

**SULPHUR NUTRITION TO PULSES THROUGH DIFFERENT
SULPHUR CARRYING FERTILIZERS**

**By
M. R. MAYADEVI**

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE – 641003**

2007

**SULPHUR NUTRITION TO PULSES THROUGH DIFFERENT
SULPHUR CARRYING FERTILIZERS**

Thesis submitted in part fulfillment of the requirements for the degree of
MASTER OF SCIENCE (AGRICULTURE) in
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
to the Tamil Nadu Agricultural University, Coimbatore

By

M. R. MAYADEVI. B. Sc. (Ag.)

(ID. No. : 05-617-007)

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE – 641003**

2007

CERTIFICATE

This is to certify that the thesis entitled “**SULPHUR NUTRITION TO PULSES THROUGH DIFFERENT SULPHUR CARRYING FERTILIZERS**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURE** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Miss. MAYADEVI, M. R.** under my supervision and guidance and no part of this thesis has been submitted for the award of any degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place : Coimbatore

Date :

(Dr. B. RAJKANNAN)
Chairperson

Approved by

Chairperson : **(Dr. B. RAJKANNAN)**

Members : **(Dr. V. P. DURAISAMI)**

(Dr. R. M. VIJAYAKUMAR)

EXTERNAL EXAMINER:

DATE:

ACKNOWLEDGEMENT

*Would it be all envisaging to offer salutations at the feet of **the Lord** who kindly imparted the energy and enthusiasm through ramifying paths of thick and thin of my efforts.*

*I wish to place on record my heartfelt thanks to the beacon light, the moving spirit, the great source of stimulating, intellectual inspiration, **Dr. B. Rajkannan, Ph.D.**, Professor, Department of Soil Science & Agricultural Chemistry, for reposing full confidence in my ability to work and write on a subject, for his unceasing, and steady encouragement, patient counseling and guidance. I wish to gratefully thank him for his fatherly care and affection, without which this thesis would not have seen the light of the day.*

*My sincere thanks are also due to **Dr. V.P. Duraisami**, Professor, Department of Soil Science and Agricultural Chemistry, **Dr. R. M. Vijay Kumar**, Professor, Department of fruits, Members of the Advisory Committee for their valuable suggestions and constructive criticisms.*

*My sincere heartfelt gratitude is due to **Dr. C. Paulraj, Ph D.**, Professor and Head, Department of Soil Science & Agricultural Chemistry for his kind attention and constructive criticisms and efficient guidance throughout the study.*

*My whole hearted and ever-rememberable thanks to **Dr. A. Vadivel**, Professor, Soil Science and Agricultural Chemistry who helped me a lot by providing all the necessary lab facilities for doing the laboratory analysis and instrumentation.*

*On a personal note, I am fortunate in having **Dr. T. Chitdeshwari**, Associate Professor, Department of Soil Science and Agricultural Chemistry, Agricultural Research Station, Bhavanisagar, with me during the entire period of field experimentation. I owe my profound sense of sincere and evergreen thanks for her unwearied attention, constant inspiration, inestimable and ever willing help, ebullient company and sharpening me psychologically to complete my field study.*

I place my heartfelt thanks to Dr. S. Ramasamy, Professor (Agronomy) for his valuable and timely help in the development of statistical analysis package.

I am extremely grateful to Dr. R. Jagadeeswaran, Assistant Professor and Dr. M. Sudhalakshmi, for their earnest guidance and valuable suggestions for formulating my programme of research.

I owe my sincere thanks to Dr. Shanmugham, Mr. Paneerselvam Farm Managers, ARS Bhavanisagar, for their kind co-operation and providing all facilities in time to carryout the field experiments.

My sincere thanks are due to Dr. S. Chellamuthu, Dr. D. Vasanthi, Dr. V. Velu and Dr. P. Natesan, Professors, Department of Soil Science and Agricultural Chemistry, Dr. S. Thiyaageshwari, Assistant Professor, for their timely help to utilize the facilities to conduct chemical analysis and instrumentation.

Sincere thanks are due to Dr. N. Chandrasekaran, Assistant Professor; Dr. V. V. Krishnamurthi, Professor, Department of Soil Science and Agricultural Chemistry for their constant encouragement and mental support.

I am deeply indebted to Dr. A. C. Suryaprabha, Dr. S. Sukanya, Dr. S. Ramasubramaniam, Dr. C. Bharathi, Miss Thillaiselvi, Mrs Tamilchelvi and Miss. R. Umadevi for their timely help and valuable guidance in soil and plant sample analysis.

Deep gratitude is due to Mr. Rajendran, Miss. K. Suthandhra and Mr. N. Nagarajan for their invaluable and timely help.

I owe my heartfelt thanks to all the field workers, ARS, Bhavanisagar, whose parental affection, timely help and support which enabled me to complete my field experiment.

My lovable and indebted thanks to my special friend Miss. Vandana L. Jayan, for her timely help, commitment and mental support.

*As said "Dearest is the friends love" who's volunteered help at the time of need for achieving my cherished goal paves me to offer my loveable and indebted thanks to my friends **Vineetha P. Pillai, Prathibha R, P. Mangayarkarasi, R. Geetha, N. Kanchana, G. Lakshmi Prabha, Ancy Francis, S. Yamuna, Rasana K, P, P. B. Neeraj, P. Valarmathi, A. Anandhan and S. Arun.***

*I owe much and I am deeply indebted to my parents **Mr. M. S. Ramachandran Nair and Mrs. N.D. Indiradevi**, My sister, **Miss Soumya M. R** and my fiancée **Dr. S. Sandeep, Ph.D**, for their deep love and enthusiastic support and constant encouragement during the course of this investigation.*

*I greatly acknowledged to the financial assistance sponsored by **Indian Council of Agricultural Research, New Delhi**, in the form of **Junior Research Fellowship**.*

*My deep gratitude is due to **Tamil Nadu Agricultural University** for authorization of this work.*

*Last by no means the least, I wish to express my heartfelt thanks to **Vignesh Computers and Sree Kumaran Computers** for the excellent and flawless typing and neat execution of this work.*

(Mayadevi, M. R)

ABSTRACT

SULPHUR NUTRITION TO PULSES THROUGH DIFFERENT SULPHUR CARRYING FERTILIZERS

By

MAYADEVI, M. R

Degree : **M. Sc (Agriculture) in Soil Science and
Agricultural Chemistry**

Chairperson : **Dr. B. RAJKANNAN, Ph.D.,**
Professor
Soil Science and Agricultural Chemistry,
Tamil Nadu Agricultural University,
Coimbatore - 641003.

2007

A field experiment was carried out with blackgram (Co5) and greengram (Co6) in a S deficient (8.7ppm) inceptisol (Typic ustropept - Irugur series) soil at Agricultural Research station, Bhavanisagar, Erode District, Tamil Nadu, to study the effect of different sources and levels of sulphur on the seed yield, nutrient uptake and protein content. The treatments consists of three sources of sulphur fertilizers viz., gypsum (M₁) magnesium sulphate (M₂), and single super phosphate (M₃) at three levels viz., 10 (L₁), 20 (L₂) and 30 (L₃) kg S ha⁻¹. There were ten treatments including a single control (NPK alone) with three replications in a factorial randomized block design. The salient features of the investigation are presented below.

A stupendous effect of the sulphur on enhancing the seed yield of both black gram and greengram was evidenced by the application of sulphur at 30 kg ha⁻¹ through gypsum and single super phosphate. The increase in seed yields was 21 and 14 per cent for blackgram and greengram respectively over the treatment that received N, P and K fertilizers alone.

Remarkable influence of sulphur on the yield attributes viz., number of pods per plant and hundred seed weight were found due to sulphur application through gypsum and SSP at 30 kg ha⁻¹. The protein content of both blackgram and greengram was also significantly influenced by the S fertilization at 30 kg ha⁻¹.

A concomitant increase in uptake of all the nutrients was observed due to application of sulphur through gypsum and single super phosphate at higher levels (30 kg S ha⁻¹).

The present investigation revealed clearly the overwhelmed effect of S application at 30 kg ha⁻¹ on seed yield, dry matter production, protein content and nutrients uptake and productivity of both blackgram and greengram. Among the S sources, gypsum and single super phosphate were found to be equally good in improving the productivity of both blackgram and greengram. Though gypsum and SSP were equally good, when we consider the cost factor, gypsum is cheaper and hence it could be effectively used as sulphur source.

The study emphatically brought out the need for sulphur fertilization at 30 kg level for improving the productivity of pulse crops.

CONTENTS

CHAPTER	TITLE	PAGE NO.
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIALS AND METHODS	
IV	RESULTS	
V	DISCUSSION	
VI	SUMMARY AND CONCLUSION	
	REFERENCES	
	APPENDICES	

LIST OF TABLES

Table No.	Title	Page No.
1	Analytical methods employed in soil and plant analysis	
2	The physical and chemical characteristics of initial soil	
3	Effect of sources and levels of S on seed yield (kg ha ⁻¹) of blackgram (Co5)	
4	Effect of sources and levels of S on seed yield (kg ha ⁻¹) of greengram (Co6)	
5	Effect of sources and levels of S on haulm yield (kg ha ⁻¹) of blackgram (Co5)	
6	Effect of sources and levels of S on haulm yield (kg ha ⁻¹) of greengram (Co6)	
7	Effect of sources and levels of S on DMP (kg ha ⁻¹) of blackgram (Co5)	
8	Effect of sources and levels of S on DMP (kg ha ⁻¹) of greengram (Co6)	
9	Effect of sources and levels of S on N content (%) of blackgram (Co5)	
10	Effect of sources and levels of S on N content (%) of greengram (Co6)	
11	Effect of sources and levels of S on P content (%) of blackgram (Co5)	
12	Effect of sources and levels of S on P content (%) of greengram (Co6)	
13	Effect of sources and levels of S on K content (%) of blackgram (Co5)	
14	Effect of sources and levels of S on K content (%) of greengram (Co6)	
15	Effect of sources and levels of S on Ca content (%) of blackgram (Co5)	
16	Effect of sources and levels of S on Ca content (%) of greengram (Co6)	
17	Effect of sources and levels of S on Mg content (%) of blackgram (Co5)	
18	Effect of sources and levels of S on Mg content (%) of greengram (Co6)	
19	Effect of sources and levels of S on S content (%) of blackgram (Co5)	
20	Effect of sources and levels of S on S content (%) of greengram (Co6)	

Table No.	Title	Page No.
21	Effect of sources and levels of S on N content of seed (%) of blackgram (Co5)	
22	Effect of sources and levels of S on N content of seed (%) of greengram (Co6)	
23	Effect of sources and levels of S on P content of seed (%) of blackgram (Co5)	
24	Effect of sources and levels of S on P content of seed (%) of greengram (Co6)	
25	Effect of sources and levels of S on K content of seed (%) of blackgram (Co5)	
26	Effect of sources and levels of S on K content of seed (%) of greengram (Co6)	
27	Effect of sources and levels of S on Ca content of seed (%) of blackgram (Co5)	
28	Effect of sources and levels of S on Ca content of seed (%) of greengram (Co6)	
29	Effect of sources and levels of S on Mg content of seed (%) of blackgram (Co5)	
30	Effect of sources and levels of S on Mg content of seed (%) of greengram (Co6)	
31	Effect of sources and levels of S on S content of seed (%) of blackgram (Co5)	
32	Effect of sources and levels of S on S content of seed (%) of greengram (Co6)	
33	Effect of sources and levels of S on N uptake (kg ha ⁻¹) of blackgram (Co5)	
34	Effect of sources and levels of S on N uptake (kg ha ⁻¹) of greengram (Co6)	
35	Effect of sources and levels of S on P uptake (kg ha ⁻¹) of blackgram (Co5)	
36	Effect of sources and levels of S on P uptake (kg ha ⁻¹) of greengram (Co6)	

Table No.	Title	Page No.
37	Effect of sources and levels of S on K uptake (kg ha ⁻¹) of blackgram (Co5)	
38	Effect of sources and levels of S on K uptake (kg ha ⁻¹) of greengram (Co6)	
39	Effect of sources and levels of S on Ca uptake (kg ha ⁻¹) of blackgram (Co5)	
40	Effect of sources and levels of S on Ca uptake (kg ha ⁻¹) of greengram (Co6)	
41	Effect of sources and levels of S on Mg uptake (kg ha ⁻¹) of blackgram (Co5)	
42	Effect of sources and levels of S on Mg uptake (kg ha ⁻¹) of greengram (Co6)	
43	Effect of sources and levels of S on S uptake (kg ha ⁻¹) of blackgram (Co5)	
44	Effect of sources and levels of S on S uptake (kg ha ⁻¹) of greengram (Co6)	
45	Effect of sources and levels of S on available N (kg ha ⁻¹) of blackgram (Co5)	
46	Effect of sources and levels of S on available N (kg ha ⁻¹) of greengram (Co6)	
47	Effect of sources and levels of S on available P (kg ha ⁻¹) of blackgram (Co5)	
48	Effect of sources and levels of S on available P (kg ha ⁻¹) of greengram (Co6)	
49	Effect of sources and levels of S on available K (kg ha ⁻¹) of blackgram (Co5)	
50	Effect of sources and levels of S on available K (kg ha ⁻¹) of greengram (Co6)	
51	Effect of sources and levels of S on exchangeable Ca (c mol (p+) kg ⁻¹) of blackgram (Co5)	
52	Effect of sources and levels of S on exchangeable Ca (c mol (p+) kg ⁻¹) of greengram (Co6)	
53	Effect of sources and levels of S on exchangeable Mg (c mol (p+) kg ⁻¹) of blackgram (Co5)	
54	Effect of sources and levels of S on exchangeable Mg (c mol (p+) kg ⁻¹) of greengram (Co6)	
55	Effect of sources and levels of S on available S (ppm) of blackgram (Co5)	
56	Effect of sources and levels of S on available S (ppm) of greengram (Co6)	

Table No.	Title	Page No.
57	Effect of sources and levels of S on seed protein (%) of blackgram (Co5)	
58	Effect of sources and levels of S on seed protein (%) of greengram (Co6)	
59	Effect of sources and levels of S on number of nodules per plant of blackgram (Co5)	
60	Effect of sources and levels of S on number of nodules per plant of greengram (Co6)	
61	Effect of sources and levels of S on number of pods per plant of blackgram (Co5)	
62	Effect of sources and levels of S on number of pods per plant of greengram (Co6)	
63	Effect of sources and levels of S on hundred seed weight (g) of blackgram (Co5)	
64	Effect of sources and levels of S on hundred seed weight (g) of greengram (Co6)	

LIST OF FIGURES

Figure No.	Title	Page No.
1	Field lay out	
2	Effect of sources and levels of S on seed yield (kg ha ⁻¹) of blackgram (Co5)	
3	Effect of sources and levels of S on seed yield (kg ha ⁻¹) of greengram (Co6)	
4	Effect of sources and levels of S on DMP (kg ha ⁻¹) of blackgram (Co5)	
5	Effect of sources and levels of S on DMP (kg ha ⁻¹) of greengram (Co6)	
6	Effect of sources and levels of S on N, P and K uptake (kg ha ⁻¹) of blackgram (Co5)	
7	Effect of sources and levels of S on N, P and K uptake (kg ha ⁻¹) of greengram (Co6)	
8	Effect of sources and levels of S on Ca, Mg and S uptake (kg ha ⁻¹) of blackgram (Co5)	
9	Effect of sources and levels of S on Ca, Mg and S uptake (kg ha ⁻¹) of greengram (Co6)	
10	Effect of sources and levels of S on protein content (%) of blackgram (Co5)	
11	Effect of sources and levels of S on protein content (%) of greengram (Co6)	
12	Effect of sources and levels of S on number of nodules per plant of blackgram (Co5)	
13	Effect of sources and levels of S on number of nodules per plant of greengram (Co6)	
14		
15	Effect of sources and levels of S on number of pods per plant of greengram (Co6)	
16	Effect of sources and levels of S on hundred seed weight (g) of blackgram (Co5)	
17	Effect of sources and levels of S on hundred seed weight (g) of greengram (Co6)	

LIST OF PLATES

Plate No.	Title	Page No.
1.	General view of field	
2.	Field view at pod development stage	

ABBREVIATIONS USED

N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
Ca	-	Calcium
Mg	-	Magnesium
S	-	Sulphur
CD	-	Critical Difference
t	-	Tonnes
NS	-	Non Significant
%	-	per cent
ha	-	hectare
kg	-	kilogram
g	-	gram
ppm	-	parts per million
c mol (p+) kg ⁻¹	-	centimole proton per kg
dSm ⁻¹	-	deciSiemens per metre
EC	-	Electrical Conductivity
FRBD	-	Factorial Randomized Block Design
DMP	-	Dry matter production
Fig	-	Figure
r	-	Correlation
SSP	-	Single Super Phosphate

CHAPTER I

INTRODUCTION

Pulses occupy a significant position in India especially for vegetarians, as it is considered as rich source of protein. Besides being a rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture (Kannaiyan, 1999). In our country, pulse crops are predominantly grown under rainfed condition and on low fertility neglected soils. Even then, India is the largest producer and consumer of pulses in the world, accounting for 33 per cent of the world's area and 22 per cent of the world's production (Singal, 1999). But its productivity is far below than that of other agriculturally advanced countries.

In Tamil Nadu, the area under total pulses declined from 6.8 lakh hectares in 2001 to 5.9 lakh hectares in 2005. Similarly the production of total pulses also showed a declining trend i.e., from 3 lakh tonnes in 2001 to 2 lakh tonnes in 2005. Among the pulses, the area under greengram has gradually increased from 1.2 lakh hectares in 2001 to 1.5 lakh hectares in 2005. However, the area under blackgram showed a declining trend i.e., from 2.7 lakh hectares in 2001 to 2.2 lakh hectares in 2005. (Season and Crop Report, 2005). The productivity of pulses in Tamil Nadu is about 500 kg ha⁻¹, which is only 50 per cent the national average and one fifth of the world average that necessitates import of pulses and drain of foreign exchange. Soil is one of the major limiting factors in pulse production. The challenge of a quantum jump in pulses production in India and especially in Tamil Nadu is formidable as it requires addressing of various researchable issues.

In Tamil Nadu, mostly the pulses are being grown under rain fed situations and also in rice fallow situations and not much attention is being paid to these crops. This might be the reason for the low productivity of pulses in our state compared to national and International productivity. The intensification of agriculture through high yielding varieties, multiple cropping with better irrigation created a long gap between addition of nutrients to soil and their removal by crop plants. Sulphur is one of the important nutrients, which was neglected for a long time and hence, most of the soils in our state

are becoming deficient in sulphur and the soils are unable to provide the adequate S, to meet the crop demand resulting in sub optimal yields. Thirty years ago, it was stated that “ As intensive farming practices are followed and use of concentrated fertilisers free from sulphur become more popular, the areas which are now presumed to contain adequate amounts of sulphur may also begin to show sulphur deficiency. In countries such as India, sulphur is one element that must not be overlooked” (Kanwar, 1976).

Sulphur is one of the essential nutrients required for plant growth and being recognized as the fourth major plant nutrient after nitrogen (N), phosphorus (P) and potassium (K). Though S uptake by many crops is generally comparable to P (Mengel and Kirkby, 1982), it has not received much attention until recently (Fox and Hue, 1986). Sulphur deficiencies were reported in 72 countries (Morris, 1988). Nearly 41% of Indian soils are deficient in S (Singh, 1998). The deficiency of sulphur has recently become widespread. Previously, requirements of the crops were obtained from the frequent incidental additions of S to soils through N and P fertilizers, such as ammonium sulphate and single super phosphate. Over the last two decades, there has been a shift in the S balance towards deficit in agricultural soils due to the use of high analysis N and P fertilizers, which contains no S. In addition, during the last two decades, the yields of the agricultural crops have increased markedly and in some cases, the increase was more than double, resulting in increased removal of nutrients including S from soils (Aulakh, 2003).

Sulphur (S), which has long been known to play a major role in plant metabolism (Leustek *et al.* 2000), is related to certain parameters that determine the nutritional status of plants (Schung, 1990). The sulphur nutrition of a plant strongly influences biomass production (Zhao *et al.*, 1997).

Responses of over 40 crops to S application have been reported under field conditions. Researchers have documented through numerous experiments that, S applications result in significant increases in crop yields wherever the soils are deficient in S. Mean yield increase due to S application are in the range of 638 to 813 kg ha⁻¹ for cereals, 168 to 428 kg ha⁻¹ for pulses, and 144 to 566 kg ha⁻¹ for oil seeds. Response of pulses to applied S varies widely due to differences in management, soil and crops (Singh, 1999).

Evidences have accumulated stating that, there is a scope to improve the productivity of pulses in Tamil Nadu, if we resorted to balanced nutrition especially the S nutrition, which proved its necessity beyond doubt. Hence, the present study was undertaken with the following objectives

- i) To evaluate the different sources and levels of sulphur fertilization on growth parameters and seed yield of blackgram and greengram.
- ii) To study the effect of treatments on protein content and nodulation of blackgram and greengram
- iii) To study the effect of treatments on availability and uptake of nutrients

CHAPTER II

REVIEW OF LITERATURE

Protein availability in Tamil Nadu is around 39 g per capita per day, which is far below as compared to World Health Organization's recommendation of 85 g (Anonymous, 1988). To overcome this problem, the productivity of pulses needs to be increased. The productivity could be increased through multi pronged approaches and one of the important approaches is application of balanced fertilization to the pulse crops. It is not enough to apply N, P, K fertilizers alone, the required secondary nutrients and also micronutrients needs to be applied, wherever there is deficiency. Among this, S application to pulses is very important since, the response of pulse crops to S fertilization was found to be good as reported by many researchers. (Lal and Jaiswal, 1981; Mehta and Singh, 1979; Naphade and Wankhede, 1987; Nambiar, 1988; Tiwari, 1990; Tandon, 1995). In this chapter, the research works carried out regarding the different sources and levels of S fertilization on pulses were reviewed and presented.

2.1. Sulphur in agriculture

Sulphur is one of the essential elements for the plant growth, and its requirement is equal to that of P (Scherer, 2001). It can therefore be rightly called as the fourth major nutrient in Indian agriculture (Tandon, 1986). It is a major component of amino acids, such as methionine, cysteine and cystine – the building blocks of protein. Sulphur application not only enhances the grain yield, but also improves the quality of pulse crops. This is mainly attributed to its association with S- containing amino acids and quality of proteins.

Some major reasons for the growing incidence of S deficiencies are :

- Increased removal by high yielding varieties, higher cropping intensity and wide gap between the removal and addition of S in agriculture
- Large scale shift towards S free products in the fertilizer use pattern and inadequate recycling of crop residues in most cropping systems
- Losses of S through leaching and soil erosion and low level of fertilizer input in high S requiring crops (Tandon, 1995).

Investigation of soil samples of Tamil Nadu for S status revealed that on an average, 19.9% of the area was under S deficiency. But, in Nilgiris (42.5%) and Kanyakumari districts (38%), the deficiency was found to be higher as compared to Coimbatore, Erode, Vellore and Kamarajar districts (Anonymous, 2000). Areas prone to S deficiency are those that are remote from industrial and domestic burning of fossil fuel, areas away from the sea, areas where weather patterns are controlled by air masses originating in remote regions etc. In view of the increasing incidence of sulphur deficiencies in soils and crops, application of S assumes added importance. This is necessary to sustain intensive agriculture and high yield levels.

2.2. Crop responses to sulphur

Deb and Sachdev (1997) reported that, to produce 1 ton of oil seed, on an average, 12 kg sulphur is required and they also opined that, among all the crops, oil seeds found to respond well to sulphur application.

An experiment conducted in alluvial soils of Barrakhpore, West Bengal, revealed that, rice crop responded well to sulphur application with an average yield increase of 1200kg ha⁻¹ during 1974-1985 (Nambiar, 1988). In red loamy soils of Hyderabad, the average yield increase of rice was reported to be 86% in kharif and 79% in rabi over a period of 14 years. (Nambiar and Abrol, 1989).

Ali (1991) reported that, the per cent response of kharif pulses to sulphur application was in the order of pigeon pea > blackgram > greengram.

Pulses and oilseeds are having high requirement of S per unit yield production. It has been established that, more than 40 crops have responded to S fertilizers under field conditions. The response rates were obtained with mean application rates ranged from 24 to 85 kg S ha⁻¹ with a majority of cases being in the range of 30-40 kg S ha⁻¹. Mean yield increase due to S application were in the range of 638 to 813 kg ha⁻¹ for cereals, 168 to 428 kg ha⁻¹ for pulses and 144 to 566 kg ha⁻¹ for oil seeds. The yield increase for S application was to the tune of 17.1 % in rice, 25.3 % in wheat, 30.0 % in rape seed and 31.7 % in groundnut when grown in S deficit soils (Tandon, 1995).

2.3. Sulphur on dry matter production

Increased dry matter yield of soybean crop due to application of sulphur up to 60 ppm in a sandy loam soil which was rated low in available Sulphur (8.9 ppm) was reported by Pasricha and Randhawa (1973).

In a green house experiment conducted in sandy loam soil of Punjab, by Aulakh and Pasricha (1977) reported that, application of S at 20 ppm increased the yield of moong to the tune of 20.0 to 23.3 g per pot.

An increase in the dry matter production of alfalfa was reported by Aulakh *et al.* (1977) in a non calcareous brown soil, when sulphur was applied at the rate of 20 ppm.

Kumar and Singh (1980) conducted a green house experiment on light textured soil which was deficient in available S and observed that, the application of S at 80 ppm as potassium sulphate enhanced the dry matter yield of soybean.

A green house trial conducted on soybean by Sacchidanand *et al.* (1980) to study the response of soybean to sulphur and phosphorus fertilization revealed that, the effect of sulphur on dry matter yield of soybean was significant up to 50 ppm level and beyond that level, there was decline in DMP.

In a study conducted in vertisol of North Western Madhya Pradesh, on effect of levels of P and S on growth and yield of rain fed blackgram by Khandkar *et al.* (1985) found that, both phosphorus and sulphur increased the dry matter yield of black gram at the rate of 60 kg P₂O₅ and 24 kg S ha⁻¹.

An investigation carried out in green house to study the direct and residual effect of S and Mg application in three crop sequence of two legumes and oil seeds (cowpea - mustard-moong) on alluvial soils by Nad and Goswami (1983) revealed that, the uptake of both S and Mg significantly increased with increased levels of their applications. The dry matter yield of cowpea increased significantly with 30 kg S ha⁻¹ as ammonium sulphate in normal soils and 60 kg S ha⁻¹ produced higher dry matter in soils which are low in S. However, magnesium found to have no influence on dry matter yield.

