reported that soil application of 10 kg ha^{-1} of boron as borax, improved the plant growth in groundnut. Similar result had been reported in rapeseed, where application of boron promoted growth and drymatter accumulation in rapeseed (Yang et al., 1989).

of pods plant^{-1}, pod weight and seed weight. Similar result was reported by Asokan and Raj (1974) in a pot culture experiment, wherein application of 0.3-0.8 ppm B as boric acid or borax slightly increased the yield of unshelled nuts

Sankaran _et_ _al_. (1977) found that the shelling percentage of groundnut was slightly reduced by boron application at 10 kg ha^{-1}.

According to Saxena and Mehrotra (1984) groundnut showed significant yield response to 11.2 kg borax ha^{-1} (1.3 kg B. ha^{-1}) on a medium loam soil at Kanpur and to only 5.6 kg borax ha^{-1} (0.64 kg B. ha^{-1}) on a sandy loam soil at Mainpuri. The treatments showed no effect on shelling percentage or 100 seed weight.

Groundnut cv. Kopergaon, SB. XI and Spanish Improved when supplied with 0.1 ppm B solution at 35 and 50 DAS, increased the pod yields by 1.3-24.1 percent (Deore and Kadam, 1984).

Data from 20 trials on cultivators field in Dhule district of Maharashtra showed that yield responses to 5 kg borax ha^{-1} (0.57 kg B. ha^{-1}) averaged 13.25 percent (Shinde and Kale, 1985).

In a trial conducted by Karle and Babula (1985) the pod yield of groundnut var. JL-24 was found to increase from 870.1 kg ha^{-1} to 1032.1 kg ha^{-1} as the level of boron applied was increased from 0 to 15 kg borax ha^{-1} (0 to 1.73 kg B. ha^{-1}).

Mahale <u>et</u> <u>al</u>. (1985) observed that increased pod yields of groundnut cv. SB XI could be obtained by foliar application of 0.1 ppm B at 35 and 55 DAS. In another study conducted by Patel and Golakiya (1986) boron at 2 ppm gave the highest pod yield in cv. GAUG-10.

Zhang <u>et</u> <u>al</u>. (1986) concluded that basal application of 0.5 kg borax mu^{-1} (0.86 kg B. ha^{-1}) had the highest effect with respect to yield in groundnut. They calculated that 9 g boron was needed to produce 100 kg seeds.

In trials with groundnuts grown on a boron deficient soil, Patel <u>et</u> <u>al</u>. (1987) reported that application of 50 kg P_2O_5 as single superphosphate + 0.57 kg boron ha^{-1} as borax or 50 kg P_2O_5 + 0.5 kg B. ha^{-1} as boronated superphosphate recorded dry pod yields of 2.14 and 1.91 t ha^{-1}, shelling percentage of 65 and 62.25 and 1000 seed weight of 306.25 g and 300 g.

Nagaraj (1987) obtained no effect on pod yields of groundnut, by application of two foliar sprays of boron.

The application of boron enriched superphosphate to groundnut gave average pod yield of 1.92 t ha^{-1} compared to 1.76 t ha^{-1} when the crop was supplied with superphosphate @ 100 kg ha^{-1} of P_2O_5 (Wani <u>et</u> <u>al</u>., 1988).

In trials with groundnuts grown on a shallow vertisol containing 0.16 ppm B, application of NPK + 0.57 kg B. ha^{-1} at sowing and 2 foliar sprays of 0.1 percent borax, gave average pod yields of 0.95 t ha^{-1} compared with 0.85 t with NPK + 1.15 kg B. ha^{-1} and 0.80 t ha^{-1} with NPK alone (Jadhao _et al_., 1989).

The majority of the studies reviewed here, show that application of small doses of boron, either in soil or as foliar spray in crops grown in boron deficient soil, helps in obtaining high yields from the crop.

2.2.3 Effect of boron on quality of groundnut seeds and related crops

Jayachandran (1966) reported that application of 20 kg B. ha^{-1} has been found to increase the oil content in groundnut cv. TMV-2.

From pot culture experiments, Asokan and Raj (1974) observed that boron @ 0.3-0.8 ppm improved the quality of seed oil by decreasing its acid value.

Hill and Morrill (1975) observed that application of high levels of calcium (176 ppm) in the absence of applied boron resulted in increased yields, but lower seed quality and very severe internal damage due to boron deficiency.

Karle and Babula (1985) reported that the crude protein and true protein contents in groundnut kernels ranged from 28.67 to 29.25 percent and 20.97 to 21.49 percent respectively, when boron level was increased from 0-15 kg borax ha^{-1} (0-1.7 kg B. ha^{-1}). They further reported a significant increase in oil content of groundnut kernels (48.15 to 51.50 percent) with progressive levels of boron application.

Application of 50 kg P_2O_5 as single superphosphate + 0.57 kg B. ha^{-1} as borax or 50 kg P_2O_5 + 0.5 kg B. ha^{-1} as boronated superphosphate gave seed protein content of 25.86 percent and 26.87 percent, and oil content of 49.50 percent and 50.83 percent, compared with respective values of 22.02 and 44.38 percent in the control (Patel et al., 1987).

In trials with groundnut on a medium black soil with low available boron, Wani et al. (1988) found that application of P as boron enriched superphosphate gave a protein content of 28.81 percent and oil content of 48.67 percent compared to 25.32 percent and 45.37 percent in the control.

Results of the above studies show that boron has an important role in the protein and oil synthesis of groundnut crop.

2.2.4 Effect of boron on nodulation in roots of groundnut and related crops

The symbiosis between the nodule of a legume and bacteria would be complete only if was adequately supplied with boron (Brenchley and Thornton, 1926).

Jayachandran (1966) reported that in groundnut var. TMV-2, the mean number of nodules plant^{-1} was increased by the application of 20 kg ha^{-1} of boron.

Dobrey and Roy (1967) reported that boron has a positive correlation with nitrogen fixation by Azotobacter

In groundnut, fertilization with Zn, Co, Mo, and B at 10 kg B. ha^{-1}, in a medium calcareous soil, with and without rhizobium inoculation increased the nodule number, percent pink coloured nodule and dry weight significantly (Joshi et al., 1987).

Soil application of 10 kg B. ha^{-1} as borax increased the nodule number in the roots of groundnut but the dry weight of the nodules did not differ significantly (Kulkarni et al., 1989).

Significant response of applied boron on nodulation in groundnut roots is evident from the above cited literature. But the studies conducted on this aspect is very limited.

2.2.5 Effect of boron on nutrient content and uptake by groundnut and related crops

Sankaran *et al.* (1977) reported that in groundnut cv. TMV-7, grown in red loam soil supplied with 0, 10, 20 and 30 kg ha^{-1} of boron, N uptake and boron content of the haulms increased with increasing boron application.

In a pot culture experiment with black calcareous soils, boron at 2 ppm increased the uptake of N, P, K, Fe, Cu and B, but decreased that of Ca, Mn and Zn (Patel and Golakiya, 1986).

In a trial with groundnuts grown on a sandy loam soil and supplied with 50 kg P_2O_5 + 0.5 kg B/ha as boron enriched superphosphate, significantly increased N, P and K contents in seeds, N and P contents in haulm and N, P and K uptake by both seeds and haulm (Patel *et al.*, 1986).

2.3 COMBINED APPLICATION OF SULPHUR AND BORON

2.3.1 Effect of combined application of sulphur and boron on growth characters of groundnut

Application of sulphur in combination with boron, has been found to reduce the excessive vegetative growth in groundnut (Dongale and Zende, 1976).

The interaction effects of magnesite, lime and gypsum with boron was found to be significant with respect to height of plant, number of branches and dry weight of haulms in groundnut in a field study in red loam soil, using different sources of Ca and Mg with K and B at 0-10 kg ha^{-1} (Sureshkumar, 1985).

The combined application of sulphur and boron @ 120 kg elemental sulphur and 15 kg borax ha^{-1} increased the haulm yield of groundnut var. JL-24 (Karle and Babula, 1985).

2.3.2 Effect of combined application of sulphur and boron on yield and yield attributes of groundnut

Sanjeevaiaih (1969) reported an increase of 10-28.3 percent in the yields of groundnut cv. HG-8 with the application of S, B, Mg, Ca, Fe or Mn over a basal dressing of farmyard manure and NPK.

In trials with groundnut grown in medium black calcareous soil, 5.65 kg boric acid and/or 62 kg S. ha^{-1} with or without 5.5 t FYM ha^{-1} applied to the soil or 2 foliar sprays of 0.1 ppm B, increased average yields of unshelled nuts in groundnut. Application of B + S + FYM was the most effective (Patel et al , 1981).

Karle and Babula (1985) reported that interaction of boron and sulphur contributed to enhanced pod and kernel yields in groundnut cv. JL-24. Application of boron @ 15 kg borax ha^{-1} and sulphur @ 120 kg S. ha^{-1} recorded highest pod yield of 2184.4 kg ha^{-1}.

In field trials conducted by Survase et al (1986) with groundnut cv. M-13, application of 60 kg Ca or S, 0.92 kg B and 5.5 t FYM ha^{-1} alone or in various combinations increased the dry pod yield by 13 to 86 percent of that without added nutrients

2.3.3 Effect of combined application of sulphur and boron on quality

In trials with groundnut grown in medium black calcareous soils supplied with sulphur and boron (30 kg S, 10 kg B), Patel et al. (1981) reported an increase in seed oil and protein contents.

There was a significant and positive effect of boron x sulphur on oil yield of groundnut cv. JL-24 (Karle and Babula, 1985) Boron @ 15 kg ha^{-1} as borax and sulphur @ 120 kg S ha^{-1} recorded the highest oil yield. But the interaction effect of B and S on protein content was not significant.

2.3.4 Effect of combined application of sulphur and boron on nodulation

Patel et al. (1982) and Bulbule (1983) found a positive interaction of B and S for increase in nodulation in calcareous soils. Karle et al. (1991) reported that relative response of 15 kg ha^{-1} of borax and 120 kg S. ha^{-1} to nodule count was maximum at mid flowering.

2.3.5 Effect on nutrient uptake by the crop

Dongale and Zende (1976) reported that application of sulphur in combination with boron, increased N, P and K uptake by plants.

Survase *et al*. (1986) reported a synergistic effect of application of Ca, S and B on macronutrient uptake by groundnut crop.

Studies conducted on the interaction effects between sulphur and boron in groundnut is very little. Available literature showed that the interactions were significant with respect to yield, quality and nutrient uptake by the crop.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken with the objectives of studying the effect of different levels and time of application of sulphur and boron for groundnut cv. TG-3 in the red loam soil of Kerala. The investigation comprised of an initial pot culture study, followed by a field experiment. The materials used and the methods adopted for the study are briefly described below:

A. Pot culture

The pot culture study was conducted with the objective of finding out suitable levels of sulphur and boron for the groundnut cv. TG-3, in the red sandy clay loam of Kerala

3.1 Materials

3.1.1 Experimental site

The pot culture study was carried out in the crop museum, attached to the department of agronomy.

3.1.2 Soil

The soil used for the study was red sandy clay loam. The data on the physico-chemical properties of the soil used in the pot culture study are given below:

A. Mechanical composition

Constituent	Content in soil (percent)	Method used
Coarse sand	14.50	Bouyoucos
Fine sand	32.40	Hydrometer method
Silt	29.00	(Bouyoucos 1962)
Clay	24.10	
Textural class	Sandy clay loam	

B. Chemical composition

Constituent	Content in soil	Rating	Method used
Organic carbon	0.72 percent	High	Walkey and Black Rapid Titration method (Jackson, 1973)
Available nitrogen	225 kg ha^{-1}	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5	38 kg ha^{-1}	Medium	Bray colorimetric method (Jackson, 1973)
Available K_2O	138 kg ha^{-1}	Medium	Ammonium acetate method (Jackson, 1973)
Available sulphur	21.5 kg ha^{-1}	Low	Turbidimetric method (Chesnin and Yien, 1951)
Water soluble boron	0.34 kg ha^{-1}	Low	Curcumin method (Jackson, 1973)
pH	5.2	Acidic	1 2 soil solution using pH meter

3.1.3 Season

The study was conducted during the period from 21st April to 29th July 1990.

3.1.4 Weather data

The meteorological data during the cropping period were collected from the meteorological observatory attached to the department of agronomy, College of Agriculture, Vellayani and are presented as standard week averages in Appendix 1 and Fig. 1.

3.1.5 Crop and variety

The groundnut variety used for the study was TG-3. This was developed through mutation of Spanish Improved variety at Bhabha Atomic Research Centre, Trombay and is recommended for cultivation in the red loam soils of Kerala. It is a high yielding, bunch variety of about 100-110 days duration and produces medium sized pods with 46-50 percent oil and 26-27 percent protein.

3.1.6 Source of the seed material

The seeds were obtained from the Nuclear Agriculture Division, BARC, Trombay, Bombay

3.2 Methods

3.2.1 Design

The pot culture study was carried out in CRD design

$T_1 = s_1b_1$

$T_2 = s_1b_2$

$T_3 = s_1b_3$

$T_4 = s_1b_4$

$T_5 = s_1b_5$

$T_6 = s_2b_1$

$T_7 = s_2b_2$

$T_8 = s_2b_3$

$T_9 = s_2b_4$

$T_{10} = s_2b_5$

$T_{11} = s_3b_1$

$T_{12} = s_3b_2$

$T_{13} = s_3b_3$

$T_{14} = s_3b_4$

$T_{15} = s_3b_5$

$T_{16} = s_4b_1$

$T_{17} = s_4b_2$

$T_{18} = s_4b_3$

$T_{19} = s_4b_4$

$T_{20} = s_4b_5$

$T_{21} = s_5b_1$

$T_{22} = s_5b_2$

$T_{23} = s_5b_3$

$T_{24} = s_5b_4$

$T_{25} = s_5b_5$

$T_{26} = s_6b_1$

$T_{27} = s_6b_2$

$T_{28} = s_6b_3$

$T_{29} = s_6b_4$

$T_{30} = s_6b_5$

3.2.4 Seeds and sowing

The soil from the proposed experimental site was collected and mixed with farmyard manure. 90 mud pots of uniform size (30 x 30 cm) were selected and filled with the soil. From the weight of the empty pot and weight of pot + soil, the weight of soil in each pot was computed. All the fertilizers on weight basis were applied as basal dose and thoroughly mixed with soil in the pots. Two bold, disease free kernels were dibbled in each pot. Sowing was done on 22-4-'90.

with 3 replications The treatments comprised of 6 levels of sulphur and 5 levels of boron as shown below·

Levels of sulphur	Levels of boron
s_1 = 5 kg ha^{-1}	b_1 = 2 kg ha^{-1}
s_2 = 10 kg ha^{-1}	b_2 = 4 kg ha^{-1}
s_3 = 15 kg ha^{-1}	b_3 = 6 kg ha^{-1}
s_4 = 20 kg ha^{-1}	b_4 = 8 kg ha^{-1}
s_5 = 25 kg ha^{-1}	b_5 = 10 kg ha^{-1}
s_6 = 30 kg ha^{-1}	

N, P_2O_5 and K_2O @ 10 75 75 kg ha^{-1} and lime @ 1.5 t ha^{-1} were applied uniformly to all the treatments.

3.2.2 Fertilizers

Fertilizers with the following analysis were used for the study.

Urea	=	46 percent nitrogen
Mussoriephos	=	22 percent P_2O_5 (citrate soluble)
Muriate of potash	=	60 percent K_2O
Gypsum	=	18.5 percent sulphur
Borax	=	11.5 percent boron

3.2.3 Treatment combinations

The treatment combinations were as follows

3.2.5 After cultivation

Seven days after sowing (29-4-'90) gap filling and thinning were done so that one healthy plant was retained in each pot. All the weeds were removed by handweeding and the pots were kept completely weed free. At flowering, (26-5-'90) along with lime application raking of the soil was done to facilitate easy penetration of pegs at the base of the plant.

3.2.6 Plant protection

After pegging rat poisons were applied periodically to protect the plants from rodents and squirrels.

3 2.7 Harvesting

The crop was harvested on 29-7-'90 by pulling out the individual plants when the leaves showed signs of yellowing and shedding.

3.3 Observations recorded

3.3.1 Plant height

The height of the plant in each pot was measured in cm. and the mean value of the 3 replications were computed at 20, 40, 60, 80 DAS and at harvest.

3.3.2 Number of branches plant^{-1}

The number of branches plant^{-1} in each pot was counted, and the mean value of the 3 replications were computed at

20, 40, 60, 80 DAS and at harvest.

3.3.3 Number of pods plant^{-1}

The number of pods plant^{-1} in each pot was counted at the time of harvest, and the mean value was computed.

3.3.4 Weight of pods plant^{-1}

The weight of pods plant^{-1} in each pot was taken at the time of harvest and the mean value was computed.

3.3.5 Weight of bold kernels plant^{-1}

The weight of bold kernels plant^{-1} in each pot was taken and the mean value was computed.

3.3.6 Shelling percentage

The pods from each pot were de-shelled and the weight of the kernel was expressed as percentage. Then the mean value was computed.

The statistical analysis of the data on the above mentioned biometric observations and yield attributes was done and based on the results, three levels of sulphur (15, 20, and 25 kg ha^{-1}) and two levels of boron (4 and 6 kg ha^{-1}) were selected for the field experiment.

B. Field experiment

The field experiment was conducted for finding out the optimum doses and time of application of sulphur and boron for the groundnut cv. TG-3 in the red loam soils of Kerala. The materials and methods used for the study are briefly described below

3.4 Materials

3.4.1 Experimental site

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani. The site selected was an open terraced land with good sunlight. The land was lying fallow during the preceding eleven months of the present investigation.

3.4.2 Soil

The data on the physico-chemical properties of the soil are the same as that of the soil used for pot culture study and presented in para 3.1.2 A & B

3.4.3 Season

The experiment was conducted during the period from 16th August to 29th November 1990

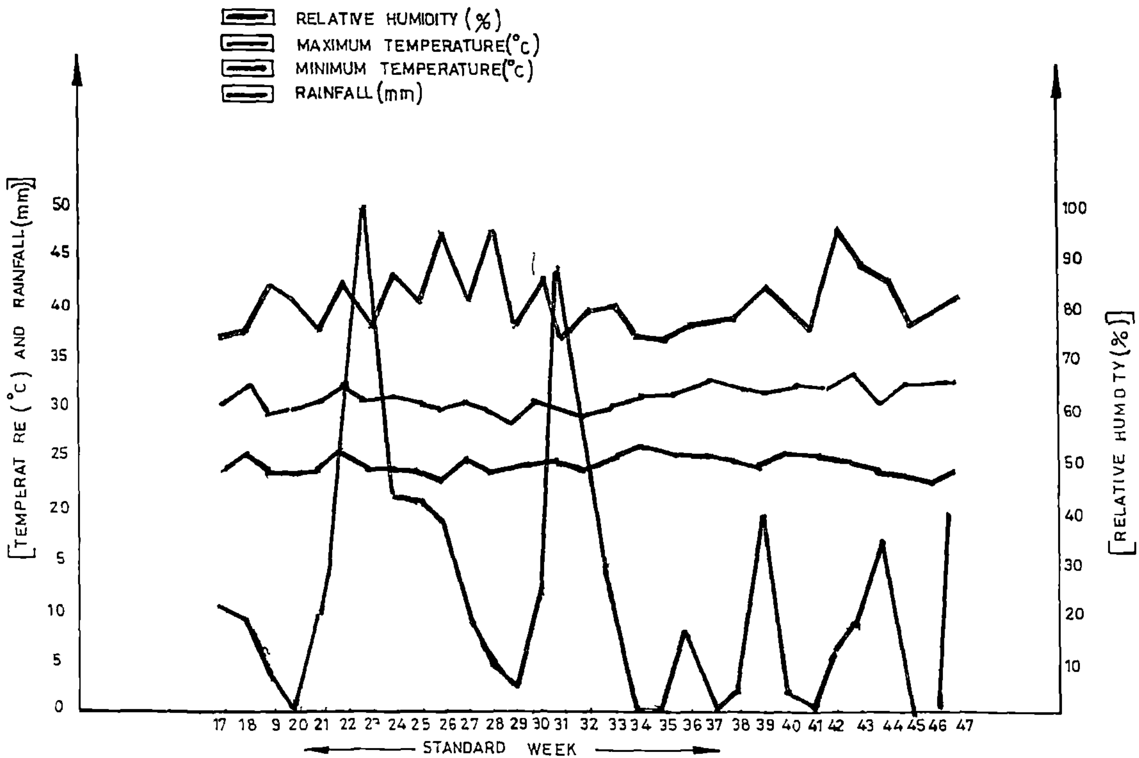
3.4.4 Weather conditions

The weather data during the entire crop season were collected from the meteorological observatory, attached to the department of agronomy, College of Agriculture, Vellayani and are presented as standard week averages in Appendix 1 and Fig. 1.

FIGURE-1

WEATHER CONDITIONS DURING THE CROPPING PERIOD

(21 4 90 TO 24 11 90)



3.4.5 Crop and variety

Groundnut variety TG-3 was used for the study. The seed material was supplied by the Nuclear Agriculture Division, Bhabha Atomic Research Centre, Trombay.

3.4.6 Fertilizers

Fertilizers with the following analysis were used for the study

Urea	=	46 percent nitrogen
Mussoriephos	=	22 percent P_2O_5 (citrate soluble)
Muriate of potash	-	60 percent K_2O
Gypsum	=	18 5 percent sulphur
Borax	=	11.5 percent boron

3 5 Methods

3.5.1 Land preparation

The experimental site was tilled with a power tiller The weeds and stubbles were removed and the soil was mixed with cowdung.

3.5.2 Seeds and sowing

Bold kernels were selected and dibbled into the soil at a spacing of 15 x 15 cm.

3.5.3 Fertilizer application

Urea, mussoriephos and muriate of potash were applied @ 10·75·75 kg N, P_2O_5 and K_2O ha^{-1}, to all the plots, as basal dose on the day of planting Organic matter as cowdung was applied @ 2 t ha^{-1}. Lime @ 1.5 t ha^{-1} was applied to all the plots at the time of flowering of the crop Sulphur in the form of gypsum and boron in the form of borax were applied in stipulated doses and time, as per the treatment except in the control plots.

3.5.4 After cultivation

Gap filling was done seven days after sowing. Two weeding operations were carried out to keep the plots weed free upto flowering. Thirty days after sowing, ten plants were selected randomly from the net plot area and tagged as observational plants. At the time of flowering, along with lime application, earthing up was done to facilitate easy penetration of pegs into the soil. The experimental fields were protected from crow menace with a twine pandal.

