INFLUENCE OF SULPHUR AND BORON ON THE GROWTH, YIELD AND OIL CONTENT OF BARI SOYBEAN-6 (*Glycine max* L.)

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June, 2017

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REGISTRATION NO. 11-04659

A Thesis
Submitted to the Faculty of Agriculture, Dept. of Soil Science
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

SOIL SCIENCE

SEMESTER: January - June, 2017

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CERTIFICATE

This is to certify that the thesis entitled, ***"INFLUENCE OF SULPHUR AND BORON ON THE GROWTH, YIELD AND OIL CONTENT OF BARI SOYBEAN-6 (Glycine max L.)"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***SOIL SCIENCE,*** *embodies the result of a piece of bona fide research work carried out by* ***MST. FARHANA SIDDIKI****, Registration No.* ***11-04659*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Place: Dhaka, Bangladesh

(Prof. Mst. Afrose Jahan)

Supervisor

Dedicated to

My Beloved Parents

ACKNOWLEDGEMENTS

All praises are due to Omnipotent"Allah Rabbul Al-Amin" Who enabled me to pursue higher study and to complete the research work as well as to submit the thesis for the degree of Master of Science (M.S.) in Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

I would like to express my heartfelt respect, deepest sense of gratitude, profound appreciation and ever indebtedness to my supervisor, ***Professor Mst. Afrose Jahan,*** *Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism, extending generous help and constant inspiration throughout the course and in preparation of the manuscript of thesis.*

I express my sincere respect to my Co-supervisor, ***Professor Dr. Alok Kumar Paul*** *Department of Soil Science, Sher-e-Bangla Agricultural University, (SAU), Dhaka for his utmost co-operation, constructive suggestion to conduct the research work as well as preparation of the manuscript of thesis.*

I express my sincere respect to the Chairman, ***Dr. Saikat Chowdhury*** *and all the teachers of Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

I express my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my parents, also pleasant to my brothers and my husband whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study.

Place: Dhaka
Dated: The June 2018

ABSTRACT

The experiment was conducted during the period from November, 2016 to April 2017 to Influence of sulphur and boron on the growth, yield and oil content of BARI Soybean-6 (*Glycine max L.)*. In this experiment, the treatment consisted of four Levels of sulphur viz. 0 kg S ha^{-1} (control), 10 kg S ha^{-1}, 20 kg S ha^{-1}, 40 kg S ha^{-1} and three levels of boron viz. 0 kg B ha^{-1} (control), 1.0 kg B ha^{-1} and 2 kg B ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters. Different levels of sulphur showed significant variation on all parameters of soybean. The maximum number of pods plant^{-1}, and number of seeds pod^{-1} was recorded from 40 kg S ha^{-1}. The highest seed yield (1.93 t ha^{-1}) was observed from 40 kg S ha^{-1}. The maximum number of pods plant^{-1}, number of seeds pod^{-1} and number of seeds pod^{-1} was attained from 2 kg B ha^{-1}. Interaction effect of different levels of sulphur and boron showed significant variation on all parameters of BARI soybean 6. The highest seed yield (1.85 t ha^{-1}) was recorded from 2 kg B ha^{-1}. The highest seed yield (1.99 t ha^{-1}) was found from 40 kg S ha^{-1} and 2 kg B ha^{-1}. The combined use of 40 kg S/ha and 2 kg B/ha along with recommended doses of other fertilizer would be beneficial to increase the seed yield of soybean variety BARI soybean 6.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.*)* belongs to the family Leguminosae, sub-family papilionidae is one of the leading oil and protein containing crops of the world. The crop is cultivated in about 90.19 million hectare of land with annual production of 220.5 metric ton in the world (FAO, 2009). As a grain legume crop it is gaining an important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh. In Bangladesh, soybean is called the *Golden bean*. It is considered as miracle crop of 20th Century on account of having high protein and oil content. It contains lysine comparable with cow milk. Soybean oil is either directly used as edible oil or for manufacturing of vanaspati ghee. It is widely used in variety of foods and also in production of different antibiotics. Tripsin inhibitor is a major anti –nutritional factor in soybean. Soybean grain contains 29.6-50.3% protein, 13.5-24.2% fat and 3.3-6.4% ash (Purseglove, 1984) and 24-26% carbohydrate (Gowda and Kaul, 1982). Besides, it also contains various vitamins and minerals. It provides around 60% of the world supply of vegetable protein and 30% of the oil (Fehr, 1989). It also meets up different nutritional needs. Furthermore, soybean oil is cholesterol free and is easily acceptable in our daily diet.

There are 17 essential elements, among them some elements required in relatively high amounts, are called macronutrients and some in trace amounts are called micronutrients. Micronutrients play an important role in increasing yield of pulses and oilseed legumes through their effects on the plant itself and on the nitrogen fixing symbiotic process. While micronutrients are required in relatively smaller quantities for plant growth, they are as important as macronutrients for the plants and if any element is lacking in the soil or not adequately balanced, growth suppression or even complete inhibition may result (Mengel *et al.*, 2001). Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration and their deficiency can impede vital physiological processes thus limiting yield (Marschner, 1995).

Sulphur plays a pivotal role in various plant growth and development processes being a constituent of sulphur containing amino acids and other metabolites. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. The role of sulphur in the seed production of soybean has been reported by several investigators (Dubey and Billore, 1995; Fontanive *et al*., 1996). Among the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). Application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and quality of soybean grain in sulphur deficient soil (Kandpal and Chandel, 1993). Kedar and Rajendra (2003) found that sulphur at 30 kg ha^{-1} treated had higher number of grains per plant which was 24.18% higher than the control. Sulphur is involved in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine (Havlin *et al*., (1999). In soybean Bhuiyan *et al*., (1998) found that application of sulphur at 20 kg per ha produced the highest seed yield, but Mohanti *et al*., (2004) reported sulphur at 30 kg ha^{-1} produced the highest seed yield. Soybean requires an adequate supply of available sulphur, especially during flowering and seed development.

World-wide, boron deficiency is more extensive than any other plant micronutrients (Gupta, 1979). Boron deficiency in soybean was first documented in some soybean producing areas in Arkansas (Slaton et al., 2002). Boron deficiency is the second most widespread micronutrients problem globally (Alloway, 2008). Boron belongs to the metalloid group of element which shows intermediate properties between metals and non-metals. It is one of the essential micronutrient required by the plant in very small quantity. Total B in Indian soils has been found to vary from 7 to 630 mg kg^{-1}.Boron is directly involved in several physiological and bio-chemical processes during plant growth (Yamagishi and Yamamoto, 1994) and (Shelp, 1993).The possible roles of B include sugar transport, cell wall synthesis, lignifications, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes (Ahmad et al., 2009). Dubey (1996) reported that major role of boron in plants is also to maintain the membrane integrity and cell wall development, which affects permeability, cell-division and its extension more over to this boron, is responsible for pollen tube growth in soybean crop. It increases the solubility of calcium as well as mobility of calcium in plants. He also reported boron is required for development of new cells in meristematic tissue. Boron is necessary for proper pollination and fruit or seed setting, helps in preserving membrane stability of cells, increase ion transport capacity, and is involved in pollen germination (Al-Molla, 1985). Boron is absorbed by roots as undissociated boric acid [$B(OH)_3$ or H_3BO_3] (Mengel & Kirkby, 1982; Marschner, 1995). Among the elements required by plants, B is the only element that is taken up by plants as an uncharged molecule (Miwa and Fujiwara, 2010).

Boron deficiency causes several physiological disorders and diseases such as brown heart of turnip, heart rot of sugar beet, dry rot of marigold, cracked stem of celery and brown rot of cauliflower which reduces the yield of crops severely. Structural damage described as cracked stem of celery, stalk rot of cauliflower, heart rot and internal black spot of beets, top rot of tobacco, internal cork of apples, and yellows of alfalfa was attributed to boron deficiency by Gauch and Dugger (1954). The symptoms of toxicity are fruit disorders (gummy nuts, internal necrosis), bark necrosis which appears to be plant.

Under the above perspective and above all situation the present experiment was conducted with different levels of sulphur and boron on BARI soybean-6 with the following objectives:

A. To find out the effect of S and B on growth and yield of BARI soybean- 6;
B. To obtain optimum dose of S and B for maximizing yield of BARI soybean- 6;
C. To identify combined effect of S and B and oil content in seed due to the application of different level of S and B.

CHAPTER II

REVIEW OF LITERATURE

Soybean is one of the leading oil and protein containing crops of the world. The crop has conventional less attention by the researchers on various aspects because normally it grows with minimum care or management practices. However, researches are going on in home and abroad to maximize the yield of soybean with different management practices especially on NPK fertilizer, spacing, variety, weeding, biofertilizers etc, but not other macro and micro nutrients. Sulphur and boron play an important role in improving soybean growth and yield. But research works related to sulphur and boron fertilizer are limited in Bangladesh context. However, some of the important and informative works and research findings related to the sulphur and boron so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Sulphur on plant growth, yield attributing characters and yield

A field experiment on "sulphur nutrition in soybean" was carried out by Hosmath *et al*. (2014) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, India. To workout the optimum sulphur dose the treatments comprised of four sulphur levels (0, 10, 20, 30, and 40 kg ha^{-1}). Pooled data revealed that the soybean seed yield was significantly increased with the application of sulphur @ 20 kg ha^{-1} (2534 kg ha^{-1}) compared to sulphur levels; 30 kg ha^{-1} (2494 kg ha^{-1}), 40 kg ha^{-1} (2376 kg ha^{-1}) and 10 kg ha^{-1} (2226 kg ha^{-1}).

