EFFECTS OF SULFUR AND BORON ON THE GROWTH, YIELD, OIL AND SULFUR CONTENT OF BARI Til-4

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECTS OF SULFUR AND BORON ON THE GROWTH, YIELD, OIL AND SULFUR CONTENT OF BARI Til-4"*** *submitted to the* ***DEPARTMENT OF AGRICULTURAL CHEMISTRY****, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY****, embodies the results of a piece of bonafide research work carried out by* ***MEER TOWHID-UL-ISLAM****, Registration.* ***No. 08-02828****, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.*

I further certify that any help or sources of information received during the course of this investigation have duly been acknowledged.

Dated:
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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka-1207 with a view to evaluate the effect of sulfur and boron on the growth, yield, oil and nutrient content of BARI Til-4 during the period from April to July, 2014. The experiment was consisted of four levels of sulfur (S_0= 0, S_1= 10, S_2= 20 and S_3 = 30 kg S ha^{-1}) and four levels of boron (B_0 = 0, B_1 = 10, B_2= 1.5 and B_3= 2 kg B ha^{-1}). It was replicated thrice in a randomized complete block design. The results showed that sulfur, boron and their interaction significantly influenced most of the growth and yield contributing characters such as plant height, number of leaves per plant number of branches per plant, fresh and dry weight of leaves, fresh and dry weight of stem, number of capsules, number of seeds per capsule, 1000-seed weight, fresh weight of pods, seed dry weight, stover dry weight, seed-stover ratio (on dry weight basis), seed yield, stover yield, biological yield, harvest index, oil content and sulfur concentration in seed of sesame. All parameters studied in this experiment increased with the increasing sulfur levels, 30 kg S ha^{-1} gave the highest results in all cases. Except 1000-seedweight and S concentration in seed, the yield contributing parameters increased with the increasing boron levels up to 1.5 kg ha^{-1} which showed statistically similar results with most of the parameters of 2 kg ha^{-1}. The highest seed yield (1.657 ton ha^{-1}), oil content (44.60 %) and S concentration (0.2157 %) were obtained from the interaction of S_3B_2 (30 kg S ha^{-1} and 1.5 kg B ha^{-1}) treatment due to the production of the highest number of capsules $plant^{-1}$, maximum number of seeds $capsule^{-1}$ and highest weight of 1000-seed.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full words
FAO	Food and Agriculture Organization
BBS	Bangladesh Bureau of Statistics
LSD	Least significant difference
et al.	Et alibi (and others)
i.e.	That is
kg	Kilogram
mt	Metric-ton
mL	Milli liter
nm	Nano meter
ppm	Parts per million
%	Percentage
g	Gram
t	Ton
cm^2	Square centimeter
yr	Year
m^2	Square meter
cm^3	Cubic centimeter (Solid)
m	Meter
df	Degree of freedom
ha	Hectare
pH	Negative log of hydrogen ion concentration
NS	Not significant
BARI	Bangladesh Agricultural Research Institute
AEZ	Agro Ecological Zone
C.V.	Coefficient of Variation
cv.	Cultivar
DAS	Days after sowing

Chapter I
Introduction

CHAPTER I
INTRODUCTION

BARI Til-4 is a well-known sesame variety of Bangladesh developed by Oilseed Research Centre under Bangladesh Agricultural Research Institute (BARI) in 2009. This variety is developed by selection method from the intensive collection of sesame germ plasm. Sesame (*Sesamum indicum* L.) is one of the most ancient oil crops in the world which is also known as "Til" in Bangla. It belongs to the Pedaliaceae family having bell-shaped flowers and opposite leaves. It had earned a poetic label "Queen of Oilseeds" (Sanga, 2013).

Sesame is a rich source of edible oil (48 – 55%), carbohydrate (14 – 20%) and protein (20 – 28%) compared with 20% seed oil in other oil seed crops (FAO, 2001). It also contains 0.156- 0.288% 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). Sesame oil taste and odour is pleasant because of presence of aldehyde and acetyl pyragin. It contains fewer amounts of eurocic acid but more than 80% high quality unsaturated fatty acid including large amount of oleic and linoleic acid (BINA, 2004) which offer resistance to rancidity. It is a fairly high value food crop, being harvested both for whole seed used in baking and for the cooking oil extracted from the seed. Sesame has pronounced antioxidant activity, thereby offering high shelf life, and is also called "seed of immortality" (Sanga, 2013).

Sesame is an ancient and important oilseed crop being cultivated for centuries in tropical and sub-tropical parts of the world, particularly in Asia and Africa. It ranks 4th among the oil crops in the world. The world production of sesame is 2.9 million metric tons (FAO, 2003). The leading sesame producing countries are India, Egypt, Pakistan, U.S.A, China, Sudan, Nigeria, Uganda, Chad, Morocco and Bangladesh. According to cultivable area and production it occupies second position as oil crop followed by rape and mustard (BARI, 2009).

Sesame is drought resistant annually cultivated herb which can be easily grown under rainfed upland condition. The crop is grown in both *rabi* and *kharif* seasons in

Bangladesh but the kharif season covers about two-third of the total sesame area. Crop coverage in 2005- 2006 was 30.7 thousand ha (BBS, 2007). Khulna, Faridpur, Pabna, Barisal, Rajshahi, Jessore, Comilla, Dhaka, Patuakhali, Rangpur, Sylhet and Mymensingh districts are the leading sesame producing areas of Bangladesh.

Sesame is a versatile crop with high quality edible oil having diversified usage. Sesame oil is used mostly for edible purpose and in confectionery and illumination. It is also used for other purposes, such as in manufacture of margarine, soap, paint, perfumery products and of pharmaceuticals as an ingredients for drugs and as dispersing agent for different kinds of insecticides (Cobley, 1967; Masefield, 1965; Mcllroy, 1967). Sesameolin, a constituent of the oil, is used for its synergistic effect in pyrethrum, which increase the toxicity of insecticides (Mcllroy, 1967).

The sesame oilcake is a very good cattle feed since it contains high amount of good quality protein. Sesame seed meal is rich in minerals and contains available fatty acids and amino acids which may be a good feed of fish and animal (Nwokolo, 1987). Sesame oilcake contains 6.2-6.3%N, 2.0-2.1%P_20_5 and 1.1-1.3% K_2O (Chatterjee and Mondal, 1983). The cake is also used as manure (Cobley, 1967). Fried seed of sesame mixed with sugar or in the form of sweetmeat *tiler khaja* is a tasty snack in Bangladesh. The use of seed for decoration on the surface of breads, nimkies, biscuits and cookies is most popular to the Americans.

Bangladesh faces an acute shortage of edible oil as its population growth is 1.34% (BBS, 2013). So the requirement of edible oil is increasing. Sesame can play an important role to fulfill the demand because of the suitable climate of Bangladesh. As sesame is a short duration and photo insensitive crop with wider adaptability, it can be cultivated both in Rabi and Kharif seasons. Bangladesh produces 22 thousand metric tons of sesame from 36.84 thousand hectare of land every year (BBS, 2004). But in our country yield of sesame per unit area is very low, the average yield of sesame at farmer's level is only 0.59 ton per hectare (BARI, 1999). The main reasons for poor yield are lack of suitable varieties, lack of production inputs, improper management practices and inappropriate cultural operations. At present the country is experiencing 70% oil deficit (Wahhab, 2002). So the sesame production should be increased by increasing yield per unit area through the practice of intensive cropping with modern varieties. But it causes a marked depletion of inherent nutrient reserves in soil of Bangladesh.

Sulfur is an important macro nutrient element after nitrogen, phosphorus and potassium. In broad sense, the functions of nitrogen and sulfur are similar and they are synergistic. Additional sulfur application increased the seed and oil content of the sesame (Nageshwar *et al.*, 1995). Sulfur increases dry matter accumulation and seed yield in sesame (Saren *et al.*, 2004). Oil crops are sulfur loving plants. As an oil crop, sesame requires more sulfur for the synthesis of certain amino acids such as cystine, cystein, metheonine and also plant hormones and vitamins. Besides this, it involves metabolic and enzymatic processes of the plant. Approximately 12 kg S is required to produce one ton of oil seed (Ghosh *et al.*, 2000). But sulfur deficiency has been found to occur in soils of Bangladesh. Current intensive use of agricultural land for crop production without proper replenishment of nutrient elements and organic matter has extended the sulfur deficient areas to about 80% in Bangladesh (Khan, *et al.*, 2007). Sulfur deficiency in crops results in a reduction of leaf area, seed number, seed weight, delayed floral initiation and anthesis. Sulphur deficiency alone reduces crop yield by 10-20% (Bhuiyan and Shah, 1990).

Boron is one of the factors for yield and oil content of sesame. Besides primary nutrient some micronutrient deficiency viz. B, Zn, and Mo have also appeared in some soils and crops (Khanam *et al.*, 2001). Especially boron deficiency is reported on some soils and crops (Islam *et al.*, 1997). Boron is involved in several physiological and biochemical process during plant growth. Its deficiency may be one of the factors responsible for low yield. It is stated that Bangladesh had one million hectare of land which had been boron deficient (Ahmed and Hossain, 1999). Boron deficiency causes great depreciation in grain set and results in severe yield reduction (Rerkasem and Jamjod, 2001). This element deficiency is usually observed in light textured and high pH soils.

Improved sesame varieties are suggested to increase yield probably due to their high yield potential and resistance to pests and diseases (Ssekabembe *et al.*, 2002).The average yield of sesame in Bangladesh is 908 kg ha^{-1} (BBS, 2011) as against the genetic potential of around 1500 kg ha^{-1} (Kokilavani *et al.*, 2007). BARI Til-4 is the latest high yielding variety of sesame developed by Bangladesh Agricultural Research

Institute (BARI) in 2009. The main identifying character of this variety is about 70% pods have eight chambers. It contains 20-40% more seeds in its chamber than that of BARI Til-2 and BARI Til-3. It is mainly cultivated in kharif season in our country. The yield is 1.4-1.5 ton per hector which is 8-10% more than the yield of BARI Til-2 and BARI Til-3 (BARI 2009). The cultivation of BARI Til-4 is such profitable variety. So there is a great possibility of increasing sesame yield per unit area with the appropriate use of sulfur and boron fertilizer to meet the requirement of edible oil to the people of Bangladesh.

Besides these, different combinations of S and B may have a great importance on sesame. Nutrient content of crop is markedly improved due to application of S and B. The crop growth rate, relative growth rate, net assimilation rate, specific leaf weight and apparent translocation rate improved due to application of S and B (Smeia, 2006).The gap between the actual and achievable yields for sesame is wide and better nutrient management practices-with special emphasis to secondary and micronutrients like S and B-offers a solution to bridging the yield gap.

Though a number of relevant research works have been done on some sesame, but the effects of S and B on the chemical parameters of sesame cv. BARI Til-4 are yet to be reported. Keeping this in view, the present study was undertaken to see the effect of sulfur and boron on BARI Til-4 with the following objectives:

a) To examine the effects of different levels of sulfur and boron application on growth, yield and oil content of BARI Til-4,
b) To assess the sulfur accumulation in seed of sesame and
c) To quantify the suitable rate of sulfur and boron for its cultivation.

Chapter II
Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

Sesame is one of the most important oil yielding crops in Bangladesh. It may play an important role to mitigate shortage of edible oil demand of the country. But the production of this crop is still low compared to other sesame producing countries of the world due to various reasons. Among the reasons, fertilizer management is one of the key factors, which directly influence the yield. Sulfur is a macronutrient occurring in the soil both in organic and inorganic forms. Sulfur performs many important functions in plant growth. Boron is also an essential and vital element for growth and yield of sesame. Here some important research findings relevant to the present study have been reviewed in this chapter.

2.1 Effect of sulfur on growth and yield of sesame

Sanga L. (2013) conducted an experiment in Dodoma district, Tanzania to assess and optimize the soil fertility status for sesame (*Sesamum indicum* L.) production. The study showed that application of N, P, S and Zn at rates of 45 kg ha^{-1}, 20 kg ha^{-1}, 45 kg ha^{-1} and 25 kg ha^{-1}, respectively increase sesame growth, yield and oil content significantly.

Kabir (2011) conducted experiments at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University during 2009 to 2011 to find out the influence of NPKS with source sink manipulation on growth, nutrient uptake and productivity of sesame. The results revealed that application of 40 kg S ha^{-1} gave the highest seed yield and highest amount of soil than the application of 20 kg S ha^{-1} and 60 kg S ha^{-1}.while nitrogen, phosphorus and potassium was applied at the rate of 100, 40 and 60 kg ha^{-1}, respectively.

Tripathi *et al.* (2007) conducted a field experiment during 2003 to 2005 on sulfur deficient clay loam soil. Four levels of sulfur were applied to sesame cv. JTS-8 through single super phosphate, elemental sulfur and gypsum. The results revealed that growth, yield attributes and yield were influenced with increasing levels of sulfur. Application of 45 kg S ha^{-1} through single super phosphate was found more economical followed by 30 and 15 kg S ha^{-1}. Single super phosphate was found to be a relatively better source of sulfur than gypsum and elemental sulfur.

Maragatham *et al.* (2006) studied the effects of S fertilizer (S material from Cochin Refineries) at 0, 20, 40, 60 and 80 kg ha^{-1} on the performance of sesame (cv. Co 1 karosathena) in Coimbatore, Tamil Nadu, India, during 2000. The experiment showed that S at 40 and 60 kg ha^{-1} gave comparable yields, whereas S at 80 kg ha^{-1} registered a lower yield, indicating that 40 kg S ha^{-1} was optimum for sesame. The seed oil content was not markedly affected by the various amendments. The application of 40 kg S ha^{-1} increased the seed oil content over control from 47.63 to 49.83%. Among the treatment combinations, 40 kg S ha^{-1} applied with FYM + Thiobacillus increased the seed oil content by 3.7%. The protein content increased by 3.3% following the application of 40 kg S ha^{-1} and by 7.4% following the application of S + FYM + Thiobacillus.

Amudha *et al.* (2005) carried out an investigation during the summer and kharif seasons 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 press mud each applied at 10 ton 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 yields (870.2 and 898.1 kg ha^{-1}) and stover yields (2853.2 and 3155.7 kg ha^{-1}) for rabi and kharif seasons, respectively, as well as the maximum Sulfur Use Efficiency.

Sriramachandrasekharan (2004) showed the effects of S (0, 15, 30 or 45 kg ha^{-1} through gypsum) and poultry manure (10 ton ha^{-1}) on the yield and sulfur uptake and use efficiency of sesame cv. TMV 3 was studied in Annamalainagar, Tamil Nadu, India, during 2001. The apparent S recovery (15.8 and 12.9) and physiological efficiency (67.4 and 56.2 [kg grain kg^{-1} S uptake]) were highest at 15 kg ha^{-1}, decreasing with further increase in S rate.

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 use (nitrogen, phosphorus, potassium, sulfur and trace elements) in different oilseeds (viz., rapeseed, sunflower, soybean, safflower, groundnut, mustard, sesame and linseed).

Sharma and Gupta (2003) carried out a study to determine the effect of S on the growth and yield of selected rainy season crops such as cowpea, cluster bean, pearl millet, castor and sesame in Rajasthan, India, during the rainy season of 1998. They found that sulfur level lengthen the height of all tested crops. Increasing S rates also increased the dry matter accumulation per plant. Supply of S also promoted floral primordial initiation, resulting in higher number of pods (or earheads) plant^{-1} and seed number per pod (or earhead), and ultimately in enhanced seed yield. Application of S had positive effects on the yields of all crops.

Sharma and Gupta (2003) also stated that sulfur has a great influence on the growth and yield of sesame. Treatments comprised four sulfur rates (0, 20, 40 and 60 kg ha^{-1}) in the experiment. Application of sulfur at 40 kg ha^{-1} increased the height and dry matter accumulation. Floral primordial initiation higher number of pods plant^{-1} and seed number capsule^{-1} and ultimately enhanced seed yield of sesame up to 27% over control. 60 kg ha^{-1} which also gave statistically same result as 40 kg S ha^{-1}.

Vaiyapuri *et al.* (2003) evaluate the effects of sulfur (0, 15, 30 and 45 kg ha^{-1}) and organic amendments (10 ton 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 sulfur uptake. Application of poultry manure resulted in the highest oil content, oil yield and crude protein content of sesame.

Dayanand and Shivan (2002) conducted a field experiment to study the effects of sulfur 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. Giza 32 in Assiut, Egypt, in 2000 and 2001. Sulfur containing 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.

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} were more effective in improving leaf area index, crop growth rate, relative growth rate, net assimilation rate, yield attributes, and crop yield than applying at 25 kg S ha^{-1}.

Tiwari *et al.* (2000) conducted a field experiment with nitrogen (15, 30 or 60 kg ha^{-1}) and sulfur (0, 15 or 30 kg ha^{-1}) which were applied to sesame varieties to investigate optimum dose of nitrogen and sulfur. 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}. Sulfur at 30 kg ha^{-1} resulted significant increase only in the number of capsules $plant^{-1}$, seeds $capsule^{-1}$, 1000-seed weight and seed yield, compared with sulfur 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 sulfur application enhanced both seed oil and seed protein.

Radhamani *et al.* (2001) studied the effect of different level of sulfur on seed yield of sesame and found that 20 kg sulfur (gypsum) 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.

Ghosh *et al.* (2000) found that oilseed crops are responsive to sulfur. Approximately 12 kg S is required to produce one ton 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} depending on soil type. Applications of sulfur increase the number of capsule $plant^{-1}$, number of seeds $capsule^{-1}$ and oil content of seed markedly. Gypsum has been found an effective source of sulfur for the crops like groundnut, castor and sesame. Water logging and scarcity are 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.

Leustek *et al.*, (2000) observed that oilseeds not only respond to applied S but their requirement for sulfur is also the highest among crop plants. Further, low availability of S in soil limits N use efficiency. Even if sulfur is only 3% to 5% as abundant as nitrogen in plants, it plays essential roles in various important mechanisms such as S clusters in enzymes, vitamin cofactors, glutathione in redox homeostasis and detoxification of xenobiotics.

Subrahmaniyan *et al.* (1999) treated sesame cv. TMV-4 plants with 35 kg S, 10 kg $ZnSO_4$, 10 kg $MgSO_4$ and 10 kg Borax ha^{-1} singly or in combination with 5 ton FYM ha^{-1} in a field experiment conducted in Tamil Nadu, India during the summer seasons of 1996-1997. Sole application of sulfur, trace elements and farmyard manure (FYM) increased the number of branches and capsules $plant^{-1}$ and seed yield compared to the control in both seasons. The highest seed yield was recorded with the application 35 kg S ha^{-1} + 5 ton FYM ha^{-1} in 1996 (892 ton ha^{-1}) and 1997 (896 ton ha^{-1}).

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

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

Thorve *et al*. (1997) evaluate the yield and yield attributing characters of three sesame cultivars in a field experiment. Sesame crops required application of 40 and 60 kg S ha^{-1} in Vertisol and Alfisol soil. The seed yield of the crops was maximum when N: S ratio in plant was 10:4. Sesame showed a response at 60 kg S ha^{-1} applied as gypsum by improving the crude protein content and oil contents of seed. They maintained the same management level and found that cv. Tapi, Phule and Hawari (local) produced seed yields of 0.95, 0.91 and 0.52 ton ha^{-1}, respectively.

Chaplot (1996) stated that application of sulfur at 50 kg ha^{-1} with 40 or 60 kg P_20_5 gave the best growth and yield of sesame (*Sesamum indicum* L.). Phosphorus singly has no significant effect on oil content of sesame but sulfur has. The highest net return and benefit cost ratio was obtained with the application of sulfur in at 50 kg ha^{-1} 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 sulfate, 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 ton FYM ha^{-1}, the highest dry matter was obtained with 75% fertilizer + S + crop residues, and this treatment also gave most capsules $plant^{-1}$ and best 1000 seed weight. Highest seed yield of 1.40 ton ha^{-1} was obtained with 75% NPK + S + FYM, followed by 100%

NPK + S (1.36 ton ha^{-1}) and 75% NPK + S + crop residues (1.35 ton ha^{-1}), while the lowest yield was given by 75% NPK without S (0.9 ton ha^{-1}).

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

Najeeb (1987) compared the performance of oil seed (sesame, castor and sunflower) and pulses (black gram, cow pea and green gram) crops on alfisol with an available S content of 8.2 mg kg^{-1}. Application of 20 kg S ha^{-1} in pulse and sesame resulted in significantly higher yield over control.

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

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 ton 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 sulfur 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 sulfur fertilization. Oil content and seed protein content also found to be affected by them.

2.2 Effect of boron on growth and yield of sesame

Sarkar (2008) carried out to investigate the effect of nitrogen and boron on the growth and yield of sesame cv. T-6 at the field laboratory of Sher-e-Bangla Agricultural University, Dhaka. The results revealed that nitrogen and boron had significant effect on sesame. 60 kg N ha^{-1} along with 1.60 kg B ha^{-1} produced highest number of capsules, 1000 seed weight, seed yield ha^{-1} and harvest index.

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 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 treatment for increasing row 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 boron concentration gave the highest biomass and economic yield in case 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 pods or seeds was produced. Both deficiency and toxicity reduced seed quality by reducing the protein and starch contents and increasing the accumulation of carbohydrates and phenols.

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. 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 boronated super phosphate along with application of FYM, N and P.

Srivastava *et al.* (1996) observed 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 *Sesamum indicum* in Hoagland No. 2 nutrient solution supplemented with 0.05 mg B L^{-1} or throughout the growth or until 20, 30 or 40-day old when B was either reduced to 0.25 mg L^{-1} 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 pods.

Sakal *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 ton ha^{-1}) alone and in *combinations* on crops in maize-lentil cropping system. Increasing levels of B up to 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 ton 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 20 kg 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 2.5 kg 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.

Sakal *et al.* (1988) observed that seed yield of chickpea increased from 1.4 ton ha^{-1} with no B to 1.49 ton 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.

Sakal *et al.* (1988) also 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

Galrao (1989) reported that yield of soybean was 2.38 ton ha^{-1} for using B, whereas yield was 2.24 ton 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}).

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 decrease 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 was affected by B.

Vaughan (1977), and Cheng 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.

2.3 Effect of sulfur and boron on growth and yield of sesame

Huq (2012) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to investigate the effect of sulfur and boron on the growth and yield of sesame and observed that the combination of 20 kg S ha^{-1} and 3 kg B ha^{-1} produced maximum plant height, number of capsule $plant^{-1}$, number of seed $capsule^{-1}$, length of capsule, 1000-seed weight, seed yield, stover yield, biological yield and harvest index.

Mathew and George (2011) conducted two field experiments in two consecutive summer seasons of 2008 and 2009 in the fields of the Onattukara Regional Agricultural Research Station, Kayamkulam, Kerala to see the effect of sulfur and boron on the yield of sesame. They observed that inclusion of S and B at 30 and 2.5

kg ha^{-1}, respectively, within the State fertilizer recommendation has the potential to improve yield, harvest index, and economics of growing sesame in Kerala. Gypsum (18% S) and borax (11% B) were used as sources of S and B where the S treatments were 0, 7.5, 15 and 30 kg ha^{-1} and the B treatments were 0, 2.5, 5 and 7.5 kg ha^{-1}.

Haque (2008) carried out an experiment to investigate the effect of sulfur and boron on the growth and yield of sesame at the field laboratory of Sher-e-Bangla Agricultural University, Dhaka. The results revealed that sulfur and boron had significant effect on sesame. 27 kg S ha^{-1} along with 2 kg B ha^{-1} produced highest number of capsules, 1000 seed weight, seed yield ha^{-1} and harvest index.

Singh *et al.* (2006) conducted field experiments during the 2001-03 kharif seasons in Jharkhand, India, on soybean cv. Birsa. The seed and stover yields of soybean were significantly influenced by graded levels of S and B application. The crop yield increased more due to S compared to B application. The S x B treatment revealed that maximum seed yield was obtained with 60 kg S and 2.0 kg B ha^{-1}. The total S and B uptake by crop increased significantly with increased levels of up to 60 kg S + 2.0 kg B ha^{-1}. The total S uptake at 0 and 60 kg S ha^{-1} was 10.27 and 16.72 kg ha^{-1}, respectively, whereas total B uptake at 0 and 2.0kg B ha^{-1} was 98.58 and 198.72 kg ha^{-1}, respectively. The oil and protein contents in soybean seed increased with successive increase of S and B levels. Increasing levels of S significantly increased the protein content in soybean seed. The maximum protein content (37.79%) in seed was recorded at 40 kg S + 0.5 kg B ha^{-1}.