3.5.5 Plant protection

Rat poisons were applied periodically after pegging to protect the crop from rodents. A prophylactic spray of Metacid at 0.5 percent concentration was given to check the attack of leaf eating caterpillars. One spraying of

Dithane M-45 @ 2 kg ha^{-1} at 0.2 percent concentration was given on the foliage to protect the crop from tikka disease

3 5 6 Harvesting

The crop was harvested, by pulling out the plants at 105 DAS when the plants showed symptoms of yellowing and shedding of leaves A day prior to harvest, the observational plants were pulled out and necessary observations were recorded. On the day of harvest (29 11.'90) the border plants were harvested first and then the net plot area

3 5 7 Layout and analysis

The experiment was laid out in randamised block design The possible combinations of sulphur and boron along with three times of application were the treatments which are listed below -

Time of application

t_1 full dose of S and B as basal application

t_2 two equal split doses at sowing and flowering

t_3 - half at sowing, ¼th 20 DAS, ¼th at flowering.

Combinations of S and B.

Levels of Sulphur

S_1 15 kg ha^{-1}

S_2 = 20 kg ha^{-1}

S_3 = 25 kg ha^{-1}

L vels of boron

b_1 4 kg ha 1

b_2 6 kg ha^{-1}

Tr atment combinations

$S_1b_1t_1$	$S_2b_2t_2$
$S_1b_1t_2$	$S_2b_2t_3$
$S_1b_1t_3$	$S_3b_1t_1$
$S_1b_2t_1$	$S_3b_1t_2$
$S_1b_2t_2$	$S_3b_1t_3$
$S_1b_2t_3$	$S_3b_2t_1$
$S_2b_1t_1$	$S_3b_2t_2$
$S_2b_1t_2$	$S_3b_2t_3$
$S_2b_1t_3$	Absolute control
$S_2b_2t_1$	

Number of replications - 3

Gro s plot size = 3 75x3 75m

Net plot size - 2 85x3 15m

Spacing 15x15cm

Net area of one plot - 8.97 Sq m

Note Two rows around each plot were left as border rows One ro on one side was left for destructive sampling. The next row as also left as border.

ll ly is w is don as follows

ANALYSIS OF VARIANCE

Source	df
Replication	2
Treatments	18
Sulphur	2
Boron	1
Time of application	2
Interactions	
Sulphur x boron	2
Sulphur x Time of application	4
Boron x Time of application	2
Sulphur x Boron x Time of application	4
Treatment Vs Control	1
Error (Pooled)	36
TOTAL	56

3.6 Observations

A. Growth characters

3.6.1 Height of the plant

The mean value of the height of 10 sample plants were computed at periodical intervals of 30, 60, 90 DAS and at harvest and recorded The height was taken from the base of the plant to the terminal node and expressed in centimetres

3.6.2 Number of branches plant^{-1}

The mean value for the number of branches plant^{-1} were computed from ten observational plants at 30, 60, 90 DAS and at harvest and was recorded

3 6.3 Number of leaves plant^{-1}

The mean value for the number of leaves plant^{-1} in 10 sample plants were computed at 30, 60, 90 DAS and at harvest and was recorded

3.6.4 Leaf area index (LAI)

The leaf area of 10 observational plants in each plot was measured with the help of a Leaf areameter, at 30, 60, 90 DAS and at harvest. The LAI was worked out from the data on leaf area and corresponding ground area as follows.

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.6.5 Number and weight of root nodules plant^{-1}

This was recorded at flowering stage Three plants were dug at uniform depth of approximately 40 cm from the rows set apart for this observation The roots of the plants were washed free of soil particles. The nodules were removed from the roots and counted and the average number of nodules plant^{-1} was recorded. The nodules were then ovendried to a constant weight and the weight of the nodules plant^{-1} was recorded.

3.7 Yield and yield attributes

3.7.1 Number of pods plant^{-1}

The pods from the observational plants were collected and the number was recorded Then the average number plant^{-1} was found out.

3.7.2 Weight of pods plant^{-1}

The pods collected from the observational plants were sundried and the dry weight was recorded. Then the average weight plant^{-1} was found out.

3.7.3 Weight of kernels plant^{-1}

The dried pods obtained from 10 observational plants were de-shelled and bold kernels separated. The kernel weight was recorded and the average plant^{-1} was found out.

3.7.4 Shelling percentage

100 grams of pods were taken randomly from each plot and were de-shelled and the weight of kernels were expressed as percentage

3.7 5 100 kernel weight

100 randomly selected bold kernels from each plot were weighed and recorded

3.7.6 Pod yield

The dry weight of pods obtained from each plot was recorded separately and expressed in kg ha^{-1}.

3.7.7 Haulm yield

The dry weight of haulm of each plot was taken separately and expressed in kg ha^{-1}.

3.7.8 Harvest index (HI)

Harvest index was worked out from the data on drymatter production by the pods and haulms as follows

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.8 Chemical analysis

3.8.1 Plant analysis

The pods and haulms were analysed separately. The sun-dried plant samples were chopped and dried in an air oven at 80°C till constant weight was obtained. The samples were then ground to 0.5 mm size. The required quantity of samples were then weighed out and analysed for nitrogen, phosphorus, potassium, sulphur and boron contents at harvest.

3.8.1.1 Nitrogen

Total nitrogen content of the plant sample was estimated by the modified microkjeldahl method (Jackson, 1973)

3.8.1.2 Phosphorus

The phosphorus content of the plant samples were estimated colorimetrically, after wet digestion of the sample and developing colour by vanadomolybdo phosphoric yellow colour method and the colour intensity was read in a Klett Summerson photoelectric colorimeter (Jackson, 1973).

3.8.1.3 Potassium

Total potassium content in plant sample was estimated by the Flame Photometric method in the Perkin-Elmer 3030 Atomic Absorption Spectrophotometer, after wet digestion of the sample using di-acid mixture (Cooksey and Barnett, 1979).

3 8 1.4 Sulphur

Total sulphur content in plant samples were determined as per the procedure outlined by AOAC (1960) and the turbidity developed was read in a Klett Summerson photoelectric colorimeter using a blue filter.

3.8 1.5 Boron

The boron content in plant samples were determined colorimetrically by the Curcumin method (Jackson, 1973) and the colour intensity was read in a Klett Summerson photo-electric colorimeter using a blue filter.

3.8.1.6 Protein content of kernel

The percentage of protein in the kernel was calculated by multiplying the nitrogen content of the kernel by the factor 6.25 (Simpson et al , 1965).

3.8.1.7 Sulphur content of kernel

The percentage of sulphur in the kernel was determined turbidimetrically (AOAC, 1960).

3.8.1.8 Boron content of kernel

The percentage of boron in the kernel was determined colorimetrically by the Curcumin method (Jackson, 1973).

3.8.1.9 Oil content of kernel

The content of oil in the kernel samples was determined by the Soxhlet extraction procedure using petroleum ether as the extractant (Chopra and Kanwar, 1976).

3.8.1.10 Uptake of nutrients by the crop

The total uptake of N, P, K, S and B by the plant was calculated from the nutrient contents and dry weight of the plant at harvest and expressed as kg ha^{-1}.

3.8.2 Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples were analysed for available nitrogen by the alkaline potassium permanganate method (Subbiah and Asija, 1956), available P_2O_5 by Bray colorimetric method (Jackson, 1973), available K_2O by the ammonium acetate method (Jackson, 1973), available sulphur by the turbidimetric method (Chesnin and Yien, 1951) and water soluble boron by the Curcumin method (Jackson, 1973).

RESULTS

4. RESULTS

A. POT CULTURE

The results of the pot culture experiment, to find out the best combination of sulphur and boron for groundnut var. TG-3 are presented below

4.1 Growth characters

The effect of sulphur and boron treatment on growth characters viz plant height and number of branches plant^{-1} of groundnut var TG-3 are presented in Table 1.

Results showed no significant increase in plant height or number of branches plant^{-1} by sulphur and boron treatment at any of the growth stages.

4.2 Yield attributes

The influence of sulphur and boron on various yield attributes viz. number of pods plant^{-1}, weight of pods plant^{-1}, weight of kernels plant^{-1}, haulm yield plant^{-1} and total drymatter production plant^{-1} are presented in Table 2

The number of pods plant^{-1} was significantly influenced by application of sulphur and boron Highest number of pods plant^{-1} (28) was recorded by s_4b_3 and s_5b_2 However, these treatments were on par with s_5b_3, s_4b_2, s_3b_2 and s_3b_3 It was also noted that there was an increasing trend in pod

Table 1 Effect of sulphu and boron application on growth cha acters of groundnut var TG-3

Treatments	Plant height (cm					umber o oranches plant^{1}				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest	20 DAS	0 DAS	60 DA	80 DAS	Harvest
s_1b_1	10 00	21 00	34 75	37 75	38 75	4 00	6 00	7 00	8 00	9 50
s_1b_2	9 25	21 00	34 50	37 50	38 50	4 50	6 50	7 50	8 50	10 50
s_1b_3	10 75	22 00	33 00	37 00	38 00	5 00	6 50	7 50	8 50	10 50
s_1b_4	10 75	22 50	33 50	36 50	38 50	4 50	6 50	50	8 50	9 50
s_1b_5	10 75	21 00	33 00	37 00	38 00	5 50	00	8 50	9 50	10 00
s_2b_1	10 25	20 50	33 00	37 75	38 50	4 50	6 50	7 50	8 50	10 00
s_2b_2	10 75	21 50	33 00	37 00	38 50	4 00	6 50	7 50	8 50	10 00
s_2b_3	11 00	21 00	33 75	37 75	38 75	5 00	7 00	8 00	9 00	10 50
s_2b_4	10 50	20 00	33 50	37 50	38 00	4 50	7 00	8 50	9 00	10 00
s_2b_5	11 00	20 00	33 25	36 50	38 00	5 00	6 00	7 50	8 00	10 00
s_3b_1	10 75	20 00	34 50	36 50	38 50	5 00	6 50	7 50	9 00	10 50
s_3b_2	10 00	22 00	34 00	37 00	39 00	5 50	6 50	7 50	9 00	10 50
s_3b_3	11 25	22 00	34 50	37 50	39 50	5 50	7 00	8 00	9 00	10 50
s_3b_4	10 75	21 50	34 50	36 50	38 50	5 00	7 50	8 50	9 50	10 50
s_3b_5	10 50	21 50	33 50	36 50	37 50	5 00	7 00	8 00	9 00	10 50
s_4b_1	11 00	21 50	33 75	36 75	38 75	5 00	6 00	7 00	8 00	9 50
s_4b_2	10 50	22 50	34 75	38 75	39 25	5 50	7 00	8 00	9 00	10 50
s_4b_3	10 50	22 75	34 50	38 50	39 75	5 50	7 50	8 50	9 50	10 50
s_4b_4	10 75	20 75	34 50	36 50	38 50	5 00	7 00	8 00	9 00	10 50
s_4b_5	10 00	21 50	33 00	36 00	38 75	5 00	7 00	8 00	9 00	10 00
s_5b_1	9 25	21 50	34 00	37 50	39 00	5 00	7 50	8 50	9 50	10 50
s_5b_2	10 00	22 50	34 50	38 00	39 50	5 50	7 50	8 50	9 50	10 50
s_5b_3	10 25	22 50	33 00	38 50	39 75	5 50	7 50	8 50	9 50	11 00
s_5b_4	10 50	22 50	33 00	36 50	38 50	5 00	7 00	8 00	9 00	11 00
s_5b_5	10 00	22 50	33 25	37 50	39 00	5 00	7 00	8 00	9 00	10 50
s_6b_1	10 00	22 75	33 75	37 75	38 00	5 50	6 50	7 50	8 50	9 50
s_6b_2	10 00	20 75	33 75	37 00	39 00	4 50	6 50	7 50	8 50	9 00
s_6b_3	9 50	22 50	33 00	37 00	38 00	4 50	6 50	7 50	8 50	9 00
s_6b_4	9 50	21 50	34 50	37 50	38 50	5 00	6 00	7 00	8 00	9 50
s_6b_5	9 25	21 50	34 00	37 00	39 00	5 00	6 50	7 50	8 50	9 50
F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD	-	-	-			-				
SE	1 129	1 251	2 460	2 843	2 991	0 832	0 892	0 901	0 924	0 997

number $plant^{-1}$, as the sulphur level in combination with different boron levels were increased But the combination of s_6 with various boron levels, recorded significantly lower pod number $plant^{-1}$ in comparison with s_4, s_5 and s_3 levels

The weight of pods $plant^{-1}$ followed the same trend as the number of pods $plant^{-1}$ Maximum weight of pods $plant^{-1}$ was recorded by s_4b_3, followed by s_5b_2 and s_3b_3 However, the treatment combinations s_4b_3, s_5b_2, s_3b_3, s_3b_2, s_4b_2 and s_5b_3 were on par with each other Here also, the combination of s_6 with various levels of boron, recorded a significantly lower weight of pods $plant^{-1}$ in comparison with s_3, s_4 and s_5 levels.

Maximum weight of kernels $plant^{-1}$ was obtained at s_5b_3 level, recording 17 5 g, but this combination was on par with s_5b_2, s_4b_3, s_4b_2 and s_3b_3 It was also noted that the combination of s_1, s_2 and s_6 with various boron levels recorded significantly lower kernel weight $plant^{-1}$ in comparison with the combinations involving s_3, s_4 and s_5 with boron levels

The haulm yield $plant^{-1}$ was also significantly influenced by application of sulphur and boron The treatment s_5b_3 recorded significantly higher haulm yield $plant^{-1}$, which was on par with s_5b_2, s_5b_3, s_4b_3, s_3b_3 and s_3b_2.

Table 2 Effect of sulphur and boron application on yield and yield attributes of groundnut var JG 3

Treatments	Number of pods plant^{-1}	Weight of pods plant^{-1}	Weight of kernels plant^{-1}	Bhusa yield plant^{-1} (g)	TDM plant^{-1} (g)
s_1b_1	21 00	22 [illegible]0	11 2[illegible]	25 00	47 [illegible]
s_1b_2	20 00	23 20	11 30	26 40	49 60
s_1b_3	21 00	22 90	11 30	23 20	46 10
s_1b_4	2[illegible] [illegible]0	22 [illegible]	11 00	20 50	47 90
s_1b_5	21 00	22 [illegible]0	10 [illegible]0	23 10	[illegible]5 [illegible]0
s_2b_1	22 [illegible]	23 50	13 [illegible]0	25 10	48 6[illegible]
s_2b_2	23 00	24 50	13 90	25 [illegible]0	[illegible]9 90
s_2b_3	22 00	23 50	13 50	2[illegible] 50	48 0[illegible]
s_2b_4	2[illegible] 00	23 00	13 [illegible]0	27 90	50 90
s_2b_5	23 00	25 00	1[illegible] 90	26 10	51 10
s_3b_1	23 00	27 80	1[illegible] 50	28 10	55 90
s_3b_2	26 00	28 10	15 50	28 40	56 50
s_3b_3	2[illegible] 00	28 80	15 90	28 50	57 30
s_3b_4	2[illegible] 00	26 70	1[illegible] [illegible]0	27 10	53 8[illegible]
s_3b_5	22 00	23 50	14 70	24 10	47 60
s_4b_1	25 00	26 50	15 30	27 10	53 [illegible]0
s_4b_2	26 00	27 90	16 [illegible]0	27 50	55 [illegible]
s_4b_3	28 00	28 90	16 [illegible]0	28 50	57 [illegible]
s_4b_4	25 00	26 20	15 [illegible]0	26 [illegible]0	[illegible]2 [illegible]
s_4b_5	[illegible]	2[illegible] 20	15 [illegible]0	25 [illegible]	[illegible]
s_5b_1	[illegible]	2[illegible]	1[illegible]	2[illegible] 10	[illegible]
s_5b_2	2[illegible] 00	28 80	16 80	29 [illegible]0	[illegible]
s_5b_3	27 00	27 50	17 [illegible]0	28 50	5[illegible] [illegible]
s_5b_4	26 00	27 10	16 00	27 80	5[illegible] [illegible]0
s_5b_5	25 00	26 [illegible]0	16 10	27 10	53 50
s_6b_1	2[illegible] 00	2[illegible] 50	15 [illegible]0	25 [illegible]0	49 [illegible]0
s_6b_2	23 00	23 50	16 10	24 10	[illegible]7 60
s_6b_3	22 00	21 50	13 80	23 10	[illegible] 60
s_6b_4	21 00	2[illegible] 50	13 50	21 [illegible]0	[illegible]1 90
s_6b_5	22 [illegible]0	22 50	1[illegible] 30	2[illegible] 50	[illegible]7 [illegible]
F	S	S	S	S	S
CD	2 [illegible]3	1 [illegible]32	1 [illegible] 2	2 [illegible]21	2 193
SE	1 005	0 712	0 808	0 995	1 061

The total drymatter production plant^{-1} was significantly influenced by the different combinations of sulphur and boron. Highest value for total drymatter production plant^{-1} was recorded by the treatment combination s_5b_2, which was on par with s_5b_3, s_4b_3, s_3b_2 and s_3b_3

The above results showed that the sulphur levels s_3, s_4 and s_5, in combination with b_2 and b_3 levels of boron were found to be significantly superior to the rest of the treatments, and hence they were selected and tested in the field, along with different times of application

B FIELD EXPERIMENT

The results of the study on sulphur and boron nutrition of groundnut var. TG-3 are presented below -

4.1 Growth characters

4.1.1 Height of the plant

The effect of sulphur, boron, time of application and their interactions on height of the plant at various stages of growth and at harvest are presented in Tables 3a and 3b respectively.

There was marked difference in height between the control and plots treated with sulphur @ 25 kg $S.ha^{-1}$ at all growth stages The plants in the control plots recorded the lowest height at all stages of growth An increase in the level of sulphur by 5 kg resulted in an increase in plant height by about 2 cm at all growth stages

Application of boron at 6 kg B ha^{-1} has been found to increase the plant height significantly at 60 DAS, 90 DAS and at harvest, but it was on par with 4 kg $B.ha^{-1}$.

The different times of application of sulphur and boron did not have any significant effect on the height of the plant at any of the stages of growth

Significant interaction was observed between sulphur and boron from 60 DAS onwards At the time of harvest no

Table 3a Effect of sulphur, boron and time of application on height of the plant at 30, 60, 90 DAS and at harvest

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Harvest
Control	6 24	20 29	35 44	38 54
Sulphur				
s_1	6 83	20.48	35 89	40.42
s_2	7 68	22 15	38 23	42 56
s_3	8 47	24 25	40 93	44 15
$F_{(2,36)}$	S	S	S	S
CD	1 767	2 387	2 923	1 325
SE	0 616	0 832	1 019	0 462
Boron				
b_1	7 41	21 95	37 75	39 74
b_2	7 91	22 63	38 96	39 91
$F_{(1,36)}$	NS	S	S	S
CD		1 049	2 087	1 002
SE	0 386	0 366	0 728	0 349
Time of application				
t_1	7 69	23 30	38 79	42 68
t_2	7 65	22 17	37 65	42 26
t_3	7 62	21 39	38 62	42 18
$F_{(2,36)}$	NS	NS	NS	NS
CD	-	-	-	
SE	0 616	0 832	1 019	0 462
Treatment vs control				
Mean	7 66	22 28	38 36	42 37
$F_{(1,36)}$	NS	S	S	S
CD	-	1 049	2 087	1 002
SE	0 386	0 366	0 728	0 349

Table 3b Effect of the interactions between sulphur, boron and time of application on plant height at 30, 60, 90 DAS and at harvest

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Harvest
<u>S x B</u>				
s_1b_1	6 54	20 18	35 42	40.01
s_1b_2	7.12	20 77	36 37	40.83
s_2b_1	7 38	21 81	37 56	42 15
s_2b_2	7 97	22 48	38 91	42 96
s_3b_1	8 30	23 84	40.27	43 88
s_3b_2	8 03	24 65	41 60	44 42
F	NS	S	S	S
CD	-	2 387	2 923	1.325
<u>B x T</u>				
b_1t_1	7.43	22.91	38 37	42.29
b_1t_2	7 41	21 83	36 64	41 79
b_1t_3	7 38	21 10	38 23	41 94
b_2t_1	7 96	23 09	39.22	43.07
b_2t_2	7 90	22 52	38 66	42 74
b_2t_3	7.87	21 70	39 01	42.41
F	NS	NS	NS	NS
CD	-	-	-	-
SE	0 616	0 832	1 019	0 462
<u>S x T</u>				
s_1t_1	7 12	21 35	35 85	40.35
s_1t_2	6 50	20.51	35 22	40 19
s_1t_3	6 88	19 58	36 62	40 72
s_2t_1	7 48	23 17	38 82	43 05
s_2t_2	7 78	22 28	37 05	42 45
s_2t_3	7 78	20 98	38 84	42 17
s_3t_1	8 50	25 38	41 72	44 64
s_3t_2	8 68	23 73	40 68	44 17
s_3t_3	8 22	23 64	40.40	43 65
F	NS	NS	S	NS
CD	-	-	3 212	-
SE	1 213	1 401	1 120	1 843

Table 4a Effect of sulphur boron and time of application on number of branches plant^{-1} at 30, 60 90 DAS and at harvest

Treatments	Number of branches			
	30 DAS	60 DAS	90 DAS	Harvest
Control	2 78	6 01	8 46	8 04
<u>Sulphur</u>				
s_1	3 28	6 01	8 87	9 82
s_2	3 65	6 21	9 52	10 51
s_3	3 76	6 56	10 24	11 04
$F(2,36)$	NS	NS	NS	NS
CD	-	-		
SE	0 735	0 504	1 106	1 812
<u>Boron</u>				
b_1	3 59	6 23	9 46	10 32
b_2	3 54	6 29	9 62	10 59
$F(1,36)$	NS	NS	S	NS
CD	-		0 589	
SE	0 600	0 411	0 416	1 418
<u>Time of application</u>				
t_1	3 38	6 19	9 65	10 51
t_2	3 47	6 23	9 33	10 27
t_3	3 51	6 30	9 64	10 59
$F(2,36)$	NS	NS	NS	NS
CD	-	-		
SE	0 735	0 504	1 106	1 812
<u>Treatment vs control</u>				
Mean	3 16	6 25	9 04	10 15
$F(1\ 36)$	NS	NS	S	NS
CD			0 589	
SE	0 600	0 411	0 416	1 418

significant difference was observed in height, within sulphur when the level of boron was changed, but the height increases were significant at various levels of sulphur within boron

The S x T interaction was significant at 90 DAS, but s_3t_1, s_3t_2, s_3t_3, s_2t_3 and s_2t_1 were on par with each other

The B x T interaction was found to be not significant.