A field experiment was conducted by Akter *et al*. (2013) at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh to evaluate the effect of P and S (viz. 0, 10, 20, 40 kg S ha^{-1}) and their interaction on the growth and yield of soybean. Application of different levels of sulphur showed significant effect on yield and yield attributes studied. In case of S, the positive response was observed only upto 20 kg S ha^{-1}. Application of sulphur @ 20 kg S ha^{-1} gave rise to the highest number of pods $plant^{-1}$ (30.07), number of seeds $plant^{-1}$ (84.94), thousand seed weight (94.61 g), and in turn produced highest seed yield (2.29 t ha^{-1}).

A field experiment was conducted by Yadav *et al*. (2013) at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh to know the effect of phosphorus and sulphur on oil content, nutrient uptake and quality of summer soybean. Result of the experiment revealed that the levels of sulphur @ 30 kg ha^{-1} showed significantly highest content and uptake in grain and stover.

Pable and Patil (2011) studied the effect of sulphur and zinc on nutrient uptake and yield of soybean var. JS 335 crop on Vertisol. The different doses of sulphur were applied singly with recommended dose of fertilizer and along with constant dose of zinc also. Results indicated that application of 30 kg S ha^{-1} and 2.5 kg Zn ha^{-1} with fertilizer dose of 30:75:0 kg NPK ha^{-1} recorded higher seed yield and straw yield. Total uptake of nutrients and micronutrients was recorded significantly highest in same treatment after harvest of crop.

Farhad *et al*. (2010) conducted a field experiment was at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207 to study the role of potassium and sulphur on the growth, yield and oil content of soybean. The experimental soil was clay loam in texture having pH of 6.3. The experiment included four levels of potassium viz. 0, 20, 40 and 70 kg K ha^{-1} and four levels of sulphur viz. 0, 10, 20 and 40 kg S ha^{-1}. Application of of sulphur @ 20 kg ha^{-1} produced the highest plant height, seed yield, 1000-seed weight and straw yield.

A pot culture experiment was conducted by Arunageeta *et al.* (2006) at a glasshouse in the Department of Agricultural Microbiology, Tamil Nadu, India, on a clay loam soil with four levels of S as 0, 7.5, 15 and 30 kg ha^{-1} in the presence and absence of *Bradyrhizobium.* Data revealed that the number of pods $plant^{-1}$ (51.7) and seed yield (2295 g pot^{-1}) were recorded with 30 kg S ha^{-1}.

Manchanda *et al.* (2006) conducted a field experiment in Ludhiana, Punjab, India, on a loamy sand soil to study the effects of S fertilizer with 0, 7.5, 15.0 and 30 kg S/ha as gypsum on soybean cv. SL 295. The grain yield of soybean increased by 23.1 and 30.5% over the control with application of 7.5 and 15.0 kg S/ha, respectively. The availability of Zn, Cu, Fe and Mn in soil, and the concentrations of these nutrients increased significantly due to S application.

A pot culture experiment was carried out by Vijayapriya *et al*. (2005) with soybean in a glasshouse on a clay loam soil deficient in available S. The treatments consisted of four levels of S as 0, 7.5, 15, 30 kg ha^{-1}. They reported that nutrient availability of nutrients were significantly influenced by the addition of S compared to the control. The nutrient availability were significantly higher in plants the availability of N, P, K and S was the highest at 30 kg S ha^{-1}.

A field experiment was conducted by Arshad *et al. (*2005) in New Delhi, India to assess the growth characteristics, seed and oil yield of two cultivars of soyabean (G. max), i.e. PK-416 (V1) and PK-1024 (V2), in relation to sulfur and nitrogen nutrition. Six combinations of two levels of sulfur (0 and 40 kg ha^{-1}) and two levels of nitrogen (23.5 and 43.5 kg ha^{-1}) were applied. Results indicated significant effect of sulfur and nitrogen, when applied together, on the growth characteristics, yield components, and seed and oil yield. Maximum response was observed with treatment with 40 kg S and 43.5 kg N ha^{-1}. The results obtained in these experiments clearly suggest that balanced and judicious application of nitrogen and sulfur can improve both seed and oil yield of soyabean cultivars by enhancing their growth.

Gokhale *et al*. (2005) conducted a field experiment to study the effect of different S levels as 0, 10, 20, 30, 40 and 50 kg ha^{-1} on soybean in Maharashtra, India. Application of increasing S levels up to 30 kg ha^{-1} increased the seed yields over the control. Thus, the highest soybean yield of 25.1 q ha^{-1} was observed at 30 kg S ha^{-1}. Treatments with 40 and 50 kg S ha^{-1} slightly reduced the yields as the soil under study was marginally low in S content (9.6 mg kg^{-1}) which showed responses to lower S levels. S application increased N and S availability in soil. Oil contents in soybean increased with increasing S levels up to 30 kg ha^{-1}. Thereafter, 40 and 50 kg S ha^{-1} showed a declining trend. Available N and S contents in the soil also increased with increasing S levels applied to soybean.

The effects of S rate (0, 10, 20 or 30 kg ha^{-1}) and source (50% through ammonium sulfate + 50% through elemental S or compound fertilizer 13-33-0-15S) on the performance of soyabean (cv. JS 335) grown on Typic Haplusterts and on soil properties were studied in Indore, Madhya Pradesh, India, by Sharma *et al.* (2004) and observed that the values of the evaluated parameters increased as the S rate increased and when the compound fertilizer was applied. Thus, 30 kg S ha^{-1} supplied resulted in the highest number of pods $plant^{-1}$ (50.0), number of seeds pod^{-1} (2.08), 100-grain weight (11.94 g), grain yield (1747 kg ha^{-1}), straw yield (2214 kg ha^{-1}) and oil content (20.19%).

Sangale *et al*. (2004) conducted a field experiment to investigate the effects of S fertilizer sources (single super phosphate, elemental S and gypsum) and levels (0,10 and 20 kg ha^{-1}) on the seed yield, quality and S uptake of soybean cv. JS 335 grown on deep black soil in the Marathwada region of Maharashtra, India. Gypsum and single super phosphate were given at the time of sowing whereas elemental S was applied 15 days before sowing. Application of S at 20 kg ha^{-1} gave highest yield.

Mohanti *et al*. (2004) conducted a field experiment at Raipur, Chhattisgarh, India to evaluate the effects of different levels of S as 0, 10, 20 and 30 kg ha^{-1} and B on soybean cv. JS-335. Data were recorded for plant height, number of branches $plant^{-1}$ and seed yield. S at 30 kg ha^{-1} recorded the highest values for these parameters. Net realization per investment was highest with S at 20 kg ha^{-1}, followed by S at 30 kg ha^{-1}.

A pot culture experiment was conducted by Praharaj *et al.* (2003) using a clay loam soil to investigate the effect of S application *and Bradyrhizobium japonicum* inoculation on nodulation, nitrogenase activity and yield of soyabean cv. CO_1. Sulfur was applied as 0, 7.5, 15.0 and 30.0 kg ha^{-1} through gypsum with or without *B. japonicum* inoculation. With increasing levels of S, there was gradual increase in seed yield.

Singh *et al*. (2001) conducted a field experiment in New Delhi, India to assess the growth characteristics, seed and oil yield of two cultivars of soybean, in relation to sulfur and nitrogen nutrition. Six combinations of two levels of sulfur (0 and 40 kg ha^{-1}) and two levels of nitrogen (23.5 and 43.5 kg ha^{-1}) were applied as nutrients. Results indicated significant effect of sulfur and nitrogen, when applied together, on the growth characteristics, yield components, and seed and oil yield. Maximum response was observed with 40 kg S and 43.5 kg N ha^{-1}.

A field experiment was conducted by Tomar *et al.* (2000) at College of Agriculture, Indore, Madhya Pradesh, India, to study the effect of various levels and sources of sulfur on yield and biochemical composition of soybean. The treatments comprised 5 levels of S as10, 20, 30, 40 and 50 kg ha^{-1} and 3 sources, sulfur, along with an absolute control. Findings revealed that the highest seed yield, protein and oil content of 2257 kg ha^{-1}, 41.29% and 20.51%, respectively, were recorded with the application of 50 kg S ha^{-1} regardless of sources.

Mohan and Sharma (1991) observed that S @ 75 kg ha^{-1} significantly increased primary and secondary branches $plant^{-1}$. Sulphur @ 50 kg ha^{-1} increased the plant height significantly. Saran and Giri (1990) reported from a couple of experiments that branches plant^{-1} significantly increased with 60 kg ha^{-1} of S. Number of pods influenced the plant growth and attributes. They found that height and primary branches plant^{-1}, number of seeds plant^{-1}, number of leaves plant^{-1}and 1000 seed weight were also increased significantly with 60 kg ha^{-1} of S.

2. 2 Effect of boron levels on plant growth and yield of soybean

Jeaniche *et al.* (1996) reported that boron deficiency may cause yellow leaves, chlorosis between veins, downward curling of leaf tips, crinkling of leaves, dieback of tips, no flowering and stunted roots. However, Huang et al. (1996) reported in wheat, that youngest emerged leaves expanded normally even though the leaves had less than 2 mg B kg^{-1} dry matter. Similarly, Bell (1997) observed boron requirements for plant growth vary with plant species.

Eguchi (2000) investigate the effect of boron on growth. The results showed that visual symptoms were not observed in the boron-deficient plot until the period of terminal leaf development and the leaves remained green during the harvesting stage in the boron-deficient plot, delay of maturity was clearly observed.

observed in the boron-deficient plot compared with the boron-treated plot. Similarly, Benton (2003) reported boron is characterized by normal or retarded elongation of apical meristem.

Sinha and Chatterjee (2003) found that boron deficiency in soybean depressed growth, biomass, pod and seed yield, concentration of boron and ribonuclease activity in leaves and increased the peroxides, acid phosphates and starch phosphorylase. The quality of seeds deteriorated with low boron as reflected in decreased content of boron, starch, protein and oil along with stimulated concentration of sugars and phenols. Studies also showed that B increased main stem length volume and dry weight of the roots above ground biomass leaves and photosynthesis rate of soybean,(Peng *et al*. 2003 and Liv *et al*. 2005).

