GROWTH, YIELD AND OIL CONTENT OF SESAME (*Sesamum indicum*L.) AS INFLUENCED BY SULPHUR AND BORON FERTILIZATION

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Dedicated to

My

Beloved Parents

CERTIFICATE

This is to certify that the thesis entitled, "GROWTH, YIELD AND OIL CONTENT OF SESAME AS INFLUENCED BY SULPHUR AND BORON FERTILIZATION" submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY embodies the result of a piece of bonafide research work carried out by MD. RASHEDUL HAQUE, Registration No. 00793 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by him.

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The Author

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ABSTRACT

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka to investigate growth, yield and oil content of sesame under different level of fertilization of sulphur and boron during summer season of 2008. Four levels of sulphur viz. 0, 9, 18 and 27 kg $ha^{-1}$and four levels of boron viz. 0, 1, 2 and 3 kg ha^{-1} were used as treatment variables. The experiment was laid out in randomized complete block design (factorial) with three replications. Results revealed that both sulphur and boron had significant effect on most of the growth, yield and yield parameters of sesame. Application of 27 kg S ha^{-1} showed the highest seed yield (1.19 t ha^{-1}) by producing higher number of branches $plant^{-1}$, capsules $plant^{-1}$, seeds $capsule^{-1}$ and 1000- seed weight. On the other hand, 2 kg B ha^{-1} showed its superiority by producing the highest seed yield (1.20 t ha^{-1}) as well as the highest yield contributing characters. The result also indicated that combination of 27 kg S ha^{-1} and 2 kg B ha^{-1} produced the highest amount of oil content (42.07% and 41.01%, respectively). Plant height, leaves dry weight $plant^{-1}$, petiole dry weight $plant^{-1}$, stem dry weight $plant^{-1}$, capsule dry weight $plant^{-1}$, number of branches $plant^{-1}$, number of capsule $plant^{-1}$, number of seeds $capsule^{-1}$, 1000- seed weight, seed yield, stover yield, oil content and harvest index increased significantly by the combining effect of 27 kg S ha^{-1} and 2 kg B ha^{-1}.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Celcius
DAS	=	Days after sowing
et al.	=	and others *(et alibi)*
Kg	=	Kilogram
Kg ha^{-1}	=	Kilogram per hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
DMRT	=	Duncan's Multiple Range Test
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion concentration
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t ha^{-1}	=	ton per hectare
%	=	Percent

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Seasame (*Sesamum indicum* L.) is one of the most important oil crops under Pedaliaceae family and extensively grown in different parts of the world. It ranks 4th among the oil crops in the world. The world production of sesame is 2.9 million metric tones (FAO, 2003). The leading sesame producing countries are India, Egypt, Pakistan, U.S.A, China, Sudan, Nigeria, Uganda, Chad, Morocco and Bangladesh. In Bangladesh, according to cultivable area and production it occupies second position as oil crop followed by rape and mustard (BARI, 2001). It is locally known as Til. Sesame is drought resistant cultivated annual herb, which can be easily grown under rainfed upland condition. It has been grown all over the world for thousands of years and today its major production areas are the tropics and subtropics of Asia, Africa, East and Central America.

Sesame is a versatile crop with high quality edible oil having diversified usage. Due to varietal differences, it contains 37 to 63% oil (BINA, 2004), 14 to 20% carbohydrate and 25% protein (BARI, 2001). It also contains 0.16- 0.29% S, 1.12-1.51% reducing sugars, 5.6-7.25% total sugar, 0.8-1.4% Ca, 0.41-0.71% P, 0.4-0.95% K and 40.4-52.7% protein on oil free basis (Dhindsa and Gupta, 1973). Taste and odour of sesame oil is pleasant because of presence of aldehyde and acetylpyragin. It also contain more than 80% unsaturated fatty acid including large amount of oleic and linoleic acid (BINA, 2004). Sesame oil is used mostly for edible purpose and in confectionery and illumination. It is also used for manufacture of margarine, soap, paint, perfumery products and in pharmaceuticals as an ingredient for drugs and as dispersing agent for different kinds of insecticides.

Bangladesh faces an acute shortage of edible oil. The total production of edible oil in the country is not sufficient to meet her requirement. The area and production of oil seed crops in Bangladesh during 2001-02 were 386.63 thousand hectare and 376 thousand metric tons, respectively (BBS, 2005). This production only ensures 4 g of oil per capita. People can consume only 10 g of oil day^{-1} summing local production and foreign import. But, the expert says, an adult should consume 22 g oil day^{-1} for better health. So, at present the country is experiencing 70% oil deficit (Wahhab, 2002).

In a view of population growth, the requirement of edible oil is increasing day by day. It is, therefore, highly expected that the production of edible oil should be increased considerably to fulfil the increasing demand. The production may be increased either by increasing cropping area under oil crop or increasing yield per unit area. But in the present condition, scope of expansion of oil crop area is narrow. So, there is a general consensus that increasing yield vertically is most reasonable way to increase total production.

Sesame can play an important role to fulfil the local demand of edible oil. Because the climate of our country is suitable for sesame production. Bangladesh produced 22 thousand metric tons of sesame from 36.84 thousand hectare of land every year (BBS, 2004). As sesame is short duration and photoinsensitive crop with wider adaptability, it can be cultivated both in rabi and kharif seasons. But yield of sesame per unit area in our country is very low, compared to other sesame producing countries. The average production of sesame in farmers level is only 0.55 t ha^{-1} (BARI, 1998). The main reasons for poor yield are lack of suitable modern varieties, production inputs, improper management practices and cultural operations.

It is also reported that sulphur deficiency may be one of the factors responsible for such low yield. Sulphur is called the fourth major nutrient after nitrogen, phosphorus and potassium, with its manifold functions. Additional sulphur application increased the seed and oil content of the sesame (Nageswar *et al.* 1995). Sesame has a high requirement for sulphur. An oil seed grower should include at least one sulphur containing fertilizer in the fertilizer dose of this crop to correct the sulphur deficiencies. sulphur is essential for the synthesis of certain amino acids – methionine, cestine etc. beside this, it involves metabolic and enzymatic processes of the plant. Besides primary nutrients, some micronutrient deficiency viz., B, Zn, and Mo have also appeared in some soils and crops (Khanam *et al.,* 2001). Ahmed and Hossain (1999) stated that Bangladesh had one million hectare of land, which had been boron deficient. The deficiency of this element is usually observed in light textured and high pH soils.

Besides the role of S and B, different combinations of sulphur and boron may have a great importance on this crop. But studies on this line are very rare. Hence, the experiment was undertaken to study the effect of sulphur and boron along with their combinations on sesame cv. BARI Til-3 with following objectives:

i. to find out the effect of different levels of sulphur on the yield, yield attributes and oil content of sesame,

ii. to find out the effect of different levels of boron on the yield, yield attributes and oil content of sesame, and

iii. to find out the interaction effect of sulphur and boron on the yield, yield attributes and oil content of sesame.

Chapter 2

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

2.1 Effect of sulphur on growth and yield of sesame

Maragatham *et al.* (2006) observed the effects of sulfur at 0, 20, 40, 60 and 80 kg/ha, applied alone or in combination with farmyard manure on the seed and oil yield, as well as S uptake of sesame cv. Co1. Application of sulfur at 40 kg/ha resulted in the highest dry matter plant^{-1}, seed yield (8.17 q ha^{-1}) and oil yield (4.03 kg ha^{-1}), as well as S uptake by the plants (5.88 kg ha^{-1}).

Amudha *et al.* (2005) carried out an investigation during the kharif season to study the effects of sulfur at varying rates 0, 15, 30 and 45 kg ha^{-1} and different organics (farmyard manure, poultry manure and pressmud each applied at 10 t ha^{-1}) on the yield and sulfur use efficiency (SUE) of sesame (*Sesamum indicum* cv. TMV 3). The seed and stover yields progressively increased with increasing S levels. While the response ratio, apparent S recovery and agronomic efficiency, but not physiological efficiency, were decreased with increasing S levels. Treatment with 45 kg S ha^{-1} registered the maximum seed yield (898.1 kg ha^{-1}) and stover yields (3155.7 kg ha^{-1}) for kharif season, respectively, as well as the maximum SUE.

Hegde and Babu (2004) stated that profitable oilseeds cultivation is possible with integrated use of nutrient sources to improve the productivity and quality oil and protein. The quality responses due to fertilizer (nitrogen, phosphorus, NPK, S and trace elements) use in different oilseeds (viz., rapeseed, sunflower, soyabean, safflower, groundnut, mustard, sesame and linseed).

Vaiyapuri *et al.* (2003) evaluate the effects of sulphur (0, 15, 30 and 45 kg ha^{-1}) and organic amendments (10 t ha^{-1} each of farmyard manure, poultry manure and press mud) on the seed quality and nutrient uptake of sesame cv. TMV 3. They found that application of 45 kg S ha^{-1} gave the best result in terms of seed quality, yield and yield attributing characters and nitrogen, phosphorus, potassium and sulphur uptake. Application of poultry manure resulted in the highest oil content, oil yield and crude protein content of sesame.

Sharma and Gupta (2003) conducted experiment on sesame using four sulphur rates like 0, 20, 40 and 60 kg ha^{-1} and reported that application of sulfur at 40 kg ha^{-1} increased plant height and dry matter accumulation. They also reported that this treatment gave higher number of capsules $plant^{-1}$ and seed number $capsule^{-1}$, 1000 seed weight and ultimately enhanced seed yield of sesame up to 27% over control. Application of 60 kg S ha^{-1} gave statistically similar result with 40 kg S ha^{-1}.

Dayanand *et al.* (2002) conducted a field experiment to study the effects of sulphur on nutrient uptake, yield and food value of sesame (*S. indicum*). They reported that the nitrogen content of straw, the total nitrogen uptake and oil yield of sesame increased significantly up to 40 kg S ha^{-1}. Biomass production, nitrogen content, seed yield, straw yield, protein and oil content of sesame significantly increased up to 60 kg S ha^{-1}.

Allam (2002) in a field study evaluated the effects of gypsum (0, 500 and 1000 kg ha^{-1}) and nitrogen (45, 60 and 75 kg ha^{-1}) rates on sesame. cv. Gizn 32. Gypsum was applied during sowing and 55 days after sowing and nitrogen was applied after thinning and 3 weeks thereafter. He found that increasing gypsum and nitrogen rates increased plant height, length of fruiting zone, number of oil percentage and oil yield of sesame. Seed yield and capsule lengths were highest with 60 and 75 kg N ha^{-1}.

Sarkar and Banik (2002) conducted a field experiment during spring to study the effects of sulfur application at the rate of 0, 25, and 50 kg ha^{-1} on the growth and productivity of sesame cv. B 67. Applying 50 kg S ha^{-1} was more effective in improving leaf area index, crop growth rate, relative growth rate, net assimilation rate, yield attributes, and crop yield over applying at 25 kg S ha^{-1}.

Radhamani *et al*. (2001) studied the effect of different level of sulphur on seed yield of sesame and found that 20 kg sulphur ha^{-1} singly gave the tallest plants and the highest dry matter production with 100 ppm salicylic acid (SA). At harvest, the tallest pants were recorded for 20 kg S ha^{-1} at 100 ppm SA + 1.5% potassium chloride while 20 kg S ha^{-1} singly or in combination with 100 ppm SA and 100 ppm SA + 0.5 potassium chloride and 20 kg S ha^{-1} + 100 ppm SA + 0.5% potassium chloride gave the highest number of capsules plant^{-1}, number of seeds capsule^{-1}, seed yield and oil content.

Tiwari *et al.* (2000) conducted a filed experiment with nitrogen (15, 30 or 60 kg ha^{-1}) and sulphur (0, 15 or 30 kg ha^{-1}) were applied to sesame varieties to investigate optimum dose of nitrogen and sulphur. They found that significant improvement in growth and yield (plant height, number of seeds $capsule^{-1}$ 1000-seed weight, and seed and straw yield) was observed for nitrogen at 60 kg ha^{-1} compared with 15 kg ha^{-1}. Sulphur at 30 kg ha^{-1} resulted significant increase only in the number of capsules $plant^{-1}$, seed $capsule^{-1}$, 1000-seed weight and seed yield, compared with sulphur at 0 and 15 kg ha^{-1}. Plant height, capsule $plant^{-1}$, seeds $capsule^{-1}$, length of capsule bearing area, 1000-seed weight, seed yield, stover yield, oil yield, protein yield and net return were statistically highest in cv. TKG 21 grown with 60 kg N ha^{-1} and 30 kg S ha^{-1}. Seed oil decreased and seed protein content increased significantly with increasing nitrogen while sulphur application enhanced both seed oil and seed protein.

Ghosh *et al.* (2000) found that oilseed crops are responsive to sulphur. Approximately 12 kg S is required to produce one tone of oilseed. Therefore, productivity of oilseeds is still very low (842 kg ha^{-1}). The response of S application in oilseed crops is marked, ranging from 15 to 62 kg S ha^{-1}. Gypsum has been found an effective source of sulphur for the crops like groundnut, castor and sesame. Water scarcity is the biggest constraint in oilseed growing regions. Suitable package involving minimum use of water with adequate fertilizer S in conjunction with N and P and other limiting nutrients is needed for increasing yield of oilseeds.

Subrahmaniyan *et al*. (1999) treated sesame cv. TMV-4 plants with 35kg S, 10 kg $ZnSO_4$, 10 kg $MgSO_4$ and 10 kg B ha^{-1} singly or in combination with 5 t FYM ha^{-1} in field experiment conducted in Tamil Nadu, India during the summer seasons of 1996-1997. Sole application of sulphur, trace elements and farmyard manure (FYM) increased the number of branches and capsules $plant^{-1}$ and seed yield compared to the control in both years. The highest seed yield was recorded with the application 35 kg sulphur + 5 t FYM ha^{-1}.