4.1.2 Number of branches plant^{-1}

The effect of sulphur, boron, time of application and their interactions on number of branches plant^{-1} are presented in Tables 4a and 4b respectively

The number of branches plant^{-1} was not significantly influenced by an increase in levels of sulphur at any of the growth stages

The effect of boron on number of branches plant^{-1} was also found to be not significant at all stages except 90 DAS. At 90 DAS, the highest number of branches was produced at the highest level of boron tried (6 kg ha^{-1}) but this was on par with 4 kg B.ha^{-1}.

The different times of application and none of the interaction effects were found to have significant influence on this character.

Table 4b Effect of the interactions between sulphur boron and time of application on number of branches plant [1] at 30 60 90 DAS and at harvest

Treatments	Number of branches			
	30 DAS	60 DAS	90 DAS	Harvest
S x B				
s_1b_1	3 27	5 93	8 77	9 66
s_1b_2	3 30	6 08	8 97	9 98
s_2b_1	3 73	6 26	9 41	10 34
s_2b_2	3 56	6 17	9 62	10 68
s_3b_1	3 77	6 50	10 20	10 94
s_3b_2	3 76	6 22	10 28	11 13
F	NS	NS	NS	NS
CD				
B x T				
b_1t_1	3 41	6 20	9 62	10 32
b_1t_2	3 62	6 26	9 22	10 18
b_1t_3	3 73	6 23	9 53	10 43
b_2t_1	3 53	6 20	9 68	10 70
b_2t_2	3 53	6 30	9 43	10 35
b_2t_3	3 50	6 37	9 76	10 75
F	NS	NS	NS	NS
CD				
SE	0 735	0 504	1 106	1 812
S x T				
s_1t_1	3 15	6 02	9 05	9 78
s_1t_2	3 32	5 95	8 63	9 98
s_1t_3	3 38	6 05	8 92	9 68
s_2t_1	3 57	6 08	9 57	10 62
s_2t_2	3 65	6 23	9 18	10 22
s_2t_3	3 72	6 32	9 80	10 70
s_3t_1	3 70	6 50	10 33	11 13
s_3t_2	3 77	6 65	10 17	10 90
s_3t_3	3 82	6 53	10 22	11 08
F	NS	NS	NS	NS
CD				
SE	0 761	0 611	1 117	2 004

4.1.3 Number of leaves $plant^{-1}$

The effect of sulphur, boron, time of application and their interaction effects on number of leaves $plant^{-1}$ at various growth stages and at harvest are presented in Tables 5a and 5b respectively

The number of leaves $plant^{-1}$ was influenced significantly by the application of sulphur at all growth stages, except at 30 DAS At 90 DAS, s_3 level recorded the highest number of leaves viz. 40.92 which was significantly superior to all other levels However at 60 DAS and at the time of harvest, the levels s_2 and s_3 were on par with each other

Boron also had significant influence on leaf number $plant^{-1}$ at 90 DAS and at harvest. However the values for b_1 and b_2 were on par with each other at both these stages

The number of leaves was significantly high when the fertilizer was applied at t_2 and t_3 times, which were on par, in comparison with t_1 at the time of harvest

The S x B interaction was significant at all stages, except 30 DAS Maximum number of leaves $plant^{-1}$ was produced by s_3b_2 combination at 90 DAS and at harvest However this was on par with s_3b_1 at 90 DAS and with s_3b_1 and s_2b_2 at the time of harvest

At 60 DAS, S x T interaction produced the highest number of leaves at s_3t_2 level which was significantly superior

Table 5a Effect of sulphur, boron and time of application on number of leaves plant^{-1} at 30, 60, 90 DAS and at harvest

Treatments	Number of leaves plant^{-1}			
	30 DAS	60 DAS	90 DAS	Harvest
Control	13 13	24 17	33 83	36 27
<u>Sulphur</u>				
s_1	13 20	23 75	35 47	37 09
s_2	14 49	24 81	38 06	42 02
s_3	14 97	26 27	40 92	44 15
$F_{(2,36)}$	NS	S	S	S
CD	-	2 097	1 797	2 499
SE	0 788	0 731	0 627	0 871
<u>Boron</u>				
b_1	14 25	24 80	37 84	41 23
b_2	14 06	25 08	38 67	40 95
$F_{(1,36)}$	NS	NS	S	S
CD	-	-	1 183	2 041
SE	0 276	0 597	0 413	0 712
<u>Time of application</u>				
t_1	13 73	24 57	38 57	39 84
t_2	14 19	25 06	37 34	41 05
t_3	14 53	25 18	38 55	42 35
$F_{(2,36)}$	NS	NS	NS	S
CD	-	-		2 499
SE	0 788	0 731	0 627	0 871
<u>Treatment vs control</u>				
Mean	14 05	24 94	36 15	39 08
$F_{(1,36)}$	NS	S	S	S
CD	-	1 712	1 183	2 041
SE	0 276	0 597	0 413	0 712

Table 5b Effect of the interactions between sulphur, boron and time of application on number of leaves plant^{-1} at 30, 60, 90 DAS and at harvest

Treatments	Number of leaves plant^{-1}			
	30 DAS	60 DAS	90 DAS	Harvest
<u>S x B</u>				
s_1b_1	12 92	23 38	35 08	38.60
s_1b_2	13 08	24 12	35 81	35 59
s_2b_1	14 91	24 98	37 66	41 36
s_2b_2	14 08	24 63	38 47	42.69
s_3b_1	14 91	26 04	40.78	43 73
s_3b_2	15 02	26 48	41 06	44 56
F	NS	S	S	S
CD	-	2 097	1 797	2 499
<u>B x T</u>				
b_1t_1	13 48	24 43	38 44	41 26
b_1t_2	14 36	25 01	36 96	40 72
b_1t_3	14 91	24 96	37 73	41 71
b_2t_1	13 98	24 70	38 67	41.43
b_2t_2	14 03	25 11	37 73	41.39
b_2t_3	14 17	25 43	38 69	43 01
F	NS	NS	NS	NS
CD	-	-	-	-
SE	0 788	0 731	0 627	0 871
<u>S x T</u>				
s_1t_1	12 20	23 40	36 13	32 59
s_1t_2	13 25	23 65	34 63	38 75
s_1t_3	13 55	24 20	35 65	39 93
s_2t_1	14.20	24 30	38 27	42 43
s_2t_2	14 45	24 88	36 73	40.83
s_2t_3	14 83	25 23	39 83	42 80
s_3t_1	14.78	26 00	41 23	44 50
s_3t_2	14 88	26 65	40.67	43 58
s_3t_3	15.23	26 15	40 82	44 35
F	NS	S	S	S
CD	-	2 324	1 819	4 284
SE	0 814	0 810	0 634	1 494

to all other combinations except s_3t_3, s_3t_1, s_2t_3 and s_2t_2 At 90 DAS, s_3t_1 produced the highest number of leaves plant^{-1}, which was significantly superior to all other combinations except s_3t_2, s_3t_3 and s_2t_3. At the time of harvest, the treatment combinations s_3t_1, s_3t_3, s_3t_2, s_2t_3, s_2t_1 and s_2t_2 were on par with each other with s_3t_1 producing the highest number of leaves plant^{-1} (44.50)

The B x T interaction was found to be not significant at any of the stages

4.1.4 Leaf area index (LAI)

The effect of sulphur, boron, time of application and their interactions on leaf area index at different growth stages and at harvest, are presented in Tables 6a and 6b respectively.

Application of sulphur significantly increased the LAI at 60 DAS and at 90 DAS At 60 DAS, the highest LAI of 8.31 was recorded by s_3 level, but this was on par with s_2 At 90 DAS, the highest LAI of 10.78 recorded by s_3, was significantly superior to all other levels of sulphur.

Application of boron influenced LAI at 60 DAS and at 90 DAS In both these stages b_1 was on par with b_2, but significantly superior to the control treatment

Table 6a Effect of sulphur, boron and time of application on leaf area index at 30, 60, 90 DAS and at harvest

Treatments	Leaf area index			
	30 DAS	60 DAS	90 DAS	Harvest
Control	0.78	7.79	8 78	7 99
Sulphur				
s_1	0.82	7 83	8 65	8.02
s_2	0 91	8 27	9 26	8 55
s_3	0 99	8.31	10 78	9 58
$F_{(2,36)}$	NS	S	S	NS
CD	-	0 800	0 523	-
SE	0 172	0 279	0 182	0 057
Boron				
b_1	0 92	7 85	9 23	8.53
b_2	0 89	7 89	9 49	8 90
$F_{(1,36)}$	NS	S	S	NS
CD	-	0 059	0 281	-
SE	0 506	0 021	0 098	0 214
Time of application				
t_1	0.92	7 55	9.40	9 39
t_2	0 89	7 54	9 27	9 15
t_3	0 85	7 61	9 20	9 23
$F_{(2,36)}$	NS	NS	NS	S
CD	-		-	0 163
SE	0 172	0 279	0 182	0 057
Treatment vs control				
Mean	0 81	7 87	9 56	8 71
$F_{(1,36)}$	NS	S	S	S
CD	-	0 059	0 281	0 613
SE	0 506	0 021	0 098	0 214

Table 6b Effect of the interactions between sulphur boron and time of application on leaf area index at 30, 60 90 DAS and at harvest

Treatments	Leaf area index			
	30 DAS	60 DAS	90 DAS	Harvest
<u>S x B</u>				
s_1b_1	0 80	7 81	8 80	8 11
s_1b_2	0 84	7 69	9 00	8 22
s_2b_1	0 89	8 22	8 80	8 58
s_2b_2	0 77	8 31	9 72	8 52
s_3b_1	0 92	8 34	10 60	9 19
s_3b_2	0 98	8 19	10 97	9 97
F	NS	NS	NS	NS
CD	-	-		
<u>B x T</u>				
b_1t_1	0 94	7 92	9 42	8 62
b_1t_2	0 92	7 83	9 21	8 40
b_1t_3	0 90	7 79	9 07	8 56
b_2t_1	0 96	7 89	9 91	9 08
b_2t_2	0 88	7 79	9 87	8 83
b_2t_3	0 84	8 01	9 81	8 79
F	NS	NS	NS	NS
CD				
SE	0 172	0 279	0 182	0 057
<u>S x T</u>				
s_1t_1	0 86	6 93	8 70	8 70
s_1t_2	0 82	6 88	8 57	7 82
s_1t_3	0 78	7 28	8 68	8 13
s_2t_1	0 95	8 43	9 48	8 73
s_2t_2	0 92	8 33	9 23	8 48
s_2t_3	0 85	8 03	9 07	8 43
s_3t_1	0 93	8 34	9 97	9 73
s_3t_2	0 97	8 22	10 80	9 55
s_3t_3	0 98	8 38	10 57	9 45
F	NS	NS	NS	NS
CD	-	-	-	-
SE	0 734	1 312	1 448	1 157

The time of application significantly influenced the LAI only at the time of harvest. The highest LAI of 9.39 was recorded by the treatment t_1, but it was on par with t_3 which recorded a value of 9.23.

None of the interaction effects were significant in influencing this character

4.1.5 Number of nodules plant^{-1} at flowering stage

The effect of sulphur, boron, time of application and their interaction effects on number of nodules plant^{-1} at flowering stage are presented in Tables 7a and 7b respectively

The nodule number plant^{-1} at flowering time was significantly increased by application of sulphur. The maximum number of nodules plant^{-1} (22.56) was obtained at s_3 level, which was on par with s_2 level, which produced 18.95 nodules plant^{-1}, which was again on par with s_1 at which 17.17 nodules were recorded

Application of boron increased the number of nodules plant^{-1} significantly. Maximum number of nodules (20.29) was recorded by b_2 level, but this was on par with b_1.

There was no significant difference between the time of application of sulphur on nodule number plant^{-1} at flowering stage

Table 7a Effect of sulphur boron and time of application on nodule number and nodule weight of the plant at flowering stage

Treatments	Nodule number at flowering	Weight of nodules at flowering
Control	17 11	0 05
<u>Sulphur</u>		
s_1	17 17	0 06
s_2	18 95	0 07
s_3	22 56	0 08
$F_{(2\ 36)}$	S	NS
CD	3 673	-
SE	1 281	0 018
<u>Boron</u>		
b_1	18 82	0 07
b_2	20 29	0 07
$F_{(1\ 36)}$	S	NS
CD	2 727	-
SE	0 951	0 050
<u>Time of application</u>		
t_1	18 17	0 07
t_2	19 22	0 07
t_3	21 27	0 06
$F_{(2,36)}$	NS	NS
CD	-	-
SE	1 281	0 018
<u>Treatment vs control</u>		
Mean	19 83	0 067
$F_{(1\ 36)}$	S	NS
CD	2 727	-
SE	0 951	0 050

Among the interaction effects, the treatment combination s_3b_2 recorded the highest number of nodules plant^{-1} (23.67). This combination was on par with s_3b_1, which recorded a value of 21.45

None of the other interaction effects were significant in influencing this character

4.1.6 Weight of nodules plant^{-1} at flowering stage

The effect of sulphur, boron, time of application and their interaction effects on weight of nodules plant^{-1} at flowering stage are presented in Tables 7a and 7b respectively

The weight of nodules plant^{-1} recorded an increasing trend with increasing levels of sulphur, but the difference in weight was not significant.

The weight of nodules plant^{-1} was found to be unaffected by the application of boron, and the different times of application

None of the interaction effects were significant in influencing this character

4.2 Yield attributes

4.2.1 Number of pods plant^{-1}

The effect of sulphur, boron, time of application and their interaction effects on number of pods plant^{-1} are presented in Tables 8a and 8b respectively.

The number of pods plant^{-1} was significantly increased by the application of sulphur Maximum number of pods plant^{-1} (23.61) was obtained at s_3 level, with s_2 level on par with it, producing 21.33 pods plant^{-1} The control registered the lowest number of pods plant^{-1} (19.01)

The number of pods plant^{-1} increased with increasing levels of boron, with b_1 and b_2 on par with each other, but significantly superior to the control treatment

The time of application showed no significant effect on this character.

Among the S x B interactions, s_3b_2 recorded the highest value of 25 66 which was significantly superior to all other combinations.

Significant positive interaction was noticed for the treatment combination s_3t_1, which recorded 24.84 pods plant^{-1} but this was on par with s_3t_2, s_3t_3 and s_2t_1.

The interaction effects of levels of boron and times of application were not significant in influencing this character

4 2.2 Weight of pods plant^{-1}

The effect of sulphur, boron, time of application and their interaction effects on weight of pods plant^{-1} are presented in Tables 8a and 8b respectively.

Table 8a Effect of sulphur boron and time of application on number of pods $plant^{-1}$ weight of pods $plant^{-1}$ weight of kernels $plant^{-1}$ and 100 kernel weight

Treatments	Number of pods $plant^{-1}$	Weight of pods $plant^{-1}$ (g)	Weight of kernels $plant^{-1}$ (g)	100 kernel weight (g)
Control	19.01	20.43	13 03	47 10
Sulphur				
s_1	20 17	20 48	13 56	47 09
s_2	21 33	22 99	15 46	47 48
s_3	23 61	25 62	15 92	50 81
$F_{(2,36)}$	S	S	S	S
CD	2 324	3 298	1 735	2 329
SE	0 810	1 150	0 605	0 812
Boron				
b_1	21 06	23 41	14 37	48 67
b_2	22 41	23 98	15 48	48 90
$F_{(1,36)}$	S	S	NS	NS
CD	2 004	2 693		-
SE	0 699	0 939	0 559	0 468
Time of application				
t_1	22 44	24 28	15 25	49 08
t_2	24 33	23 66	15 02	48 87
t_3	24 45	23 15	14 36	48 40
$F_{(2,36)}$	NS	NS	NS	NS
CD	-	-	-	-
SE	0 810	1 150	0 605	0 812
Treatment vs control				
Mean	21 71	23 69	14 87	48 79
$F_{(1,36)}$	S	S	S	S
CD	2 004	2 693	1 602	1 341
SE	0 699	0 939	0 559	0 468

Table 8b Effect of the interactions between sulphur boron and time of application on number of pods $plant^{-1}$ weight of pods $plant^{-1}$ weight of kernels $plant^{-1}$ and 100 kernel weight

Treatments	Number of pods $plant^{-1}$	Weight of pods $plant^{-1}$ (g)	Weight of kernels plant 1 (g)	100 kernel weight (g)
S x B				
s_1b_1	20 56	22 82	13 31	47 40
s_1b_2	19 78	22 13	13 81	46 76
s_2b_1	20 89	23 31	14 44	47 28
s_2b_2	21 78	22 68	15 83	47 69
s_3b_1	21 56	24 10	15 34	51 34
s_3b_2	25 66	27 13	16 49	52 27
F	S	S	S	S
CD	2 324	3 298	1 735	2 329
B x T				
b_1t_1	21 56	24 41	14 32	49 12
b_1t_2	20 56	22 81	14 43	48 65
b_1t_3	20 89	23 01	11 14	48 24
b_2t_1	22 33	24 16	15 97	49 06
b_2t_2	22 11	24 52	15 60	49 10
b_2t_3	21 78	23 27	14 56	48 55
F	NS	NS	NS	NS
CD		-		
SE	0 810	1 150	0 605	0 812
S x T				
s_1t_1	20 00	21 74	12 37	47 27
s_1t_2	20 17	23 02	14 13	47 05
s_1t_3	20 34	22 68	14 19	46 92
s_2t_1	22 50	24 32	16 78	47 62
s_2t_2	20 67	22 55	14 95	47 45
s_2t_3	20 83	22 12	13 69	47 38
s_3t_1	24 84	26 80	16 58	50 38
s_3t_2	23 17	25 43	15 97	52 13
s_3t_3	22 84	24 62	15 20	50 90
F	S	NS	NS	NS
CD	3 386	-	-	-
SE	1 181	1 396	1 125	1 177

The levels of sulphur and boron influenced this character significantly, whereas the time of application did not have any effect Highest value for weight of pods plant^{-1} (25.62 g) was obtained at s_3 level, with s_2 level on par with it producing 22 99 g pods plant^{-1}. The control treatment recorded a mean weight of 20 43 g

The maximum weight of pods plant^{-1} (23.98) was recorded by b_2 level, but it was on par with b_1, which recorded a mean weight of 23.41 g

Among the various interactions s_3b_2 recorded the maximum value for weight of pods plant^{-1} (27.13 g) and this was on par with s_3b_1

The other interaction effects were not significant.

4.2.3 Weight of kernels plant^{-1}

The effect of sulphur, boron, time of application and their interactions on weight of kernels plant^{-1} are presented in Tables 8a and 8b respectively.

Application of sulphur showed a favourable effect on weight of kernels plant^{-1}. An increase in sulphur level from s_1 to s_2 produced significant effect on weight of kernels. A further increase in sulphur did not improve the result. However, application of boron and times of application of fertilizers did not produce any significant influence on this character.

Among the S x B interaction effects s_3b_2 gave a mean weight of 16.49 g, which was on par with s_2b_2 and s_3b_1

The S x T and B x T interactions were found to be not significant.

4.2.4 Weight of 100 kernels

The effect of sulphur, boron, time of application and their interactions on weight of 100 kernels are presented in Tables 8a and 8b respectively.

No significant difference was observed in the 100 kernel weight at the s_1 and s_2 levels The weight of 100 kernels increased with increasing levels of sulphur and the highest value of 50.81 g recorded by s_3 level is significantly superior to all other treatments.

Application of boron and time of application of fertilizers did not show any significant influence in this character

The S x B interaction recorded a value of 52.27 g for the combination s_3b_2 This combination however was on par with s_3b_1, which recorded a value of 51.34 g, but was significantly superior to all other combinations

The B x T and S x T interactions had no influence on this character.

4.2.5 Shelling percentage

The effect of sulphur, boron, time of application and their interactions on shelling percentage of groundnut are presented in Tables 9a and 9b respectively

Shelling percentage was significantly increased by sulphur application. The s_3 level registered the highest shelling percentage of 59.08, which was on par with s_2 (58.55)

Application of boron and time of application had no significant effect on shelling percentage.

Significant interaction effect was noted for s_3b_1 which recorded a value of 59.14 percent, which was on par with s_3b_2, s_2b_1, s_2b_2 and s_1b_2. None of the other interaction effects were significant

4.2.6 Pod yield

The effect of sulphur, boron, time of application and their interactions on pod yield of groundnut are presented in Tables 9a and 9b respectively

Application of sulphur had significant influence in enhancing the pod yield of groundnut. Maximum pod yield of 1658.82 kg ha^{-1} recorded by s_3 level was significantly superior to s_1 level and control, but was on par with s_2. Control plots recorded the lowest yield of 1048 kg ha^{-1}.