Bolanos *et al*. (2004) observed that plant ability to adopt at high or low concentration of boron may depend on the germplasm, physiological mechanism and genetic diversity of species. Tanaka and Fujiwara, (2008) also observed that boron uptake by the roots is carried out by different molecular mechanisms. Whereas, Bozoglu *et al.* (2008) determining the effect of boron fertilization was on some agronomic characteristics of chickpea. This study designed with randomized completed blocks design with 3 replications. Boron (B_0:0, B_1:0.25 ppm, B_2:0.50 ppm) doses were been applied from leaf when the plants were in vegetative period. The effect of years was found to be statistically significant on characteristics expect for seed yield and ratio of seed above 9 mm sieve. The highest seed yields were found for B2 dose (1462.2 kg ha^{-1}).

Ahmad *et al*. (2009) reported Boron is considered as an essential element for plant growth and development. Sexual reproduction in plant is more sensitive to low B, than vegetative growth. Considerable research activities have been directed at accentuating the physiological and biochemical role of B in plant growth and development. This paper reviews of the literature (up to the year 2006) focusing on the role of boron in cell wall integrity, cell division, plasma membranes, phenol metabolism, and its requirement for the nitrogen fixation and in the reproductive growth of plants.

El-Yazied and Mady (2012) study the effect of separate and combined foliar applications of boron (0, 25 and 50 ppm) and yeast extracts (0, 2.5 and 5 ml/L) on growth, yield and some biochemical constituents. The results revealed that, foliar application with boron and yeast extract either individually or in a mixture, significantly stimulate many growth aspects as number of leaves per plant, dry weights of both stems and leaves per plant, total leaf area and absolute growth rate as compared with the control treatment. In addition, foliar spraying with boron at 50 ppm and yeast extract at 5 ml L^{-1} increased photosynthetic pigments, NPK, B, total sugars, total free amino acids and crude protein content in leaves at 70 and 85 days after sowing. Moreover, boron and yeast extract treatments not only increased auxins and cytokinins but also decreased abscissic acid at 75 days after sowing during second season. All treatments not only increased number of formed flowers, setted pods per plant, green pod and dry seed yields, as well as satisfactory effect upon shedding percentage, i.e. reduced it. Hence, it could be recommended that foliar spraying with boron at 50 ppm and yeast extract at 57 ml L^{-1} can be used to increase the final green pods and seed yield as well as seed quality of broad bean plants.

Arora *et al*. (2012) examined the optimum concentration of boron needed to mitigate the harmful effect of salinity at early establishment of seedlings including seed germination. The decrease was reverted with specific optimal concentration of B ($3X10^{-3}$ Mm) and based on maximum germination percentage.

However, Patil *et al*. (2012) studied the individual and combined effects of boron and salinity on soybean seed germination. The result revealed that the treatments of both NaCl and boron (5 ppm) delayed the germination .However higher concentration (50 and 100 ppm) of boron was found to be enhanced germination percentage over control by 10%. The combination of boron with NaCl specially 5 and 100 ppm Boron with 100 Mm NaCl) effectively mitigate the adverse effects of NaCl on germination of soybean seeds. In addition to it 50 mM NaCl concentration was found to be reduced the delayed effects of 5 ppm boron on germination.

Huang *et al*. (2012) investigated the effects of different phosphorous and boron treatments on soybean growth, P and B uptake, and the genetic variations at different growth stages in five soybean genotypes. The results showed different P and B treatments significantly affected soybean growth, and there were significant interactions between P and B. Among which, P availability was the primary factor on soybean growth and B uptake. At the same B level, increasing P availability could significantly increase soybean plant dry mass, grain yield and P, B uptake. At the normal P level, increasing B availability only increased plant dry mass and P, B uptake of the P efficient genotypes, but not the P inefficient genotypes, particularly at mature stage. Improving B status could significantly increase the yield of P efficient soybean genotypes.

Hajiboland *et al.* (2012) reported that boron (B) is a structural component of plant cell wall and boron deficiency causes disruption in development of plants. Visual boron deficiency symptoms were observed in all studied species including curling of leaf margins in turnip, reduction of red coloration in red cabbage, shoot stunting in tobacco and turning dark purple colors in celery, Hypertrophy of leaf parenchyma cells in tobacco and increased thickening of collenchyma cell walls in the stem of celery were also observed. They further reported anatomical alterations due to boron deficiency were more pronouncelly observed in the leaf blades followed by the petiole, stem and roots. Also found that remarkable disruptions occur in development of leaf primordia and vascular bundles upon boron starvation.

Rajni and Meitei (2004) determine the effect of foliar spraying of boron (0.5 and 1.0 ppm) and zinc (0.01 and 0.10 ppm) and their combinations with a control. They found that combined application of boron (1.0 ppm) and zinc (0.10 ppm) after 20 and 40 days of sowing of the seeds was found to be beneficial for growth in terms of plant height, leaf number, branch number and shoot weight, earliness, yield in terms of number, length, fresh weight, dry weight and percent dry matter of pod and number of seeds per pod. However, Shivpurkar et al. (2005) found that a significant increase in plant height, growth characters and total dry matter in soybean with the application of boron (0.5 and 10 kg ha^{-1}), 10 t ha^{-1} FYM and RDF (30 N: 60 P: 90 K).

Crak *et al*. (2006) examined the effect of soil and foliar application of boron (66.14% B_2O_3) at different rates (0, 0.5, 1, 1.5 and 2 kg ha^{-1}) on plant height, first pod height, pod $plant^{-1}$, boron content of seed, germination rate, 1000-seed weight of soybean during 2002-03. They reported that increasing boron rates applied either as soil or foliar improved yield (40%), first pod height (17%), boron content of seed (42%), germination rate (11%) and 1000-seed weight (5%) of soybean. For maximum yield, 1.09 kg ha^{-1} rate of boron was recommended).

Singh *et al*. (2011) study the effect of boron on plant height, fresh and dry plant weight at reproductive stage of pea at two fertility status namely F1 (30 mg P_2O_5+20 mg S+2.5 mg Zn, per kg soil) and F_2 (60 mg P_2O_5+40 mg S+5.0 mg Zn, per kg soil). The study reveals that plant height, fresh weight and dry weight of the plant at flowering and pod filling stage increased significantly with increasing levels of soil fertility in both the years. The micronutrients have shown significant impact on plant metabolism absorption and translocation of materials synthesis of essential macro and micro molecule and enzyme synthesis and their activity regulation.

Devi *et al.* (2012) evaluate the effects of foliar application of borax @ 0.1% solution on cabbage [Bassica oleracea (L.) var. capitata]. The growth in terms of plant height, leaf numbers, leaf length and fresh biomass production was affected by the boron levels. The foliar spray was done twice at 25 and 50 days after transplanting showed significant increase in plant height, number of leaves, shoot fresh weight, dry weight, root fresh weight and dry weight and yield. The head diameter was increased with application of borax.

Ross *et al*. (2006) determine the influence of B application on tissue B concentration and seed yield in Soybean. Boron fertilizer was applied at the rate of 0, 0.28, 0.56, 1.12, and 2.24 kg B ha^{-1} near the V_2 or R_2 growth stages. Boron fertilization had no significant effect on soybean yield at one site but increased seed yields from 4 to 130% at three sites. At the most responsive site, B application at V_2 increased yields by 13% compared with applications at R_2. In contrast, at a site where leaf B concentrations were sufficient for soybean receiving no B, B applied at the R2 stage significantly increased seed yields by 5% compared with V 2 B applications. Trifoliate leaf B concentrations at the R2 stage increased as B rate increased. Seed B concentrations also increased as B rate increased. Boron applied at the R2 stage resulted in equal or greater seed B concentrations than B applied at the V2 stage. Application of 0.28 to 1.12 kg B ha^{-1} during early vegetative or reproductive growth was sufficient to produce near maximal yields. The expected severity of B deficiency plus fertilizer and application costs associated with B fertilization should be considered when selecting the most appropriate B fertilization strategy. Kappes et al. (2008) also evaluate the effect of foliar application of boron on the agronomic characteristics, morphological characteristics and production components were determined.

Saxena and Nainwal (2010) evaluate the response of boron nutrition on yield attributes in kharif seasons of 2007 and 2008 with five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg B/ha). The effect of different doses of boron application on seed yield of soybean was significant. On mean performance basis, the application of 2.0 kg B per ha gave maximum yield.

Vaiyapuri *et al*. (2010) study the effect of boron fertilization on yield attributes of soybean. Application of B (0, 0.5, 1.0, 2.0 and 4.0 kg B ha-1 revealed that levels of B (1.5-2.0) kg ha-1 recorded better yield attributes (branches plant-1 , pods plant-1, seeds pod-1 and 100 seed weight) than other treatment.

Chaturvedi *et al.* (2012) reported that soybean yield attributed viz., pods/plant, seeds/pod and hundred seed weight were increased significantly by the addition of boron and FYM at the fertility levels of 50% and 100% NPK. However, Devi et al. (2012) study the effect of boron fertilization on yield of soybean at five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron ha^{-1}). The study revealed that number of branches per plant; pods per plant and 100 seed weight were increased with the application of boron as compare to control. The overall result revealed that application of 1.5 kg B ha^{-1} were found to be the optimum levels of boron for obtaining maximum yield attributes.

Singh *et al.* (2012) reported Influence of boron on yield attributes of soybean. There were 25 treatment combinations consisting of five rates of B (0, 0.5, 1.0, 2.0 and 4.0 kg B ha^{-1}). The results of the experiments revealed that application of 2.0 kg ha^{-1}recorded better yield attributes (branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and 100 seed weight and higher yield than the other treatments. Seidel and Basso (2012) also evaluated the effects of boron applied to leaf spraying at different stages of soybean, on yield components and productivity of soybean. Results showed that application of B did not influence soybean yield in any application stage and the yield components (pod number $plant^{-1}$, grain number pod $^{-1}$, grain weight) did not differ significantly with application to leaf spraying of B, probably due to their adequate content in soil and water availability during the growing season.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November, 2016 to April 2017 to study the Influence of sulphur and boron on the growth, yield and oil content of BARI Soybean-6 (*Glycine max L.)*. This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude.