Hegde (2003) were studied in Tamil Nadu, India, during 2000 on the effects of S fertilizer on the performance of sesame. Sulfur 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 the best 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 ton 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 $plant^{-1}$ 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 ton FYM 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 was obtained with the application of 30 kg S ha^{-1} in combination with 2 kg B ha^{-1}.

From the above discussed literature, it is noticed that sulfur level exerted a profound influences on yield and yield contributing characters and oil content of sesame. Sulfur is a major macro element. The various physio-chemical properties of soil are also influenced by the application of S. Most of the authors showed that increasing sulfur level increased grain yield and oil content if the soil lacks the nutrient. It is also evident that plant height, number of branches $plant^{-1}$, number of capsules $plant^{-1}$ seed yield and stalk yield are influenced by different levels of boron application. Seed yield of sesame showed differential behaviors due to different levels of applied boron in different parts of the globe. More researches on this aspect are therefore necessary to arrive at a definite conclusion.

Chapter III

Materials and Methods

CHAPTER-III

MATERIALS AND METHODS

The experiment was conducted at Agronomy Farm in Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the effect of different levels of sulfur and boron application on the growth, yield, oil and sulfur content of sesame. This chapter deals with a detail description of different materials used and methodology followed during the experimental period including site, soil, design, land preparation, intercultural operations, chemical analysis, data collection, procedure of statistical analysis etc.

3.1 Description of experimental site

3.1.1 Location

The experiment was conducted at the Central Farm and Agricultural Chemistry Laboratory of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

3.1.2 Experimental duration

The field research work was carried out at the Sher-e-Bangla Agricultural University during the period from 12 April to 17 July, 2014. The chemical analysis was conducted in agricultural chemistry laboratory after harvest.

3.1.3 Agro-ecological region

The experimental area belongs to Modhupur Tract, Agro-Ecological Zone 28 (Anon., 1988). The land area was situated at 23°41' N latitude and 90°22' E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I (a).

3.1.4 Soil

The soil of the experimental field belongs to the general soil type, shallow red brown terrace soil under Tejgaon series. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. The soil was clay loam in texture and having soil pH varied from 5.55 to 5.90. Organic matter content was very low (1.09%). The physical composition such as sand, silt, clay content were 22.26%, 56.72% and 20.75%, respectively. The morphological properties with physical and chemical characteristics of soil at experimental site have been presented in Appendix I (b) and I (c), respectively.

3.1.5 Climate

The experimental area was under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (November-March). Plenty of sunshine, high temperature and moderate rainfall prevails during the experimental period, which is suitable for sesame cultivation in Bangladesh. The prevailing weather data during the study period at the experimental site have been presented in Appendix II.

3.2 Planting material

The variety of sesame used for the present study was BARI Til-4. The seeds of this variety were collected from the Bangladesh Agricultural Research Institute (BARI), Gazipur which was released in 2009 and developed by Oilseed Research Centre. 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 are as the plant height of BARI Til-4 is 90-120 cm. The seeds are deep brown bold and flower color is white. Stem is branched and contains 3–5 branches. Every plant contains 85-90 pods. About 70% pods contain 20-40% more seeds in its chamber than that of BARI Til-2 and BARI Til-3. The crop duration is 90-95 days. The yield is 1.40-1.50 ton ha^{-1} which is 8-10% more than the yield of BARI Til-2 and BARI Til-3. Seeds contain 42 - 50% oil and 25% protein (BARI Leaflet).

3.3 Experimental treatment

The treatments included in the experiment were two factorials.

Factor A: 4 doses of sulfur -

1. S_0: 0 kg S ha^{-1} (control)
2. S_1: 10 kg S ha^{-1}
3. S_2: 20 kg S ha^{-1}
4. S_3: 30 kg S ha^{-1}

Factor B: 4 doses of boron -

1. B_0: 0 kg B ha^{-1} (control)
2. B_1: 1.0 kg B ha^{-1}
3. B_2:1.5 kg B ha^{-1}
4. B_3: 2.0 kg B ha^{-1}

Combining two factors, (4×4) 16 treatments combination were obtained which designed in the experimental land.

3.4 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each block was divided into 16 plots. The total numbers of unit plots were 48. The plot size was 2.5 m x 1.4 m. The distances between plot to plot and block to block were 0.25 m and 0.5 m, respectively.

3.5 Land preparation

The experimental field was opened in the 1st week of April with a power tiller and later on, the land was ploughed and cross-ploughed three times by country plough followed by laddering to obtain the desirable tilth. The corners of the land were spaded. All kinds of weeds and stubbles were removed from the field and the land was made ready. Whole experimental land was divided into unit plots following the design of experiment. Finally basal doses of nitrogen, phosphorus and potassium fertilizers were applied in unit plots and the plots were made ready by thorough spading and leveling before sowing BARI Til-4 seeds. Gypsum and boric acid were applied as the sources of sulfur and boron doses as per treatments respectively and mixed with the soil of each unit plot.

3.6 Fertilizer application

Urea, triple super phosphate (TSP) and muriate of potash (MOP) were used as source of nitrogen, phosphorus and potassium, respectively according to the recommendation of Bangladesh Agriculture Research Institute (BARI). Half ($^1/_2$) amount of urea, whole amount of TSP and MOP were applied at the time of final land preparation. The remaining urea ($^1/_2$) was applied as top dressing on 25 days after sowing on 7 May, 2014. Sulfur and boron were applied as per treatment.

Gypsum and boric acid were used as the sources of Sulfur and Boron. The amount of fertilizers used is mentioned in the following Table (a):

Table a. Doses and method of fertilizers application in sesame field

Fertilizers	Doses ($Kg\ ha^{-1}$)	Application (%)	
		Basal	25 DAS
N (as Urea)	100	50	50
P_2O_5(as TSP)	30	100	--
K_2O (as MOP)	50	100	--
S (as $CaSO_4$)	As treatment	--	--
B (as Boric Acid)	As treatment	--	--

3.7 Germination test

Germination test was performed before sowing the seeds in the field. For laboratory test, petridishes were used. Filter papers were placed on petridishes and the papers were wetten with water. Seeds were set for germination at random in petridish. Data on emergence were collected and converted 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 of sesame (BARI Til-4) were sown on the 12 April 2014 in 2-3 cm deep furrows made by hand rake keeping 25 cm distance from row to row. After placement of seeds in furrow, seeds were covered with soil followed by a light pressure by hand. The seed rate was 8 kg ha^{-1}.

3.9 Emergence of seedlings

Seedling emergence started after 3 days and completed within 7 days of sowing. After establishment, on 29 April 2014 keeping the healthy seedlings within a distance of 5 cm, the remaining seedlings were carefully uprooted by hand pulling.

3.10 Intercultural operations

After emergence of seedlings, the following intercultural operations were done for ensuring better growth and development of sesame seedlings.

3.10.1 Weed control

The crop field was weeded twice; first weeding was done at 17 DAS (Days after sowing) and second weeding at 35 DAS. Demarcation boundaries and drainage channels were also kept weed free. The weeding was done manually with Nirani.

3.10.2 Thinning

Thinning was done once 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 17 DAS (Days after sowing) and second thinning at 35 DAS to maintain the distance of 5 cm between two seedlings in a row.

3.10.3 Irrigation

Three irrigations were done upon moisture status of soil retained as requirement of plants. Excess water was not given, because sesame plants are always very sensitive to moisture.

3.10.4 Plant protection measure

Some crops were attacked by the fungus, *Colletotrichum dematium* at vegetative stage. It was controlled by spraying Bavistin at the rate of 1g $litre^{-1}$. The spraying was done in the afternoon while the pollinating bees were away from the field. It was also controlled by draining excessive water after rain. No other prominent infestation of insect-pests and diseases were observed in the field.

3.11 Harvest and post harvest operation

The crop maturity varied with fertilizer treatments. When around 80% of the plant leaves turned straw-yellow in color then crops were harvested. Harvest of sesame was done on 17 July, 2014. Collection of sample was done as per requirement. Ten plant samples were collected randomly from different places of each plot leaving border plants outside the central 1 m^2 area. After collection of the sample, harvest and threshing were done. The harvested crops of one meter square area and samples were tied into bundled and tagged separately, carried to the threshing floor and recorded different parameters. The crops were sun dried by spreading on the threshing floor. After oven dry, the seeds were separated from the pods by beating with bamboo sticks, cleaned and later brought to the Agricultural Chemistry Laboratory for further experimentation.

3.12 Recording of data

The experimental data were recorded from 30 DAS and continued until harvest. Dry weights of different plant parts were taken after oven drying. The chemical analysis was done after oven drying. The data of the following crop characters were collected during the experimentation.

1. Plant height at 30, 40, 50, 60 DAS and at harvest.
2. Number of leaves plant^{-1} at 30, 40, 50, 60 DAS and at harvest.
3. Number of branches plant $^{-1}$ at 40, 50, 60 DAS and at harvest.
4. Fresh and dry weight of leaves plant^{-1}
5. Fresh and dry weight of stem plant^{-1}
6. Number of capsules plant $^{-1}$
7. Number of seeds capsules^{-1}
8. 1000-seed weight
9. Fresh weight of pods plant^{-1}
10. Seed dry weight
11. Stover dry weight
12. Seed-Stover Ratio (on dry weight basis)
13. Seed yield
14. Stover yield
15. Biological yield
16. Harvest index
17. Oil content
18. Sulfur concentration in seed

3.13 Procedure of data collection

3.13.1 Plant height

Plant height refers to the length of the plant from ground level (stem base) to the tip of the tallest stem. It was measured at an interval of 10 days starting from 30 DAS till 60

DAS and at harvest. The height of ten sample plants was measured in cm with the help of a meter scale and mean was calculated.

3.13.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at an interval of 10 days starting from 30 DAS till 60 DAS and at harvest. Leaves number plant^{-1} were recorded by counting all leaves from each of randomly selected ten plants. Mean value of data were calculated and recorded.

3.13.3 Number of branches plant^{-1}

The number of branches was counted and recorded at an interval of 10 days starting from 40 DAS till 60 DAS and at harvest. The branches were counted from the ten sampled plants from each plot and average was taken.

3.13.4 Fresh and dry weight of leaves plant^{-1}

After harvest, the fresh weight (g) of the leaves plant^{-1} from the pre-selected 10 plants was taken first. Then the samples of leaves were dried in an oven at 70°C for 72 hours and weight was taken in gram carefully. The collected data were finally averaged.

3.13.5 Fresh and dry weight of stem plant^{-1}

The stems of randomly selected ten plants were weighed just after harvest. Then the plant samples were oven dried at 70°C for 72 hours and measured carefully with the help of electric balance. Thus the fresh and dry weight (g) of stem were collected and finally averaged for calculating weight plant^{-1}.

3.13.6 Number of capsules plant^{-1}

The number of capsules plant^{-1} was counted from the total capsules of 10 sample plants from each unit plot after harvest and the mean number was recorded. The mean number was expressed on plant^{-1} basis.

3.13.7 Number of seeds capsule^{-1}

The number of seeds capsule^{-1} were counted from the ten capsules of each of ten randomly selected plants taking three capsules from bottom, another three from middle and the rest from the top of the plant and then the average number of seeds capsule^{-1} was determined.

3.13.8 1000 seed weight

Thousand cleaned dried seeds were counted at random from the seed stock of sample plants. Then the weight (g) of thousand seeds was recorded by using a digital electric balance and the mean weight was expressed in gram.

3.13.9 Fresh weight of pods plant^{-1}

The pods of ten plant samples were collected from each treatment after harvest and the pods were weighted in gram. The fresh weight (g) of pods plant^{-1} was determined by dividing the total value by ten and the data were recorded.

3.13.10 Seed dry weight

The randomly selected ten samples of seeds were collected from each treatment. After harvest, the seeds of the samples were dried in oven at 70°C for 72 hours. From which the dry weights of seeds were weighted and mean value of data were calculated in gram.

3.13.11 Stover dry weight

Randomly ten plants were collected from each plot after harvest. The seed and stover of the sample plants were separated from the pods by beating with bamboo sticks after oven dried at 70°C for 72 hours. Thus stover dry weight was calculated and expressed in gram on plant^{-1} basis.

3.13.12 Seed-stover ratio (on dry weight basis)

The dry weight of seed and the dry weight of stover collected from the randomly selected plants of each treatment were expressed in ratio. The mean results were recorded and converted into percentage.

3.12.13 Seed yield

The crop of each unit plot data was harvested, dried and then threshed separately. The entire quantity of seeds obtained from each unit plot was dried in the sun to bring them to normal storable state and the seed yield was recorded in terms of kg m^{-2}. Thereafter the yield was converted to ton ha^{-1}.

3.13.14 Stover yield

After separating the seeds from the crop of each plot, the stover was taken by threshing the plants and was sun-dried to constant weight. The stover yield was recorded in terms of kg m^{-2} from respective unit plot and it was converted into ton ha^{-1} on dry weight basis.

3.13.15 Biological yield

The summation of seed yield and stover yield per hectare was considered as biological yield (ton ha^{-1}). Biological yield was calculated on dry weight basis by using the following formula:

Biological yield (ton ha^{-1}) = Seed yield + Stover yield

3.13.16 Harvest index

The harvest index (%) denotes the ratio of economic yield to biological yield in percentage and was calculated with the following formula (Gardner *et al.*, 1985).

Harvest index (%) = Grain yield (t /ha)/Biological yield (t/ha) ×100

3.13.17 Oil content in seed

After harvest, Seed samples from each plot were dried at 70°C for constant weight and ground for determination of total oil contents (%). Oil content of seed was determined by adopting Soxhlet Ether Extraction method (Sadasivam and Manickam, 1996) and expressed in percentage (%). For this purpose 25 g clean seed sample was used from each plot. This was done in the laboratory of Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

3.13.18 Determination of sulfur content (%) in seed

Procedure: The collected plant sample from each plot was dried in an oven at 70°C for about 48 hours and then ground to pass through a 20 mesh in a grinding mill. The prepared samples (straw) were then put into paper bags and kept in a desiccator before analysis.

Exactly 1 g of each plant sample was placed in 250 mL conical flask. 10 mL of diacid mixture (concentrated nitric acid: 60% perchloric acid = 2:1) was added to each conical flask. The flask was then placed on an electrical hot plate and heated gradually to 180 °C. The temperature was raised to 220°C after 30 minutes. When white fumes of perchloric acid were observed, the flasks were removed from the hot plate and were allowed to cool. The volume of digest was then made up to 30-40 mL with distilled water. Then the digest was filtered through Whatman No. 42 filter paper and volumed to 100 mL with distilled water. Sulfur content of seed extract was determined by turbidometric method with the help of a spectrophotometer, set at 420 nm (Wolf, 1982 and Tandon, 1993).

3.14 Statistical analysis

The recorded data for different parameters were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance (ANOVA) was done following the computer package MSTAT-C program developed by Russel, 1986. The mean differences among the treatments were adjusted by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984) for interpretation results.

Chapter IV

Results and Discussion

CHAPTER-IV

RESULTS AND DISCUSSION

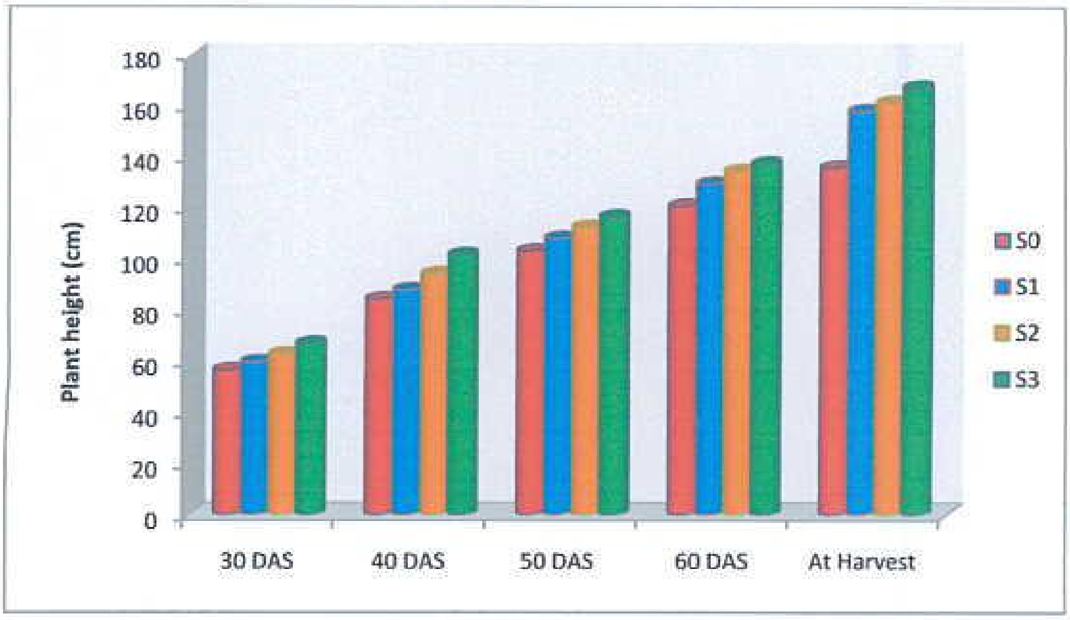
The experiment was conducted to study the effect of sulfur and boron on growth, yield, oil and sulfur content of BARI Til-4. The results of this study regarding the effect of sulfur and boron and their interactions have been presented with possible interpretations under the following headings:

4.1 Plant height

4.1.1 Effect of sulfur

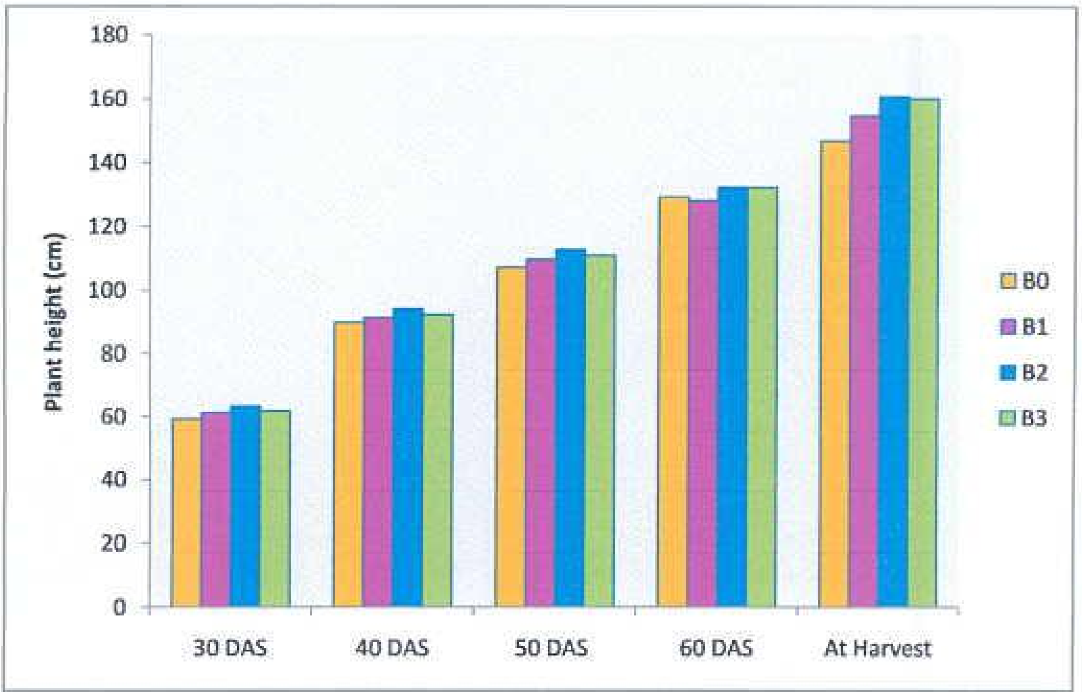
The plant height (cm) of BARI Til-4 was significantly influenced by different treatments of sulfur doses at 30, 40, 50, 60 DAS (days after sowing) and at harvest [Figure 1 and Appendix IX(a)]. In general, higher was the sulfur doses taller was the plant height. The results revealed that the S_3 treatment gave the highest plant height at 30, 40, 50, 60 DAS and at harvest which were 66.96 cm, 101.6 cm, 116.6 cm, 137.4 cm and 167.3cm on the other hand, the S_0 treatment showed the lowest plant height that were 56.63 cm, 84.30 cm, 103.2 cm, 120.7 cm and 135.9 cm at 30, 40, 50, 60 DAS and at harvest [Appendix IX(a)]. From Figure 1 it was observed that plant height increased with increasing the rate of S at every growth stage under this experiment.

This might be due to synthesis of more amino acids, increase in chlorophyll content in growing region and improving the photosynthetic activity, ultimately enhancing cell division and thereby increased the crop growth rate (Raja *et al.*, 2007).Similar result was found by Sharma and Gupta (2003) who stated that sulfur has a great influence on the growth of sesame and among four sulfur rates 40 kg S ha^{1} increased the plant height over control. Fazal and Sissodia (1989) found that soybean increase with increase sulfur level. Ravi *et al.* (2008) observed that the application of 30 kg S ha^{-1} give the highest plant height in safflower.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 1. The effect of sulfur on plant height (cm) of BARI Til-4 at different growth stages



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 2. The effect of boron on plant height of BARI Til-4 at different days after sowing

4.1.2 Effect of boron

Different doses of boron had significant effect on plant height at 30, 40, 50, 60 DAS and at harvest [Figure 2 and Appendix IX(b)]. At 30 DAS, the highest plant height (63.43 cm) was observed from the B_2 treatment which was statistically similar with that of B_3 (61.88 cm). At 40 and 50 DAS, the highest plant heights were 94.28 cm and 112.7 cm, respectively observed from the B_2 (1.5 kg B ha^{-1}). At 60 DAS and at harvest, the B_2 treatment showed the highest plant height (132.4 and 160.8 cm respectively), which were statistically similar at the application of 2 kg B ha^{-1}(B_3) at 60 DAS and at harvest, respectively. The shortest plant was recorded from control treatment at all stages.

Similar result was found by Hemantaranjan *et al.* (2000) that plant height of soybean was higher at optimum boron fertilization than higher doses. Lewis (1980) stated that B plays an important role in the physiological process such as cell elongation, cell division etc which ultimately helped to make the plant taller.

From figure 2, it was observed that plant height increased with the increase of boron doses up to 1.5 kg ha^{-1}.

4.1.3 Interaction effect of sulfur and boron

The interaction effect of sulfur and boron levels had significantly influenced the plant height (Table 1). The highest plant heights (71.33 cm, 104.7 cm, 121.9 cm and 172.9 cm) were obtained from the combination of S_3B_2 treatment at 30, 40, 50 DAS and at harvest, respectively except at 60 DAS. At 60 DAS the S_3B_2 (138.4 cm) and S_3B_3 (140.8 cm) showed statistically similar plant height. Irrespective of treatment combinations, plant height increased with the advancement of growth stages and the highest increase was found at harvest. At every stage, the lowest plant height was obtained from S_0B_0.

Chaplot (1996) observed similar result who stated that the optimum combination of S and B gave the best plant height of sesame. Huq (2012) conducted an experiment to evaluate the effect of sulfur and boron levels on sesame which results are not contradictory with this interaction finding.