An experiment was conducted on silty clay loam soil of Uttar Pradesh with different levels and sources of S on soybean revealed that, S at 40 kg ha⁻¹ as gypsum found to increase the plant dry matter and it was found to be on par with 30 kg ha⁻¹ (Kandpal and Chandel, 1993).

Singh, *et al.* (1994) conducted experiment in sandy loam alkaline soil on summer moong and found that, the dry matter yield increased with successive increase in sulphur levels up to 60 kg S ha⁻¹ but, the dry matter yield found to be declined significantly at 80 kg ha⁻¹ sulphur application at all the stages of crop growth. Similar findings were also observed by Aulakh and Pasricha (1977) on moong bean and by Kumar and Singh (1980a) on soybean.

The field experiments conducted on greengram in sandy loam soil (Udic ustochrepts) with different doses of S indicated that, DMP of green gram was found to be increased up to 60 kg ha⁻¹ of S application (Naidu and Ram, 1996). Similar findings were also reported by Naphade and Wankhade (1987), Misra (1995) and Tiwari (1997).

Singh and Singh (2004) conducted field experiment on a sandy loam soil of Agra, Uttar Pradesh and concluded that, increasing levels of S significantly increased the dry matter yield of blackgram. They also reported that, significant increase in total dry matter yield was observed when 60 kg P was applied in combination with 60 kg S.

2.4. Sulphur on yield of crops

Sulphur plays a significant role in cell and tissue developments. It activates proteolytic enzymes and is needed for the formation of chlorophyll and all these are related to crop yield (Tandon 1987)

A green house trial conducted on soybean by Sacchidanand *et al.* (1980) to study the response of soybean to sulphur and phosphorus indicated that, the application of 25 ppm S and 80 ppm P₂O₅ was found to be most efficient in increasing the yield of soybean.

Field experiments conducted by Lal and Jaiswal (1981) on urd in Gangetic alluvial soil revealed that, the grain yield of urd were significantly increased by the application of 30 kg S ha⁻¹ as gypsum and there was a reduction in urd grain yield beyond that level of sulphur application.

In a study conducted in vertisol of North Western Madhya Pradesh, on the effect of levels of P and S on growth and yield of rain fed blackgram by Khandkar *et al.* (1985) found that, the grain and straw yield of blackgram at harvest responded well to the sulphur application at 30 kg ha⁻¹ level.

Increased grain yield of blackgram due to application of 15 kg S ha⁻¹ was reported by Upadhyay *et al.* (1991). Sulphur application at the rate of 25 kg ha⁻¹ in vertisol increased the blackgram seed yield from 2.6 to 3.3 g per plant and straw from 4.1 to 5.5 g per plant as reported by Khandkar and Shinde (1991).

Field experiments conducted on sandy clay loam soil, Gwalior with four levels of S through gypsum to 4 crops by Bansal (1991) revealed that, increasing levels of S increased the seed yield of the crops. Highest yield was noticed with the application of 80 kg of S ha⁻¹, which was significantly superior over control. However, difference between 40 and 80 kg S was not significant.

A field experiment conducted at Tamil Nadu Agricultural University, Coimbatore to study the effect of S nutrition indicated that, a significant increase in total dry matter production was observed in blackgram by the application of both gypsum and elemental sulphur at 100 kg ha⁻¹ and 18.5 kg ha⁻¹ (Kasthuri *et al.*, 1992). Similar results were reported by Dhillon and Dev (1980) in soybean.

Experiments conducted by Hari Ram and Dwivedi (1992) on sandy loam soils of Kanpur, Uttar Pradesh, on chickpea revealed that, application of 40 kg S ha⁻¹ through gypsum recorded higher seed yield. The yield was found to be increasing with increasing levels of S up to 40 kg ha⁻¹ with gypsum and pyrite. Beyond that level, the seed yield found to decline.

Field experiments conducted on Vertic ustochrepts of Madhya Pradesh on soybean by Subharao and Ganeshamurthy (1994) revealed that, application of S at 40 kg ha⁻¹ significantly increased the seed yield of soybean. The extent of crop response to S varied from 110-340 kg ha⁻¹. Similar findings were also reported by Tandon (1991).

Singh and Singh (1995) studied the response of S on soybean and concluded that, application of S at 40 kg ha⁻¹ enhanced the seed yield of soybean to 2.28 t ha⁻¹ compared to control which registered 1.72 t ha⁻¹. However, the different sources of S viz., gypsum, pyrite and SSP had no significant difference on the yield of soybean.

Soybean found to respond well to both P and S application and a highly synergistic relationship was observed between P and S at 35 kg P and 50 kg S ha⁻¹ resulting in highest seed and straw yields as concluded by Khajanchilal *et al.* (1996) in an isotopic study with ³²P and ³⁵S.

Field experiments conducted on greengram in sandy loam soil (Udic ustochrepts) with different doses of S indicated that, seed and haulm yield of green gram were enhanced significantly with S application up to 60 kg S ha⁻¹ (Naidu and Ram, 1996). Similar findings were also reported by Naphade and Wankhade (1987), Misra (1995) and Tiwari (1997).

Singh *et al.* (1997) conducted a field experiment in sandy loam soil on sulphur fertilization in Uttar Pradesh on summer moong revealed that, application of S at 30 kg ha⁻¹ significantly increased the grain yield .

An experiment conducted on acid alfisol of Bihar plateau showed that, increasing levels of S application up to 24 kg ha⁻¹ significantly increased the straw and grain yields of blackgram (Surendra Singh *et al.*, 1998).

Field experiments conducted at National Pulses Research Centre, Vamban, Tamil Nadu, in sandy clay loam soil by Srinivasan *et al.* (2000) to find the best source and level of S on blackgram indicated that, sulphur at 40 kg ha⁻¹ as gypsum registered 1245 kg ha⁻¹ and 979 kg ha⁻¹ of grain yield during kharif and rabi seasons respectively, which was 25.2 % and 19.3% increased yield over pyrite and elemental sulphur.

Field experiments conducted by Jagadeeswaran *et al.* (2001) on calcareous red soil (Udic ustochrept) of Coimbatore on groundnut revealed that, the highest pod yield was recorded with gypsum at 400 kg ha⁻¹ and FeSO₄ at 50 kg ha⁻¹.

Srinivasan and Sankaran (2001) reported that, application of S at 30 kg ha⁻¹ in the form of gypsum proved to be the best sulphur management practice for irrigated blackgram in red sandy clay loam soils with high benefit cost ratio.

Subramanian *et al.* (2005) reported that, the combination of S with micronutrient fertilizers increased the grain and haulm yields of blackgram over control to the tune of 10-17 % depending on the nutrient combinations.

2.5. Sulphur on yield attributes

Dube and Mishra (1970) reported that, in black gram, S deficiency caused a reduction in the number of branches per plant. There was little fruit setting and uneven maturity observed. The number of seeds per pod was less and protein content was found to be low in S deficient plants.

Field experiments conducted by Singh *et al.* (1994) to study the effect of S on growth and yield of summer moong in sandy loam alkaline soils of Faizabad showed that, the plant height, test weight and number of pods per plant were found to be increased continuously and significantly with increasing levels of S up to 40 kg ha⁻¹ at all the stages of crop growth.

Field experiments conducted on sandy loam soil (Udic ustochrepts) of Varanasi by Naidu and Ram (1996) on the effect of sulphur on grain yield of green gram indicated that, S at 40 kg ha⁻¹ produced greater number of pods as well as seed yield.

Potkile and Bobde (1996) conducted experiments in clayey soils, to study the effect of P and S on yield and quality of soybean reported that, the highest number of seeds per pod and 1000 seed weight were found to be higher in the treatment which received 40 kg S + 50 kg P ha⁻¹. Phosphorus and S at higher levels showed antagonistic effects.

Sharma and Singh (1997) conducted field experiments in silty loam soil of Uttar Pradesh and concluded that, S application at 40 kg ha⁻¹ significantly increased the plant height and number of branches per plant. The leaf area was significantly increased due to application of 40 kg S ha⁻¹ as reported by Potkile and Bobde, (1996a). Increase in plant height with P₂O₅ and S application was also reported by Ankomah and Osci (1992) and Prasad *et al.* (1991) in soybean.

2.6. Sulphur on nutrient content of plants

A green house pot culture experiment conducted to study the interaction effect of P and S on nutrient content of moong in a loamy sand soil showed that, S application reduced the P content of both straw and grains of greengram. Application of 40 ppm S depressed the P content of vegetative portion and grains of moong by 18 and 12 per cent respectively. At all levels of applied P and S, accumulation of these nutrients was found to be comparatively higher in grain than in straw (Aulakh and Pasricha, 1977).

Pareek *et al.* (1978) in a study on effect of S on blackgram on calcareous soils reported that, the increase in sulphur content was associated with increase in N, K contents. Contents of P, Ca were not affected due to S application.

Sacchidanand *et al.* (1980) reported that, application of S and P significantly increased the S and P content in soybean. S content increased with higher doses over control at all stages of growth except, at harvesting stage. S application enhanced P content of soybean significantly only at harvesting.

Pot experiment conducted by Bapat *et al.* (1986) in sandy clay loam soil of Madhya Pradesh, to study the effect S and P on nutrient content of blackgram showed that, a significant increase in sulphur content in plant was observed by the application of S up to 75 ppm level. Phosphorus application up to 50 ppm enhanced the S content whereas, 75 ppm level found to reduce the S content. The greater proportion of total S was found to present in protein form under low S levels while, non-protein S found to accumulate with higher doses (Aulakh *et al.*, 1976).

A green house study conducted by Singh and Singh (1990) on sandy loam soil to study the effect of S, Mg and K on yield and nutrient uptake by linseed showed that, application of S and K significantly increased the S content whereas, application of Mg decreased the S content of linseed grain. The concentration of K in linseed grain increased significantly by the S application.

Field experiments conducted during kharif 1985 and 1986, to study the effect of S on yield and leaf S content in soybean by Habeebullah and Francis (1991) on red sandy loam soil, Coimbatore showed that, the leaf S content was significantly influenced by different levels of S in both the seasons. Among the sources, potassium sulphate registered the highest leaf S content during kharif 1985 and super phosphate during kharif 1986.

Kandpal and Chandel (1993) studied the effect of gypsum and pyrite on soybean and reported that, the S content of grain increased significantly with an increase in the level of S and the highest S content was at 40 kg S ha⁻¹ as gypsum which was on par with 40 kg as pyrite and remained significantly greater than rest of treatments.

A field experiment conducted by Jagee *et al.* (1995) on linseed in a silty clay loam soil reported that, under field conditions, S application at 20 kg ha⁻¹ increased the N, P and S concentration at flowering, pod formation and harvesting stages.

Field experiments conducted by Ganeshamurthy (1996) in vertic ustochrepts of Madhya Pradesh on Soybean showed that, the S content in soybean grain and straw increased with S application at all the stages even up to 60 kg S ha⁻¹.

Field experiment on sandy loam soils of Uttar Pradesh on blackgram revealed that, S application increased S and P content in seed as well as in straw. Total P content increased with applied P and decreased with S application. Application of 60 kg S in combination with 90 kg P ha⁻¹ gave higher P content in both grain and straw (Singh and Singh, 2004).

2.7. Sulphur on nutrient uptake

An investigation carried out in green house to study the direct and residual effect of S and Mg application in a crop sequence consisting of two legumes, and an oil seed

crop (cowpea – mustard - moong) in alluvial soils by Nad and Goswami (1983) revealed that, the uptake of both S and Mg significantly increased with their increased level of applications in all the soils.

In a green house study conducted by Singh and Singh (1990) to study the effect of S, Mg and K on yield and uptake of nutrients by linseed on sandy loam soils of Uttar Pradesh showed that, there was a significant increase in S uptake by linseed grain due to increasing levels of S application. Magnesium addition significantly decreased the uptake of S over control. The uptake of S was greater in plants supplied with K.

Field experiment conducted on soybean, greengram, blackgram and cowpea with four levels of S, in alluvial soils of Gwalior by Bansal (1991) indicated that, the uptake of N, P, K and S increased with increasing levels of S. The uptake of N, P and K was observed to be higher with the application of 80 kg S ha⁻¹.

Field study conducted by Hariram and Dwivedi (1992) on sulphur source on uptake of some of the nutrients by chickpea found that, the uptake of N, P and K due to S application was significantly higher than control. Maximum uptakes of N, P and K were recorded through application of gypsum. Elemental S proved inferior to other two sources of S.

Response studies of blackgram to sulphur on acid alfioils of Bihar plateau by Surendra Singh *et al.* (1998) suggested that, the sulphur uptake by straw and grain of the crop showed significant increase up to 24 kg S ha⁻¹ level.

Field experiment conducted on sandy loam soil of Uttar Pradesh, to find the interaction effect of S and P on growth of blackgram by Singh and Singh (2004) revealed that, application of S through gypsum significantly increased the uptake of P. The highest uptake of P in grain and straw was observed when P and S were applied at 60 kg ha⁻¹ each.

2.8. Sulphur on nutrient availability

A Greenhouse experiment conducted with wet land rice (BR 4) in an inceptisol of Dhaka, to study the effect of N and S fertilization on availability of N and S in soil indicated that, application of N and S at different rates caused a marked change in

available N and S contents of soil at all stages of growth. Available N and S contents of soil decreased with growing periods and the lowest values were found at post harvest stage (Ahmed *et al.*, 1988).

Pot culture and field studies conducted by Poorani (1992) to study the interaction effect of application of P and S on available nutrients of greengram (Co 4) indicated that, soil available P and S at vegetative stage increased significantly in both pot culture and field experiments and declined subsequently as the crop advanced towards maturity. The combination of P and S at 60 kg ha⁻¹ was found to be the best in releasing P and S into soil available pool. The P and S derived from fertilizer (Pd ff) and (Sd ff) increased with the P and S levels, showing higher utilization of P and S at lower levels of its application.

Mandhata Singh *et al.* (1994) reported that, available N, P and S in sandy loam soil increased with increased rate of S application. Application of 20 kg S ha⁻¹ was found to increase the Sulphate-S content above critical level in vertisols, while in alfisols, there was increase at 40 and 60 kg S ha⁻¹ levels, as reported by Sreemannarayana and Sreenivasaraju (1994).

In a study conducted by Krishnamurthy (1994), to study the influence of S and Mg on yield and quality of Sunflower in alfisols showed that, the application of S at 45 kg ha⁻¹ significantly increased the availability of N, P, K and S at vegetative and flowering stages.

Sharma *et al.* (1995) opined that application of 30 Kg N with 60 kg S ha⁻¹ registered higher trace element content under blackgram. Soil available status was found to be decreased with increased N, P levels and increased with S application. In contrary, soil available iron increased with increasing N and P levels while decreased with increased S levels.

An incubation study on sandy soil (Fatehpur series of typic ustipsamment) and loamy soil (Nabha series of typic ustochrept) with five rates of P and S to study their effect on their availability in soils by Randhawa and Arora (1997) showed that, the available P increased significantly with increasing rates of P application and tended to decline with time up to 30 days. Sulphur increased the available P form, native as well as applied source. Available S increased significantly with its increasing rates and increase in incubation period. The increasing rates of P also increased the available S.

Field experiment conducted in sandy loam soils of Orissa, by Jena *et al.* (2006) to study the effect of sources and levels of S on groundnut - rice cropping system revealed that, irrespective of the sources, the available S increased with increasing levels of S. The available S in soil was found to be higher in elemental S than gypsum treatment.

2.9. Sulphur on Protein content

Pot experiments conducted with sandy loam soil of Ludhiana by Chopra and Kanwar (1966) on groundnut and berseem found that the application of S in combination with N, NP and NPK increased the total protein content as well as the amount of S containing amino acids in groundnut. The effect was in the order of NPK >NP>N and it also increased with the increased dose of sulphur with other nutrients. The protein content and S containing amino acids in groundnut kernel were highly correlated.

Field experiments conducted by Kamat *et al.* (1981) in vertisols of Akola, Maharashtra, on greengram showed that, application of S at 30 kg ha⁻¹ significantly increased the protein content of greengram grains. The cystine and methionine contents of the grains were also tended to increase with S application. They also opined that, the significant increase in protein content of greengram, as a result of application of S is due to greater synthesis of S containing amino acids.

Kasthuri *et al.* (1992) suggested that, both elemental sulphur and gypsum increased the protein content of blackgram grains. The amount of methionine content of blackgram was not affected by the application of sulphur in both the forms. Elemental sulphur at 55kg ha⁻¹ significantly increased the protein content of grains.

Field experiments conducted on sandy loam soils of Kanpur to study the effect of source and level of sulphur on grain quality of chickpea revealed that, protein and methionine contents were found to be increased due to S application. The maximum protein and amino acid contents were recorded with application of gypsum. They found that gypsum at 40 kg S ha⁻¹ was the best in increasing the nutritional quality of chickpea (Hariram and Dwivedi, 1992).

Kandpal and Chandel (1993) conducted experiments on silty clay loam soils of Uttar Pradesh, on soybean and found that, application of S at 30 kg ha⁻¹ as gypsum found to enhance the protein content of soybean significantly. But, pyrites did not show any significant variation in protein and oil contents of soybean grain.

A field experiment by Surendra Singh *et al.* (1998) on sandy loam soils of Ranchi to evaluate the indigenous S sources (phosphogypsum and pyrites) on protein content of black gram revealed that, increased levels of S (36 kg ha⁻¹) had increased the protein content. Application of phosphogypsum resulted in higher protein content of blackgram grain as compared to pyrites.

Experiments conducted in sandy clay loam soils of Tamil Nadu to study the influence of different sources and levels of S application on protein content of blackgram showed that, sulphur at 40 kg ha⁻¹ through gypsum synthesized highest crude protein content of 21.8% and 20.9% during kharif and rabi respectively. The higher protein content synthesized through gypsum application contributed 9.8% and 8.7% increase over elemental S and pyrite (Srinivasan *et al.*, 2000).

2.10. Sulphur on nodulation

Nodulation of legumes is a unique character, which is affected by S application (Khandkar *et al.*, 1985). Leguminous crops have higher S requirement than cereal crops because, it increases the number of N-fixing bacteria as well as, it helps in conversion of fixed N to organic forms (Pandey, 1972).

A field experiment to study the effect of P and S fertilization on nodules of rainfed blackgram in vertisol, Madhya Pradesh by Khandkar *et al.* (1985) showed that, number of nodules per plant at forty days of growth was significantly increased by both P and S application. The interaction of P and S resulted in more nodules per plant at the levels of 60 kg P₂O₅ and 24 kg S ha⁻¹.

Field experiments conducted on sandy loam (Udic ustochrepts) soils by Naidu and Ram (1996), in Varanasi on greengram showed that, application of S at 60 kg ha⁻¹ had significantly increased the number of nodules. When S nutrition was combined with

Rhizobium inoculation, the number of nodules was increased considerably than S alone. (Pahwa, 1985)

Field trials conducted by Srinivasan *et al.* (2000) during 1995 and 1996 to evaluate the influence of S on nodulation of blackgram in alfisols with sandy clay loam texture reported that, S application had a significant role in increasing number of effective nodules per plant during both the years. Increasing levels of S up to 40 kg ha⁻¹ increased the nodule number markedly. Among the different sources of S, gypsum proved its superiority by recording the highest number of root nodules per plant over pyrite and elemental S. Similar results were reported by Singh *et al.* (1997) for summer moong in inceptisols of Uttar Pradesh.

CHAPTER III

MATERIALS AND METHODS

The details regarding the field experiment, to study the effect of different sources and levels of sulphur on yield and quality parameters of blackgram and greengram and the laboratory analytical techniques followed for soil and plant samples analysis as well as the statistical methods adopted in the present investigation are furnished in this chapter.

3.1. Field Experiment

Field experiment was conducted with blackgram (Co 5) and greengram (Co 6) at Agricultural Research Station, Bhavanisagar, Erode District, Tamil Nadu during 2006-2007 to evaluate the different sources and levels of sulphur through different S carrying fertilizers.

3.1.1 Location

The field experiment was carried out on red sandy loam soil (Irugur series – Typic ustropept), of Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu. The experimental site was located at an altitude of 256 metres above mean sea level, 11^o.19' North latitude and 77^o.08' East longitude. The experimental field was irrigated by canals from Lower Bhavani Project.

3.1.2. Season and Weather

The experiment was conducted in winter season 2006 (Dec.-March). The mean minimum and maximum temperature during the cropping season were 17°C and 34°C. The weather variables like solar radiation, minimum and maximum temperature recorded at the agro meteorological observatory in the station during the crop growth period, were taken for this study.

3.1.3. Soil Characteristics

The soil of the experimental field was red sandy loam belonging to Irugur series. Composite soil samples were collected from the experimental site, after the field preparation. The soil samples were air dried and ground to pass through 2mm sieve and

used for the analysis of various physico-chemical characteristics. The soil of the experimental site was low in organic carbon content (0.3%), neutral in pH (7.0). The EC was 0.21dSm^{-1} . The available status of N and P were medium and that of K was high in the initial soils. The available S content was 8.7 ppm, which is below the critical limit of 10 ppm. The available Ca and Mg contents were 8.5 and 3.0 c mole (p+) kg^{-1} respectively. The details of the analytical methods employed in soil and plant analysis are presented in Table 1.

3.1.4 Crops

The test crops selected for the experiments were greengram (Co 6) and blackgram (Co 5).

3.1.5. Field layout and Design

The experiment was laid out in sandy loam soil (Irugur series – Typic Ustropept), in field number NA 30 of the Northern block of Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu in an area of 0.25 acre. After preparing the field into fine tilth, the experimental area was divided into 60 equal plots of dimension $3.5 \times 3.0 \text{ m}^2$ after allowing outs on all the four sides of the field. The experimental design adopted in this experiment was Factorial Randomized Block design with single control. Ten treatments were tried for each crop with three replications. The sowing was done on 11th December, 2006 and harvested on 15th March, 2007. The layout of the field experiment is given in Fig.1

3.1.6 Treatment details

Control (NPK alone)

<u>Sources</u>		<u>Levels</u>	
M ₁	Gypsum	L ₁	10 kg ha^{-1}
M ₂	Magnesium sulphate	L ₂	20 kg ha^{-1}
M ₃	Single super phosphate	L ₃	30 kg ha^{-1}

3.1.7. Treatment combinations

- T₁ - Control (NPK)
 T₂ - S @ 10kg ha⁻¹ through gypsum (M₁L₁)
 T₃ - S @ 20kg ha⁻¹ through gypsum (M₁L₂)
 T₄ - S @ 30kg ha⁻¹ through gypsum (M₁L₃)
 T₅ - S @ 10kg ha⁻¹ through magnesium sulphate (M₂L₁)
 T₆ - S @ 20 kg ha⁻¹ through magnesium sulphate (M₂L₂)
 T₇ - S @ 30 kg ha⁻¹ through magnesium sulphate (M₂L₃)
 T₈ - S @ 10 kg ha⁻¹ through single super phosphate (M₃L₁)
 T₉ - S @ 20 kg ha⁻¹ through single super phosphate (M₃L₂)
 T₁₀ - S @ 30 kg ha⁻¹ through single super phosphate (M₃L₃)

3.2 Manuring

All the fertilizers used for the experiment viz., urea, di-ammonium phosphate, muriate of potash, gypsum, magnesium sulphate and single super phosphate were applied as basal as per the recommendations given in crop production guide. A uniform dose of 25:50:25 kg NPK ha⁻¹ was applied to all the plots. All the cultural operations and need based plant protection measures right from sowing to harvest were carried out. The various fertilizers used in the experiment and their nutrient contents are given below.

Fertilizers	Nutrient content (%)					
	N	P ₂ O ₅	K ₂ O	Ca	Mg	S
Urea	46	-	-	-	-	-
Di-Ammonium Phosphate	18	46	-	-	-	-
Muriate of Potash	-	-	60	-	-	-
Gypsum	-	-	-	32.6	-	18.6
Magnesium sulphate	-	-	-	-	9	13
Single Super Phosphate	-	16	-	-	-	13.5

3.2.1. Sources and levels of sulphur

The sulphur carrying materials viz., gypsum, magnesium sulphate and single super phosphate were quantified and applied to the different treatmental plots to achieve 10, 20 and 30 kg ha⁻¹ of S as envisaged in the treatmental schedule of the experiment.

3.3 Analysis of samples

3.3.1. Soil

Soil samples were collected from each experimental plot at three stages viz., flowering, pod development and at harvest. The collected soil samples were air dried, powdered with a mallet, sieved through 2mm sieve and stored in polythene bags for various analyses. The processed soil samples were analysed for chemical constituents viz., N, P, K, Ca, Mg and S.

3.3.2. Plant

Plant samples were collected at three stages viz., flowering, pod development and at harvest. The collected samples were shade dried and kept in a hot air oven at 60°C and ground in a willey mill (stainless steel). Powdered plant samples at the rate of 0.5 g were taken and digested with diacid and nitrogen estimations were done using the extracts. Phosphorus and potassium estimation were carried out by digesting the samples with triacid extract. Sulphur contents were estimated using 9: 4 nitric acid and perchloric acid extract. The standard procedures adopted for the various plant and soil analyses are given in Table 1.

3.4. Field observations

3.4.1. Biometric observations

Five plants were selected randomly from each plot and tagged for recording the yield parameters viz., number of pods per plant and hundred seed weight etc.

3.4.2. Number of nodules

Number of nodules was recorded at three stages viz. flowering, pod development, and at harvest.

3.4.3. Protein content

The total N content of the seeds was multiplied with the factor 6.25 to get the crude protein content since, the crude protein contains 16 % nitrogen.

3.5. Yield

3.5.1. Seed and Haulm yield

The harvested pods from each treatment plot were threshed and seed yields were sun dried, winnowed separately and the pure seed yields were recorded. Haulms were removed completely, dried under sun to a constant weight and then oven dried. The yields were recorded plot wise. Seed and haulm yields were expressed in kg ha^{-1}

3.5.2. Dry Matter Production

Five plants were removed at each sampling stage from each plot, shade dried initially and then dried in a hot air oven at 60°C for constant weight, based on which, dry matter production was calculated.

3.6. Derived parameters

3.6.1. Uptake of nutrients

Uptake of nutrients was calculated by multiplying the biomass yield (kg ha^{-1}) with corresponding nutrient concentration (per cent) of the plant at each growth stage.

3.7. Statistical Analysis

The data pertinent to seed and haulm yields, dry matter production, biometric observations and chemical determination of soil and plant samples were subjected to statistical scrutiny (Panse and Sukhatme, 1978) to find out the influence of various treatments on the availability of the nutrient in soils, nutrient contents in plant samples, uptake of nutrients, seed and haulm yields. Then possible relationships were worked out between various characters.