3.2 Soil characteristics

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of sandy loam with pH and Cation Exchange capacity 5.6 and 2.64 meq 100 g $soil^{-1}$, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I.

3.3 Climate condition

The climate of experimental site is subtropical, characterized by three distinct seasons and the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

3.4 Planting material

The variety BARI Soybean-6 was used as the test crop. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.5 Land preparation

The land was irrigated before ploughing. After having 'joe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 26th November and 1st December, 2016, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment comprised of two factors

Factor A: Levels of sulphur (Gypsum) (4 levels)

i) S_0: 0 kg S ha^{-1} (control)

ii) S_1: 10 kg S ha^{-1}

iii) S_2: 20 kg S ha^{-1}

iv) S_3: 40 kg S ha^{-1}

Factors B: Levels of boron (Boric Acid) (3 levels)

i) B_0: 0 kg B ha^{-1} (control)

ii) B_1: 1.0 kg B ha^{-1}

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

There were in total 12 (4×3) treatment combinations such as S_0B_0, S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_2, S_2B_0, S_2B_1, S_2B_2, S_3B_0, S_3B_1 and S_3B_2.

3.7 Fertilizer application

Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, boric acid and molybdenum were used as a source of nitrogen, phosphorous, potassium, sulphur, boron and molybdenum, respectively. The fertilizers urea, TSP, MoP, and molybdenum were applied at the rate of 60, 175, 120 and 8 kg $hectare^{-1}$, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation (BARI, 2011). Sulphur and boric acid were applied as per treatment of the experiment. All of the fertilizers were applied in broadcast during final land preparation.

3.8 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 25.5 m × 12.4 m was divided into blocks. The size of the each unit plot was 2.8 m × 1.5 m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of soybean were sown on 1 December, 2016 in solid rows in the furrows having a depth of 2-3 cm , row to row distance was 30 cm and plant to plant 5-6 cm.

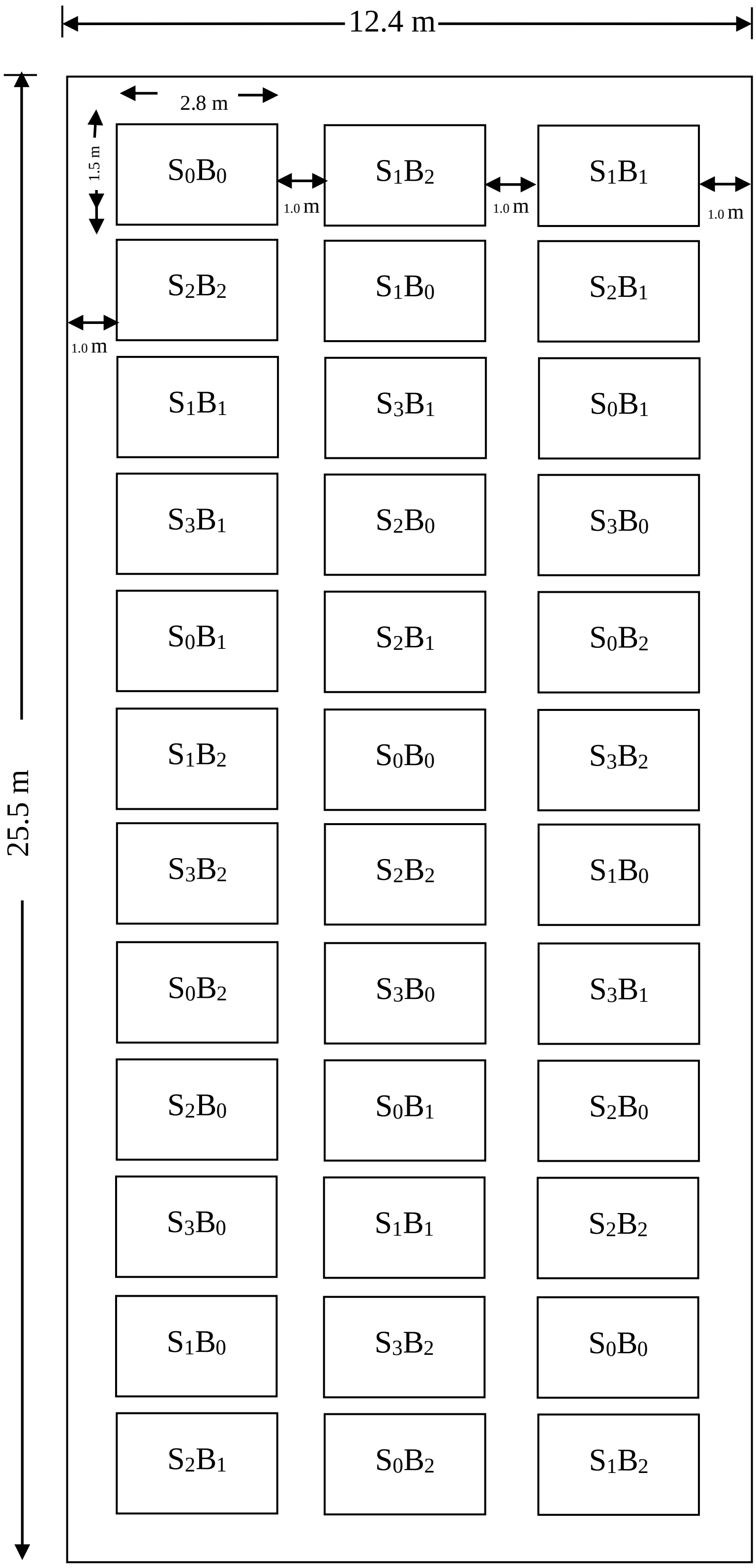
3.10 Intercultural operations

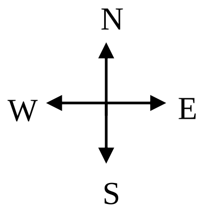
3.10.1 Thinning

The seeds started germination within four to five days after sowing (DAS). Thinning was at 20 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was supplied two times at 25 DAS and 55 DAS for all experimental plots equally. The crop field was weeded at 20 DAS and 50 DAS.





Plot size: 2.8 m × 1.5 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Levels of sulphur (4 levels)

S_0: 0 kg S ha^{-1} (control)

S_1: 10 kg S ha^{-1}

S_2: 20 kg S ha^{-1}

S_3: 40 kg S ha^{-1}

Factors B: Levels of boron (3 levels)

B_0: 0 kg B ha^{-1} (control)

B_1: 1.0 kg B ha^{-1}

B_2: 2kg B ha^{-1}

Figure 1. Layout of the experimental plot

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was applied at the rate of 1 mL with 1 litre water for two times at 15 days interval after seedlings germination.

3.11 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height and number of branches plant^{-1} were recorded from selected plants at an interval of 20 days started from 40 DAS to 60 DAS and at harvest.

3.12 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown in color**.** The matured pods were collected by hand picking from the area of 4.2 m^2 of each plot.

3.13 Data collection

The following data were recorded

i. Plant height

ii. Number of branches plant^{-1}

iii. Number of pods plant^{-1}

iv. Pod length

v. Number of seeds pod^{-1}

vi. Weight of 1000 seeds

vii. Seed yield hectare^{-1}

3.14 Procedure of data collection

3.14.1 Plant height

The plant height was measured at 40, 60 DAS with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.14.2 Number of branches plant^{-1}

The total number of branches plant^{-1} was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at 40, 60 DAS and at harvest

3.14.3 Pod length

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod^{-1} basis.

3.14.4 Number of pods plant^{-1}

Numbers of total pods of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.14.5 Number of seeds pod^{-1}

The number of seeds pods^{-1} was recorded from randomly selected 10 pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

3.14.6 Weight of 1000 seeds

One hundred cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.14.7 Seed yield hectare^{-1}

The seed collected from 4.2 (2.8 m ×1.5 m) square meter of each plot was cleaned. The weight of seeds was taken and converted into the yield in t ha^{-1}.

3.14.8 Oil content in seed

One gram sesame seed was taken in a mortar. The seeds were completely ground with a pestle. Thirty milliliter Filch reagent (chloroform: methanol = 2: 1) was added to it. After through mixing, the melt was filtered through Whatman No. 42 filter paper and the filtrate taken in a beaker. The filtrate was allowed to stand for about six hours for air drying and then dried in an oven for about half an hour to determine total oil. Proper care was taken so that chloroform and methanol mixture completely had dried out. Oil content was calculated by the following formula:

$$\text{Oil content (\%)} = \frac{\text{Weight of extract (g)}}{\text{Sample weight (g)}} \times 100$$

3.15 Chemical analysis of seeds samples

3.15.1 Collection of samples

Seeds samples were collected after threshing then finely ground by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K, S and B.

3.15.2 Preparation of samples

The plant samples were dried in an oven at 70^0C for 72 hours and ground by a grinding machine to pass through a 20-mesh sieve. The seeds samples were analyzed for N, P, K, S and B concentrations as follows:

3.15.3 Digestion of samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 5 ml conc. H_2SO_4 were added. The flasks were heating at 120^0C and added 2.5 ml 30% H_2O_2 then heated was continued at 180^0C until the digests became clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask; the volume was made up to the mark with de-ionized water. The reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.15.4 Digestion of samples with nitric-perchloric acid for P, K, S and B

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K, S and Mo were determined from this digest.

3.15.5 Determination of P, K, S and B from plant samples

3.15.5.1 Phosphorus

Phosphorus was digested from the plant sample (grain and straw) with 0.5 M Na_2CO_3 solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grain sample and 2 ml for straw sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.15.5.2 Potassium

Five milli-liter of digest sample for the grain and 10 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the emission of sample were measured within the range of standard solutions. The emission was measured by atomic absorption flame photometer.