Table 1: The interaction effect of different doses of sulfur and boron on plant height at different days after sowing

Treatment		Plant height (cm)				
		30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
S_0	B_0	52.90 h	82.30 i	99.70 i	118.0 i	107.3 i
	B_1	58.20 fg	83.90 hi	104.3 h	118.8 i	134.8 h
	B_2	57.07 g	84.73 ghi	104.9 gh	122.7 h	153.2 fg
	B_3	58.37 fg	86.27 fgh	103.8 h	123.3 h	148.2 g
S_1	B_0	59.30 efg	87.20 fg	105.1 gh	128.9 fg	155.7 def
	B_1	59.47 efg	87.93 f	107.7 fg	125.7 gh	160.8 cd
	B_2	60.07 efg	88.50 ef	110.2 def	131.4 ef	155.1 ef
	B_3	59.90 efg	88.00 f	109.5 ef	132.1 ef	160.9 cd
S_2	B_0	60.60 ef	91.27 de	111.1 cde	133.7 cde	160.6 cd
	B_1	62.13 de	92.80 d	112.9 cd	133.6 cde	159.0 cde
	B_2	65.27 bcd	99.20 c	113.6 c	136.9 bc	162.0 c
	B_3	62.50 cde	93.37 d	112.5 cde	132.9 de	163.9 bc
S_3	B_0	64.00 bcd	98.47 c	113.3 cd	136.5 bcd	164.2 bc
	B_1	65.73 bc	100.7 bc	114.0 c	134.0 cde	164.4 bc
	B_2	71.33 a	104.7 a	121.9 a	138.4 ab	172.9 a
	B_3	66.77 b	102.4 ab	117.2 b	140.8 a	167.8 b
$LSD_{(0.05)}$		3.145	2.92	3.035	3.456	5.025
CV (%)		8.30	4.61	4.53	4.63	10.4
Level of significance		**	*	*	*	*

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level
** - Significant at 1% level

Note: $S_0 = 0$ kg ha^{-1}, $S_1 = 10$ kg ha^{-1}, $S_2 = 20$ kg ha^{-1}, $S_3 = 30$ kg ha^{-1}
$B_0 = 0$ kg ha^{-1}, $B_1 = 1$ kg ha^{-1}, $B_2 = 1.5$ kg ha^{-1}, $B_3 = 2$ kg ha^{-1}

4.2 Number of leaves plant^{-1}

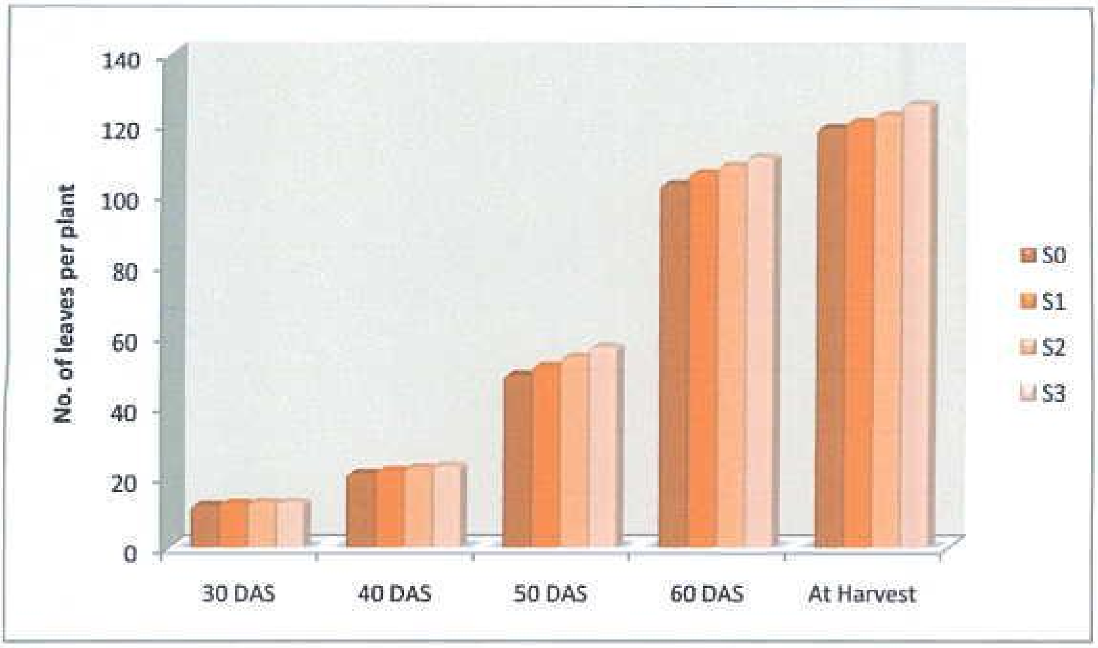
4.2.1 Effect of sulfur

The number of leaves plant^{-1} varied significantly due to the individual application of different levels of sulfur at 30, 40, 50, 60 DAS and at harvest [Figure 3 and Appendix IX(a)]. At 30 DAS, number of the leaves plant^{-1} did not vary significantly as the S_1 (12.42), S_2 (12.67) and S_3 (12.62) were statistically similar and S_0 (11.88) gave the lowest number of leaves. At 40 DAS, the S_3 treatment showed highest (23.03) number of leaves plant^{-1} which was statistically similar with those of the S_2 (22.52). At 50 DAS, the highest number of leaves plant^{-1} was counted from the S_3 (56.86). At 60 DAS, the S_3 treatment showed highest (110.7) number of leaves plant^{-1} which was statistically similar with that of the S_2 (108.3). At harvest the highest number of leaves plant^{-1} was 125.9 from the S_3 whereas the lowest (119.1) was from S_0 treatment at all stages. Similar results were observed from the experiment conducted by Heidari *et al.* (2011) and Fazal and Sissodia (1989).

4.2.2 Effect of boron

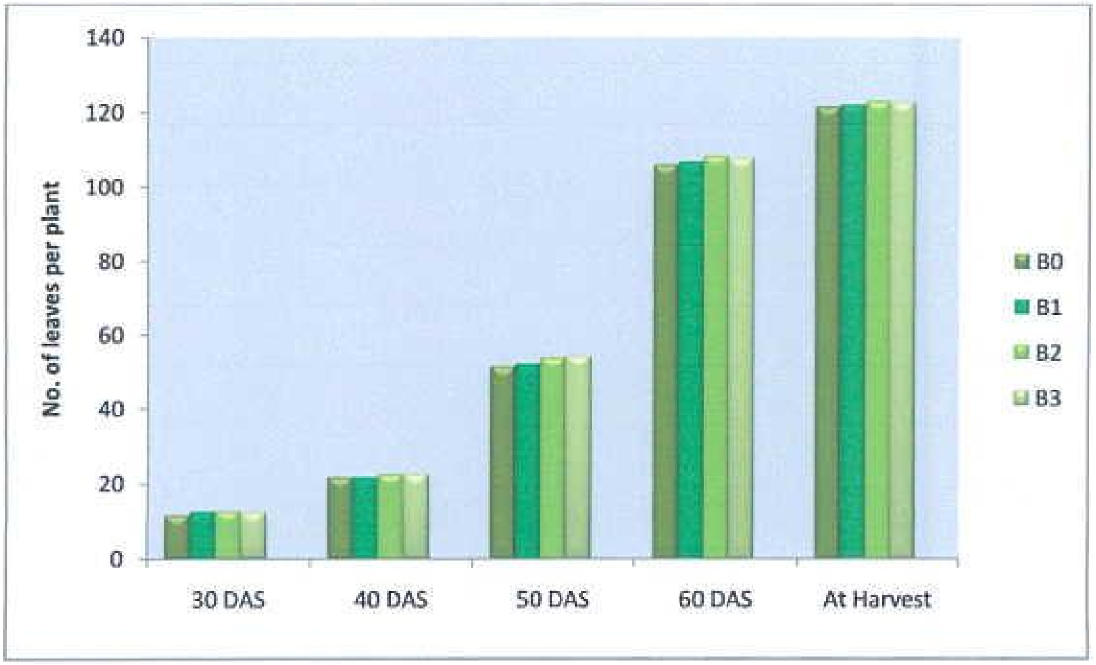
The effect of boron on the number of leaves plant^{-1} was not statistically significant at 60 DAS and at harvest [Figure 4 and Appendix IX(b)]. At 30 DAS, the B_1 (12.67), B_2 (12.80) and B_3 (12.33) showed statistically similar results except that of the B_0 which contained the lowest (11.78) number of leaves per plant. At 40 DAS, B_2 (22.60) produced the highest leaf number per plant which was statistically similar with that of the B_3 (22.25) over the control (21.78) treatment. At 50 DAS, B_3 (53.97) produced the highest number of leaves which was statistically similar with that of B_1 (52.22) and B_2 (53.77) whereas, the lowest (51.32) was observed from B_0 treatment. Numerically at 60 DAS and at harvest, the maximum number of leaves was observed from B_2 (108.2 and 122.9) where B_0 treatment gave the minimum number 105.8 and 121.2, respectively.

The ultimate results are in contradiction with Sarkar (2008) who carried out a field trial to study the effect of nitrogen and boron on sesame and stated that boron has no significant effect on the number of leaves per plant. But several studies have reported that soybean (Touchton and Boswell, 1975), cotton (Roberts *et al.*, 2000) and peanut



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 3. The effect of sulfur on number of leaves plant^{-1} of BARI Til-4 at different stages of growth



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 4. The effect of boron on number of leaves plant^{-1} of BARI Til-4 at different stages of growth

(Devis and Rhoades, 1994) yields may respond positively to pre-plant incorporated or post-emergence foliar applications of boron.

4.2.3 Interaction effect of sulfur and boron

Interaction of sulfur and boron fertilizer doses showed significant variation on number of leaves plant^{-1} of sesame BARI Til-4 at 30, 40, 50, 60 DAS and at harvest (Table 2). At 30 DAS, the highest number of leaves plant^{-1}(14.27) was observed from the S_2B_1treatment which was statistically similar to S_0B_2 (13.20), S_1 B_2 (13.47), S_2 B_3 (13.13) and S_3B_0 (13.00) whereas the lowest (11.13) was observed from S_0B_0 treatment which was statistically similar to S_0B_1 (11.20) and S_2B_0 (11.20). At 40 DAS, the highest number of leaves plant^{-1} (23.87) was observed from the S_3B_2 treatment which was statistically similar to S_2B_2 (22.73), S_2B_3 (22.67), S_3B_0 (22.67), S_3B_1 (22.73) and S_3B_3 (22.73) whereas, the lowest (20.60) was observed from S_0B_0 treatment which was statistically similar to S_0B_1 (21.00).

At 50 DAS, the highest number of leaves plant^{-1}(58.33) was observed from the S_3B_2 treatment which was statistically similar to S_2B_1 (54.23), S_2B_2 (54.80), S_2B_3 (54.93), S_3B_0 (55.27), S_3B_1 (56.10) and S_3B_3 (57.73) whereas, the lowest (47.60) was observed from S_0B_0 treatment which was statistically similar to S_0B_1 (48.20). At 60 DAS, the highest number of leaves plant^{-1}(111.9) was observed from the S_3B_2 treatment which was statistically similar to S_1B_2 (107.3), S_2B_0 (107.5), S_2B_1 (107.9), S_2B_2 (109.8), S_2B_3 (108.1), S_3B_0 (109.1), S_3B_1 (110.3) and S_3B_3 (111.6) whereas the lowest (101.1) was observed from S_0B_0 treatment which was statistically similar to S_0B_1 (103.1) and S_0B_2 (103.7).

At harvest, the S_3B_2 treatment showed highest number of leaves plant^{-1} (127.1) which was statistically similar with S_3B_3 (126.8) and the lowest (118.1) was observed from S_0B_0 treatment.

This result was in agreement with the experiment of Haque (2008). He stated that interaction of sulfur and boron fertilizer produced greater number of leaves which indicate better growth and development of sesame, results greater photosynthetic area and consequently give higher yield. Chaplot (1996) also agreed with this as optimum doses of sulfur and boron fertilizer increases the leaf area index.

Table 2: The interaction effect of different doses of sulfur and boron on number of leaves of BARI Til-4 at different days after sowing

Treatment		No. of leaves plant^{-1}				
		30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
S_0	B_0	11.13 d	20.60 f	47.60 f	101.1 e	118.1 e
	B_1	11.20 d	21.00 ef	48.20 ef	103.1 de	119.1 de
	B_2	13.20 abc	21.33 def	49.53 def	103.7 de	119.3 de
	B_3	12.00 bcd	21.40 cdef	50.33 cdef	104.5 cde	119.7 cde
S_1	B_0	11.80 cd	21.67 bcdef	50.13 cdef	105.3 bcde	120.5 cde
	B_1	12.53 bcd	21.27 def	50.33 cdef	105.7 bcde	120.6 cde
	B_2	13.47 ab	22.47 bcd	52.40 bcd	107.3 abcd	121.6 bcde
	B_3	11.87 cd	22.07 bcde	52.87 bcd	106.3 bcd	120.9 cde
S_2	B_0	11.20 d	22.20 bcde	52.27 bcde	107.5 abcd	121.5 cde
	B_1	14.27 a	22.47 bcd	54.23 abc	107.9 abcd	122.9 abcde
	B_2	12.07 bcd	22.73 ab	54.80 ab	109.8 ab	123.5 abcd
	B_3	13.13 abc	22.67 abc	54.93 ab	108.1 abcd	123.1 abcde
S_3	B_0	13.00 abc	22.67 abc	55.27 ab	109.1 abc	124.7 abc
	B_1	12.67 bcd	22.73 ab	56.10 ab	110.3 ab	125.0 abc
	B_2	12.47 bcd	23.87 a	58.33 a	111.9 a	127.1 a
	B_3	12.33 bcd	22.73 ab	57.73 a	111.6 a	126.8 ab
LSD $_{(0.05)}$		1.431	1.168	3.785	4.636	4.817
CV (%)		7.89	9.47	13.87	13.48	9.61
Level of significance		**	*	*	**	**

In a column, same letters (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level
** - Significant at 1% level

Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}
B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.3 Number of branches plant^{-1}

4.3.1 Effect of sulfur

Various doses of sulfur had significant effect on the number of branches plant^{-1} of sesame, BARI Til-4 [Figure 5 and Appendix X(a)]. At 40 and 50 DAS, the highest number of branches plant^{-1} (3.917 and 4.192 respectively) were observed from the S_3 treatment and the lowest (1.858 and 3.133 respectively) were observed from S_0 treatment. The highest number of branches plant^{-1} were obtained from S_3 that was 4.725 at 60 DAS and at harvest (5.275) which are statistically similar with S_2 (4.483 and 4.992, respectively) whereas the lowest number of branches plant^{-1} (3.667 at 60 DAS and 4.175 at harvest) was observed from S_0 treatment.

The increased number of branches might be attributed by the stimulatory effect of sulfur in cell division, cell elongation and setting of cell structure which has been reported by Hell (1997). Devi *et al.* (2010) conducted an experiment where application of sulfur @ 30 kg per ha resulted into the highest number of branches per plant. Raja *et al.*, (2007) reported that application of sulfur produced more branches per plant. Increased number of branches plant^{-1} was found due to increased sulfur application in soybean (Fazal and Sissodia, 1989) and in safflower (Ravi *et al.*, 2008).

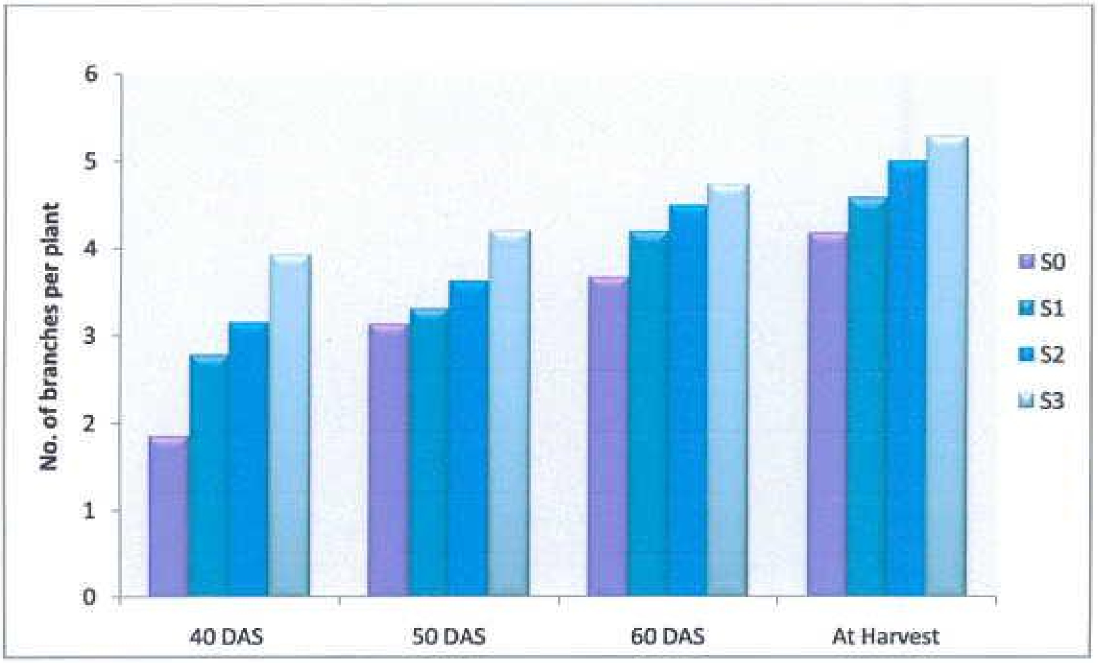
4.3.2 Effect of boron

The number of branches plant^{-1} of sesame, BARI Til-4 was significantly influenced by different treatments of boron doses [Figure 6 and Appendix X(b)]. The result revealed that at 40 DAS, the highest number of branches plant^{-1} (3.150) was observed from B_2 treatment which was statistically similar to B_3 (3.033) where the lowest (2.683) was observed from B_0 which was statistically similar to B_1 (2.842) treatment. At 50 DAS, the highest number of branches plant^{-1} (3.767) was observed from the B_2 treatment which was statistically similar to B_3 (3.650) and the lowest (3.367) was observed from B_0 treatment which was statistically similar to B_1 (3.467).

At 60 DAS, the highest number of branches plant^{-1} was obtained from B_2 (4.450) which was statistically similar to B_3 (4.425) where the lowest number of branches plant^{-1} (4.033) was observed from B_0 which was statistically similar to B_1 (4.158) treatment.

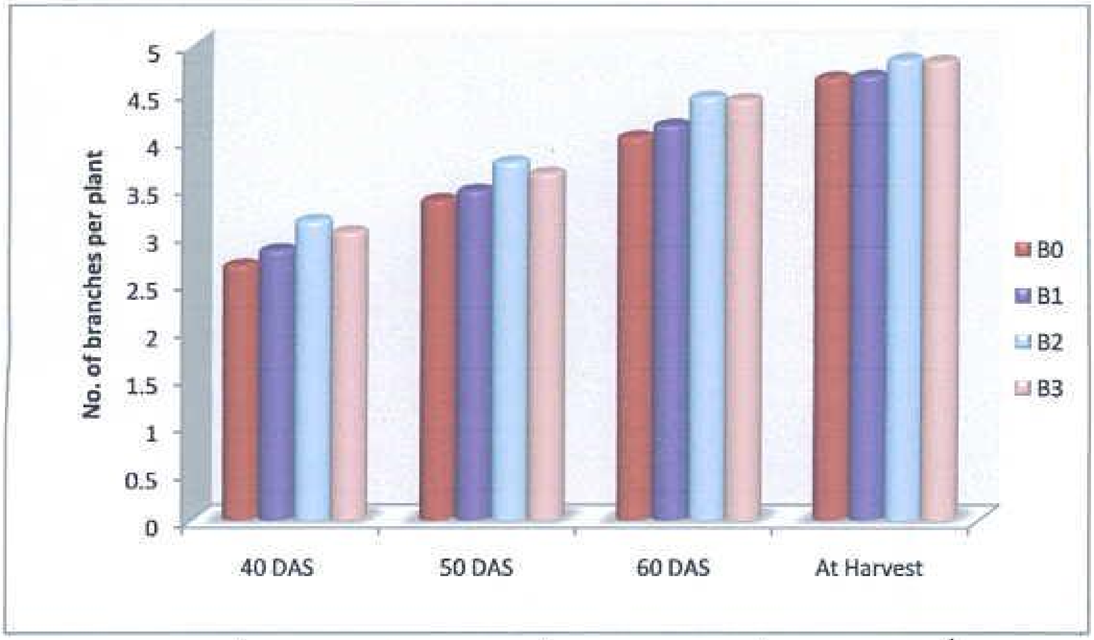
At harvest, the highest number of branches plant^{-1} was obtained from B_2 (4.850) which was statistically similar to B_3 (4.833) where the lowest number of branches plant^{-1} (4.658) was observed from B_0 which was statistically similar to B_1 (4.675) treatment.

In all cases, control B fertilization showed the lowest number of branches plant^{-1} and B_2 produced the highest number of branches plant^{-1}. Similar pattern in number of branches plant^{-1} was got from the study of Sarkar (2008). Much of the B fertilization research conducted has examined B fertilization for the purposed of increasing soybean yield potential by increasing branching (Schon and Blevins, 1990).



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 5. The effect of sulfur on number of branches plant^{-1} of BARI Til-4 at different stages of growth



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B2 = 1.5 kg ha^{-1}, B3 = 2 kg ha^{-1}

Figure 6. The effect of boron on number of branches plant^{-1} of BARI Til-4 at differentstages of growth

4.3.3 Interaction effect of sulfur and boron

The number of branches plant^{-1} of sesame showed significant variation by the interaction of sulfur and boron fertilizers doses at 40, 50, 60 DAS and at harvest (Table 3). At 40, 50 and 60 DAS, the highest number of branches plant^{-1} (4.467, 4.667 and 4.967 respectively) were found from the S_3B_2 treatment which was statistically similar to that of S_3B_3 (4.067, 4.267 and 4.867 respectively). The number of branches was lowest (1.667 and 2.90) which was observed from S_0B_0 treatment at 40 and 50 DAS, respectively.

At 60 DAS, the lowest number of branches (3.267) was observed from S_0B_1 treatment which was statistically similar to that of S_0B_0 (3.467). At harvest, the S_2B_3 treatment showed highest number of branches plant^{-1}(5.400) which was statistically identical with that of S_3B_1 (5.367) and it was lowest (4.000) in S_0B_0 treatment.

Subrahmaniyan *et al.* (1999), Hedge (2003) and Haque (2008) also reported that number of branches plant^{-1} of sesame significantly increased with the interaction of S and B fertilizer.

Table 3: The interaction effect of different doses of sulfur and boron on number of branches of sesame at different days after sowing

Treatment		No. of branches plant^{-1}			
		40 DAS	50 DAS	60 DAS	At Harvest
S_0	B_0	1.667 f	2.900 d	3.467 ef	4.000 e
	B_1	1.833 ef	3.167 cd	3.267 f	4.367 cde
	B_2	1.867 ef	3.200 cd	3.867 def	4.133 de
	B_3	2.067 def	3.267 cd	4.067 cde	4.200 de
S_1	B_0	2.667 cdef	3.267 cd	4.067 cde	4.533 abcde
	B_1	2.800 cde	3.300 cd	4.200 bcd	4.900 abcd
	B_2	2.867 cde	3.333 cd	4.267 bcd	4.400 bcde
	B_3	2.800 cde	3.333 cd	4.233 bcd	4.467 bcde
S_2	B_0	2.867 cde	3.400 bcd	4.267 bcd	4.833 abcd
	B_1	3.133 bcd	3.467 bcd	4.433 abcd	4.767 abcde
	B_2	3.400 abc	3.867 abc	4.700 abc	4.967 abcd
	B_3	3.200 bc	3.733 bcd	4.533 abcd	5.400 a
S_3	B_0	3.533 abc	3.900 abc	4.333 abcd	5.267 ab
	B_1	3.600 abc	3.933 abc	4.733 abc	5.367 a
	B_2	4.467 a	4.667 a	4.967 a	5.200 abc
	B_3	4.067 ab	4.267 ab	4.867 ab	5.267 ab
LSD $_{(0.05)}$		1.012	0.826	0.6126	0.7836
CV (%)		19.38	14.27	16.02	13.26
Level of significance		*	*	*	*

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level

Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}
B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.4 Fresh and dry weight of leaves plant^{-1}

4.4.1 Effect of sulfur

The result showed that the effect of sulfur application on the variation of leaves weight (g) plant^{-1} was highly significant at harvest and after oven dry [Figure 9 and Appendix XI(a)]. Just after harvest, the maximum leaves fresh weight plant^{-1} (27.14 g) was observed from the S_3 treatment whereas, the minimum fresh weight plant^{-1} (18.24 g) was observed from S_0 treatment.