Meng *et al*. (1999) studied the effects of sulphur application on sesame and rapeseed in field trials in 1997 in Zhejiang Chaina. They applied sulphur at the rate of 0, 20 or 40 kg ha^{-1} as gypsum and found that application of sulphur increased seed yield of sesame and rape, and soil available sulphur with SSP giving the best results. Sulphur fertilization significantly increased the contents of nitrogen, sulphur and oil in sesame seeds.

Raja and Sreemannarayana (1998) observed that pulse and oilseed crops showed responses to sulphur application, the magnitude of response being dependent on native status. Sesame and sunflower showed highest response with sulphur application. The crops required application of 40 and 60 kg S ha^{-1}.

Chaplot (1996) observed in a field experiment where sesame was given 20, 40 or 60 kg P_2O_5 ha^{-1} as DAP (diammonium phosphate) or SSP (single superphosphate) with or without 50 kg S ha^{-1}. Application of 40 or 60 kg P_2O_5 ha^{-1} gave the best growth and yield. P source was not significant. The highest net return and benefit:cost ratio were obtained with the application of S in combination with 40 kg P_2O_5 ha^{-1} as DAP.

Yadav *et al.* (1996) found in an experiment, the response of sesame cv. Pratap to different sources of sulfur applied through ammonium sulphate, gypsum, pyrites and elemental sulfur was studied on an alkaline sandy loam soil. Seed and stalk yields, S uptake and oil content of sesame increased significantly with increasing levels of sulfur. Amongst the sources of S tested, ammonium sulfate and gypsum were the best followed by pyrites and elemental sulfur in respect of yield, oil content and S uptake.

Mondal *et al.* (1993) observed the crop sesame cv. B 67 given 75 or 100% of recommended rates of NPK + S with or without either crop residues or 10 t FYM ha^{-1}, the highest dry matter was obtained with 75% fertilizer + S + crop residues, and this treatment also gave maximum capsules $plant^{-1}$ and 1000 seed weight. Highest seed yield of 1.40 t/ha was obtained with 75% NPK + S + FYM, followed by 100% NPK + S (1.36 t ha^{-1}) and 75% NPK + S + crop residues (1.35 t ha^{-1}), while the lowest yield was given by 75% NPK without S (0.9 t ha^{-1}).

Chaplot *et al.* (1992) stated that yield of sesame cv. TC 25 grows at Udaipur, India was 0.66 t ha^{-1} with the application 0 kg S ha^{-1} whereas it was significantly high 0.76 t ha^{-1} when receiving 50 kg S ha^{-1}. The residual effects of sulphur in the next season wheat the grain yield was increased markedly.

Ruhal and Paliwal (1987) found that application of sulphur fertilizer as solution increased dry matter production on sesame. They sprayed sulphur solution of 4-32 ppm and observed that symptoms of sulphur deficiency appeared at 0 and 4 ppm sulphur. Increasing sulphur concentration increased sulphur content in crop plants. Nitrogen and phosphorus contents decreased with decreasing sulphur up to 16 ppm, and increased at the higher sulphur concentration for sesame.

Vijay *et al.* (1987) found that application of nitrogen at 40 kg ha^{-1} to sesame cv. C-6 increased seed yield from 0.73 to 0.98 t ha^{-1}, seed oil content from 48.1 to 56.3% and protein content from 19.4 to 20.9%, further increases in nitrogen rates to 120 kg ha^{-1} produced linear increases in protein contents but had no effect on other parameters. Increasing sulphur rates (0-120 kg ha^{-1}) produced linear increase in protein and oil contents but no significant effects on other parameters.

On the basis of findings presented in this review of literature, it is clear that seed yield of sesame can be greatly influenced by sulphur fertilization. Oil content and seed protein content also found to be affected by the nutrients.

2.2 Effect of boron on growth and yield of sesame

Sarkar and Saha (2005) conducted an experiment in West Bengal, India, found that sesame CV-B-67 produced 10.4% higher seed yield at the rate of 1 kg B ha^{-1} compared to the control.

Liu *et al.* (2003) studied the effects of Mo and B, alone or in combination, on seed quality of pot growth soybean cultivars Zhechum 3, Zhechun 2, and 3811. Application of Mo and/or B increased the content of protein, in dispensable amino acids, total amino-acids (excluding proline), N, P, K and decrease the content of Ca and oil.

Deasarker *et al*. (2001) conducted an experiment with soybean, was given 2, 4 and 6 kg B ha^{-1}. 2 kg B ha^{-1} was the best among the boron treatment for increasing seed yield.

Hemantaranjan *et al* (2000) reported that soybean (*Glycine max* cv. PK-27) was sown in sandy loam soil and given boron as boric acid at 50 and 100 ppm as foliar application and soil application individual and combined, plant height, root length, chlorophyll B content, total dry matter production and seed yield of soybean were higher at 50 than 100 ppm B. However, chlorophyll A content was higher at 100 ppm.

Sinha *et al*. (1999) observed that the optimum B concentration gave the highest biomass and economic yield incase of sesame cv. T-4. The visible symptoms of deficiency were apparent up to 0.165 mg and those of toxicity from 3.3 mg. At 0.0033 mg number of capsules or seeds were produced. Both deficiency and toxicity reduced seed quality by reducing the protein and starch contents and increasing the accumulation of carbohydrates and phenols.

Srivastava *et al*. (1999) observed that the average grain yield of chickpea and other legume crops was 0.1 t ha^{-1} where B was not applied, while the yield was 1.4 t ha^{-1} where 0.5kg ha^{-1} B was applied

Hua and Yan (1998) observed that the addition of B promoted elongation of epicotyle and hypocotyle of mungbean and increased seedling height and dry weight in the treated plants.

Miller and Donahue (1997) observed that boron is essential for growth of new cells of sesame. Without, adequate supply of boron, the number and retention of flowers reduces, and pollen tube growth is less; consequently less fruits are developed. Adequate supply of boron increase leaves dry weight, petiole dry weight, capsule dry weight and above all yield is increased significantly.

Talashikar and Chapan (1996) observed that pod production of groundnut was enhanced significantly with the addition of B by 44 percent. The maximum pod and haulm yields were recorded in the treatment receiving B through horonated super phosphate along with application of FYM, N and P.

Srivastava *et al.* (1996) in a field study with B deficient soil growing chickpea cv. Kaliaka and applying no fertilizer, complete fertilizer (P, K, S, B, Zn, Mo, Cu, Mn and Fe) or the complete fertilizer minus each of the trace elements observed that flower abortion was highest and no seed was produced in the treatment given no B.

Ramirez and Linares (1995) observed that B deficiency caused yellowing of shoots and of the youngest leaves. Upper leaves became dark green, coriaceous, with edges curved down. B - deficiency symptoms were related to 30 day old youngest leaf which fully expanded leaf. Dry matter production of leaves, stems, and roots were severely decreased when B in the leaf tissue was below to its required level; however seed oil content and dry weight were decreased when B concentration of leaf was decreased.

Posypanov *et al.* (1994) observed that applying 1 kg B ha^{-1} to peas and soybeans and treating seeds with the equivalent of 50 g ammonium molyddate ha^{-1} increased nodule weight, atmospheric N fixation, plant height, dry matter, 1000 seed weight and seed yield.

Sindoni *et al.* (1994) grown *Sesamun indicum* in Hoagland No. 2 nutrient solution supplemented with 0.05 mg B/litre or throughout the growth or until 20-30 or 40-day-old when B was either reduced to 0.25 mg/L or eliminated completely. Elimination of B at all ages reduced root and shoot dry weight but reduction of B supplementation significantly reduced dry weight only at 30 day. Reduction of B concentration significantly decreased seed production and concentration of B in leaves, stems and pods. Seed weight was linearly and significantly correlated with concentration of B in capsules.

Sakai *et al.* (1994) evaluated the direct and residual effect of varying levels of B (0, 8, 16, 32 and 64 kg Borax ha^{-1}) and FYM (0.25 and 5.0 t ha^{-1}) alone and in combinations on crops in maize-lentil cropping system. Increasing levels of B upto 16 kg broax ha^{-1} significantly increased the yield of crop and higher levels of B decreased the yield of first crop. Application of 16 kg Borax ha^{-1} in conjunction with 5 t FYM ha^{-1} was an ideal combination which appreciably enhanced the cumulative grain yield response, and sustained the productivity of four crops in this cropping system.

Singh and Singh (1994) noted that green pod yield of french beans increased with increase in P application and with B application up to 1 kg B ha^{-1}. Application of more than 1 kg B ha^{-1} caused a toxic effect.

Bennetti (1993) reported that sesame mineral composition, capsule development, seed yield and stover yield were affected by boron fertilizer application.

Li *et al.* (1992) observed in a field experiment where borax solution at 0.2% was sprayed at seedling and flowering growth stages. In the pot experiments boric acid at 0.7 ppm was given and in hydroponic experiments 0.01, 0.02, 0.2 and 2.0 ppm boric acid were applied. Average yield increases of 4.6-21.2%, 3.3-19.9% and 2.117.1 % were obtained with B application for Zhongzhi 8, Golden Turkey and Qingma, respectively. Application of rates higher than 0.20 ppm in the hydroponic experiments was detrimental, depressing growth, of or even causing death to the plant.

Roy *et al.* (1992) observed that soil application of 20kg borax ha^{-1} increased seed yield of lentil, while soil application of 3 kg sodium molybadate ha^{-1} gave only small (about 14%) increase.

Sinha *et al.* (1991) studied the response of five kharif crops, viz. onion, groundnut, sesame, maize, sweet potato and yard long bean as well as five rabi crops, viz. mustard, onion, lentil, maize and sunflower to boron application on boron deficient calcareous soils under field condition. Boron was applied as borax @ 0, 1.5 and 2.5kg B ha^{-1}. All the crops responded to boron, but the magnitude of yield response differed from crop to crop. The optimum level of B for kharif as well as rabi crops was 1.5 kg ha^{-1}.

Mandal *et al*. (1991) noted that most of alluvial acidic soils responded to the application of B and Mo fertilizer and thereby increased the yield of pulse.

Buzetti *et al*. (1990) observed that soybean cv. Porana when treated with 0, 0.2, 0.4, 0.6 or 0.8 ppm B pot^{-1}, DM and seed yield pot^{-1} increased up to approx. 0.3 ppm B and decreased at higher B rates.

Dwivedi *et al*. (1990) reported that B uptake $plant^{-1}$ had highly significant positive correlation with yield of lentil, soybean and pea, and was a reliable index for predicting crop response to B.

Sakai *et al*. (1990) observed that seed yield of chickpea increased from 1.4 t ha^{-1} with no B to 1.49 t ha^{-1} with 3 kg B ha^{-1}. The yield response of B application was greater on low B soils. It was concluded that on soils containing <0.35 ppm B, 3 kg B ha^{-1} was optimum and on soils containing >0.35 ppm B, 2 kg B ha^{-1} was optimum.

Galrao (1989) reported that yield of soybean was 2.38 t ha^{-1} for using B, whereas yield was 2.24 t ha^{-1} in without B.

Rerkasem *et al*. (1989) reported that wheat growing in the low boron soils exhibited symptoms of male sterility, which included poorly developed anthers and nonviable pollen grains. Grain set failure, lower seed yield and male sterility symptoms were associated with low boron concentration in the flag leaf. Failure in grain set up to 100% of florets was frequently observed. They also reported that poor grain set in wheat depressed seed yield by 40-50% on Tropaqualf soils having low boron content (0.08-0.12 mg kg^{-1}). Sakai *et al.* (1988) reported on a coarse textured calcareous soil that application of 2.0 and 2.5 kg B ha^{-1} increased grain yields of blackgram and chickpea by 63 and 38%, respectively.

Lewis (1980), Pilbeam and Kirkby (1983) and Dugger (1983) stated that boron plays a vital role in the physiological processes of plants such as cell maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, acid and phenol metabolisms. The functions of B are primarily extra-cellular and related to xylem differentiation, membrane stabilization and alteration of enzymatic reactions.

Li *et al.* (1978) and Rerkasem *et al.* (1989) studied on the effect of boron on the development of the pollen grain of wheat and observed that boron deficiency decreases pollen number for seed formation.

Howeler *et al.* (1978) also observed that yield of bean was nearly doubled with the application of 1 kg B ha^{-1}. Agarwala *et al.* (1981) reported that pollen production capacity of anthers as well as the viability of the pollen grains are affected by B.

Vaughan (1977), and Chena and Rerkasem (1993) stated that process of fertilization involves the germination of the pollen grain and the growth of the pollen tube down the style into the ovary. In general, boron deficiency produces pollen grains that are small and that do not accumulate starch. Pollens that develop normally may still be affected by boron deficiency.

From the foregoing review, it was evident that plant height, number of branches $plant^{-1}$, number of capsules $plant^{-1}$, seed yield and stalk yield were influenced by different levels of sulphur and boron application. Seed yield of sesame showed differential behaviour due to different levels of applied sulphur and boron in different parts of the globe. It was , therefore, more researches on this aspect are necessary to arrive at a definite conclusion.

2.3 Effect of combination of sulphur and boron on growth and yield of sesame

Hegde (2003) were studied in Tamil Nadu, India, during 2000 on the effects of S fertilizer on the performance of sesame. Sulphur at various levels (0, 20, 40, 60 and 80 kg ha^{-1}) and boron at various levels (0, 1, 2, 3 and 4 kg ha^{-1} were applied. S at 40 and 60 kg ha^{-1} with 2 kg B ha^{-1}gave comparable yields, whereas S at 80 kg ha^{-1} with 1, 3 or 4 kg B ha^{-1} registered a lower yield, indicating that 40 kg S ha^{-1} and 2 kg B ha^{-1} were optimum for sesame in this study. The seed oil content was not markedly affected by the various amendments. Among the treatment combinations, 40 kg S ha^{-1} applied with 2 kg B ha^{-1} represented maximum plant height, branches $plant^{-1}$, dry matter accumulation, seed yield, stover yield, harvest index and oil content of sesame.