CHAPTER- IV

RESULTS

Field experiment was conducted on red soils (Irugur series) at Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu, to evaluate the different sources and levels of sulphur on the yield and yield attributes, dry matter production, nutrient content, nutrient uptake, available nutrients and protein content of blackgram (Co5) and greengram (Co6). Soil and plant samples were collected at flowering, pod development and at harvest and analyzed for major and secondary nutrients. The seed and haulm yield were recorded and the protein content of seeds was estimated. The results of the experiment are detailed in this chapter.

4.1. Characteristics of initial soil (Table 2)

Composite surface soil samples (0-15cm depth) collected from the experimental site and were analyzed for physical and chemical properties. The experimental site comes under the taxonomic classification of Typic ustropept – Irugur series. The texture of the soil was found to be sandy loam. The soil of the experimental site was low in organic carbon content (0.3%), neutral in pH (7.0). The EC was 0.21 dSm^{-1} . The available N, P and K were low, medium and high respectively. The available S content was 8.7 ppm which is below the critical limit. The exchangeable Ca and Mg contents were 8.5 and $3.0 \text{ c mol (p+) kg}^{-1}$ of soil respectively.

4.2. Seed yield

Blackgram (Table 3; Fig.2)

The data pertinent to the seed yield of blackgram (Co5) were subjected to statistical scrutiny and the results revealed that, the different treatments tried in this experiment had a significant influence on this parameter. The seed yield of the blackgram (Co5) ranged between 733 and 890 kg ha^{-1} for the different treatments tried. The highest seed yield of 890 kg ha^{-1} was registered under the treatment which received sulphur at the rate of 30 kg ha^{-1} through gypsum ($M_1 L_3$). However, the seed yield was found to be comparable with the treatment which received the same dose of S through single super phosphate ($M_3 L_3$). The seed yield increase was significantly higher than other two levels

of sulphur application i.e., 10 and 20 kg ha⁻¹ through gypsum and SSP and also from all the levels of S through magnesium sulphate. In all the sulphur levels, irrespective of the sources, the yield was significantly higher than control (733 kg ha⁻¹), which received only N, P and K fertilizers. Each level of sulphur has registered significantly superior seed yield, when compared to the previous lower level, irrespective of the sources.

Among the different sources of S fertilizers, gypsum and single super phosphate were found to be statistically superior to magnesium sulphate but were comparable among themselves. The treatment which received 30 kg S ha⁻¹ through magnesium sulphate has registered seed yield which was comparable with 20 kg S ha⁻¹ through gypsum and single super phosphate fertilizers.

Greengram (Table 4; Fig.3)

The greengram (Co6) seed yield for the various treatments varied from 783 to 896 kg ha⁻¹. The results of the seed yield data showed that, S application at the rate of 30 kg ha⁻¹ through SSP (M₃) has enhanced the seed yield (896 kg ha⁻¹), which was on par with the treatment which received same level of S application through gypsum (M₁). Here also, the lowest seed yield of 783 kg ha⁻¹ has registered under control.

As far as different sources and levels of S are concerned, the same sources as in the case of blackgram viz., SSP and gypsum found to be significantly superior in enhancing the seed yield than magnesium sulphate source. Irrespective of the sources, higher levels of S application enhanced the seed yield significantly.

4.3. Haulm yield

Blackgram (Table 5)

The haulm yield of blackgram (Co5) ranged between 1283 and 1423 kg ha⁻¹ for the different treatments envisaged in this experiment. The statistical analysis of the data showed that, application of S at higher dose i.e., 30 kg ha⁻¹ through single super phosphate (M₃L₃) has enhanced the haulm yield to 1423 kg ha⁻¹. But, this was on par with the haulm yield registered under the treatment which received at the same level of S (30 kg ha⁻¹) through gypsum (M₁L₃) and also at 20 kg S ha⁻¹ through SSP (M₃L₂). The lowest yield of 1283 kg ha⁻¹ was observed under the treatment which received N, P and K fertilizers alone.

The different sources of S fertilizers *viz.*, gypsum, magnesium sulphate and single super phosphate had a significant influence on the haulm yield of blackgram. Among the sources, gypsum and SSP were found to be significantly superior to magnesium sulphate and were on par among themselves. As far as the levels of S were concerned, irrespective of sources of S fertilizers, higher level of S (30 kg ha⁻¹) found to register higher haulm yield. As the level of S decreases, the haulm yield was also found to be decreasing.

Greengram (Table 6)

The statistical analysis of the haulm yield data of greengram (Co6) indicated that, at 30 kg S ha⁻¹ level of all the S fertilizers found to record higher haulm yield. Though gypsum has registered the highest haulm yield of 1640 kg ha⁻¹, it was on par with SSP and magnesium sulphate at that level of S. The lowest haulm yield was registered in control as in the case of blackgram.

Similar to blackgram haulm yield, the greengram haulm yield was also significantly influenced by levels of S application. However, it was not affected significantly by the source of S fertilizers.

4.4. Dry matter yield

Blackgram (Table 7; Fig.4)

The dry matter production of the blackgram (Co5) ranged from 1460 to 1664 kg ha⁻¹ for the different treatments tried. The results revealed that, the treatment which received S at 30 kg ha⁻¹ through gypsum found to register the highest DMP of 1664 kg ha⁻¹ which was comparable to the treatment which received S at 30 kg ha⁻¹ through single super phosphate and significantly superior over other treatments tried in this experiment. The next best treatments were the treatments which received S at 20 kg ha⁻¹ through gypsum and SSP and also at 30 kg S ha⁻¹ through magnesium sulphate. The lowest yield of 1460 kg ha⁻¹ was registered under control plot.

The different sources and levels of S had a significant influence on the DMP of blackgram. Among the different sources of S fertilizers tried, highest DMP was registered under SSP (M₃), which was comparable with gypsum (M₁) and significantly superior

over magnesium sulphate (M_2). Among the various levels of sulphur, 30 kg S ha^{-1} was found to record higher yield, irrespective of source of S fertilizers.

The crop growth stages had a significant influence on the DMP of blackgram. As the stage of the crop advances, the DMP also increased significantly irrespective of sources and levels of S fertilizers. The DMP was 1186 kg ha^{-1} at flowering stage and it was 2164 kg ha^{-1} at harvest.

Greengram (Table 8; Fig. 5)

The DMP of the greengram (Co6) ranged from 1551 to 1771 kg ha^{-1} for the various treatments tried. The results of the DMP of greengram showed that, the different treatments tried sources and levels of S and also the stages of the crop had a significant influence on it. The trend was similar to that of DMP of blackgram.

4.5. Plant nitrogen content

4.5. Blackgram (Table 9)

The statistical analysis of the data on plant N content revealed, that different treatments had a significant influence on this parameter. The highest value of 1.49 per cent was registered in both the plots received S at 30 kg ha^{-1} through gypsum (M_1L_3) and SSP (M_3L_3). However, it was on par with plots received S at 30 kg ha^{-1} as magnesium sulphate (M_2L_3).

There was no significant variation observed among the different sources. Irrespective of the sources, there was an increase in N content of the plant with increased level of S application.

The different growth stages also significantly influenced the plant N content. As the growth stages advances, there was a significant decrease in N content in blackgram from 1.72 per cent at flowering to 0.97 per cent at harvest.

Greengram (Table 10)

Similar trend as that of blackgram has been noticed with reference to plant N content in greengram (Co6). Higher values were registered in the plots treated with S at 30 kg ha^{-1} as SSP (1.49 per cent), which was on par with the treatment which received of S application at 30 kg ha^{-1} as gypsum (1.46 per cent).

The different sources had no significant influence on plant N content. However, the various levels of S had a significant increase in N content of greengram. Sulphur at 30 kg ha⁻¹ recorded the highest value of 1.46 per cent among different levels.

The various stages also showed a similar significant influence as in case blackgram. As the stages advanced, there was a significant reduction in plant N content.

4.6. Plant phosphorus content

Blackgram (Table 11)

The different treatments tried had a significant influence on P content of blackgram (Co5). The values ranged from 0.17 to 0.27 per cent. The highest value of 0.27 per cent was noticed in plots treated with S at 30 kg ha⁻¹ as SSP and the lowest value of 0.17 per cent was observed in the plots which received no S application but only N, P and K fertilizers.

Among the different sources, there was a significant variation in plant P content. Single super phosphate recorded the highest P content of 0.24 per cent, which was significantly superior to other two sources.

An identical trend as that of plant N was noticed in the case of plant P content. The influence of different levels of S on P content was highly significant. As the level of S increases, a corresponding significant increase in P content of the plant was noticed.

Significant variation was found to exist among the stages with respect to plant P content. As the stages advanced, there was a significant reduction in plant P content.

Greengram (Table 12)

The different treatments vary significantly in plant P content due to different sources and levels of S. The highest value of 0.26 per cent was recorded in all the plots which received S at 30 kg ha⁻¹. There was no significant difference among various sources. However, the different levels of S had a significant influence on plant P content. As the levels increased, the plant P content also got increased significantly.

The various stages of crop growth influenced the plant P content significantly as in the case of blackgram. A similar trend as that of blackgram was observed at various

stages of crop growth. The plant P content was on par in flowering and pod development stage when compared to harvest stage.

4.7. Plant potassium content

Black gram (Table 13)

The statistical scrutiny of the data on plant K content of blackgram showed that there was a significant influence of various treatments on plant K content. The highest value of 1.16 per cent was recorded in plots received S at 30 kg ha⁻¹ as SSP (M₃L₃), which was on par with S treated plots at the rate of 20 kg ha⁻¹ through magnesium sulphate (M₂L₃).

The different sources and levels significantly influenced the plant K content. Among the different sources, the highest value of 1.07 per cent plant K was recorded in SSP (M₃) treated plots.

Among the different levels, application of S at 30 kg ha⁻¹ was found to record the highest K content irrespective of the sources

Greengram (Table 14)

The results of the statistical analysis of the data pertaining to K content of greengram showed that, there was a significant influence of treatments on this parameter.

Among the treatments, plot treated with S at 30 kg ha⁻¹ through SSP (M₃L₃) has registered the highest value of 1.15 per cent.

The different sources and levels of S significantly influenced the greengram plant K content. The trend was found to be similar as in case of blackgram. Among the sources, SSP (M₃) was significantly superior to other sources and among the levels, 30 kg S ha⁻¹ (L₃) recorded significantly higher value of plant K. As the level of S increased, the plant K also increased.

Effect of stages on plant K content in greengram followed the similar trend as that of blackgram. As the stages advanced, there was a significant reduction in K content.

4.8. Plant Calcium content

Blackgram (Table 15)

The Ca content of blackgram differed significantly due to application of S and the mean value ranges from 0.91 to 1.16 per cent. The highest Ca content was observed in M₃ L₃ treatment (S at 30 kg ha⁻¹ as SSP) with 27.4 per cent increase over control followed by M₁ L₃ which is 25.2 per cent and followed by M₂ L₃ which is 24.2 per cent increase over control.

The different sources of S fertilizers had no significant variation in Ca content of the plant. There was a gradual increase in the Ca content as the S level increased, irrespective of the sources. The highest Ca content was recorded in L₃ levels compared to L₁ and L₂.

The different crop growth stages showed significant variation in the plant Ca content. As the stage advanced from flowering to harvest, the Ca content found to be decreasing significantly.

A significant interaction is seen between the various stages and sources. At flowering and pod development stages, the highest Ca content was recorded in M₂ and at harvest in M₃. Similarly a significant interaction was observed between the various stages and levels of S also. However, irrespective of all the stages, L₃ recorded the highest plant Ca content.

Greengram (Table 16)

In green gram, the mean values of calcium content varied from 0.91 to 1.18 per cent and it was positively influenced by the application of sulphur. The highest Ca content of 1.18 per cent was at 30 kg S application through SSP (M₃L₃).

Addition of S through different sources and levels also had no significant influence on this parameter. The interaction effect between sources and levels had significant influence on Ca content.

4.9. Plant magnesium content

Blackgram (Table 17)

The magnesium content of the plant attained a statistical significance among different treatmental combinations. The highest Mg content of 0.74 per cent was recorded in $M_3 L_3$ (S at 30 kg ha⁻¹ as SSP), which was on par with $M_1 L_3$ (0.72 per cent) and $M_2 L_3$ (0.71 per cent) and significantly different from other levels of S

Among the sources, SSP (M_3) was significantly superior to other two sources and among the different levels, S at 30 kg ha⁻¹ (L_3) was significantly superior to other levels. Irrespective of the sources and levels, there was a significant decrease in the plant Mg content observed from flowering to harvest stage.

Greengram (Table 18)

Similar trend was observed as that of blackgram as far as Mg content of greengram was concerned. The highest value of 0.74 per cent Mg was recorded with $M_3 L_3$ (S at 30 kg ha⁻¹ as SSP) and the lowest value was recorded in control.

4.10. Plant sulphur content

Blackgram (Table 19)

The S content was significantly altered among the treatments. The highest S content was observed in $M_3 L_3$ and $M_1 L_3$ (0.24 per cent) followed by $M_2 L_3$ and $M_3 L_2$ (0.23 per cent).

Among the different sources, M_3 recorded the highest plant S content in all the stages. S application at the rate of 30 kg ha⁻¹ has registered significantly higher value of 0.24 per cent and the lowest value of 0.19 per cent was recorded in 10 kg S ha⁻¹ level.

Among the various crop growth stages, irrespective of sources and levels, there was a significant decrease in S content of plant, as the stages advance towards harvest. During flowering stage, both $M_1 L_3$ and $M_3 L_3$ (S at 30 kg ha⁻¹ as SSP and gypsum respectively) recorded highest S content (0.34 per cent).

Greengram (Table 20)

The S content of the greengram for the different treatments ranged from 0.19 to 0.24 per cent. Similar trend as that of blackgram was also observed here. The interaction effect was found to be insignificant.

4.11. Seed N content

Blackgram (Table 21)

The different treatments varied significantly in seed N content of blackgram. The highest seed N content of 3.55 per cent was recorded under S applied at 30 kg ha⁻¹ through SSP (M₃L₃), which was on par with the sulphur content of 3.53 per cent in the plots which received S at 30 kg ha⁻¹ as gypsum (M₁L₃).

There was no significant variation in seed N content on different sources of S. The seed N content of L₂ and L₃ (S at 20 and 30 kg ha⁻¹ respectively) was on par and was significantly higher than that of L₁ (10kg ha⁻¹). The interaction effect was found to be insignificant.

Greengram (Table 22)

A similar trend was recorded in case of greengram also as far as the N content of seed is concerned. The highest seed N content of 3.83 per cent was recorded in M₃L₃ (S at 30 kg ha⁻¹ as SSP).

Different sources of S did not show any significant variation but S at 30 kg ha⁻¹ produced significantly higher seed N content (3.74 per cent) than all other levels.

4.12. Seed phosphorus content

Blackgram (Table 23)

The seed P content was increased significantly from 0.32 to 0.37 per cent for the various treatments tried in this experiment. The higher seed P content was observed in M₃L₃ (0.37 per cent) followed by M₁L₃ and M₃L₁ (0.35 per cent).

There was a significant influence on the different sources of S on seed P content. The highest seed P content 0.35 percent was observed in SSP (M₃) which was on par with gypsum (M₁) with a value of 0.34 per cent.

Greengram (Table 24)

In greengram, there was no significant variation observed among the different treatments on seed P content.

4.13. Seed potassium content

Blackgram (Table 25)

There is no significant difference in the seed K content among various treatments. Among the different levels, L₂ (S at 20 kg ha⁻¹) showed higher seed K content of 1.51 per cent which was on par with L₃ (1.49 per cent).

The interaction between sources and levels was found to be non significant.

Greengram (Table 26)

There was no significant variation observed in seed K content due to S application. Among the sources, SSP (M₃) and gypsum (M₁) were on par. However, the different levels were found to be non significant.

4.14. Seed calcium content

Blackgram (Table 27)

There was a significant variation observed due to the different treatments. Among the various treatments, the highest seed Ca content was observed in M₂ L₃ (1.51 per cent) and was on par with that of M₃ L₃ (1.50 per cent) and M₁ L₃ (1.49 per cent).

There was no significant variation in seed Ca content due to different sources of S fertilizers. However, a significant variation noticed among various levels. Among the different levels of S, L₃ recorded significantly higher seed Ca content. As the levels of S increases, Ca content also increases. The interaction among sources and levels did not show any significance on Ca content of seed.

Greengram (Table 28)

In greengram, the mean values of Ca content varied from 1.43 to 1.53 per cent and it was positively influenced by the application of sulphur. The highest Ca content of 1.53 per cent was observed at 30 kg S application through SSP.

Addition of S through different sources and levels also had significant influence on Ca content. The highest Ca content of 1.50 per cent was registered from both SSP and gypsum treated plots. However, the interaction could not register a significant effect among different sources and levels of S application.

4.17. Seed magnesium content

Blackgram (Table 29)

Statistically significant variation observed in seed Mg content of different treatments. Among the treatments, the Mg content was higher in M₂L₃ (0.29 per cent).

There observed a significant variation among the different S sources. Of all the sources, M₂ (magnesium sulphate treated plots) recorded highest Mg content which was significantly higher (0.29 per cent) than SSP (0.25 per cent) and gypsum (0.23 per cent).

Among the different levels of S, there was a significant variation. Of all the levels, L₃ was found to be statistically significant and higher than other levels. As the level increased, the Mg content was also increased. There was no significant interaction observed among the sources and levels.

Greengram (Table 30)

Similar trend was observed in greengram also as far as the Mg content of seeds is concerned. The highest value of 0.29 per cent Mg was recorded with M₂L₃ (S at 30 kg ha⁻¹ through magnesium sulphate).

Similar to blackgram, the Mg content increased significantly with the increase in the levels of S and the maximum value was recorded with 30kg S level (0.26 per cent). The different combinations of S sources and levels did not show any significant interaction effect of Mg content.

4.18. Seed sulphur content

Blackgram (Table 31)

There was a statistically significant variation observed among the different treatments. Of all the treatments, the highest seed S content of 0.45 per cent was observed in M₁L₃ and M₃L₃ and was on par with the S content of M₂L₃.

There was no significant variation noticed among the different sources. Various levels differed significantly. As the level of S increases, there was an increased seed S content. Of all the levels, L₃ recorded the highest seed S content. Here also, the interaction effect was found to be non significant.

Greengram (Table 32)

The S content of greengram responded favourably for S application. Among the treatments, S at 30 kg ha⁻¹ through gypsum and SSP registered the highest values of 0.40 per cent.

The effect of different sources on plant S content was non significant, but the different levels of S, significantly increased the S content irrespective of the sources.

4.19. Nitrogen uptake

Blackgram (Table 33; Fig.6)

The nitrogen uptake values for the various treatments ranged from 19.98 to 30.27 kg ha⁻¹ for the different treatments envisaged in the experiment. The analysis of the data showed that, the various treatments had a significant influence on N uptake of blackgram (Co5). Similar to seed yield of blackgram, the uptake of N was also higher under the treatment which received S at 30 kg ha⁻¹ through SSP and gypsum followed by S at 30 kg ha⁻¹ through magnesium sulphate and S at 20 kg ha⁻¹ through gypsum and SSP. The lowest value of 19.98 kg ha⁻¹ was registered under the treatment which received no S application.

Among the sources, irrespective of levels, gypsum and SSP found to be significantly superior to magnesium sulphate source. As far as levels of S were concerned, the uptake of N was higher with higher levels of S. The uptake of N was highest at harvest stage which has a significantly higher value than the values at the other stages.

Greengram (Table 34; Fig.7)

As far as nitrogen uptake of greengram (Co6) is concerned, a similar trend as that of N uptake of blackgram (Co5) was observed.

4.20. Phosphorus Uptake

Blackgram (Table 35; Fig.6)

The statistical scrutiny of the data pertinent to uptake of phosphorus by blackgram (Co5) showed that, application of S at the rate of 30 kg ha⁻¹ through single super phosphate (M₃L₃) has registered the significantly higher value of 4.71 kg ha⁻¹. The uptake values of phosphorus under the same level of S through gypsum (M₁L₃) and magnesium sulphate (M₂L₃) were found to be on par with each other and significantly lower uptake than (M₃L₃) treatment. The lowest value of 2.83 kg ha⁻¹ of phosphorus uptake was registered under the treatment which received only N, P and K fertilizers and no S fertilization.

The different sources and levels of S fertilizers had a significant effect on the phosphorus uptake of blackgram. Among the different sources of S fertilizers tried, SSP found to be significantly superior over other two sources, irrespective of the levels of S application. The uptake of P found to increase with increase in S levels. As the stage of the crop advances, the uptake values were found to be increased. The highest values were registered at harvest.

Greengram (Table 36; Fig.7)

The results of the uptake of P by greengram (Co6) indicated that, all the S fertilizers *viz.*, gypsum, magnesium sulphate and SSP at 30 kg S ha⁻¹ found to register significantly higher uptake than other levels of S application, but were comparable among themselves. The lowest value of 3.51 kg ha⁻¹ was registered under control.

The different sources of S fertilizers had no significant influence on the P uptake of greengram crop. However, the various levels had a significant influence on this parameter. Irrespective of the source, the higher levels of S showed higher uptake of P. As in the case of N uptake, the P uptake values were significantly higher at harvest. The values at each stage were significantly superior compared to their preceding stage of the crop.

4.21. Potassium Uptake

Blackgram (Table 37; Fig.6)

The potassium uptake value of the blackgram (Co5) for the different treatments varied between 15.43 and 19.94 kg ha⁻¹. Among the treatments tried, S application at the rate of 30 kg ha⁻¹ through SSP (M₃L₃) found to register significantly higher uptake of 19.94 kg ha⁻¹. However, the uptake value of this treatment was comparable with the plot

that received S at 30 kg ha⁻¹ through gypsum (M₁L₃) and significantly different from all other treatments. The lowest value of 15.43 kg ha⁻¹ was registered in the treatment which received only N, P and K fertilizers and no S fertilization.

The different sources and levels of S had a significant influence on this character. Irrespective of levels, gypsum and SSP were found to be significantly superior to magnesium sulphate and were on par with themselves. Whatever may be the source of S fertilization, the higher level of S had a significant influence than the lower levels of S application. As in the case of N and P uptake values, the uptake values of K were also found to increase significantly with advancement in crop growth stages. The highest values were registered at harvest in all the treatments tried.

Greengram (Table 38; Fig.7)

The uptake values of K for the greengram crop (Co6) were ranged from 16.59 to 21.03 kg ha⁻¹. The results revealed a similar trend as that of the blackgram crop.

4.22. Calcium uptake

Blackgram (Table 39; Fig.8)

The data pertained to the calcium uptake the blackgram crop (Co5) were subjected to statistical analysis and the results showed that, the different treatments tried had a significant influence on this parameters. The uptake values ranged between 16.18 kg ha⁻¹ in control and 20.18 kg ha⁻¹ in the treatment, which received S at 30 kg ha⁻¹ through SSP. Sulphur application at the higher level (30 kg ha⁻¹) in all the sources were registered significantly higher uptake than rest of the treatment, but were on par among them. As in the case of N P and K, the uptake values of Ca were lower in control treatment.

Though the interaction effect of sources and levels was non significant, at each level of S application, SSP found to register significantly higher uptake followed by gypsum and the lowest uptake values were registered in magnesium sulphate treatments. Irrespective of sources, higher levels significantly enhanced the Ca uptake of blackgram crop.

The different stages also had a significant influence on the uptake of Ca. As in the case of other nutrients, the uptake values were significantly higher at each stage compared to the preceding stage irrespective of treatments.

Greengram (Table 40; Fig.9)

The statistical analysis of the uptake values of Ca uptake on greengram (Co6) indicated the similar results as that of blackgram Ca uptake. However, the Ca uptake values pertinent to greengram were higher than the blackgram. The values varied from 17.09 kg ha⁻¹ under control to 21.25 kg ha⁻¹ under the treatment which received S at 30 kg ha⁻¹ through SSP.

4.23. Magnesium uptake

Blackgram (Table 41; Fig.8)

The magnesium uptake values of the various treatments tried in this experiment ranged between 8.22 and 10.89 kg ha⁻¹. The different treatments tried had a significant influence on the Mg uptake by the blackgram crop (Co5). More or less similar trend as that of Ca uptake was observed for this parameter.

Irrespective of the sources of S fertilizers, higher S levels had registered significantly higher Mg uptake values. As the stage of the crop advances, the uptake values were also significantly increased from the preceding stage.

Greengram (Table 42; Fig.9)

The uptake values of Mg for the greengram (Co6) ranged from 8.93 to 11.59 kg ha⁻¹. The treatments had a significant effect on the Mg uptake of the greengram crop.

The trend was similar as for as sources, levels and stages are concerned as that of blackgram.

4.24. Sulphur uptake

Blackgram (Table 43; Fig.8)

The uptake values of sulphur pertaining to blackgram (Co5) were subjected to statistical analysis. The results indicated that, the various treatments tried in this experiment had a significant influence on this parameter. The uptake values at 30 kg S ha⁻¹ through gypsum, magnesium sulphate and SSP were comparable among themselves and significantly higher than rest of the treatments. The treatment which received 20 kg S ha⁻¹ through, gypsum and SSP sources were found to be on par and magnesium sulphate in

turn on par with gypsum and registered significantly lower S uptake than SSP. The lowest value of 2.97 kg ha⁻¹ was registered under the treatment, which received only N, P and K fertilizers.

As far as sources are concerned, each source influenced significantly the uptake of S. Among the sources, SSP found to be significantly superior followed by gypsum and the lowest uptake values were registered under magnesium sulphate treatment irrespective of levels of S application.

The different levels of S application had also a significant influence on the S uptake of blackgram. The S uptake was found to be significantly higher with the higher levels of S application.

Like other nutrients, the uptake of S also found to be significantly higher at harvest compared to pod development stage which in turn registered significantly higher values than flowering stage. The various interaction effects had no significant influence on this parameter.

Greengram (Table 44; Fig.9)

The uptake values of S for the greengram crop (Co6) ranged from 3.30 to 4.66 kg ha⁻¹ for the different treatments tried. The statistical scrutiny of the data showed a similar trend as that of S uptake of blackgram. The different interaction effects were found to be insignificant as far as S uptake is concerned.

4.25. Available N

Blackgram (Table 45)

The data pertaining to available N in soil at various stages were subjected to statistical analysis and the results revealed that, among the various treatments tried, were on par in all the treatments. However, different stages had a significant influence on the available N.

The different sulphur fertilizers and various levels had no significant influence on the available nitrogen. However, the different stages had influence on the available N. As the stages advanced, the available N content in the soil was found to reduce significantly.

Greengram (Table 46)

The results of the available N showed that, the different treatments had no significant influence on available N.