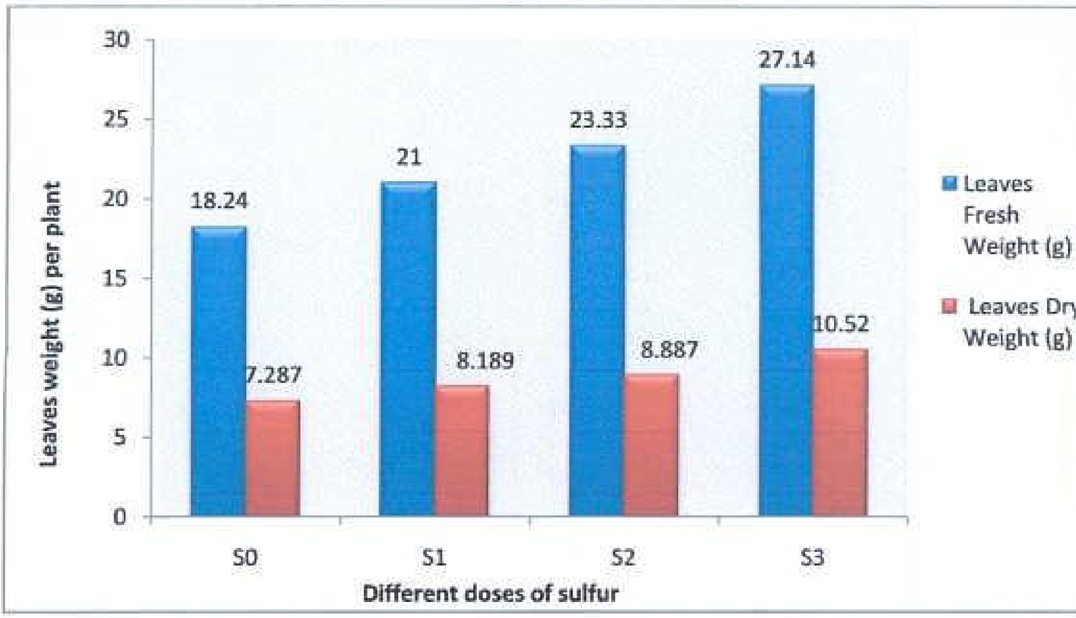
After oven dry, the maximum leaves dry weight (g) plant^{-1} (10.52 g) was measured from the S_3 treatment whereas, the minimum dry weight plant^{-1} (7.287 g) was measured from S_0 treatment which was statistically similar to S_1 (8.189 g).

The results are in contradiction of Kabir (2011) who stated that the application of highest level of sulfur (60 kg S ha^{-1}) produced the lowest amount of leaf dry matter, although he showed 40 kg S ha^{-1} produce highest leaf dry matter. This was in agreement with the findings of Sarkar and Banik (2002) that leaves dry weight at 25 kg S ha^{-1} showed higher values of leaves dry weight plant^{-1} which helped the growth and productivity of sesame.

4.4.2 Effect of boron

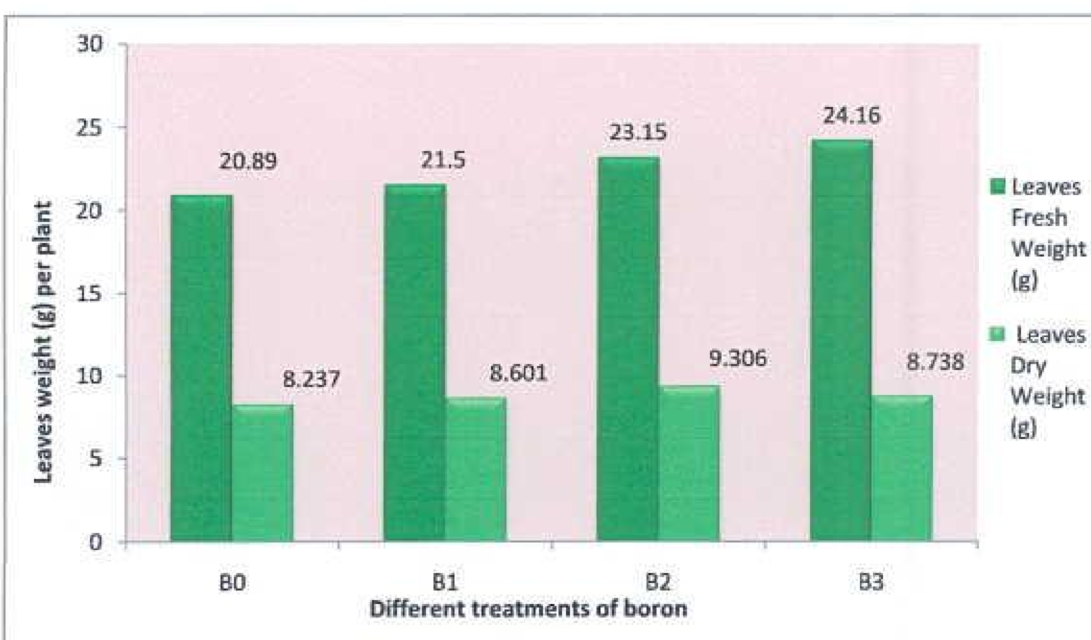
The leaves fresh and dry weight (g) plant^{-1} varied significantly due to application of different doses of B [Figure 8 and Appendix XI (b)]. The figure showed that leaves fresh weight plant^{-1} increased progressively with the increase in levels of B upto harvest. The maximum leaves fresh weight plant^{-1} (24.16 g) was observed from the B_3 treatment which was statistically similar to that of B_2 (23.15 g) whereas the minimum leaves fresh weight plant^{-1} (20.89 g) was observed from the B_0 which was statistically similar to B_1 (21.50 g).

After oven dry, the maximum dry weight plant^{-1}(9.306 g) of leaves was measured from the B_2 treatment and it was minimum (8.237 g) in B_0 treatment.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 7. The effect of sulfur on leaf fresh and dry weight plant^{-1}of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 8. The effect of boron on leaf fresh and dry weight plant^{-1} of BARI Til-4 after harvest

Boron is essential for growth of new cells and adequate supply of boron increased leaf dry weight significantly (Miller and Donahue, 1997). The result of the present study was similar with that of 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.

4.4.3 Interaction effect of sulfur and boron

Interaction effect of sulfur and boron fertilizer doses showed significant variation on leaves fresh and dry weight (g) plant^{-1} of BARI Til-4 after harvest and oven dry (Table 4). At harvest, the highest weight of fresh leaves plant^{-1} (28.66 g) was observed from the S_3B_2 treatment which was statistically similar to that of S_3B_3 (28.49 g) whereas, the lowest weight of fresh leaves plant^{-1} (15.47 g) was observed from S_0B_0 treatment.

After oven dry, the maximum leaves dry weight plant^{-1}(12.20 g) was measured from the S_3B_2 treatment whereas the minimum leaves dry weight plant^{-1}(7.043 g) was measured from S_0B_0 treatment which was statistically similar to that of S_0B_1 (7.067 g).

Similar result was found by Chaplot (1996) who observed significant effect on growth and yield of sesame and combination of 30 kg S ha^{-1} with 2 kg B ha^{-1} which gave the best leaf fresh and dry matter production.

Table 4: The interaction effect of different doses of sulfur and boron on leaf weight plant^{-1} of sesame at harvest

Treatment		Leaves fresh weight (g) plant^{-1}	Leaves dry weight (g) plant^{-1}
S_0	B_0	15.47 i	7.043 e
	B_1	17.27 hi	7.067 e
	B_2	18.45 gh	7.467 de
	B_3	21.77 ef	7.573 de
S_1	B_0	20.43 fg	7.953 de
	B_1	20.45 fg	7.923 de
	B_2	20.99 fg	8.740 bcde
	B_3	22.12 def	8.140 cde
S_2	B_0	22.57 cdef	8.477 bcde
	B_1	22.00 def	9.337 bcd
	B_2	24.51 bcd	8.820 bcde
	B_3	24.26 bcde	8.917 bcde
S_3	B_0	25.11 bc	9.473 bcd
	B_1	26.30 ab	10.08 bc
	B_2	28.66 a	12.20 a
	B_3	28.49 a	10.32 b
LSD $_{(0.05)}$		2.408	1.819
CV (%)		13.5	19.29
Level of significance		*	*

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level

Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2= 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.5 Fresh and dry weight of stem plant^{-1}

4.5.1 Effect of sulfur

The stem weight (g) plant^{-1} of BARI Til-4 varied significantly at harvest and after oven dry [Figure 9 and Appendix XI(a)] due to the effect of sulfur. At harvest, the S_3 treatment showed its superiority by producing the maximum stem fresh weight plant^{-1} (94.82 g) whereas the minimum fresh weight plant^{-1} (63.97 g) was observed from S_0 treatment.

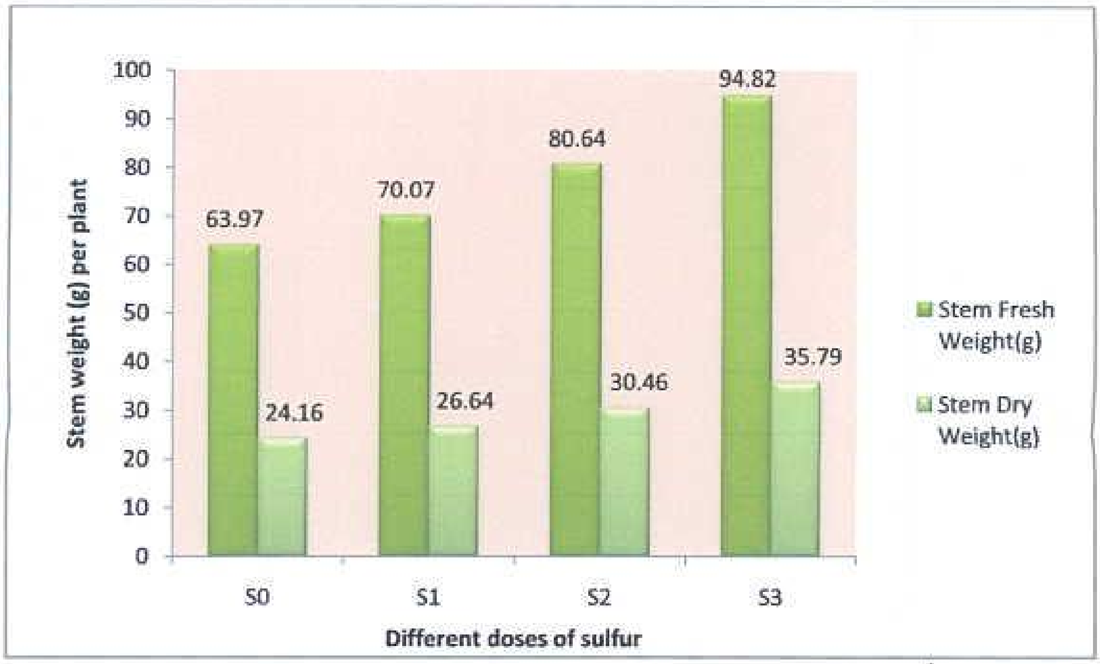
After oven dry, the maximum stem dry weight plant^{-1} (35.79 g) was measured from the S_3 treatment whereas the minimum dry weight of stem plant^{-1}(24.16 g) was measured from S_0 treatment.

Kabir (2011) stated that application of highest level sulfur (60 kg S ha^{-1}) produced the lowest amount of stem dry matter, although highest stem dry matter produced due to application of 40 kg S ha^{-1} which is not in agreement with the present study. Sarkar and Shaha (2005) and Maragatham *et al.* (2006) observed similar result with the present findings of stem dry weight of sesame.

4.6.2 Effect of boron

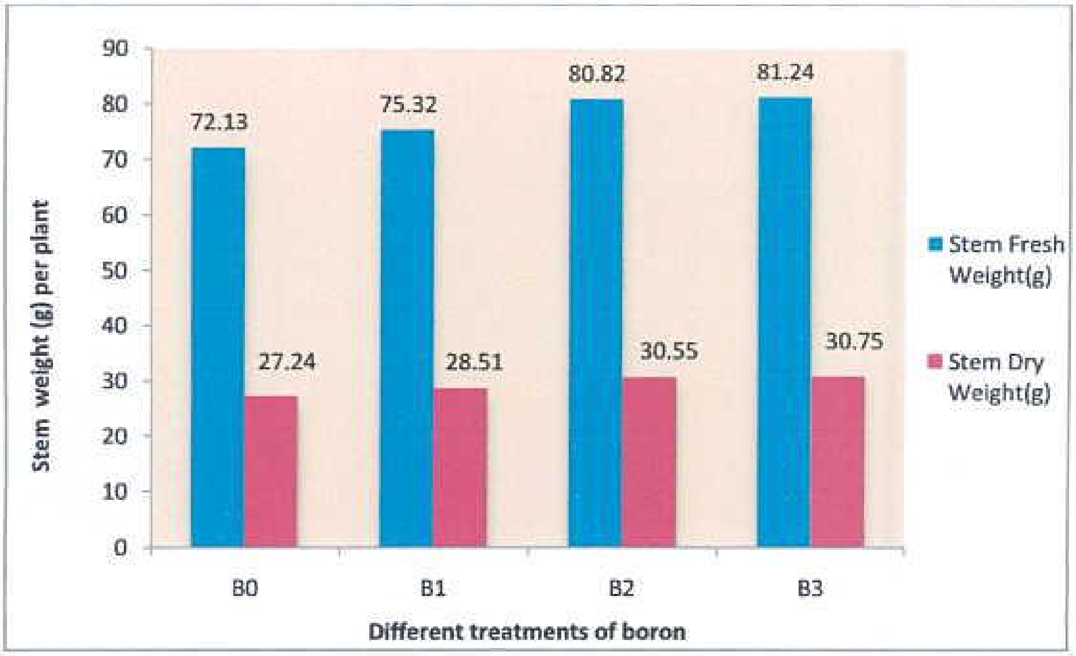
The effect of boron application on stem dry weight (g) plant^{-1} exerted significant result at harvest and after oven dry [Figure 10 and Appendix XI(b)]. After harvest, the B_3 treatment showed the highest stem weight plant^{-1} (81.24 g) which was statistically similar to B_2 (80.82 g) treatment whereas, the lowest stem fresh weight plant^{-1} (72.13 g) was observed from B_0 treatment.

After oven dry, the maximum stem dry weight plant^{-1}(30.75 g) was measured from the S_3 treatment which was statistically similar to S_2 (30.55 g) treatment whereas the minimum dry weight of stem plant^{-1}(27.24 g) was measured from B_0 treatment.
This finding was supported by Ramirez and Linares (1995) and Sakal (1991).



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 9. The effect of sulfur on stem fresh and dry weight $plant^{-1}$ of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 10. The effect of boron on stem fresh and dry weight $plant^{-1}$ of BARI Til-4 after harvest

4.5.3 Interaction effect of sulfur and boron

Interaction of sulfur and boron fertilizer doses showed significant variation on stem fresh and dry weight (g) plant^{-1} of BARI Til-4 after harvest and oven dry (Table 5). At harvest, the highest fresh weight of stem plant^{-1} (104.8 g) was observed from the S_3B_3 treatment which was statistically similar to that of S_3B_2 (102.3 g) whereas, the lowest fresh weight of stem plant^{-1} (62.87 g) was observed from S_0B_0 treatment which was statistically similar to those of S_0B_1 (63.60 g), S_0B_2 (64.27 g), S_0B_3 (65.13 g) and S_1B_0 (65.50 g).

After oven dry, the maximum stem dry weight plant^{-1} (39.53 g) was measured from the S_3B_3 treatment which was statistically similar to that of S_3B_2 (38.67 g) where the minimum stem dry weight plant^{-1} (23.37 g) was measured in S_0B_0 treatment which was statistically similar to those of S_0B_1 (24.29 g) and S_0B_2 (24.08 g) treatment.

Similar result was found by Chaplot (1996) and Haque (2008) who observed significant effect on growth and yield of sesame and combination due to 30 kg S ha^{-1} and 2 kg B ha^{-1}.

4.6 Number of capsules plant^{-1}

4.6.1 Effect of sulfur

The number of capsules plant^{-1} varied significantly due to different levels of sulfur application [Figure 11 and Appendix X (a)]. The result revealed that the maximum number of capsules plant^{-1} (64.88) was counted from the S_3 treatment and that was minimum (58.66) in the S_0 treatment.

This result is in full agreement with the finding of Kabir (2011), Mazadul (2005), Sharma and Gupta (2003) and Ghosh *et al.* (2000) who reported that increasing sulfur rate increased the number of capsules plant^{-1}. Ravi *et al.* (2008) found that 30 kg S ha^{-1} significantly increase the number of capsule plant^{-1} while Raja *et al.*,(2007) reported that application of 45 kg S ha^{-1} produce higher number of capsules and beyond this level, there was a decline due to the nutritional imbalance.

Table 5: The interaction effect of different doses of sulfur and boron on stem weight plant^{-1} of sesame at harvest

Treatment		Stem fresh weight (g) plant^{-1}	Stem dry weight (g) plant^{-1}
S_0	B_0	62.87 h	23.37 g
	B_1	63.60 h	24.29 g
	B_2	64.27 h	24.08 g
	B_3	65.13 h	24.91 fg
S_1	B_0	65.50 h	24.99 fg
	B_1	68.40 g	26.20 ef
	B_2	73.47 ef	27.47 de
	B_3	72.93 f	27.91 d
S_2	B_0	75.67 e	28.59 d
	B_1	81.50 d	30.60 c
	B_2	83.27 cd	31.99 bc
	B_3	82.13 cd	30.67 c
S_3	B_0	84.47 c	32.01 bc
	B_1	87.80 b	32.96 b
	B_2	102.3 a	38.67 a
	B_3	104.8 a	39.53 a
$LSD_{(0.05)}$		2.566	1.534
CV (%)		4.32	4.09
Level of significance		**	**

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

** - Significant at 1% level

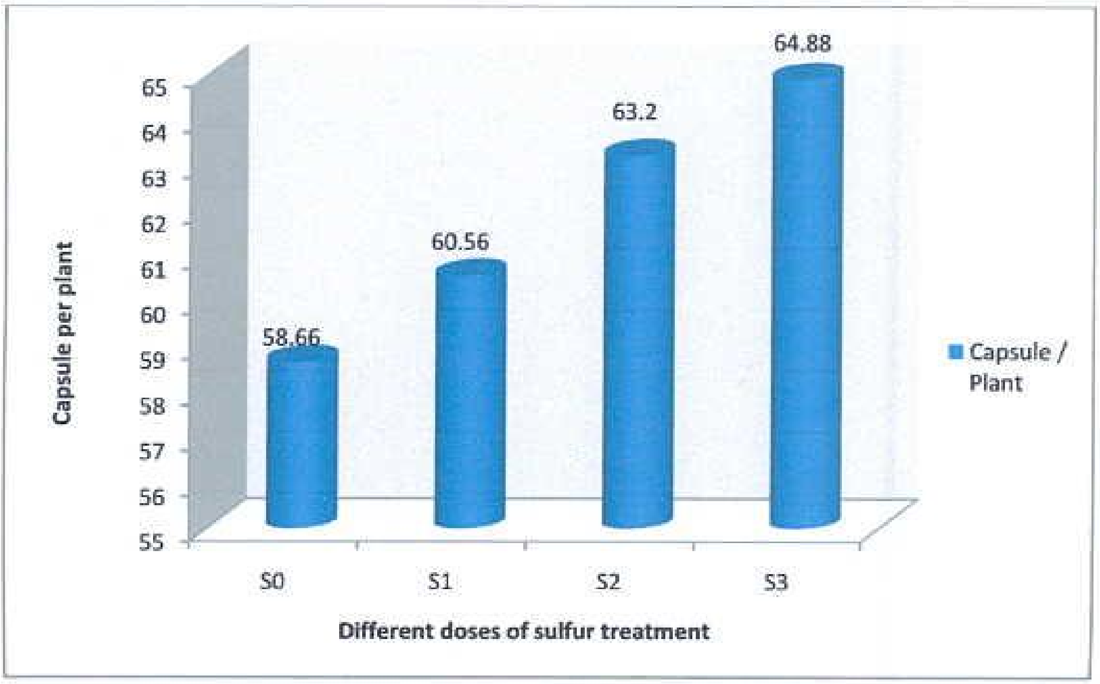
Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.6.2 Effect of boron

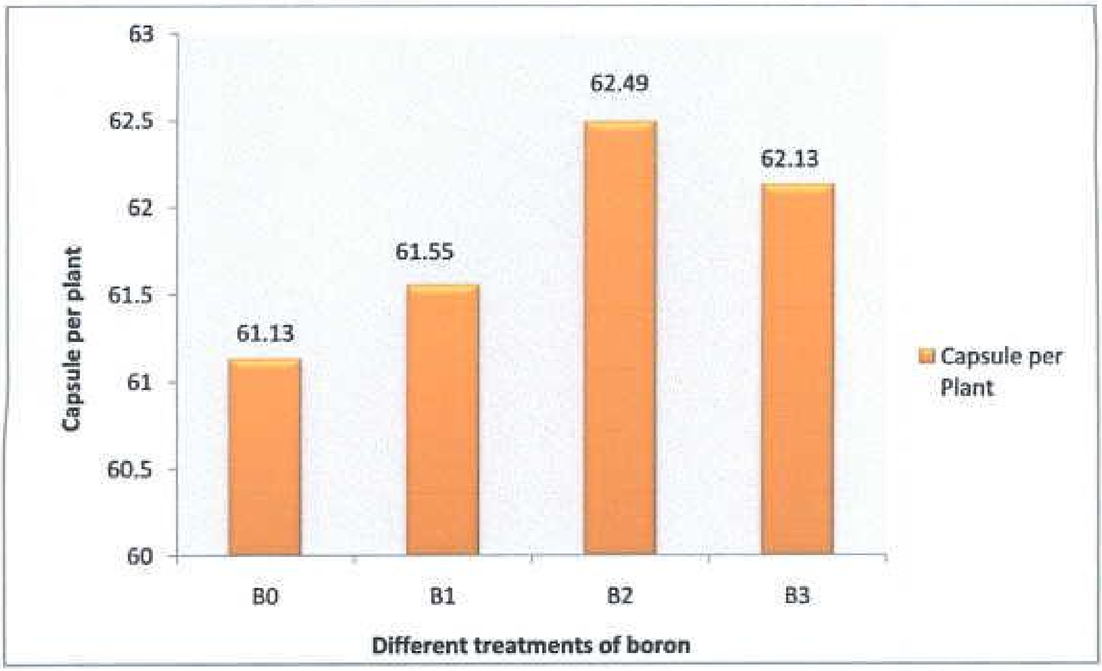
The number of capsules $plant^{-1}$ varied significantly due to different levels of boron application [Figure 12 and Appendix X(b)]. This result showed that the maximum number of capsules $plant^{-1}$ (62.49) was counted from the B_2 treatment which was statistically similar to that of B_3 (62.13) and the minimum number of capsules $plant^{-1}$ (61.13) was obtained from the B_0 treatment.

Huq (2012), Sarkar (2008) and Tripathy *et al.* (1999) also reported similar views that the number of capsules $plant^{-1}$ differed due to variation of boron application.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 11. The effect of sulfur on number of capsules $plant^{-1}$ of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 12. The effect of boron on number of capsules plant^{-1} of BARI Til-4 after harvest

4.6.3 Interaction effect of sulfur and boron

Significant influence was observed on the number of capsules per plant of BARI Til-4 due to the different interaction effects of sulfur and boron fertilizer doses (Table 6). The highest number of capsules per plant (65.93) was obtained from the S_3B_2 treatment which was statistically similar to that of S_3B_1 (64.73) andS_3B_3 (64.90) whereas, the lowest number of capsules plant^{-1} (58.03) was observed from the S_0B_0 treatment.

Haque (2008) and Huq (2012) conducted experiments separately where the results showed that interaction of sulfur and boron level significantly increased the number of capsules plant^{-1} of sesame.

Table 6: The interaction effect of different doses of sulfur and boron on different yield contributing characters of sesame at harvest

Treatment		Capsule per plant	Seeds per capsule	1000 seed weight(g)
S_0	B_0	58.03 f	55.04 i	2.940 f
	B_1	58.67 ef	58.03 h	3.047 ef
	B_2	58.80 ef	60.21 g	3.090 def
	B_3	59.13 ef	60.30 g	3.133 cdef
S_1	B_0	59.87 def	60.98 fg	3.173 cdef
	B_1	60.02 def	61.15 efg	3.200 cdef
	B_2	61.37 cde	61.48 efg	3.270 bcdef
	B_3	61.00 cdef	61.37 efg	3.217 cdef
S_2	B_0	62.67 bcd	62.15 defg	3.293 bcdef
	B_1	62.80 bcd	62.35 def	3.347 bcde
	B_2	63.87 abc	63.55 cd	3.387 abcde
	B_3	63.47 abc	63.48 cd	3.367 bcde
S_3	B_0	63.93 abc	63.09 cde	3.410 abcd
	B_1	64.73 ab	64.49 c	3.457 abc
	B_2	65.93 a	69.71 a	3.730 a
	B_3	64.90 ab	66.78 b	3.610 ab
$LSD_{(0.05)}$		2.74	1.81	0.3199
CV (%)		11.76	12.18	6.64
Level of significance		**	*	*

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level
** - Significant at 1% level

Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.7 Number of seeds capsule^{-1}

4.7.1 Effect of sulfur

The number of seeds per capsule was found to increase in response to sulfur levels [Figure 13 and Appendix X (a)]. The maximum number of seeds capsule^{-1} (66.02) was produced in BARI Til-4 with the S_3 treatment i.e. 30 kg S ha^{-1} and the lowest one (58.40) was produced by control treatment.