Table 9a Effect of sulphur boron and time of application on shelling percentage pod yield haulm yield total drymatter production and harvest index

Treatments	Shelling percentage	Pod yield kg ha^{-1}	Haulm yield kg ha^{-1}	Total drymatter production kg ha^{-1}	Harvest index
Control	57 62	1048 00	2131 96	3179 95	32 96
<u>Sulphur</u>					
s_1	57 76	1201 83	1880 53	3082 37	38 99
s_2	58 55	1460 60	2111 17	3571 78	40 83
s_3	59 08	1658 82	2549 98	4208 81	39 55
$F_{(2\ 36)}$	S	S	S	S	S
CD	1 304	298 506	381 573	994 852	1 411
SE	0 455	104 096	133 064	346 929	0 492
<u>Boron</u>					
b_1	58 39	1450 36	2072 83	3523 19	41 08
b_2	58 53	1430 47	2288 29	3718 77	38 50
$F_{(1\ 36)}$	NS	S	NS	NS	S
CD	-	268 227	-		1 151
SE	0 322	93 537	75 506	46 772	0 401
<u>Time of application</u>					
t_1	58 56	1494 22	2215 97	3710 19	40 26
t_2	58 26	1389 14	2180 88	3570 03	38 95
t_3	58 54	1437 88	2149 84	3582 73	40 16
$F_{(2\ 36)}$	NS	NS	NS	NS	NS
CD	-	-	-	-	
SE	0 455	104 096	133 064	346 929	0 492
<u>Treatment vs control</u>					
Mean	58 56	1440 41	2380 56	3620 98	39 79
$F_{(1\ 36)}$	S	S	S	S	S
CD	0 923	268 227	216 520	134 122	1 151
SE	0 322	93 537	75 506	46 772	0 401

Table 9b Effect of the interactions between sulphur boron and time of application on shelling percentage pod yield haulm yield total drymatter production and harvest index

Treatments	Shelling percentage	Pod yield kg ha^{-1}	Haulm yield kg ha^{-1}	Total dry-matter production kg ha^{-1}	Harvest index
<u>S x B</u>					
s_1b_1	57 31	1245 94	1872 52	3118 46	39 96
s_1b_2	58 20	1157 73	1888 54	3046 28	38 03
s_2b_1	58 74	1448 18	2015 54	3463 73	41 66
s_2b_2	58 35	1473 01	2206 80	3679 82	39 99
s_3b_1	59 14	1656 97	2330 43	3987 41	41 61
s_3b_2	59 02	1660 66	2569 53	4130 20	37 48
F	S	S	S	S	S
CD	1 304	298 506	381 573	994 852	1 411
<u>B x T</u>					
b_1t_1	58 29	1541 21	2113 31	3654 52	42 03
b_1t_2	58 14	1401 97	2100 62	3502 59	40 14
b_1t_3	58 77	1407 91	2004 57	3412 48	41 06
b_2t_1	58 83	1447 24	2318 62	3765 86	38 49
b_2t_2	58 40	1376 35	2261 13	3637 46	37 77
b_2t_3	58 34	1467 85	2285 12	3752 98	39 25
F	NS	NS	NS	NS	S
CD	-		-		1 411
SE	0 455	104 096	133 064	346 929	0 492
<u>S x T</u>					
s_1t_1	57 84	1208 20	1900 00	3108 51	38 85
s_1t_2	57 75	1164 55	1884 18	3048 74	38 25
s_1t_3	57 68	1232 74	1857 12	3089 86	39 89
s_2t_1	58 72	1536 43	2125 77	3662 20	41 91
s_2t_2	58 53	1425 81	2092 63	3578 45	40 55
s_2t_3	58 40	1419 56	2115 12	3534 68	40 04
s_3t_1	59 13	1738 04	2621 83	4359 87	40 03
s_3t_2	58 54	1577 07	2565 67	4142 89	38 07
s_3t_3	59 59	1661 35	2462 30	4123 65	40 55
F	NS	NS	NS	NS	NS
CD	-		-		-
SE	0 734	192 324	179 760	415 061	0 595

The pod yield of groundnut showed an increasing trend with boron application also Maximum yield was obtained at b_1 level But this level was on par with b_2.

The time of application did not influence the pod yield of groundnut significantly, though the highest yield was recorded by the treatment t_1.

The S x B interaction was significant and s_3b_2 which produced 1660 66 kg pods ha^{-1} was found to be the best combination. But this was on par with s_3b_1, s_2b_2 and s_2b_1 which produced 1656.97 kg, 1473 01 kg and 1448.18 kg ha^{-1} of pods respectively

The S x T and B x T interactions were found to be not significant

4.2.7 Bhusa yield

The effect of sulphur, boron, time of application and their interaction effects on bhusa yield of groundnut are presented in Tables 9a and 9b respectively

Maximum bhusa yield was obtained by applying sulphur at 25 kg S. ha^{-1}, which was significantly superior to all other levels.

Boron application and times of application did not influence the bhusa yield significantly.

Among the S x B interactions, s_3b_2 gave the highest bhusa yield of 2569.53 kg ha^{-1}, which was significantly superior to the other interaction effects except s_3b_1 and s_2b_2 The interactions of S x T and B x T were not significant

4.2.8 Total dry matter production (TDMP)

The effect of sulphur, boron, time of application and their interaction effects on TDMP are presented in Tables 9a and 9b respectively.

The main effect of sulphur and S x B interaction alone influenced this character TDMP was highest at s_3 level (4208.81 kg ha^{-1}) which was on par with s_2 level, but significantly high in comparison with s_1 level Among the interaction effects s_3b_2 was significant in influencing this character, which gave TDMP of 4430 20 kg ha^{-1} but this was on par with s_3b_1, s_2b_2 and s_2b_1

4.2.9 Harvest index (HI)

The effect of sulphur, boron, time of application and their interaction effects on HI are presented in Tables 9a and 9b respectively.

Harvest index, which is the ratio of economic yield to biological yield was significantly increased by application of sulphur The highest value of 40.83 was recorded by s_2

level, but an increase in sulphur above s_2 level decreased the HI, though the difference in reduction was not significant.

Application of boron produced a significant increase in harvest index over the control, with the two levels b_1 and b_2 producing 41.08 percent and 38.50 percent HI, with b_1 significantly superior to b_2 and the control treatment.

The treatments of time of application of sulphur and boron did not show any influence on this character.

Interaction effects were significant for the combinations s_2b_1, which gave a value of 41.66, and it was on par with s_3b_1.

The combination b_1t_1 recorded a value of 42.03, but it was on par with b_1t_3.

4.3 Quality attributes

4.3.1 Oil content

The effect of sulphur, boron, time of application and their interaction effects on oil content of groundnut kernels are presented in Tables 10a and 10b respectively.

The oil content in groundnut kernels was significantly increased by sulphur application. S_3 level recorded the highest oil content of 50.44 percent, which was on par with s_2 level which recorded 49.23 percent oil. S_1 level recorded 48.96 percent oil which was also significantly superior to the control treatment.

Boron application also increased the oil content significantly over the control with 49.12 percent and 49.75 percent oil in b_1 and b_2 levels respectively.

Significant S x B interaction was noticed with respect to oil content. Highest value for oil content was shown by s_3b_2 interaction, which was on par with s_3b_1, s_2b_2 and s_2b_1.

The interaction of s_3 and s_2 with t_1, t_2 and t_3 produced significantly higher oil content than the interaction of S_1 with t_1, t_2 and t_3. But B x T interaction was not significant.

4.3.2 Protein content of kernels

The effect of sulphur, boron, time of application and their interaction effects on protein content of kernels are presented in Tables 10a and 10b respectively.

Protein content of kernels increased with increasing levels of sulphur. Highest protein content of 29.38 percent was obtained at s_3 level, which was on par with s_2 level, which contained 29.18 percent protein, but significantly high in comparison with s_1 level.

Application of boron significantly influenced the protein content of kernels. The highest value of 29.24 percent was recorded by b_1, which was significantly superior to the control and b_2. It was also noticed that as the level of boron

Table 10a Effect of sulphur boron and time of application on oil content protein content sulphur content and boron content of groundnut kernels

Treatments	Oil content (/)	Protein content (/)	Sulphur content (/)	Boron content (/)
Control	47 07	27 80	0 29	0 019
<u>Sulphur</u>				
s_1	48 96	28 48	0 30	0 047
s_2	49 23	29 18	0 34	0 049
s_3	50 44	29 38	0 38	0 052
$F_{(2\ 36)}$	S	S	S	S
CD	1 863	0 876	0 081	0 013
SE	0 649	0 305	0 028	0 353
<u>Boron</u>				
b_1	49 12	29 24	0 34	0 048
b_2	49 75	28 79	0 35	0 051
$F_{(1\ 36)}$	S	S	NS	S
CD	1 521	0 326	-	0 018
SE	0 530	0 114	0 047	0 008
<u>Time of application</u>				
t_1	49 77	28 89	0 35	0 051
t_2	49 38	28 89	0 35	0 049
t_3	49 14	29 27	0 34	0 047
$F_{(2\ 36)}$	NS	NS	NS	NS
CD	-	-	-	-
SE	0 649	0 305	0 028	0 353
<u>Treatment vs control</u>				
Mean	49 63	29 01	0 34	0 049
$F_{(1\ 36)}$	S	S	NS	S
CD	1 521	0 3 6	-	0 018
SE	0 530	0 114	0 047	0 008

Table 10b Effect of the interactions between sulphur boron and time of application on oil content protein content sulphur content and boron content of groundnut kernels

Treatments	Oil content (%)	Protein content (%)	Sulphur content (%)	Boron content (%)
S x B				
s_1b_1	48 30	28 61	0 30	0 046
s_1b_2	48 96	28 36	0 31	0 049
s_2b_1	49 09	29 45	0 34	0 048
s_2b_2	49 37	28 92	0 35	0 050
s_3b_1	49 98	29 67	0 37	0 051
s_3b_2	50 91	29 09	0 38	0 054
F	S	S	NS	NS
CD	1 863	0 876	-	-
B x T				
b_1t_1	48 46	28 91	0 34	0 049
b_1t_2	48 29	29 53	0 33	0 048
b_1t_3	48 60	29 29	0 33	0 047
b_2t_1	50 09	28 87	0 35	0 053
b_2t_2	49 48	28 74	0 34	0 052
b_2t_3	49 67	29 26	0 34	0 049
F	NS	NS	NS	NS
CD	-	-	-	-
SE	0 649	0 305	0 028	0 353
S x T				
s_1t_1	48 10	28 25	0 32	0 049
s_1t_2	48 08	28 50	0 31	0 048
s_1t_3	47 70	28 72	0 29	0 046
s_2t_1	49 50	28 12	0 36	0 051
s_2t_2	49.03	28 02	0 34	0 049
s_2t_3	49 15	28 43	0 33	0 046
s_3t_1	50 73	29 86	0 36	0 053
s_3t_2	50 03	29 14	0 38	0 051
s_3t_3	50 57	29 69	0 37	0 048
F	S	S	S	NS
CD	2 145	1 112	0 085	-
SE	0 748	0 388	0 029	0 121

increased from b_1 to b_2 level, the protein content of kernels decreased.

The time of application did not influence the protein content of groundnut kernels significantly

Significant positive interaction was shown by the interaction s_3b_1 which yielded 29.67 percent protein, and this was on par with s_2b_2 level which yielded 29 09 percent protein

S_3t_1 interaction gave the highest protein content of 29 86 percent, which was significantly superior to all other interactions except s_3t_2 and s_3t_3

4.3.3 Sulphur content of groundnut kernels

The effect of sulphur, boron, time of application and their interaction effects on sulphur content of groundnut kernels are presented in Tables 10a and 10b respectively.

Results showed that with the application of sulphur, a significant increase was noted in the sulphur content of kernels over the control However, the sulphur content in the kernels were on par with each other, at the three levels of sulphur tried

Boron application had no influence on the sulphur content of kernels

The time of application, S x B interaction and B x T interaction were not significant in influencing the sulphur content of groundnut kernels But the S x T interaction was found to be significant

4.3.4 Boron content of groundnut kernels

The effect of sulphur, boron, time of application and their interaction effects on boron content of groundnut kernels are presented in Tables 10a and 10b respectively

Sulphur and boron application increased the boron content of groundnut kernels significantly Increasing levels of sulphur and increasing levels of boron enhanced the boron content of kernels, though the difference was not significant, at different levels of both sulphur and boron The time of application and their interaction effects had no significant effect on boron content.

4.4 Nutrient uptake by the crop

4.4.1 Nitrogen uptake

The effect of sulphur, boron, time of application and their interaction effects on nitrogen uptake by the crop are presented in Tables 11a and 11b respectively

The nitrogen uptake by the crop was significantly influenced by the main effects of sulphur and boron Application of sulphur at s_3 level helped in the maximum uptake of nitrogen by the crop (152 87 kg ha^{-1}) However, all the three levels of sulphur were on par in enhancing the nitrogen uptake by the crop

Application of boron at b_1 level (4 kg ha^{-1}) resulted in maximum nitrogen uptake of 152 28 kg ha^{-1}. At b_2 level (6 kg ha^{-1}) the uptake of nitrogen was found to be decreasing

None of the interaction effects were found to be significant.

4.4.2 Phosphorus uptake

The effect of sulphur, boron, time of application and their interaction effects on phosphorus uptake by the crop are presented in Tables 11a and 11b respectively

Application of sulphur alone influenced the uptake of P by the crop significantly P uptake was found to be increasing with increasing levels of sulphur, with the maximum value at s_3 level. But this was on par with s_2 level

4 4.3 Potassium uptake

The effect of sulphur, boron, time of application and their interaction effects on potassium uptake by the crop are presented in Tables 11a and 11b respectively.

The K uptake by the crop was not found to differ significantly with the different levels of sulphur, boron, time of application or their interactions.

Table 11a Effect of sulphur boron and time of application on nutrient uptake by the crop at the time of harvest

Treatments	N uptake kg ha^{-1}	P uptake kg ha^{-1}	K uptake kg ha^{-1}	S uptake kg ha^{-1}	B uptake kg ha^{-1}
Control	141 86	25 53	57 76	22 14	0 29
Sulphur					
s_1	146 51	25 99	60 78	30 06	0 44
s_2	151 37	36 08	64 48	32 56	0 49
s_3	152 87	38 63	66 10	35 47	0 47
$F_{(2,36)}$	S	S	NS	S	S
CD	6 493	5 317	-	2 700	0 043
SE	2 264	1 854	1 817	0 941	0 014
Boron					
b_1	152 28	30 92	63 30	32 42	0 43
b_2	148 21	30 21	64 27	32 97	0 46
$F_{(1\ 36)}$	S	NS	NS	S	S
CD	4 013	-	-	3 669	0 049
SE	1 399	2 236	1 989	1 279	0 017
Time of application					
t_1	149 49	33 30	63 94	33 75	0 42
t_2	150 26	35 41	63 91	32 63	0 44
t_3	150 99	35 32	63 51	31 72	0 41
$F_{(2\ 36)}$	NS	NS	NS	NS	S
CD	-	-	-	-	0 043
SE	2 264	1 854	1 817	0 941	0 014
Treatment vs control					
Mean	150 25	33 56	63 78	32 69	0 45
$F_{(1\ 36)}$	S	S	NS	S	S
CD	4 013	6 412	-	3 669	0 049
SE	1 399	2 236	1 989	1 279	0 017

Table 11b Effect of the ınteractions between sulphur boron and time of application on nutrıent uptake by the crop at the time of harvest

Treatments	N uptake kg ha^{-1}	P uptake kg ha^{-1}	K uptake kg ha^{-1}	S uptake kg ha^{-1}	B uptake kg ha^{-1}
S x B					
s_1b_1	147 87	30 43	60 22	29 41	0 42
s_1b_2	145 15	31 54	61 34	30 71	0 45
s_2b_1	153 68	34 12	63 68	32 42	0 44
s_2b_2	149 05	38 03	65 27	32 70	0 46
s_3b_1	150 29	38 21	66 01	35 43	0 45
s_3b_2	150 44	39 05	66 19	35 50	0 47
F	NS	NS	NS	S	NS
CD		-	-	2 700	-
B x T					
b_1t_1	151 11	30 66	63 27	33 11	0 44
b_1t_2	152 39	31 05	63 54	32 22	0 41
b_1t_3	153 35	31 05	63 10	31 50	0 42
b_2t_1	147 88	35 93	64 61	33 94	0 43
b_2t_2	148 12	36 44	64 28	33 03	0 46
b_2t_3	148 63	36 25	63 91	31 93	0 4d
F	NS	NS	NS	NS	NS
CD	-	-	-	-	-
SE	2 264	1 854	1 817	0 942	0 014
S x T					
s_1t_1	145 15	25 84	60 84	31 37	0 45
s_1t_2	146 80	26 05	60 97	29 78	0 43
s_1t_3	147 59	26 08	60 55	29 03	0 41
s_2t_1	151 27	35 60	64 34	33 62	0 47
s_2t_2	150 90	36 15	64 52	32 33	0 44
s_2t_3	151 92	36 49	64 57	31 74	0 42
s_3t_1	152 07	38 47	66 65	36 25	0 47
s_3t_2	153 07	39 04	66 25	35 77	0 45
s_3t_3	153 48	38 40	65 40	34 38	0 48
F	NS	NS	NS	NS	NS
CD	-	-	-	-	-
SE	4 321	4 829	3 243	2 793	0 102

4.4.4. Sulphur uptake

The effect of sulphur, boron, time of application and their interaction effects on sulphur uptake by the crop are presented in Tables 11a and 11b respectively.

The main effect of sulphur and boron and their interaction effects influenced this parameter significantly. Sulphur uptake by the crop increased with increasing dose of sulphur, with the maximum uptake at s_3 level.

Application of boron at b_1 and b_2 levels had significant effect on sulphur uptake by the crop.

Significant S x B interaction was noted at s_3b_1 and s_3b_2, which gave values of 35.43 and 35.50 kg S.ha^{-1} respectively.

4.4.5 Boron uptake

The effect of sulphur, boron, time of application and their interactions on boron uptake by the crop are presented in Tables 11a and 11b respectively.

Application of sulphur increased the boron uptake by the crop but the difference in uptake was not significant at different levels of sulphur. Similarly boron application, increased its uptake by the crop, but b1 and b_2 were found to be on par.

The time of application influenced the boron uptake by the crop significantly Maximum uptake was obtained by t_2 treatment.

None of the interaction effects were significant in influencing the boron uptake by the crop

4.5 Nutrient content in the soil after the experiment

4.5.1 Nitrogen content

The effect of sulphur, boron, time of application and their interaction effects on nitrogen content in the soil after the experiment are presented in Tables 12a and 12b respectively

As the levels of sulphur and boron were increased from 15-25 kg S ha^{-1} and 4-6 kg B ha^{-1} respectively, the N content of the soil decreased though not significantly.

4.5.2 Phosphorus content

The effect of sulphur, boron, time of application and their interaction effects on phosphorus content of the soil after the experiment, are presented in Tables 12a and 12b respectively.

The P content of the soil was not significantly influenced by the main effects as well as interaction effects of the different treatments tried.

Table 12a Effect of sulphur boron and time of application on nutrient content in the soil after the experiment

Treatment	N content kg ha $^{-1}$	P content kg ha $^{-1}$	K content kg ha $^{-1}$	S content kg ha $^{-1}$	B content kg ha $^{-1}$
Control	105 46	20 99	32 04	16 70	0 14
<u>Sulphur</u>					
s_1	108 59	23 95	39 25	23 89	0 20
s_2	110 60	24 51	36 90	23 02	0 17
s_3	104 17	22 26	35 97	20 06	0 17
$F_{(2\ 36)}$	NS	NS	NS	NS	NS
CD		-			
SE	4 912	3 412	5 923	4 592	0 101
<u>Boron</u>					
b_1	109 36	23 59	37 55	22 47	0 20
b_2	106 21	23 55	37 19	22 17	0 16
$F_{(1\ 36)}$	NS	NS	NS	NS	NS
CD	-	-			
SE	3 112	2 186	4 561	3 121	0 091
<u>Time of application</u>					
t_1	107 97	24 06	36 77	23 26	0 17
t_2	107 17	23 14	36 94	20 00	0 18
t_3	108 21	23 49	38 41	20 00	0 19
$F_{(2,36)}$	NS	NS	NS	NS	NS
CD	-		-		-
SE	4 912	3 412	5 923	4 592	0 101
<u>Treatment vs control</u>					
Mean	107 79	23 57	37 37	22 32	0 17
$F_{(1\ 36)}$	NS	NS	NS	NS	NS
CD	-				
SE	3 112	2 186	4 561	3 121	0 091

Table 12b Effect of the interactions between sulphur boron and time of application on nutrient content in the soil after the experiment

Treatments	N content kg ha^{-1}	P content kg ha^{-1}	K content kg ha^{1}	S content kg ha^{1}	B content kg ha^{1}
<u>S x B</u>					
s_1b_1	111 53	22 42	40 35	24 59	0 15
s_1b_2	105 65	25 48	38 15	23 19	0 19
s_2b_1	111 72	24 41	36 28	22 74	0 17
s_2b_2	109 48	24 61	37 52	23 29	0 17
s_3b_1	104 83	23 96	36 04	20 07	0 16
s_3b_2	103 50	20 56	35 89	20 04	0 18
F	NS	NS	NS	NS	NS
CD	-	-			
<u>B x T</u>					
b_1t_1	108 17	23 36	36 54	23 01	0 14
b_1t_2	109 78	23 48	37 80	22 28	0 16
b_1t_3	110 15	23 94	38 33	22 11	0 17
b_2t_1	107 78	24 76	37 00	23 50	0 19
b_2t_2	104 58	22 84	36 08	22 13	0 18
b_2t_3	110 15	23 04	38 48	20 89	0 18
F	NS	NS	NS	NS	NS
CD	-				
SE	4 912	3 412	5 923	0 592	0 101
<u>S x T</u>					
s_1t_1	110 50	23 72	38 74	24 25	0 16
s_1t_2	108 14	23 52	38 84	23 87	0 17
s_1t_3	107 14	24 62	40 17	23 57	0 19
s_2t_1	110 54	24 65	36 75	23 88	0 16
s_2t_2	109 63	24 30	36 77	22 68	0 17
s_2t_3	111 64	24 59	37 19	22 48	0 18
s_3t_1	102 89	23 82	35 82	21 65	0 18
s_3t_2	103 77	21 67	35 22	20 07	0 18
s_3t_3	105 85	21 28	37 87	18 45	0 17
F	NS	NS	NS	NS	NS
CD		-			
SE	4 999	3 841	5 946	5 012	0 120

4.5.3 Potassium content

The effect of sulphur, boron, time of application and their interaction effects on K content of the soil after the experiment are presented in Tables 11a and 11b respectively.

The K content of the soil was not significantly influenced by the main effects as well as interaction effects of the different treatments tried.

4.5.4 Sulphur content

The effect of sulphur, boron, time of application and their interaction effects on sulphur content of the soil after the experiment are presented in Tables 12a and 12b respectively.

The sulphur content of the plots which received sulphur treatment was found to be slightly higher than the control plots, but the difference was not significant

4.5.5 Boron content

The effect of sulphur, boron, time of application and their interaction effects on boron content of the soil after the experiment, are presented in Tables 12a and 12b respectively.

The boron content of the plots which received boron treatment was found to be slightly higher than the control plots, but the difference was not significant

4.6 Economics of cultivation

The cost of cultivation of the individual treatment combinations are presented in Table 13.

The cost of production excluding the treatments worked out to be Rs.9400/-. Application of sulphur at 25 kg $S.ha^{-1}$ and boron at 4 kg ha^{-1}, as basal dose realised the highest net profit (Rs.7507/-). The maximum benefit : cost ratio was also shown by the same treatment combination, followed by $s_3b_1t_1$ (1 709) and $s_2b_1t_1$ (1.662). The control treatment showed a net profit of Rs.1080/- and benefit . cost of 1.114.