The different growth stages showed a significant influence on the available N status. As the stage advanced, there was a decline in the available N status of the soil.

4.26. Available P

Blackgram (Table 47)

The statistical analysis of the data on available P showed that the highest value of 19.44 kg ha⁻¹ of P obtained from control plot which was on par with M₁ L₁ (18.77 kg ha⁻¹), M₂L₁ (18.81 kg ha⁻¹) and M₃L₁ (18.67 kg ha⁻¹) and significantly different from other treatments.

The different sources and levels had no significant influence on available P. There was a significant reduction in the available P as the crop growth advanced from flowering to pod development stage, thereafter the reduction was not significant.

Greengram (Table 48)

The available P content of soil in greengram was similar as in case of blackgram. The highest available P was registered under control plot (19.27 kg ha⁻¹).

The different sources and levels of S had no significant influence on available P status. The different stages of plant growth showed a significant variation among the various treatments on available P status. All the stages indicated a significant difference among themselves.

4.27. Available K

Blackgram (Table 49)

The statistical analysis of the data on available K showed that, the highest value of 364.6 kg ha⁻¹ was obtained in the control plot. However, all the treatments were on par.

A non significant influence of sources on available K was noticed. However, the different levels of S had a significant influence on available K in soil. As the S dose increased, the available K reduced significantly.

However, a significantly declining trend in available K was noticed as the growth stages advanced from flowering to harvest. The highest K content was noticed in L₁ (plots received S at 10 kg ha⁻¹), irrespective of the stages.

Greengram (Table 50)

Similar trend was noticed in available K as in the case of blackgram. Among the levels, S at 10 kg ha⁻¹ showed highest available K (362.2 kg K ha⁻¹) in soil. However, as the level of S increases, there was a significant reduction in K status in soil.

4.27. Exchangeable Ca

Blackgram (Table 51)

There was a significant influence on the soil exchangeable Ca due to application of S. The highest value of 8.75 c mol (p+) kg⁻¹ of soil was obtained from M₁ L₃.

A significant influence of sources of S on exchangeable Ca was noticed. Among the different sources, M₁ (gypsum) showed higher exchangeable Ca, which was significantly higher than other two sources.

Among the different levels of S, L₃ recorded the highest value of 7.43 c mol (P⁺) kg⁻¹ of soil exchangeable calcium. As the level of S increased, there was a significant increase in exchangeable Ca in soil. There was a reduction in exchangeable Ca as the stage of the crop advanced. There exists a non significant relationship from flowering to pod development stage. However, thereafter the Ca content reduced significantly.

There was a significant interaction noticed between the stages and sources. Irrespective of all the stages, M₁ (gypsum) showed higher exchangeable Ca content in soil.

Greengram (Table 52)

Similar to blackgram, in greengram also, the different treatments had significant influence on exchangeable Ca in soils. The highest value of 8.96 c mol (p+) kg⁻¹ of Ca was noticed under the treatment which received S at 30 kg ha⁻¹ as gypsum.

Among the sources, gypsum was found to be significantly superior to other sources, and as far as the levels are concerned, application of S at 30 kg found to be

superior to other levels. In case of green gram, a significant interaction between sources and levels of S at various stages was observed.

4.28. Exchangeable Mg

Blackgram (Table 53)

There was a significant influence in the soil exchangeable Mg due to different treatments tried in this experiment. The highest value of 3.24 c mol (p⁺) kg⁻¹ of exchangeable Mg was recorded in M₂ L₃ (S at 30 kg ha⁻¹ as magnesium sulphate)

Different sources had a significant influence on exchangeable Mg in soil. M₂ (Magnesium sulphate) has registered the highest value of 3.05 c mol (p⁺) kg⁻¹ of exchangeable Mg in soil, which was significantly higher than other two sources.

The influence of levels of S, on exchangeable Mg followed the same trend as that of exchangeable Ca. The highest value of 2.44 c mol (p⁺) kg⁻¹ of soil was noticed in L₃. A non significant effect of Mg on stages was noticed.

Greengram (Table 54)

There was a significant influence in the soil exchangeable Mg due to different treatments. The highest value of 3.19 c mol (p⁺) kg⁻¹ was recorded in S applied plots at 30 kg ha⁻¹ as magnesium sulphate (M₂L₃)

Among the different sources, magnesium sulphate (M₂) produced the highest soil exchangeable Mg of 3.0 c mol (p⁺) kg⁻¹ of soil which was significantly superior to other sources.

A significant interaction among the different sources and levels of S at different stages was noticed. As the stage advanced, there was a significant reduction in exchangeable Mg in soil was observed.

4.29. Available S

Blackgram (Table 55)

The statistical analysis of available S showed that, there was a significant influence of treatments on soil available S. Of all the treatments, M₂ L₃ recorded a highest value of 10.24 ppm of S. However, it was on par with M₃ L₃ (10.12 ppm) and M₁ L₃ (9.96 ppm).

The effect of different sources and levels of S, on soil available S was significant. Among the different sources, M₂ (magnesium sulphate) recorded significantly higher soil S availability than other two sources.

Among the different levels, L₃ recorded a maximum of 10.11 ppm of S in soil. A significant influence of soil available S at various stages of growth was observed. As the stages advanced, there was a significant reduction in soil available S.

There was a significant interaction among the stages and levels of S on soil available S. In all the stages, L₃ recorded the maximum soil available S.

Greengram (Table 56)

Different treatments tried had a significant influence on soil available S on greengram. An identical trend was observed in greengram as that of blackgram as far as the available S content was concerned. The highest value of 10.28 ppm of available S was noticed under S applied at 30 kg ha⁻¹ as magnesium sulphate (M₂S₃).

Among the different sources, magnesium sulphate (M₂) recorded highest available S in soil (9.75 ppm). However, it was on par with other sources. Among the different levels, S application at 30 kg ha⁻¹ (L₃) recorded highest available S in soil (10.18 ppm).

There was no significant interaction found among different stages, sources and levels of S on available S content in greengram.

4.30. Protein content

Blackgram (Table 57; Fig.10)

The results pertaining to seed protein content were found to be statistically significant. There was a significant variation in seed protein content among the treatments, which ranged from 20.79 (M₂ L₁) to 22.17 per cent (M₃ L₃). Among the treatments, a maximum of 22.17 per cent of protein was recorded in the treatment, M₃L₃ (30 kg S ha⁻¹ as SSP) followed by M₁ L₃ (22.06%) then by M₃ L₂ (21.54%) and then by M₂L₂ (21.56%).

Among the levels, L₂ and L₃ were on par and significantly superior to L₁. Among the sources, there was no significant variation noticed in seed protein content.

Irrespective of the sources of S, the increased level of S application has enhanced the protein content of the blackgram.

Greengram (Table 58; Fig.11)

There was a significant variation in seed protein content among the treatments tried in greengram, which ranged from 21.83 (control) to 23.96 per cent (M_3L_3). Among the treatments, a maximum of 23.96 per cent of protein was recorded by M_3L_3 (30 kg S ha^{-1} as SSP) followed by M_1L_3 (23.15 per cent). The levels L_2 and L_3 were on par and significantly superior to L_1 . Irrespective of the sources of S, the increased level of S application has enhanced the protein content of the greengram also.

4.31. Number of nodules per plant

Blackgram (Table 59; Fig.12)

The results pertaining to the number of nodules per plant in blackgram (Co5) showed that, higher level of S (30 kg ha^{-1}) through gypsum and SSP found to register significantly higher numbers of nodules per plant than rest of the treatments, followed by the treatments which received 20 kg S ha^{-1} through the above sources and 30 kg S ha^{-1} through magnesium sulphate. The lowest value of 26.20 was observed under control.

Among the different sources of sulphur, gypsum and SSP found to register significantly higher number of pods irrespective of levels of S. As far as S levels are concerned, higher number of pods per plant was observed with higher level of S application irrespective of the sources. Number of nodules found to be significantly higher at harvest than flowering stage but on par with pod development stage.

Greengram (Table 60; Fig.13)

The results on the number of pods per plant with respect to greengram (Co6) also indicated the significant influence of various treatments tried in this experiment. The values ranged between 25.51 and 33.29. The number of nodules per plant paralleled the S levels. Among the sources of S fertilizers, as reported for blackgram, gypsum and SSP were found to be significantly superior to magnesium sulphate. Irrespective of levels of S as far as stages were concerned, similar trend as that of blackgram was observed.

4.32. Number of pods per plant

Blackgram (Table 61; Fig.14)

The number of pods per plant varied between 33.53 and 41.33 for the various treatments envisaged in this experiment. A significant influence was noticed among the various treatments envisaged in the experiment on this parameter. Sulphur at 30 kg ha⁻¹ through gypsum had registered the highest value and the lowest value was observed in the treatment, which received no sulphur and only N, P and K fertilizers.

The sources and levels of S also had a significant effect on this character. Irrespective of the levels, gypsum and SSP had recorded significantly higher numbers than magnesium sulphate treatment. Irrespective of sources, the higher levels of S had registered higher number of pods per plant.

Greengram (Table 62; Fig.15)

The statistical analysis of the data pertinent to number of pods per plant of green gram (Co6) indicated a similar trend as that of blackgram with respect to different treatments, sources and levels of sulphur.

4.33. Hundred Seed Weight

Blackgram (Table 63; Fig.16)

The hundred seed weight of blackgram (Co5) varied between 5.13 and 5.69 g. The data on hundred seed weight were subjected to statistical security and the results indicated that, the treatment which received S at 30 kg ha⁻¹ through gypsum had registered the significantly highest 100 seed weight of 5.69 g than other treatments, but was comparable to the same level of S application through SSP (M₃ S₃). The lowest 100 seed weight was registered under the treatment, which received only N, P and K fertilizers.

The different sources of S fertilizers had no significant influence on the 100 seed weight. However, the different levels of S had a significant influence on this parameter. The results showed that, as the level of S application increased, the 100 seed weight also increased significantly. The highest 100 seed weight of 5.62 g was registered under the treatment, which received 30 kg S ha⁻¹ and the lowest value of 5.28 g was observed under the treatment which had 10 kg S ha⁻¹.

Greengram (Table 64; Fig.17)

The results of the 100 seed weight of greengram (Co6) revealed that, the different treatments tried had a significant effect on this character. The values varied between 3.02 g in control and 3.35 g in the treatment, which received S at 30 kg ha⁻¹ through gypsum (M₁L₃). The treatments which received S at highest level (30 kg ha⁻¹) had enhanced the 100 seed weight irrespective of the source of S fertilizers. The lowest value of 3.02 g was recorded under control.

The different sources of S fertilizers had no significant influence on the 100 seed weight of greengram. However, the levels had a significant effect. Sulphur at 30 kg ha⁻¹ has recorded the highest value of 3.31 g, which was significantly higher value than remaining levels of S application. Sulphur at 10 and 20 kg ha⁻¹ levels was comparable among themselves.

CHAPTER – V

DISCUSSION

The results obtained from the investigation on the effect of different sources and levels of sulphur on the seed and haulm yield, quality, nutrient contents, nutrient uptake and availability of nutrients of blackgram (Co5) and greengram (Co6) crops are discussed hereunder.

5.1. General characteristics of experimental soils

The field experiment was laid out in field No. NA 30 of Agricultural Research Station, Bhavanisagar, Erode district, Tamil Nadu. The soil was sandy loam in texture and belongs to Irugur series and sub group Typic ustropepts. The soil was neutral with a pH of 7.0. The fertility status was low, medium and high with respect to available nitrogen, phosphorus and potassium and the soils were found to be low in available sulphur.

5.2. Sulphur on yield and yield attributes

The yield level and productivity of pulses are comparatively lower than cereals. Among the factors responsible for the low yield, adequate fertilization which boosts greater uptake may be the most important one. Therefore efforts are necessary, to take care of not only the major nutrients, but also the secondary nutrients especially sulphur, the deficiency of which is quite spreading now a days. Field experiment was carried out to evaluate the different sources and levels of sulphur for its suitability on blackgram (Co5) and greengram (Co6).

The statistical analysis of the yield data indicated significant difference among the different fertilizers i.e., NPK alone and in combination with various sulphur fertilizers at different levels. The maximum influence was recorded with gypsum and SSP treatments at 30 kg S ha⁻¹ which resulted in an enhanced yield of 890 and 896 kg seed ha⁻¹ in blackgram and greengram respectively, registering an increase of 21.42 and 14.43 per cent over control. The beneficial role played by S on seed and haulm yield has been clearly brought out in this investigation. This might be due to the important role played by sulphur in the formation of various vitamins, enzymes and other organic components like protein (Kumar, 1983). The yield increase of pulses due to sulphur application was well

documented by many workers (Singh *et al.*, 1997; Srinivasan *et al.*, 2000; Srinivasan and Sankaran, 2001).

Increasing level of S application has produced a perceptible increase in seed yield, irrespective of sources of sulphur. Similar view emphasizing the superiority of 30 kg S ha⁻¹ has been reported earlier by many authors (Tandon, 1995; Patel *et al.*, 1992; Singh *et al.*, 1997 and Srinivasan *et al.*, 2000). However, response up to 40 kg S ha⁻¹ has been realized by Gupta and Dubey (1998).

Similarly, different S containing fertilizers play an important role in S availability to plant and in turn contribute towards higher yield. Among three S sources, both gypsum and SSP excelled and were on par in their performance over magnesium sulphate. High responses to gypsum in respect of seed yield might be due to readily available sulphate sulphur in gypsum. Similar results were already reported by many authors (Sridhar *et al.*, 1985; Hariram and Dwivedi, 1992; Lal and Jaiswal, 1981). The superiority of SSP and gypsum over other sources in increasing the yield of different crops have been reported by Dalal *et al.* (1963) and Sahu and Nayak (2001) in groundnut and Subbiah and Singh (1970) in oil seed crops.

The synergistic effect of sulphur on haulm yield of greengram has been evidenced by the increased haulm yield under 30 kg S ha⁻¹ through SSP, which was on par with gypsum. Both were on par in their performances. The increase in haulm yield of greengram due to S fertilization has already reported by Naphade and Wankhade (1987), Surendra Singh *et al.* (1998) in blackgram.

Sulphur at 30 kg ha⁻¹ through gypsum produced greater number of pods as well as hundred seed weight in both blackgram (Co5) and greengram (Co6). Formation of more number of pods ultimately leads to the maximum seed yield (Kamat *et al.*, 1981). However, S at 40 kg ha⁻¹ along with Rhizobium inoculation increased the number of pods per plant as reported by Naidu and Ram (1996). Similar findings were reported by Singh *et al.* (1994) with increased levels of S up to 40 kg ha⁻¹. The superiority of sulphur treated plants on the yield contributing characters was reported by Dube and Mishra (1970). The possible reason for increase in number of pods per plant and test weight could be due

to growth of crops as influenced by sulphur application which got converted into reproductive phase at advanced stage of the crop, which endorses the results of Dwivedi *et al.* (1989) and Mishra *et al.* (1989). The crop supplied with adequate doses of S during the growth period produces the optimum number of pods and also optimize the size and length of pods due to the availability of higher amounts of photo assimilates. The increased supply of photosynthates to pods would likely provide an opportunity for seeds to grow to their full size, with an obvious increase in hundred seed weight. (Ahmad *et al.*, 2005).

5.3. Dry matter production

Healthy plants are a pre requisite in any yield maximization process. The level of growth as measured by dry matter production is more directly and significantly related with the output of the economic product. So the attempts are being made to attain balanced nutrition which will tap the maximum potential from the crops.

The highest dry matter accumulation was observed in the plots received sulphur at 30 kg ha⁻¹ through gypsum for both blackgram (Co5) and greengram (Co6). Similar results were reported by Kandpal and Chandel (1993). Dry matter accumulation increased with the advancement of crop growth stages and compared to flowering stage, the DMP in pod development stage was higher and the accumulation was steeply increased thereafter i.e., at harvest showing that, the total dry matter accumulation was nearly sigmoid in nature. The increased dry matter production due to S application was reported earlier by Singh and Singh (2004), Aulakha and Pasricha (1977) on moong bean and by Kumar and Singh (1980) on soybean. The sulphur enhances the photosynthesis and is involved in N₂ fixation by nodule bacteria due to its active role in the formation of ferredoxins, a type of nonhaem Fe-S protein that acts as an electron carrier in photosynthesis. The greater N₂ fixation could be attributed more to vegetative growth. This might be the reason for the higher DMP at harvest stage. A significant increase in total dry matter production was observed in blackgram by the application of gypsum. The same type of results was already reported by Kasthuri *et al.* (1992), Dhillon and Dev (1980) in soybean. It appears that, at early stages, the sulphur present in the soil was quite sufficient (8.7ppm) for meeting the requirement. While at later stages (at harvest)

when requirement of the plant sulphur increased, the applied S caused an improvement in the dry matter yield, as reported by Sacchidanand *et al.* (1980). The effect of sulphur in improving the dry matter yield could be attributed to the low S content of the soil which might have enhanced the availability of the fertilizer sulphur as supported by Patel *et al.* (1971).

5.4. Nutrient content

The nutrient content in the plant was significantly affected by the S application. The increase in the content of N was higher in plots received S at 30 kg ha⁻¹ through SSP and gypsum. There was a significant difference in the N content of plant at flowering stage and at harvest. When the concentration of N in different plant parts are compared, the higher accumulation of N was found in seeds due to higher translocation of nutrients from source to sink, resulting in an improvement in the very important factor, the seed protein. The increased N content may be attributed to the production of healthy plant with applied S leading to better absorption as well as translocation. The concentration at flowering significantly related to seed yield. However, in case of all the nutrients, the stages of growth had a significant influence on the nutrient content. As the stages advanced, there was a significant reduction in the plant nutrient content. The possible reason for this might be the production of dry matter yield and subsequent dilution in the plant body as reported by Sacchidanand *et al.* (1980)

The P content was also significantly affected by S application. The increase in the P content due to increased level of S application may be attributed to the strong synergistic relationship between P and S. The similar results were supported by the findings of Kumar and Singh (1980). Similarly, Sacchidanand *et al.* (1980) reported that the increased P content due to S application was significant only at flowering stage. The concentration of P at flowering and harvest varied significantly, but the magnitude was in the lower order.

The content of potassium was also found to be altered by different levels of S. The increase in K content in the crops with the increased S levels may be due to better absorption of nutrients, as the result of S application. Higher concentration of K was found to be associated with S at 30 kg ha⁻¹ through SSP and magnesium sulphate

however, this was on par with 20 kg S ha⁻¹ SSP. Similar results were reported by Aruna Geetha (2001). The increase in K contents due to S application in blackgram as reported by Parek *et al.* (1978) supports the present finding.

The Ca and Mg content of the seed and plant varied highly due to S application. As the level of S increased, there was an increase in the Ca content. The added Ca through SSP and gypsum might have contributed to the Ca pool and might have increased its availability. However, this was contrary to the results of Pareek *et al.* (1978) who reported that the Ca content of the plant was not affected due to S application.

The Mg content of both the crops was significantly altered due to S application. The highest Mg content was reported in plots received S at 30 kg ha⁻¹ through magnesium sulphate. The Mg added through magnesium sulphate might have been released to the soil, along with increased S levels. Similar increase in Mg through S addition was reported in linseed by Singh and Singh (1990) and Nad and Goswami (1983).

Irrespective of all the sources, the application of S increased the S content of the plant. The increase in the concentration of S with its application is a common feature (Aruna Geetha, 2001) and such an effect has been brought out in this study too. However, the increased S due to S addition was reported by many workers (Nad and Goswami, 1983; Pareek *et al.*, 1978). Ganeshamurty (1996) reported an increased S content in soybean seed and straw with increased S application up to 60 kg S ha⁻¹.

5.5. Nutrient uptake

5.5.1 Major nutrients

The uptake of all the nutrients *viz.*, N, P, K, Ca, Mg and S followed more or less similar trend due to sulphur application. The superiority of SSP and gypsum was well proved among the three sources in case of nutrient uptake also. At 30 kg ha⁻¹ of S application, performance of all the sources was on par. Similarly at 20 kg S ha⁻¹ also, the different sources were on par in their performance.

Production of healthy plant as a consequence of sulphur application in a deficient soil leading to better absorption of nitrogen probably is the reason for the increased N uptake due to S application. Earlier investigators, Trivedi *et al.* (1997) and Masood Ali

and Mishra (2000) have recorded substantial increase in the uptake of N with S addition in blackgram that lends support to the present observation. There were 51 and 52 per cent increased N uptake recorded for the application of S at 30 kg ha⁻¹ over control in blackgram (Co5) and greengram (Co6).

A highly profound influence for the application of sulphur on the uptake of P has been observed particularly at 30 kg S ha⁻¹ level, registering 66 and 33 per cent increase in case of blackgram and greengram respectively. The synergism existed between S and P as identified by Ram *et al.* (1998) might have contributed to the higher uptake of P through enhanced dry matter production. This is supported by the highly significant and positive relationships obtained in this study between dry matter production and P uptake, ($r = 0.95$). Increased P uptake with S addition has been visualized earlier by Khandkar and Shinde (1992) and Masood Ali and Mishra (2000).

The uptake pattern of potassium right from flowering to the harvest followed a similar trend as that of N and P with reference to the various treatments tried in both blackgram (Co5) and greengram (Co6). The beneficial role of S in enhancing the uptake of K in blackgram has been amply demonstrated earlier by Bansal (1991) and Masood Ali and Mishra (2000).

5.5.2. Secondary nutrients

As expected, the influence of S at 30 kg ha⁻¹ irrespective of sources on the uptake of S in all parts of both blackgram (Co5) and greengram (Co6) was so striking. An improvement in the S uptake to the level of 54 and 41 per cent was obtained at 30 kg S application over control in both blackgram and greengram respectively.

At the flowering stage, though the dry matter production was low, owing to high availability of S in soil due to basal application of S fertilizers, the nutrients uptake was high. In pod development stage, though the DMP was higher, the increase in S uptake was only meagre. This may be due to the dilution effect of S content in plant due to increased production of dry matter. The same is the case for other nutrients also. The same results of decreased S uptake due to dilution effect and higher drymatter production have been reported by Nabi *et al.* (1990). At harvest stage, though the S content was low, the increased production of

dry matter over shadowed the S uptake in other two stages. This is supported by the highly significant and positive relationships obtained in this study between dry matter production and S uptake at flowering ($r = 0.69$) and at pod development ($r = 0.80$) and at harvest ($r = 0.98$).

There was an increased uptake of S at higher levels of S application (10 kg to 30 kg ha⁻¹). This significant increase in S uptake due to S application could be described in terms of increased available S content of soil causing its increased absorption. Increase in S uptake due to S fertilization was reported by Sacchidanand *et al.* (1980) and Khatik *et al.* (1992). A profuse vegetative growth and higher yield due to S application might have contributed to the greater S uptake by the crops. Increased S uptake by S application might be due to low S status (8.7 ppm) of the soil which resulted in the high response of the fertilizer S added. Such results had also been reported by Das and Das (1994) and Kumar *et al.* (2001).

The S application found to have a synergistic effect on Mg uptake. There was an increased Mg uptake observed with increased levels of S from 10 to 30 kg S ha⁻¹. Similar type of synergistic relationship between S and Mg was reported by Nad and Goswami (1983). Similar increase in Mg uptake by linseed due to S application was reported by Singh and Singh (1990). Among the sources, SSP and gypsum registered higher uptake of Mg. This might be due to higher release of S from gypsum and SSP which increased the Mg uptake from the soil, due to its synergistic effect with S. Since, the release of sulphur from magnesium sulphate treated plots are low, the magnesium uptake also low. This is well corroborated with the strong and positive correlation between soil available S and Mg uptake ($r = 0.80$).

Calcium uptake also increased with sulphur application. This may be due to the high amount of dry matter production supported by the positive and significant relation between Ca uptake and dry matter production ($r = 0.98$).

5.6. Nodulation

The impact of S fertilization on nodulation was highly significant. Application of S, through gypsum and SSP at 30 kg S ha⁻¹ level registered higher number of nodules in both

blackgram (Co5) and greengram (Co6) and was found to be on par with S at 20 kg ha⁻¹, when applied through the same sources. Similar findings were reported by Srinivasan *et al.* (2000) and Pahwa (1985). The possible reason for increased nodulation under S fertilization might be the essential role played by S in the formation of leg-haemoglobin, without which there is no nitrogen fixation in legumes, which in turn cause reduction in number of nodules (Virtanen *et al.*, 1947). The highest number of nodules under the gypsum treated plots might be attributed to the readily available sulphate form of sulphur in gypsum (Pandey, 1989). Increasing levels of sulphur increased the nodule number markedly. Increased nodulation under increased S levels is due to the involvement of sulphur in the production of ferredoxin and nitrogenase enzyme which is the key factor for increasing the Rhizobium infection sites and nitrogen fixation (Kandpal and Chandel, 1993). The increased nodulation under S application up to 60 kg ha⁻¹ was also reported by Naidu and Ram, (1996).

5.7. Protein content

The results of the protein content in blackgram (Co5) and greengram (Co6) under S fertilization showed that, S at 30 kg ha⁻¹ through SSP and gypsum registered higher seed protein content. However, Ram and Dwivedi (1992) reported increased protein content up to 40 kg S ha⁻¹ through gypsum. The possible reason for high protein content under SSP is due to supply of both P and S wherein, sulphur helps in the synthesis of S containing amino acids and phosphorus in protein synthesis (Khatik *et al.*, 1992). Higher levels of S produced higher protein content which might be due to the fact that, S as an essential plant nutrient, promoted nodulation and thereby enhanced N fixation and ultimately lead to higher protein production (Naidu and Ram, 1996). These findings were in line with the findings of the earlier workers (Dwivedi *et al.*, 1988; Singh and Ram, 1990). According to Arora and Luthra (1972), the different sulphur fertilizers could make up the deficiency of sulphur containing amino acids, so that the nutritive value of protein will be increased substantially.

5.8. Nutrient availability

The results of the effect of S application on nutrient availability showed that, there was positive influence of different treatments on availability of all nutrients except N and K. In case of N and K, the non responsiveness of different treatments might be attributed to the sufficient quantities of these nutrients in the soil which could meet the crop requirements. All the nutrients showed a significant decline in their availabilities, as the crop growth stages proceeding towards maturity. This might be attributed to the higher uptake of the nutrients by crops and subsequent reduction of those nutrients in soil (Ahmad *et al.*, 1989).

There was a significant reduction in the available P as the earlier crop growth stages. This might be due the increased uptake of P due to increased dose of S. Similar findings were reported by Hariram and Dwivedi (1992). Different sources and levels had no significant influence on available P.