3.15.5.3 Sulphur

Sulphur content was determined from the digest of the plant samples (seeds and stover) with CaCl2 (0.15%) solution as described by (Page et al.,1982).The digested S was determined by developing turbidity by adding acid seed solution (20 ppm as K_2SO_4 in 6N HCL) AND $BaCl_2$ crystals.The intensity of the turbidity was measured by spectrophotometer at 420 nm wave lengths (Hunter,1984).

3.15.5.4 Boron

For B, the extractant of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated $H_2SO_4$and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.16 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried and crushed then passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.17 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter S and B contents. The soil samples were analyzed by the following standard methods as follows:

3.17.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.17.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.17.3 Available Sulphur

For available S, the extractant composed of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1984). Sulphur concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H_2SO_4 and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the soil extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.17.4 Available B

Available boron (B) content in the soil samples was determined by the method described by Hunter (1984). The extracting agent used was monocalcium phosphate [CaH4(Po4)2. H2O] solution and colour was developed by curcumin solution. The absorbance was read on spectrophotometer at 555 nm wavelengths.

3.18 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different levels of sulphur and boron soybean. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the influence of sulphur and boron on the growth, yield and oil content of BARI Soybean-6 (*Glycine max L.)*. Data on different growth parameter, yield was recorded. The findings of the experiment have been presented and discusses with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Plant height

Plant height of BARI soybean 6 showed statistically significant variation due to different levels of sulphur at 60 days after sowing (DAS) and at harvest. Data revealed that at 60 DAS and at harvest, the tallest plant (27.89 and 31.81 cm, respectively) was recorded from S_3 (40 kg S ha^{-1}), whereas the shortest plant (24.06 and 26.31 cm, respectively) was found from S_0 (0 kg S ha^{-1}) treatment (Figure 2). ABng the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). Sulphur plays a pivotal role in various plant growth and development processes being a constituent of sulphur containing amino acids and other metabolites. In soybean Bhuiyan *et al*., (1998) found that application of sulphur at 20 kg per ha produced the longest plant. Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes like as plant height. Farhad *et al*. (2010) reported that application of of sulphur @ 20 kg ha^{-1} produced the highest plant height.

Different levels of boron differed significantly in terms of plant height of BARI soybean 6 at 60 DAS and at harvest. At 60 DAS and at harvest, the tallest plant (28.38 and 33.12 cm, respectively) was found from B_2 (2.00 kg B ha^{-1}) which were statistically identical with B_1 (1.0 B ha^{-1}), while the shortest plant (23.92 and 25.61 cm, respectively) was observed from B_0 (0 kg B ha^{-1}) treatment (Figure 3) These results suggest that B has no contribution to elongation of the axis of the plant during growth period.

Interaction effect of different levels of sulphur and boron showed statistically significant variation on plant height of BARI soybean 6 at 60 DAS and at harvest. At 60 DAS and at harvest, the tallest plant (28.96 and 36.53 cm, respectively) was recorded from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}) and the shortest plant (20.31 and 21.39 cm, respectively) was observed from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 1).

4.2 Number of branches plant^{-1}

Insignificant variation was recorded in terms of number of branches plant^{-1} of BARI soybean 6 due to different levels of sulphur. The maximum number of branches plant^{-1} (3.28) was observed from S_3 (40 kg S ha^{-1}), while the minimum number of branches plant^{-1} (2.33) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 2). Farhad *et al*. (2010) reported that application of sulphur @ 20 kg ha^{-1} produced the maximum number of branches plant^{-1}.

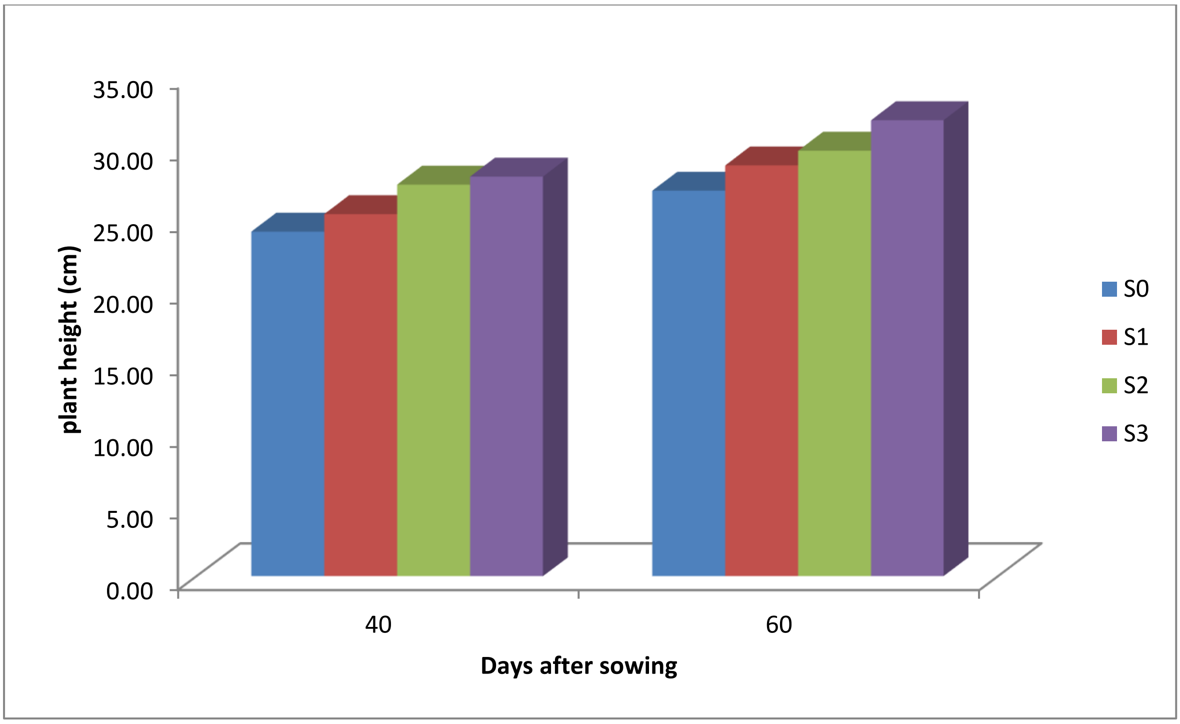


Fig. 2. Effect of sulphur on plant height of soybean

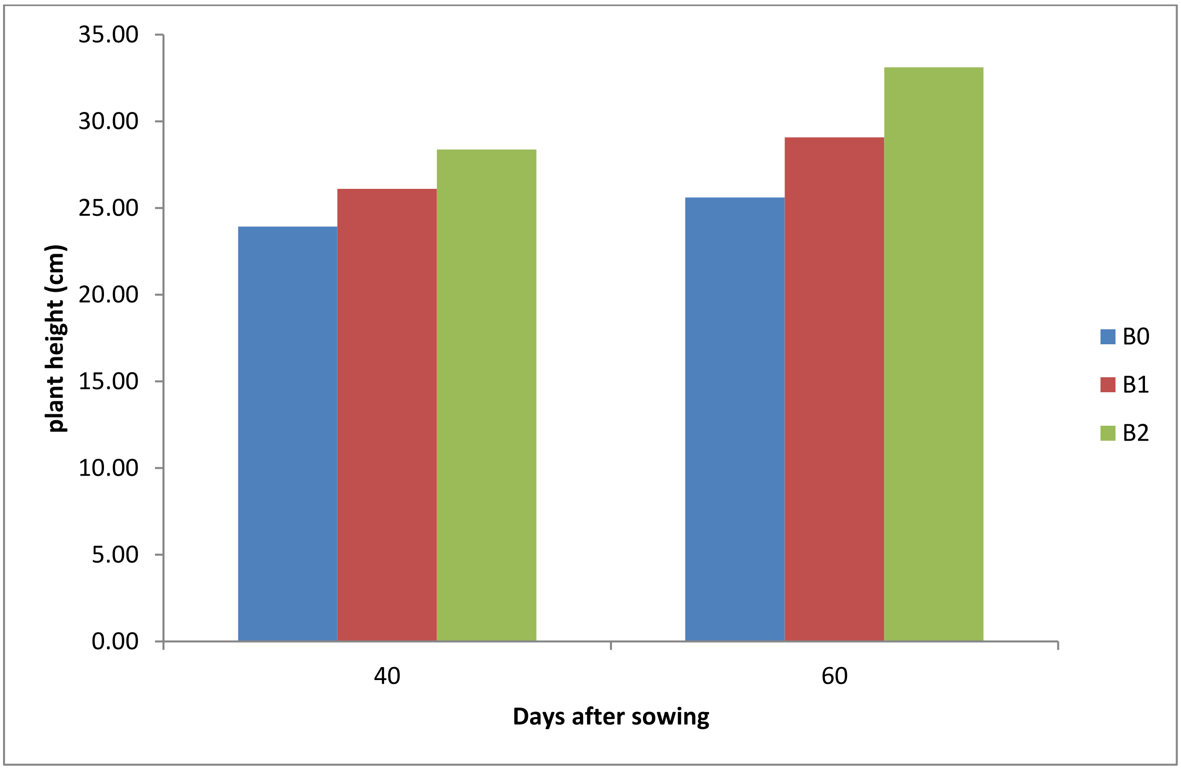


Fig. 3. Effect of boron on plant height of soybean

Table 1. Interaction effect of sulphur and boron on plant height at different days after sowing (DAS) of BARI soybean 6

Treatment	Plant height 40 DAS		Plant height 60 DAS	
S_0B_0	20.31	e	21.39	d
S_0B_1	23.44	d	27.58	bc
S_0B_2	28.43	ab	31.75	abc
S_1B_0	22.46	de	26.57	c
S_1B_1	25.78	c	27.93	bc
S_1B_2	27.60	abc	31.50	bc
S_2B_0	26.15	bc	26.50	c
S_2B_1	26.88	abc	29.90	bc
S_2B_2	26.78	abc	32.68	ab
S_3B_0	28.35	ab	27.98	bc
S_3B_1	28.53	ab	30.90	bc
S_3B_2	28.96	a	36.53	a
$LSD_{(0.05)}$	2.27		4.57	
CV(%)	5.13		9.21	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: 0 kg S ha^{-1} (control)
S_1: 10 kg S ha^{-1}
S_2: 20 kg S ha^{-1}
S_3: 40 kg S ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.0 kg B ha^{-1}
B_2: 2 kg B ha^{-1}

Number of branches plant^{-1} of BARI soybean 6 was not varied significantly due to different levels of boron. The maximum number of branches plant^{-1} (3.60) was attained from B_2 (2 kg B ha^{-1}) and the minimum number (2.28) was observed from B_0 (0 kg B ha^{-1}) treatment (Table 3). Schon (1990) stated that a rate of 1.12 kg B ha^{-1} significantly increased the number of branches plant^{-1}.