Table 13. Economics of cultivation

Treatments	Cost of production excluding treatment	Additional cost of treatments	Total cost	Pod yield	Value	Net profit	Benefit Cost
Control	9400	-	9400.00	1048.00	10480.00	1080.00	1.114
$s_1b_1t_1$	9400	564.40	9964.40	1256.[illegible]0	12561.00	2596.60	1.261
$s_1b_1t_2$	9400	788.40	10188.40	1198.35	11983.50	1795.10	1.176
$s_1b_1t_3$	9400	956.40	10356.40	1283.37	12833.70	2477.30	1.239
$s_1b_2t_1$	9400	738.30	10138.30	1160.31	11603.10	1464.80	1.144
$s_1b_2t_2$	9400	962.30	10362.30	1130.76	11307.60	945.30	1.091
$s_1b_2t_3$	9400	1130.30	10530.30	1182.12	11821.20	1290.90	1.123
$s_2b_1t_1$	9400	580.60	9980.60	1659.23	16592.30	6611.70	1.662
$s_2b_1t_2$	9400	804.60	10204.60	1443.34	14433.40	4228.80	1.414
$s_2b_1t_3$	9400	972.60	10372.60	1241.99	12419.90	2047.30	1.197
$s_2b_2t_1$	9400	754.50	10154.50	1413.64	14136.40	3981.90	1.392
$s_2b_2t_2$	9400	978.50	10378.50	1408.28	14082.80	3704.30	1.357
$s_2b_2t_3$	9400	1146.50	10546.50	1597.13	15971.30	5424.80	1.514
$s_3b_1t_1$	9400	596.80	9996.80	1708.31	17083.10	7086.30	1.709
$s_3b_1t_2$	9400	820.80	10220.80	1564.23	15642.30	5421.50	1.530
$s_3b_1t_3$	9400	988.80	10388.80	1698.38	16983.80	6595.00	1.635
$s_3b_2t_1$	9400	770.70	10170.70	1767.77	17677.70	7507.00	1.738
$s_3b_2t_2$	9400	994.70	10394.70	1589.92	15899.20	5504.50	1.529
$s_3b_2t_3$	9400	1162.70	10562.70	1624.32	16243.20	5680.50	1.537

Labour cost = Rs.56/-　　Cost of Sulphur = Rs 3.24/kg

Cost of groundnut = Rs.10/kg　　Cost of Boron = Rs 86.95/kg

DISCUSSION

5 DISCUSSION

An investigation was carried out at the College of Agriculture, Vellayani, to study the effect of sulphur and boron application on growth, yield and quality of groundnut cv TG-3 The results of the study, which were found significant are discussed below

5.1 Growth characters

Plant height was significantly influenced at various stages of growth by sulphur application @ 25 kg $S.ha^{-1}$ In general an increase in plant height by about 2 cm was observed by an increase in the level of sulphur by 5 kg. At all growth stages the highest level of sulphur tried, 25 kg $S.ha^{-1}$ recorded the maximum plant height. The number of leaves $plant^{-1}$ and the leaf area index increased with increasing dose of sulphur Application of 25 kg S ha^{-1} recorded the maximum number of leaves of 44.15 at harvest. The highest LAI of 10 78 recorded by the application of 25 kg sulphur ha^{-1} was significantly superior to all other levels

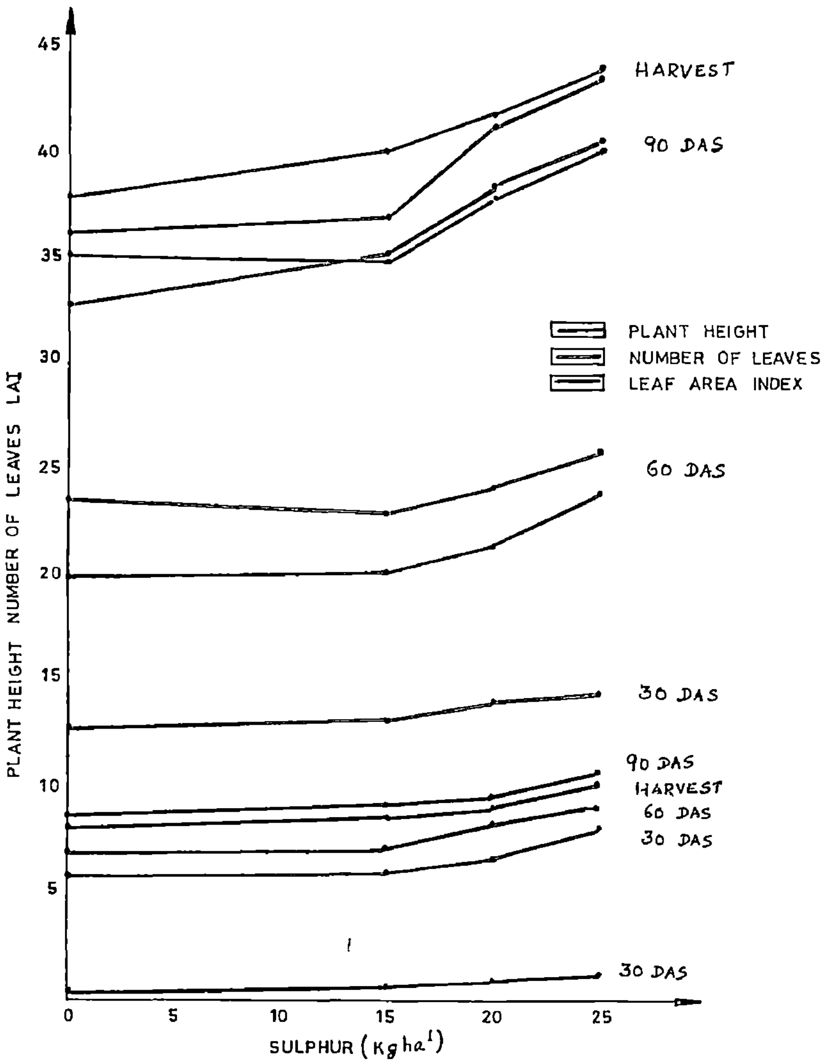
The data on nutrient uptake by groundnut presented in Table 11a show that the uptake of nitrogen by groundnut increased with increasing levels of sulphur. Nitrogen being the most potential nutrient element for the vegetative growth and development of plants (Tisdale *et al* , 1990) its availability would have helped the plant to grow taller and produce more leaves. According to Russel (1973) as the nitrogen supply increases, the extra protein produced allow the plant leaves to grow large and hence have more surface area available for photosynthesis This might be the reason for the increase in LAI due to increased supply of sulphur. Similar increase in growth characters in groundnut by sulphur application was reported by Nankumba and Edji (1974) and Singh _et al_ (1991) Singh and Saran (1987) also observed an increase in plant height in Indian rape due to sulphur application

Applied boron also significantly increased the plant height, number of leaves, and leaf area index of groundnut The effect of boron on growth characters was significant only at 90 DAS, in some cases and not at harvest Significant response was noted only upto 4 kg B ha^{-1} Here also, the data on nitrogen uptake as influenced by boron application presented in Table 11a showed that the uptake of nitrogen increased with boron application and the maximum uptake was noted at 4 kg B ha^{-1} Thereafter a significant reduction in uptake was seen This increased uptake of nitrogen might be the reason for the increased growth in groundnut due to boron application

Growth of an annual plant follows a general pattern and growth is expressed as increase in weight or height of

FIGURE 3

GROWTH CHARACTERS OF GROUNDNUT AS INFLUENCED BY SULPHUR



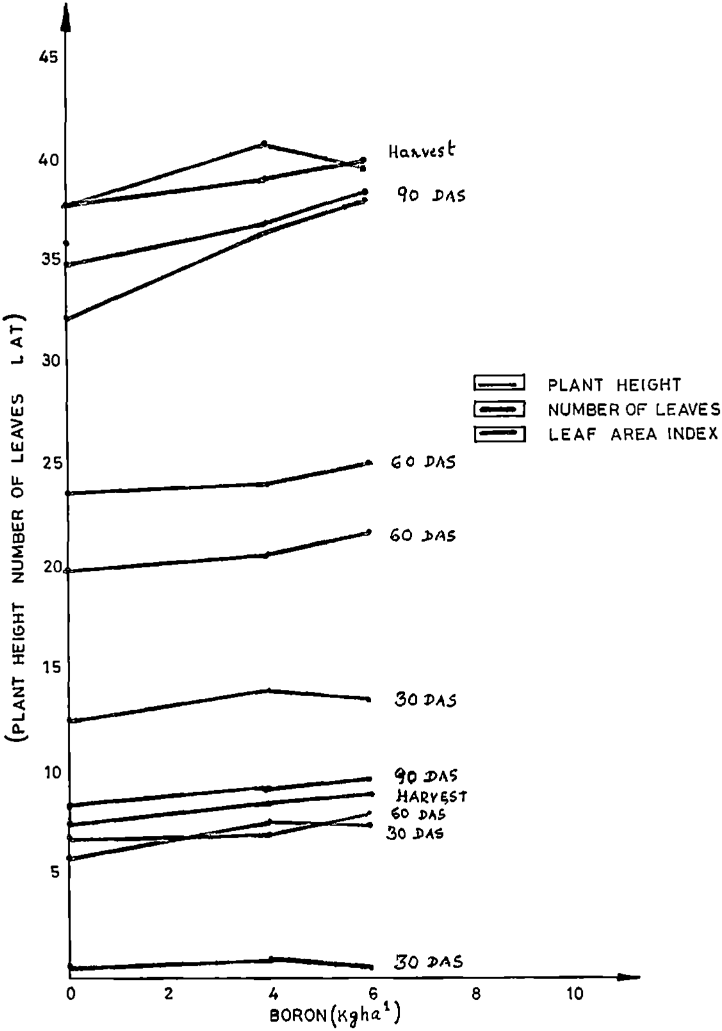
the plant. The general pattern is one of an initial small increase in size, followed by large increases During the final stages, the size of the plant increases very slowly or almost ceases (Tisdale et al., 1985) This might be the reason for not getting significant influence on growth characters of groundnut due to boron application at harvest stage. Promotion of plant growth and drymatter accumulation by boron application has been reported by Kulkarni et al (1989) in groundnut and Yang et al (1989) in rapeseed Jayachandran (1966) also reported increase in plant height in groundnut due to boron application.

The influence of different times of application of sulphur and boron on growth characters like plant height, number of leaves, and LAI showed that the differences were not significant at various stages to draw conclusions A study of the data showed that it was not possible to say whether one method is better than the other This shows that any one of the three times of application can be adopted for sulphur and boron.

The interactions S x B and S x T were found to be significant for plant height and number of leaves plant^{-1}. The additive effects of individual factors would have resulted in the significant influence of these interactions

FIGURE 4

GROWTH CHARACTERS OF GROUNDNUT AS INFLUENCED BY BORON



5.2 Number and weight of nodules plant^{-1} at flowering

The number of nodules plant^{-1} at flowering stage increased with the application of sulphur. As the level of sulphur increased from control to 25 kg S ha^{-1} the nodule number increased from 17.11 to 22 56 But the 3 levels of sulphur tried were found to be on par This confirms the role of sulphur containing plant proteins in enhancing the multiplication and growth of symbiotic bacteria The influence of sulphur in increasing the root system and the number of nodules in plants is well known (Miller, 1938) Poor nodule development and a low rate of nitrogen fixation are also associated with sulphur deficiency (Nelson and Bear, 1949) Bharadwaj and Pathak (1968) has reported that in groundnut, the number of nodules plant^{-1} increased from 1.8 to 23.7 as the sulphur concentration in the nutrient solution was increased from 0-9 ppm and further increase adversely affected nodulation. Similar increase in nodule number of groundnut was reported by Sagare et al. (1986).

The nodule number of plants which received boron (20.29) was also more than that in control (17 11) In this case also, the two levels of boron tried (4 and 6 kg B ha^{-1}) were found to be on par. The symbiosis between bacteria and nodule of a plant could be complete only if it was adequately supplied with boron as otherwise the vascular tissue between the nodule and the root may not develop properly (Brenchley and Thornton, 1926). Jayachandran (1966) and Joshi et al (1987) has reported that in groundnut, the number of nodules was increased by the application of boron

The interaction S x B was found to be significant for number of nodules plant^{-1} at flowering stage Karle et al. (1991) also reported a similar increase in nodule number at mid-flowering due to the combined application of sulphur and boron Positive interaction of boron and sulphur to increase nodulation in groundnut was also reported by Patel et al (1982) in calcareous soils

Though the number of nodules plant^{-1} increased with sulphur and boron application, the weight of nodules plant^{-1} at flowering stage was not significantly influenced by the application of either sulphur or boron A similar result has been reported by Kulkarni et al (1989) where soil application of boron increased the nodule number in groundnut significantly over the control, but the dry weight of the nodules did not differ significantly

5.3 Yield attributes

5.3.1 Number of pods plant^{-1}

The number of pods plant^{-1} increased with increasing levels of both sulphur and boron The pod number increased from 19.01 to 23.61, as the level of sulphur was increased from 0 to 25 kg S ha^{-1}. However sulphur application at 25 kg S ha^{-1} was on par with sulphur application at 20 kg S ha^{-1}, which gave a mean number of 21 33 pods $plant^{-1}$.

Flower production in groundnut is directly related to the vegetative growth of the plant (Goldin and Har-Tzook, 1966). In the present study sulphur application had a significant influence on growth parameters like height of the plant (Table 3a), number of leaves $plant^{-1}$ (Table 5a) and leaf area index (Table 6a) and this might be the reason for the increased pod production.

Moreover, adequate P supply is an important factor in fruiting and seed production in legumes (Buckman and Brady, 1969). In legumes a reserve supply of inorganic P in the plant is essential for pod formation because in this stage the inorganic phosphates combine rapidly with other organic compounds to build up the contents of the grain (Raheja, 1966). It is evident from Table 11a that the P uptake by the crop increased by sulphur application. The maximum uptake of P was noted by the application of 25 kg S ha^{-1} but the value was on par with 20 kg S ha^{-1} This increased P uptake might have contributed to the increase in number of mature pods $plant^{-1}$ Similar increase in pod number $plant^{-1}$ by sulphur application has been reported by Nitsure *et al*. (1988).

The number of pods plant^{-1} has been found to increase from 19.01 to 22.40 as the boron level was increased from 0 to 6 kg B ha^{-1} However the 2 levels of boron tried viz 4 kg B ha^{-1} and 6 kg B ha^{-1} were on par. The element boron plays a major role in the reproductive phase of the plant, and it helps in increased flower production and fruit setting in plants (Epstein, 1972) This role of boron might have resulted in increased number of pods plant^{-1}. Similar increase in pod number plant^{-1} by boron treatment has been reported by Jayachandran (1966) and Muthuswamy and Soundarajan (1973).

The S x B and S x T interaction effects were found to be significant. Among the S x B interactions, sulphur at 25 kg S ha^{-1} and boron at 6 kg B ha^{-1} recorded the highest value, and was significantly superior to all other combinations. The additive effects of individual nutrients might have resulted in significant influence of this interaction

5.3.2 Weight of pods plant^{-1}

Highest value for weight of pods plant^{-1} was obtained by the application of 25 kg S ha^{-1}, but this was on par with 20 kg S ha^{-1}. A similar trend was noticed with number of pods plant^{-1} also (Table 8a) by sulphur application Nitsure et al. (1988) also reported an increase in pod weight of groundnut due to sulphur application upto 30 kg S ha^{-1}.

The observation on weight of pods plant^{-1} by boron treatment also followed the same pattern as that of number of pods plant^{-1}. Application of boron at 4 and 6 kg B ha^{-1} produced significant increase in pod weight over that of control. A similar increase in pod number plant^{-1} and a consequent increase in pod weight in groundnut by boron application had been reported by Muthuswamy and Soundarajan (1973).

5.3.3 Weight of kernels plant^{-1} and 100 kernel weight

Application of sulphur had a favourable effect on weight of kernels plant^{-1}. This parameter increased with increasing levels of sulphur but the values obtained by the application of 20 kg S ha^{-1} and 25 kg S ha^{-1} were on par with each other.

The weight of 100 kernels also increased with increasing levels of sulphur and the highest value of 50 81 g recorded by the application of 25 kg S ha^{-1} was significantly superior to all others. Thirumalaisamy et al. (1986) also reported an increase in the 100 kernel weight from 38 to 41.5 g with a basal application of 22 kg S ha^{-1} Similarly, Nitsure et al (1988) also reported an increase in the 100 seed weight due to sulphur application.

The S x B interaction was found to influence both these characters significantly But the results were not consistent enough to draw any conclusion regarding the combination which is superior.

5 3.4 Shelling percentage

The shelling percentage which is an important yield attribute in groundnut was favourably influenced by sulphur application Application of sulphur at 25 kg S ha^{-1} gave the highest shelling percentage of 59.08, which was on par with that (58.55) obtained by the application of 20 kg S ha^{-1} The increase in pod weight (Table 8a) and kernel weight (Table 8a) of groundnut due to sulphur application might have resulted in this increase in shelling percentage

Similar increase in shelling percentage in groundnut by the application of sulphur was reported by Verma et al (1973), Badiger et al (1982), Nitsure et al (1988) and Sahu (1991)

Among the interactions S x B interaction alone was significant but conclusions could not be drawn about the best combination from the results

5 3.5 Pod yield

Sulphur application had a significant effect in increasing the pod yield of groundnut Application of 25 kg S ha^{-1} gave the maximum pod yield of 1658 83 kg ha^{-1}, (58.3 percent increase over the control) but this was on par with the yield obtained by the application of 20 kg S ha^{-1} Boron application also recorded a significant increase in yield over that of the control Application of B at 4 kg ha^{-1} recorded 38 percent increase in yield over the control and at 6 kg B ha^{-1} the increase was 36.49 percent over control However, the differences between the two levels of boron were found to be not significant

The yield of any crop is a very complex competitive character resulting from different factors, the more important being the number of plants in unit area and the yield plant^{-1}. The yield plant^{-1} is controlled by many factors such as the nutrient taken up by the plant, the genetic potential and the environmental conditions to which it is subjected during its life cycle. Yield is the fixed expression of all the yield attributing characters (Tanaka et al., 1964) The present study also showed an increase in yield attributes viz number of pods plant^{-1}, weight of pods plant^{-1}, 100 kernel weight and shelling percentage due to sulphur application, and number of pods plant^{-1} and weight of pods plant^{-1} by boron application This favourable effect of sulphur and boron application on these yield attributes have resulted in increased yield of groundnut In a field experiment Dalal et al. (1963) reported 41 percent increase in groundnut yield due to sulphur application Singh et al (1970), Dungarwal et al. (1974), Dongale and Zende (1976), Talukder and Islam (1982), Giri and Saran (1985), Karle and Babula (1985), Thirumalaisamy et al. (1986), Naphade and Wankhade (1988), Nitsure et al. (1988), Singh et al (1989) and Sahu (1991) also reported similar increase in groundnut yield by sulphur application

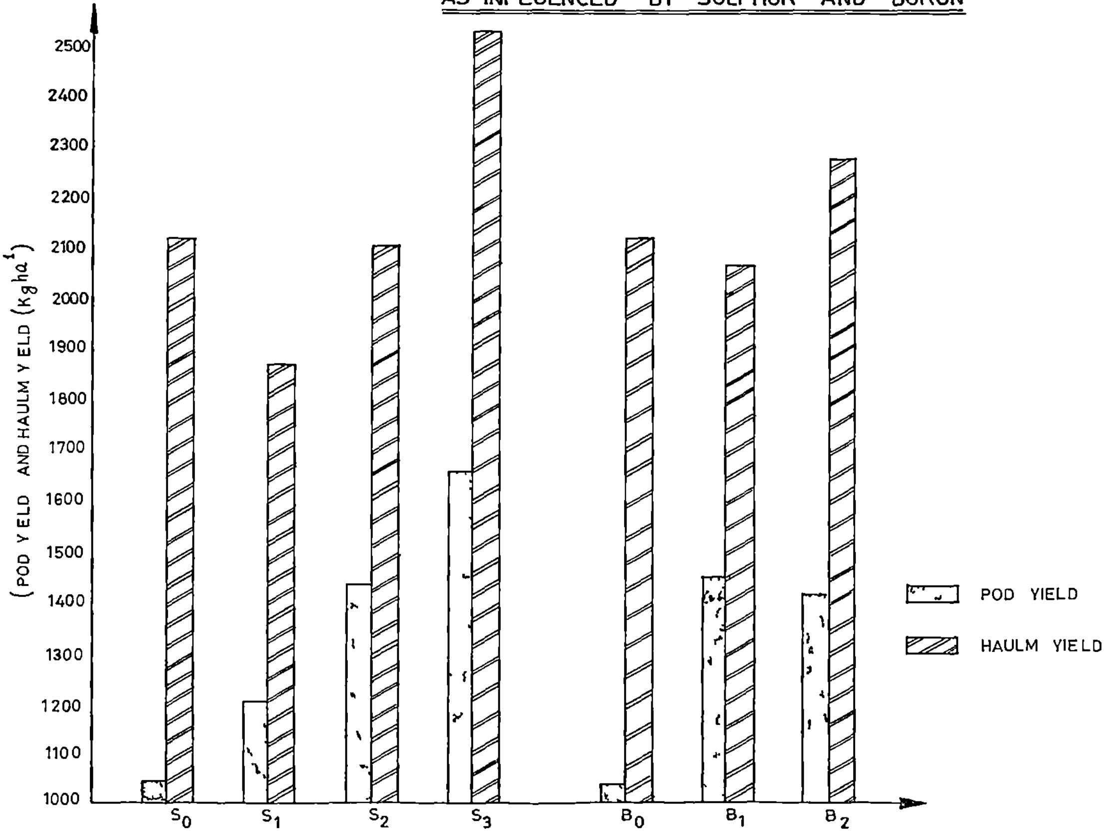
Increase in pod yield of groundnut by boron application has been reported by Deore and Kadam (1984), Mahale et al (1985), Karle and Babula (1985), Patel et al (1987), Wani et al. (1988) and Jadhao et al (1989)

The interactions of S x B was found to be significant, but the results were not consistent enough to draw conclusions regarding, which combination is the best

5.3.6 Haulm yield

A progressive increase in haulm yield of groundnut by different levels of sulphur was noticed in groundnut Application of 25 kg S ha^{-1} recorded the maximum haulm yield of 2549.98 kg ha^{-1} which was significantly superior to all other levels. Increased haulm yields in groundnut by sulphur application may be attributed to increased vegetative growth resulting from increased nitrogen uptake due to sulphur fertilization Such increase in haulm yield by sulphur application has been reported by Badiger et al (1982), Karle and Babula (1985) and Thirumalaisamy et al (1986).