Available S content in soil increased with the level of S application, irrespective of the sources. The increased levels of S might have released more S to the soil system and in turn more availability of S in soil. The available S was found to be more with magnesium sulphate source. This might be due to the decreased uptake of sulphate from magnesium sulphate treatments. The other sources *viz.*, gypsum and SSP treated plots recorded comparatively lower available S. This may be due to the more easily available sulphate-S and its higher solubility in gypsum which might have caused an increased uptake by the plants. The present findings is in line with the findings of Srinivasan *et al.* (2000) and Biswas *et al.* (1986).

The availability of calcium was the highest in gypsum treated plots, which may be attributed to the high exchangeable Ca content in gypsum, which is readily available (Tisdale *et al.*, 1993). This is well supported by the positive and significant relation between Ca uptake and dry matter production ($r = 0.98$). In case of exchangeable Mg, the addition of Mg through magnesium sulphate showed significantly high magnesium availability in soil. The possible reason for the high availability of Mg might be the increase in solution concentration of Mg with its application (Sudhir and Ananthanarayana, 1986).

CHAPTER – VI

SUMMARY AND CONCLUSIONS

6.1. Summary

The present investigation was carried out to study the source and levels of S fertilization on pulse crops viz., blackgram (Co5) and greengram (Co6) on seed yield, nutrient uptake, available nutrients ,protein content and also yield attributes.

Three sources of S fertilizers viz., gypsum, magnesium sulphate and SSP and three levels of S viz., 10, 20 and 30 kg ha⁻¹ and control were the treatments imposed.

Soil and plant samples were collected at three stages viz., flowering pod development and at harvest and plant and seed samples were analyzed for N, P, K, Ca, Mg and S contents , soil samples were analyzed for available N,P,K , S, Exchangeable Ca and Mg. Yield attributes like number of pods per plant and hundred seed weight were observed. Protein contents for both the crops were estimated. The salient findings emanated from the study are presented below.

- The seed yields of both blackgram and greengram were found to be enhanced by the application of gypsum and SSP than magnesium sulphate. In all the sources, higher levels of S (30 kg ha⁻¹) were good in improving the yield than lower levels.
- The haulm yields of black gram and greengram were also influenced significantly by the S fertilization. Sulphur at 30 kg ha⁻¹ found to be good and when supplied through gypsum and SSP, than through magnesium sulphate.
- The treatments had a significant influence on the DMP of both the crops tried in this experiment. Here again, the higher dose of S fertilization through gypsum and SSP were better than magnesium sulphate source. The DMP increased significantly with advancement in crop growth stages.
- The nutrient content of both blackgram and green gram viz., N, P, K, Ca, Mg and S were not significantly influenced by the source of S fertilization. However, the levels had a good effect on this parameter. Higher levels of S application had a

positive effect on nutrient contents. As the stage of the crop advances, the content decreased significantly.

- Nutrients uptake viz., N, P, K, Ca, Mg and S were influenced significantly by the sources and levels of S nutrition. All the nutrient uptakes were significantly higher with higher levels of S fertilization, irrespective of the sources. The uptake values were significantly superior at each crop growth stage compared to the proceeding stage of the crop.
- The major nutrients in the soil (N, P, and K) were not much influenced by the source and levels of S fertilization both in blackgram and greengram.
- The exchangeable Ca content in soil is significantly higher in gypsum treatment followed by SSP in both the crops.
- The Exchangeable Mg content in the soil is significantly higher in magnesium sulphate source than gypsum and SSP for both the pulse crops.
- The available S content of the soil was not influenced by the source of S fertilization. However, higher S availability was observed in higher levels of S application.
- Protein content was increased with the increase in S application through SSP and gypsum than magnesium sulphate.
- The yield attributes viz., number of pods per plant and hundred seed weights were more in 30 kg S ha⁻¹ level, when supplied through gypsum or SSP.

6.2. Conclusion

The present study succinctly brought out the favourable effect of S fertilization to pulse crops viz., blackgram and greengram at the rate of 30 kg ha⁻¹, which equally improving the productivity either through gypsum or SSP in improving the seed yield, DMP, nutrient uptake and protein content. To achieve higher productivity in pulses, the N, P and K fertilizations alone are not sufficient. It should be supplemented with secondary nutrients especially S. The S fertilization could be supplemented through gypsum source since, it is cost effective compared to SSP.

REFERENCES

- Agricultural Statistics at a glance, 2002, Agricultural Statistical Division, Directorate of Economics and Statistics; Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.
- Ahmad, A., Ishrat Khan, N. A. Anjum, Iram Diva, M. Z. Abdin And Muhammad Iqbal. 2005. Effect of timing of sulphur fertilizer application on growth and yield of rapeseed. **Journal of Plant Nutrition**, **28**:1049- 1059.
- Ahmed, I. U., S. M. A. Faiz, S. Rahman and A.K.M. Anwar Hussain. 1988. Effect of nitrogen and sulphur fertilization on yield, N-S composition and availability of N and S in soil. **J. Indian. Soc. Soil. Sci.**, **36**(4): 698-703
- Ali, 1991. Consolidated report on kharif pulses (1990-91). Directorate of Pulses Research, Kanpur.
- Ankomah, A. B. and Osei, K. V. 1992. External and internal critical P requirements of soybean in three Ghanaian soils. Tropical Agriculture Department of Crop Science, University of Science and Technology, **Kumasi Ghana** **69**(4): 315-318.
- Anonymous, 1988. Agricultural Situation in India, Directorate of Economics and statistics, Ministry of Agriculture, Government of India.
- Anonymous. 1997. Sulphur in balanced fertilization. **Fert.News**, **42**(2): 13-14.
- Anonymous. 2000. Glimpses of micronutrient research in Tamil Nadu. Published by: Department of Soil Science and Agricultural Chemistry, Directorate of Soil and Crop Management Studies, Tamil Nadu Agricultural University, Coimbatore, India, pp. 6.
- Anonymous. 2005 Annual Report-pulses, Integrated Scheme for Oil seeds, Pulses, Oilpalm and Maize (ISOPOM). Directorate of Pulses Development, Government of India, Ministry of Agriculture.
- Arora, S. K. and Y. P.Luthra. 1972. Improvement in the quality of *Phaseolus aureus* Linn. by the application of sulphur, phosphorus and nitrogen. **Indian Journal of Agricultural Chemistry**, **5** :77- 83

- Aruna Geeta, S. 2001. Evaluation of sulphur material on yield and quality of soybean and blackgram. M. Sc (Ag). Dissertation submitted and approved by Tamil Nadu Agricultural University.
- Asthana, A.N. and S.K. Chaturvedi, 1999. A little impetus needed. The Hindu survey of Indian Agriculture, 1999 p.61-65.
- Aulakh, M. S. 2003. Crop responses to sulfur nutrition. In: Sulfur in plants. Eds. Y. P. Abrol and A. Ahmad, 341-358. Dordrecht, Netherlands, Kluwer Academic Publishers.
- Aulakh, M. S. and Pasricha, N. S. 1977. Interaction effect of S and P on growth and nutrient content of moong. **Plant and Soil**, **47**:341-350.
- Aulakh, M. S., G. Dev and B.R. Arora.1976. Effect of sulphur fertilization on nitrogen-sulphur relationship in alfalfa (*Medicago sativa*. L. Pers.). **Plant and Soil** **45**:75-80.
- Aulakh, M. S., Pasricha, N. S and Dev, G. 1977. Response of different crops to sulphur fertilization in Punjab. **Fert. News.**, **22**(9),32-36.
- Bansal, K.N., 1991. Effect of levels of S on the yield and composition of soybean (*Glycine max* (L).Merr) greengram (*Vigna radiatus* L.),. blackgram (*Vigna mungo* L.) and cowpea (*Vigna sinensis* L.). **Madras Agric. J.**, **78**(5-8): 188-190.
- Bapat, P. N., S. B. Sinha and B. B. Shinde. 1986. Effect of sulphur and phosphorus on yield and nutrient content of blackgram. **J. Indian. Soc. Soil. Sci.**, **34**: 82-85.
- Biswas, B. C., S. Maheswari and D.S. Yadav. 1986. Uses of indigenous sources of sulphur in Indian agriculture. **Fert. News.**, **31**: 459-565.
- Chaudhry I. A. and Cornfield.1966. The determination of total sulphur in soil and plant material. **Analyst**, **911**(1085):528-530
- Cheema, H. S. and Arora, C. L. 1984. Sulphur status of tubewell waters and plants in some areas of Ludhiana under groundnut- wheat cropping system. **Fert. News.** **29**(3), 28-31.
- Chesnin, L.and C. H. Yien. 1964. Turbidimetric determination of available sulphate. **Soil Sci. Soc. Amer. Proc.**, **15**: 149-151.

- Chitralkha Chatterjee, Saubra Saukla and Neena Khurana. 1992. Effect of sulphur deficiency on metabolism of green gram (*Phaseolus radiatus*). **Indian J. Agric. Soc.**, **65** (7): 445-449.
- Chopra, S. L. and J. S. Kanwar. 1966. Effect of sulphur fertilization on chemical composition and nutrient uptake by legumes. **J. Indian Soc. Soil Sci.**, **14**:69-76
- Dalal, J. L., J. S. Kanwar, J. S. Saini. 1963. Gypsum as a fertilizer for groundnut in Punjab. **Indian J. Agric. Sci.**, **33**(3): 199-204.
- Das, K. N. and Das, K. 1994. Effect of sulphur and nitrogen fertilization on yield and N uptake by rapeseed. **J. Indian Soc. Soil Sci.**, **42**: 113-122.
- Deb, D. L. and M. S. Sachdev. 1997. In: Proc. Symp. Sulphur in balanced fertilization held during Feb 13-14, 1997 at, New Delhi, India, pp. SII 1/1-SU-1/13.
- Dhillon, N. S. and Dev, G.1980. Studies on S nutrition of soybean (*Glycine max*. L.) from three sulphate sources. **J. Indian Soc. Soil. Sci.**, **28**: 361- 365.
- Dube, S. D., Misra, P. H., 1970 Effect of S-deficiency on growth, yield and quality of some important leguminous crops. **J. Indian Soc. Soil. Sci.**, **18**, 375-378.
- Dubey, S, K. and S.B. Bellore. 1995. Effect of level and source of sulphur on symbiotic and biometrical parameters of soybean (*Glycine max*) **Indian J. Agri. Sci.**, **65**(2): 140-144.
- Dwivedi, A. K., S. B. Sinha and J.P. Mahajan. 1989. Phosphorus utilization by soybean genotypes in blacksoils. **J. Nuclear. Agric. Biol.** **19**:232-235
- Fox, R. L. and Hue, N. V. 1986.Sulphur cycling in the tropics and sulphur requirement for agriculture. Inter. Symp. Sulphur agricultural soils, Dhaka, Bangladesh,20-23 April, 1986,Bangladesh Agricultural Research Council, Dhaka, Bangladesh.
- Ganeshamurthy, A.N. 1996. Critical plant sulphur content and effect of sulphur application on grain and oil yield of rainfed soybean in vertic ustochrepts. **J. Indian Soc. Soil. Sci.**,**44**(2):290-294
- Gill, M. S., B.S. Mankotia and S. S. Walia. 2000. Production technology for sustaining pulse productivity. **Fert. News**, **45**(3): 33-38,41-43.

- Gupta, R. K. and S. K. Dubey. 1998. Sulphur management in rainfed cropping system in Madhya Pradesh. **Fert. News.**, **43**(7): 57-60 and 63-67.
- Gupta, R. P. and C. Dakshinamurthi. 1980. Procedures for physical analysis of soils and collection of agrometeorological data. Division of Agricultural Physics, IARI, New Delhi.
- Habeebulla, B. and J. Honora Francis. 1991. Effect of sulphur on seed yield and leaf sulphur content in soybean. **Madras Agric. J.**, **78**(5-8): 308-309.
- Hariram and K. N. Dwivedi. 1992. Effect of source and level of sulphur on yield and grain quality of chick pea (*Cicer arietinum*). **Indian J. Agron.**, **37**(1): 112-114.
- Humphries, E. C. 1956. Mineral components and ash analysis. In: Modern methods of plant analysis. **Springer Verlag British**, **1**: 468-562
- Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi.
- Jagadeeswaran, R., V. Murugappan and P. Singaram. 2001. Effect of ferrogypsum on yield, nutrient uptake and quality in groundnut. **Madras Agri. J.** **88**(4-6): 210-213.
- Jagee, R.C., R.S. Kanwal and S. P. Dixit. 1995. Effect of fertilizer nitrogen and sulphur interaction on composition and uptake of nutrients by linseed on acid alfisols. **J. Indian. Soc. Soil. Sci.**, **43**(4):611-615
- Jena, D., R. Sahoo., D. R. Sarangi and M. V. Singh. 2006. Effect of different sources and levels of sulphur on yield and nutrient uptake by groundnut-Rice Cropping system in an Inceptisol of Orissa. **J. Indian. Soc. Soil. Sci.**, **54**(1):126-129.
- Jogendra P. Singh., J. C. Tarafadar and B. R. Gupta 1997. Sulphur fertilization for increased production of summer moong (*Vigna radiata* L.). **J. Indian. Soc. Soil. Sci.**, **45** (3): 526-528.
- Kadamdhad, G.R., Babhulkar, V. P., and Banhulkar, P. S. 1996. Response of soybean (*Glycine max*) to sulphur and zinc in vertisols. **Annals of Plant Physiology.** **10**.153.

- Kamat, V. N., Kantata, V. G., Puranik, R. B., Kohadhar, W. S. and Joshi, R. P. 1981 Effect of sulphur and molybdenum application on yield, protein and sulphur amino acids content of green gram. **J. Indian Soc. Soil. Sci.**, (29):225-227.
- Kandpal, B. M. and A. S. Chandel. 1993. Effect of gypsum and pyrite as sources of sulphur on nitrogen fixation, dry matter yield and quality of soybean (*Glycine max*). **Indian J. Agron.**, **38**(1): 137-139.
- Kannaiyan, S. 1999. Bioresources Technology for Sustainable Agriculture, Associated Publishing Company, New Delhi. p.422.
- Kanwar, J. S. 1976. Calcium, Magnesium and sulphur. In: Soil fertility theory and practice, ICAR, New Delhi, pp.202-228
- Kasthuri, R., M. Jayapragasam and S.R. Sreerangasamy. 1992. Effect of sulphur nutrition on seed protein and yield in black gram (*Vigna mungo*). **Legume Research**, **15**(1): 15-18
- Khajanchilal, D. L. Deb, M. S. Sachdev and P. Sachdev. 1996. Phosphorus – sulphur interrelationship in soybean using ^{32}P and ^{35}S . **J. Nuclear Agric. Biol.**, **25**(4): 196-204.
- Khandkar, M. R., Shinde, D. A., Kanikar, V. S. and Jain, N. J. 1985. Growth, nodulation and yield of rainfed blackgram as influenced by P and S nutrition in vertisol. **Indian J. Pl. Physiol.**, **28** :318-322.
- Khandkar, U. R. and D. A. Shinde. 1991 Phosphorus nutrition of black gram as influenced by P and S application. **J. Indian Soc. Soil Sci.**, **39**: 583-585.
- Khatik, S. K., S. K. Vishwakarma and S. K. Sharma. 1992. Effect of phosphorus and sulphur application on nutrient use efficiency and uptake by soybean in chromustert soil. **J. Soils and Crops**, **2**(2):25- 29.
- Krishna.1995. Effect of sulphur and zinc application o yield, S and Zn uptake and protein content of mung (green gram). **Legume Research**, **18**(2):89-92.

- Krishnamurthy, V. 1994. Influence of sulphur and magnesium on yield and quality of sunflower in alfisols. Ph.D. Dissertation submitted to Tamil Nadu Agricultural University, Coimbatore.
- Kumar, S., B. Singh and A.L Rajput. 2001. Response of Indian mustard (*Brassica juncea*) to source and level of sulphur. **Indian J. Agron.**, **46**, 528-532.
- Kumar, V and M. Singh. 1980. Interaction in relation to growth, uptake and utilization of sulphur in soybean. **Soil Sci.**, **5**: 297- 304.
- Kumar, V. and Singh, M. 1980. Sulphur, phosphorus and molybdenum interactions in relation to growth, uptake and utilization of S in soybean. **Soil. Sci.**, **129**: 297-304.
- Kumar, V. and Singh, M. 1980a. Sulphur and Zinc interaction in relation to yield, uptake and utilization of sulphur in soybean. **Soil Sci.**, **130**: 19-25.
- Kumar, V., 1983. Effect of sulphate, phosphate and molybdenum application on the quality of soybean grain, **Pl. Soil.**, **59** : 3-8.
- Lal, R. B. and P. C. Jaiswal. 1981. Influence of sulphur fertilization on grain yield and economics of Urd cultivation. **Indian J. Agron.**, **26**(3): 329-330
- Luestek, T., M. N. Martin, J. A. Bick and J. P. Davies. 2000. Pathways and regulation of sulfur metabolism revealed through molecular and genetic studies. **Annual Review of Plant Physiology and Molecular Biology**, **51**:141-165
- Mandhata Singh, R.P.Singh and B. Singh.1994. Influence of sulphur application on N, P and S content of plant and soil. **Crop Res., (Hissar)**. **7**(1):8-12.
- Massod Ali and Mishra. 2000. Nutrient management in pulses and pulse based cropping systems. **Fert. News.** **45**(4):57, 59: 61-67.
- Mehta, U. R. and Singh, H. G. 1979. Response of greengram to S on calcareous soils. **Indian J Agr Sci.**, **49**: 703-706.
- Mengal, K and Kirkby, E. A. 1982.Principles of plant nutrition,^{3rd} ed, International Potash Institute, Bern, Switzerland.
- Misra, S. N. and Anand P. Singh. 1989. Studies on soils and phosphorus availability and uptake by groundnut. **Legume Research**, **12**(14) : 160-164

- Misra, U. K. 1995. Soil sulphur deficiencies and crop responses to sulphur in Orissa, India. **Sulphur in Agriculture**, **19**, 16-20.
- Morris, R. J. 1988 Proceedings of TSI-FAI symposium "Sulphur in Indian Agriculture" pp KS/1-(1-14).
- Nabi, G., Rahamathullah and M Salim. 1990. Utilization of added sulphur by groundnut on two udi hapludalfs. **J. Indian. Soc. Soil Sci.**, **38**: 70 -72.
- Nad, B.K. and N. N. Goswami.1983. Response of legume and oilseed crops to different sources of sulphur and magnesium in some alluvial soils. **J. Indian Soc. Soil Sci.**, **31**:60-64
- Naidu, M. V. S and Hanuman Ram 1996. Effect of sulphur and Rhizobium inoculation on dry matter, grain yield and protein content in green gram (*Vigna radiata* L). **Legume Research.**, **19**(1):10-14
- Nambiar, K. K.M and Abrol, I. P. 1989. Long-term fertilizer experiments in India – A review. **Fert. News**, **34**(4): 11-20.
- Nambiar, K.K. M. 1988. Crop responses to S and S- balances in intensive cropping system. Proc. TSI-FAI Symp. Sulphur in Agriculture, New Delhi, SIII/3/1-6.
- Naphade, P. S. and Wankhade, S. G. 1987 Effect of varying levels of Sulphur and Molybdenum on the content and uptake of nutrients and yield of moong. **P. K. V. J. Res.**, **11**:139-143.
- Olsen, S. R., C. V. Cole, F. S. Watnebe and L. Dean.1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. by Circ.939, U. S. Govt.Printing office, Washington DC.
- Pahwa, M. R. 1985. Annual Report, Indian Grassland and Forest Research Institute, Jhansi, Uttar Pradesh, India.
- Pandey, S. N.1972. Effect of sulphur application on nodule formation in legumes. **Agri. Agro. Ind. J.**, **5**:11-12.
- Panse, V. G. and Sukhatme. 1978. Statistical methods for agricultural workers. ICAR, New Delhi.

- Pareek, S. K., M. S. Saroha and H. G. Singh. 1978. Effect of sulphur on chlorosis and yield of blackgram on calcareous soils. **Indian J. Agron.**, **23**(3):102-107.
- Pasricha, N. S. and Randhawa, N.S 1973. Sulphur nutrition of crops for native and applied sources. **Indian J Agr Sci.**, **43**: 270-274.
- Pasricha, N. S., Bahl, G. S., Aulakh, M.S. and Dhillon, K.S. 1991. Fertilizer use research in oil seed and pulse crops in India. ICAR, New Delhi, pp.99
- Patel, K. S., N. J. Sawarkar and S. S. Khanna. 1971. Proc. Int. Symp. Use of Radiation and Isotope in Agric. Anim. Husb. Res., New Delhi, 555.
- Patel, L. R., N. M. Salvi and R. H. Patel. 1992. Response of green gram (*Phaseolus vulgaris*) varieties to sulphur fertilization under different levels of nitrogen and phosphorus. **Indian J. Agron.**, **37**(4): 831-833.
- Patel, M. S. and Zalwadia, n. M. 1982. Note on the accumulation of dry matter and nutrients in summer grown groundnut. **Indian J. Agric. Soc.**, **52**. 704 -705.
- Pemberton, H. 1945. Estimation of total phosphorus. **J. Amer. Chem. Soc.**, **30**:563-565
- Piper, C. S. 1966. Soil and plant analysis. Hans Publishers, Bombay.
- Poongothai, S and Chitdeshwari, T. 2003. Response of black gram to multimicronutrients. **Madras Agric. J.** **90**: 442-43
- Poorani, B.1992. Radiotracer studies on the interaction effects of application of phosphorus and sulphur on available nutrients, yield and quality of greengram (VAR.Co4). M. Sc (Ag). Dissertation submitted and approved by Tamil Nadu Agricultural University.
- Potkile, S. N. and G. N. Bobde. 1996. Growth responses of soybean to phosphorus and sulphur application. **Ann. Plant Physiol.**, **10**(2):186-190.
- Potkile, S. N. and G. N. Bobde. 1996a. Effectivity of phosphorus and sulphur application on yield and quality of soybean. **Ann. Plant Physiol.**, **10**(2):191-194.
- Prasad, F. M., Sisodia, D. S., Varshney, M. L. and Verma, M. M.1991. Effect of different levels of P and S on growth, dry matter, oil content and uptake of nutrient by soybean. **New Agriculturist** **2**(1): 15-18.

- Puri, D. N. 1984. Place of secondary nutrients in intensive cropping and problems of availability of their products in North India – industry view point. Proc. FAI – NR Seminar on Balanced Fertilization Programme with Special Reference to Secondary and Micro nutrients Nutrition of Crops under Intensive Cropping. Jaipur, 175- 185.
- Ram, H., C. K.Jha and Jagadish Prasad. 1998. Effect of sulphur and Rhizobium on soil pH, available N and P in greengram. **Fert. News**, **43(10)** : 51, 53 & 55.
- Ramamoorthy, K., A. Balasubramaniam and A. Arokyaraj.1997.Response of rainfed black gram (*Phaseolus mungo*) to phosphorus and sulphur nutrition in red lateritic soils. **Indian J. Agron.**, **42(1)**: 191-193.
- Randhawa, P.S. and C.L. Arora. 1997. Effect of phosphorus and sulphur on their availabilities in soils. **J. Indian. Soc. Soil. Sci.**, **45(2)**:306-310.
- Sacchidanand, B., N. J.Sawarkar, R. S. Ghurayya, D. A. Shinde and S.B. Sinha. 1980. Response of soybean (*Glycine max*) to sulphur and phosphorus. **J. Indian Soc. Soil. Sci.**, **28(2)**: 189- 192.
- Saha, S. K and Luthra, K. L. 1984. Amjhore pyrites as a potential source of fertilizer sulphur for oilseed and pulse crops. Proc. FAI-NR Seminar, Jaipur, 185-191.
- Sahu, S. K. and S. C. Nayak, 1999 – 2001. Annual Progress reports, AICRP Micro and Secondary Nutrients and Pollutant Elements in Soil and Plants, OUAT, Bhubaneswar.
- Scherer, H. W. 2001. Sulphur in crop production. **European Journal of Agronomy**, **14**: 81-111
- Schung, E.1990. Sulfur nutrition and quality vegetables, **Sulfur Agric.** **14**:3-7
- Season and Crop Report of Tamil Nadu, 2005. Department of Economics and Statistics, Government of Tamil Nadu. www.tn.gov.in/crop/.
- Sharma, M. P. and R. Singh. 1997.Effect of phosphorus and sulphur on green gram (*Phaseolus radiatus*). **Indian J. Agron.**,**42(4)**:650-652.
- Sharma, S. C., H. O. Tiwari and R.J.Tiwari. 1995 Effect of nitrogen, phosphorus on micronutrient content of black gram (*Phaseolus mungo*). **Crop Res.**, **9(1)**: 54 – 58.

- Singal, V. 1999. Indian economic data research centre. New Delhi, pp. 105-110.
- Singh, Y. P., and Ranbir Singh., 2004 Interaction effect of sulphur and phosphorus on growth and nutrient content of black gram (*Phaseolus mungo* L.). **J. Indian Soc. Soil. Sci.**, **52**(3): 266-269.
- Singh, A. L. and Vidya Chaudhari. 1995. Sources and mode of sulphur application on groundnut productivity. **J. Plant. Nutr.**, **18**(12): 2739-2759.
- Singh, D and V. Singh 1995. Effect of potassium and sulphur on growth characters, yield attributes and yield of soybean (*Glycine max*). **Indian. J. Agron.**, **40**(2):223-227;
- Singh, H. G. 1988. Sulphur management in fine- textured calcareous soils. Proc. TSI-FAI Symp. on Sulphur in Agriculture, New Delhi, S.III/2/1-9.
- Singh, J.P., J.C. Tarafdar and B.R. Gupta. 1997. Sulphur fertilization for increased production of summer moong (*Vigna radiata* L.) **J. Indian Soc. Soil Sci.**, **45**(3): 526-528.
- Singh, M. V. 1998. 28th Progress Report of the AICRP of Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants. IISS, Bhopal, pp102+xxxi.
- Singh, M. V., and Saha, J. K. 1995. A review of the sulphur research activities of the ICAR-AICRP micro- and secondary nutrients project. **Sulphur in Agriculture**, **19**:35-47.
- Singh, P. N. and H. Ram. 1990. Effect of phosphorus and sulphur application on protein and amino acid contents in chickpea. **Indian J. Pulses Res.**, **15**.
- Singh, R. P. and Vinay Singh.1990. Effect of S, Mg and K on yield and uptake by Linseed. **J. Indian Soc. Soil. Sci.**, **38**: 169-170.
- Singh, S.K., Room Singh and H. P. Singh. 1994. Effect of sulphur on growth and yield of summer moong (*Vigna radiata* (L.) Wilczek). **Legume Research.**, **17**(1): 53-56.
- Sreemannarayana, B. and A. Sreenivasa Raju. 1994. Influence of native and applied sulphur on yield and uptake of sunflower at different stages of growth. **J. Indian. Soc. Soil. Sci.**, **42**: 80-84.