Subrahmaniyan *et al.* (1999) treated sesame cv. TMV 4 with 35 kg S ha^{-1}, 10 kg zinc sulfate ha^{-1}, 10 kg magnesium sulfate ha^{-1} and 10 kg borax ha^{-1}, singly or in combination with 5 t FYM ha^{-1} in a field experiment during the summer seasons. Sole application of S, trace elements and farmyard manure (FYM) increased the number of branches and capsules per plant and seed yield compared to the control in both seasons. However, the highest seed yield was recorded with the application of 35 kg S ha^{-1} + 5 t FYM ha^{-1} + 10 kg B ha^{-1}.

Chaplot (1996) conducted a field experiment in kharif season, Rajasthan, India, sesame was given 20, 30, 40, 50 kg S ha^{-1} application of 1, 2 and 3 kg B ha^{-1}. It was observed that there was a significant effect on growth and yield of sesame. 30 kg S ha^{-1} with 2 kg B ha^{-1}gave the best growth results (plant height, dry matter production, branches plant^{-1} and leaf area index) and yield contributing characters (capsule plant^{-1}, seeds capsule^{-1}, capsule length, 1000 seed weight and grain yield) and oil content of sesame. The highest net return and benefit:cost ratio were obtained with the application of 30 kg S ha^{-1} in combination with 2 kg B ha^{-1}.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

In this chapter, the details of different materials used and methodology followed during the experimental period are described.

3.1 Experimental site

The research work was carried out at the research field of the Department of Agronomy, Sher-e- Bangla Agricultural University, Dhaka during the period from March to June 2008. The experimental field was located at 90° 33' E longitude and 23° 71' N latitude at a height of 9 m above the sea level. The land belonges to the Agro-ecological zone "Madhupur Tract" (AEZ-28) of Nodda soil series.

3.2 Soil

The soil of the experimental site was well drained and medium high. The physical and chemical properties of soil of the experimental site was examined prior to experimentation from 0-15 cm depth. The soil was clay loam in texture and having soil pH varied from 5.41-5.63. Organic matter content was very low (0.83%). The physical composition such as sand, silt and clay content were 40%, 40% and 20%, respectively. The chemical properties of soil of experimental field have been presented in Appendix I.

3.2 Climate

The climate of the experimental field was sub-tropical and was characterized by high temperature, heavy rainfall during kharif-1 season (March - June) and scanty rainfall during rabi season (October - March) associated with moderately low temperature. The average temperature during experimentation was 20°- 25°C. The prevailing weather data during the study period have been presented in Appendix II.

3.2 Planting material

The variety of sesame used for the present study was BARI Til-3. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristics of this variety is mentioned below:

BARI Til -3 : Plants are of average 100 -110 cm in height. Leaves are darker green and rough. Stem is branched and contains 3 – 5 branches. Number of capsule plant^{-1} is 60 – 65 and seeds capsule^{-1} is 50 – 55. Maximum yield is 1200 - 1400 kg ha^{-1}. Seeds contain 42 - 50% oil and 25% protein.

3.3 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 ploughings and laddering with country plough and ladder, respectively. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 9

March and 16 March 2008, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly before planting.

3.4 Fertilizer application

Urea, triple super phosphate (TSP) and muriate of potash (MP) were used as source of nitrogen, phosphorus and potassium, respectively. Two third ($^2/_3$) amount of urea, whole amount of TSP and MP were applied at the time of final land preparation. Rest amount of urea ($^1/_3$) was applied as top dressing at the time of 1^{st} irrigation (18 DAS). Sulphur and boron were applied as per treatment illustrated later as basal dose. The rate of urea, TSP and MP was 125, 150 and 50 kg ha^{-1}, respectively.

3.5 Treatments of the experiment

The experiment consisted of two factors as follows:

Factor A : Sulphur levels- 4

i. No S (control) (S_0)
ii. 9 kg S ha^{-1} (S_1)
iii. 18 kg S ha^{-1} (S_2)
iv. 27 kg S ha^{-1} (S_3)

Factor B : Boron levels- 4

i. No B (control) (B_0)

ii. 1 kg B ha^{-1} (B_1)

iii. 2 kg B ha^{-1} (B_2)

iv. 3 kg B ha^{-1} (B_3)

Combining two factors, 16 treatments combination were obtained;

i.S_0B_0	v. S_1B_0	ix.S_2B_0	xiii.S_3B_0
ii.S_0B_1	vi.S_1B_1	x.S_2B_1	xiv.S_3B_1
iii.S_0B_2	vii.S_1B_2	xi.S_2B_2	xv.S_3B_2
iv.S_0B_3	viii.S_1B_3	xii.S_2B_3	xvi.S_3B_3

3.6 Experimental design and lay out

The experiment was laid out in a Randomized Complete Block Design (factorial) with three replications. The size of a unit plot was 4 m x 2.5 m. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m. The inter block and inter row spaces were used as footpath and irrigation/drainage channels.

3.7 Germination test

Germination test was performed before sowing the seeds in the field. Petridishes were used for laboratory test. Filter paper were placed on petridishes and the papers were soaked with water. Seeds were set for germination at random in petridish. Data on emergence were recorded on percentage basis by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds set for germination}} \times 100$$

3.8 Sowing of seeds

Seeds were sown in 19^{th} march' 2008, following line to line distance 30 cm and plant to plant distance 5 cm. Seeds were placed 2 cm depth and then rows were covered with loose soil properly.

3.9 Intercultural operations

3.9.1 Weeding

The crop field was weeded twice; first weeding was done at 15 DAS (Days after sowing) and second weeding at 25 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.9.2 Thinning

Thinning was done in all the unit plots with care so as to maintain a uniform plant population in each plot. Thinning was done twice; first thinning was done at 10 DAS (Days after sowing) and second thinning at 20 DAS.

3.9.3 Irrigation

Pre-sowing irrigation was done to maintain equal and uniform germination. After sowing two irrigations were done during the life cycle. First irrigation was done at 20 DAS and second was at 30 DAS.

3.9.4 Application of pesticides

The crop was attacked by myrids at the time of vegetative stage. It was controlled by spraying Dimacron 60 EC at the rate of 1litre ha^{-1}. Malathion

57 EC at the rate of 2 ml/litre of water was sprayed to control hawkmoth and jute hairy caterpillar at the time of capsule formation. The spraying was done in the afternoon while the pollinating bees were away from the field.

3.10 Harvesting and threshing

The crop was harvested when leaves, stem and capsules became yillowish in colour. Four square meter area from middle of each plot was harvested and yield was recorded per unit plot. The harvested plants were tied into bundles and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the pods by beating with bamboo sticks and cleaned, dried and weighed. The weights of the dry straw were also taken.

3.11 Sampling

The first crop sampling was done at 20 DAS and it was continued at an interval of ten days, viz. 30, 40, 50 and 60 DAS. At each harvest, five plants were selected randomly from each plot. The selected plants of each plot were uprooted carefully by a khurpi and washed in running tap water to remove the soil. The heights of plants were measured with a meter scale placed on the ground level to top of the leaves. The number of leaves, branches, flowers and capsules were recorded separately and oven dried at 70 °C for 72 hours to record constant dry weights. Total dry matter was determined by recording the dry weight of each portion of the plants. From each plot the weight of the straw were taken.

3.12 Data collection

The data on the following parameters of five plants were recorded at each harvest.

A. Growth data

1) Plant height (cm) (at 10 days intervals starting from 20 DAS)

2) Dry matter weight at different plant parts (g plant^{-1}) (at 20, 30, 40, 50 and 60 DAS)

   a) Leaf

   b) Petiole

   c) Stem

   d) Capsule

B. Yield data

1) Branches plant^{-1} (no.)

2) Capsule plant^{-1} (no.)

3) Seeds capsule^{-1} (no.)

4) 1000 - seed weight (g)

5) Seed yield (t ha $^{-1}$)

6) Stover yield (t ha $^{-1}$)

8) Oil content (%)

3.13 Procedure of data collection

3.13.1 Plant height (cm) (at 10 days intervals)

The heights of pre-selected five plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.13.2 Dry matter weight plant^{-1} (g)

For measuring the dry matter weight plant^{-1}, the plant parts were separated and then dried in an oven at 70 ^{0}C for 72 hours and weight was taken carefully. The weight of separated parts was taken separately. The sum of the plant parts constituted the total dry matter of a single plant.

3.13.3 Number of branches plant^{-1}

The number of branches plant^{-1} was counted from pre-selected five plants and mean values were calculated.

3.13.4 Number of capsule plant^{-1}

Number of total capsule of pre-selected five plants from each unit plot was noted and the mean value was calculated.

3.13.5 Number of seeds capsule^{-1}

The number of seeds were counted from ten capsules taking randomly from each plot and averaged them to calculate seeds capsule^{-1}.

3.13.6 Weight of 1000-seeds

One thousand cleaned dried seeds were counted randomly from each harvested sample and weighed by using a digital electric balance and the mean weight was expressed in gram.

3.13.7 Seed yield (t ha^{-1})

Weight of seed of the demarcated area (4.0 m^2) at the centre of each plot was taken and then converted to the yield in t ha^{-1}.

3.13.8 Stover yield (kg ha^{-1})

The dry weight of the plants containing grain was taken. The stover weight was calculated by subtracting the grain weight from the total weight after threshing and separation of grain from the sample and then expressed in kg ha^{-1}.

3.13.9 Seed oil content (%)

Seed sample was taken from each plot and then each sample was tested for oil percentage in the laboratory of Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI) and it was determined by Folch method (Folch *et al.*, 1957).

3.13.10 Biological yield (kg ha^{-1})

The summation of grain yield and stover yield was considered as biological yield. Biological yield was calculated by using the following formula,

Biological yield = Grain yield + Stover yield

3.13.11 Harvest index (%)

The harvest index was calculated on the ratio of grain yield to biological yield and expressed in terms of percentage. It was calculated by using the following formula (Donald and Hamblim, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.14 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT computer package program developed by Russel (1986). Mean differences among the treatments were tested with Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Chapter 4

Results

CHAPTER 4

RESULTS AND DISCUSSION

Present experiment was conducted with different levels of sulphur and boron fertilizer to study their effects on growth, yield and oil content of sesame. The results regarding the effect of sulphur and boron and their interactions on different growth, yield and oil content parameters are presented and discussed in this chapter.

4.1 Response of growth characters of sesame

4.1.1 Plant height

4.1.1.1 Influence of sulphur fertilization

Plant height is one of the most important growth characteristics of sesame. The result showed that the effect of sulphur application on plant height was significant at 30, 40, 50 and 60 days after sowing (DAS) but not significant at 20 DAS (Fig. 1). It was observed that 27 kg S ha^{-1} gave the highest plant height (11.29, 71.76, 87.46, 103.00 and 107.40 cm at 20, 30, 40, 50 and 60 DAS, respectively) and no sulphur fertilizer application showed the lowest plant height at all stages., Moreover, 9 and 18 kg S ha^{-1} showed intermediate level of plant height at 20, 30, 40, 50 and 60 DAS, which were significantly different from that of 27 kg S ha^{-1} application. Similar result was found by Sharma and Gupta (2003) who stated that sulphur has a great influence on the growth of sesame and among four sulphur rates 40 kg S ha^{-1} increased the plant height over control (no S application).

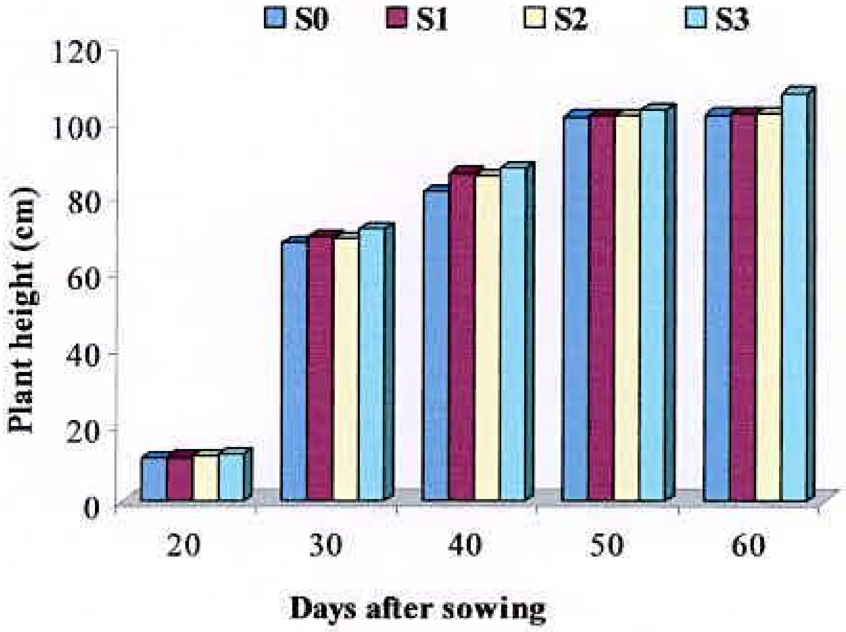

Fig. 1 Effect of sulphur fertilization on plant height of sesame at different days after sowing ($S_{\bar{x}}$ = 0.236, 0.236, 0.264, 0.248 and 0.238 at 20, 30, 40, 50 and 60 DAS, respectively)

S_0 = Without S (control)		S_2 = 18 kg S ha^{-1}
S_1 = 9 kg S ha^{-1}		S_3 = 27 kg S ha^{-1}

4.1.1.2 Influence of boron fertilization

The result showed that the effect of boron application on plant height was not significant at 20, 30, 40, 50 and 60 DAS (Table 1). But it was observed that 2 kg B ha^{-1} gave the highest plant height and no boron fertilizer application showed the lowest height at 40, 50 and 60 DAS, respectively. Similar result was found by Hemantaranjan *et al.* (2000) that plant height of soybean was higher at optimum boron fertilization (2 kg ha^{-1}) than higher doses.