FIGURE 5 POD YIELD ($Kg\ ha^{-1}$) AND HAULM YIELD ($Kg\ ha^{-1}$) OF GROUNDNUT AS INFLUENCED BY SULPHUR AND BORON



Boron fertilization and the different times of application did not influence this character significantly but there was a significant S x B interaction Similar combined effect of sulphur and boron on haulm yield of groundnut was reported by Karle and Babula (1985)

5.3.7 Total drymatter production (TDMP)

The total drymatter production was maximum when sulphur was applied @ 25 kg S ha^{-1} and this was on par with the TDMP obtained at 20 kg S ha^{-1} Similar increase in TDMP have been reported by Thirumalaisamy et al (1986) where the TDMP was increased from 46.3 to 51.2 g $plant^{-1}$ when sulphur was applied @ 22 kg ha^{-1} In the present study, the pod yield and haulm yield was increased by sulphur application and hence it is quite natural that the TDMP also increased by sulphur application

5.3.8 Harvest index (HI)

Harvest index, which is the ratio of economical yield to biological yield was significantly increased by application of sulphur The harvest index obtained by the application of 20 kg S ha^{-1} and 25 kg S ha^{-1} were on par Application of boron also produced a significant increase in HI over the control, with the 2 levels on par with each other Higher HI (higher percentage contribution by pods to total drymatter over and above that of leaf and stem) indicates the efficiency in translocation of assimilates from source to sink Higher HI reported in the present study, may be ascribed to the greater efficiency in translocation An increase in harvest index by sulphur application had been reported by Thirumalaisamy et al (1986)

5.4 Quality attributes

5.4.1 Oil content

The data presented in Tables 10a and 10b reveal that the oil content of groundnut kernels increased with progressive levels of sulphur and boron application The magnitude of response of sulphur to increase oil content in groundnut was of the order of 7.1, 4.6 and 4.0 percent over that of the control by the application of sulphur at 25 kg ha^{-1}, 20 kg ha^{-1} and 15 kg ha^{-1} respectively In fatty acid synthesis acetyl Coenzyme A is converted to malonyl Coenzyme A In this conversion an enzyme acetic thiokinase is involved, the activity of which depends on sulphur supply Moreover, acetyl Co A itself contains sulphur and sulphydryl group (Karle and Babula, 1985) This might be the reason for increase in oil content of groundnut with sulphur application Singh et al (1970) also reported an increase of 3.7 percent in the oil content of groundnut due to sulphur application Similar increase in oil content of groundnut was reported by Barhanpure (1976), Walker and Keisling (1978), Reddy and Patil (1980), Karle and Babula (1985), Naphade and Wankhade (1988), Koti *et al* (1989) and Singh *et al*. (1991)

The response of added boron to increase oil content was 5 69 (with 6 kg B ha^{-1}) and 4 36 (with 4 kg B ha^{-1}) percent over the control Jayachandran (1966) reported increased oil content due to the application of boron in groundnut In another study Karle and Babula (1985) reported that the oil content increased from 48 15 to 51 50 percent due to boron application. Similar findings were reported by Patil *et al* (1987) and Wani *et al*. (1988)

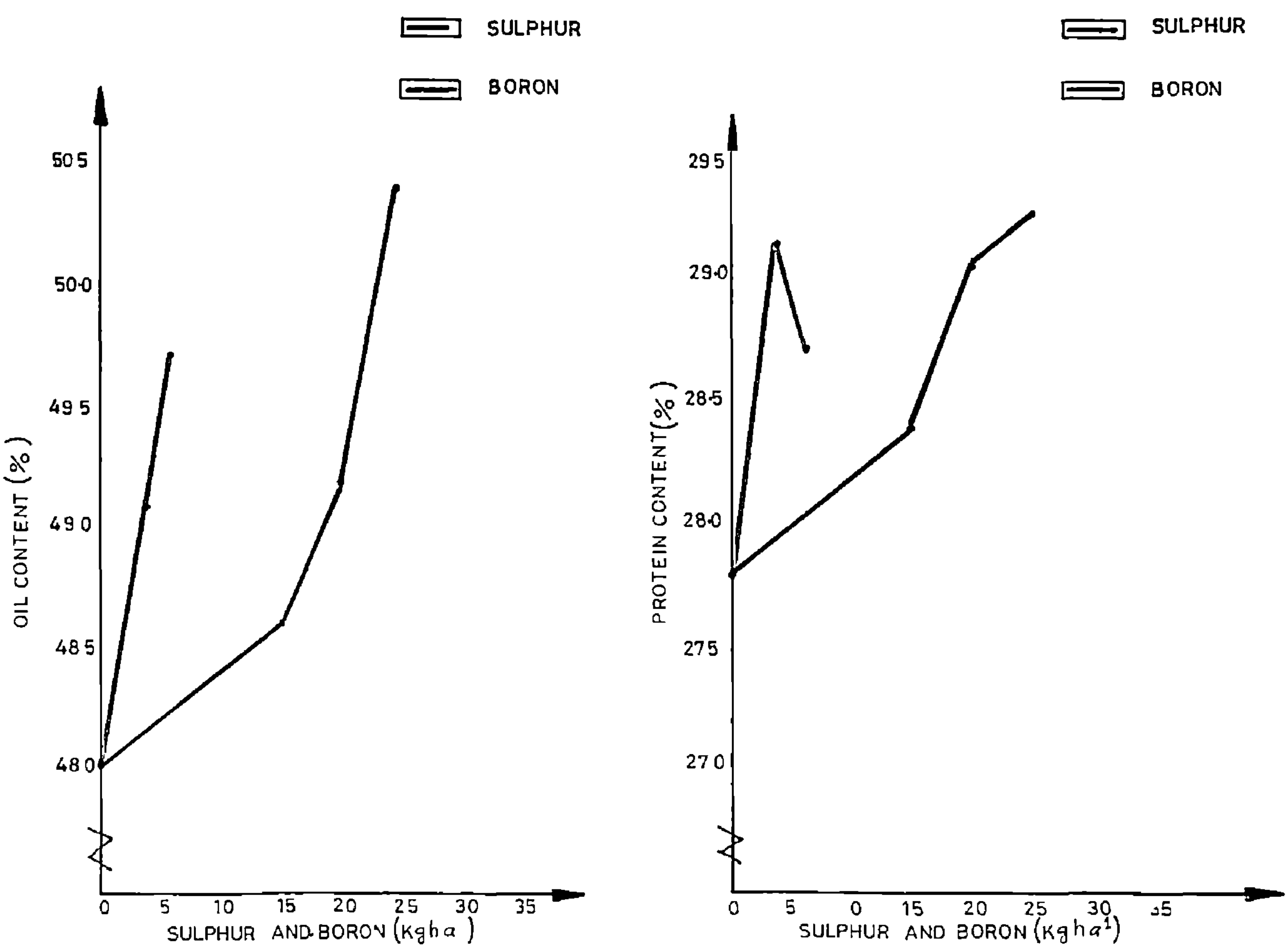
S x B and S x T interactions were found to be significant. Similar significant positive interaction between sulphur and boron on oil content and oil yield have been reported by Patel *et al*. (1981) and Karle and Babula (1985).

5.4.2 Protein content

Results revealed that application of sulphur and boron were effective in increasing the protein content of groundnut kernels But the time of application did not influence this character significantly

FIGURE-6

OIL CONTENT AND PROTEIN CONTENT OF GROUNDNUT AS INFLUENCED BY SULPHUR AND BORON



Application of 25 kg S ha^{-1} showed maximum protein content of 29.38 percent Sulphur is a constituent of aminoacids like cystine, cysteine and methionine and helps in the conversion of these aminoacids into protein (Chopra and Kanwar, 1966) Sulphur provides disulphide (-S-S-) bonds for cross linkage of two polypeptide chains and thus helps in formation of protein (Allaway and Thompson, 1966) The increased protein content in groundnut as a result of sulphur fertilization was also reported by Singh et al (1970) Barhanpure (1976), Karle et al (1985), Karle and Babula (1985), Thirumalaisamy et al (1986), Naphade and Wankhade (1988) and Mashi and Sharma (1991)

The protein content of groundnut kernels increased with boron application and maximum content of 29 79 percent was recorded at 4 kg B ha^{-1} Boron deficiency often results in accumulation of ammoniacal nitrogen, soluble organic N, amino acids and amides in mature plant parts and shows corresponding decrease in protein content (Scripture and Mc Hargue, 1943) In the present study, supply of boron might have helped in the conversion of these accumulated metabolites to protein and thereby increased the protein content of kernels This finding is in agreement with the findings of Karle and Babula (1985), Patel et al (1987) and Wani et al. (1988) The protein content at 6 kg B ha^{-1} (28 79 percent) was lower in comparison with 4 kg B ha^{-1}

(29.24 percent) This might be due to lesser uptake of nitrogen at 6 kg B ha^{-1} in comparison with 4 kg B ha^{-1} (Table 11a)

S x B and S x T interaction effects were found significant Significant interaction effect between sulphur and boron in increasing the protein content of groundnut kernels have been reported by Patel et al (1981)

5.4.3 Sulphur content of groundnut kernels

Sulphur content of groundnut kernels increased with increase in levels of sulphur application, but the three levels were on par with each other. This confirms the accepted phenomenon that the whole of applied sulphur is not metabolised to protein and a part remained in the plant (Dhillon and Dev, 1974) They attributed the cause to luxury consumption by the plant This finding is in agreement with the reports of Naphade et al (1969) Yadav and Singh (1970), Rathee and Chahal (1977) and Maliwal and Tank (1988)

5.4.4 Boron content of groundnut kernels

Application of sulphur enhanced the boron content of kernels, though the difference was not significant at different levels of sulphur. The uptake of boron due to sulphur application (Table 11a) also followed the same pattern

Application of boron increased the boron content of kernels, compared to the control treatment but the two levels tried were found to be on par A study of the uptake pattern of boron (Table 11a) also showed that boron uptake increased with increased levels of boron and this increased uptake may be the reason for the high content of boron in kernels

5.5 Nutrient uptake by the crop

5.5.1 Nitrogen uptake

The nitrogen uptake by the crop was significantly influenced by the application of sulphur and boron The beneficial effect of sulphur on nodule bacteria might have resulted in fixation of nitrogen, and consequent increase in N uptake. Maximum nitrogen uptake was obtained at 25 kg S ha^{-1}. Such increase in nitrogen uptake by the crop due to sulphur application has been reported by Daftardar et al. (1969) Yadav and Singh (1970), Singh and Singh (1977), Brar and Singh (1982) and Mashi and Sharma (1991)

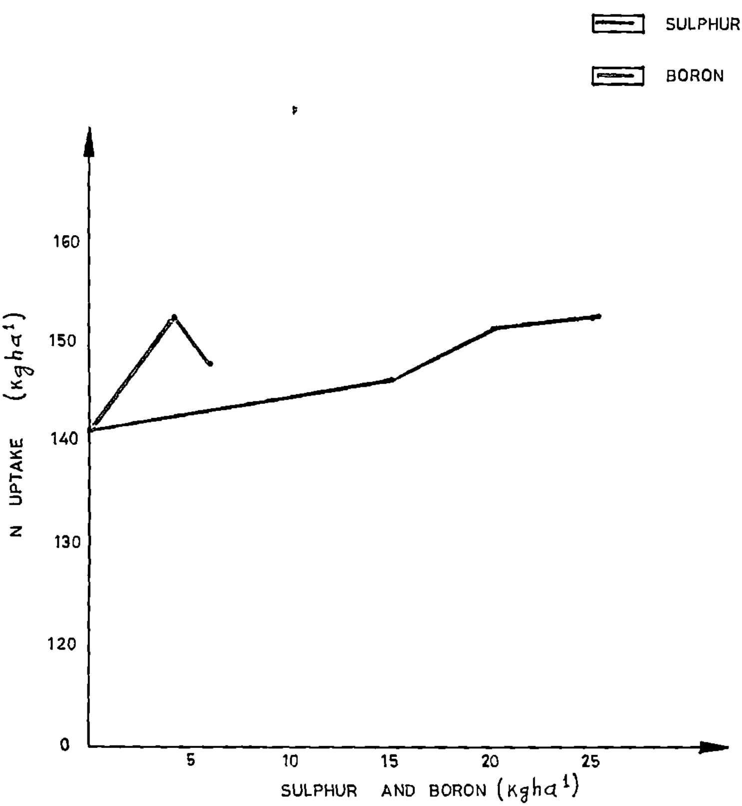
Sankaran et al. (1977) has reported an increase in the N uptake of groundnut cv TMV-7 grown in red loam soils, supplied with boron Similar findings were reported by Patel and Golakiya (1986) and Patel et al (1986)

5.5.2 Phosphorus uptake

Application of sulphur influenced the uptake of P by

FIGURE-7

NITROGEN UPTAKE BY GROUNDNUT AS INFLUENCED BY SULPHUR AND BORON



the crop significantly Maximum P uptake of 38 63 kg ha^{-1} was obtained at 25 kg S ha^{-1} and this was on par with 20 kg S ha^{-1} The higher uptake of P due to sulphur application, obtained in the present study may be due to the synergistic effect of sulphur on phosphorus This might be attributed to formation of sulphuric acid in soil, which solubilises more P (Kanwar, 1976) Rathee and Chahal (1977) also observed that P and S showed synergistic effects on uptake of each other Such increases in the uptake of P due to S application have been reported by Naphade et al (1969), Yadav and Singh (1970), Naphade and Wankhade (1988), Mishra and Singh (1989) and Mashi and Sharma (1991)

5.5.3 Sulphur uptake

Sulphur uptake by the crop increased with increasing dose of sulphur, with maximum uptake obtained at the highest dose - 25 kg S ha^{-1}. This might be due to greater availability of sulphur in soil at higher dose of sulphur application Increased S uptake by S application has also been reported by , Yadav and Singh (1970), Dungarwal et al (1974), Bulbule (1983), Naphade and Wankhade (1988), Mashi and Sharma (1991) and Singh and Tiwari (1991)

5 5.4 Boron uptake

As the level of boron increased from 4 to 6 kg B ha^{-1}, boron uptake was found to increase from 0.43 to 0.46 kg ha^{-1}, but the 2 levels were on par Increase in the uptake of boron by boron application had been reported by Sankaran *et al* (1977) in red loam soils.

The time of application influenced the boron uptake by the crop significantly, and maximum uptake was noted, when boron was applied 1/2 at sowing and 1/2 at flowering. This might be due to the efficient utilization of boron due to split application.

5.6 Nutrient content in the soil after the experiment

The nutrient content in the soil after the experiment, was not significantly influenced by any of the treatments

SUMMARY

6. SUMMARY

An investigation was undertaken at the College of Agriculture, Vellayani during the period from April to November 1990, to study the effect of different levels and time of application of sulphur and boron for groundnut cv. TG-3 in the red loam soil of southern Kerala. The investigation comprised of an initial pot culture study, followed by a field experiment. The pot culture study was laid out in completely randomised design, and the field experiment in randomised block design with three replications

Observations on biometric characters, yield attributes and yield were recorded. The uptake of nutrients by the crop and the nutrient content of the soil after the experiment were also determined. The results of the study are summarised below:-

1. Application of sulphur at 25 kg $S.ha^{-1}$ produced taller plants at all growth stages, whereas boron application at 4 Kg $B.ha^{-1}$ produced taller plants at 60 DAS, 90 DAS and at harvest.
2. The number of branches $plant^{-1}$ was significantly increased by application of boron only at 90 DAS. But the doses 4 kg and 6 kg $B.ha^{-1}$ were found to be on par.

3 At 90 DAS, 25 kg S ha^{-1} recorded the maximum leaf number, but at 60 DAS and at the time of harvest, there was no significant difference between the levels of sulphur tried Boron had significant influence on leaf number $plant^{-1}$ at 90 DAS and at harvest, with the two levels (4 kg and 6 kg B ha^{-1}) on par with each other

4 Sulphur application at 25 kg S ha^{-1} recorded the maximum LAI at 90 DAS Boron @ 4 and 6 kg B ha^{-1} were on par with respect to LAI at 60 DAS and 90 DAS At the time of harvest, maximum LAI was noted in plots which received full dose of fertilizers as basal dose, but it was on par with fertilizer application in 3 split doses

5 Sulphur application increased the nodule number $plant^{-1}$ at flowering significantly, but 15, 20 and 25 kg S ha^{-1} were on par with each other Similarly boron at 4 and 6 kg B.ha^{-1} were equally effective in increasing the nodule number.

6 The weight of nodules $plant^{-1}$ at flowering stage, was not significantly influenced by any of the treatments

7 Maximum number of pods $plant^{-1}$ was obtained by the application of 25 kg S ha^{-1}, but it was on par with 20 kg S ha^{-1} Similar was the case with boron, wherein 4 and 6 kg B ha^{-1} were on par with each other A significant positive interaction was noted when 25 kg S ha^{-1} and 6 kg B ha^{-1} were applied in combination

8. The weight of pods plant^{-1} followed the same pattern as the pod number plant^{-1}

9 The weight of kernels plant^{-1} was maximum when sulphur was applied @ 25 kg S.ha^{-1}, but this was on par with 20 kg S ha^{-1}

10. The 100 kernel weight recorded was maximum from plots which received 25 kg S.ha^{-1}

11. Application of 20 kg and 25 kg S.ha^{-1} were on par with each other, in increasing the shelling percentage.

12. Application of sulphur and boron significantly increased the pod yield of groundnut cv TG-3 Sulphur at 25 kg and 20 kg S.ha^{-1} were on par and the maximum yield was obtained by the application of 25 kg S.ha^{-1} Boron at 4 kg ha^{-1} recorded the highest yield, but it was on par with 6 kg B.ha^{-1}

13 Maximum bhusa yield was obtained by applying sulphur at 25 kg S.ha^{-1}.

14 Total drymatter production was highest at 25 kg S.ha^{-1}, which was on par with 20 kg S.ha^{-1}.

15. The harvest index of the crop was found to be high when sulphur was applied @ 20 kg S ha^{-1}. Boron at 4 kg B.ha^{-1} produced significantly higher harvest index compared to 6 kg B.ha^{-1} and the control treatment.

16. Highest oil content of 50.44 percent was recorded by 25 kg $S.ha^{-1}$, but it was on par with 20 kg $S.ha^{-1}$. Boron application also increased the oil content significantly over the control, but the two levels (viz. 4 kg and 6 kg $B.ha^{-1}$) were on par with each other

17. Sulphur application @ 25 kg $S.ha^{-1}$ recorded the highest protein content of 29 38 percent, but it was on par with 20 kg S ha^{-1}. Boron application @ 4 kg $B.ha^{-1}$ recorded the maximum protein content, and the content decreased as the level was increased to 6 kg

18 Application of sulphur significantly increased the sulphur content of kernels, though 15, 20 and 25 kg $S.ha^{-1}$ were on par with each other. Boron application had no influence on sulphur content of kernels.

19. Sulphur and boron application enhanced the boron content of kernels compared to the control, but the difference was not significant at different levels of these elements tried.

20. Maximum N uptake was observed when sulphur was applied @ 25 kg $S.ha^{-1}$ and it was on par with 20 kg $S.ha^{-1}$ and 15 kg $S.ha^{-1}$ Application of boron @ 4 kg B ha^{-1} resulted in maximum N uptake by the crop, and a further increase to 6 kg $B.ha^{-1}$ resulted in decreased uptake

21. Maximum P uptake was noted when sulphur was applied @ 25 kg $S.ha^{-1}$ and this was on par with 20 kg $S.ha^{-1}$.

22. Maximum S uptake was observed at 25 kg $S.ha^{-1}$.

23. Application of boron upto 4 kg $B.ha^{-1}$ significantly increased the boron uptake by the crop. Sulphur application also increased the boron uptake by the crop, but the difference in uptake was not significant at different levels of sulphur.

24. The nutrient content in the soil after the experiment was not significantly influenced by any of the treatments.

25. Application of sulphur @ 25 kg ha^{-1} and boron at 4 kg ha^{-1} as basal dose realised the maximum benefit cost of 1.738.

The results of the study revealed that application of sulphur @ 25 kg $S.ha^{-1}$, recorded the highest value for most of the parameters but it was on par with 20 kg $S.ha^{-1}$. Similarly in the case of boron also 4 kg and 6 kg $B.ha^{-1}$ were found to be on par in most of the cases. With regard to time of application, there was no significant difference between the three times of application in most of the cases. Hence the treatment t_1 (application of full dose of fertilizers as basal) can be adopted, which has the least demand for labour. Therefore, by considering the economics of cultivation sulphur at 20 kg $S.ha^{-1}$ and boron at 4 kg ha^{-1} may be recommended for groundnut cv. TG-3, in the red sandy clay loam of southern Kerala.

Future line of work

Since this is a fertilizer trial done for one season, it has to be repeated for getting more confirmatory results. Similarly trials with other micronutrients could also be initiated, since groundnut showed very good response to boron.

REFERENCE

REFERENCES

*Aboushoba, L.M., Shahin, N. and El-Afry, M.M. (1985). Physiological response of sunflower plants to foliar application of COC and boron. Tropenlandwirt 85/86. 32-40.

Achaya, K.T. (1989). The Take off in oilseeds. The Hindu Survey of Indian Agriculture pp. 87-93.

Aipe, K.C. (1981). Effect of potassium, magnesium and sulphur on the yield and quality of sesamum. M.Sc.(Ag.) Thesis submitted to Kerala Agricultural University.

Allaway, W.H. and Thompson, J.P. (1966). Sulphur in the nutrition of plants and animals. Soil Sci. 101: 240-247.

Alva, A.K., Gascho, G.J. and Guang, Y (1989). Gypsum material effects on peanut and soil calcium. Comm. in Soil Sci. and Pl. Analysis 20(17/18) 1727-1744.

Ankineedu, G., Rao, J.V. and Reddy, B.N. (1983). Advances in fertilizer management for rainfed oilseeds. Fert. News 28(9) 76-90.

Asokan, S. and Raj, D. (1974). Effects of forms and seeds of boron application on groundnut. Madras Agric. J. 61(8). 467-471.