Number of branches plant^{-1} showed statistically significant differences due to the interaction effect of different levels of sulphur and boron. The maximum number of branches plant^{-1} (4.50) was recorded from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}), which was statistically similar with S_2B_2 while the minimum number (2.11) from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination, which was statistically similar with S_0B_1 (Table 4).

4.3 Number of pods plant^{-1}

Statistically significant variation was recorded due to different levels of sulphur in terms of pod length of BARI soybean 6. The longest pod (4.22 cm) was observed from S_3 (40 kg S ha^{-1}), which were statistically similar with (4.28 cm and 3.94 cm) with S_1 (10 kg S ha^{-1}) and S_2 (20 kg S ha^{-1}), while the shortest pod (2.94 cm) was found from S_0 (0 kg S ha^{-1}) treatment (Table 2). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes.

Table 2. Effect of sulphur on Number of branch, Number of pod per plant and Pod length of BARI soybean 6

Treatment	Number of branch	Number of pods per plant	Pod length (cm)
S_0	2.33 a	18.04 b	3.66 c
S_1	2.74 a	25.52 a	3.89 bc
S_2	3.19 a	25.64 a	4.20 ab
S_3	3.28 a	28.12 a	4.34 a
$LSD_{(0.05)}$	1.88	3.66	0.41
CV(%)	8.53	8.1	4.46

Table 3. Effect of boron on Number of branch, Number of pod per plant and Pod length of BARI soybean 6

Treatment	Number of branch	Number of pod per plant	Pod length (cm)
B_0	2.28 a	18.32 b	3.54 b
B_1	2.78 a	25.16 a	4.18 a
B_2	3.60 a	29.51 a	4.35 a
$LSD_{(0.05)}$	1.67	4.83	0.43
CV(%)	8.53	8.1	4.46

Table 4. Interaction effect of sulphur and boron on Number of branch, Number of pod per plant and Pod length of BARI soybean 6

Treatment	Number of branch		Number of pod per plant		Pod length (cm)	
S_0B_0	2.11	c	11.91	h	3.30	f
S_0B_1	2.15	c	17.43	g	3.73	de
S_0B_2	2.78	bc	24.77	de	3.93	cd
S_1B_0	2.33	bc	20.00	fg	3.67	de
S_1B_1	2.89	bc	26.30	cde	3.90	cd
S_1B_2	3.00	b	30.27	ab	4.10	c
S_2B_0	2.34	bc	18.12	g	3.68	de
S_2B_1	3.11	b	28.20	bcd	4.50	b
S_2B_2	4.11	a	30.61	ab	4.43	b
S_3B_0	2.34	bc	23.27	ef	3.53	ef
S_3B_1	3.00	b	28.69	bc	4.57	b
S_3B_2	4.50	a	32.40	a	4.93	a
$LSD_{(0.05)}$	0.73		3.34		0.25	
CV(%)	8.53		8.1		4.46	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: 0 kg S ha^{-1} (control)
S_1: 10 kg S ha^{-1}
S_2: 20 kg S ha^{-1}
S_3: 40 kg S ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.0 kg B ha^{-1}
B_2: 2 kg B ha^{-1}

Different levels of boron varied significantly in terms of pod length of soybean. The longest pod (4.35 cm) was recorded from B_2 (2 kg B ha^{-1}) which were statistically similar (4.18cm) with B_1 (1.0 kg B ha^{-1}) and the shortest pod (3.54 cm) from B_0 (0 kg B ha^{-1}) treatment (Table 3). The similar results have also been reported by Zajone *et al*. (1985) observed that boron had positive effect on the formantion of large pods with 25-26 seeds pod^{-1} of mustard.

Pod length of soybean showed statistically significant variation due to the interaction effect of different levels of sulphur and boron. The longest pod (4.93 cm) was recorded from S_2B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}), whereas the shortest pod (3.30 cm) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4).

4.4 Pod length

Different levels of sulphur showed statistically significant variation on number of pods $plant^{-1}$ of BARI soybean 5. The maximum number of pods $plant^{-1}$ (28.12) was recorded from S_3 (40 kg S ha^{-1}), which were statistically similar (25.64 and 25.52) with S_2 (20 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), whereas the minimum number (18.04) was attained from S_0 (0 kg S ha^{-1}) treatment (Table 2). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes.

Number of pods $plant^{-1}$ soybean varied significantly due to different levels of boron. The maximum number of pods $plant^{-1}$ (29.51) was recorded from B_2 (2 kg B ha^{-1}) which were statistically similar (25.16) with B_1 (1.0 kg B ha^{-1}), while the minimum number (18.32) from B_0 (0 kg B ha^{-1}) treatment (Table 3). These results are in conformity with those of Islam *et.al* (1983) and Dutta et al. (1984), who have observed increased number of siliquae per plant of rapeseed by increasing rate of B.

Interaction effect of different levels of sulphur and boron varied significantly in terms of number of pods $plant^{-1}$ of BARI soybean 6. The maximum number of pods $plant^{-1}$ (32.40) was found from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}) and the minimum number (11.91) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4).

4.5 Number of seeds pod^{-1}

Different levels of sulphur showed statistically significant variation on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (4.28) was found from S_2 (40 kg S ha^{-1}), which were statistically similar (4.22) with S_2 (20 kg S ha^{-1}), while the minimum number (2.94) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 5). Kedar and Rajendra (2003) found that sulphur at 30 kg ha^{-1} treated had higher number of seeds per plant which was 24.18% higher than the control of rapeseed.

Number of seeds pod^{-1} of soybean was not varied significantly due to different levels of boron. The maximum number of seeds pod^{-1} (4.46) was recorded from B_2 (2 kg B ha^{-1}) which were closely followed (3.53) by B_1 (1.0 kg B ha^{-1}), while the minimum number (3.25) from B_0 (0 kg B ha^{-1}) treatment (Table 6).

Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and boron on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (5.17) was observed from S_2B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}) and the minimum number (2.17) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 7).

4.6 Weight of 1000 seeds

Weight of 1000 seeds of BARI soybean 6 varied significantly due to different levels of sulphur under the present trial. The highest weight of 1000 seeds (128.5 g) was observed from S_1 (10 kg S ha^{-1}), while the lowest weight (117.4 g) was attained from S_0 (0 kg S ha^{-1}) treatment (Table 5). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attri-butes. Farhad *et al*. (2010) reported that application of of sulphur @ 20 kg ha^{-1} produced the highest 1000-seed weight.

Statistically significant variation was recorded in terms of weight of 1000 seeds of BARI soybean 6 due to different levels of boron. The highest weight of 1000 seeds (133.90 g) was found from B_2 (2 kg B ha^{-1}), again the lowest weight (113.80 g) from B_0 (0 kg B ha^{-1}) treatment (Table 6).

Interaction effect of different levels of sulphur and boron showed statistically significant variation in terms of weight of 1000 seeds of BARI soybean 6. The highest weight of 1000 seeds (141.60 g) was observed from S_1B_2 (10 kg S ha^{-1} and 2 kg B ha^{-1}), whereas the lowest weight (103.60 g) from S_0B_0 (0 kg S ha^{-1} and 0 kg

B ha^{-1}) treatment combination, which was statistically similar with S_2B_0 (20 kg S ha^{-1} and 0 kg B ha^{-1}) (Table 7).

4.7 Seed yield hectare^{-1}

Seed yield hectare^{-1} of soybean varied significantly due to different levels of sulphur. The highest seed yield (1.93 t ha^{-1}) was observed from S_3 (40 kg S ha^{-1}). On the other hand, the lowest seed yield (1.66 t ha^{-1}) was observed from S_0 (0 kg S ha^{-1}) treatment (Table 5). Bhuiyan *et al.*, (1998) found that application of sulphur at 20 kg per ha produced the highest seed yield.

Levels of boron varied significantly in terms of seed yield hectare^{-1} of BARI soybean 6. The highest seed yield (1.85 t ha^{-1}) was recorded from B_2 (2 kg B ha^{-1}) whereas the lowest seed yield (1.76 t ha^{-1}) from B_0 (0 kg B ha^{-1}) (Table 6). This result showed that the yield of soybean increased gradually with the higher doses of B fertilizer. Sakal et al. (1991), Sinha et al. (1991), Banuels et al. (1990), obtained a similar result by applying 1 to 2 kg B/ha. Malewar (2001) found that seed yield significantly increased with each levels of B. Interestingly, this result is consistent with the B-induced yield components such as number of branch /plant, seed weight of 100 seed, seed weight / plant, thousand seed weight, seed yield and harvest index (Table 6) rather than growth parameters (Fig. 2, 4, 6, 8). Therefore, higher dose of B can increase seed yield of soybean.

Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and boron on seed yield hectare of BARI soybean 6. The highest seed yield (1.99 t ha^{-1}) was found from S_2B_3 (40 kg S ha^{-1} and 2 kg B ha^{-1}), while the lowest seed yield (1.57 t ha^{-1}) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 7).