Table 1. Effect of boron fertilization on plant height of sesame at different days after sowing

Boron levels	Plant height (cm)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
B_0	11.62	69.99	84.52	100.68	101.70
B_1	11.89	69.01	85.39	102.10	103.30
B_2	11.78	69.02	86.15	103.40	105.30
B_3	11.47	70.22	84.70	101.30	102.80
$s_{\bar{x}}$	**0.236**	**0.236**	**0.264**	**0.248**	**0.238**
CV (%)	**7.00**	**11.83**	**14.18**	**6.78**	**9.76**

B_0 = Without B (control) B_2 = 2 kg B ha^{-1}

B_1 = 1 kg B ha^{-1} B_3 = 3 kg B ha^{-1}

4.1.1.3 Interaction effect of sulphur and boron fertilization

The Interaction effect was found to be significant for plant height at different DAS except 20 DAS (Table 2). Irrespective of treatment combinations, plant height increased with the advancement of growth stages and the highest increase was found at 60 DAS. The rate of increase among the growth stages was much higher from 20 and 30 DAS than other stages for all combinations. At 30, 40, 50 and 60 DAS, the significantly higher plant height was recorded from S_3B_2 treatment i.e., 74.70, 92.47, 107.30 and 109.50 cm, respectively. At 50 DAS, the combinations of S_2B_3 (108.30 cm) and S_3B_2 (107.30 cm) showed statistically similar plant height. The combination of S_3B_2 (109.50 cm), S_2B_3 (108.90 cm) and S_2B_1 (108.20 cm) showed statistically similar level of plant height at 60 DAS. The lowest plant height at 20, 30, 40, 50 and

60 DAS (10.55, 65.67, 79.33, 89.93 and 97.93 cm, respectively) was obtained from S_0B_0. Chaplot (1996) observed similar result who stated that optimum combination of S and B gave the best plant height of sesame.

Table 2. Interaction effect of sulphur and boron fertilization on plant height of sesame at different days after sowing

Treatment Combination	Plant height (cm)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_0B_0	10.55	65.67 i	79.33 g	89.93 i	97.13 g
S_0B_1	11.16	65.90 hi	81.47 f	97.07 h	97.93 g
S_0B_2	11.27	66.53 g-i	81.07 f	95.87 h	105.20 c
S_0B_3	11.58	68.23 ef	81.40 f	98.53 g	100.60 f
S_1B_0	11.45	67.35 f-h	82.53 ef	104.70 bc	100.50 f
S_1B_1	11.26	67.33 f-h	89.00 b	100.20 f	102.30 e
S_1B_2	11.72	73.93 ab	89.40 b	101.50 ef	100.60 f
S_1B_3	11.91	71.17 c	84.20 d	103.10 d	104.70 c
S_2B_0	11.80	68.41 ef	84.33 d	103.10 d	104.60 c
S_2B_1	12.46	73.17 b	87.73 bc	104.90 bc	108.20 a
S_2B_2	11.41	67.50 fg	83.60 de	102.90 de	102.90 de
S_2B_3	11.34	70.73 cd	87.87 bc	108.30 a	108.90 a
S_3B_0	12.69	73.47 ab	88.63 bc	103.40 cd	106.90 b
S_3B_1	12.68	69.63 de	87.27 c	105.70 b	98.20 g
S_3B_2	12.73	74.70 a	92.47 a	107.30 a	109.50 a
S_3B_3	11.05	69.23 e	82.73 d-f	103.00 de	104.10 cd
$S_{\bar{x}}$	**0.472**	**0.473**	**0.528**	**0.497**	**0.478**
CV (%)	**7.00**	**11.83**	**14.18**	**6.78**	**9.76**

S_0 = Without S (control) B_0 = Without B (control)

S_1 = 9 kg S ha^{-1} B_1 = 1 kg B ha^{-1}

S_2 = 18 kg S ha^{-1} B_2 = 2 kg B ha^{-1}

S_3 = 27 kg S ha^{-1} B_3 = 3 kg B ha^{-1}

4.1.2 Leaf dry weight plant^{-1}

4.1.2.1 Influence of sulphur fertilization

The result showed that the effect of sulphur application on leaf dry weight plant^{-1} was significant at 20, 30, 40, 50 and 60 DAS (Table 3). It was observed that 18 kg S ha^{-1} gave the highest leaf dry weight plant^{-1} at 20 DAS (6.37 g) where as, 27 kg S ha^{-1} gave the highest leaf dry weight plant^{-1} at all the other stages studied (19.18, 26.68, 28.04 and 28.94 g at 30, 40, 50 and 60 DAS, respectively). It was also observed that leaf dry weight plant^{-1} was statistically similar among 18 and 27 kg S ha^{-1} application at all stages except 20, 30 and 40 DAS. No sulphur application gave the lowest leaf dry weight plant^{-1} at all growth stages. At 20, 30, 40, 50 and 60 DAS, 9 kg S ha^{-1} showed the significantly different leaf dry weight from that of 18 and 27 kg S ha^{-1} application for leaf dry weight plant^{-1}. The result agreed with the findings of Sarkar and Banik (2002) where leaf dry weight plant^{-1} at 25 kg S ha^{-1} which increaseded growth and productivity of sesame .

Table 3. Effect of sulphur fertilization on leaf dry weight plant^{-1} of sesame at different days after sowing

Sulphur levels	Leaf dry weight plant^{-1} (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_0	4.69 d	15.39 d	24.37 d	26.89 b	27.09 c
S_1	5.64 c	17.67 c	25.70 c	27.22 b	28.13 b
S_2	6.37 a	18.98 b	26.50 b	27.84 a	28.92 a
S_3	6.21 b	19.18 a	26.68 a	28.04 a	28.94 a
$s_{\bar{x}}$	**0.016**	**0.009**	**0.009**	**0.127**	**0.022**
CV (%)	**8.96**	**7.17**	**9.12**	**11.61**	**8.26**

S_0 = Without S (control) S_2 = 18 kg S ha^{-1}

S_1 = 9 kg S ha^{-1} S_3 = 27 kg S ha^{-1}

4.1.2.2 Influence of boron fertilization

Effect of B on leaf dry weight plant^{-1} has been presented in Fig 2. The figure showed that leaf dry weight plant^{-1} increased progressively with the advancement of growth stages. The rate of increase in dry weight was much higher upto 40 DAS and then the rate of increase was slower. Application of 2 kg B ha^{-1} showed its superiority by producing higher leaf dry weight than other doses of B for all growth stages. However, no boron application treatment showed lowest level of leaf dry weights for all growth stages. The result supported by Ramirez and Linares (1995) who reported that optimum application of B increased dry matter production of leaves of sesame but severely decreased when B in the leaf tissue was lower.

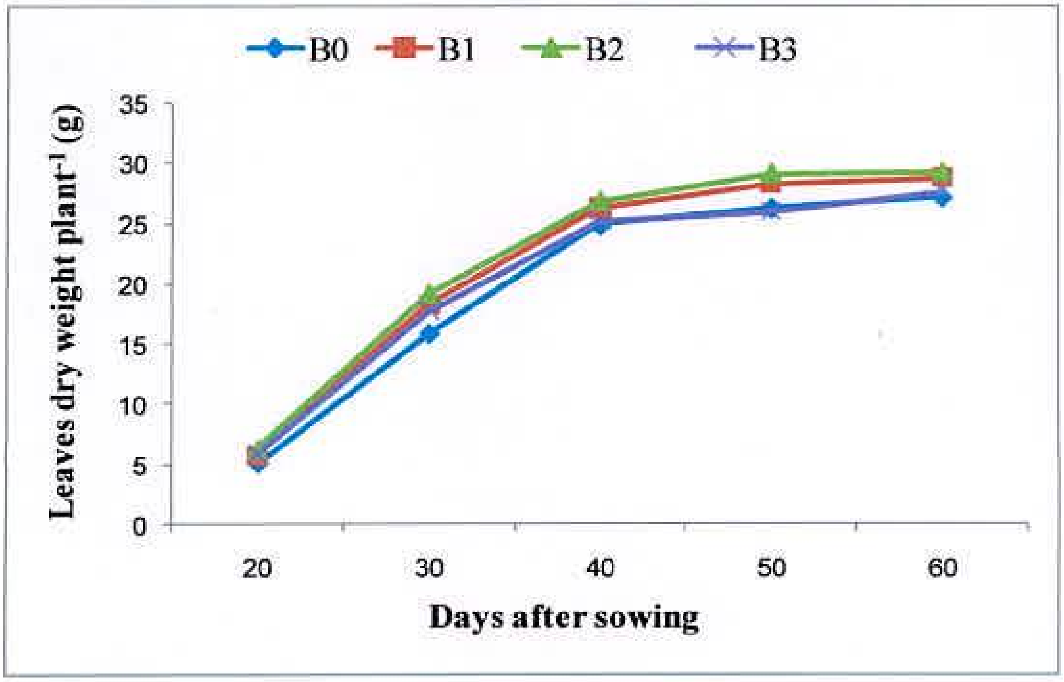

Fig. 2. Effect of boron fertilization on leaves dry weight plant^{-1} of sesame at different days after sowing ($S_{\bar{x}}$ = 0.126, 0.173, 0.271, 0.255 and 0.163 at 20, 30, 40, 50 and 60 DAS, respectively)

B_0	=	Without B (control)	B_2	=	2 kg B ha^{-1}
B_1	=	1 kg B ha^{-1}	B_3	=	3 kg B ha^{-1}

4.1.2.3 Interaction effect of sulphur and boron fertilization

The interaction effect of S and B was found to be significant for leaf dry weight plant^{-1} at different growth stages (Table 4). The table showed that leaf dry weight plant^{-1} increased progressively with the advancement of growth stages for all interactions. The rate of increase in leaves dry weight plant^{-1} was more rapid in the early stages (up to 40 DAS) thereafter it was much slower than that of early stages. At all the growth stages, the highest leaf dry weight plant^{-1} was recorded from S_3B_2 (7.25, 21.08, 28.12, 30.17 and 30.66 g, respectively) which were significantly differences from other treatments. The combination S_2B_3 at 20 DAS showed the leaf dry weight plant^{-1} which was statistically similar with S_3B_2. The interaction of S_2B_2 and S_3B_1 at 40 DAS showed statistically similar leaf dry weight plant^{-1}with S_3B_2. The lowest leaf dry weight plant^{-1} at 20, 30, 40, 50 and 60 DAS (4.11, 14.08, 23.41, 25.31 and 26.44 g, respectively) was obtained from S_0B_0. The interaction S_0B_1 at 20 DAS and S_0B_1, S_0B_2, S_0B_3 and S_1B_0 at 50 DAS showed statistically similar leaf dry plant^{-1} with S_0B_0 at the respective growth stages (20 and 50 DAS, respectively). Similar result was found by Chaplot (1996) who observed that combination of 30 kg S ha^{-1} with 2 kg B ha^{-1}gave the maximum dry matter production.

Table 4. Interaction effect of sulphur and boron fertilization on leaves dry weight plant^{-1} of sesame at different days after sowing

Treatment combination	Leaf dry weight plant^{-1} (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_0B_0	4.11 h	14.08 j	23.41 h	25.31 i	26.44 j
S_0B_1	4.18 h	15.10 i	24.50 fg	25.91 hi	26.93 i
S_0B_2	4.82 g	16.26 h	25.45 de	25.76 hi	27.35 hi
S_0B_3	5.62 de	16.11 h	24.12 gh	25.95 hi	27.16 hi
S_1B_0	5.16 fg	15.31 i	24.21 gh	25.98 hi	27.63 gh
S_1B_1	6.06 c	18.23 ef	26.19 cd	27.52 ef	28.86 e
S_1B_2	6.48 b	19.38 d	26.80 bc	28.25 de	29.12 de
S_1B_3	4.86 g	17.77 f	25.61 de	26.44 gh	27.39 hi
S_2B_0	5.47 ef	16.90 g	25.79 de	26.86 fg	28.28 f
S_2B_1	6.23 bc	19.83 cd	27.11 b	28.76 cd	29.51 cd
S_2B_2	6.58 b	20.44 b	27.38 ab	29.75 ab	30.01 b
S_2B_3	7.18 a	18.74 e	25.73 de	28.89 cd	27.95 fg
S_3B_0	5.50 ef	17.17 g	26.08 cd	27.12 fg	28.19 f
S_3B_1	6.56 b	20.12 bc	27.40 ab	29.12 bc	29.67 bc
S_3B_2	7.25 a	21.08 a	28.12 a	30.17 a	30.66 a
S_3B_3	5.91 cd	18.34 e	25.14 ef	28.19 de	27.15 hi
$s_{\bar{x}}$	**0.126**	**0.173**	**0.271**	**0.255**	**0.163**
CV (%)	**8.96**	**7.17**	**9.12**	**11.61**	**8.26**

S_0 = Without S (control) B_0 = Without B (control)
S_1 = 9 kg S ha^{-1} B_1 = 1 kg B ha^{-1}
S_2 = 18 kg S ha^{-1} B_2 = 2 kg B ha^{-1}
S_3 = 27 kg S ha^{-1} B_3 = 3 kg B ha^{-1}

4.1.3 Petiole dry weight plant^{-1}

4.1.3.1 Influence of sulphur fertilization

The result showed that the effect of sulphur application on petiole dry weight plant^{-1} was significant at 40, 50 and 60 DAS but insignificant at 20 and 30 DAS (Table 5). It was observed that at 40, 50 and 60 DAS, application of 27 kg S ha^{-1} gave the highest petiole dry weight plant^{-1} (11.49, 12.95 and 13.43 g, respectively). Sulphur applied lower than 27 kg ha^{-1} reduced the petiole dry weight plant^{-1} gradually and this reduction continued up to no sulphur dose treatment. At 60 DAS, 18 and 9 kg S ha^{-1} showed similar petiole dry weight with 27 kg S ha^{-1}. At 50 DAS, 18 kg S ha^{-1} showed similar petiole dry weight plant^{-1} with that of 27 kg S ha^{-1}. No sulphur application gave the lowest petiole dry weight plant^{-1} at all stages. This findings agreed with that of Maragatham *et al.* (2006) who reported that application of sulfur fertilizer at 40 kg ha^{-1} resulted in the highest petiole dry weight plant^{-1} as well as S uptake by the plants.