- Sridhar, V., Soundararajan, M. S., Sudhakar Rao, R and Sreeramulum C.1985. Response of JL 24 groundnut to rates, time and methods of gypsum application. **Madras Agric. J.**, **72(1)**: 47 – 53.
- Srinivasan, K and N. Sankaran. 2001. Sulphur management in black gram and its effect on yield and economics. **Madras Agric. J.**, **88(10-12)**.654-656.
- Srinivasan, K. N. Sankaran and J. Prabhakaran. 2000. Influence of sulphur application on nodulation and protein content of black gram. **Madras Agric. J.**, **87(7-9)**
- Stanford, S. and L.English. 1949. Use of flame photometer in rapid soil test of K and Ca. **Agron. J.**, **41**:446.
- Subbaiah, B. V., N. Singh. 1970. Efficiency of gypsum as a source of sulphur to oilseed crops studied with radioactive sulphur and radioactive calcium. **Indian J. Agric. Sci.** **40(3)**:227 – 237.
- Subbarao, A and A. N. Ganeshamurthy. 1994. Sulphur responses to applied phosphorus and sulphur on vertic ustochrepts in relation to available phosphorus and sulphur. **J. Indian Soc. Soil Sci.**, **42(4)**:606-610.
- Subbiah, B. V. and G. L. Asija.1956. A rapid procedure for estimation of available nitrogen in soils. **Curr. Sci.**, **25**:259-260.
- Subbiah, B. V. and Singh, N.1970. Efficiency of gypsum as a source of S to oilseed crops studied with radioactive sulphur and radioactive calcium. **Indian J. Agric. Sci.**, **40(3)**: 227-237.
- Subramanian. K.S., S.Poongothai, T.Chitdeshwari and V.P.Duraisami. 2005. Nutritional and yield responses of blackgram to multi-micronutrients in Western Agro-Ecological zone of Tamil Nadu. **Crop Res.**, **29(3)**: 406-410.
- Sudhir, K. and A. Ananthanarayana. 1986. Magnesium fertilization of groundnut. **J. Indian Soc. Soil Sci.**, **34**: 215-16.
- Surendra Singh and A. K. Sarkar. 1999. Response of oil seeds and pulses to indigenous sulphur sources in Bihar plateau. **Fert. News**, **44(7)**:23- 26.

- Surendra Singh, K. P. Singh, S. K. Singh and Gautam Kumar. 1998. Response of blackgram (*Phaseolus mungo*) to sulphur on acid alfisol of Bihar Plateau. **J. Indian Soc. Soil. Sci.**, **46**(2): 257-260.
- Tandon, H. L. S. 1991. Secondary and micronutrients in agriculture- A Guidebook- cum- Directory. FDCO, New Delhi, pp.122.
- Tandon, H. L. S. 1993. Fertilizer Management in Plantation Crops. FDCO, New Delhi, pp. 83.
- Tandon, H. L. S. 1995. Sulphur fertilizers for Indian Agriculture – A Guide book – Fertilizer Development and consultation organization, New Delhi, pp. 16-23.
- Tandon, H. L.S. 1986. Sulphur research and agricultural production in India. 2nd Ed. FDCO, New Delhi, pp.76.
- Tandon, H. L.S. 1987. Sulphur research and agricultural production in India. Fertilizer Development and Consultation Organization. New Delhi.
- Teotia, U. S., V. S. Mehta, D. Ghosh and P. C. Srivastava. 2000. Phosphorus – sulphur interaction in mungbean (*Vigna radiata* L. Wilczek) I. Yield, phosphorus and sulphur contents. **Legume Res.**, **23**(1):1 06-109.
- Tiwari, K. N. 1997 Proceedings of the TSI/FAI/ IFA Symposium on Sulphur in Balanced Fertilization, New Delhi, pp.SI-1/1-1/15.
- Tiwari, K.N. 1990. Sulphur research and agricultural production in U. P. Bulletin, CSAUT, Kanpur, pp.46.
- Toth, S. J and A. L. Prince, 1949. Estimation of cation exchange capacity and exchangeable calcium, potassium and sodium contents of soil by flame photometer techniques. **Soil. Sci.**, **69**: 439-445.
- Toth, S. J. and A. L. Prince. 1949. Estimation of cation exchange capacity and exchangeable calcium, potassium and sodium contents of soils by flame photometer technique. **Soil Sci.**, **67**:439-445.
- Tripathi, P.N. and Sharma, N. L. 1993. Pyrite – A good source of sulphur for mustard – rice cropping system. **Fert. News**, **38**(10): 27-30.

- Trivedi, S. K., Vijay Singh, C. P. Shinde and Rajasree Patil. 1997. Effect of N, P and S on yield and nutrient uptake of black gram (*Phaseolus mungo*). **Bhartiya Krishi Anusandhan Patrika**, **12**(2):90-94.
- TSI-FAI.1998.Proceedings of Symposium on Sulphur in Indian Agriculture, New Delhi.
- Upadhyay, R. M., Bharat Singh and S. K. Katiyar. 1991. Effect of nitrogen, phosphorus, sulphur application to black gram on yield and fate of P in an inceptisol. **J. Indian Soc. Soil Sci.**, **39**(2): 298-301.
- Virtamen. A. I. 1947. Biochemistry of symbiotic nitrogen fixation. **Acta. Chem. Scand.** **I**, 861.
- Walkley, A.J. and I.A. Black.1934. An estimation of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. **Soil Sci.**, **37**: 93-101.
- Williams, C. H and A. Stienbergs. 1959. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. **Aust. J. Agrl. Res.**, **10**: 340-352
- Zhao, F. J., P. J. A. Withers, E. J. Evans, J. Monghan, S. E. Salmon, P. R. Shewry and S. P. Mcgrath. 1997. Sulfur nutrition: An important factor for the quality of wheat and rapeseed. **Soil Science and Plant Nutrition**, **43**:1137-1142.

Table 1. Analytical methods employed in soil and plant analyses

Particulars	Method	Reference
1. Soil Analyses		
A. Physico-chemical properties		
Soil Reaction	Potentiometry (1:2.5 soil water suspension)	Jackson (1973)
Electrical Conductivity	Conductometry (1:2.5 soil water suspension)	Jackson (1973)
Cation Exchange Capacity	Neutral normal ammonium acetate method	Piper (1966)
B. Physical properties		
Particle size analysis	International pipette method	Piper (1966)
Bulk Density	Core sampler method	Gupta and Dakshnamoorthy (1980)
Porosity	Core sampler method	Gupta and Dakshnamoorthy (1980)
Hydraulic conductivity	Core sampler method	Gupta and Dakshnamoorthy (1980)
C. Chemical properties		
Organic Carbon	Chromic acid wet digestion method	Walkely and Black (1934)
Available N	Alkaline permanganate method	Subbiah and Asija (1956)
Available P	Colorimetric method	Olsen <i>et al.</i> (1954)
Available K	Neutral normal ammonium acetate method- Flame photometry	Stanford and English (1949)
Available S	Turbidimetry	Williams and Steinbergs (1959)
Exchangeable Ca and Mg	Versanate titration method	Jackson (1973)
Total Nitrogen	Macro Kjeldahl digestion and distillation method	Piper (1966)
Total Phosphorus	Colorimetry	Pemberton (1945)

Total Potassium	Flame photometry	Toth and Prince (1949)
Total Calcium	Versanate titration using HCl extract	Jackson (1973)
Total Magnesium	Versanate titration using HCl extract	Jackson (1973)
Total Sulphur	Turbidimetry	Chaudhry and Cornfield (1966)
2. Plant analysis		
Total N	Micro Kjeldahl method	Humphries (1956)
Total P	Vanadomolybdate method	Jackson (1973)
Total K	Flame photometry	Toth and Prince (1949)
Total Ca	Versanate titration	Jackson (1973)
Total Mg	Versanate titration	Jackson (1973)
Total S	Turbidimetry	Choudhry and Cornfield (1966)

Table 2. The physical and chemical characteristics of initial soil.

Characteristics	Values
Clay (per cent)	18.05
Silt (per cent)	11.57
Coarse sand (per cent)	21.32
Fine sand (per cent)	44.04
Texture	Sandy loam
Bulk Density (Mg m^{-3})	1.42
Porosity (per cent)	47.62
Hydraulic Conductivity (cm h^{-1})	3.76
Organic carbon (per cent)	0.2
Soil pH	7.0
Electrical Conductivity (dSm^{-1})	0.21
Available nitrogen (kg ha^{-1})	228
Available phosphorus (kg ha^{-1})	16.4
Available potassium (kg ha^{-1})	378
Available sulphur (ppm)	8.7
Cation exchange capacity (c mol(p+) kg^{-1})	16.5
Exchangeable calcium (c mol(p+) kg^{-1})	8.5
Exchangeable magnesium (c mol(p+) kg^{-1})	3.0
Total nitrogen (per cent)	0.68
Total phosphorus (per cent)	0.56
Total potassium (per cent)	0.25
Total calcium (per cent)	0.90
Total magnesium (per cent)	0.40
Total sulphur (ppm)	124.0

Table 3. Effect of sources and levels of S on seed yield (kg ha⁻¹) of blackgram (Co5)

Treatments	Seed yield (kg ha⁻¹)
Control	733.0
M ₁ L ₁	780.6
M ₁ L ₂	832.0
M ₁ L ₃	890.0
M ₂ L ₁	763.3
M ₂ L ₂	794.0
M ₂ L ₃	841.3
M ₃ L ₁	794.0
M ₃ L ₂	826.0
M ₃ L ₃	875.3
CD (P = 0.05)	20.5

Levels Sources	L₁	L₂	L₃	Mean
M ₁	780.6	832.0	890.0	834.2
M ₂	763.3	794.0	841.3	799.5
M ₃	794.0	826.0	875.3	831.7
Mean	779.3	817.3	868.8	
CD (P = 0.05)				
M	:	11		
L	:	11		

Table 4. Effect of sources and levels of S on seed yield (kg ha⁻¹) of greengram (Co6)

Treatments	Seed yield (kg ha ⁻¹)
Control	783
M ₁ L ₁	827
M ₁ L ₂	865
M ₁ L ₃	894
M ₂ L ₁	806
M ₂ L ₂	833
M ₂ L ₃	871
M ₃ L ₁	833
M ₃ L ₂	866
M ₃ L ₃	896
CD (P = 0.05)	28

Sources \ Levels	L ₁	L ₂	L ₃	Mean
	M ₁	827	865	894
M ₂	806	833	871	837
M ₃	833	866	896	865
Mean	822	855	887	
CD (P = 0.05)				
M	:	14		
L	:	14		

Table 5. Effect of sources and levels of S on haulm yield (kg ha⁻¹) of blackgram (Co5)

Treatments	Haulm yield (kg ha⁻¹)
Control	1283
M ₁ L ₁	1335
M ₁ L ₂	1395
M ₁ L ₃	1411
M ₂ L ₁	1305
M ₂ L ₂	1353
M ₂ L ₃	1343
M ₃ L ₁	1328
M ₃ L ₂	1411
M ₃ L ₃	1423
CD (P = 0.05)	48

Levels Sources	L₁	L₂	L₃	Mean
M ₁	1335	1395	1411	1380
M ₂	1305	1353	1343	1333
M ₃	1328	1411	1423	1387
Mean	1322	1386	1392	
CD (P = 0.05)				
M	:	38		
L	:	38		

Table 6. Effect of sources and levels of S on haulm yield (kg ha⁻¹) of greengram (Co6)

Treatments	Haulm yield (kg ha⁻¹)
Control	1416
M ₁ L ₁	1523
M ₁ L ₂	1598
M ₁ L ₃	1640
M ₂ L ₁	1506
M ₂ L ₂	1578
M ₂ L ₃	1615
M ₃ L ₁	1546
M ₃ L ₂	1605
M ₃ L ₃	1615
CD (P = 0.05)	55

Levels Sources	L₁	L₂	L₃	Mean
M ₁	1523	1598	1640	1587
M ₂	1506	1578	1615	1566
M ₃	1546	1605	1615	1588
Mean	1525	1593	1623	
CD (P = 0.05)				
M	:	NS		
L	:	46		

Table 7. Effect of sources and levels of S on DMP (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1100	1265	2016	1460
M ₁ L ₁	1168	1306	2115	1530
M ₁ L ₂	1195	1378	2227	1600
M ₁ L ₃	1285	1406	2301	1664
M ₂ L ₁	1128	1288	2068	1495
M ₂ L ₂	1153	1320	2147	1540
M ₂ L ₃	1200	1356	2184	1580
M ₃ L ₁	1190	1310	2122	1540
M ₃ L ₂	1206	1370	2237	1604
M ₃ L ₃	1286	1393	2298	1659
CD (P=0.05)				
T	:	58		
S	:	39		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1100	1265	2016	1460
M ₁	1216	1363	2214	1598
M ₂	1160	1321	2133	1538
M ₃	1227	1357	2219	1601
L ₁	1162	1301	2102	1522
L ₂	1185	1356	2204	1581
L ₃	1257	1385	2261	1634
CD (P=0.05)				
M	:	39		
L	:	39		
M x S	:	NS		
L x S	:	NS		

Table 8. Effect of sources and levels of S on DMP (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1181	1273	2199	1551
M ₁ L ₁	1241	1331	2351	1641
M ₁ L ₂	1298	1418	2464	1726
M ₁ L ₃	1330	1448	2534	1771
M ₂ L ₁	1201	1306	2313	1607
M ₂ L ₂	1236	1346	2411	1665
M ₂ L ₃	1301	1451	2485	1746
M ₃ L ₁	1256	1326	2380	1654
M ₃ L ₂	1303	1410	2471	1728
M ₃ L ₃	1333	1450	2511	1765
CD (P=0.05)				
T	:	66		
S	:	48		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1181	1273	2199	1551
M ₁	1290	1399	2449	1713
M ₂	1240	1368	2403	1672
M ₃	1297	1395	2454	1715
L ₁	1233	1321	2348	1634
L ₂	1279	1391	2448	1706
L ₃	1321	1450	2510	1760
CD (P=0.05)				
M	:	48		
L	:	48		
M x S	:	NS		
L x S	:	NS		

Table 9. Effect of sources and levels of S on N content (%) of blackgram (Co5)

Stages				
	Flowering	Pod development	Harvest	Mean
Treatments				
Control	1.54	0.98	0.91	1.14
M ₁ L ₁	1.61	1.30	0.94	1.28
M ₁ L ₂	1.67	1.48	0.98	1.38
M ₁ L ₃	1.86	1.57	1.03	1.49
M ₂ L ₁	1.58	1.24	0.91	1.25
M ₂ L ₂	1.67	1.38	1.04	1.37
M ₂ L ₃	1.91	1.44	1.07	1.47
M ₃ L ₁	1.66	1.32	0.87	1.29
M ₃ L ₂	1.83	1.43	0.95	1.40
M ₃ L ₃	1.91	1.52	1.04	1.49
CD (P = 0.05)				
T	:	0.10		
S	:	0.03		
M x L x S	:	NS		

Stages(S)				
	Flowering	Pod development	Harvest	Mean
Treatments				
Control	1.54	0.98	0.91	1.14
M1	1.72	1.45	0.98	1.38
M2	1.72	1.36	1.01	1.36
M3	1.80	1.42	0.96	1.39
L1	1.62	1.29	0.91	1.27
L2	1.73	1.43	0.99	1.38
L3	1.89	1.51	1.05	1.48
CD (P = 0.05)				
M	:	NS		
L	:	0.03		
M x S	:	NS		
L x S	:	NS		

Table 10. Effect of sources and levels of S on N content (%) of greengram (Co6)

Stage Treatments	Flowering	Pod development	Harvest	Mean
Control	1.59	1.05	0.91	1.18
M ₁ L ₁	1.62	1.20	0.89	1.24
M ₁ L ₂	1.73	1.44	0.94	1.37
M ₁ L ₃	1.85	1.53	0.99	1.46
M ₂ L ₁	1.61	1.22	0.86	1.23
M ₂ L ₂	1.69	1.36	0.93	1.33
M ₂ L ₃	1.81	1.52	0.97	1.43
M ₃ L ₁	1.67	1.37	0.90	1.31
M ₃ L ₂	1.82	1.47	0.92	1.40
M ₃ L ₃	1.89	1.55	1.01	1.49
CD (P = 0.05)				
T	:	0.10		
S	:	0.06		
M x L x S	:	NS		

Stage Treatments	Flowering	Pod development	Harvest	Mean
Control	1.59	1.05	0.91	1.18
M ₁	1.73	1.39	0.94	1.35
M ₂	1.70	1.37	0.92	1.33
M ₃	1.79	1.46	0.94	1.40
L ₁	1.63	1.26	0.88	1.26
L ₂	1.75	1.42	0.93	1.37
L ₃	1.85	1.54	0.99	1.46
CD (P = 0.05)				
M	:	NS		
L	:	0.06		
M x S	:	NS		
L x S	:	NS		

Table 11. Effect of sources and levels of S on P content (%) of blackgram (Co5)

Stage (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.22	0.19	0.09	0.17
M ₁ L ₁	0.22	0.20	0.11	0.18
M ₁ L ₂	0.23	0.22	0.13	0.19
M ₁ L ₃	0.24	0.26	0.15	0.22
M ₂ L ₁	0.22	0.23	0.10	0.18
M ₂ L ₂	0.23	0.26	0.13	0.21
M ₂ L ₃	0.27	0.27	0.15	0.23
M ₃ L ₁	0.25	0.22	0.15	0.21
M ₃ L ₂	0.28	0.27	0.17	0.24
M ₃ L ₃	0.30	0.29	0.21	0.27
CD (P = 0.05)				
T	:	0.03		
S	:	0.01		
M x L x S	:	NS		

Stage (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.22	0.19	0.09	0.17
M ₁	0.23	0.22	0.13	0.19
M ₂	0.24	0.25	0.13	0.21
M ₃	0.28	0.26	0.18	0.24
L ₁	0.23	0.22	0.12	0.19
L ₂	0.25	0.25	0.15	0.21
L ₃	0.27	0.27	0.17	0.24
CD (P = 0.05)				
M	:	0.01		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 12. Effect of sources and levels of S on P content (%) of greengram (Co6)

Stage(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.27	0.28	0.11	0.22
M ₁ L ₁	0.25	0.23	0.12	0.20
M ₁ L ₂	0.28	0.29	0.13	0.23
M ₁ L ₃	0.30	0.30	0.17	0.26
M ₂ L ₁	0.23	0.23	0.13	0.20
M ₂ L ₂	0.28	0.25	0.17	0.23
M ₂ L ₃	0.31	0.30	0.18	0.26
M ₃ L ₁	0.26	0.24	0.14	0.21
M ₃ L ₂	0.28	0.26	0.15	0.23
M ₃ L ₃	0.30	0.29	0.18	0.26
CD (P = 0.05)				
T	:	0.03		
S	:	0.01		
M x L x S	:	NS		

Stage(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.27	0.28	0.11	0.22
M ₁	0.27	0.27	0.14	0.23
M ₂	0.27	0.26	0.16	0.23
M ₃	0.28	0.26	0.16	0.23
L ₁	0.24	0.23	0.13	0.20
L ₂	0.28	0.27	0.15	0.23
L ₃	0.30	0.30	0.18	0.26
CD (P = 0.05)				
M	:	NS		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 13. Effect of sources and levels of S on K content (%) of blackgram (Co5)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	1.24	0.99	0.73	0.99
M ₁ L ₁	1.28	1.03	0.77	1.03
M ₁ L ₂	1.30	1.07	0.77	1.05
M ₁ L ₃	1.36	1.14	0.83	1.11
M ₂ L ₁	1.30	1.02	0.75	1.02
M ₂ L ₂	1.32	1.04	0.80	1.05
M ₂ L ₃	1.36	1.17	0.85	1.13
M ₃ L ₁	1.34	1.07	0.79	1.07
M ₃ L ₂	1.36	1.16	0.83	1.12
M ₃ L ₃	1.39	1.22	0.87	1.16
CD (P=0.05)				
T	:	0.04		
S	:	0.01		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	1.24	0.99	0.73	0.99
M ₁	1.31	1.08	0.79	1.06
M ₂	1.33	1.08	0.80	1.07
M ₃	1.36	1.15	0.83	1.12
L ₁	1.31	1.04	0.77	1.04
L ₂	1.33	1.09	0.80	1.07
L ₃	1.37	1.18	0.85	1.13
CD (P=0.05)				
M	:	0.01		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 14. Effect of sources and levels of S on K content (%) of greengram (Co6)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	1.25	1.05	0.73	1.01
M ₁ L ₁	1.29	1.04	0.74	1.02
M ₁ L ₂	1.31	1.09	0.76	1.05
M ₁ L ₃	1.33	1.20	0.84	1.12
M ₂ L ₁	1.28	1.03	0.78	1.03
M ₂ L ₂	1.30	1.16	0.82	1.09
M ₂ L ₃	1.34	1.20	0.86	1.13
M ₃ L ₁	1.32	1.07	0.79	1.06
M ₃ L ₂	1.35	1.12	0.85	1.11
M ₃ L ₃	1.39	1.17	0.89	1.15
CD (P=0.05)				
T	:	0.07		
S	:	0.02		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	1.25	1.05	0.73	1.01
M ₁	1.31	1.11	0.78	1.07
M ₂	1.31	1.13	0.82	1.09
M ₃	1.35	1.12	0.85	1.11
L ₁	1.30	1.05	0.77	1.04
L ₂	1.32	1.12	0.81	1.08
L ₃	1.35	1.19	0.86	1.14
CD (P=0.05)				
M	:	0.02		
L	:	0.02		
M x S	:	NS		
L x S	:	NS		

Table 15. Effect of sources and levels of S on Ca content (%) of blackgram (Co5)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.83	1.05	0.87	0.91
M ₁ L ₁	1.25	1.06	0.90	1.07
M ₁ L ₂	1.30	1.11	0.93	1.11
M ₁ L ₃	1.33	1.16	0.95	1.14
M ₂ L ₁	1.29	1.12	0.86	1.09
M ₂ L ₂	1.34	1.15	0.91	1.13
M ₂ L ₃	1.33	1.13	0.95	1.13
M ₃ L ₁	1.27	1.11	0.91	1.10
M ₃ L ₂	1.30	1.14	0.94	1.13
M ₃ L ₃	1.33	1.17	0.98	1.16
CD (P=0.05)				
T	:	0.22		
S	:	0.07		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.83	1.05	0.87	0.91
M ₁	1.29	1.11	0.92	1.11
M ₂	1.34	1.15	0.91	1.13
M ₃	1.30	1.14	0.94	1.13
L ₁	1.27	1.10	0.89	1.08
L ₂	1.31	1.13	0.93	1.12
L ₃	1.35	1.13	0.96	1.16
CD (P=0.05)				
M	:	NS		
L	:	NS		
M x S	:	0.13		
L x S	:	0.13		

Table 16. Effect of sources and levels of S on Ca content (%) of greengram (Co6)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.84	1.01	0.88	0.91
M ₁ L ₁	1.29	1.02	0.91	1.07
M ₁ L ₂	1.35	1.04	0.93	1.11
M ₁ L ₃	1.38	1.10	0.99	1.16
M ₂ L ₁	1.27	1.10	0.85	1.07
M ₂ L ₂	1.33	1.10	0.86	1.10
M ₂ L ₃	1.35	1.11	0.92	1.13
M ₃ L ₁	1.29	1.10	0.88	1.09
M ₃ L ₂	1.34	1.13	0.91	1.13
M ₃ L ₃	1.38	1.17	1.00	1.18
CD (P=0.05)				
T	:	0.22		
S	:	0.07		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.84	1.01	0.88	0.91
M ₁	1.34	1.06	0.94	1.11
M ₂	1.32	1.11	0.88	1.10
M ₃	1.34	1.14	0.93	1.13
L ₁	1.27	1.08	0.88	1.08
L ₂	1.34	1.09	0.90	1.11
L ₃	1.37	1.13	0.97	1.16
CD (P=0.05)				
M	:	NS		
L	:	NS		
M x S	:	0.13		
L x S	:	0.13		

Table 17. Effect of sources and levels of S on Mg content (%) of blackgram (Co5)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.76	0.65	0.55	0.65
M ₁ L ₁	0.78	0.67	0.56	0.67
M ₁ L ₂	0.81	0.70	0.59	0.70
M ₁ L ₃	0.83	0.75	0.58	0.72
M ₂ L ₁	0.75	0.64	0.56	0.65
M ₂ L ₂	0.79	0.69	0.57	0.68
M ₂ L ₃	0.82	0.72	0.58	0.71
M ₃ L ₁	0.82	0.70	0.55	0.69
M ₃ L ₂	0.85	0.73	0.59	0.72
M ₃ L ₃	0.88	0.74	0.60	0.74
CD (P=0.05)				
T	:	0.04		
S	:	0.01		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.76	0.65	0.55	0.65
M ₁	0.81	0.71	0.58	0.70
M ₂	0.79	0.68	0.57	0.68
M ₃	0.85	0.72	0.58	0.72
L ₁	0.78	0.67	0.56	0.67
L ₂	0.82	0.71	0.58	0.70
L ₃	0.84	0.74	0.59	0.72
CD (P=0.05)				
M	:	0.01		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 18. Effect of sources and levels of S on Mg content (%) of greengram (Co6)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.77	0.67	0.55	0.66
M ₁ L ₁	0.81	0.68	0.54	0.68
M ₁ L ₂	0.84	0.70	0.57	0.70
M ₁ L ₃	0.87	0.75	0.60	0.74
M ₂ L ₁	0.73	0.66	0.54	0.64
M ₂ L ₂	0.81	0.71	0.56	0.69
M ₂ L ₃	0.85	0.74	0.58	0.72
M ₃ L ₁	0.82	0.69	0.55	0.69
M ₃ L ₂	0.86	0.72	0.57	0.72
M ₃ L ₃	0.90	0.73	0.59	0.74
CD (P=0.05)				
T	:	0.05		
S	:	0.02		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.77	0.67	0.55	0.66
M ₁	0.84	0.71	0.57	0.71
M ₂	0.80	0.71	0.56	0.69
M ₃	0.86	0.71	0.57	0.72
L ₁	0.79	0.67	0.56	0.67
L ₂	0.84	0.71	0.56	0.70
L ₃	0.87	0.74	0.59	0.72
CD (P=0.05)				
M	:	0.02		
L	:	0.02		
M x S	:	NS		
L x S	:	NS		