4.8 Oil content in seeds

Oil content of seeds of BARI soybean 6 varied significantly due to different levels of sulphur. The highest oil content (26.27%) was observed from S_3 (40 kg S ha^{-1}), which were statistically identical (23.99%) with S_2 (20 kg S ha^{-1}). On the other hand, the lowest oil content (17.11%) was observed from S_0 (0 kg S ha^{-1}) treatment (Figure 4).

Levels of boron varied significantly in terms of oil content of BARI soybean 6. The highest oil content (23.65%) was recorded from B_2 (1.5 kg B ha^{-1}), whereas the lowest oil content (20.7%) from B_0 (0 kg B ha^{-1}) treatment (Figure 5).

Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and boron on oil content of BARI soybean 6. The highest oil content (27.20%) was found from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}), while the lowest oil content (15.98%) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg Bha^{-1}) treatment combination (Figure 6).

Table 5. Effect of sulphur on yield and yield contributing character of BARI soybean 6

Treatment	Seeds per pod	1000 seed weight (g)	Seed Yeild(t/ha)
S_0	2.94 b	117.40 b	1.66 d
S_1	3.94 ab	128.50 a	1.77 c
S_2	4.22 a	124.40 ab	1.86 b
S_3	4.28 a	123.70 ab	1.93 a
$LSD_{(0.05)}$	1.01	10.24	0.03
CV(%)	12.73	4.09	5.09

Table 6. Effect of boron on yield and yield contributing character of BARI soybean 6

Treatment	Seeds per pod	1000 seed weight (g)	Seed Yield(t/ha)
B_0	3.25 a	113.80 c	1.76 c
B_1	3.83 a	122.80 b	1.80 b
B_2	4.46 a	133.90 a	1.85 a
$LSD_{(0.05)}$	1.31	8.27	0.04
CV(%)	12.73	4.09	5.09

Table 7. Interaction effect of sulphur and boron on plant height at different days after sowing (DAS) of BARI soybean 6

Treatment	Seeds per pod		1000 seeds weight		Yield t/ha	
S_0B_0	2.17	e	103.60	e	1.57	g
S_0B_1	3.17	d	118.60	d	1.67	f
S_0B_2	3.50	cd	129.90	bc	1.75	de
S_1B_0	4.50	ab	122.60	cd	1.78	cde
S_1B_1	3.83	bcd	121.30	cd	1.72	ef
S_1B_2	4.50	ab	141.60	a	1.80	cd
S_2B_0	3.17	d	107.60	e	1.82	c
S_2B_1	4.00	bcd	128.60	bc	1.90	b
S_2B_2	4.67	ab	136.90	ab	1.87	b
S_3B_0	3.17	d	121.30	cd	1.89	b
S_3B_1	4.33	abc	122.60	cd	1.92	b
S_3B_2	5.17	a	127.30	cd	1.99	a
$LSD_{(0.05)}$	0.83		8.56		0.05	
CV(%)	12.73		4.09		5.09	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: 0 kg S ha^{-1} (control)
S_1: 10 kg S ha^{-1}
S_2: 20 kg S ha^{-1}
S_3: 40 kg S ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.0 kg B ha^{-1}
B_2: 2 kg B ha^{-1}