The results reveal that sulfur nutrient might have given metabolic energy to the plant, which enhanced the seeds per capsule with increasing sulfur fertilization. Raja *et al.* (2007), Sharma and Gupta (2003) and Tiwari *et al.* (2000) stated that increasing sulfur rate resulted in a significant increase in the seeds per capsule of sesame.

4.8.2 Effect of boron

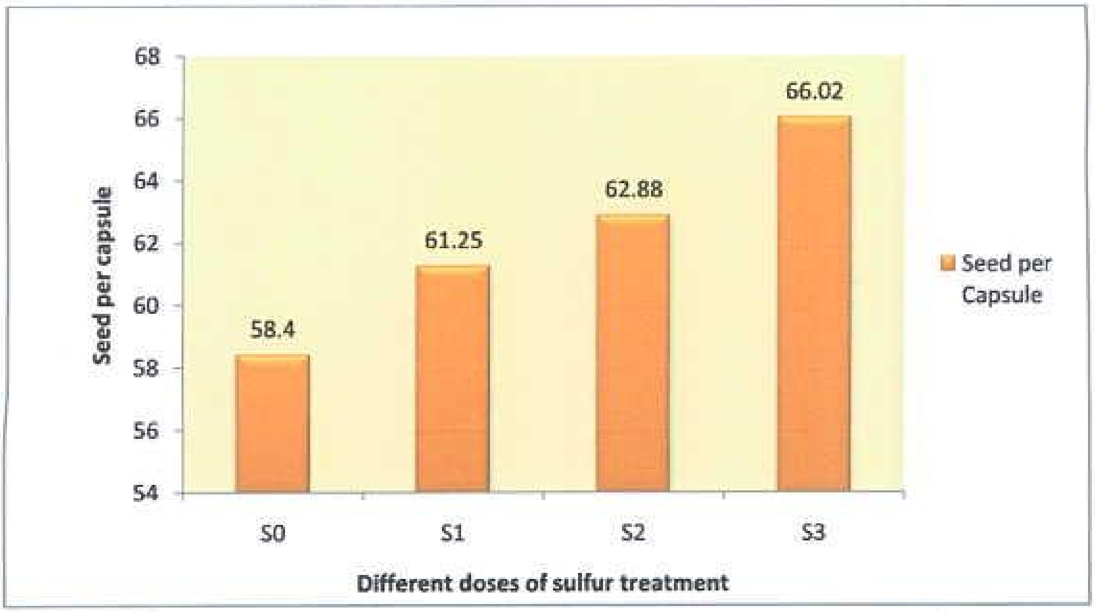
The number of seeds per capsule was significantly influenced by the different level of boron application [Figure 14 and Appendix X(b)].The highest number of seeds per capsule (63.74) was produced by the B_2 treatment which was statistically similar to that of B_3 (62.99). However the lowest number of seeds per capsule (60.32) was produced by the B_0 treatment.

The lowest seeds per pod in control plot might be due to boron deficiency as it has been reported to help in seed formation (Brady, 1996). Sarkar (2008) and Miller and Donahue (1997) also observed that without adequate supply of boron less fruits were developed.

4.7.3 Interaction effect of sulfur and boron

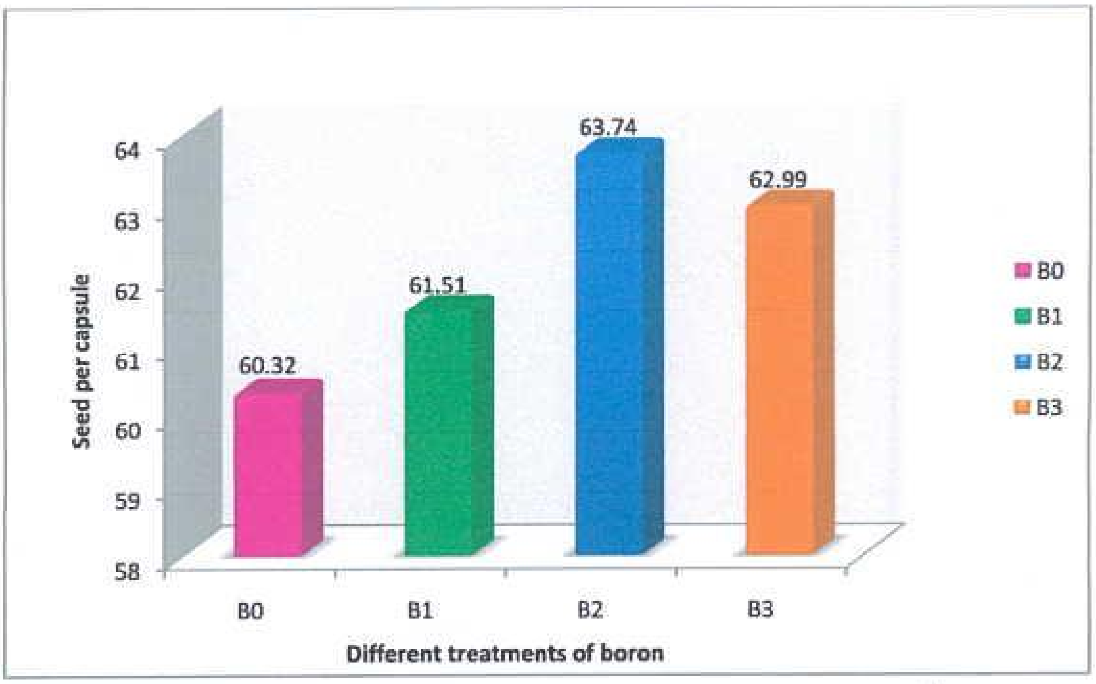
The number of seeds per capsule at harvest was significantly influenced by interaction effect of different levels of sulfur and boron (Table 6). It was observed that the combination S_3B_2 produced highest number of seeds per capsule (69.71). The lowest number of seeds capsule^{-1} (55.04) was produced by the combination S_0B_0.

Huq (2012) and Haque (2008) reported that the number of seeds per capsule increased when S and B levels were increased. Chaplot (1996) also observed similar findings.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 13. The effect of sulfur on number of seeds capsule^{-1} of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 14. The effect of boron on number of seeds capsule^{-1} of BARI Til-4 after harvest

4.8 1000 seed weight

4.8.1 Effect of sulfur

Different levels of sulfur application have significant effect on 1000 seed weight (g) of BARI Til-4 [Figure 15 and Appendix X (a)]. The highest weight of 1000 seed (3.552 g) was found in S_3 and the lowest 1000 seed weight (3.053g) was found in S_0 treatment.

Such findings were in agreement with Huq (2012), Kabir (2011) and Tiwari *et al.* (2000) who reported that increasing rate of sulfur also increased 1000 seed weight of sesame. Ravi *et al.* (2008) found that application of 30 kg S ha^{-1} significantly increased 1000 seed weight in safflower and decreased gradually with decrease in the sulfur application. But Haque (2008) conducted an experiment where he found that there was no significant effect of S on 1000 seed weight.

4.8.2 Effect of boron

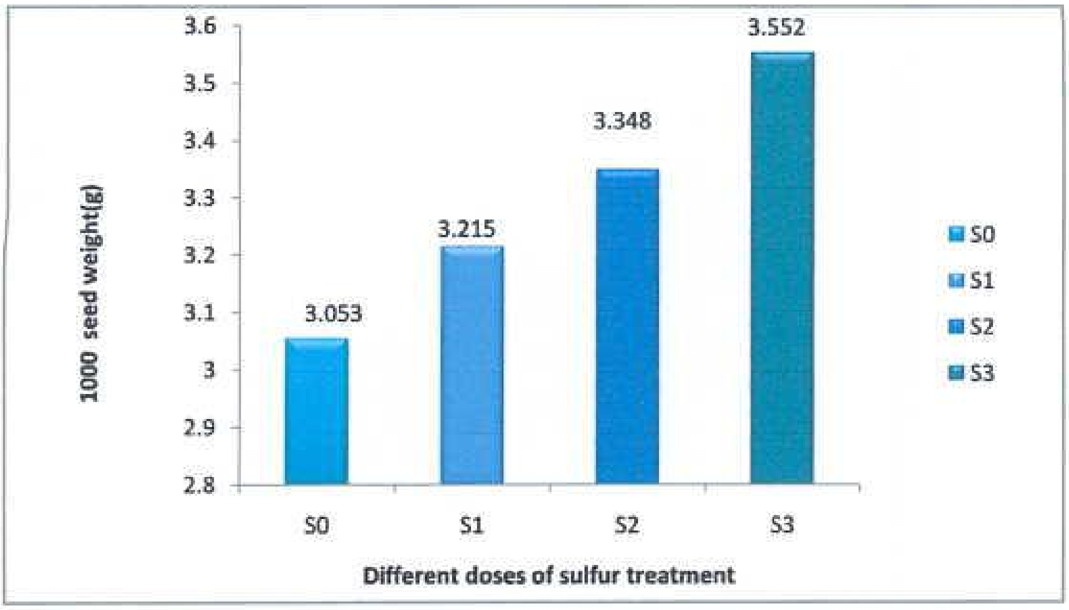
The 1000 seed weight of BARI Til-4 was statistically insignificant and hence was not influenced by different level of boron [Figure 16 and Appendix X(b)]. Numerically the highest 1000 seed weight (3.369 g) was observed in the B_2 treatment and it was lowest (3.204 g) in B_0 treatment.

Result of the present findings was not in agreement with the results reported by Sarkar (2008) and Sindoni *et al.* (1994) in respect of 1000 seed weight of sesame. Sarkar (2008) also reported that the application of 1.6 kg B ha^{-1} gave significantly the highest 1000 seed weight.

4.8.3 Interaction effect of sulfur and boron

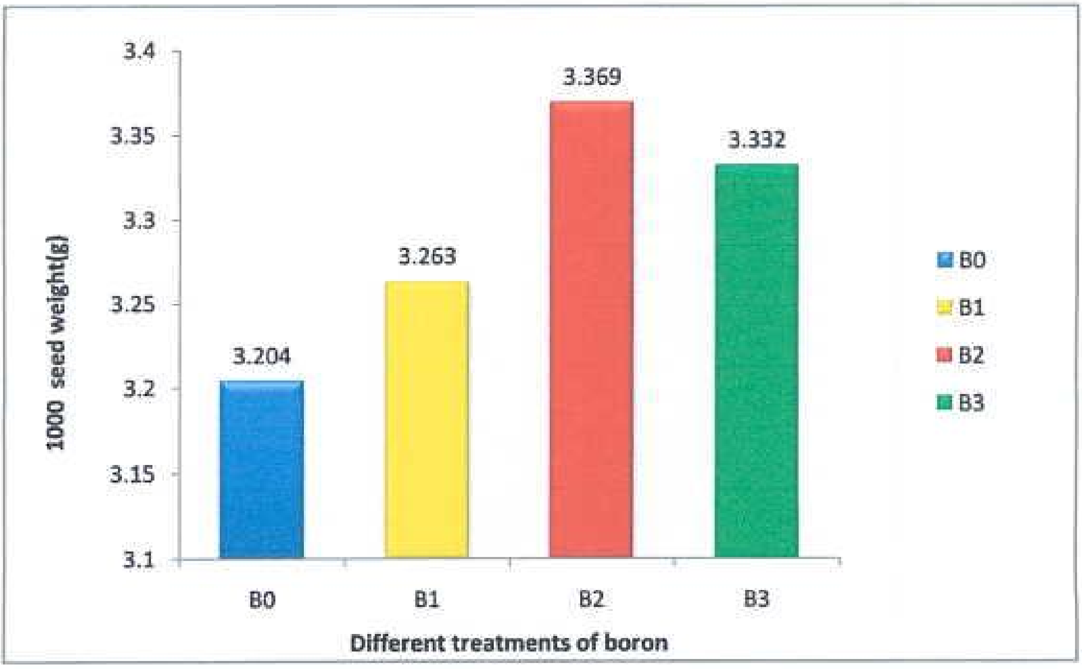
1000 seed weight of BARI Til-4 was significantly influenced by the interaction effect sulfur and boron fertilizers application (Table 6). The highest 1000 seed weight (3.730 g) was recorded from S_2B_3 treatment which was statistically similar with that of S_3B_3 (3.610 g). On the other hand, S_0B_0 showed the lowest (2.940 g) result.

Huq (2012) conducted an experiment to find out the influence of sulfur and boron fertilizers application on growth and yield of sesame and result showed that sulfur and boron fertilizers application had significant effect on 1000 grain weight. Haque (2008) and Chaplot (1996) also conclusively reported this finding and stated that sulfur and boron interaction increase 1000-seed weight of sesame significantly.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 15. The effect of sulfur on 1000 seed weight of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 16. The effect of boron on 1000 seed weight of BARI Til-4 after harvest

4.9 Fresh weight of pod plant^{-1}

4.9.1 Effect of sulfur

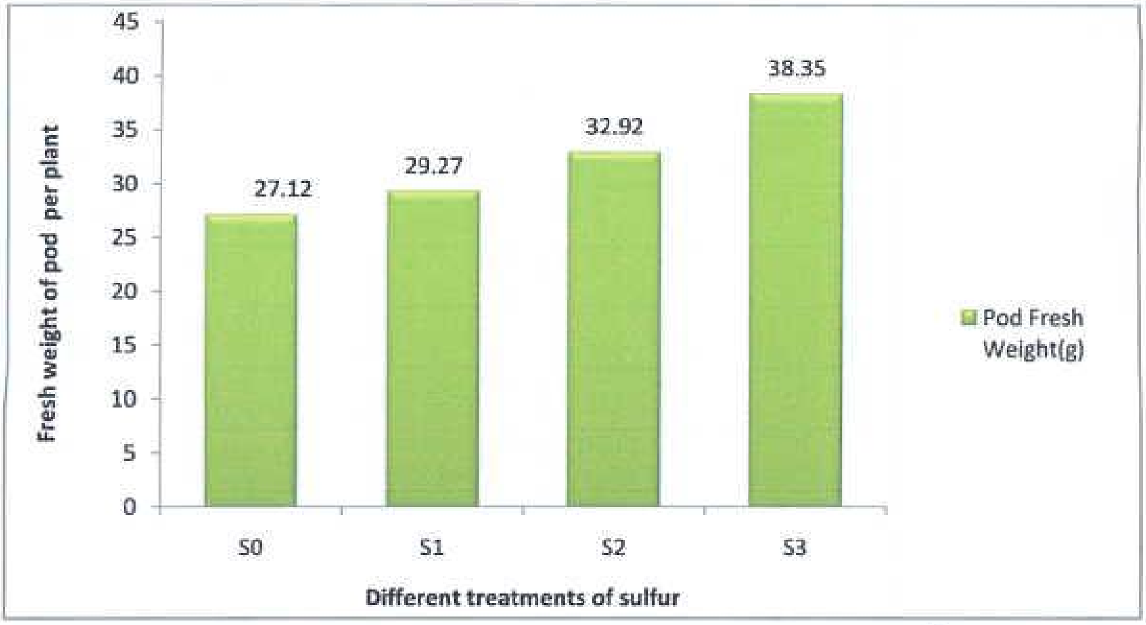
The fresh weight (g) of pod plant^{-1} of BARI Til-4 varied significantly at harvest due to the effect of sulfur application [Figure 17 and Appendix XI(a)]. After harvest, the S_3 treatment showed its superiority by producing the maximum pod fresh weight plant^{-1} (38.35 g) whereas the minimum pod fresh weight plant^{-1} (27.12 g) was observed from application of 0 kg S ha^{-1}.

4.9.2 Effect of boron

The effect of boron application on fresh weight (g) of pod plant^{-1} exerted significant result at harvest [Figure 18 and Appendix XI(b)]. After harvest, the B_2 treatment showed the highest pod fresh weight plant^{-1} (33.27 g) whereas the lowest pod fresh weight plant^{-1} (30.52 g) was observed from B_0 treatment.

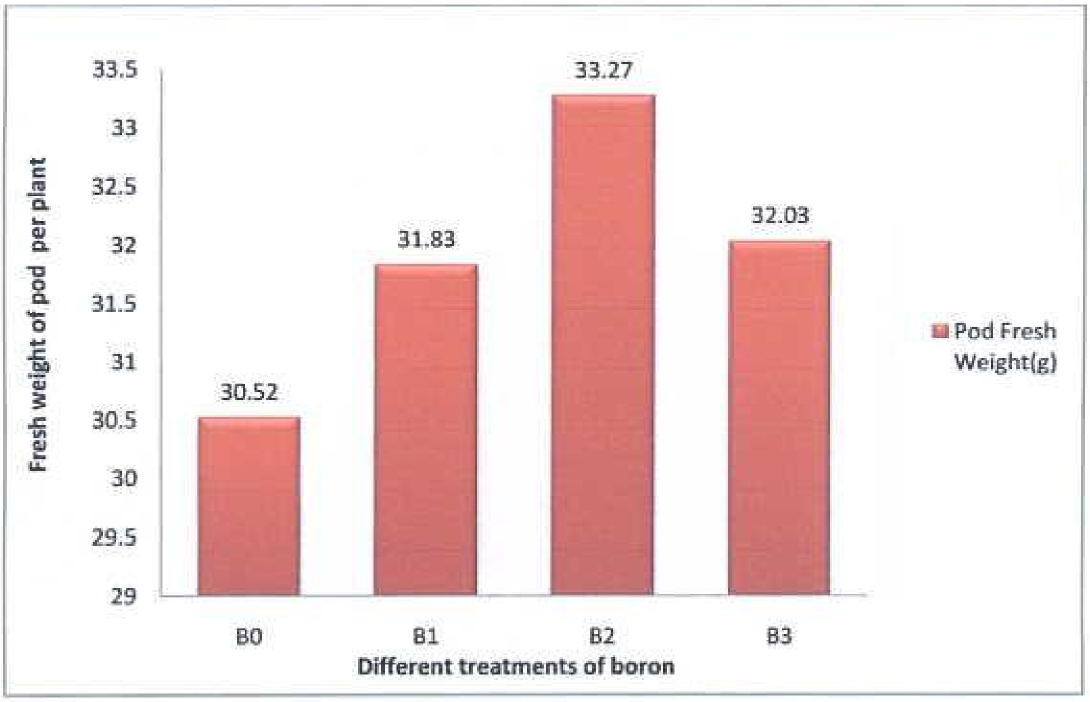
4.9.3 Interaction effect of sulfur and boron

The interaction effect of sulfur and boron fertilizers doses showed significant variation on pod fresh weight plant^{-1} of BARI Til-4 after harvest (Table 7). At harvest, the highest pod weight plant^{-1} (39.60 g) was observed from the S_3B_2 treatment which was statistically similar to that of S_3B_1 (38.93 g) and S_3B_3 (39.07 g) whereas the lowest pod fresh weight plant^{-1} (26.47 g) was observed from S_0B_0 treatment.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 17. The effect of sulfur on fresh weight of pod plant^{-1} of BARI Til-4 after harvest



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 18. The effect of boron on fresh weight of pod plant^{-1} of BARI Til-4 after harvest

4.10 Seed dry weight plant^{-1}

4.10.1 Effect of sulfur

The dry weight (g) of seed plant^{-1} of BARI Til-4 was significantly influenced by different levels of sulfur application [Figure 19 and Appendix XI (a)]. The result revealed that the S_3 treatment produced the maximum seed dry weight plant^{-1} (6.242 g) and the S_0 treatment gave the minimum seed dry weight plant^{-1} (4.139 g).

4.10.2 Effect of boron

Significant influence was observed on the seed dry weight (g) plant^{-1} of BARI Til-4 due to different boron fertilizer doses [Figure 20 and Appendix XI (a)]. The maximum seed dry weight (5.553 g) plant^{-1} was recorded from the B_3 treatment whereas the lowest seed dry weight (4.771 g) plant^{-1} was observed from the control treatment.

4.10.3 Interaction effect of sulfur and boron

The seed dry weight (g) plant^{-1} of BARI Til-4 significantly varied due to the interaction effect of sulfur and boron fertilizer doses after oven dry (Table 7). The highest seed dry weight (6.680 g) plant^{-1} was recorded from the S_3B_2 treatment which was statistically similar with that of S_3B_3 (6.530 g).In contrast the lowest seed dry weight (3.590 g) plant^{-1} was recorded from the treatment combination S_0B_0 which was statistically similar with that of S_0B_1 (3.883 g).

Table 7: The interaction effect of different doses of sulfur and boron on different parameters of sesame at harvest

Treatment		Pod fresh weight (g) $plant^{-1}$	Seed dry weight (g) $plant^{-1}$	Stover dry weight (g) $plant^{-1}$	Seed –Stover Ratio (%) $plant^{-1}$
S_0	B_0	26.47 f	3.590 i	3.487 j	103.0 a
	B_1	27.13 ef	3.883 i	4.333 i	89.59 e
	B_2	27.07 ef	4.353 h	4.493 i	96.90 b
	B_3	27.80 def	4.730 g	4.977 h	95.03 c
S_1	B_0	28.13 def	4.807 fg	5.070 h	94.78 c
	B_1	28.60 de	4.853 fg	5.303 gh	91.51 d
	B_2	31.13 c	4.830 fg	5.817 f	83.04 g
	B_3	29.20 d	5.080 ef	5.610 fg	90.57 de
S_2	B_0	31.67 c	4.927 efg	5.990 ef	82.22 gh
	B_1	32.67 c	5.237 de	6.670 cd	78.53 i
	B_2	35.27 b	5.467 cd	6.320 de	86.49 f
	B_3	32.07 c	5.873 b	6.717 c	87.42 f
S_3	B_0	35.80 b	5.760 bc	7.120 b	80.87 h
	B_1	38.93 a	6.000 b	7.363 b	81.48 gh
	B_2	39.60 a	6.680 a	8.143 a	82.06 gh
	B_3	39.07 a	6.530 a	7.853 a	83.19 g
$LSD_{(0.05)}$		1.81	0.3199	0.3694	1.742
CV (%)		5.36	1.16	1.01	1.75
Level of significance		*	**	**	**

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability

* - Significant at 5% level
** - Significant at 1% level

Note: S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}
B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.11 Stover dry weight plant^{-1}

4.11.1 Effect of sulfur

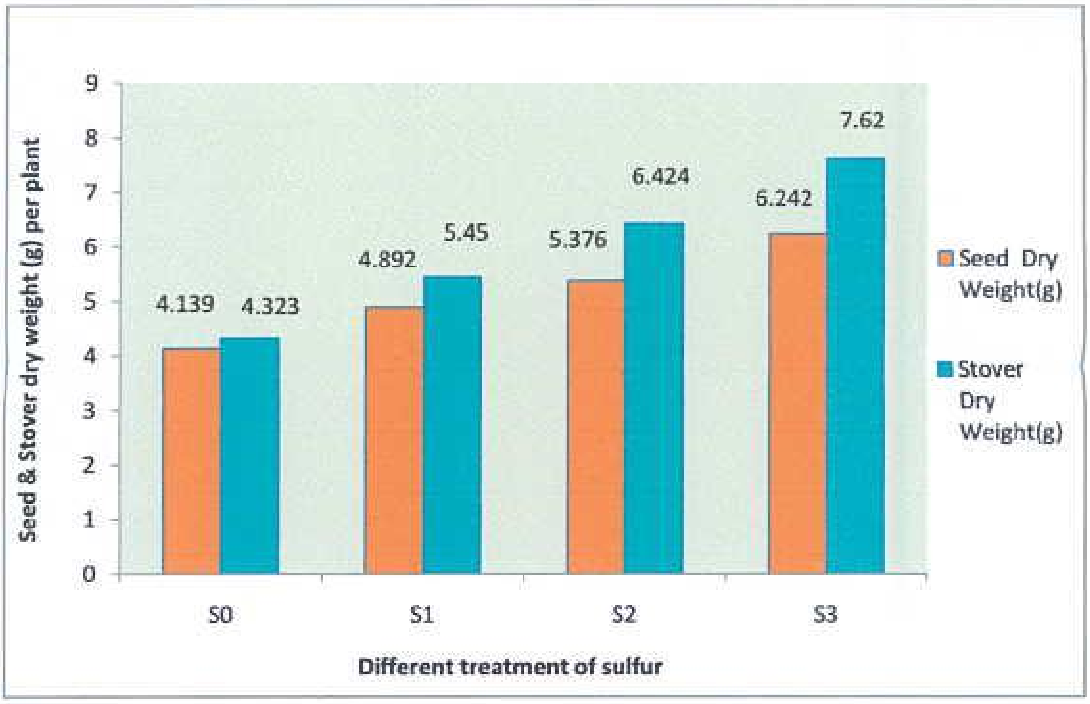
A clear difference was observed in case of stover dry weight plant^{-1} (g) of BARI Til-4 by different doses of sulfur fertilizer [Figure 19 and Appendix XI(a)]. The maximum stover dry weight plant^{-1} (7.620 g) was recorded from the S_3 treatment whereas, the lowest stover dry weight plant^{-1} (4.323 g) was observed from the S_0 treatment.