Table 5. Effect of sulphur fertilization on petiole dry weight plant^{-1} of sesame at different days after sowing

Sulphur levels	Petiole dry weight plant^{-1} (g)				
	20 DAS	**30 DAS**	**40 DAS**	**50 DAS**	**60 DAS**
S_0	0.93	3.42	10.04 d	11.70 c	12.16 b
S_1	1.07	3.86	10.75 c	12.35 b	12.74 ab
S_2	1.20	4.06	11.06 b	12.79 ab	13.15 a
S_3	1.28	4.31	11.49 a	12.95 a	13.43 a
$s_{\bar{x}}$	**0.004**	**0.004**	**0.024**	**0.183**	**0.283**
CV (%)	**6.33**	**10.35**	**9.75**	**5.09**	**7.61**

S_0 = Without S (control) S_2 = 18 kg S ha^{-1}

S_1 = 9 kg S ha^{-1} S_3 = 27 kg S ha^{-1}

41.3.2 Influence of boron fertilization

The result showed that the effect of boron application on petiole dry weight plant^{-1} was significant at 40, 50 and 60 DAS (Table 6). It was observed that application of 2 kg B ha^{-1} gave significantly the highest petiole dry weight plant^{-1} (12.17, 13.31 and 13.57 g) at 40, 50 and 60 DAS and no boron fertilizer application showed significantly the lowest petiole dry weight plant^{-1} at 40, 50 and 60 DAS, respectively. Boron applied lower and higher than 2 kg ha^{-1} reduced the production of petiole dry weight plant^{-1} significantly for all the growth stages. On the other hand, irrespect of B application, petiole dry weight plant^{-1} increased with the advance of growth stages and this increase was higher up 40 DAS after that the rate of increase was much slower.The results was similar with that of Miller and Donahue (1997), where he reported that boron is essential for growth of new cells and adequate supply of boron increased petiole dry weight significantly.

Table 6. Effect of boron fertilization on petiole dry weight plant^{-1} of sesame at different days after sowing

Boron levels	Petiole dry weight plant^{-1} (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
B_0	0.87	3.20	9.48 d	11.89 c	12.59 b
B_1	1.15	4.12	10.14 c	12.07 bc	12.74 b
B_2	1.37	4.45	12.17 a	13.31 a	13.57 a
B_3	1.10	3.89	11.54 b	12.52 b	12.57 b
$s_{\bar{x}}$	**0.004**	**0.004**	**0.024**	**0.183**	**0.283**
CV (%)	**6.33**	**10.35**	**9.75**	**5.09**	**7.61**

B_0 = Without B (control)

B_1 = 1 kg B ha^{-1}

B_2 = 2 kg B ha^{-1}

B_3 = 3 kg B ha^{-1}

4.1.3.3 Interaction effect of sulphur and boron fertilization

The interaction effect was found to be significant for petiole dry weight $plant^{-1}$ at 40, 50 and 60 DAS (Table 7). At 20 and 30 DAS, there was no significant effect on petiole dry weight $plant^{-1}$. At 40, 50 and 60 DAS, the highest petiole dry weights $plant^{-1}$ was recorded from S_3B_2 (12.87, 14.00, and 14.70 g, respectively). The treatment combination of S_1B_2, S_2B_3, S_3B_3 at 40 DAS and S_2B_2 at 60 DAS showed the petiole dry weight $plant^{-1}$ which was similar with S_3B_2 for the respective growth stages. The lowest petiole dry weight $plant^{-1}$ at 40, 50 and 60 DAS (8.76, 11.23, and 12.05 g, respectively) was obtained from S_0B_0. The combination S_3B_2 was found to be superior in respect of producing petiole dry weight $plant^{-1}$ at all growth stages.

Table 7. Interaction effect of sulphur and boron fertilization on petiole dry weight plant^{-1} of sesame at different days after sowing

Treatment combination	Petiole dry weight plant^{-1} (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_0B_0	0.69	2.97	8.76 g	11.23 d	12.05 c
S_0B_1	1.05	3.54	9.13 fg	11.36 cd	12.13 c
S_0B_2	1.07	3.79	9.51 ef	12.28 b-d	12.37 bc
S_0B_3	0.93	3.40	10.97 c	11.92 b-d	12.10 c
S_1B_0	0.88	3.11	9.94 de	11.92 b-d	12.54 bc
S_1B_1	1.08	4.11	11.30 c	12.14 b-d	12.80 bc
S_1B_2	1.31	4.49	12.17 b	13.04 ab	13.15 a-c
S_1B_3	1.04	3.76	11.37 c	12.29 b-d	12.48 bc
S_2B_0	0.94	3.30	9.78 de	12.06 b-d	12.82 a-c
S_2B_1	1.18	4.29	10.23 d	12.30 b-d	12.97 a-c
S_2B_2	1.50	4.60	12.33 b	13.91 a	14.07 ab
S_2B_3	1.18	4.04	11.87 b	12.89 ab	12.72 bc
S_3B_0	0.98	3.42	9.87 de	12.35 b-d	12.95 a-c
S_3B_1	1.28	4.57	11.27 c	12.49 bc	13.08 a-c
S_3B_2	1.62	4.91	12.87 a	14.00 a	14.70 a
S_3B_3	1.26	4.36	11.97 b	12.96 ab	12.98 a-c
$s_{\bar{x}}$	**0.127**	**0.173**	**0.152**	**0.366**	**0.566**
CV (%)	**6.33**	**10.35**	**9.75**	**5.09**	**7.61**

S_0 = Without S (control) B_0 = Without B (control)

S_1 = 9 kg S ha^{-1} B_1 = 1 kg B ha^{-1}

S_2 = 18 kg S ha^{-1} B_2 = 2 kg B ha^{-1}

S_3 = 27 kg S ha^{-1} B_3 = 3 kg B ha^{-1}

4.1.4 Stem dry weight plant^{-1}

4.1.4.1 Influence of sulphur fertilization

The result showed that the effect of sulphur application on stem dry weights plant^{-1} was significant at 20, 30, 40, 50 and 60 DAS (Fig. 3). The figure showed that application of 27 kg S ha^{-1} gave the highest stem dry weight plant^{-1} at all stages (5.65, 16.04, 20.36, 22.05 and 24.67 g, respectively) and reducing S rate from 27 kg ha^{-1} to no S application reduced the stem dry weight plant^{-1} gradually at all growth stages. However, no sulphur application showed the lowest stem dry weight plant^{-1} at all stages (2.90, 12.11, 16.44, 19.92 and 21.33 g, respectively). Maragatham *et al.* (2006) observed similar result with the present findings of stem dry weight of sesame.

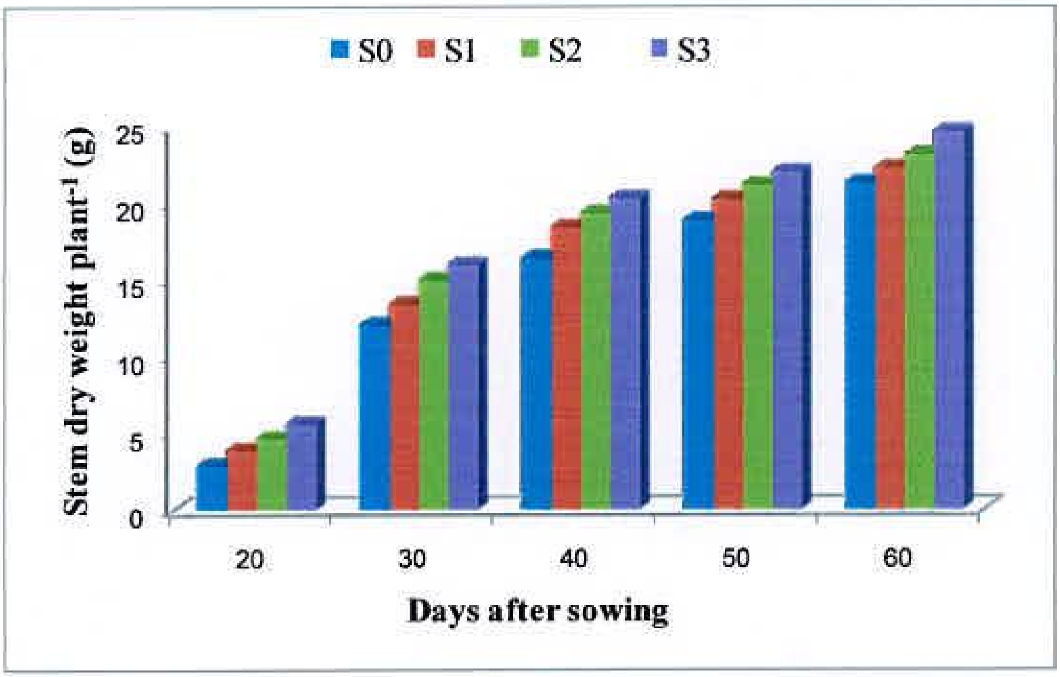

Fig. 3 Effect of sulphur fertilization on stem dry weight plant^{-1} of sesame at different days after sowing ($S_{\bar{x}}$ = 0.298, 0.389, 0.009, 0.083 and 0.486 at 20, 30, 40, 50 and 60 DAS, respectively)

S_0	=	Without S (control)	S_2	=	18 kg S ha^{-1}
S_1	=	9 kg S ha^{-1}	S_3	=	27 kg S ha^{-1}

4.1.4.2 Influence of boron fertilization

Effect of boron application on stem dry weight $plant^{-1}$ exerted significant result at 20, 30, 40, 50 and 60 DAS (Fig. 4). The figure showed that application of 2 kg B ha^{-1} showed its superiority by producing the highest stem dry weight $plant^{-1}$ at all the growth stages (4.91, 16.13, 21.14, 22.41 and 24.32 g at 20, 30, 40, 50 and 60 DAS, respectively). Application of 3 kg B ha^{-1} showed similar stem dry weight $plant^{-1}$ with that of 2 kg B ha^{-1} at 20, 30 and 60 DAS. No boron fertilizer application showed the lowest stem dry weight $plant^{-1}$ at all the growth stages. For all boron rates, the rate of increase of stem dry weight was higher at early stages than later ones. These findings were supported by Ramirez and Linares (1995).

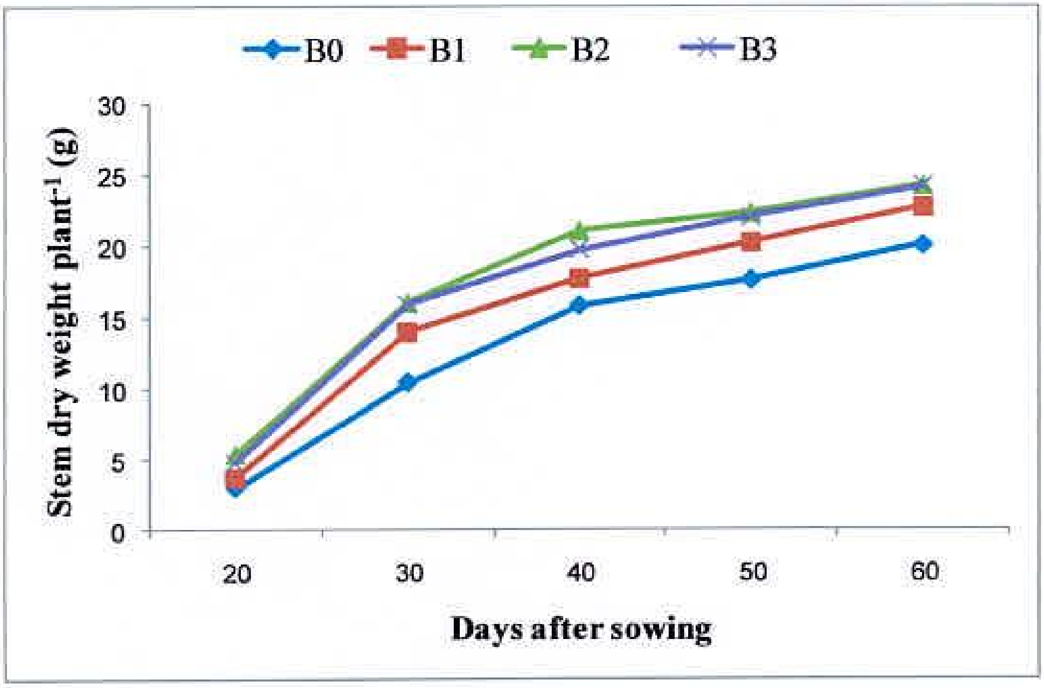

Fig. 4 Effect of boron fertilization on stem dry weight $plant^{-1}$ of sesame at different days after sowing ($S_{\bar{x}}$ = 0.595, 0.777, 0.332, 0.166 and 0.972 at 20, 30, 40, 50 and 60 DAS, respectively)

B_0 = Without B (control) B_2 = 2 kg B ha^{-1}

B_1 = 1 kg B ha^{-1} B_3 = 3 kg B ha^{-1}

4.1.4.3 Interaction effect of sulphur and boron fertilization

The interaction effect was found to be significant for stem dry weight plant^{-1} at different DAS (Table 8). The combination S_3B_2 performed best in producing highest stem dry weight 6.98, 18.93, 22.46, 23.96 and 26.93 g plant^{-1} at 20, 30, 40, 50 and 60 DAS, respectively. The combination S_3B_3 at 50 DAS showed the stem dry weight plant^{-1} which was not significantly different from S_3B_2. The treatment combination of S_2B_3 at 20 DAS; S_2B_2, S_2B_3, S_3B_3 at 30 DAS; S_2B_3, S_3B_3 at 40 DAS and S_3B_3 at 60 DAS showed the stem dry weight which was similar with S_3B_2 for their respective growth stages. At all stages (20, 30, 40, 50 and 60 DAS), S_0B_0 showed the lowest stem dry weight plant^{-1} (1.92, 9.20, 13.65, 15.36 and 18.56 g, respectively). The combination S_0B_1, S_0B_2 S_1B_0, S_2B_0 at 20 DAS; S_1B_0 at 30 and 60 DAS gave statistically similar result with S_0B_0. Similar result was found by Chaplot (1996) who observed that combination of optimum doses of S and B represented the best dry matter production of sesame.