Table 19. Effect of sources and levels of S on S content (%) of blackgram (Co5)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.28	0.14	0.11	0.18
M ₁ L ₁	0.25	0.16	0.12	0.17
M ₁ L ₂	0.27	0.18	0.13	0.20
M ₁ L ₃	0.34	0.24	0.14	0.24
M ₂ L ₁	0.26	0.16	0.11	0.18
M ₂ L ₂	0.30	0.18	0.13	0.20
M ₂ L ₃	0.33	0.22	0.15	0.23
M ₃ L ₁	0.31	0.21	0.11	0.21
M ₃ L ₂	0.33	0.22	0.13	0.23
M ₃ L ₃	0.34	0.24	0.14	0.24
CD (P=0.05)				
T	:	0.03		
S	:	0.01		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.28	0.14	0.11	0.18
M ₁	0.29	0.19	0.13	0.20
M ₂	0.30	0.19	0.13	0.20
M ₃	0.33	0.22	0.13	0.23
L ₁	0.27	0.18	0.11	0.19
L ₂	0.30	0.20	0.13	0.21
L ₃	0.34	0.23	0.14	0.24
CD (P=0.05)				
M	:	0.01		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 20. Effect of sources and levels of S on S content (%) of greengram (Co6)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.27	0.17	0.11	0.19
M ₁ L ₁	0.28	0.21	0.12	0.20
M ₁ L ₂	0.29	0.22	0.13	0.21
M ₁ L ₃	0.34	0.24	0.12	0.23
M ₂ L ₁	0.30	0.16	0.11	0.19
M ₂ L ₂	0.32	0.19	0.13	0.21
M ₂ L ₃	0.34	0.23	0.14	0.23
M ₃ L ₁	0.28	0.22	0.11	0.20
M ₃ L ₂	0.33	0.21	0.13	0.22
M ₃ L ₃	0.34	0.24	0.14	0.24
CD (P=0.05)				
T	:	0.02		
S	:	0.01		
M x L x S	:	NS		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	0.27	0.17	0.11	0.19
M ₁	0.30	0.22	0.12	0.22
M ₂	0.32	0.19	0.13	0.21
M ₃	0.32	0.23	0.13	0.22
L ₁	0.29	0.20	0.11	0.20
L ₂	0.31	0.20	0.13	0.22
L ₃	0.34	0.24	0.13	0.24
CD (P=0.05)				
M	:	0.01		
L	:	0.01		
M x S	:	NS		
L x S	:	NS		

Table 21. Effect of sources and levels of S on N content of seed (%) of blackgram (Co5)

Treatments	Seed N (%)
Control	3.33
M ₁ L ₁	3.39
M ₁ L ₂	3.43
M ₁ L ₃	3.53
M ₂ L ₁	3.33
M ₂ L ₂	3.45
M ₂ L ₃	3.39
M ₃ L ₁	3.38
M ₃ L ₂	3.45
M ₃ L ₃	3.55
CD (P = 0.05)	0.10

Sources	Levels			Mean
	L₁	L₂	L₃	
M ₁	3.39	3.43	3.53	3.45
M ₂	3.33	3.45	3.39	3.39
M ₃	3.38	3.45	3.55	3.46
Mean	3.37	3.44	3.49	
CD (P = 0.05)				
M	:	NS		
L	:	0.06		

Table 22. Effect of sources and levels of S on N content of seed (%) of greengram (Co6)

Treatments	Seed N (%)
Control	3.49
M ₁ L ₁	3.58
M ₁ L ₂	3.63
M ₁ L ₃	3.70
M ₂ L ₁	3.52
M ₂ L ₂	3.59
M ₂ L ₃	3.69
M ₃ L ₁	3.51
M ₃ L ₂	3.68
M ₃ L ₃	3.83
CD (P = 0.05)	0.12

Sources	Levels	L₁	L₂	L₃	Mean
	M ₁		3.44	3.60	3.74
M ₂		3.57	3.63	3.73	3.60
M ₃		3.56	3.68	3.83	3.67
Mean		3.54	3.63	3.74	
CD (P = 0.05)					
M	:	NS			
L	:	0.07			

Table 23. Effect of sources and levels of S on P content of seed (%) of blackgram (Co5)

Treatments	Seed P (%)
Control	0.32
M ₁ L ₁	0.34
M ₁ L ₂	0.32
M ₁ L ₃	0.35
M ₂ L ₁	0.32
M ₂ L ₂	0.33
M ₂ L ₃	0.32
M ₃ L ₁	0.35
M ₃ L ₂	0.33
M ₃ L ₃	0.37
CD (P = 0.05)	0.02

Levels Sources	L₁	L₂	L₃	Mean
M ₁	0.34	0.32	0.35	0.34
M ₂	0.32	0.33	0.32	0.33
M ₃	0.35	0.33	0.37	0.35
Mean	0.34	0.33	0.35	
CD (P = 0.05)				
M	:	0.01		
L	:	0.01		

Table 24. Effect of sources and levels of S on P content of seed (%) of greengram (Co6)

Treatments	Seed P (%)
Control	0.32
M ₁ L ₁	0.34
M ₁ L ₂	0.33
M ₁ L ₃	0.35
M ₂ L ₁	0.32
M ₂ L ₂	0.33
M ₂ L ₃	0.34
M ₃ L ₁	0.33
M ₃ L ₂	0.34
M ₃ L ₃	0.35
CD (P = 0.05)	NS

Sources	Levels	L₁	L₂	L₃	Mean
	M ₁		0.34	0.33	0.35
M ₂		0.32	0.33	0.34	0.33
M ₃		0.33	0.34	0.35	0.34
Mean		0.33	0.33	0.34	
CD (P = 0.05)					
M	:	NS			
L	:	NS			

Table 25. Effect of sources and levels of S on K content of seed (%) of blackgram (Co5)

Treatments	Seed K (%)
Control	1.44
M ₁ L ₁	1.45
M ₁ L ₂	1.52
M ₁ L ₃	1.50
M ₂ L ₁	1.45
M ₂ L ₂	1.52
M ₂ L ₃	1.46
M ₃ L ₁	1.45
M ₃ L ₂	1.50
M ₃ L ₃	1.52
CD (P = 0.05)	NS

Levels Sources	L₁	L₂	L₃	Mean
M ₁	1.45	1.52	1.50	1.49
M ₂	1.45	1.52	1.46	1.48
M ₃	1.45	1.50	1.52	1.49
Mean	1.45	1.51	1.49	
CD (P = 0.05)				
M	:	NS		
L	:	0.04		

Table 26. Effect of sources and levels of S on K content of seed (%) of greengram (Co6)

Treatments	Seed K (%)
Control	1.44
M ₁ L ₁	1.45
M ₁ L ₂	1.50
M ₁ L ₃	1.49
M ₂ L ₁	1.42
M ₂ L ₂	1.43
M ₂ L ₃	1.45
M ₃ L ₁	1.46
M ₃ L ₂	1.48
M ₃ L ₃	1.52
CD (P = 0.05)	NS

Levels Sources	L₁	L₂	L₃	Mean
M ₁	1.45	1.50	1.49	1.48
M ₂	1.42	1.43	1.45	1.43
M ₃	1.46	1.48	1.52	1.49
Mean	1.44	1.47	1.48	
CD (P = 0.05)				
M	:	0.03		
L	:	NS		

Table 27. Effect of sources and levels of S on Ca content of seed (%) of blackgram (Co5)

Treatments	Seed Ca (%)
Control	1.41
M ₁ L ₁	1.43
M ₁ L ₂	1.46
M ₁ L ₃	1.49
M ₂ L ₁	1.45
M ₂ L ₂	1.48
M ₂ L ₃	1.51
M ₃ L ₁	1.44
M ₃ L ₂	1.47
M ₃ L ₃	1.50
CD (P = 0.05)	0.03

Sources \ Levels	Levels			Mean
	L ₁	L ₂	L ₃	
M ₁	1.43	1.46	1.49	1.46
M ₂	1.45	1.48	1.51	1.48
M ₃	1.44	1.47	1.50	1.47
Mean	1.44	1.47	1.50	
CD (P = 0.05)				
M	: NS			
L	: 0.02			

Table 28. Effect of sources and levels of S on Ca content of seed (%) of greengram (Co6)

Treatments	Seed Ca (%)
Control	1.43
M ₁ L ₁	1.49
M ₁ L ₂	1.50
M ₁ L ₃	1.51
M ₂ L ₁	1.45
M ₂ L ₂	1.47
M ₂ L ₃	1.50
M ₃ L ₁	1.49
M ₃ L ₂	1.50
M ₃ L ₃	1.53
CD (P = 0.05)	0.03

Levels Sources	L₁	L₂	L₃	Mean
M ₁	1.49	1.50	1.51	1.50
M ₂	1.45	1.47	1.50	1.47
M ₃	1.49	1.50	1.53	1.50
Mean	1.48	1.49	1.51	
CD (P = 0.05)				
	M	:	0.01	
	L	:	0.01	

Table 29. Effect of sources and levels of S on Mg content of seed (%) of blackgram (Co5)

Treatments	Seed Mg (%)
Control	0.14
M ₁ L ₁	0.17
M ₁ L ₂	0.19
M ₁ L ₃	0.23
M ₂ L ₁	0.26
M ₂ L ₂	0.28
M ₂ L ₃	0.29
M ₃ L ₁	0.22
M ₃ L ₂	0.24
M ₃ L ₃	0.25
CD (P = 0.05)	0.02

Levels Sources	L₁	L₂	L₃	Mean
M ₁	0.17	0.19	0.23	0.20
M ₂	0.26	0.28	0.29	0.28
M ₃	0.22	0.24	0.25	0.24
Mean	0.22	0.24	0.26	
CD (P = 0.05)				
	M	:	0.01	
	S	:	0.01	

Table 30. Effect of sources and levels of S on Mg content of seed (%) of greengram (Co6)

Treatments	Seed Mg (%)
Control	0.16
M ₁ L ₁	0.19
M ₁ L ₂	0.22
M ₁ L ₃	0.23
M ₂ L ₁	0.26
M ₂ L ₂	0.27
M ₂ L ₃	0.29
M ₃ L ₁	0.22
M ₃ L ₂	0.25
M ₃ L ₃	0.26
CD (P = 0.05)	0.02

Levels Sources	L₁	L₂	L₃	Mean
M ₁	0.19	0.22	0.23	0.22
M ₂	0.20	0.23	0.27	0.28
M ₃	0.22	0.25	0.29	0.25
Mean	0.20	0.23	0.26	
CD (P = 0.05)				
	M	:	0.01	
	S	:	0.01	

Table 31. Effect of sources and levels of S on S content of seed (%) of blackgram (Co5)

Treatments	Seed S (%)
Control	0.36
M ₁ L ₁	0.39
M ₁ L ₂	0.42
M ₁ L ₃	0.45
M ₂ L ₁	0.38
M ₂ L ₂	0.37
M ₂ L ₃	0.43
M ₃ L ₁	0.39
M ₃ L ₂	0.42
M ₃ L ₃	0.45
CD (P = 0.05)	0.04

Levels Sources	L₁	L₂	L₃	Mean
M ₁	0.39	0.42	0.45	0.42
M ₂	0.38	0.37	0.43	0.39
M ₃	0.39	0.42	0.45	0.42
Mean	0.39	0.40	0.44	
CD (P = 0.05)				
M : NS				
L : 0.02				

Table 32. Effect of sources and levels of S on S content of seed (%) of greengram (Co6)

Treatments	Seed S (%)
Control	0.37
M ₁ L ₁	0.37
M ₁ L ₂	0.38
M ₁ L ₃	0.40
M ₂ L ₁	0.37
M ₂ L ₂	0.39
M ₂ L ₃	0.39
M ₃ L ₁	0.38
M ₃ L ₂	0.38
M ₃ L ₃	0.40
CD (P = 0.05)	0.02

Levels Sources	L₁	L₂	L₃	Mean
M ₁	0.37	0.38	0.40	0.38
M ₂	0.37	0.39	0.39	0.38
M ₃	0.38	0.38	0.40	0.39
Mean	0.37	0.38	0.40	
CD (P = 0.05)				
	M	:	NS	
	L	:	0.01	

Table 33. Effect of sources and levels of S on N uptake (kg ha⁻¹) of blackgram (Co5)

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	12.35	11.55	36.04	19.98
M ₁ L ₁	16.64	18.32	39.05	24.67
M ₁ L ₂	19.87	19.51	42.25	27.21
M ₁ L ₃	20.98	23.54	45.92	30.15
M ₂ L ₁	17.33	17.10	37.30	23.91
M ₂ L ₂	18.30	18.85	41.47	26.21
M ₂ L ₃	19.72	21.77	42.95	28.15
M ₃ L ₁	16.73	19.08	38.43	24.75
M ₃ L ₂	18.27	20.96	41.93	27.05
M ₃ L ₃	20.90	24.02	45.90	30.27
CD (P = 0.05)				
T	:	3.45		
S	:	1.15		
M x L x S	:	NS		

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	12.35	11.55	36.04	19.98
M ₁	19.16	20.46	42.41	27.34
M ₂	18.45	19.24	40.57	26.09
M ₃	18.64	21.35	42.09	27.36
L ₁	16.90	18.17	38.26	24.44
L ₂	18.81	19.77	41.88	26.82
L ₃	20.53	23.11	44.92	29.52
CD (P = 0.05)				
M	:	1.15		
L	:	1.15		
M x S	:	NS		
L x S	:	NS		

Table 34. Effect of sources and levels of S on N uptake (kg ha⁻¹) of greengram (Co6)

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	13.46	18.53	40.29	24.09
M ₁ L ₁	17.37	19.80	42.03	26.40
M ₁ L ₂	19.51	21.66	46.15	29.11
M ₁ L ₃	21.50	22.89	49.72	31.37
M ₂ L ₁	14.00	19.42	41.74	25.05
M ₂ L ₂	16.12	21.50	44.84	27.49
M ₂ L ₃	20.09	22.19	48.19	30.16
M ₃ L ₁	18.55	20.74	43.54	27.61
M ₃ L ₂	19.61	23.48	46.61	29.90
M ₃ L ₃	20.86	24.41	50.69	31.99
CD (P = 0.05)				
T	:	2.20		
S	:	0.73		
M x L x S	:	NS		

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	13.46	18.53	40.29	24.09
M ₁	19.46	21.45	45.97	28.96
M ₂	16.74	21.04	44.93	27.57
M ₃	19.67	22.87	46.95	29.83
L ₁	16.64	19.99	42.44	26.36
L ₂	18.41	22.21	45.87	28.83
L ₃	20.82	23.16	49.53	31.17
CD (P = 0.05)				
M	:	0.73		
L	:	0.73		
M x S	:	NS		
L x S	:	NS		

Table 35. Effect of sources and levels of S on P uptake (kg ha⁻¹) blackgram (Co5)

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	2.46	2.53	3.50	2.83
M ₁ L ₁	2.65	2.48	4.14	3.09
M ₁ L ₂	2.59	2.99	4.52	3.37
M ₁ L ₃	2.91	3.89	5.19	4.00
M ₂ L ₁	2.48	2.88	3.80	3.05
M ₂ L ₂	2.72	3.48	4.45	3.55
M ₂ L ₃	3.08	3.30	4.69	3.69
M ₃ L ₁	2.93	2.93	4.72	3.53
M ₃ L ₂	3.25	3.88	5.15	4.10
M ₃ L ₃	3.78	4.14	6.20	4.71
CD (P = 0.05)				
T	:	0.35		
S	:	0.12		
M x L x S	:	0.35		

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	2.46	2.53	3.50	2.83
M ₁	2.72	3.12	4.62	3.49
M ₂	2.76	3.22	4.31	3.43
M ₃	3.32	3.65	5.36	4.11
L ₁	2.69	2.76	4.22	3.22
L ₂	2.85	3.45	4.71	3.67
L ₃	3.26	3.78	5.36	4.13
CD (P = 0.05)				
M	:	0.12		
L	:	0.12		
M x S	:	NS		
L x S	:	NS		

Table 36. Effect of sources and levels of S on P uptake (kg ha⁻¹) of greengram (Co6)

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	3.24	3.20	4.09	3.51
M ₁ L ₁	3.39	3.06	4.67	3.71
M ₁ L ₂	4.07	3.60	5.07	4.25
M ₁ L ₃	4.32	3.92	5.89	4.71
M ₂ L ₁	3.09	2.80	4.59	3.49
M ₂ L ₂	3.43	3.46	5.12	4.00
M ₂ L ₃	4.11	3.93	5.73	4.59
M ₃ L ₁	3.03	3.08	4.97	3.69
M ₃ L ₂	3.45	3.57	5.46	4.16
M ₃ L ₃	3.95	4.04	6.12	4.70
CD (P = 0.05)				
T	:	0.50		
S	:	0.17		
M x L x S	:	0.50		

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	3.20	3.24	4.09	3.51
M ₁	3.53	3.93	5.21	4.22
M ₂	3.40	3.54	5.15	4.03
M ₃	3.56	3.48	5.52	4.19
L ₁	2.98	3.17	4.74	3.63
L ₂	3.54	3.65	5.22	4.14
L ₃	3.96	4.13	5.92	4.67
CD (P = 0.05)				
M	:	NS		
L	:	0.17		
M x S	:	0.29		
L x S	:	NS		

Table 37. Effect of sources and levels of S on K uptake (kg ha⁻¹) of blackgram (Co5)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	12.52	13.89	19.88	15.43
M ₁ L ₁	13.50	15.00	21.56	16.69
M ₁ L ₂	14.07	15.49	23.41	17.87
M ₁ L ₃	16.04	17.56	25.12	19.57
M ₂ L ₁	13.27	14.48	20.92	16.22
M ₂ L ₂	13.55	15.27	22.87	17.23
M ₂ L ₃	16.10	16.40	23.62	18.71
M ₃ L ₁	15.33	16.08	22.04	17.82
M ₃ L ₂	14.57	16.38	24.13	18.36
M ₃ L ₃	16.30	17.84	25.68	19.94
CD (P = 0.05)				
T	:	0.95		
S	:	0.32		
M x L x S	:	NS		

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	12.52	13.89	19.88	15.43
M ₁	14.75	16.02	23.36	18.04
M ₂	14.31	15.38	22.47	17.39
M ₃	15.40	16.76	23.95	18.71
L ₁	14.04	15.19	21.51	16.91
L ₂	14.27	15.71	23.47	17.82
L ₃	16.15	17.27	24.81	19.41
CD (P = 0.05)				
M	:	0.32		
L	:	0.32		
M x S	:	NS		
L x S	:	NS		

Table 38. Effect of sources and levels of S on K uptake (kg ha⁻¹) of greengram (Co6)

Stages (S) Treatments	Flowering	Pod development	Harvest	Mean
Control	13.33	14.81	21.62	16.59
M ₁ L ₁	14.36	16.10	23.25	17.90
M ₁ L ₂	15.31	17.02	25.11	19.15
M ₁ L ₃	16.87	17.96	27.02	20.61
M ₂ L ₁	14.83	15.76	23.26	17.95
M ₂ L ₂	15.82	16.75	24.86	19.14
M ₂ L ₃	16.47	17.47	26.55	20.16
M ₃ L ₁	14.85	17.13	24.46	18.81
M ₃ L ₂	15.30	17.73	26.51	19.85
M ₃ L ₃	16.76	18.36	27.97	21.03
CD (P = 0.05)				
T	:	1.15		
S	:	0.38		
M x L x S	:	NS		

Stages(S) Treatments	Flowering	Pod development	Harvest	Mean
Control	13.33	14.81	21.62	16.59
M ₁	15.51	17.03	25.12	19.22
M ₂	15.71	16.66	24.89	19.09
M ₃	15.64	17.74	26.32	19.90
L ₁	14.68	16.33	23.66	18.22
L ₂	15.48	17.17	25.49	19.38
L ₃	16.70	17.93	27.18	20.60
CD (P = 0.05)				
M	:	0.38		
L	:	0.38		
M x S	:	NS		
L x S	:	NS		

Table 39. Effect of sources and levels of S on Ca uptake (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	13.25	13.83	21.47	16.18
M ₁ L ₁	13.85	14.61	23.16	17.21
M ₁ L ₂	15.35	15.50	25.15	18.66
M ₁ L ₃	16.31	17.05	26.62	19.99
M ₂ L ₁	14.47	14.52	22.26	17.08
M ₂ L ₂	15.23	15.41	23.99	18.21
M ₂ L ₃	16.01	16.52	25.50	19.34
M ₃ L ₁	14.59	15.08	23.48	17.72
M ₃ L ₂	15.58	15.70	25.46	18.91
M ₃ L ₃	16.35	17.07	27.13	20.18
CD (P = 0.05)				
T	:	0.85		
S	:	0.28		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	13.25	13.83	21.47	16.18
M ₁	15.17	15.72	24.98	18.62
M ₂	15.24	15.48	23.92	18.21
M ₃	15.50	15.95	25.36	18.94
L ₁	14.30	14.74	22.97	17.34
L ₂	15.38	15.54	24.87	18.60
L ₃	16.22	16.88	26.42	19.84
CD (P = 0.05)				
M	:	0.28		
L	:	0.28		
M x S	:	NS		
L x S	:	NS		

Table 40. Effect of sources and levels of S on Ca uptake (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	12.90	14.74	23.64	17.09
M ₁ L ₁	13.63	16.02	26.17	18.60
M ₁ L ₂	14.80	17.57	27.80	20.06
M ₁ L ₃	16.00	18.31	29.72	21.34
M ₂ L ₁	14.42	15.26	24.48	18.05
M ₂ L ₂	14.82	16.45	25.77	19.02
M ₂ L ₃	16.15	17.58	27.96	20.57
M ₃ L ₁	14.64	16.22	25.95	18.93
M ₃ L ₂	15.94	17.47	27.59	20.33
M ₃ L ₃	17.01	18.45	29.79	21.75
CD (P = 0.05)				
T	:	1.01		
S	:	0.34		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	12.90	14.74	23.64	17.09
M ₁	14.81	17.30	27.90	20.00
M ₂	15.13	16.43	26.07	19.21
M ₃	15.86	17.38	27.78	20.34
L ₁	14.23	15.83	25.53	18.53
L ₂	15.19	17.16	27.06	19.80
L ₃	16.39	18.11	29.16	21.22
CD (P = 0.05)				
M	:	0.34		
L	:	0.34		
M x S	:	NS		
L x S	:	NS		

Table 41. Effect of sources and levels of S on Mg uptake (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.19	8.15	8.33	8.22
M ₁ L ₁	8.71	8.78	9.16	8.88
M ₁ L ₂	9.70	9.88	9.68	9.75
M ₁ L ₃	10.55	10.27	10.71	10.51
M ₂ L ₁	8.25	8.79	8.46	8.50
M ₂ L ₂	9.06	9.54	9.12	9.24
M ₂ L ₃	9.81	10.02	9.80	9.88
M ₃ L ₁	9.13	9.07	9.75	9.32
M ₃ L ₂	10.00	10.38	10.25	10.21
M ₃ L ₃	10.36	11.00	11.32	10.89
CD (P = 0.05)				
T	:	0.61		
S	:	0.20		
M x L x S	:	0.61		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.19	8.15	8.33	8.22
M ₁	9.65	9.64	9.85	9.72
M ₂	9.04	9.45	9.13	9.21
M ₃	9.83	10.15	10.44	10.14
L ₁	8.70	8.88	9.12	8.90
L ₂	9.59	9.93	9.68	9.73
L ₃	10.24	10.43	10.61	10.43
CD (P = 0.05)				
M	:	0.20		
L	:	0.20		
M x S	:	0.35		
L x S	:	NS		

Table 42. Effect of sources and levels of S on Mg uptake (kg ha^{-1}) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.58	9.09	9.12	8.93
M ₁ L ₁	9.01	10.12	9.80	9.64
M ₁ L ₂	9.93	10.92	10.99	10.61
M ₁ L ₃	10.81	11.53	11.87	11.40
M ₂ L ₁	8.63	8.81	9.78	9.07
M ₂ L ₂	9.61	10.03	10.73	10.12
M ₂ L ₃	10.79	11.08	11.64	11.17
M ₃ L ₁	9.11	10.36	10.34	9.94
M ₃ L ₂	10.11	11.26	11.29	10.88
M ₃ L ₃	10.63	12.00	12.15	11.59
CD (P = 0.05)				
T	:	0.82		
S	:	0.27		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.58	9.09	9.12	8.93
M ₁	9.92	10.85	10.89	10.55
M ₂	9.67	9.97	10.72	10.12
M ₃	9.95	11.21	11.26	10.80
L ₁	8.92	9.76	9.98	9.55
L ₂	9.88	10.73	11.01	10.54
L ₃	10.74	11.53	11.89	11.39
CD (P = 0.05)				
M	:	0.27		
L	:	0.27		
M x S	:	0.47		
L x S	:	NS		

Table 43. Effect of sources and levels of S on S uptake (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1.82	3.05	4.03	2.97
M ₁ L ₁	2.09	2.88	4.60	3.19
M ₁ L ₂	2.53	3.14	5.34	3.67
M ₁ L ₃	3.33	4.33	6.03	4.56
M ₂ L ₁	2.06	2.97	4.40	3.15
M ₂ L ₂	2.38	3.42	4.74	3.51
M ₂ L ₃	2.98	3.93	5.59	4.17
M ₃ L ₁	2.71	3.66	4.53	3.63
M ₃ L ₂	3.06	3.94	5.28	4.09
M ₃ L ₃	3.39	4.42	5.95	4.59
CD (P = 0.05)				
T	:	0.42		
S	:	0.14		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1.82	3.05	4.03	2.97
M ₁	2.65	3.45	5.32	3.81
M ₂	2.47	3.44	4.91	3.61
M ₃	3.05	4.01	5.26	4.10
L ₁	2.29	3.17	4.51	3.32
L ₂	2.66	3.50	5.12	3.76
L ₃	3.23	4.23	5.86	4.44
CD (P = 0.05)				
M	:	0.14		
L	:	0.14		
M x S	:	NS		
L x S	:	NS		

Table 44. Effect of sources and levels of S on S uptake (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	2.21	3.24	4.45	3.30
M ₁ L ₁	2.75	3.44	4.84	3.68
M ₁ L ₂	3.12	3.81	5.29	4.07
M ₁ L ₃	3.47	4.52	5.52	4.51
M ₂ L ₁	2.14	3.61	4.62	3.45
M ₂ L ₂	2.52	4.00	5.27	3.93
M ₂ L ₃	3.34	4.39	5.63	4.45
M ₃ L ₁	2.92	3.56	4.84	3.77
M ₃ L ₂	3.01	4.26	5.41	4.22
M ₃ L ₃	3.53	4.58	5.88	4.66
CD (P = 0.05)				
T	:	0.38		
S	:	0.13		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	2.21	3.24	4.45	3.30
M ₁	3.12	3.92	5.22	4.09
M ₂	2.67	4.00	5.17	3.95
M ₃	3.15	4.13	5.37	4.22
L ₁	2.60	3.54	4.77	3.63
L ₂	2.88	4.02	5.32	4.07
L ₃	3.45	4.50	5.68	4.54
CD (P = 0.05)				
M	:	0.13		
L	:	0.13		
M x S	:	NS		
L x S	:	NS		