Aulakh, M.S. and Pasricha, N.S. (1988). Sulphur fertilization of oilseeds for yield and quality. Proc. TSI-FAI Symp. Sulphur in Indian Agriculture, New Delhi.

Aulakh, M.S., Sidhu, B.S., Arora, B.R. and Singh, B. (1980). Content and uptake of nutrients by pulses and oilseed crops. Indian J. Ecology 12(2) 238-242.

A.O.A.C. (1960). Methods of analysis Non-metals In Horwitz, W., Robertson, A.H., Fischer, H.J., Epps, E.A., Quackenbush, F.W. and Helen Reynolds (ed.). Official methods of analysis of A.O.A.C. Published by Association of Official Agricultural Chemists. 9th edition. pp. 84.

Badiger, M.K., Reddy, N.P.S., Michael, R. and Shivraj, B. (1982). Influence of fertilizer potassium, sulphur and calcium on field and quality attributes of groundnut. J. Indian Soc. Soil Sci. 30(2). 166-169.

Badiger, M.K., Reddy, N.P.S. and Reddy, B.P. (1988). Yield and quality attributes of groundnut with the use of fertilizer potassium and sulphur on an Alfisol. J. Potassium Res. 4(2) 71-74.

Balasubramaniyan, Y. and Yayock, J.Y. (1981). Effect of gypsum and moisture stress on growth and pod fill of groundnut (Arachis hypogaea L). Plant and Soil 62(2). 209-219.

*Barhanpure, P.B. (1976). Study on the effect of sulphur bearing compounds and elemental sulphur on yield, uptake and quality of groundnut. M.Sc.(Ag.) Thesis submitted to PKV, Akola.

Bharadwaj, S.P. and Pathak, A.K. (1968). Effect of sulphur on bacterial nodulation of groundnut roots. Current Sci. 37(12): 351-352.

Blamey, F.P.C. (1976). Effect of secondary nutrients and boron on some growth characters and yield of sunflower. J. Oilseeds Res. 7 136-139.

Blamey, F.P.C., Chapman, J. and Smith, H.F. (1981). Boron fertilization and soil amelioration effects on boron nutrition of Spanish groundnuts. Crop Production 10 143-146.

Bouyoucos, G.J. (1962). Hydrometer method improved for mating particle size analysis of soil. Agron. J. 54: 464-465.

Brar, S.P.S. and Singh, B. (1982). Relationship of soil characteristics and sulphur content of soil and response of groundnut to sulphur and phosphorus. Indian J. Ecology 9(2) 270-276.

*Brenchley, W.E. and Thornton, H.G. (1926). Nodulation in broad beans by boron application. Proc. Roy. Soc. 98 B. 373.

Buckman, H.O. and Brady, N.C. (1969). Nature and Properties of Soil. The Macmillan Publishing Co. INC Newyork. 7th Edition. 653 pp.

*Bulbule, A.V. (1983). Effect of boron and sulphur on yield, uptake of nutrient and quality of groundnut. M.Sc.(Ag.) Thesis submitted to M.A.U., Parbhani.

Chahal, R.S. and Virmani, S.M. (1973). Preliminary study on yield and nutrient uptake by groundnut. Indian J. agric. Sci. 43(7). 731-733.

Channal, H.T. and Rao, K.B. (1981). Effect of sulphur and micronutrients (iron and zinc) on the yield of sunflower. Current Agriculture 5. 180-182.

Chawdhary, A.K. and Sharma, J.C. (1986). Sulphur for better yields of mustard. Indian Fmg. 35(11). 12.

Chesnin, L. and Yien, C.H. (1951). Turbidimetric determination of available sulphates. Soil Sci. Soc. American Proc. 15. 149-151.

*Chopde, A.T. (1964). Effect of application of sulphur on the composition, uptake of nutrients and quality of groundnut. M.Sc.(Ag.) Thesis submitted to Nagpur University.

Chopra, S.L. and Kanwar, J.S. (1966). Effect of sulphur fertilization on the chemical composition and nutrient uptake by legumes. J. Indian Soc. Soil Sci. 14. 69-76.

Chopra, S.L. and Kanwar, J.S. (1976). Analytical Agricultural Chemistry. Kalyani Publishers, Ludhiana. pp. 339.

Cooksey, M. and Barnett, W. (1979). Sequential Multielement Atomic Absorption Analysis of Agricultural samples. At. Absorpt. News L. 18 1.

Daftardar, S.U., Naphade, K.T. and Padols, S.C. (1969). Effect of soil application of sulphur on the chemical composition of groundnut crop. Indian Oilseeds J. 10: 33-35.

Dalal, J.L., Kanwar, J.S. and Saini, J.S. (1963). Investigations on soil sulphur. II. Gypsum as a fertilizer for groundnut in the Punjab. Indian J. Agric. Sci. 33. 199-204.

Deore, D.R. and Kadam, S.K. (1984). Effects of foliar application of boron on groundnut yields. J. Maha. Agric. Uni. 9(1): 100-101.

Dhillon, N.S. and Dev, G. (1974). Effect of elemental sulphur application on soybean. J. Indian Soc. Soil Sci. 26 55-57.

Dobrey, M. and Roy, N. (1967). Role of boron in groundnut. In Kanwar, J.S. and Randhawa, N.S. (ed.). Micronutrient Research in soils and plants in India. ICAR, New Delhi. 185 pp.

Dongale, J.H. and Zende, G.K. (1976). Response of groundnut to the application of manganese, boron and sulphur both in the presence and absence of FYM through soil and foliar spray. Indian J. Agron. 21(4) 321-326.

Dungarwal, H.S., Mathur, P.N. and Singh, H.G. (1974). Effect of foliar sprays of sulphuric acid with and without elemental sulphur in the prevention of chlorosis in peanut. Comm. in Soil Sci. and Pl. Analysis 5(4).

Dwivedi, R.S. (1981). Fertilizer use in groundnut based cropping systems under different agroclimatic conditions. Fert. News. 26(10) 28-34.

Epstein, E. (1972). Mineral nutrition of plants - Principles and Perspectives. John Wiley and Sons, Inc. Newyork. 1st edition pp. 1-407.

*Fazal, M. and Sisodia, D.S. (1989). Effect of sulphur and phosphorus on growth, nutrients and oil content in soybean and their residual effect on wheat. Ann. Agri. Sci. Cairo. 34(2) 915-924.

Ferreira, M.E., Fornasieri, D., Vitti, G.C. and Marvulo, C. (1979). Study of amounts and time of gypsum application to groundnut. Cientifica 7(2) 235-240.

Gaur, B L (1980) Fertilise your sesame with sulphur and magnesium for more oil Oilseed J 10 81-82.

Giri, G and Saran, G (1985) Influence of calcium and sulphur on groundnut under rainfed conditions. Indian J Agron 34(1) 146-147.

Goldin, E and Har-Tzook, A. (1966). The effect of fertilization on the vegetative and reproductive development of Virginia bunch improved groundnut. Oleagineux 21(1)· 17-20.

Gopal, N.H and Rao, J.M (1969) Effect of excess boron supply in germination and seedling growth of groundnut (*Arachis hypogaea* L). Plant and Soil 31(1) 188-192

Hago, T H and Salama, M A (1987). The effects of elemental sulphur on flowering and pod maturation in groundnut (*Arachis hypogaea* L) under irrigation. Fert. Res. 13(1). 71-76.

Harris, H.C and Brolmann, J.B (1966). Effect of imbalance of boron nutrition on the peanut. Agron. J 58(1) 97-99.

Hill, W E and Morrill, L G (1975) Boron, calcium and potassium interactions in Spanish peanuts Soil Sci. Soc. American Proc 39(1) 80-83.

Hocking, P.J., Randall, P.J and Pinkerton, A (1987). Sulphur nutrition of sunflower as affected by nitrogen supply, effects on vegetative growth, the development of yield components and seed yield and quality. Field Crops Research 16(2) 157-175.

Jackson, M L (1973). Soil Chemical Analysis Prentice-Hall of India (Pvt.) Ltd New Delhi. 2nd Edition 498 pp.

Jadhao, P.N , Fulzele, G R , Bhalerao, P D. and Thorve, P.V. (1989) Response of peanut to boron application under shallow soils Annals Pl Physio 3(1) 44-48.

Jayachandran, S.K. (1966). Studies on the effect of molybdenum, boron and manganese on the yield and quality of groundnut. M Sc (Ag) thesis submitted to Kerala Agricultural University.

Joshi, P.K., Bhatt, D.M and Kulkarni, J.H. (1987). Groundnut root nodulation as affected by micronutrient application and Rhizobium inoculation. International J. Tropical Agric. 5(3-4) 199-202.

*Kadar, I. and Shalaby, M.H (1985). Effect of K and B fertilizer application on the nutrient content of soil and sunflowers. Novenytermeles 34(4) 321-327.

Kanwar, J.S. (1976). Soil fertility - Theory and Practice. ICAR, 519 pp.

*Karle, B.G. (1982). Influence of phosphorus, sulphur fertilization and rhizobium inoculation on yield, nutrient uptake, protein and oil content of groundnut. Ph.D. Thesis submitted to M.A.U., Parbhani.

Karle, B G. and Babula, V.B (1985). Effect of boron and sulphur on yield attributes and quality of groundnut. In Siddaramappa, R., Vijayachandran, P.K. and Susheela Devi (ed). Proc National Seminar on Sulphur in Agriculture. UAS, Bangalore and FACT, Udhyogamandal. pp. 158-168.

*Karle, B.G and Ghonsikar, C P. (1980) Influence of phosphorus and sulphur on nutrioperiodism in groundnut with special reference to the absorption of potassium at different stages of growth. AGRESCO Report of MAU, Parbhani.

*Karle, B.G , Ghosikar, C.P. and Malewar, G U (1985). Effect of different sources of sulphur on nodulation, yield and quality of groundnut AGRESCO Report of MAU, Parbhani.

Karle, B.G , Bulbule, A V and Malewar, G U (1991) Yield and quality of groundnut as effected by boron and sulphur fertilization In Siddaramappa, R., Vijayachandran, P.K. and Susheela Devi (ed) Proceedings of the National Seminar on sulphur in Agriculture. UAS, Bangalore and FACT, Udhyogamandal pp. 214.

Koti, R V , Panchal, Y.C and Manjunath, S (1989) Effects of sulphur on pod yield and oil content of groundnut. J Maha Agric Uni 14(2) 243-244.

Kulkarni, J H , Sojithra, V.K and Bhatt, D M (1989) Effect of micronutrient application on nodulation and pod yield of groundnut (Arachis hypogaea L) Legume Res 12(1) 49-51.

Laurence, R C N., Gibbons, R W and Young, C T (1976). Changes in yield, protein, oil and maturity of groundnut cultivars with the application of sulphur fertilizers and fungicides. J Agric Sci U K 86(2) 245-250.

Mahale, T G , Shinde, B N and Patel, A.J (1985) Effects of boron and drum rolling on the yield of groundnut. Curr Res Reporter 1(1) 110-111

Mandal, B.K and Chatterjee, B N (1990). Effects of sulphates and chlorides of nutrient elements on crop productivity under rice-groundnut sequence Proc Int Symp. Rice Res. Hyderabad

Maliwal, G.L. and Tank, N.K (1988). Effect of phosphorus in presence and absence of sulphur and magnesium on yield and uptake of P, S and Mg by GAUG-10 groundnut. Indian J. Agric Sci 58(10) 757-760.

Mashi, M R. and Sharma, S.N (1991) Response of groundnut to sulphur and nitrogen application In Siddaramappa, R., Vijayachandran, P.K. and Susheela Devi (ed) Proc of the National Seminar on Sulphur in Agriculture. UAS, Bangalore and FACT Udhyogamandal. pp. 82-88.

Miller, C E (1938). Plant Physiology Mc.Graw Hill Book Co. 1st edition pp 154.

Misra, U.K., Sahu, S K , Das, R and Mitra, G N (1990). Effect of sulphur and lime on yield and oil content of kharif groundnut grown in an Aeric Haplaquept. J. Indian Soc Soil Sci. 38 772-774.

Misra, S.N and Singh, A.P. (1989) Studies on sulphur and phosphorus availability and uptake by groundnut Legume Research. 12(4) 160-164

Muthuswamy, T D and Soundararajan, S R (1973) Effect of boron on bunch groundnut Madras agric J 60(6) 403

Nagaraj, G. (1987) Effects of foliar spray of micronutrients on yield and chemical composition of peanut in calcareous soils of Junagadh Ann Pl Physio 1(2) 196-202

Naphade, P S and Wankhade, S G (1988) Response of groundnut (Arachis hypogaea L) to different levels and sources of sulphur P K V Research J 12(1)

*Naphade, K.T., Chopde, A T and Ballal, D K (1969) Effects of sulphur on nutrient contents in groundnut Nagpur Agric Coll Mag 1-4 44-48

*Natarajan, T (1981) Response of groundnut to different levels of calcium and sulphur Indian J Agric Sci 45 280-284.

Nelson, W L and Bear, F E (1949) Hunger Signs of Crops American Society of Agronomy and National Fertilizer Association, 1st edition pp 183

Nitsure, S A and Ramteke, J R (1987) A note on the influence of sulphur levels and earthing up on dry-matter production and sulphur uptake of groundnut varieties J Indian Soc Coastal Agric Res 5(2) 465-468

Nitsure, S A., Ramteke, J R and Kadrekar, S.B (1988) Effect of sulphur and earthing up on pod yield and quality of groundnut J Indian Soc Coastal Agric Res. 6(2) 99-104.

*Nankumba, J S and Edji, O T (1974) Effect of phosphorus, sulphur dust and plant population on groundnut yield and yield components Research Bulletin of Bunda 5 34-43.

*Omar, M A., El-Damaty, A.H , Hamdi, H and El Sherbini, A E. (1970) Effect of gypsum on yield, quality, mineral constituents of peanut plants. J Soil Sci U A R 10(1) 115-121

Pasricha, N S. and Randhawa, N S. (1973) Sulphur nutrition of crops from native and applied sources. Indian J Agric Sci. 43 270-274.

Patel, M S. and Golakiya, B A. (1986) Effect of calcium carbonate and boron application on yield and nutrient uptake of groundnut J. Indian Soc Soil Sci 34(4) 815-820

Patel, M S., Gundalia, K.B., Polara and Tak, N.K. (1991) Response of summer groundnut to gypsum. In Siddaramappa, R., Vijayachandran, P K. and Susheela Devi (ed.). Proc. of the National Seminar on sulphur in Agriculture UAS Bangalore and FACT Udhyogamandal pp. 211-212.

Patel, M.S and Patel, J J (1985) Effect of different levels of lime, sulphur, iron and moisture on yield and nutrient absorption by groundnut Indian J. Agric Res. 19(3) 124-130.

Patel, G.D., Patel, M.D., Adsule, R.N and Patel, N D (1986) Influence of superphosphate, borax and boronated superphosphate on nutrient concentration and uptake of groundnut. J. Maha. Agric Uni 11(3) 321-324.

Patel, G.D., Patel, N.D., Patel, N.D and Adsule, R N (1987) Effects of boronated superphosphate, single superphosphate and boron on yield and quality of groundnut J Maha. Agric. Uni. 12(2) 168-170.

Patel, J.D., Shinde, P.H., More, D A. and Zende, G K. (1981). Effect of application of boron, sulphur, and FYM on the yield and quality of groundnut J. Maha Agric. Uni 6(1) 17-18.

*Patel, J.D , Shinde, P.H., Shingte, A K and Patel, N D. (1982) Effect of boron application on groundnut yields FCA 36(7) pp. 652.

Polaria, J V. and Patel, M S (1991) Effect of principal and inadvertently applied nutrients though different fertilizer carriers on the yield and nutrient uptake by groundnut GAU J Res 16(2)

Raheja, P C. (1966). Soil Productivity and Crop growth. Asia Publishing House, Bombay 1st edition 474 pp

Rai, R., Ashraf, M.H and Chowdhary, S N (1977) Pyrite as an amendment of soil. Fert Tech. 14(4) 370-372.

Ramanathan, S. and Ramanathan, G (1982) Effect of calcium and sulphur application on quality characteristics of POL-2 groundnut Madras Agric J 69(11) 760-761.

Rathee, O.P. and Chahal, R S (1977). Effect of P and S application on yield and chemical composition of groundnut in Ambala soils Haryana Agric Uni. J. Res 7(4) 173-177.

Reddy, K.C and Krishnamurthy, P. (1986). Influence of applied nutrients on protein, amino acid composition and oil quality of groundnut on sandy loam soils. Indian J Agric Res 23(2) 93-100

Reddy, S.C and Patel, S V (1980) Effect of calcium and sulphur and certain minor nutrient elements on the growth, yield and quality of groundnut Oleagineux 35(11) 507-510.

Russel, E.W (1973) Soil conditions and Plant Growth. English Language Book Society and Longman 10th Edition. 834 pp.

Sagare, B.N., Bhalker, D.V. and Deshmukh, V A (1986). Studies on nodulation and N fixation by groundnut as affected by various levels of sulphur and phosphate. P.K.V. Research J. 10(1) 10-15.

Sahu, S.K (1991). Growing groundnut with sulphur Farmer and Parliament 16(2) 17-18

Sanjeevaiah, B.S (1969) Effect of micronutrients on groundnut Mysore J. Agric Sci. 3(1) 83-85

Sankaran, N., Sennian, P. and Morachan, Y.B (1977) Effects of forms and levels of calcium and levels of boron on the uptake of nutrients and quality of groundnut. Madras Agric J. 64(6) 384-388.

*Sakyarajan, S., Raghaviah, V and Shanmugam, K.S (1975). Gypsum for groundnut. Seeds and Farms 10(1) 51-56.

Saxena, H.K and Mehrotra, O.N. (1984). Effect of boron and molybdenum in presence and absence of phosphorus and calcium in groundnut Indian J Agric Res. 18(2) 91-94.

Schon, M.K. and Blevins, D G (1990) Foliar boron application increase the number of branches and pods on branches of field grown soybeans Pl Physio 92(3) 602-607.

Scripture, P.N. and Mc Hargue, J S (1943). Effect of boron deficiency on the soluble N and carbohydrate content of Alfalfa. J. Amer. Soc. Agron. 35 988-992

Shinde, B.N. and Kale, S P (1985). Boron for groundnut in dryland agriculture Fert News 30(5) 53-54.

Shiralipour, A., Harris, H C. and West, S.H (1969) Boron deficiency and aminoacid and protein content of peanut leaves Crop Sci 9(4) 455-456.

Sichmann, W., Neptune, A.M L. and Mello, FAF-De (1982) Effects of lime and gypsum application on pod yield and various characteristics of groundnut fruits in a pot experiment conducted in pedzolic soils from Lins and Marilia. Anais da Escola Superior de Agricultura 39(1) 337-347

Simpson, J E , Adair, C.R , Kohler, G O , Dawson, E N , Debald, H.A., Kester, E.B and Klick, J T (1965) Quality evaluation studies of foreign and domestic rices Tech Bull No 1331 Serives, U S D A 1-86

Singh, R P and Kalra, G S (1983) Effect of varying levels of P, S and plant densities on pod yield of different varieties of groundnut Indian J Agric Res 17(3) 171-176

Singh, S and Saran, G (1987) Effect of sulphur and nitrogen on growth, yield, quality and nutrient uptake of Indian rape Indian J Agron 32(4) 474-475.

Singh, T.P. and Singh, H.P (1975) Response of Indian rape to nitrogen and sulphur. Indian J Agron 29(4) 539-542.

Singh, M. and Singh, N (1977) Effect of sulphur and selenium on sulphur containing amino acids and quality of oil in raya Indian J Pl Physio 20(1) 56-62.

Singh, B. and Singh, A.P. (1978). Effect of magnesium and sulphur on the yield and quality of mustard Oilseed J 8(1-4) 32-35.

Singh, S.K and Tiwari, R.C (1991). Effect of applied and residual sulphur on sesamum-mustard In. Siddaramappo, R., Vijayachandran, P.K. and Susheela Devi (ed) Proc of the National Seminar on sulphur in Agriculture. UAS, Bangalore and FACT Udhyogamandal. pp. 208

Singh, B., Singh, A.P. and Singh, S (1989) Effects of small doses of pyrites on yield and quality of groundnut and mustard grown in rotation Agric Sci. Digest. 9(2) 57-61.

Singh, N., Subbiah, B.V and Gupta, Y.P (1970) Effect of sulphur fertilization on the chemical composition of groundnut and mustard Indian J Agron. 15(1) 24-28

Singh, A L., Joshi, Y.C., Devi, D. and Misra, J B (1991) Application of different sources of sulphur in groundnut. In Siddaramappa, R., Vijayachandran, P.K and Susheela Devi (ed.). Proc. of the National Seminar on Sulphur in Agriculture. UAS Bangalore and FACT, Udhyogamandal. pp. 76-81.

Sistani, K.R and Morrill, L R (1989). Benefit of foliar spray of phosphorus on peanuts in relation to gypsum and P application to soil J Environ Sci and Health Part A Environmental Science and Engineering. 24(4) 429-439

Sridhar, V., Soundararajan, M.S , Rao, S.I . and Sreeramulu, C (1985). Response of JL-24 groundnut to rates, time and method of gypsum application. Madras Agric J 72(1). 47-53.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for the estimation of available nitrogen in soils. Current Sci. 25(8): 259-260.

Sureshkumar, P (1985) Evaluation of the role of elements Ca, Mg, S and B on the nutrition of groundnut with reference to monovalent (K) and divalent (Ca+Mg) cationic ratios M.Sc (Ag.) Thesis submitted to KAU

Survase, D.N., Dongale, J.H and Kadrekar, S.B. (1986) Growth, yield, quality and composition of groundnut as influenced by FYM, Ca, S and B in lateritic soil. J. Maha. Agric. Uni. 11(1) 49-51.

*Talukder, M.K.H and Islam, H S. (1982) The yield response of groundnut to S and Zn fertilization in grey terrace soils of Joydebpur. Bangladesh J Agric Res 7(1) 49-53

Tanaka, A , Navasero, S A , Garcia, C V , Parao, G T and Remirez, E (1964) Growth habit of the rice plant in the tropics and its effect on nitrogen response Int Rice Res. Inst Tech Bull 3 1-80

Thirumalaisamy, K., Sathasivan, K. and Natarajaratnam (1986). Effect of sulphur fertilization on nutrient content, drymatter production and yield of groundnut Madras Agric J. 73(3) 151-154.