Table 8. Interaction effect of sulphur and boron fertilization on stem dry weight plant^{-1} of sesame at different days after sowing

Treatment combination	Stem dry weight plant^{-1} (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_0B_0	1.920 f	9.200 f	13.65 h	15.36 i	18.56 g
S_0B_1	2.24 ef	10.98 d-f	15.55 g	18.60 g	21.17 d-g
S_0B_2	3.18 ef	13.19 cd	17.23 f	19.77 f	22.38 c-f
S_0B_3	4.23 b-e	14.81 bc	19.33 de	21.93 d	23.21 b-e
S_1B_0	2.98 ef	10.09 ef	15.73 g	17.43 h	19.73 fg
S_1B_1	3.28 d-f	13.25 cd	17.58 f	19.77 f	22.19 c-f
S_1B_2	4.22 b-e	15.22 bc	19.33 de	21.83 d	23.37 b-e
S_1B_3	5.19 a-d	15.32 bc	21.28 bc	22.15 cd	23.94 a-d
S_2B_0	3.05 ef	11.24 d-f	16.73 f	18.48 g	20.62 e-g
S_2B_1	4.19 b-e	15.24 bc	18.56 e	20.82 e	23.29 b-e
S_2B_2	5.26 a-c	17.19 ab	20.33 cd	22.89 b	24.60 a-c
S_2B_3	6.11 ab	16.71 ab	21.83 ab	22.57 bc	24.07 a-d
S_3B_0	4.09 de	11.80 de	17.51 f	19.52 f	21.63 c-g
S_3B_1	5.29 a-c	16.27 b	19.34 e	21.77 d	24.33 a-d
S_3B_2	6.98 a	18.93 a	22.46 a	23.95 a	26.93 a
S_3B_3	6.23 a	17.16 ab	22.13 ab	22.98 b	25.81 ab
$s_{\bar{x}}$	**0.595**	**0.777**	**0.332**	**0.166**	**0.972**
CV (%)	**12.07**	**9.51**	**10.16**	**8.40**	**7.36**

S_0 = Without S (control)
S_1 = 9 kg S ha^{-1}
S_2 = 18 kg S ha^{-1}
S_3 = 27 kg S ha^{-1}

B_0 = Without B (control)
B_1 = 1 kg B ha^{-1}
B_2 = 2 kg B ha^{-1}
B_3 = 3 kg B ha^{-1}

4.1.5 Capsule dry weight plant^{-1}

4.1.5.1 Influence of sulphur fertilization

The result showed that the effect of sulphur application on capsule dry weight plant^{-1} was significant at 50 and 60 DAS (Fig. 5). The trend of capsule dry weight plant^{-1} increased gradually with the increase of S doses for both the growth stages. Application of 27 kg S ha^{-1} gave the highest capsule dry weight plant^{-1} at all stages (21.03 and 26.51 g at 50 and 60 DAS, respectively) and no sulphur application showed the lowest stem dry weight plant^{-1} at all stages (17.61 and 22.51 g for 50 and 60 DAS, respectively). Application of 27 kg S ha^{-1} showed 19.42 %, 13.92 %, and 6.75 % higher capsule dry weight plant^{-1} than 0, 9 and 18 kg S ha^{-1}, respectively at 50 DAS and that of 17.61 %, 12.86 % and 6.61 % higher at 60 DAS.

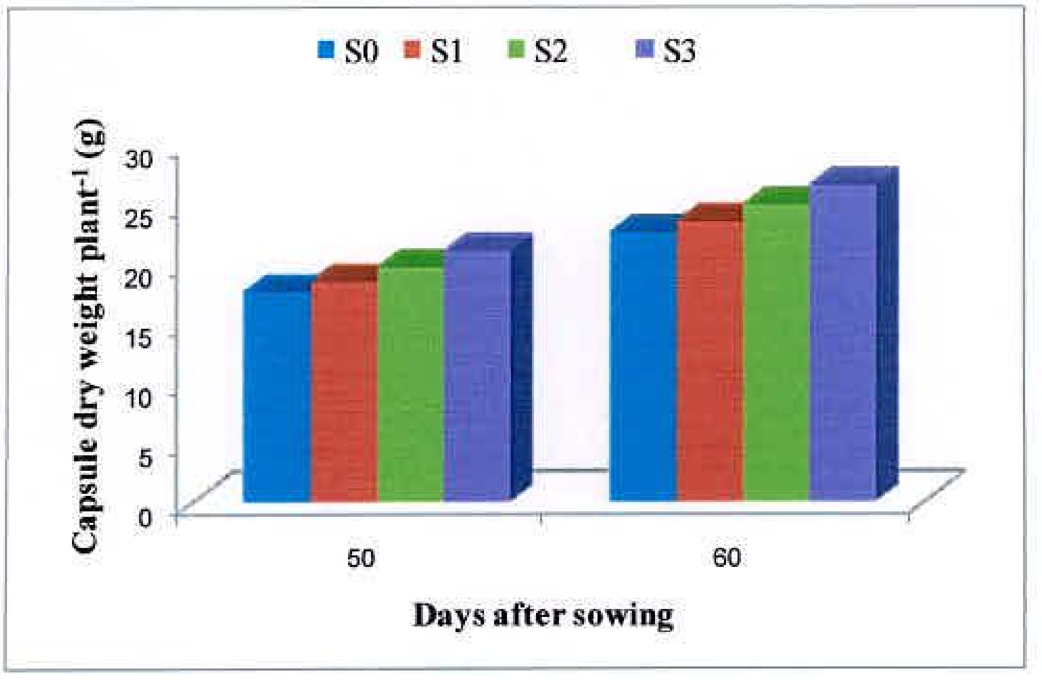

Fig. 5 Effect of sulphur fertilization on capsule dry weight plant^{-1} of sesame at different days after sowing ($S_{\bar{x}}$ = 0.030 and 0.009 at 50 and 60 DAS, respectively)

S_0	=	Without S (control)	S_2	=	18 kg S ha^{-1}
S_1	=	9 kg S ha^{-1}	S_3	=	27 kg S ha^{-1}

4.1.5.2 Influence of boron fertilization

Effect of B application exerted significant effect on capsule dry weight plant^{-1} of sesame at 50 and 60 DAS (Fig. 6). It appeared from the figure that capsule dry weight plant^{-1} showed an increasing trend with the increases of B doses up to 2 kg B ha^{-1} and a further increase of B rate reduced the capsule dry weight significantly at both the growth stages (50 and 60 DAS). Application of 2 kg B ha^{-1} showed 14.07 % and 2.06 % higher capsule dry weight than the preceding and succeeding dose of B, respectively at 50 DAS and that of 13.18 % and 3.61 % higher at 60 DAS, respectively. The result was supported by Bennetti (1993) that capsule development of sesame was affected by boron fertilizer.

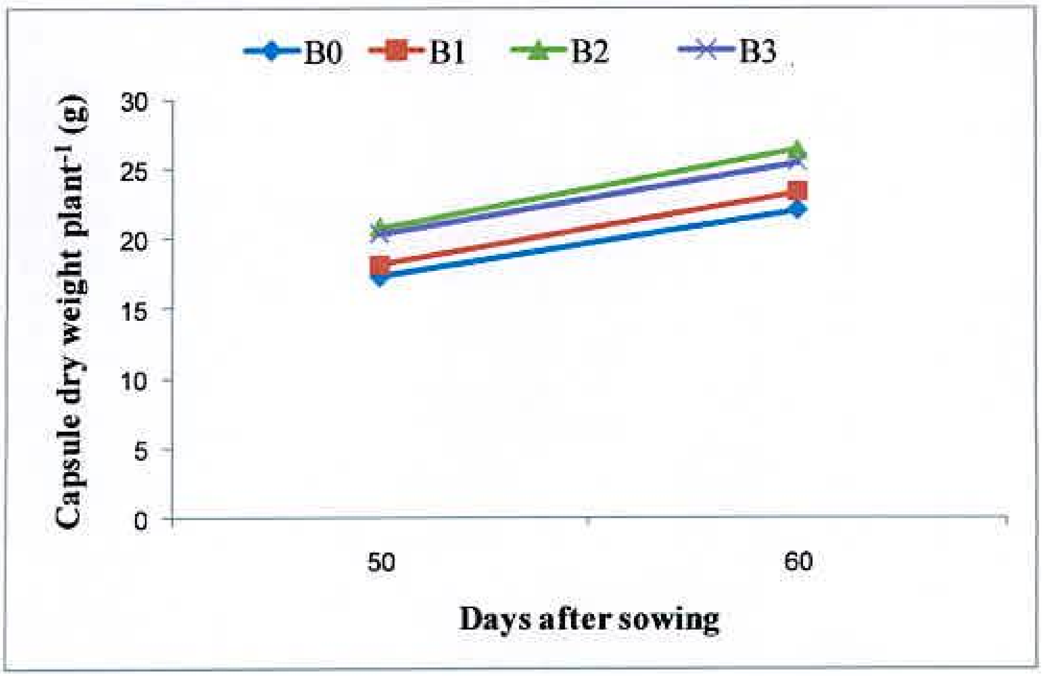

Fig. 6 Effect of boron fertilization on capsule dry weight plant^{-1} of sesame at different days after sowing ($S_{\bar{x}}$ = 0.030 and 0.009 at 50 and 60 DAS, respectively)

B_0	=	Without B (control)	B_2	=	2 kg B ha^{-1}
B_1	=	1 kg B ha^{-1}	B_3	=	3 kg B ha^{-1}

4.1.5.3 Interaction effect of sulphur and boron fertilization

The interaction effect of sulphur and boron was significant for capsule dry weight plant^{-1} at different DAS (Table 9). At 50 and 60 DAS, the highest capsule dry weight plant^{-1} was recorded from S_3B_2 (23.78 and 29.94 g, respectively). The combination of S_0B_0 at both for 50 and 60 DAS showed the lowest capsule dry weight plant^{-1} (15.80 and 20.48 g, respectively).

Table 9. Interaction effect of sulphur and boron fertilization on capsule dry weight plant^{-1} of sesame at days after sowing

Treatment combination	**Capsule dry weight plant^{-1} (g)**	
	50 DAS	**60 DAS**
S_0B_0	15.80 h	20.48 h
S_0B_1	16.15 h	21.73 g
S_0B_2	18.92 e	23.73 e
S_0B_3	19.57 d	24.23 de
S_1B_0	16.83 g	21.35 g
S_1B_1	17.75 f	22.81 f
S_1B_2	19.45 d	25.02 d
S_1B_3	19.81 d	24.77 d
S_2B_0	17.85 f	22.71 f
S_2B_1	18.94 e	23.90 e
S_2B_2	21.23 bc	27.08 b
S_2B_3	20.78 c	25.86 c
S_3B_0	18.90 e	23.90 e
S_3B_1	19.93 d	24.98 d
S_3B_2	23.78 a	29.94 a
S_3B_3	21.53 b	27.22 b
$s_{\bar{x}}$	**0.171**	**0.271**
CV (%)	**8.12**	**7.54**

S_0 = Without S (control)
S_1 = 9 kg S ha^{-1}
S_2 = 18 kg S ha^{-1}
S_3 = 27 kg S ha^{-1}

B_0 = Without B (control)
B_1 = 1 kg B ha^{-1}
B_2 = 2 kg B ha^{-1}
B_3 = 3 kg B ha^{-1}

4.2 Response of plant characters, yield and yield components of characters of sesame

4.2.1 Plant height (at harvest)

4.2.1.1 Influence of sulphur fertilization

The levels of sulphur had significant effect on plant height at maturity (Table 10). The trend of plant height increased with increasing S doses. The tallest plant 130.60 cm was observed from 27 kg S ha^{-1} which was statistically similar to that of 18 and 9 kg S ha^{-1} (128.90 and 128.00 cm, respectively). Plants grown without sulphur gave the lowest plant height (126.80 cm).

4.2.1.2 Influence of boron fertilization

Boron had a significant effect on plant height of sesame (Table 11). The tallest plant height (131.50 cm) was recorded from the 2 kg B ha^{-1}, which was statistically similar with the preceding boron dose (1 kg B ha^{-1}). Boron applied higher or lower than these two doses (1 and 2 kg B ha^{-1}) showed significantly lower plant height. This findings were supported by that of Hemantaranjan *et al.* (2000).