Table 45. Effect of sources and levels of S on available N (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	223.9	211.9	209.2	215.0
M ₁ L ₁	221.6	211.4	211.0	214.7
M ₁ L ₂	218.7	215.7	212.1	215.5
M ₁ L ₃	216.7	217.5	211.4	215.2
M ₂ L ₁	221.2	211.3	210.9	214.5
M ₂ L ₂	219.5	212.8	212.1	214.8
M ₂ L ₃	217.5	214.5	213.1	215.0
M ₃ L ₁	221.6	210.2	208.7	213.5
M ₃ L ₂	218.7	211.7	210.5	213.6
M ₃ L ₃	217.2	215.0	212.1	214.8
CD (P = 0.05)				
T	:	NS		
S	:	6.0		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	223.9	211.9	209.2	215.0
M ₁	219.0	214.8	211.5	215.1
M ₂	219.4	212.8	212.0	214.7
M ₃	219.1	212.3	210.4	214.0
L ₁	221.5	210.9	210.2	214.2
L ₂	219.0	213.4	211.5	214.6
L ₃	217.1	215.7	212.2	215.0
CD (P = 0.05)				
M	:	NS		
L	:	NS		
M x S	:	NS		
L x S	:	NS		

Table 46. Effect of sources and levels of S on available N (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	226.5	217.6	213.7	219.2
M ₁ L ₁	220.9	215.0	212.4	216.1
M ₁ L ₂	217.6	212.8	211.4	213.9
M ₁ L ₃	215.0	210.6	208.9	211.5
M ₂ L ₁	220.8	215.6	213.0	216.4
M ₂ L ₂	217.5	213.6	212.1	214.4
M ₂ L ₃	215.5	212.0	210.0	212.5
M ₃ L ₁	220.3	214.6	212.8	215.9
M ₃ L ₂	217.4	212.0	211.4	213.6
M ₃ L ₃	214.4	210.8	208.8	211.3
CD (P = 005)				
T	:	NS		
S	:	5.0		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	226.5	217.6	213.7	219.2
M ₁	217.8	212.8	210.9	213.8
M ₂	217.9	213.7	211.7	214.4
M ₃	217.4	212.5	211.0	213.6
L ₁	220.6	215.1	212.7	216.1
L ₂	217.5	212.8	211.6	214.0
L ₃	215.0	211.1	209.2	211.8
CD (P = 0.05)				
M	:	NS		
L	:	NS		
M x S	:	NS		
L x S	:	NS		

Table 47. Effect of sources and levels of S on available P (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	21.14	19.01	18.17	19.44
M ₁ L ₁	20.11	18.55	17.64	18.77
M ₁ L ₂	19.09	17.75	16.65	17.83
M ₁ L ₃	18.27	16.93	16.16	17.12
M ₂ L ₁	19.79	18.79	17.84	18.81
M ₂ L ₂	18.34	17.97	16.87	17.73
M ₂ L ₃	17.96	16.99	16.51	17.15
M ₃ L ₁	20.11	18.24	17.65	18.67
M ₃ L ₂	19.09	11.71	16.64	15.81
M ₃ L ₃	18.03	16.98	16.06	17.03
CD (P = 0.05)				
T	:	1.24		
S	:	1.04		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	21.14	19.01	18.17	19.44
M ₁	19.16	17.74	16.82	17.91
M ₂	18.70	17.92	17.07	17.90
M ₃	19.08	15.64	16.78	17.17
L ₁	20.00	18.53	17.71	18.75
L ₂	18.84	15.81	16.72	17.12
L ₃	18.09	16.97	16.24	17.10
CD (P = 0.05)				
M	:	NS		
L	:	NS		
M x S	:	NS		
L x S	:	NS		

Table 48. Effect of sources and levels of S on available P (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	20.64	18.96	18.20	19.27
M ₁ L ₁	20.04	18.42	17.69	18.72
M ₁ L ₂	19.07	17.94	16.63	17.88
M ₁ L ₃	18.32	16.90	16.11	17.11
M ₂ L ₁	19.75	18.70	17.80	18.75
M ₂ L ₂	18.50	17.93	16.85	17.76
M ₂ L ₃	17.97	17.05	16.39	17.13
M ₃ L ₁	20.09	18.23	17.49	18.60
M ₃ L ₂	19.05	17.67	16.61	17.78
M ₃ L ₃	18.22	16.93	15.95	17.03
CD (P = 0.05)				
T	:	0.69		
S	:	0.80		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	20.64	18.96	18.20	19.27
M ₁	19.14	17.75	16.81	17.90
M ₂	18.74	17.89	17.01	17.88
M ₃	19.12	17.61	16.68	17.81
L ₁	19.96	18.45	17.66	18.69
L ₂	18.87	17.85	16.70	17.81
L ₃	18.17	16.96	16.15	17.09
CD (P = 0.05)				
M	:	NS		
L	:	NS		
M x S	:	NS		
L x S	:	NS		

Table 49. Effect of sources and levels of S on available K (kg ha⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	370.6	363.9	359.5	364.6
M ₁ L ₁	366.1	362.4	357.7	362.1
M ₁ L ₂	362.9	360.7	356.3	360.0
M ₁ L ₃	360.4	359.0	354.6	358.0
M ₂ L ₁	366.0	362.5	359.2	362.6
M ₂ L ₂	363.0	360.6	356.5	360.0
M ₂ L ₃	362.6	360.2	354.2	359.0
M ₃ L ₁	366.7	362.6	359.1	362.8
M ₃ L ₂	364.1	359.5	355.2	359.6
M ₃ L ₃	360.6	358.4	353.8	357.6
CD (P = 0.05)				
T	:	NS		
S	:	NS		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	370.6	363.9	359.5	364.6
M ₁	363.1	360.7	356.2	360.0
M ₂	363.9	361.1	256.6	360.5
M ₃	363.8	360.2	356.0	360.0
L ₁	366.3	362.5	358.7	362.5
L ₂	363.3	360.3	356.0	359.9
L ₃	361.2	359.2	354.2	358.2
CD (P = 0.05)				
M	:	NS		
L	:	0.7		
M x S	:	NS		
L x S	:	NS		

Table 50. Effect of sources and levels of S on available K (kg ha⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	369.9	363.3	358.7	364.0
M ₁ L ₁	366.3	362.2	358.2	362.2
M ₁ L ₂	362.8	360.9	355.3	359.6
M ₁ L ₃	359.9	359.5	351.4	356.9
M ₂ L ₁	365.9	362.4	356.8	361.7
M ₂ L ₂	363.6	360.6	354.8	356.7
M ₂ L ₃	361.1	360.2	351.6	357.6
M ₃ L ₁	366.3	362.4	355.6	361.4
M ₃ L ₂	363.0	259.6	353.5	358.7
M ₃ L ₃	359.6	358.2	351.8	356.5
CD (P = 0.05)				
T	:	NS		
S	:	NS		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	369.9	363.3	358.7	364.0
M ₁	363.0	360.9	355.0	359.6
M ₂	363.5	361.0	354.4	359.7
M ₃	362.9	360.0	353.6	358.9
L ₁	366.2	362.3	356.9	361.8
L ₂	363.1	360.3	354.5	359.3
L ₃	360.2	359.3	351.6	357.0
CD (P = 0.05)				
M	:	NS		
L	:	0.61		
M x S	:	NS		
L x S	:	NS		

Table 51. Effect of sources and levels of S on exchangeable Ca (c mol (p+) kg⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	6.77	6.57	6.06	6.47
M ₁ L ₁	7.78	7.26	7.08	7.37
M ₁ L ₂	8.38	8.15	7.33	7.95
M ₁ L ₃	9.36	8.87	8.01	8.75
M ₂ L ₁	6.59	6.38	6.65	6.54
M ₂ L ₂	6.75	6.57	6.94	6.75
M ₂ L ₃	6.93	6.74	6.99	6.89
M ₃ L ₁	6.54	6.41	5.91	6.29
M ₃ L ₂	6.75	6.56	6.03	6.45
M ₃ L ₃	6.89	6.67	6.40	6.65
CD (P = 0.05)				
T	:	0.40		
S	:	0.28		
M x L x S	:	0.85		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	6.77	6.57	6.06	6.47
M ₁	8.51	8.09	7.47	8.02
M ₂	6.76	6.56	6.86	6.73
M ₃	6.73	6.55	6.11	6.46
L ₁	6.97	6.68	6.55	6.73
L ₂	7.29	7.09	6.77	7.05
L ₃	7.73	7.43	7.13	7.43
CD (P = 0.05)				
M	:	0.28		
L	:	0.28		
M x S	:	0.49		
L x S	:	NS		

Table 52. Effect of sources and levels of S on exchangeable Ca (c mol (p+) kg⁻¹ of soil) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	6.84	6.44	6.07	6.45
M ₁ L ₁	7.70	7.17	7.05	7.31
M ₁ L ₂	8.48	8.01	7.98	8.16
M ₁ L ₃	9.43	8.92	8.54	8.96
M ₂ L ₁	6.84	6.29	5.94	6.36
M ₂ L ₂	6.87	6.36	6.01	6.41
M ₂ L ₃	6.74	6.34	5.97	6.35
M ₃ L ₁	6.79	6.50	5.98	6.42
M ₃ L ₂	6.87	6.44	6.04	6.45
M ₃ L ₃	6.91	6.31	6.03	6.42
CD (P = 0.05)				
T	:	0.30		
S	:	0.10		
M x L x S	:	0.30		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	6.84	6.44	6.07	6.45
M ₁	8.54	8.03	7.86	8.14
M ₂	6.82	6.33	5.97	6.37
M ₃	6.86	6.42	6.02	6.43
L ₁	7.11	6.65	6.32	6.70
L ₂	7.41	6.94	6.68	7.01
L ₃	7.69	7.19	6.85	7.24
CD (P = 0.05)				
M	:	0.10		
L	:	0.10		
M x S	:	NS		
L x S	:	NS		

Table 53. Effect of sources and levels of S on exchangeable Mg (c mol (p+) kg⁻¹) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1.45	1.81	1.82	1.69
M ₁ L ₁	1.94	1.89	1.76	1.86
M ₁ L ₂	2.05	1.98	1.87	1.97
M ₁ L ₃	2.16	2.02	1.92	2.03
M ₂ L ₁	2.078	2.89	2.76	2.81
M ₂ L ₂	3.07	3.14	3.05	3.09
M ₂ L ₃	3.35	3.21	3.15	3.24
M ₃ L ₁	1.96	1.93	1.82	1.91
M ₃ L ₂	2.04	1.96	1.88	1.96
M ₃ L ₃	2.11	2.08	1.95	2.05
CD (P = 0.05)				
T	:	0.40		
S	:	0.13		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	1.45	1.81	1.82	1.69
M ₁	2.05	1.96	1.85	1.95
M ₂	3.07	3.08	2.99	3.05
M ₃	2.04	1.99	1.88	1.97
L ₁	2.23	2.24	2.11	2.19
L ₂	2.39	2.36	2.27	2.34
L ₃	2.54	2.44	2.34	2.44
CD (P = 0.05)				
M	:	0.13		
L	:	0.13		
M x S	:	NS		
L x S	:	NS		

Table 54. Effect of sources and levels of S on exchangeable Mg (c mol (p+) kg⁻¹) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	2.07	1.92	1.81	1.94
M ₁ L ₁	2.09	1.97	1.87	1.98
M ₁ L ₂	1.97	2.01	1.84	1.94
M ₁ L ₃	2.03	1.87	1.87	1.93
M ₂ L ₁	2.86	2.85	2.67	2.79
M ₂ L ₂	3.11	2.98	2.95	3.01
M ₂ L ₃	3.32	3.14	3.11	3.19
M ₃ L ₁	1.94	1.87	1.85	1.89
M ₃ L ₂	1.97	1.92	1.93	1.94
M ₃ L ₃	1.94	1.92	1.83	1.90
CD (P = 0.05)				
T	:	0.17		
S	:	0.06		
M x L x S	:	0.17		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	2.07	1.92	1.81	1.94
M ₁	2.03	1.95	1.86	1.95
M ₂	3.10	2.99	2.91	3.00
M ₃	1.95	1.90	1.87	1.91
L ₁	2.30	2.23	2.13	2.22
L ₂	2.35	2.30	2.24	2.30
L ₃	2.43	2.31	2.27	2.34
CD (P = 0.05)				
M	:	0.06		
L	:	0.06		
M x S	:	0.10		
L x S	:	NS		

Table 55. Effect of sources and levels of S on available S (ppm) of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.26	8.28	7.93	8.16
M ₁ L ₁	9.19	9.05	8.98	9.07
M ₁ L ₂	9.53	9.53	9.54	9.54
M ₁ L ₃	10.15	10.08	9.65	9.96
M ₂ L ₁	9.29	9.25	9.26	9.27
M ₂ L ₂	9.56	9.71	9.67	9.65
M ₂ L ₃	10.49	10.26	9.99	10.24
M ₃ L ₁	9.15	9.04	8.95	9.05
M ₃ L ₂	9.73	9.48	9.45	9.56
M ₃ L ₃	10.45	10.08	9.84	10.12
CD (P = 0.05)				
T	:	0.48		
S	:	0.19		
M x L x S	:	0.28		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.26	8.28	7.93	8.16
M ₁	9.62	9.56	9.39	9.52
M ₂	9.78	9.74	9.64	9.72
M ₃	9.78	9.53	9.41	9.57
L ₁	9.21	9.11	9.06	9.13
L ₂	9.61	9.57	9.56	9.58
L ₃	10.36	10.14	9.82	10.11
CD (P = 0.05)				
M	:	0.19		
L	:	0.19		
M x S	:	NS		
L x S	:	0.16		

Table 56. Effect of sources and levels of S on available S (ppm) of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.25	8.18	8.04	8.16
M ₁ L ₁	9.19	9.04	8.98	9.07
M ₁ L ₂	9.74	9.57	8.53	9.61
M ₁ L ₃	10.42	10.10	9.86	10.13
M ₂ L ₁	9.30	9.19	9.03	9.18
M ₂ L ₂	9.84	9.86	9.69	9.80
M ₂ L ₃	10.51	10.22	10.12	10.28
M ₃ L ₁	9.21	9.05	8.93	9.07
M ₃ L ₂	9.65	9.49	9.48	9.54
M ₃ L ₃	10.35	10.13	9.88	10.12
CD (P = 0.05)				
T	:	0.43		
S	:	0.13		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	8.25	8.18	8.04	8.16
M ₁	9.78	9.57	9.46	9.60
M ₂	9.88	9.76	9.62	9.75
M ₃	9.74	9.56	9.43	9.58
L ₁	9.23	9.10	8.98	9.10
L ₂	9.74	9.64	9.57	9.65
L ₃	10.43	10.15	9.95	10.18
CD (P = 0.05)				
M	:	0.13		
L	:	0.13		
M x S	:	NS		
L x S	:	NS		

Table 57. Effect of sources and levels of S on seed protein content (%) blackgram (Co5)

Treatments	Protein content (%)
Control	20.79
M ₁ L ₁	21.21
M ₁ L ₂	21.44
M ₁ L ₃	22.06
M ₂ L ₁	20.79
M ₂ L ₂	21.56
M ₂ L ₃	21.21
M ₃ L ₁	21.13
M ₃ L ₂	21.54
M ₃ L ₃	22.17
CD (P = 0.05)	0.65

Sources \ Levels	L₁	L₂	L₃	Mean
M ₁	21.21	21.44	22.06	21.57
M ₂	20.79	21.56	21.21	21.19
M ₃	21.13	21.54	22.17	21.61
Mean	21.04	21.52	21.81	
CD (P = 0.05)				
M	:	NS		
L	:	0.37		

Table 58. Effect of sources and levels of S on seed protein content (%) greengram (Co6)

Treatments	Protein content (%)
Control	21.83
M ₁ L ₁	22.85
M ₁ L ₂	22.69
M ₁ L ₃	23.15
M ₂ L ₁	21.98
M ₂ L ₂	22.46
M ₂ L ₃	23.06
M ₃ L ₁	21.96
M ₃ L ₂	22.98
M ₃ L ₃	23.96
CD (P = 0.05)	0.77

Levels Sources	L₁	L₂	L₃	Mean
M ₁	21.21	21.44	22.06	22.73
M ₂	20.79	21.56	21.21	22.50
M ₃	24.13	21.54	22.17	22.97
Mean	22.10	21.52	21.81	
CD (P = 0.05)				
	M	:	NS	
	L	:	0.44	

Table 59. Effect of sources and levels of S on number of nodules per plant of blackgram (Co5)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	23.53	27.60	27.47	26.20
M ₁ L ₁	26.33	30.60	31.07	29.33
M ₁ L ₂	28.13	33.27	33.33	31.58
M ₁ L ₃	31.47	35.67	35.60	34.24
M ₂ L ₁	25.27	28.67	28.73	27.56
M ₂ L ₂	26.97	30.67	30.93	29.52
M ₂ L ₃	28.27	32.93	33.20	31.47
M ₃ L ₁	26.07	30.53	31.03	29.21
M ₃ L ₂	28.60	33.07	33.33	31.67
M ₃ L ₃	31.07	35.43	35.86	34.12
CD (P=0.05)				
T	:	1.42		
S	:	0.47		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	23.53	27.60	27.47	26.20
M ₁	28.64	33.18	33.33	31.72
M ₂	26.83	30.76	30.96	29.51
M ₃	28.58	33.01	33.41	31.67
L ₁	25.89	29.93	30.28	28.70
L ₂	27.90	32.33	32.53	30.92
L ₃	30.27	34.68	34.89	33.28
CD (P=0.05)				
M	:	0.47		
L	:	0.47		
M x S	:	NS		
L x S	:	NS		

Table 60. Effect of sources and levels of S on number of nodules per plant of greengram (Co6)

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	23.33	26.60	26.60	25.51
M ₁ L ₁	26.27	30.07	30.60	28.98
M ₁ L ₂	27.40	32.80	32.53	30.91
M ₁ L ₃	30.60	35.07	34.87	33.51
M ₂ L ₁	24.87	28.00	28.00	26.96
M ₂ L ₂	25.73	30.27	30.60	28.87
M ₂ L ₃	27.80	32.47	32.47	30.91
M ₃ L ₁	25.20	30.20	30.33	28.58
M ₃ L ₂	28.13	32.73	32.87	31.24
M ₃ L ₃	30.07	35.20	34.60	33.29
CD (P=0.05)				
T	:	1.45		
S	:	0.48		
M x L x S	:	NS		

Stages Treatments	Flowering	Pod development	Harvest	Mean
Control	23.33	26.60	26.60	25.51
M ₁	28.09	32.64	32.67	31.13
M ₂	26.13	30.24	30.36	28.91
M ₃	27.80	32.71	32.60	31.04
L ₁	25.44	29.42	29.64	28.17
L ₂	27.09	31.93	32.00	30.34
L ₃	29.49	34.24	33.98	32.57
CD (P=0.05)				
M	:	0.48		
L	:	0.48		
M x S	:	NS		
L x S	:	NS		

Table 61. Effect of sources and levels of S on number of pods per plant blackgram (Co5)

Treatments	Number of pods per plant
Control	33.53
M ₁ L ₁	36.60
M ₁ L ₂	38.33
M ₁ L ₃	41.33
M ₂ L ₁	35.33
M ₂ L ₂	37.13
M ₂ L ₃	39.40
M ₃ L ₁	36.80
M ₃ L ₂	38.73
M ₃ L ₃	41.20
CD (P = 0.05)	1.54

Levels Sources	L₁	L₂	L₃	Mean
M ₁	36.60	38.33	41.33	38.76
M ₂	35.33	37.13	39.40	37.29
M ₃	36.80	38.73	41.20	38.91
Mean	36.24	38.07	40.64	
CD (P = 0.05)				
	M	:	0.89	
	L	:	0.89	

Table 62. Effect of sources and levels of S on number of pods per plant greengram (Co6)

Treatments	Number of pods per plant
Control	33.53
M ₁ L ₁	36.47
M ₁ L ₂	37.53
M ₁ L ₃	40.40
M ₂ L ₁	36.13
M ₂ L ₂	36.67
M ₂ L ₃	38.07
M ₃ L ₁	36.40
M ₃ L ₂	37.33
M ₃ L ₃	40.00
CD (P = 0.05)	1.68

Levels Sources	L₁	L₂	L₃	Mean
M ₁	36.47	37.53	40.40	38.13
M ₂	36.13	36.67	38.07	36.96
M ₃	36.40	37.33	40.00	37.91
Mean	36.33	37.18	39.49	
CD (P = 0.05)				
M : NS				
L : 0.97				

Table 63. Effect of sources and levels of S on hundred seed weight (g) of blackgram (Co5)

Treatments	Hundred seed weight (g)
Control	5.13
M ₁ L ₁	5.25
M ₁ L ₂	5.43
M ₁ L ₃	5.69
M ₂ L ₁	5.29
M ₂ L ₂	5.39
M ₂ L ₃	5.53
M ₃ L ₁	5.29
M ₃ L ₂	5.45
M ₃ L ₃	5.66
CD (P = 0.05)	0.18

Levels Sources	L₁	L₂	L₃	Mean
M ₁	5.25	5.43	5.69	5.46
M ₂	5.29	5.39	5.53	5.4
M ₃	5.29	5.45	5.66	5.47
Mean	5.28	5.43	5.62	
CD (P = 0.05)				
	M	:	0.14	
	L	:	0.14	

Table 64. Effect of sources and levels of S on hundred seed weight (g) of greengram (Co6)

Treatments	Hundred seed weight (g)
Control	3.02
M ₁ L ₁	3.16
M ₁ L ₂	3.15
M ₁ L ₃	3.35
M ₂ L ₁	3.11
M ₂ L ₂	3.12
M ₂ L ₃	3.26
M ₃ L ₁	3.17
M ₃ L ₂	3.21
M ₃ L ₃	3.32
CD (P = 0.05)	0.13

Levels Sources	L₁	L₂	L₃	Mean
M ₁	3.16	3.15	3.35	3.22
M ₂	3.11	3.12	3.26	3.16
M ₃	3.17	3.21	3.32	3.23
Mean	3.15	3.16	3.31	
CD (P = 0.05)				
	M	:	NS	
	L	:	0.08	

Appendix –I Simple correlation matrix on yield and yield attributes, dry matter production, uptake of nutrients in Blackgram (Co5)

	Yield	DMP	No. of pods	Test weight	N	P	K	Ca	Mg	S
Yield	1.000									
DMP	0.990	1.000								
No. of pods	0.973	0.980	1.000							
Test weight	0.948	0.951	0.977	1.000						
N	0.903	0.925	0.964	0.957	1.000					
P	0.883	0.878	0.880	0.868	0.818	1.000				
K	0.958	0.961	0.979	0.952	0.927	0.921	1.000			
Ca	0.950	0.963	0.987	0.985	0.958	0.899	0.976	1.000		
Mg	0.969	0.979	0.970	0.940	0.904	0.944	0.979	0.972	1.000	
S	0.947	0.947	0.965	0.960	0.894	0.925	0.983	0.973	0.972	1.000
Haulm yield	0.859	0.910	0.937	0.910	0.962	0.789	0.908	0.941	0.901	0.875

Appendix –II Simple correlation matrix yield and yield attributes, dry matter production, uptake of nutrients in greengram (Co6)

Yield	haulm yield	No. of pods	protein	test weight	DMP	N uptake	P uptake	K uptake	Ca uptake	Mg Uptake	S uptake
1.000											
0.901	1.000										
0.956	0.905	1.000									
0.932	0.798	0.880	1.000								
0.926	0.848	0.960	0.814	1.000							
0.956	0.968	0.932	0.832	0.901	1.000						
0.974	0.931	0.929	0.876	0.919	0.983	1.000					
0.913	0.874	0.900	0.839	0.882	0.946	0.953	1.000				
0.945	0.951	0.939	0.857	0.919	0.963	0.976	0.924	1.000			
0.968	0.940	0.938	0.875	0.924	0.983	0.997	0.958	0.987	1.000		
0.960	0.944	0.942	0.871	0.925	0.979	0.991	0.959	0.993	0.998	1.000	
0.951	0.921	0.922	0.859	0.918	0.974	0.988	0.976	0.976	0.993	0.993	1.000

Plate.1. General field view

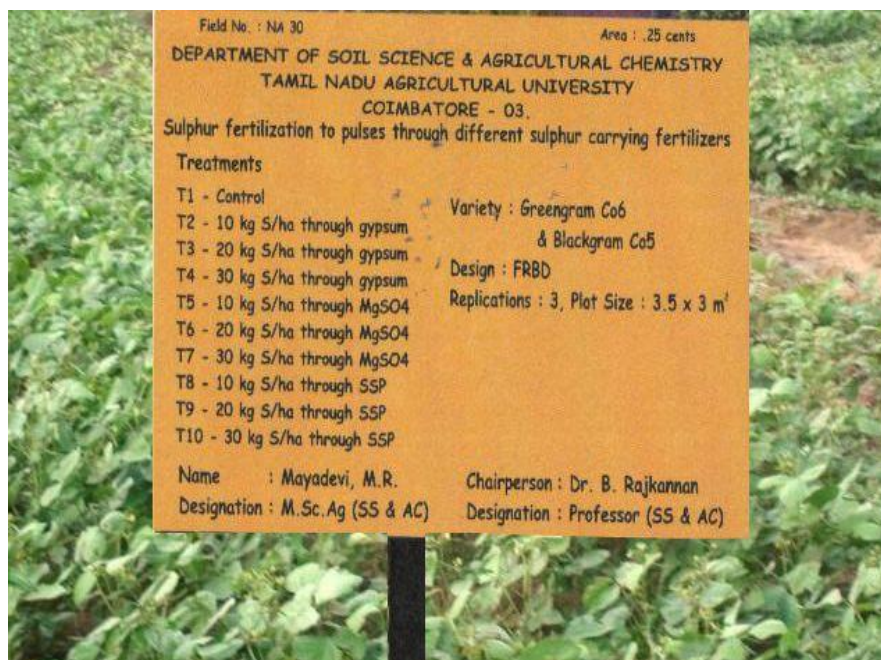


Plate.2. Field view at the time of flowering