Tisdale, S L , Nelson, W L and Beaton, J D (1985) Soil Fertility and Fertilizers Mac Millan Publishing Co. Inc. Newyork. 4th edition pp 1-733

Tisdale, S L., Nelson, W L. and Beaton, J D (1990) Soil Fertility and Fertilizers Maxwell Macmillan International editions. 5th edition pp 1-754

Verma, L.P. and Ram, P.C (1986) Response of mustard (Brassica juncea L) to sulphur Proc National Seminar on Sulphur in Agriculture. TNAU-FACT pp. 1 88.

Verma, U.K., Thakur, A and Rai, U K (1973) A note on the effect of sulphur sources on quality of groundnut. Indian J. Agron. 18(1) 105-108.

*Walker, M.E., Gaines, T.P. and Henning, R.J (1983) FCA 36(9) pp. 751.

Walker, M.E. and Keisling, T C (1978) Response of 5 peanut cultivars to gypsum fertilization on soils varying in calcium content Peanut Sci 5(1) 57-60.

Wani, B.B., Patel, G D. and Patel, M D (1988) Effects of levels of single superphosphate and boronated superphosphate on yield and quality of groundnut J Maha. Agric. Uni. 13(3) 302-304

Yadav, R and Singh, D (1970) Effect of gypsum on chemical composition, nutrient uptake and yield of groundnut J. Indian Soc. Soil Sci. 18(2) 183-186.

*Yang, Y.A., Xu, H.K., Jie, Z Q and Wang, B.Y (1989) Influence of B, N and K nutritional level on boron uptake, quality and yield of rapeseed Scientia Agricultura Sinica 22(1) 44-51

*Zajonc, I., Borchmann, W and Rohl, W (1985) Effect of timed boron application on the yield components of spring rape Karl Marx Universitat 148-154

*Zhang, J.H , Zhang, D J., Jiang, Z L. and Liu, C X. (1986). A study on boron nutrition and application of boron to groundnut. J Soil Sci China 17(4) 173-176.

* Original not seen

APPENDICES

APPENDIX Ia

Weather data during the Cropping Season (weekly averages) (from 21 4 90 to 24 11 90)

Standard week	Period From	Period To	Maximum temperature °C	Minimum temperature °C	Relative humidity %	Rainfall (mm)
17	21 4 90	28 4 90	30 80	24 10	76 12	10 40
18	29 4 90	5 5 90	31 60	25 0	77 41	9 70
19	6 5 90	12 5 90	28 50	24 21	83 21	3 43
20	13 5 90	19 5 90	29 60	23 44	81 72	
21	20 5-90	26 5 90	30 50	23 56	77 41	10 90
22	27 5 90	2 6 90	31 60	25 10	83 28	22 80
23	3 6 90	9 6 90	29 46	24 11	78 20	49 53
24	10-6 90	16 6-90	30 20	24 12	87 13	20 63
25	17 6 90	23 6 90	29 53	24 07	81 07	20 83
26	24 6 90	30 6 90	29 14	22 2	93 64	18 25
27	1-7 90	8-7 90	30 13	24 07	81 14	9 40
28	9 7 90	15 7 90	28 30	23 16	93 28	5 00
29	16 7 90	22 7 90	27 5	23 42	77 00	2 60
30	23 7 90	29 7 90	29 37	23 5	86 00	11 70
31	30 7 90	5 8 90	29 34	23 57	76 60	44 40
32	6 8 90	12 8 90	28 00	22 90	79 90	3 18
33	13 8 90	19 8-90	29 08	23 90	81 10	10 80
34	20 8 90	26 8 90	30 30	24 80	78 00	
35	27 8 90	2 9 90	30 60	24 60	75 90	
36	3 9 90	9 9 90	30 80	24 10	76 20	7 10
37	10 9 90	16 9 90	31 40	24 50	77 00	
38	17 9 90	23 9 90	30 80	24 20	77 90	1 30
39	24 9-90	30 9 90	29 90	23 50	84 50	19 30
40	1-10-90	7 10 90	30 50	24 70	79 90	1 85
41	8-10 90	14 10-90	30 90	24 30	77 07	0 65
42	15 10 90	21 10 90	30 40	24 02	93 20	5 34
43	22 10-90	28 10 90	31 80	23 70	88 69	7 70
44	29 10 90	4 11-90	28 80	23 10	88 50	16 60
45	5 11 90	1 11 90	30 40	22 90	76 90	
46	12-11 90	18 11 90	30 40	22 08	79 07	
47	19 11 90	25 11 90	30 60	23 50	81 20	19 90

APPENDIX I b

LAY OUT PLAN

Rep I

$s_1b_2t_1$	$s_3b_2t_3$	$s_2b_2t_2$	$s_2b_2t_3$	$s_3b\,t_2$	$s_2b\,t$	$s\,b_2t_3$	$s_3b_2t_2$	$s\,b\,t$	$s_2b\,t_3$
$s_1b_2t_2$	$s_3b_1t_1$	CONTROL	$s_2b_2t_1$	$s_1b\,t_3$	$s_1b\,t_2$	$s_3b_2t_1$	$s_3b\,t_3$	$s_2b_1t_2$	

Rep II

$s_1b_1t_2$	$s_2b_2t_1$	$s_2b\,t_3$	$s_2b_2t_2$	$s_1b\,t_1$	$s_3b_2t_3$	CONTROL	$s_1b_1t_3$	$s\,b_2t_2$	$s_2b_2t_3$
$s_3b_1t_3$	$s_3b_1t_2$	$s_1b_2t_1$	$s_1b_2t_3$	$s_2b_1t_2$	$s_2b\,t_1$	$s_3b_2t_2$	$s_3b\,t_1$	$s_2b_2t_1$	—

Rep III

$s_1b\,t_3$	$s_2b_1t_2$	$s_2b_2t_1$	$s_2b_2t_1$	$s_1b_2t_3$	$s_1b\,t_1$	$s_2b_2t_3$	$s_1b_2t_2$	$s_3b_2t_1$	CONTROL
$s_1b_2t_1$	$s_3b\,t_3$	$s_3b_2t_2$	$s_3b_1t_2$	$s_2b\,t_3$	$s_2b_2t_2$	$s_3b_1t_1$	$s_3b_2t_3$	$s_1b_1t_2$	—

APPENDIX II

Effect of individual treatments on growth characters of groundnut var. TG-3

Treatments	Plant height (cm)				Number of branches plant^{-1}			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
$s_1b_1t_1$	6.82	21.08	35.37	40.00	3.03	6.00	9.17	9.73
$s_1b_1t_2$	6.27	20.18	34.77	39.68	3.23	5.87	8.50	9.57
$s_1b_1t_3$	6.53	19.28	36.12	40.33	3.53	5.93	8.63	9.67
$s_1b_2t_1$	7.42	21.62	36.33	40.70	3.27	6.03	8.93	9.83
$s_1b_2t_2$	6.73	20.83	35.67	40.70	3.40	6.03	8.77	9.80
$s_1b_2t_3$	7.22	19.87	37.12	41.10	3.23	6.17	9.20	10.30
$s_2b_1t_1$	7.12	22.67	38.52	42.60	3.57	6.17	9.40	10.23
$s_2b_1t_2$	7.50	22.07	35.45	41.78	3.93	6.30	9.07	10.17
$s_2b_1t_3$	7.53	20.70	38.70	42.07	3.70	6.30	9.77	10.63
$s_2b_2t_1$	7.83	23.67	39.12	43.49	3.57	6.00	9.73	11.00
$s_2b_2t_2$	8.05	22.50	38.65	43.12	3.37	6.17	9.30	10.27
$s_2b_2t_3$	8.03	21.27	38.97	42.27	3.73	6.33	9.83	10.77
$s_3b_1t_1$	8.37	24.98	41.23	44.28	3.63	6.43	10.30	11.00
$s_3b_1t_2$	8.45	23.23	39.70	43.93	3.70	6.60	10.10	10.83
$s_3b_1t_3$	8.08	23.32	39.87	43.43	3.97	6.47	10.20	11.00
$s_3b_2t_1$	8.63	25.77	42.20	45.00	3.77	6.57	10.37	11.27
$s_3b_2t_2$	8.92	24.22	41.67	44.40	3.83	6.70	10.23	10.97
$s_3b_2t_3$	8.35	23.97	40.93	43.87	3.67	6.60	10.23	11.17
Control	6.24	20.29	35.44	38.54	2.78	6.01	8.46	8.94

APPENDIX III

Effect of individual treatments on growth characters of groundnut var TG.3

Treatments	Number of leaves plant^{-1}				Leaf area index			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
$s_1b_1t_1$	11 67	22 90	36 57	38.93	0.83	6.80	8.40	7.87
$s_1b_1t_2$	12 93	23 43	34.13	38.23	0.80	6.80	8 30	7.47
$s_1b_1t_3$	14.17	23 80	34 53	38.63	0.77	7.03	8.20	8.10
$s_1b_2t_1$	12 73	23 90	35.70	26.27	0.90	7 07	9.00	8 33
$s_1b_2t_2$	13 57	23 87	35 13	39.27	0.83	6.97	8 83	8.17
$s_1b_2t_3$	12 93	24 60	36 77	41 23	0.80	7.53	9.17	8.17
$s_2b_1t_1$	14 23	24 63	37 63	40.90	1.07	8.40	9.10	8.67
$s_2b_1t_2$	15.70	25.13	36 30	40.63	1 10	8.30	8.73	8.57
$s_2b_1t_3$	14.80	25 17	39 03	42.53	0.97	7.97	8.57	8.50
$s_2b_2t_1$	14 17	23 97	38.90	43.97	0.83	8.47	9.87	8.80
$s_2b_2t_2$	13 20	24 63	37 17	41 03	0.73	8.37	9.73	8.40
$s_2b_2t_3$	14.87	25.30	39.33	43.07	0.73	8.10	9.57	8.37
$s_3b_1t_1$	14 53	25 77	41 13	43.93	0.93	8.55	10.77	9.33
$s_3b_1t_2$	14.43	26 47	40.43	43 30	0.87	8.40	10.60	9.17
$s_3b_1t_3$	15.77	25 90	40.77	43.97	0.97	8.37	10.43	9.07
$s_3b_2t_1$	15.03	26.23	41.42	45.07	1.13	8.13	11.17	10.13
$s_3b_2t_2$	15.33	26 83	40.90	43.87	1.07	8 03	11.03	9.93
$s_3b_2t_3$	14.70	26.39	40.87	44.73	1.00	8.40	10.70	9.83
Control	13.13	24.17	33.83	36 27	0.78	7.79	8.78	7.99

APPENDIX IV

Effect of individual treatments on nodule number and nodule weight at flowering stage

Treatments	Nodule number at flowering	Nodule weight at flowering
$s_1b_1t_1$	14.00	0.04
$s_1b_1t_2$	16 33	0.06
$s_1b_1t_3$	20.33	0.07
$s_1b_2t_1$	16.33	0.05
$s_1b_2t_2$	16.67	0.06
$s_1b_2t_3$	19.33	0.05
$s_2b_1t_1$	16.67	0.05
$s_2b_1t_2$	17.33	0.07
$s_2b_1t_3$	20.33	0.08
$s_2b_2t_1$	19.33	0.07
$s_2b_2t_2$	19.67	0.06
$s_2b_2t_3$	20.33	0.05
$s_3b_1t_1$	20.33	0.08
$s_3b_1t_2$	21.67	0.07
$s_3b_1t_3$	22 33	0.07
$s_3b_2t_1$	22 33	0.10
$s_3b_2t_2$	23.67	0.10
$s_3b_2t_3$	25.00	0.08
Control	17.11	0.05

APPENDIX V

Effect of individual treatments on yield and yield attributes of groundnut var TG-3

Treatments	Number of pods plant^{-1}	Weight of pods plant^{-1}	Weight of kernels plant^{-1} (g)	100 kernel weight (g)	Shelling percentage
$s_1b_1t_1$	20.00	21.60	11.13	47 43	57.37
$s_1b_1t_2$	20.67	23 60	13 93	47 43	57.33
$s_1b_1t_3$	21.00	23.27	14.87	47 33	57.23
$s_1b_2t_1$	20.00	21.87	13.60	47 10	58.30
$s_1b_2t_2$	19.67	22 43	14.33	46.67	58.17
$s_1b_2t_3$	19.67	22.10	13.50	46.50	58.13
$s_2b_1t_1$	21.67	24.90	16 03	47 43	58.87
$s_2b_1t_2$	20.00	21 90	14.43	47.30	58.70
$s_2b_1t_3$	21 00	23.13	12.87	47.10	58.67
$s_2b_2t_1$	23.33	23.73	17.53	47.80	58.57
$s_2b_2t_2$	21.33	23 20	15.47	47 60	58.37
$s_2b_2t_3$	20.67	21.10	14 50	47.67	58.13
$s_3b_1t_1$	23.00	26.73	16 40	52.50	58.63
$s_3b_1t_2$	21 00	22.93	14.93	51.23	58.40
$s_3b_1t_3$	20.67	22.63	14.70	50.30	60.40
$s_3b_2t_1$	26.67	26.87	16.77	52.27	59.63
$s_3b_2t_2$	25.33	27 93	17.00	53.03	58.67
$s_3b_2t_3$	25.00	26.60	15.70	51.50	58.77
Control	19 01	20.43	13.03	46.10	57.62

APPENDIX VI

Effect of individual treatments on yield and yield attributes of groundnut var TG-3

Treatments	Pod yield kg ha^{-1}	Haulm yield kg ha^{-1}	Total drymatter production kg ha^{-1}	Harvest index
$s_1b_1t_1$	1256 10	1942 33	3198 43	39.27
$s_1b_1t_2$	1198 35	1771 20	2969 55	40.35
$s_1b_1t_3$	1283 37	1904 03	3187 40	40.26
$s_1b_2t_1$	1160.31	1858.27	3018 58	38 43
$s_1b_2t_2$	1130 76	1997 17	3127 93	36 15
$s_1b_2t_3$	1182 12	1820 20	2992 32	39.51
$s_2b_1t_1$	1659.23	2062 27	3721.49	44.58
$s_2b_1t_2$	1443.34	2014 00	3457 34	41 75
$s_2b_1t_3$	1241.99	1970.37	3212 36	38 66
$s_2b_2t_1$	1413 64	2189 27	3602 91	39.24
$s_2b_2t_2$	1408.28	2171 27	3579 55	39.34
$s_2b_2t_3$	1597 13	2259 87	3857 00	41 41
$s_3b_1t_1$	1708 31	2335 33	4043 64	42 25
$s_3b_1t_2$	1564.23	2516.67	4080 90	38 33
$s_3b_1t_3$	1698.38	2139 30	3837 68	44.26
$s_3b_2t_1$	1767.77	2908 33	4676 10	37 80
$s_3b_2t_2$	1589 92	2614 97	4204.89	37.81
$s_3b_2t_3$	1624.32	2785.30	4409.62	36 84
Control	1048.00	2131 96	3179.95	32.96

APPENDIX VII

Effect of individual treatments on quality attributes of groundnut var TG-3

Treatments	Oil content (%)	Protein content (%)	Sulphur content (%)	Boron contert (%)
$s_1b_1t_1$	48.80	28.23	0 31	0.047
$s_1b_1t_2$	49 10	28.83	0.30	0.046
$s_1b_1t_3$	47.00	28 67	0.29	0.045
$s_1b_2t_1$	49 40	28.17	0.32	0.051
$s_1b_2t_2$	49 07	28.17	0.31	0.050
$s_1b_2t_3$	48.40	28.76	0.30	0.047
$s_2b_1t_1$	49.33	28.90	0.35	0.049
$s_2b_1t_2$	49 27	29 93	0.34	0.048
$s_2b_1t_3$	48 67	29.53	0.33	0.046
$s_2b_2t_1$	49.67	29.34	0.37	0.053
$s_2b_2t_2$	48 80	28 10	0.34	0.051
$s_2b_2t_3$	49.63	29 33	0.34	0.047
$s_3b_1t_1$	50.26	29 51	0.36	0.053
$s_3b_1t_2$	49.50	29.83	0.38	0.051
$s_3b_1t_3$	50.17	29.67	0.37	0.049
$s_3b_2t_1$	51.20	29.11	0.37	0.055
$s_3b_2t_2$	50 57	28.45	0.39	0.054
$s_3b_2t_3$	50 97	29.71	0.39	0.052
Control	48.07	27.80	0.29	0.019

APPENDIX VIII

Effect of individual treatments on nutrient uptake by groundnut var TG-3

Treatments	Nutrient uptake by the crop kg ha^{-1}				
	N uptake	P uptake	K uptake	S uptake	B uptake
$s_1b_1t_1$	147.13	20.70	60 30	30.93	0.44
$s_1b_1t_2$	147.80	20.57	60.43	29 07	0.41
$s_1b_1t_3$	148.70	20.03	59.93	28.23	0.40
$s_1b_2t_1$	143.17	30.97	61.37	31.80	0.47
$s_1b_2t_2$	145.80	31.53	61.50	30.50	0.45
$s_1b_2t_3$	146.47	32.13	61.17	29.83	0.44
$s_2b_1t_1$	152.37	33 57	63.40	33 27	0.46
$s_2b_1t_2$	153.53	34.30	64.03	32.13	0.44
$s_2b_1t_3$	155.13	34.50	63.60	31 87	0.43
$s_2b_2t_1$	150.17	37.63	65.27	33.97	0.48
$s_2b_2t_2$	148.27	38.00	65.00	32.53	0.45
$s_2b_2t_3$	148.70	38.47	65.53	31.60	0.43
$s_3b_1t_1$	153.83	37.73	66.10	36.43	0.47
$s_3b_1t_2$	155.83	38.27	66.17	35.47	0.46
$s_3b_1t_3$	156.23	38.63	65.77	34.40	0.44
$s_3b_2t_1$	150.30	39.20	67.20	36.07	0.50
$s_3b_2t_2$	150.30	39.80	66.33	36.07	0.49
$s_3b_2t_3$	150.73	38.17	65.03	34.37	0.48
Control	141.86	23.53	57.76	22.14	0.29

APPENDIX IX

Effect of individual treatments on nutrient content in the soil after the experiment

Treatments	Nutrient content in the soil after the experiment (kg ha^{-1})				
	N content	P content	K content	S content	B content
$s_1b_1t_1$	112 83	21 53	39.37	24 17	0.23
$s_1b_1t_2$	112.97	22 30	40 80	24 60	0.24
$s_1b_1t_3$	108.80	23 43	40.87	25.00	0.25
$s_1b_2t_1$	108.17	25.90	38.10	24.33	0.15
$s_1b_2t_2$	103.30	24.73	36.87	23 13	0.16
$s_1b_2t_3$	105.47	25.80	39.47	22.13	0.17
$s_2b_1t_1$	109.77	24.50	34.87	23 20	0.17
$s_2b_1t_2$	111.53	24.27	36 67	22.60	0.17
$s_2b_1t_3$	113.87	24 47	37.30	22.43	0.18
$s_2b_2t_1$	111.30	24.80	38.63	24.57	0.15
$s_2b_2t_2$	107.73	24.33	36 87	22.77	0.16
$s_2b_2t_3$	109.40	24.70	37.07	22.53	0.19
$s_3b_1t_1$	101.93	24.07	35.37	21.67	0.19
$s_3b_1t_2$	104.83	23.87	35 93	19.63	0.19
$s_3b_1t_3$	107.77	23.93	36.83	18.90	0.20
$s_3b_2t_1$	103.87	23.57	34.27	21.63	0.13
$s_3b_2t_2$	102.70	19.47	34.50	20.50	0.15
$s_3b_2t_3$	103.93	18.63	38.90	18.00	0.16
Control	105.46	20.99	32.04	16 70	0.14

SULPHUR AND BORON NUTRITION OF GROUNDNUT (*Arachis hypogaea* L) var. TG-3

By

CHANDINI A. B Sc (Ag)

ABSTRACT OF A THESIS

submitted in partial fulfilment of the
requirement for the Degree

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani Trivandrum

1992

ABSTRACT

An investigation was undertaken at the College of Agriculture, Vellayani during the period from April to November 1990, to study the effect of different levels and time of application of sulphur (15 kg, 20 kg and 25 kg $S.ha^{-1}$) and boron (4 kg and 6 kg $B.ha^{-1}$) for groundnut cv. TG-3 in the red sandy clay loam of Kerala. The investigation comprised of an initial pot culture study followed by a field experiment. The pot culture study was laid out in completely randamised design and the field experiment in randomised block design with three replications

The highest dose of sulphur, viz. 25 kg $S.ha^{-1}$ recorded significant influence on growth characters like plant height, number of leaves and leaf area index of the crop. The effect of boron was significant at 90 DAS for number of branches, at 90 DAS and at harvest for number of leaves, and at 60 DAS and 90 DAS for leaf area index. Significant response was noted only upto 4 kg $B.ha^{-1}$ for growth characters.

The effect of sulphur and boron application on nodule number was significant. But the three levels of sulphur and two levels of boron were on par with each other.

Sulphur had a favourable influence on all the yield attributing characters viz. number of pods $plant^{-1}$ weight of pods $plant^{-1}$, weight of kernels $plant^{-1}$, 100 kernel weight

and shelling percentage and consequently on pod yield, total drymatter production and harvest index. Sulphur at 20 kg and 25 kg $S.ha^{-1}$ were found to be on par in their effects. Boron at 4 kg and 6 kg $B.ha^{-1}$ were on par in influencing the pod number $plant^{-1}$, pod weight $plant^{-1}$, pod yield and bhusa yield of groundnut. There was a significant interaction between 25 kg $S.ha^{-1}$ and 6 kg $B.ha^{-1}$ for pod number $plant^{-1}$.

The oil content of groundnut kernels increased with progressive levels of sulphur and boron application. Sulphur at 20 kg and 25 kg and boron at 4 kg and 6 kg were on par in their effects. The protein content of groundnut kernels also increased with progressive levels of sulphur, with the levels 20 kg S and 25 kg $S.ha^{-1}$ on par with each other. But the protein content increased upto 4 kg $B.ha^{-1}$ only.

Sulphur and boron application enhanced the boron content of kernels significantly while application of sulphur alone increased the sulphur content of kernels.

Maximum N, P and S uptake were noted when sulphur was applied @ 25 kg ha^{-1}. Maximum N uptake by the crop was noted when boron was applied @ 4 kg $B.ha^{-1}$. B uptake was also significant only upto 4 kg $B.ha^{-1}$.

The time of application did not have any significant influence on growth characters, yield attributes, or yield of the crop.