4.2.1.3 Interaction effect of sulphur and boron fertilization

Plant height at harvest was significantly influenced by the interaction effect of sulphur and boron (Table 12). It was observed that S_3B_2 combination gave the tallest plant (133.10 cm) and S_1B_2, S_2B_2, S_3B_1 gave similar height with S_3B_2. The interaction S_0B_0 gave the shortest plant (122.60 cm) and the S_1B_0 interaction gave statistically similar height with S_0B_0. These findings were in agreement with that of Chaplot (1996).

4.2.2 Number of branches plant^{-1}

4.2.2.1 Influence of sulphur fertilization

Sulphur dose exerted significant effect on number of branches plant^{-1} of sesame (Table 10). The result showed that the highest number of branches plant^{-1} (4.72) was obtained from 27 kg S ha^{-1} followed by 18 and 9 kg S ha^{-1} (4.65 and 4.53, respectively). The lowest number of branches plant^{-1} (3.99) was obtained from without S application treatment.

4.2.2.2 Influence of boron fertilization

Significant effect was observed with the application of boron fertilizer on number of branches plant^{-1} (Table 11). The highest number of branches plant^{-1} (4.84) was recorded from 2 kg B ha^{-1}, which was statistically similar with 1 kg B ha^{-1} (4.52). Treatment without B resulted the lowest number of branches plant^{-1} (4.16) which was statistically similar with that of 3 kg B ha^{-1} (4.37).

4.2.2.3 Interaction effect of sulphur and boron fertilization

Number of branches plant^{-1} at harvest significantly influenced by the interaction of sulphur and boron application (Table 12). It was observed that S_3B_2 combination gave the highest number of branches plant^{-1} (5.13), which was statistically similar with all the combinations except S_0B_0, S_0B_1 and S_0B_3. The combination S_0B_0 gave the lowest branches plant^{-1} (3.60) and S_0B_1, S_0B_3, S_1B_0, S_1B_3, S_2B_0, S_3B_0, S_3B_3 combinations gave similar results with S_0B_0. Subrahmaniyan *et al.* (1999) and Hedge (2003) also reported that number of branches plant^{-1} of sesame was significantly increased with the combination of S and B fertilizer.

4.2.3 Number of capsules plant^{-1}

4.2.3.1 Influence of sulphur fertilization

Number of capsule plant^{-1} influenced significantly due to sulphur fertilizer application (Table 10). The highest number of capsules plant^{-1} (63.10) was produced by 27 kg S ha^{-1}, which was statistically different from the second highest number of capsules plant^{-1} (60.64) produced by 18 kg S ha^{-1}. Application of 18 kg S ha^{-1} showed statistically similar number of capsule plant^{-1} with 9 kg S ha^{-1}. The lowest number of capsules plant^{-1} (57.77) was recorded from no S application treatment. Similar findings regarding capsule plant^{-1} were obtained from the reports of Sharma and Gupta (2003), and Ghosh *et al.* (2000).

4.2.3.2 Influence of boron fertilization

Boron had significant effect on the number of capsules plant^{-1} (Table 11). Significantly the highest number of capsules plant^{-1} (63.41) was produced by 2 kg B ha^{-1}. Boron higher or lower than 2 kg ha^{-1} reduced the number of capsules plant^{-1}. The lowest number of capsules plant^{-1} (56.75) was obtained from no B fertilization.

4.2.3.3 Interaction effect of sulphur and boron fertilization

The interaction effect of sulphur and boron application exerted significant effect on number of capsule plant^{-1} (Table 12). The interaction S_3B_2 gave the highest number of capsule plant^{-1} (66.50), which was statistically similar with that of S_3B_1 combination. The combination S_0B_0 gave the lowest capsule plant^{-1} (55.21), which statistically identical to that of S_0B_1, S_1B_0 and S_2B_0.

4.2.4 Number of seeds capsule^{-1}

4.2.4.1 Influence of sulphur fertilization

The number of seeds capsule^{-1} differed significantly due to application of different levels of sulphur (Table 10). The number of seeds capsule^{-1} was found the highest (54.15) with the highest dose of S (27 kg ha^{-1}) and it was decreased gradually with the reduction of S doses up to without sulphur treatment. However, seeds capsule^{-1} obtained from the treatments having 27, 18 and 9 kg S ha^{-1} was statistically similar (54.15, 53.72 and 53.54, respectively). The lowest number of seeds capsule^{-1} (51.22) was obtained from without S application. These findings were in agreement with that of Sharma and Gupta (2003) who observed that the number of seeds capsule^{-1} increased with the increasing rate of S fertilization.

4.2.4.2 Influence of boron fertilization

Number of seeds capsule^{-1} was significantly influenced by the levels of boron fertilization (Table 11). The highest number of seeds capsule^{-1} (55.03) was recorded from the treatment consisting 2 kg B ha^{-1}, which was statistically similar with that of the treatment having 1 kg B ha^{-1} (53.52). The lowest number of seeds capsule^{-1} (50.94) was obtained from no B fertilization.

4.2.4.3 Interaction effect of sulphur and boron fertilization

Number of seeds capsule^{-1} at harvest was significantly affected by the interaction effect of sulphur and boron application (Table 12). It was observed that S_3B_2 gave the best result (56.74), which was similar with that of S_2B_2. The interaction S_0B_0 gave the lowest value (49.18) in respect of seeds capsule^{-1}. The interactions S_0B_1 and S_3B_0 gave similar result with that of S_0B_0. Chaplot (1996) also observed similar findings on the number of seeds capsule^{-1} combining S and B.

4.2.5 1000-seed weight (g)

4.2.5.1 Influence of sulphur fertilization

Thousand-seed weight was not significantly differed with the levels of sulphur fertilizer (Table 10.). Moreover, the highest 1000- seed weight (3.12 g) was recorded from the application 27 kg S ha^{-1} followed by 18 (2.94 g) and 9 kg (2.88 g) S ha^{-1}. The lowest 1000 seed weight (2.78 g) was obtained from without S fertilization. Such findings were in agreement with Tiwari *et al.* (2000) who reported that increasing rate of sulphur also increased 1000- seed weight of sesame.

4.2.5.2 Influence of boron fertilization

The levels of boron fertilizer had significant effect on the 1000- seed weight of sesame (Table 11). The highest 1000- seed weight (3.03 g) was recorded from the application of 2 kg B ha^{-1} which was statistically similar with that of 3 kg B ha^{-1} (2.96 g). The lowest 1000- seed weight (2.85 g) was found from no B fertilization, which was statistically similar with that of 1kg B ha^{-1} (2.85 g). Similar findings were also reported by Sindoni *et al.* (1994) in respect of 1000- seed weight of sesame.

4.2.5.3 Interaction effect of sulphur and boron fertilization

Weight of 1000- seed was significantly influenced by the interaction effect of sulphur and boron (Table 12). It was observed that S_3B_2 combination gave the best result (3.23 g), which was statistically identical to that of S_2B_2, S_1B_3, S_0B_3 and S_3B_3. The interaction S_1B_1 gave the lowest result (2.73 g). These findings were supported by Chaplot (1996) in respect of 1000- seed weight of sesame.

4.2.6 Seed yield (t ha^{-1})

4.2.6.1 Influence of sulphur fertilization

Sulphur fertilizer had a significant effect on seed yield (Table 10). It can be inferred from the table that the highest dose of sulphur (27 kg ha^{-1}) showed its superiority by producing the highest seed yield (1.19 t ha^{-1}) than the lower doses. The seed yield showed a decreasing trend with the decreasing rate of sulphur fertilizer. The lowest seed yield (0.90 t ha^{-1}) was recorded from control treatment. It was evidented that 27 kg S ha^{-1} showed 32.22%, 9.17% and 3.48% higher seed yield over 0, 9 and 18 kg S ha^{-1}. This findings were supported by Vaiyapuri *et al.* (2003), Sarkar and Banik (2002), Dayanand *et al.* (2002) and Meng *et al.* (1999) who reported that seed yield of sesame increased with the increased rate of S fertilizer.

4.2.6.2 Influence of boron fertilization

Seed yield of sesame was significantly influenced by boron fertilization (Table 11). The highest seed yield (1.20 t ha^{-1}) was recorded from 2 kg B ha^{-1}, which was statistically different from 1.10 and 1.09 t ha^{-1} obtained respectively from 1 and 3 kg B ha^{-1}. It was interesting that B rate lower and higher than 2 kg ha^{-1} showed statistically similar seed yield. The lowest seed yield (0.95 t ha^{-1}) was obtained from the control treatment. The present result was similar with that of Bennetti (1993) where seed yield of sesame was increased with increasing B up to optimum level.

4.2.6.3 Interaction effect of sulphur and boron fertilization

Grain yield was significantly influenced by the interaction of sulphur and boron (Table 12). It was observed from the table that S_3B_2 combination gave the highest seed yield (1.33 t ha^{-1}) and the combination S_1B_1, S_1B_2, S_2B_1, S_2B_2, S_2B_3, S_3B_1 and S_3B_3 gave similar result with S_3B_2. The combination S_0B_0 gave the lowest seed yield (0.743 t ha^{-1}), which was statistically similar with that of S_0B_0 and S_1B_0. The results corroborates with the findings of Hegde (2003) who observed the maximum seed yield of sesame from the combination of higher doses of S with optimum dose of B.

4. 2.7 Stover yield (t ha^{-1})

4.2.7.1 Influence of sulphur fertilization

Sulphur had a significant effect on stover yield of sesame (Table 10.). Stover yield showed an increasing trend with the increases of sulphur rate and the highest value (2.61 t ha^{-1}) was observed with the highest dose (27 kg S ha^{-1}). Stover yield observed from the treatments of 27, 18, 9 kg S ha^{-1} were statistically similar (2.61, 2.55 and 2.41 t ha^{-1}, respectively). The lowest stover yield (2.35 t ha^{-1}) was obtained from without S application treatment.

4.2.7.2 Influence of boron fertilization

Stover yield of sesame was significantly influenced by levels of boron (Table 11). The highest stover yield (2.61 t ha^{-1}) was obtained from the application of 2 kg B ha^{-1}, which was statistically similar with the preceding dose of boron (1 kg ha^{-1}). The lowest stover yield (2.29 t ha^{-1}) was recorded from without B application, which was statistically similar with that of 3 kg B ha^{-1} (2.48 t ha^{-1}). The result was supported by Sinha *et* *al*. (1999) who reported that stover yield was increased with optimum B fertilization.

4.2.7.3 Interaction effect of sulphur and boron fertilization

The interaction of sulphur and boron had a significant effect on stover yield of sesame (Table 12). The Table showed that the combination S_3B_2 gave the highest stover yield (2.75 t ha^{-1}), which was statistically similar with that of all the interactions except S_0B_0. However, the combination S_0B_0 gave the lowest stover yield (1.93 t ha^{-1}). Similar result was also reported by Hegde (2003) who observed the higher dose of S and optimum B combination showed the higher stover yield of sesame.

4.2.8 Harvest Index (%)

4.2.8.1 Influence of sulphur fertilization

Harvest index was significantly influenced by different levels of sulphur in sesame (Table 10). The trend of harvest index was similar as observed in stover yield of sesame with sulphur fertilization. It was observed that 27 kg S ha^{-1} resulted the highest harvest index (31.25 %), which was statistically similar with that of 18 and 9 kg S ha^{-1} (30.24 % and 30.17 %, respectively). The lowest harvest index (28.34 %) was recorded from no S application treatment.

4.2.8.2 Influence of boron fertilization

Boron level had a significant effect on harvest index of sesame (Table 11). Application of 2 kg B ha^{-1} showed its superiority over lower and higher dose by producing the highest harvest index of sesame. Application of 2 kg B ha^{-1} gave the highest harvest index (31.37 %) which was statistically similar with that of 1 and 3 kg B ha^{-1} (30.73 and

30.10 %, respectively). The lowest harvest index (28.80 %) was obtained from no B application.

4.2.8.3 Interaction effect of sulphur and boron fertilization

Harvest index was significantly influenced by the interaction of sulphur and boron (Table 12). The interaction S_3B_2 gave the highest harvest index (32.59%), which was statistically similar with that of all the combinations except S_0B_0, S_0B_1, S_0B_2, S_2B_0 and S_3B_0 combinations. The interaction S_0B_0 gave the lowest harvest index (27.28 %) and it was statistically similar with that of S_0B_0. These results were in agreement with the findings of Hegde (2003) who observed that interaction of S and B fertilizer produced the higher harvest index of sesame.

4.2.9 Oil content (%)

4.2.9.1 Influence of sulphur fertilization

Sulphur fertilization significantly influenced oil content in sesame seed (Table 10). Oil percentage of sesame seed was directly proportional to the increasing level of sulphur. The results revealed that the highest oil content (42.07 %) was recorded from the highest sulphur level (27 kg ha^{-1}), which was statistically similar to that of 18 kg S ha^{-1} (41.76 %). The lowest oil content (39.46 %) was obtained from the control treatment, which was statistically identical to that of 9 kg S ha^{-1}. This might have resulted probably due to augmentation of sulphur containing fatty acids, which ultimately led to increase in seed oil content. Similar findings were also reported by Dayanand *et al.* (2002) and Radhamoni *et. al* (2001).

4.2.9.2 Influence of boron fertilization

Oil content of sesame seed was significantly influenced by boron fertilization (Table 11). The highest oil percentage (41.01 %) in sesame seed was obtained from the optimum B level (2 kg B ha^{-1}), which was statistically similar with that of 3 kg B ha^{-1} (40.96 %). The lowest oil content (40.86 %) was recorded from control treatment (no boron application), which was statistically similar with that of 1 and 3 kg B ha^{-1} (40.89 % and 40.96%, respectively). These findings were in agreement with that of Liu *et. al.* (2003) who observed similar pattern of oil content due to boron application.