4.11.2 Effect of boron

The stover dry weight plant^{-1} (g) of sesame was significantly influenced by different levels of boron application [Figure 20 and Appendix XI(b)]. The result revealed that the B_3 treatment produced the maximum stover dry weight plant^{-1} (6.289 g) which was statistically similar to that of B_2 (6.193 g) while the B_0 treatment gave the minimum (5.417 g) stover dry weight plant^{-1}.

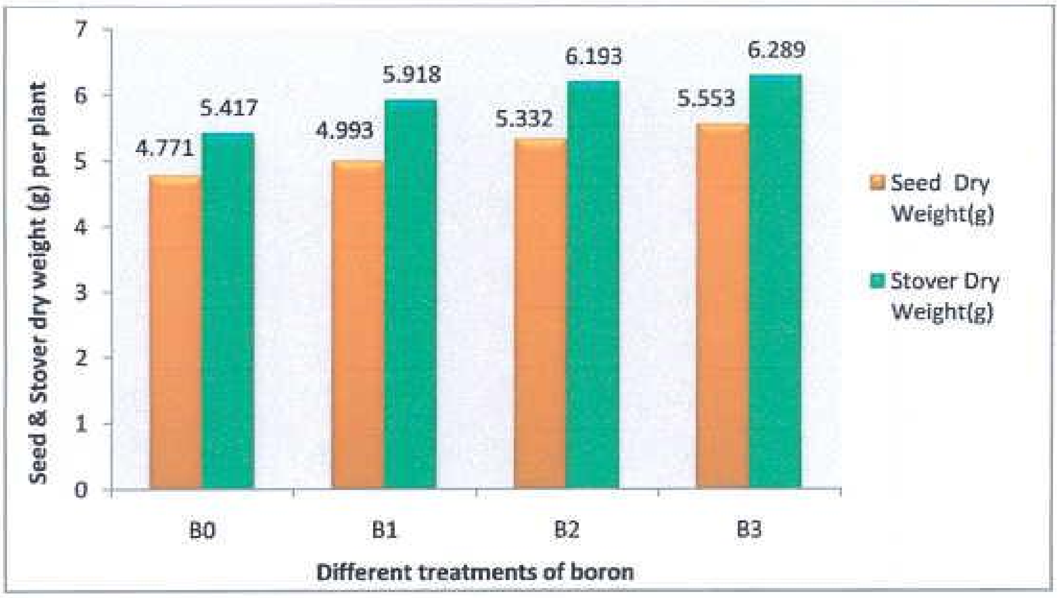
4.11.3 Interaction effect of sulfur and boron

Interaction of sulfur and boron fertilizer doses showed significant variation on stover dry weight plant^{-1} (g) of BARI Til-4 after harvest (Table 7). At harvest, the highest stover dry weight plant^{-1}(8.143 g) was observed from the S_3B_2 treatment which was statistically similar to that of S_3B_3 (7.853 g) whereas the lowest stover dry weight plant^{-1} (3.487 g) was observed from S_0B_0 treatment.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 19. The effect of sulfur on seed and stover dry weight plant^{-1} of BARI Til-4



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 20. The effect of boron on seed and stover dry weight plant^{-1} of BARI Til-4

4.12 Seed-stover ratio (on dry weight basis)

4.12.1 Effect of sulfur

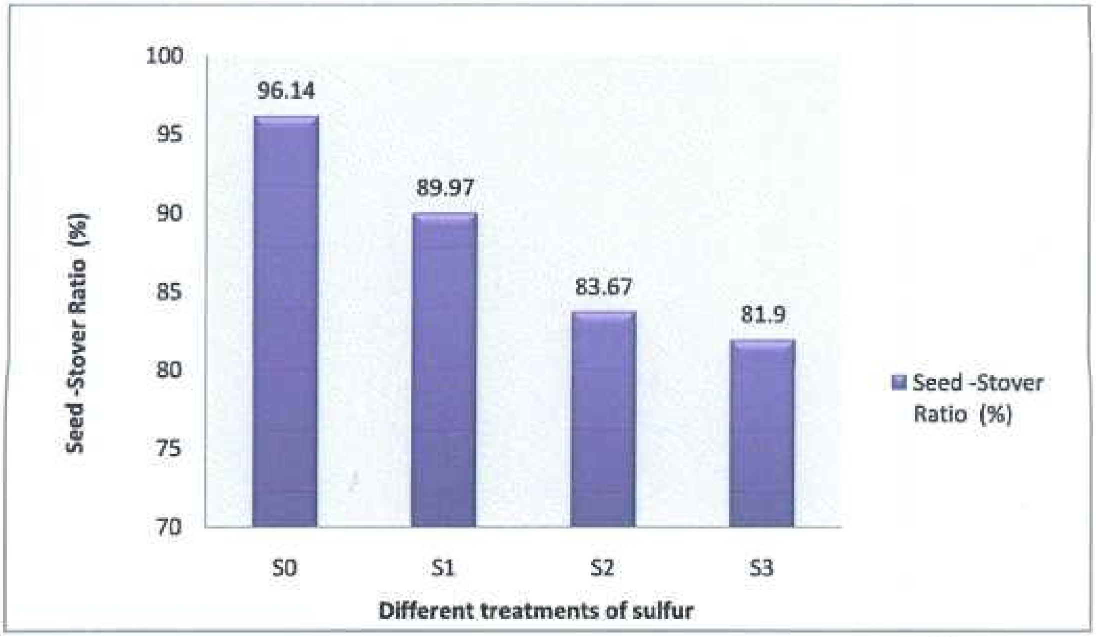
The percent (%) seed-stover ratio based on dry weight of sesame was significantly influenced by different levels of sulfur application [Figure 21 and Appendix XI(a)]. After oven dry, the maximum percentage of seed-stover ratio (96.14) was measured from the S_0 treatment whereas the lowest percentage of seed-stover ratio (81.90 %) was measured from the S_3 treatment.

4.12.2 Effect of boron

A significant variation was recorded due to the different doses of boron fertilizer for the percent (%) seed-stover ratio based on dry weight of BARI Til-4 [Figure 22 and Appendix XI(b)]. The maximum percent seed-stover ratio plant^{-1} (90.23) was recorded for the B_0 treatment and the lowest (85.28) was observed from the B_1 treatment.

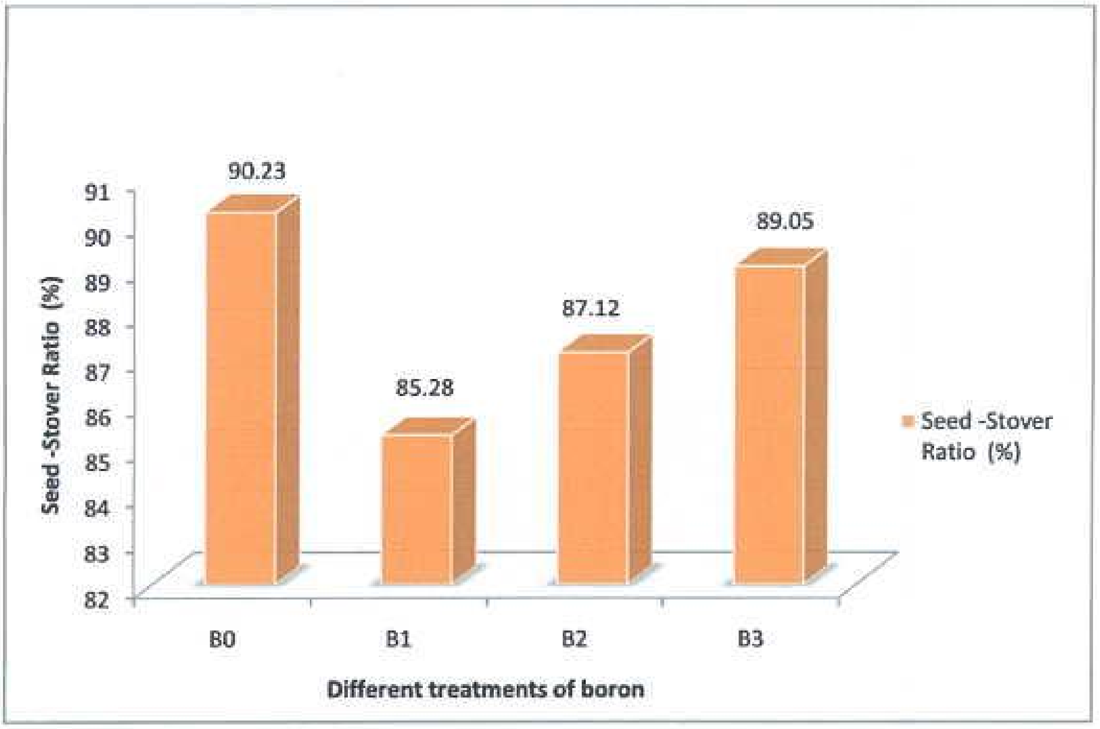
4.12.3 Interaction effect of sulfur and boron

Interaction of sulfur and boron fertilizer doses showed significant variation on the percent seed-stover ratio based on dry weight of sesame i.e. BARI Til-4 after harvest (Table7). At harvest, the highest percent seed-stover ratio plant^{-1} (103%) was observed from the S_0B_0 treatment whereas, the lowest percent seed-stover ratio per plant (78.53 %) was observed from S_2B_1 treatment.



Note: $S_0 = 0$ kg ha^{-1} (control), $S_1 = 10$ kg ha^{-1}, $S_2 = 20$ kg ha^{-1}, $S_3 = 30$ kg ha^{-1}

Figure 21. The effect of sulfur on seed–stover ratio of BARI Til-4 after harvest



Note: $B_0 = 0$ kg ha^{-1} (control), $B_1 = 1$ kg ha^{-1}, $B_2 = 1.5$ kg ha^{-1}, $B_3 = 2$ kg ha^{-1}

Figure 22. The effect of boron on seed–stover ratio of BARI Til-4 after harvest

4.13 Seed yield

4.13.1 Effect of sulfur

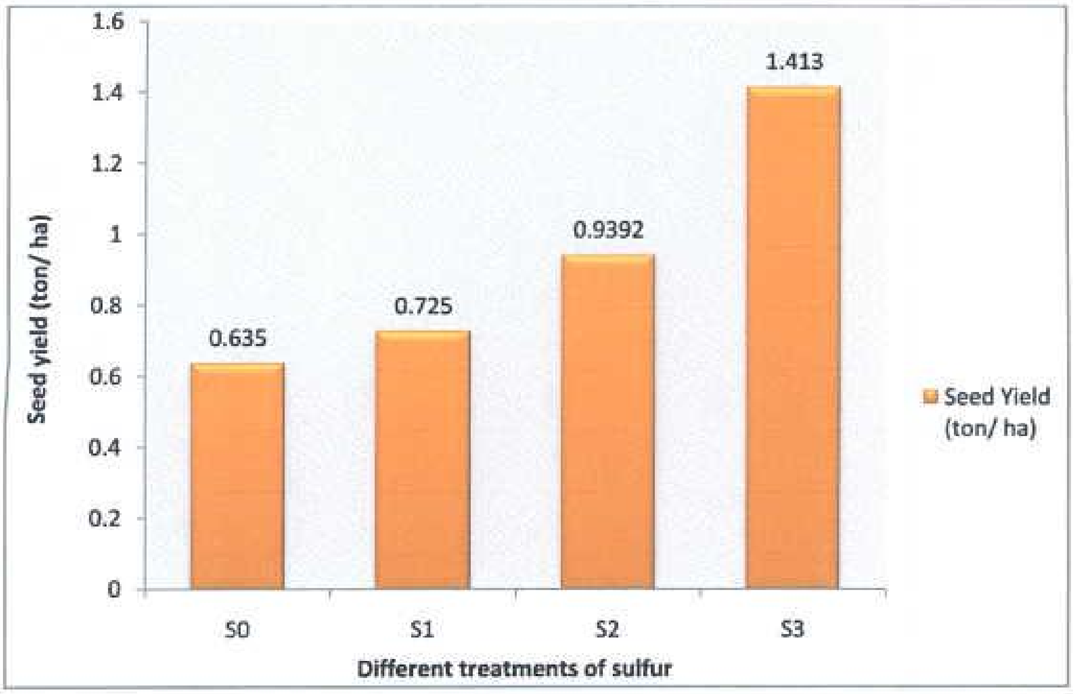
The seed yield (ton ha^{-1}) of BARI Til-4 was significantly influenced by different levels of sulfur application [Figure 23 and Appendix XII(a)]. The result revealed that the S_3 treatment produced the maximum seed yield (1.413 ton ha^{-1}). The seed yield showed a decreasing trend with the reduced rate of sulfur fertilizer. It is observed that the S_0 treatment gave the minimum seed yield (0.6350 ton ha^{-1}).

This findings were supported by Heidari *et al.*(2011), Vaiyapuri *et al.* (2003), Sarkar and Banik (2002), Dayanand and Shivran (2002) and Meng *et al.* (1999) who reported that seed yield of sesame increased with the increased rate of S fertilizer. Allam (2002) reported that sulfur fertilizer increased yield between 20% and 42% in field experiments. Increased grain yield due to increased levels of sulfur were mainly due to improvement in yield components like number of seed $capsule^{-1}$ (Kabir, 2011).

4.13.2 Effect of boron

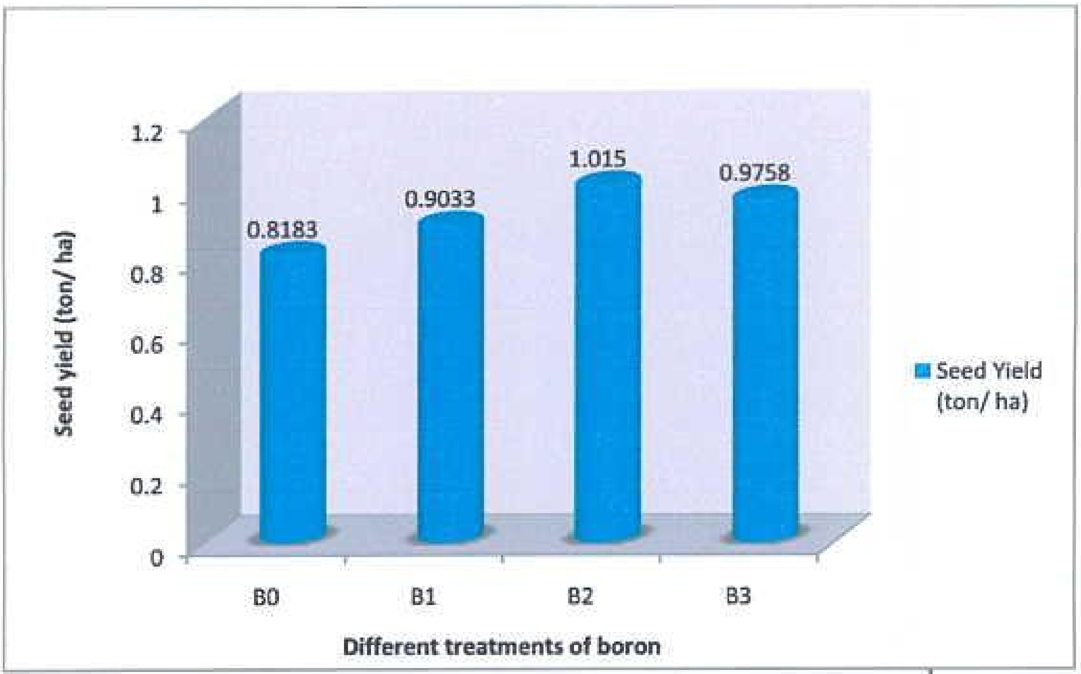
Significant influence was observed on the seed yield (ton ha^{-1}) of BARI Til-4 due to different boron fertilizer doses [Figure 24 and Appendix XII(b)]. The maximum seed yield (1.015 ton ha^{-1}) was recorded from the B_2 treatment which was statistically similar with that of B_3 (0.9758 ton ha^{-1}) whereas the lowest seed yield (0.8183 ton ha^{-1}) was observed from the control treatment.

Sarkar (2008) and Bennetti (1993) reported the similar result. Devi *et al.* (2010) and Wankhade *et al.* (1998) reported that B deficiency gave the lowest soybean yield where Singh *et al.* (2003) documented that crop yields, in general, have been promoted by regular application of boron.



Note: $S_0 = 0$ kg ha^{-1} (control), $S_1 = 10$ kg ha^{-1}, $S_2 = 20$ kg ha^{-1}, $S_3 = 30$ kg ha^{-1}

Figure 23. The effect of sulfur on seed yield of BARI Til-4 after harvest



Note: $B_0 = 0$ kg ha^{-1} (control), $B_1 = 1$ kg ha^{-1}, $B_2 = 1.5$ kg ha^{-1}, $B_3 = 2$ kg ha^{-1}

Figure 24. The effect of boron on seed yield of BARI Til-4 after harvest

4.13.3 Interaction effect of sulfur and boron

The seed yield (ton ha^{-1}) of BARI Til-4 varied significantly due to interaction of sulfur and boron fertilizers doses after harvest (Table 8). The highest seed yield (1.657 ton ha^{-1}) was recorded from the S_3B_2 treatment which was statistically similar to that of S_3B_3 (1.500 ton ha^{-1}).In contrast the lowest seed yield (0.6000 ton ha^{-1}) was recorded from the treatment combination S_0B_0 which was statistically similar to that of S_0B_1 (0.6433 ton ha^{-1}), S_0B_2 (0.6600 ton ha^{-1}), S_0B_3 (0.6367 ton ha^{-1}), S_1B_0 (0.6633 ton ha^{-1}), and S_1B_1 (0.7200 ton ha^{-1}).

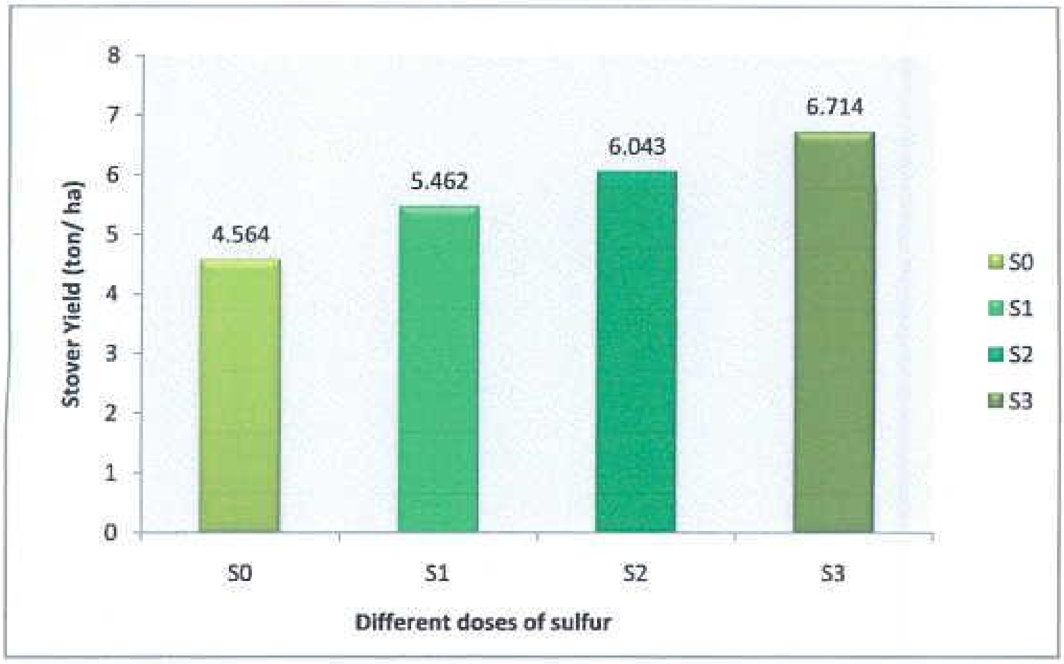
Huq (2012), Mathew and George (2011) and Haque (2008) conducted experiments to find out the influence of sulfur and boron fertilizer application on growth and yield of sesame and result showed that the best seed yield of sesame from the combination of higher doses of S with optimum dose of B. Hegde (2003) also reported this finding.

4.14 Stover yield

4.14.1 Effect of sulfur

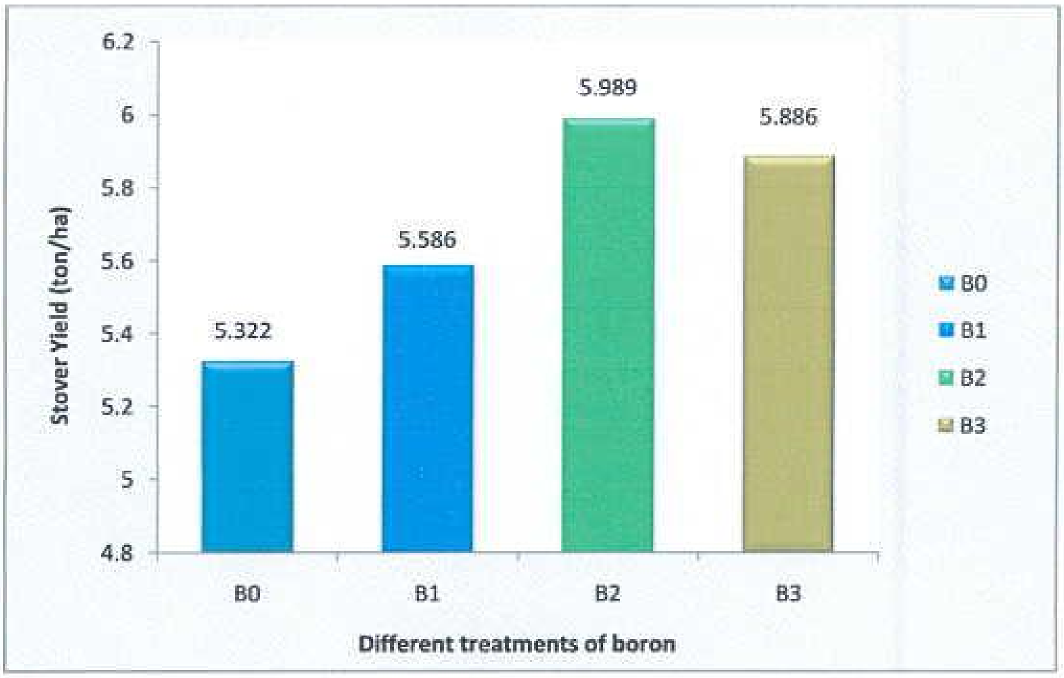
The results showed that the effect of sulfur application on variation in stover yield (ton ha^{-1}) of BARI Til-4 was highly significant [Figure 25 and Appendix XII(a)]. Stover yield showed an increasing trend with the increases of sulfur rate and the maximum stover yield (6.714 ton ha^{-1}) was observed from the S_3 treatment whereas the minimum stover yield (4.564 ton ha^{-1}) was observed from S_0 treatment.

The present result was similar with the findings of Huq (2012) and Heidari *et al.* (2011) who observed that seed yield of sesame increased with increasing S fertilization.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 25. The effect of sulfur on stover yield of BARI Til-4



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 26. The effect of boron on stover yield of BARI Til-4

4.14.2 Effect of boron

Boron levels had significant influence on the variation of stover yield (ton ha^{-1}) of sesame, BARI Til-4 after harvest [Figure 26 and Appendix XII(b)]. The stover yield was maximum (5.989 ton ha^{-1}) obtained from the B_2 treatment which was statistically similar to that of B_3 (5.886 ton ha^{-1}) treatment. The lowest stover yield (5.322 ton ha^{-1}) was obtained from 0 kg B ha^{-1}.

Mathew and George (2011) and Sarkar (2008) conducted experiments and observed the effect of boron on stover yield which supports this finding.

4.14.3 Interaction effect of sulfur and boron

Stover yield of sesame was significantly influenced by the interaction effect of sulfur and boron (Table 8). The results revealed that the maximum stover yield (7.007 ton ha^{-1}) was in S_3B_2 treatment which was statistically similar to that of S_3B_3 (6.843 ton ha^{-1}). However, the combination S_0B_0 gave the lowest stover yield (3.857 ton ha^{-1}).