4.2.9.3 Interaction effect of sulphur and boron fertilization

The interaction of S and B had significant effect on oil content of sesame seed (Table 12). The highest oil content were recorded from all the interaction of B with higher doses of S like S_3B_2, S_3B_3, S_3B_1 and S_3B_0 (42.11, 42.09, 42.06 and 42.01 %, respectively), which was significantly similar with that of S_2B_3, S_2B_2, S_2B_1, S_2B_0, S_1B_3, S_1B_2, S_1B_1 and S_1B_0, respectively. The lowest oil content (39.35 %) was recorded from S_0B_0, which was followed by S_0B_3, S_0B_2 and S_0B_1, respectively.

Table 10. Effect of sulphur fertilization on plant characters, yield and yield components of sesame at maturity

Sulphur levels	Plant height (cm)	Number of Branches plant^{-1}	No. of capsule plant^{-1}	Number of Seeds capsule^{-1}	1000- seed weight (g)	Yield (t ha^{-1})	Stover Yield (t ha^{-1})	Harvest Index (%)	Oil content (%)
S_0	126.8 b	3.99 b	57.77 c	51.21 b	2.78	0.90 c	2.35 b	28.34 b	39.46 b
S_1	128.0 ab	4.53 a	60.55 b	53.54 ab	2.88	1.09 b	2.41 ab	30.17 ab	40.43 b
S_2	128.9 ab	4.65 a	60.64 b	53.71 ab	2.94	1.15 b	2.55 a	30.24 ab	41.76 a
S_3	130.6 a	4.72 a	63.10 a	54.15 a	3.12	1.19 a	2.61 a	31.25 a	42.07 a
$s_{\bar{x}}$	**0.909**	**0.137**	**0.518**	**0.799**	**0.042**	**0.034**	**0.116**	**0.529**	**0.347**
CV (%)	**7.45**	**10.61**	**8.08**	**13.65**	**5.00**	**10.72**	**9.10**	**6.06**	**7.52**

S_0 = Without S (control)

S_1 = 9 kg S ha^{-1}

S_2 = 18 kg S ha^{-1}

S_3 = 27 kg S ha^{-1}

Table 11. Effect of boron fertilization on plant characters, yield and yield components of sesame at maturity

Boron levels	Plant height (cm)	Number of Branches plant^{-1}	No. of capsule plant^{-1}	Number of Seeds capsule^{-1}	1000- seed weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)	Oil content (%)
B_0	125.7 c	4.16 b	56.74 c	50.94 c	2.85 b	0.95 c	2.29 c	28.80 b	40.86 b
B_1	129.8 ab	4.52 ab	61.18 b	53.52 ab	2.86 b	1.09 b	2.53 ab	30.73 ab	40.89 b
B_2	131.5 a	4.84 a	63.41 a	55.03 a	3.03 a	1.20 a	2.61 a	31.37 a	41.01 a
B_3	127.4 bc	4.37 b	60.65 b	53.13 b	2.96 ab	1.09 b	2.48 b	30.10 ab	40.96 ab
$s_{\bar{x}}$	0.909	0.137	0.518	0.799	0.042	0.034	0.116	0.529	0.347
CV (%)	7.45	10.61	8.08	13.65	5.00	10.72	9.10	6.06	7.52

B_0 = Without B (control)
B_1 = 1 kg B ha^{-1}
B_2 = 2 kg B ha^{-1}
B_3 = 3 kg B ha^{-1}

Table 12. Combined effect of sulphur and boron fertilization on plant characters , yield and yield components of sesame at maturity

Treatment combination	Plant height (cm)	Number of Branches plant^{-1}	Number of capsule plant^{-1}	Number of seeds capsule^{-1}	1000- seed weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)	Oil content (%)
S_0B_0	122.6 d	3.60 c	55.21 h	49.18 e	2.73 c	0.74 f	1.98 c	27.28 e	39.35 d
S_0B_1	128.3 a-d	3.93 bc	56.75 gh	50.68 de	2.87 bc	0.84 ef	2.15 a-c	28.26 c-e	39.41 cd
S_0B_2	129.4 a-c	4.53 ab	60.66 de	52.75 b-e	2.90 bc	1.01 c-e	2.52 a-c	28.75 b-e	39.47 cd
S_0B_3	126.9 a-d	3.93 bc	58.44 fg	52.23 b-e	2.97 a-c	1.00 c-e	2.44 a-c	29.06 a-d	39.62 b-d
S_1B_0	124.3 cd	4.27 a-c	56.49 gh	51.74 c-e	2.93 bc	0.92 d-f	2.00 bc	31.67 a-c	40.35 a-d
S_1B_1	129.7 a-c	4.60 ab	61.46 c-e	54.01 a-d	2.77 c	1.16 a-c	2.59 a-c	30.98 a-d	40.39 a-d
S_1B_2	131.3 ab	4.80 ab	62.66 b-d	54.95 a-c	2.90 bc	1.20 a-c	2.59 a-c	31.66 a-c	40.52 a-d
S_1B_3	126.8 b-d	4.45 a-c	61.60 c-e	53.47 a-d	2.97 a-c	1.10 b-d	2.52 a-c	30.38 a-d	40.45 a-d
S_2B_0	126.1 b-d	4.33 a-c	56.88 gh	52.29 b-e	2.89 bc	1.04 b-e	2.71 a	27.79 de	41.67 a-d
S_2B_1	130.1 a-c	4.73 ab	61.81 c-e	54.13 a-d	2.90 bc	1.20 a-c	2.59 a-c	31.66 a-c	41.75 a-c
S_2B_2	132.1 ab	4.91 a	63.79 bc	55.67 ab	3.07 ab	1.27 ab	2.64 ab	32.48 a	41.94 ab
S_2B_3	127.5 a-d	4.63 ab	59.68 ef	52.78 b-e	2.90 bc	1.12 a-d	2.74 a	29.01 a-d	41.68 a-d
S_3B_0	129.9 a-c	4.46 a-c	58.38 fg	50.56 de	2.83 bc	1.09b-d	2.65 ab	28.45 b-e	42.01 a
S_3B_1	131.1 ab	4.83 ab	64.68 ab	55.25 a-c	2.90 bc	1.18 a-c	2.52 a-c	32.02 ab	42.06 a
S_3B_2	133.1 a	5.13 a	66.50 a	56.74 a	3.23 a	1.33 a	2.75 a	32.59 a	42.11 a
S_3B_3	128.5 a-d	4.47 a-c	62.84 b-d	54.04 a-d	3.00 a-c	1.15 a-d	2.45 a-c	31.94 ab	42.09 a
$s_{\bar{x}}$	**1.820**	**0.275**	**1.036**	**1.598**	**0.084**	**0.068**	**0.231**	**1.059**	**0.694**
CV (%)	**7.45**	**10.61**	**8.08**	**13.65**	**5.00**	**10.72**	**9.10**	**6.06**	**7.52**

S_0 = Without S (control) S_2 = 18 kg S ha^{-1} B_0 = Without B (control) B_2 = 2 kg B ha^{-1}

S_1 = 9 kg S ha^{-1} S_3 = 27 kg S ha^{-1} B_1 = 1 kg B ha^{-1} B_3 = 3 kg B ha^{-1}

Chapter 5

Summary and Conclusion

CHAPTER 5
SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate growth, yield and oil content of sesame as influenced by sulphur and boron fertilization during the period from March 2008 to June 2008. The experiment comprised of two factors such as (i) four levels of sulphur viz. S_0 (control), S_1 (9 kg S ha^{-1}), S_2 (18 kg S ha^{-1}) and S_3 (27 kg S ha^{-1}) and (ii) four levels of boron viz. B_0 (control), B_1 (1 kg B ha^{-1}), B_2 (2 kg B ha^{-1}) and B_3 (3 kg B ha^{-1}).

The experiment was set up in Randomized Complete Block Design (RCBD) (factorial) with three replications. There were 16 treatment combinations. The experimental plot was fertilized at the rate of 125 kg, 150 kg and 50 kg ha^{-1} Urea, TSP and MP, respectively. Sesame seeds of cv. BARI Til-3 were sown on 19th March 2008 and harvested on 21st June 2008. Data on different growth, yield parameters and yield were recorded and analyzed statistically.

Results showed that the effect of sulphur and boron fertilizer applications on sesame was significant in respect of various plant characters including yield and yield attributes.

Plant heights of sesame were influenced significantly by the application of sulphur and boron fertilizers at all growth stages of observations. Plant height was always highest with 27 kg S ha^{-1} (S_3) and 2 kg B ha^{-1} and the lowest with control. Plant height was significantly higher with the interaction effect of 27 kg S ha^{-1} with 2 kg B ha^{-1} (S_3B_2).

Leaves dry weight plant^{-1}, petiole dry weight plant^{-1}, stem dry weight plant^{-1} and capsule dry weight plant^{-1} of sesame at all the dates of observations was also influenced significantly by the application of sulphur and boron. Highest leaves dry weight plant^{-1}, petiole dry weight plant^{-1}, stem dry weight plant^{-1} and capsule dry weight plant^{-1} of sesame were observed with 27 kg S ha^{-1} (S_3) and 2 kg B ha^{-1} (B_2) and the lowest with control for both the fertilizers. Significantly, higher leaves dry weight plant^{-1}, petiole dry weight plant^{-1}, stem dry weight plant^{-1} and capsule dry weight plant^{-1} of sesame were presented with the combination effect of sulphur and boron fertilizers application for all growth stages at the rate of 27 kg S ha^{-1} with 2 kg B ha^{-1} (S_3B_2).

Plant, yield contributing characters and yield of sesame was also responded significantly to sulphur application. The highest value of plant height, number of branches plant^{-1}, number of capsule plant^{-1}, number of seeds capsule^{-1}, grain yield, stover yield and harvest index were observed with 27 kg S ha^{-1} (S_3) and lowest with control (S_0). But in respect of 1000- seed weight, it was not significantly influenced with 27 kg S ha^{-1}. In case of boron application, the highest value of plant height, number of branches plant^{-1}, number of capsule plant^{-1}, number of seeds capsule^{-1}, grain yield, stover yield and harvest index were observed with 2 kg B ha^{-1} (B_2) and lowest with control (B_0). But in respect of 1000- seed weight, it was not significantly influenced by 2 kg B ha^{-1}. Significantly higher plant height (133.10 cm), number of branches plant^{-1} (5.13), number of capsule plant^{-1} (66.50), number of seeds capsule^{-1} (56.74), 1000- seed weight (3.23 g), seed yield (1.33 t ha^{-1}), stover yield (2.75 t ha^{-1}) and harvest index (32.59%) of sesame were presented with the combined effect of 27 kg S ha^{-1} with 2 kg B

ha^{-1} (S_3B_2) and lowest result was obtained with the combination of 0 kg S ha^{-1} and 0 kg B ha^{-1} (S_0B_0).

Mainly sesame is cultivated in our country for the purpose of edible oil. In this experiment, it was observed that oil content of sesame was significantly influenced by sulphur and boron fertilizers. Twenty seven kg S ha^{-1} (S_3) and 2 kg B ha^{-1} (B_2) gave highest oil content. Significantly, the highest oil content (42.11 %) of sesame were presented with the combined effect of 27 kg S ha^{-1} with 2 kg B ha^{-1} (S_3B_2) and lowest result was obtained with the combined effect of 0 kg S ha^{-1} with 0 kg B ha^{-1} (S_0B_0).

From the above results, it may be concluded that both the treatments had significant effect on growth and yield contributing characters of BARI Til - 3. The growth characters; plant height, leaves dry weight $plant^{-1}$, petiole dry weight $plant^{-1}$, stem dry weight $plant^{-1}$ and capsule dry weight $plant^{-1}$ and the yield contributing characters; plant height, number of branches $plant^{-1}$, number of capsule $plant^{-1}$, number of seeds $capsule^{-1}$, 1000- seed weight, grain yield, stover yield, oil content and harvest index were enhanced significantly by 27 kg S ha^{-1} (S_3) and 2 kg B ha^{-1} (B_2), respectively. Highest grain yield and oil content were obtained from 27 kg S ha^{-1} along with 2 kg B ha^{-1} (S_3B_2) application. So, it may be concluded that significantly higher yield of sesame may be achieved using 27 kg S ha^{-1} along with 2 kg B ha^{-1}.

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Appendices

APPENDICES

Appendix I. Chemical composition of soil of the experimental plot

	Analytical results
Agrological Zone	Madhupur Tract
P^H	5.46 – 5.61
Organic matter (%)	0.83
Total N (%)	0.41
Available phosphorous (ppm)	21
Total S (ppm)	221
Exchangeable K meq / 100 g soil	0.42
Available S (ppm)	15.00
Boron (ppm)	1.72
Copper (μg/g soil)	3.56
Iron (μg/g soil)	262.9
Manganese (μg/g soil)	163.0
Zinc (μg/g soil)	3.31

Source: Soil Resources Development Institute, Farmgate, Dhaka

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (March, 2008 to July, 2008) at the experimental area (Sher-e-Bangla Agricultural University campus)

Month	Monthly average air temperature (^{0}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
	Maximum	Minimum	Mean			
March	29.21	23.52	26.37	75.09	Trace	214.38
April	29.25	25.81	27.53	77.05	351	211.50
May	30.18	24.29	27.24	79.90	680	194.00
June	30.32	26.40	28.36	80.78	853	226.50
July	31.32	25.00	28.16	82.13	942	223.30

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka – 1212