Similar result was also reported by Huq (2012), Haque (2008) and Hegde (2003) who observed that the higher dose of S and optimum dose of B combination induced higher stover yield of sesame.

4.15 Biological yield

4.15.1 Effect of sulfur

The sulfur levels showed significant influence on the biological yield (ton ha^{-1}) of sesame [Figure 27 and Appendix XII(a)]. The highest biological yield of BARI Til-4 (8.129 ton ha^{-1}) was obtained from S_3 and the lowest one (5.199 ton ha^{-1}) was found from the S_0 treatment.

This result was in agreement with the finding of Heidari *et al.* (2011) who reported that biological yield performance varied with the application of sulfur variation.

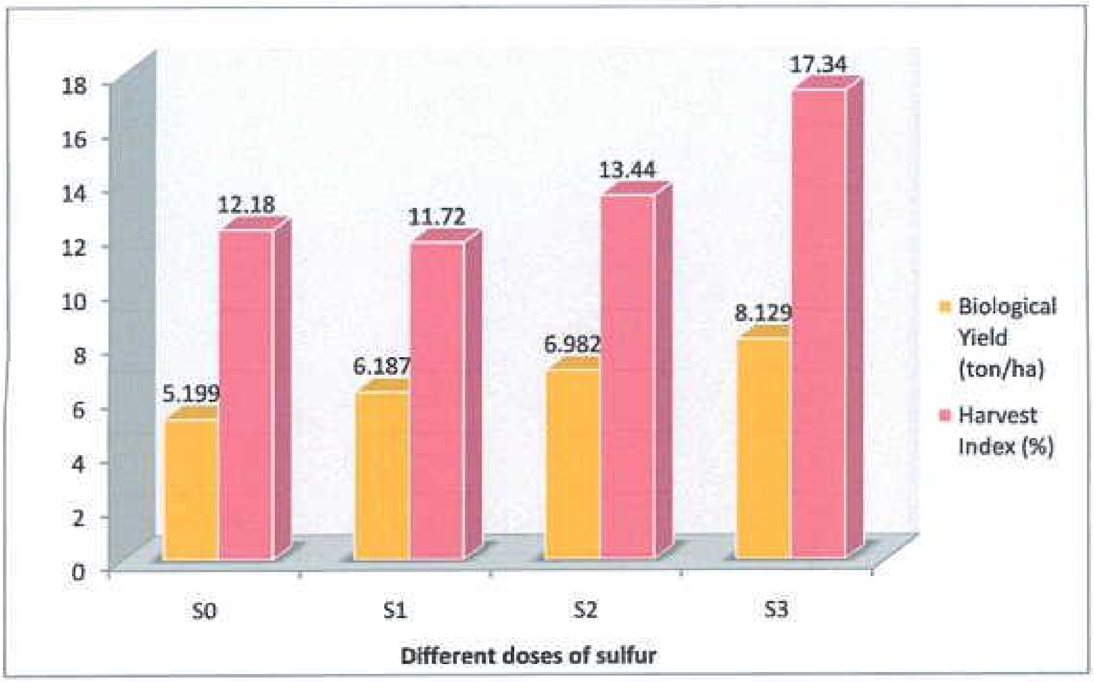
4.15.2 Effect of boron

The biological yield of BARI Til-4 was significantly influenced by different boron levels [Figure 28 and Appendix XII(b)]. The result revealed that the B_2 treatment showed the highest biological yield (7.004 ton ha^{-1}) which was statistically similar to that of B_3 (6.862 ton ha^{-1}) while the B_0 treatment gave the lowest biological yield (6.142 ton ha^{-1}). Sarkar (2008) observed that the highest biological yield was from optimum boron application.

4.15.3 Interaction effect of sulfur and boron

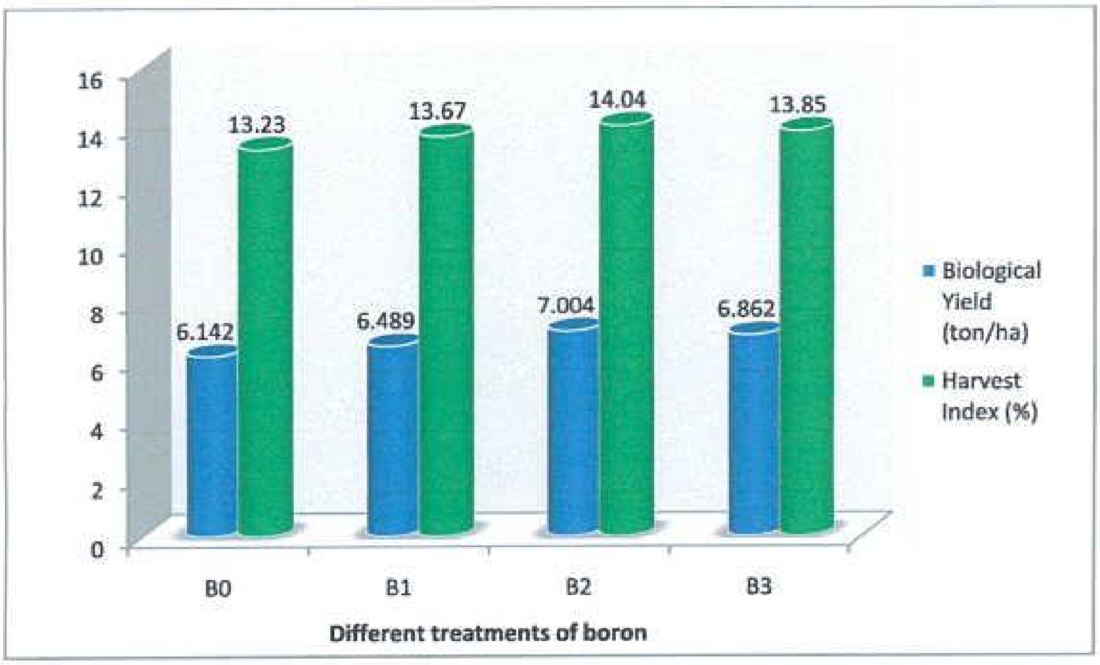
The biological yield of BARI Til-4 significantly varied due to interaction effect of sulfur and boron fertilizers (Table 8). The highest biological yield (8.663 ton ha^{-1}) was recorded from the S_3B_2 treatment which was statistically similar to that of S_3B_3 (8.343 ton ha^{-1}) whereas the lowest biological yield (4.457ton ha^{-1}) was recorded in the treatment combination S_0B_0.

Huq (2012) and Mathew and George (2011) conducted experiments to find out the influence of sulfur and boron fertilizer application on growth and yield of sesame and obtained the best biological yield of sesame from the combination of higher doses of S with optimum dose of B.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 27. The effect of sulfur on biological yield and harvest index of BARI Til-4



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 28. The effect of boron on biological yield and harvest index of BARI Til-4

4.16 Harvest Index

4.16.1 Effect of sulfur

Harvest index (%) was significantly influenced by different levels of sulfur application on sesame [Figure 27 and Appendix XII (a)]. The highest harvest index (17.34 %) was obtained from the S_3 and the lowest harvest index (11.72 %) was found from the S_1 treatment which was statistically identical to the harvest index with the S_0 treatment (12.18 %).

Heidari *et al.* (2011) and Kabir (2011) reported that the harvest index varied due to the difference in sulfur application.

4.16.2 Effect of boron

It was observed that harvest index was significantly influenced by boron levels [Figure 28 and Appendix XII (b)]. The harvest index was highest (14.04 %) in the B_2 treatment which was statistically similar to that of the B_3 (13.85 %) and the lowest harvest index (13.23 %) was found from the B_0 treatment. This finding was similar to the results reported by Huq (2012) and Sarkar (2008).

4.16.3 Interaction effect of sulfur and boron

The interaction effect of sulfur and boron showed a significant variation in harvest index (%) of sesame, BARI Til-4 (Table 8). The result reveals that the maximum harvest index (19.12%) was measured in the S_3B_2 treatment. However, the combination S_0B_3 gave the lowest harvest index (11.40 %). which was statistically similar to that of S_0B_1 (12.49%), S_0B_2 (11.78%), S_1B_0 (11.44%), S_1B_1 (12.16%), S_1B_2 (11.50%), S_1B_3 (11.50%) and S_2B_0 (12.50%).

Similar result was also reported by Huq (2012), Haque (2008) and Hegde (2003) who observed that combination of S and B fertilizers produced the higher harvest index of sesame.

Table 8: The interaction effect of different doses of sulfur and boron on different yield parameters of sesame at harvest

Treatment		Seed yield (ton ha^{-1})	Stover yield (ton ha^{-1})	Biological yield (ton ha^{-1})	Harvest Index (%)
S_0	B_0	0.6000 g	3.857 i	4.457 i	13.46 ef
	B_1	0.6433 g	4.510 h	5.153 h	12.49 fg
	B_2	0.6600 fg	4.943 g	5.603 g	11.78 g
	B_3	0.6367 g	4.947 g	5.583 g	11.40 g
S_1	B_0	0.6633 fg	5.137 g	5.800 g	11.44 g
	B_1	0.7200 fg	5.203 g	5.923 g	12.16 g
	B_2	0.7567 efg	5.823 ef	6.580 ef	11.50 g
	B_3	0.7600 efg	5.683 f	6.443 f	11.80 g
S_2	B_0	0.8400 def	5.883 ef	6.723 def	12.50 fg
	B_1	0.9233 de	6.033 def	6.957 cde	13.27 ef
	B_2	0.9867 d	6.183 de	7.170 c	13.76 e
	B_3	1.007 cd	6.070 def	7.077 cd	14.23 e
S_3	B_0	1.170 bc	6.410 cd	7.587 b	15.51 d
	B_1	1.327 b	6.597 bc	7.923 b	16.74 c
	B_2	1.657 a	7.007 a	8.663 a	19.12 a
	B_3	1.500 a	6.843 ab	8.343 a	17.98 b
$LSD_{(0.05)}$		0.1652	0.3694	0.413	0.9947
CV (%)		3.6	1.16	1.01	3.64
Level of significance		**	**	**	**

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability

** - Significant at 1% level

Note : S_0 = 0 kg ha^{-1}, S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

B_0 = 0 kg ha^{-1}, B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.17 Oil content in seed

4.17.1 Effect of sulfur

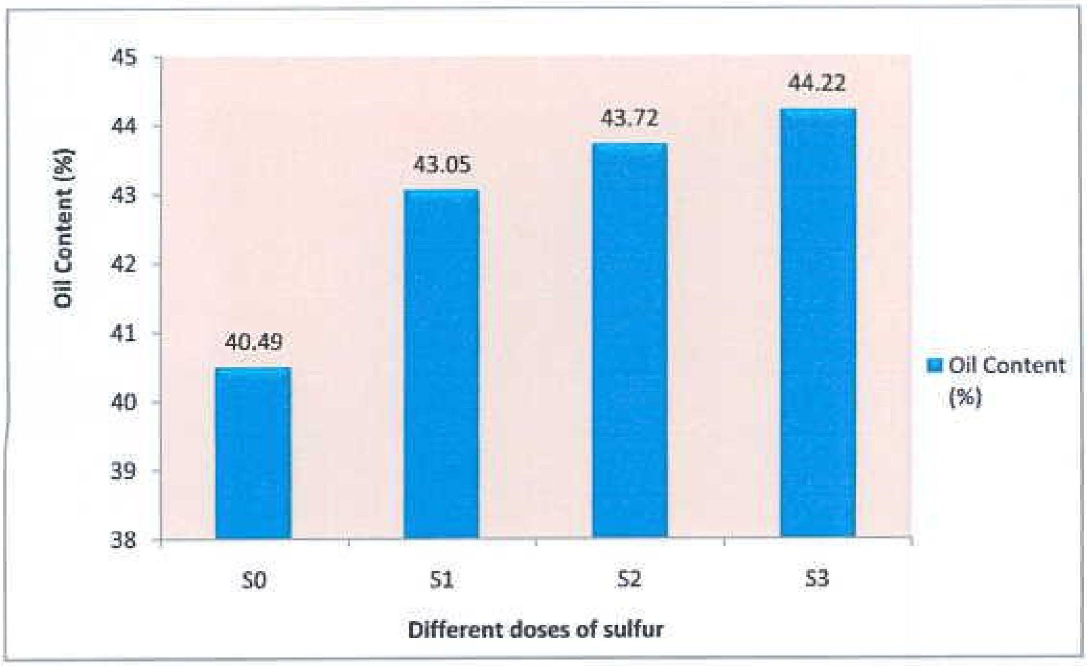
The different levels of sulfur significantly influenced oil content (%) in sesame seed [Figure 29 and Appendix XII(a)]. The percent oil content of sesame was directly proportional to the sulfur doses. The results revealed that the oil content (44.22 %) was highest when the sulfur level used was also highest (S_3treatment) and it was lowest (40.49 %) in control treatment.

This might have resulted probably due to augmentation of sulfur containing fatty acids and amino acids; such as cystine, cysteine and methionine which are essential components of protein and ultimately led to increase in seed oil content (Havlin *et al.*, 1999). Similar findings were also reported by Heidari *et al.* (2011), Kabir (2011), Dayanand and Shivran (2002) and Radhamoni *et. al.* (2001).

4.17.2 Effect of boron

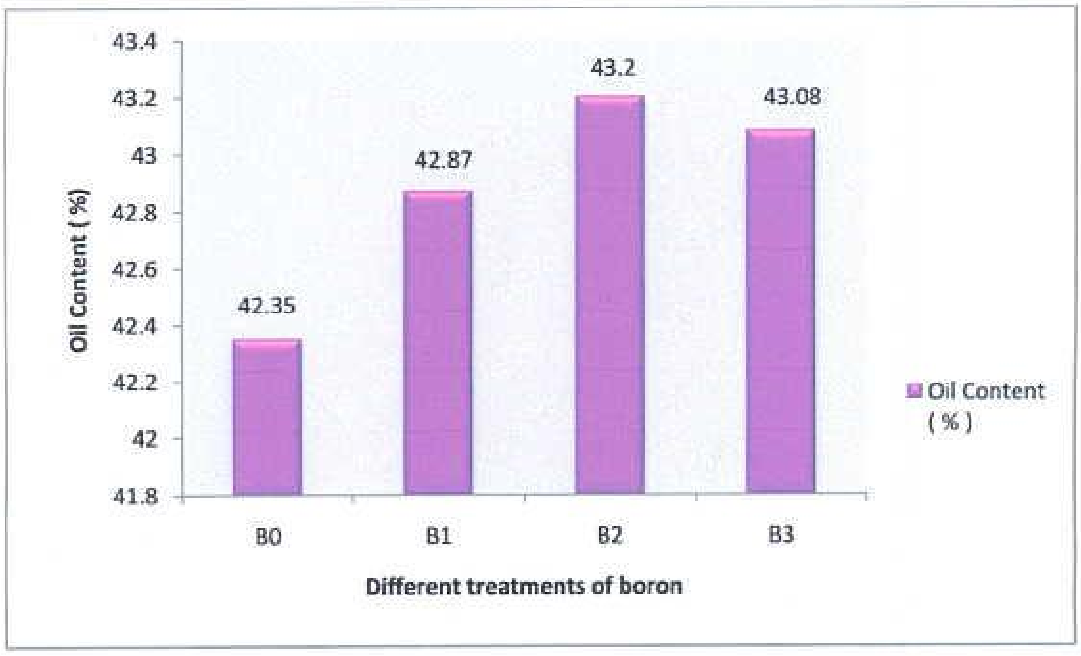
Oil content (%) in seed of sesame was significantly influenced by different levels of boron in sesame seed [Figure 30 and Appendix XII(b)]. The highest oil content (43.20 %) in sesame was obtained from the B_2 treatment which was statistically similar to that of the B_3treatment (43.08 %). The lowest oil content (42.35 %) was recorded from control treatment.

Boron is involved in the synthesis of oil (Malewar *et al.*, 2001). This finding was in agreement with Haque (2008) and Liu *et. al.* (2003) who observed similar pattern of oil content due to boron application.



Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

Figure 31. The effect of sulfur on oil content in seed of BARI Til-4



Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

Figure 32. The effect of boron on oil content in seed of BARI Til-4

4.17.3 Interaction effect of sulfur and boron

The interaction effect of sulfur and boron had significant effect on oil content (%) in seed of sesame (Table 9). The result reveals that the maximum oil content in seed (44.60 %) was measured from the S_3B_2 treatment which was statistically similar to those of S_3B_1 (44.20 %) and S_3B_3 (44.30 %). On the other hand, the S_0B_1 treatment showed the lowest result (40.27 %) which was statistically similar to those of S_0B_0 (40.30 %) and S_0B_1 (40.60 %).

Similar result was found by Mathew and George (2011) and Haque (2008) who observed significant effect on oil content (%) in seed of sesame due to increase the amount of S and B. Devi *et al.* (2010) also stated that the interaction of S and B influenced significantly on protein and oil content of soybean.

Table 09: The interaction effect of different doses of sulfur and boron on oil and sulfur content in seed of sesame after harvest

Treatment		Oil content in seed (%)	Sulfur content in seed (%)
S_0	B_0	40.30 h	0.09333 d
	B_1	40.27 h	0.09600 cd
	B_2	40.60 gh	0.1060 bcd
	B_3	40.80 g	0.1080 bcd
S_1	B_0	42.20 f	0.1130 bcd
	B_1	43.20 e	0.1160 bcd
	B_2	43.50 de	0.1177 bcd
	B_3	43.30 e	0.1170 bcd
S_2	B_0	43.10 e	0.1330 bcd
	B_1	43.80 cd	0.1350 bcd
	B_2	44.10 bc	0.1380 bcd
	B_3	43.90 bcd	0.1360 bcd
S_3	B_0	43.80 cd	0.1450 bcd
	B_1	44.20 abc	0.1590 abc
	B_2	44.60 a	0.2157 a
	B_3	44.30 ab	0.1620 ab
$LSD_{(0.05)}$		0.4524	0.05841
CV (%)		4.25	2.92
Level of significance		*	**

In a column, same letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 5% level of probability.

* - Significant at 5% level

** - Significant at 1% level

Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

4.18 Sulfur content in seed

4.18.1 Effect of sulfur

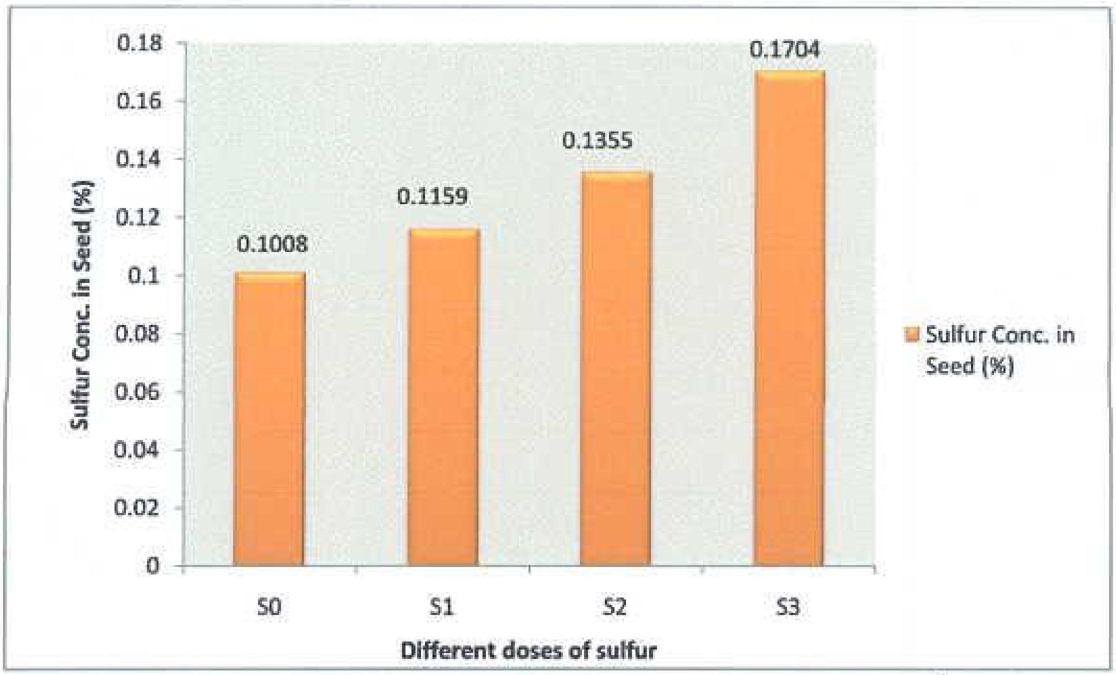
S content (%) in sesame seed showed statistically significant difference due to the different levels of sulfur [Figure 31 and Appendix XII(a)]. The results revealed that the highest S content (0.1704 %) was in the seed collected from the S_3 treatment and the lowest amount of S (0.1008 %) was in the seed obtained from the S_0 treatment.

4.18.2 Effect of boron

S content (%) in seed of BARI Til-4 did not vary significantly due to the different levels of boron [Figure 32 and Appendix XII (b)]. Numerically the highest S content (0.1443 %) was observed in seed from the B_2 treatment and the lowest amount (0.1211 %) of S content found in seed for the B_0 treatment.

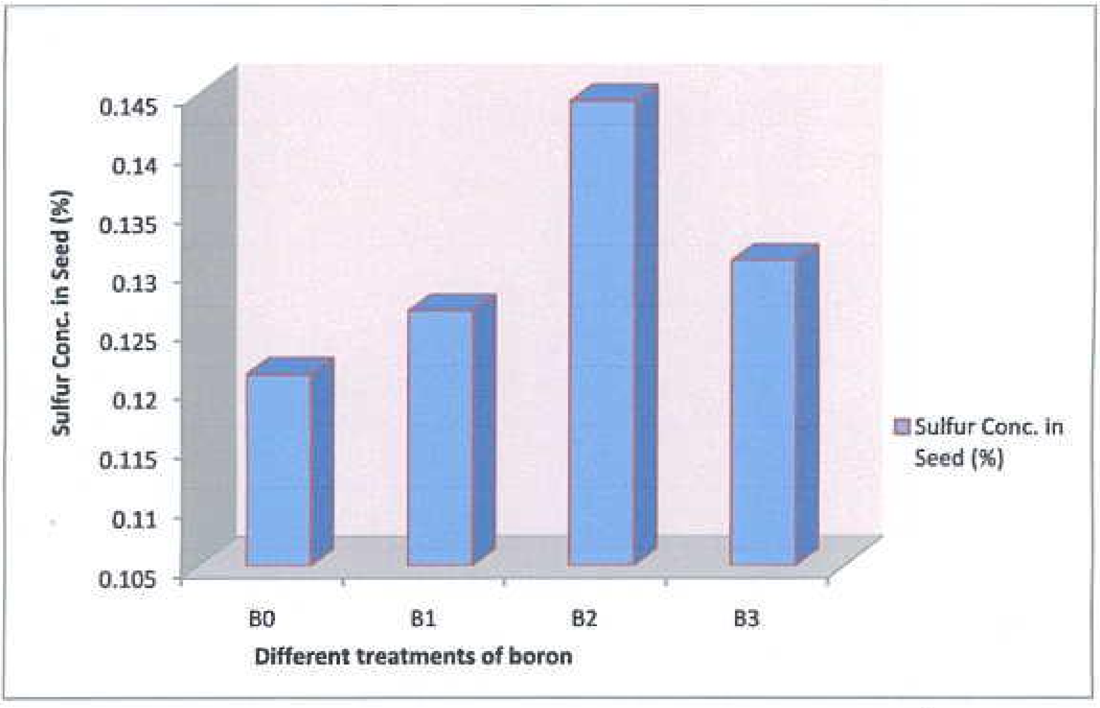
4.18.3 Interaction effect of sulfur and boron

S content (%) in BARI Til-4 seed varied significantly due to the interaction effect of different sulfur and boron doses (Table 9). The highest S content in seed (0.2157 %) was observed from S_3B_2 which is statistically similar to that of S_3B_1 (0.1590 %) and S_3B_3 (0.1620 %) while the lowest result (0.09333 %) was recorded from S_0B_0.



Note: $S_0 = 0$ kg ha^{-1} (Control), $S_1 = 10$ kg ha^{-1}, $S_2 = 20$ kg ha^{-1}, $S_3 = 30$ kg ha^{-1}

Figure 31. The effect of sulfur on sulfur content in seed of BARI Til-4



Note: $B_0 = 0$ kg ha^{-1} (control), $B_1 = 1$ kg ha^{-1}, $B_2 = 1.5$ kg ha^{-1}, $B_3 = 2$ kg ha^{-1}

Figure 32. The effect of boron on sulfur content in seed of BARI Til-4

Chapter V

Summary and Conclusion

CHAPTER-V
SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from 12th April to 17th July, 2014 to find out the effect of sulfur and boron application on the growth, yield, oil and sulfur content of sesame cv. BARI Til-4. The experiment comprised of two factors laid out in a Randomized Complete Block Design (RCBD) with three replications. Factor I: four levels of sulfur viz. S_0 (control), S_1 (10 kg S ha^{-1}), S_2 (20 kg S ha^{-1}) and S_3 (30 kg S ha^{-1}); and factor II: four levels of boron viz. B_0 (control), B_1 (1 kg B ha^{-1}), B_2 (1.5 kg B ha^{-1}) and B_3 (2 kg B ha^{-1}). The unit plot size was 3.5 m^2 (2.5m x 1.4m). There were 16 treatment combinations in the experiment. Each plot was fertilized with 100 kg N ha^{-1} as urea, 30 kg P ha^{-1} as TSP and 50 kg K ha^{-1}as MOP. Sulfur and boron were applied in the form of Gypsum and Boric acid as per experimental treatments. Common cultural practices were adopted for each plot as and when required to ensure good growth of the crop.

The data on different plant growth, yield and yield contributing characters were recorded. Grain samples were analyzed for estimating the oil and S contents.

The results revealed that all the growth and yield parameters varied significantly due to the application of sulfur. The level of sulfur 30 kg ha^{-1}(S_3) gave highest plant height at 30, 40, 50, 60 DAS and at harvest while it was lowest in S_0 treatment. The same trend was observed for S_3 treatment over S_0 in case of number of leaves at all stages except at 30 DAS where S_2 treatment gave better results. At 40, 50, 60 DAS and at harvest, the S_3 treatment produced the highest number of branches plant^{-1}. The S_3 treatment gave the maximum leaves fresh and dry weight plant^{-1}, highest fresh and dry stem weight plant^{-1}, highest pod fresh weight plant^{-1} and maximum seed and stover dry weight plant^{-1} when the lowest was found from the S_0. Though the S_0 treatment gave the maximum results for seed – stover ratio recorded on the dry weight basis. The highest number of capsules plant^{-1}, number of seeds capsule^{-1}, 1000 seed weight, seed yield, stover yield, biological yield and harvest index were observed in the S_3 treatment. Oil content and S concentration in sesame seed were highest due to the application of 30 kg S ha^{-1}. The lowest result was obtained from S_0 treatment in almost every parameter.

The growth, yield, oil and S content of BARI Til-4 varied significantly due to the application of different doses of boron. At 30, 40, 50, 60 DAS and at harvest, the highest plant height was observed from the B_2 treatment (1.5 kg B ha^{-1}) while it was lowest in B_0 treatment. At 60 DAS and at harvest, the number of leaves $plant^{-1}$ of sesame did not vary significantly due to different boron doses. But numerically maximum number of leaves $plant^{-1}$ was observed in the B_2 treatment. At 40, 50 and 60 DAS, the B_2 treatment produced the highest number of branches $plant^{-1}$, but at harvest the B_3 treatment showed the highest result. The highest number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, maximum leaves fresh and dry weight $plant^{-1}$, highest fresh and dry stem weight $plant^{-1}$and maximum stover dry weight $plant^{-1}$ were found either from the B_2 or the B_3 treatment which were statistically similar when the lowest was found in the B_0. 1000-seed weight did not show statistically significant variation among the boron levels. But numerically maximum 1000-seed weight was observed in the B_2. The highest pod fresh weight $plant^{-1}$ was found from the B_2 while the maximum seed dry weight $plant^{-1}$ was observed from the B_3 treatment. The highest value of seed yield, stover yield, biological yield, harvest index and oil content were observed from the B_2 treatment which was statistically similar to that of B_3. S content in seed did not show statistically significant difference due to the effect of boron levels. Numerically maximum S content in seed was observed in the B_2 treatment. The B_0 treatment showed the lowest result in all cases except the seed – stover ratio recorded on the dry weight basis.

All the parameters studied showed significant influence by the interaction effect of sulfur and boron levels at all stages of observations. Interaction of sulfur and boron the S_3B_2 treatment gave the highest plant height at 30, 40, 50 DAS and at harvest while the S_3B_3 showed numerically highest value at 60 DAS. The same trend was observed in the S_3B_2 treatment over S_0 in case of number of leaves at all stages except at 30 DAS where S_2B_1 gave better result. At 40, 50 and 60 DAS, the S_3B_2 treatment produced the highest number of branches $plant^{-1}$ while the S_2B_3 produced the highest number at harvest. The maximum reading of number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, 1000-seed weight, maximum leaves fresh and dry weight $plant^{-1}$, fresh and dry stem weight plant^{-1}, pod fresh weight plant^{-1}, maximum seed and stover dry weight plant^{-1} and highest value of seed yield, stover yield, biological yield, harvest index, oil content and S concentration in sesame seed showed statistically highest value in the S_3B_2 which were statistically similar to those in S_3B_3. The S_0B_0 treatment showed the highest result in case of seed - stover ratio. Otherwise the lowest values of about all parameters were observed from S_0B_0.

The overall results suggested that application of 30 kg S ha^{-1} and 1.5 kg B ha^{-1} performed the best for producing high yield of oil containing seed of sesame, variety BARI Til-4. However, the lowest values were found from the S_0B_0 combination in all the parameters studied.

From the present study, it may be concluded that among the sulfur treatments, 30 kg S ha^{-1} was found to be the most effective treatment. The application of 1.5 kg B ha^{-1} also performed better than 2 kg B ha^{-1}. The interaction of 30 kg S ha^{-1} and 1.5 kg B ha^{-1} had significant and favorable effect for improving yield component and increasing yield of sesame. However, further research at different Agro-ecological zones and in Rabi season are necessary to draw a definite conclusion and for recommendation in respect of application of sulfur and boron fertilizers for sesame cultivation.

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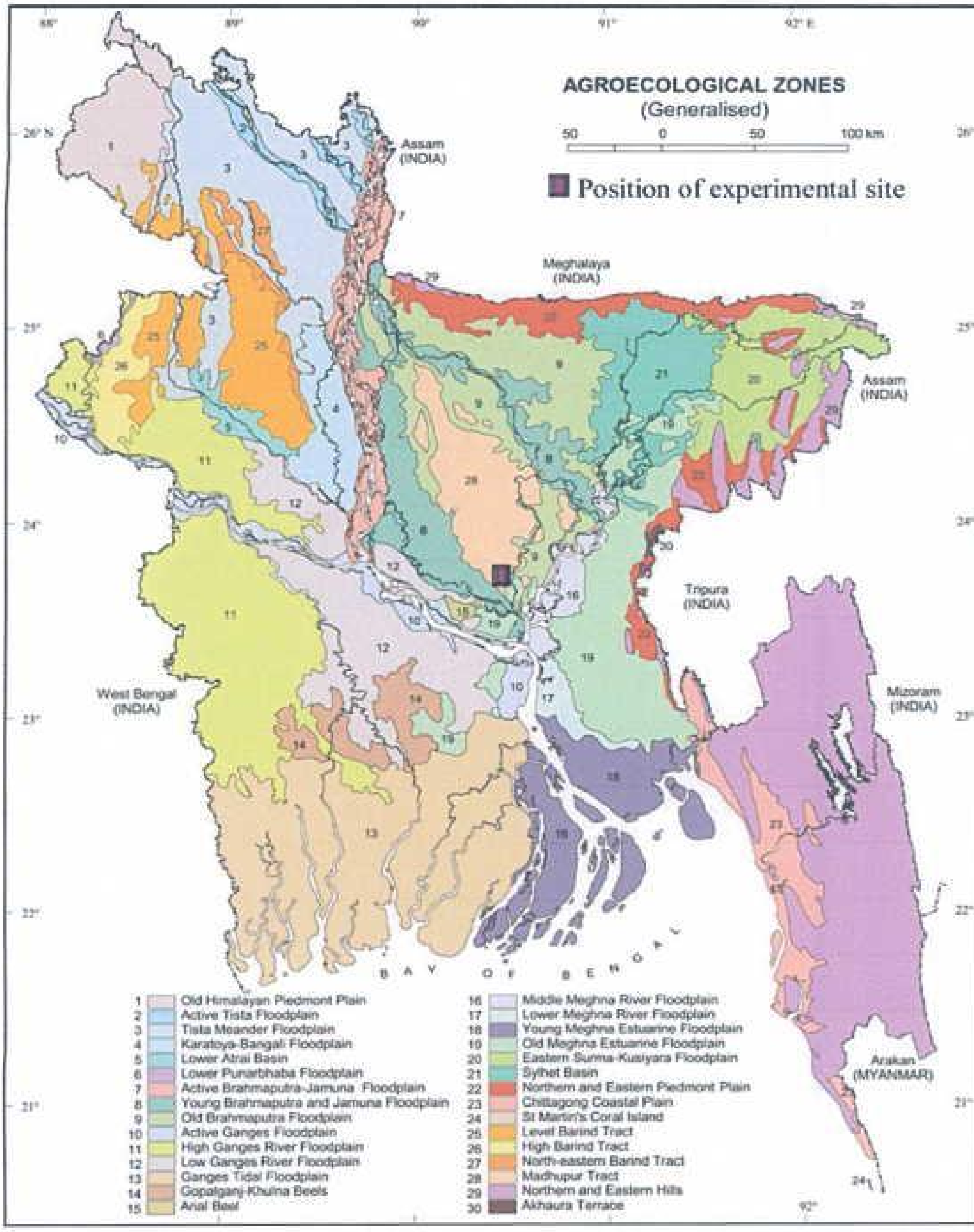
Appendices

APPENDICES

Appendix I (a). Map showing the experimental site under study



Appendix I(b). Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace.
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(SAU Farm, Dhaka)

Appendix I(c). Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions:	
% Sand (2.0-0.02 mm)	22.26
% Silt (0.02-0.002 mm)	56.72
% Clay (<0.002 mm)	20.75
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic Matter (%)	1.09
Total N (%)	0.028
Available K (ppm)	15.625
Available P (ppm)	7.988
Available S (ppm)	2.066

(SAU Farm, Dhaka)

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (April, 2014 to July, 2014) at Sher-e-Bangla Agricultural University

Month	Average air temperature (^{0} C)			Average relative humidity (%)	Total Rainfall (mm)	Total sunshine (hours)
	Maximum	Minimum	Mean			
April	33.2	25.81	29.51	79.10	351	229.30
May	33.44	26.29	29.87	80.78	680	215.12
June	33.32	26.40	29.86	87.45	853	206.50
July	32.08	25.33	28.71	89.13	942	223.30

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

Appendix III. Analysis of variance of the data on plant height plant^{-1} of BARI Til-4 as influenced by different levels of sulfur and boron fertilizers

Sources of variation	Degrees of freedom	Mean square values				
		Plant height (cm)				
		30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
Replication	2	94.489	739.621	1491.975	3207.809	670.061
Factor A (Sulfur doses)	3	232.165	688.840	398.388	636.782	2263.087
Factor B (Boron doses)	3	36.743	42.797	59.809	56.029	496.195
A X B	9	7.998	7.764	7.243	8.133	289.318

Appendix IV. Analysis of variance of the data on number of leaves plant^{-1} of BARI Til-4 as influenced by different levels of sulfur and boron fertilizers

Sources of variation	Degrees of freedom	Mean square values				
		Number of leaves plant^{-1}				
		30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
Replication	2	11.536	13.697	91.343	441.726	261.556
Factor A (Sulfur doses)	3	1.541	8.521	140.002	126.856	103.263
Factor B (Boron doses)	3	2.463	1.699	19.340	13.576	6.887
A X B	9	2.551	0.208	0.596	1.036	0.685
Error	30	0.957	4.393	53.667	208.452	137.689

Appendix V. Analysis of variance of the data on number of branches plant^{-1} of BARI Til-4 as influenced by different levels of sulfur and boron fertilizers

Sources of variation	Degrees of freedom	Mean square values			
		Number of branches per plant			
		40 DAS	50 DAS	60 DAS	At Harvest
Replication	2	1.101	0.123	0.600	0.466
Factor A (Sulfur doses)	3	8.767	2.590	2.491	2.781
Factor B (Boron doses)	3	0.511	0.387	0.499	0.124
A X B	9	0.103	0.074	0.085	0.118
Error	30	0.322	0.258	0.467	0.397

Appendix VI. Analysis of variance of the data for crop growth and yield characters of BARI Til-4 as influenced by different levels of sulfur and boron at harvest

Sources of variation	Degrees of freedom	Mean square values						
		Leaves fresh weight(g) $plant^{-1}$	Leaves dry weight(g) $plant^{-1}$	Stem fresh weight(g) $plant^{-1}$	Stem dry weight(g) $plant^{-1}$	Capsule per plant	Seeds per capsule	1000 seed weight(g)
Replication	2	146.369	12.352	39.331	160.237	54.974	22.110	0.453
Factor A (Sulfur doses)	3	170.429	22.372	2192.988	307.865	91.259	121.668	0.536
Factor B (Boron doses)	3	26.906	2.365	234.245	34.182	4.391	27.949	0.064
A X B	9	3.217	0.936	52.475	7.563	0.284	5.742	0.010
Error	30	9.164	2.830	11.167	1.431	52.848	57.264	0.048

Appendix VII. Analysis of variance of the data of different crop yield characters of BARI Til-4 as influenced by different levels of sulfur and boron fertilizers

Sources of variation	Degrees of freedom	Mean square values						
		Pod fresh weight(g) plant^{-1}	Seed dry weight(g) plant^{-1}	Stover dry weight(g) plant^{-1}	Seed-Stover Ratio (%)	Seed yield (ton ha^{-1})	Stover yield (ton ha^{-1})	Biological yield (ton ha^{-1})
Replication	2	0.017	0.003	0.006	3.773	0.002	0.003	0.010
Factor A (Sulfur doses)	3	289.801	9.328	23.650	504.492	1.451	9.971	18.459
Factor B (Boron doses)	3	15.212	1.455	1.839	56.934	0.090	1.097	1.807
A X B	9	2.562	0.133	0.211	54.303	0.023	0.101	0.092
Error	30	2.926	0.004	0.004	2.368	0.001	0.004	0.004

Appendix VIII. Analysis of variance of the data (%) for harvest index, oil content and S concentration of BARI Til-4 as influenced by different sulfur and boron levels

Sources of variation	Degrees of freedom	Mean square values		
		Harvest Index (%)	Oil Content in Seed (%)	Sulfur Conc. in Seed (%)
Replication	2	0.284	88.831	0.000
Factor A (Sulfur doses)	3	76.886	33.024	0.011
Factor B (Boron doses)	3	1.459	1.685	0.001
A X B	9	3.412	0.138	0.001
Error	30	0.248	3.322	0.000

Appendix IX(a). Effect of sulfur on plant height and number of leaves plant^{-1} of BARI Til-4 (mean of 4 treatments)

Treatment	Plant height (cm)					Number of leaves plant^{-1}				
	30 DAS	40 DAS	50 DAS	60 DAS	At Harvest	30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
S_0	56.63 d	84.30 d	103.2 d	120.7 d	135.9 d	11.88 b	21.08 c	48.92 d	103.1 c	119.1 c
S_1	59.68 c	87.91 c	108.2 c	129.5 c	158.1 c	12.42 ab	21.87 b	51.43 c	106.2 b	120.9 bc
S_2	62.63 b	94.16 b	112.5 b	134.3 b	161.4 b	12.67 a	22.52 a	54.06 b	108.3 ab	122.8 b
S_3	66.96 a	101.6 a	116.6 a	137.4 a	167.3 a	12.62 a	23.03 a	56.86 a	110.7 a	125.9 a
$LSD_{(0.05)}$	1.591	1.423	1.537	1.694	2.817	0.7116	0.581	1.883	2.663	2.396
CV (%)	8.30	4.61	4.53	4.63	10.4	7.89	9.47	13.87	13.48	9.61
Level of significance	*	*	*	*	*	*	*	*	*	*

Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

* - Significant at 5 % level

Appendix IX(b). Effect of boron on plant height and number of leaves plant^{-1} of BARI Til-4 (mean of 4 treatments)

Treatment	Plant height (cm)					No. of leaves per plant				
	30 DAS	40 DAS	50 DAS	60 DAS	At Harvest	30 DAS	40 DAS	50 DAS	60 DAS	At Harvest
B_0	59.20 c	89.81 c	107.3 c	129.3 b	146.9 c	11.78 b	21.78 b	51.33 b	105.8	121.2
B_1	61.38 b	91.34 b	109.7 b	128.1 b	154.8 b	12.67 a	21.87 b	52.22 a	106.7	121.9
B_2	63.43 a	94.28 a	112.7 a	132.4 a	160.8 a	12.80 a	22.60 a	53.77 a	108.2	122.9
B_3	61.88 ab	92.50 b	110.8 b	132.3 a	160.2 a	12.33 ab	22.25 ab	53.97 a	107.6	122.6
$LSD_{(0.05)}$	1.591	1.423	1.537	1.694	2.817	0.7116	0.581	1.883	2.663	2.396
CV (%)	8.30	4.61	4.53	4.63	10.4	7.89	9.47	13.87	13.48	9.61
Level of significance	*	*	*	*	*	*	*	*	NS	NS

Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

* - Significant at 5 % level

NS- Not significant

Appendix X(a). Effect of sulfur on different crop growth and yield contributing characters of BARI Til-4 (mean of 4 treatments)

Treatment	Number of branches per plant				Capsule per plant	Seeds per capsule	1000 seed weight(g)
	40 DAS	50 DAS	60 DAS	At Harvest			
S_0	1.858 c	3.133 c	3.667 c	4.175 c	58.66 d	58.40 d	3.053 c
S_1	2.783 b	3.308 bc	4.192 b	4.575 b	60.56 c	61.25 c	3.215 bc
S_2	3.150 b	3.617 b	4.483 ab	4.992 a	63.20 b	62.88 b	3.348 b
S_3	3.917 a	4.192 a	4.725 a	5.275 a	64.88 a	66.02 a	3.552 a
$LSD_{(0.05)}$	0.581	0.4109	0.4309	0.3898	1.363	0.9001	0.1837
CV (%)	19.38	14.27	16.02	13.26	11.76	12.18	6.64
Level of significance	*	*	*	*	*	*	*

Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

* - Significant at 5 % level

Appendix X (b). Effect of boron on different crop growth and yield contributing characters of BARI Til-4 (mean of 4 treatments)

Treatment	Number of branches per plant				Capsule per plant	Seeds per capsule	1000 seed weight(g)
	40 DAS	50 DAS	60 DAS	At Harvest			
B_0	2.683 b	3.367 c	4.033 c	4.658 b	61.13 c	60.32 c	3.204
B_1	2.842 b	3.467 bc	4.158 bc	4.850 a	61.55 bc	61.51 b	3.263
B_2	3.150 a	3.767 a	4.450 a	4.675 b	62.49 a	63.74 a	3.369
B_3	3.033 a	3.650 ab	4.425 ab	4.833 a	62.13 ab	62.99 a	3.332
$LSD_{(0.05)}$	0.1837	0.2598	0.2905	0.1233	0.8319	0.9001	0.1837
CV (%)	19.38	14.27	16.02	13.26	11.76	12.18	6.64
Level of significance	*	*	*	*	*	*	NS

Note: $B_0 = 0$ kg ha^{-1} (control), $B_1 = 1$ kg ha^{-1}, $B_2 = 1.5$ kg ha^{-1}, $B_3 = 2$ kg ha^{-1}

* - Significant at 5 % level

NS- Not significant

Appendix XI(a). Effect of sulfur on different crop parameters weight of BARI Til-4 (mean of 4 treatments)

Treatment	Leaves fresh weight(g) $plant^{-1}$	Leaves dry weight(g) $plant^{-1}$	Stem fresh weight(g) $plant^{-1}$	Stem dry weight(g) $plant^{-1}$	Pod fresh weight(g) $plant^{-1}$	Seed dry weight(g) $plant^{-1}$	Stover dry weight(g) $plant^{-1}$	Seed - stover ratio(%)
S_0	18.24 d	7.287 c	63.97 d	24.16 d	27.12 d	4.139 d	4.323 d	96.14 a
S_1	21.00 c	8.189 bc	70.07 c	26.64 c	29.27 c	4.892 c	5.450 c	89.97 b
S_2	23.33 b	8.887 b	80.64 b	30.46 b	32.92 b	5.376 b	6.424 b	83.67 c
S_3	27.14 a	10.52 a	94.82 a	35.79 a	38.35 a	6.242 a	7.620 a	81.90 d
$LSD_{(0.05)}$	1.212	0.9095	1.273	0.7686	0.9011	0.1837	0.225	0.8618
CV (%)	13.5	19.29	4.32	4.09	5.36	1.16	1.01	1.75
Level of significance	*	*	*	*	*	*	*	*

Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

* - Significant at 5 % level

Appendix XI(b). Effect of boron on different crop parameters weight of BARI Til-4 (mean of 4 treatments)

Treatment	Leaves fresh weight(g) plant^{-1}	Leaves dry weight(g) plant^{-1}	Stem fresh weight(g) plant^{-1}	Stem dry weight(g) plant^{-1}	Pod fresh weight(g) plant^{-1}	Seed dry weight(g) plant^{-1}	Stover dry weight(g) plant^{-1}	Seed - stover ratio(%)
B_0	20.89 b	8.237 b	72.13 c	27.24 c	30.52 c	4.771 d	5.417 c	90.23 a
B_1	21.50 b	8.601 ab	75.32 b	28.51 b	31.83 b	4.993 c	5.918 b	85.28 d
B_2	23.15 a	9.306 a	80.82 a	30.55 a	33.27 a	5.332 b	6.193 a	87.12 c
B_3	24.16 a	8.738 ab	81.24 a	30.75 a	32.03 b	5.553 a	6.289 a	89.05 b
$LSD_{(0.05)}$	1.212	0.9095	1.273	0.7686	0.9011	0.1837	0.225	0.8618
CV (%)	13.5	19.29	4.32	4.09	5.36	1.16	1.01	1.75
Level of significance	*	*	*	*	*	*	*	*

Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

* - Significant at 5 % level

Appendix XII(a). Effect of sulfur on crop yield and percentage of harvest index, oil content and S concentration of BARI Til-4 (mean of 4 treatments)

Treatment	Seed Yield (ton ha^{-1})	Stover Yield (ton ha^{-1})	Biological Yield (ton ha^{-1})	Harvest Index (%)	Oil Content in Seed (%)	Sulfur Conc. in Seed (%)
S_0	0.6350 d	4.564 d	5.199 d	12.18 c	40.49 d	0.1008 c
S_1	0.7250 c	5.462 c	6.187 c	11.72 c	43.05 c	0.1159 bc
S_2	0.9392 b	6.043 b	6.982 b	13.44 b	43.72 b	0.1355 b
S_3	1.413 a	6.714 a	8.129 a	17.34 a	44.22 a	0.1704 a
$LSD_{(0.05)}$	0.08217	0.1837	0.2054	0.4861	0.225	0.03437
CV (%)	3.6	1.16	1.01	3.64	4.25	2.92
Level of significance	*	*	*	*	*	*

Note: S_0 = 0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2= 20 kg ha^{-1}, S_3= 30 kg ha^{-1}

* - Significant at 5 % level

Appendix XII(b). Effect of boron on crop yield and percentage of harvest index, oil content and S concentration of BARI Til-4 (mean of 4 treatments)

Treatment	Seed Yield (ton ha^{-1})	Stover Yield (ton ha^{-1})	Biological Yield (ton ha^{-1})	Harvest Index (%)	Oil Content in Seed (%)	Sulfur Conc. in Seed (%)
B_0	0.8183 c	5.322 c	6.142 c	13.23 b	42.35 c	0.1211
B_1	0.9033 b	5.586 b	6.489 b	13.67 ab	42.87 b	0.1265
B_2	1.015 a	5.989 a	7.004 a	14.04 a	43.20 a	0.1443
B_3	0.9758 ab	5.886 a	6.862 a	13.85 a	43.08 ab	0.1308
$LSD_{(0.05)}$	0.08217	0.1837	0.2054	0.4861	0.225	0.03437
CV (%)	3.6	1.16	1.01	3.64	4.25	2.92
Level of significance	*	*	*	*	*	NS

Note: B_0 = 0 kg ha^{-1} (control), B_1 = 1 kg ha^{-1}, B_2 = 1.5 kg ha^{-1}, B_3 = 2 kg ha^{-1}

* - Significant at 5 % level

NS- Not significant