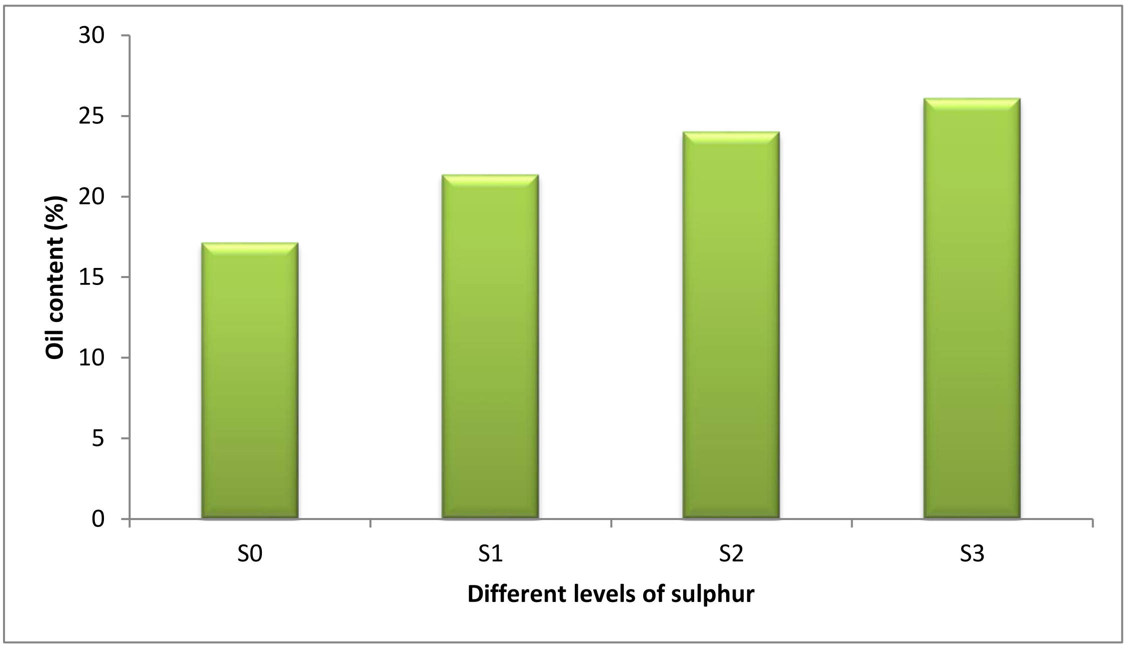


Fig. 4. Effect of different level of sulphur on oil content of soybean

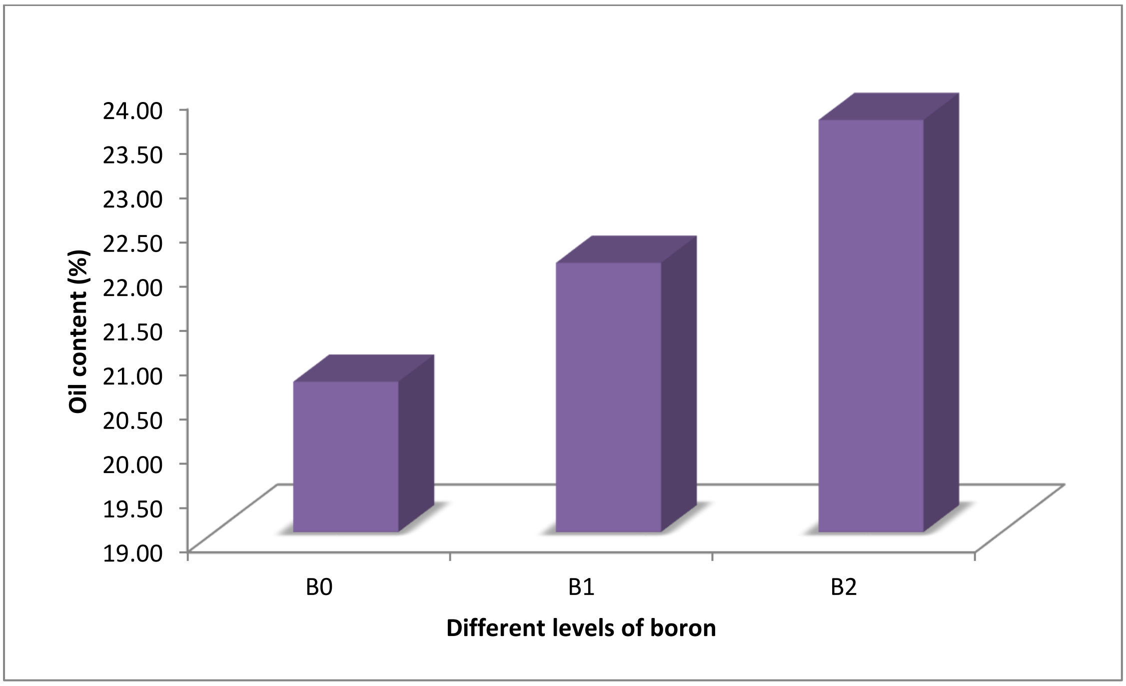


Fig. 5. Effect of different level of boron on oil content of soybean

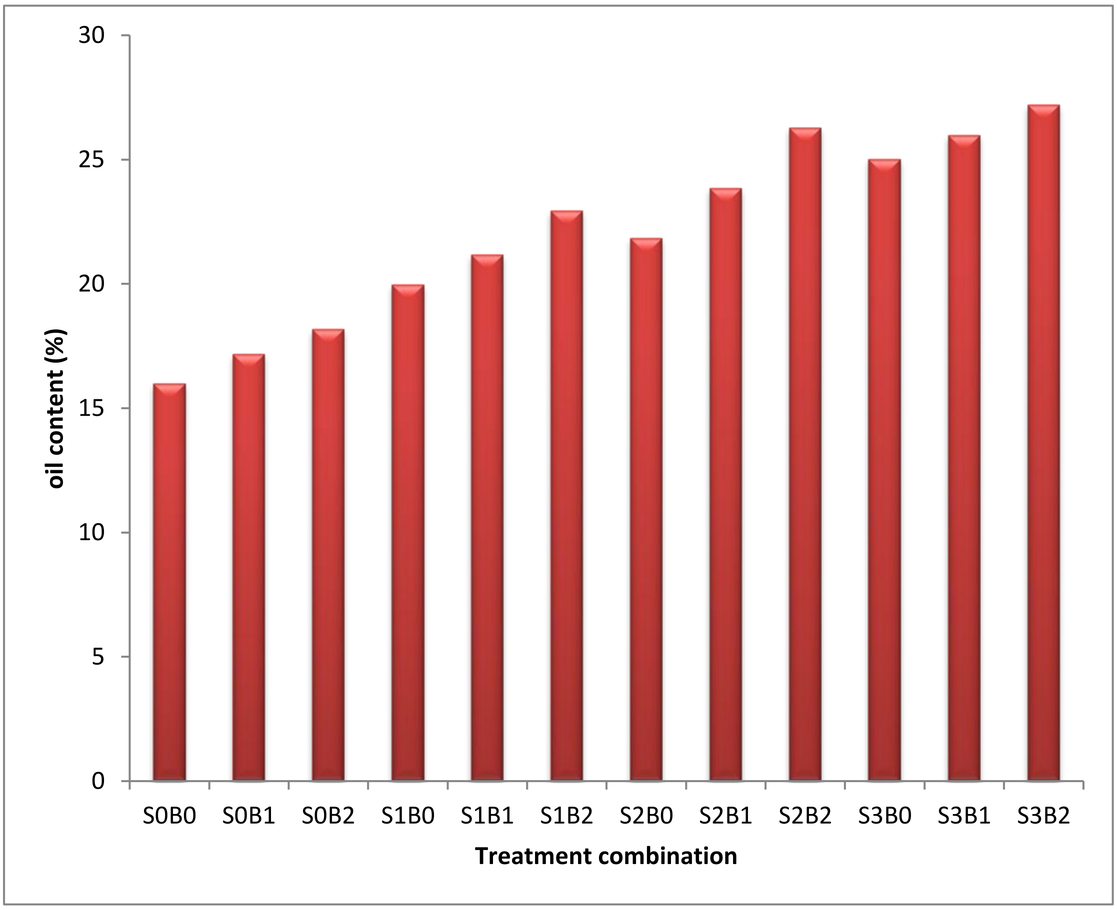


Fig. 6. Interaction effect of different level of sulphur and boron on oil content of soybean

4.9 N, P, K, S and B concentration in seeds

Insignificant variation was found for N, P, K, S and B concentration in seeds due different levels of sulphur. The maximum concentration in seeds for N (2.86%), P (0.431%), K (0.601%), S (0.35%) and B (0.0183%) was found from S_3 (40 kg S ha^{-1}), while the minimum (1.713%), P (0.37%), K (0.47%), S (0.285%) and B (0.0141%) was found from S_0 (0 kg S ha^{-1}) treatment (Table 8).

N, P, K, S and B concentration in seeds showed insignificant variation due to different levels of boron. The maximum concentration in seeds for N (2.67%), P (0.426%), K (0.577%), S (0.339%) and B (0.0178%) was observed from B_2 (1.5 kg B ha^{-1}) and the minimum concentration in seeds for N (2.23%), P (0.3659%), K (0.51%), S (0.304%) and B (0. 0153%) was recorded from B_0 (0 kg B ha^{-1}) treatment (Table 9).

Statistically significant variation was recorded due to the interaction effect of sulphur and boron in terms of N, P, K, S and B concentration in seed. The maximum concentration in seeds for N (3.13%), P (0.473%), K (0.655%), S (0.375%) and B (0.0197%) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}), whereas the minimum concentration in seeds for N (1.53%), P (0.341%), K (0.44%), S (0.268%) and B (0.0115%) from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 10).

Table 8. Effect of sulphur on N, P, K, S and B content in seeds of BARI soybean 6

Treatment	N		P		K		S		B	
S_0	1.713	b	0.368	b	0.467	c	0.285	c	0.014	b
S_1	2.522	a	0.393	b	0.542	b	0.322	b	0.017	a
S_2	2.747	a	0.416	a	0.586	a	0.343	a	0.018	a
S_3	2.863	a	0.431	a	0.601	a	0.350	a	0.018	a
$LSD_{(0.05)}$	0.427		0.022		0.042		0.012		0.003	
CV(%)	7.550		8.130		11.080		8.620		9.970	

Table 9. Effect of boron on N, P, K, S and B content in seeds of BARI soybean 6

Treatment	N		P		K		S		B	
B_0	2.233	c	0.366	b	0.508	b	0.304	b	0.015	b
B_1	2.477	b	0.414	a	0.563	a	0.332	a	0.017	a
B_2	2.674	a	0.426	a	0.577	a	0.339	a	0.018	a
$LSD_{(0.05)}$	0.158		0.011		0.157		0.027		0.002	
CV(%)	7.550		8.130		11.080		8.620		9.970	

Table 10. Interaction of effect of sulphur and boron on N, P, K, S and B content in seeds of BARI soybean 6

Treatment	N (%)		P(%)		K(%)		S(%)		B(%)	
S_0B_0	1.527	e	0.341	c	0.440	d	0.268	d	0.011	b
S_0B_1	1.737	e	0.376	abc	0.474	cd	0.290	cd	0.015	ab
S_0B_2	1.877	de	0.386	abc	0.489	bcd	0.298	cd	0.016	ab
S_1B_0	2.303	cd	0.377	abc	0.515	bcd	0.308	bcd	0.016	ab
S_1B_1	2.507	bc	0.389	abc	0.548	a-d	0.325	a-d	0.017	ab
S_1B_2	2.757	abc	0.412	abc	0.565	abc	0.333	abc	0.018	ab
S_2B_0	2.587	abc	0.385	abc	0.570	abc	0.335	abc	0.018	a
S_2B_1	2.717	abc	0.431	abc	0.591	abc	0.345	abc	0.018	a
S_2B_2	2.937	ab	0.430	abc	0.599	ab	0.349	abc	0.018	a
S_3B_0	2.517	bc	0.360	bc	0.508	bcd	0.306	cd	0.016	ab
S_3B_1	2.947	ab	0.458	ab	0.640	a	0.368	ab	0.019	a
S_3B_2	3.127	a	0.473	a	0.655	a	0.375	a	0.020	a
$LSD_{(0.05)}$	0.522		0.093		0.107		0.054		0.005	
CV(%)	7.550		8.130		11.080		8.620		9.970	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: 0 kg S ha^{-1} (control)
S_1: 10 kg S ha^{-1}
S_2: 20 kg S ha^{-1}
S_3: 40 kg S ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.0 kg B ha^{-1}
B_2: 1.5 kg B ha^{-1}

4.10 pH

Different levels of sulphur showed statistically significant variation in terms of pH in post harvest soil. The highest pH in post harvest soil (6.00) was observed from S_3 (40 kg S ha^{-1}), which was statistically identical with S_2 (20 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), while the lowest pH (5.56) was found from S_0 (0 kg S ha^{-1}) treatment (Table 11).

Statistically significant variation was recorded for pH in post harvest soil due to different levels of boron. The highest pH in post harvest soil (5.98) was recorded from B_2 (1.5 kg B ha^{-1}) which was statistically similar (6.88) with B_1 (1.0 kg B ha^{-1}), whereas the lowest pH (5.56) from B_0 (0 kg B ha^{-1}) treatment (Table 12).

Interaction effect of different levels of sulphur and boron showed significant variation on pH in post harvest soil (Appendix VIII). The highest pH in post harvest soil (6.22) was observed from S_2B_3 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}) and the lowest pH in post harvest soil (5.56) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination, which was statistically similar with S_3B_2 (Table 13).

Table 11. Effect of sulphur on pH, organic matter, available S and B of post harvest soil of BARI soybean 6

Treatment	pH	Organic matter (%)	Available S (ppm)	Available B (ppm)
S_0	5.561 b	1.383 b	3.703 c	0.289 b
S_1	5.800 ab	1.447 b	6.614 b	0.321 ab
S_2	5.910 ab	1.530 a	7.330 ab	0.341 ab
S_3	6.001 a	1.537 a	7.708 a	0.374 a
$LSD_{(0.05)}$	0.260	0.082	0.904	0.082
CV(%)	8.480	9.560	9.080	8.520

Table 12. Effect of boron on pH, organic matter, available S and B of post harvest soil of BARI soybean 6

Treatment	pH	Organic matter (%)	Available S (ppm)	Available B (ppm)
B_0	5.563 b	1.360 b	5.576 b	0.215 b
B_1	5.886 a	1.520 a	6.625 a	0.385 a
B_2	5.987 a	1.550 a	6.816 a	0.393 a
$LSD_{(0.05)}$	0.111	0.112	0.509	0.111
CV(%)	8.480	9.560	9.080	8.520

Table 13. Interaction effect of sulphur and boron on pH, organic matter, available S and B of post harvest soil of BARI soybean 6

Treatment	pH	Organic matter (%)	Available S (ppm)	Available B (ppm)
S_0B_0	5.567 b	1.300 d	3.120 f	0.207 d
S_0B_1	5.620 ab	1.390 cd	4.020 f	0.323 c
S_0B_2	5.600 ab	1.380 cd	3.970 f	0.336 bc
S_1B_0	5.593 ab	1.330 cd	6.270 de	0.207 d
S_1B_1	5.893 ab	1.530 abc	6.627 cde	0.374 bc
S_1B_2	5.913 ab	1.480 abcd	6.947 cd	0.382 b
S_2B_0	5.553 ab	1.430 bcd	7.197 cd	0.242 d
S_2B_1	5.933 ab	1.620 ab	7.557 bc	0.391 b
S_2B_2	5.967 ab	1.540 abc	7.237 cd	0.390 b
S_3B_0	5.467 b	1.380 cd	5.717 e	0.204 d
S_3B_1	6.097 ab	1.650 a	8.297 ab	0.453 a
S_3B_2	6.217 a	1.660 a	9.110 a	0.465 a
$LSD_{(0.05)}$	0.611	0.193	0.974	0.054
CV(%)	8.480	9.560	9.080	8.520

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: 0 kg S ha^{-1} (control) B_0: 0 kg B ha^{-1} (control)

S_1: 10 kg S ha^{-1} B_1: 1.0 kg B ha^{-1}

S_2: 20 kg S ha^{-1} B_2: 1.5 kg B ha^{-1}

S_3: 40 kg S ha^{-1}

4.11 Organic matter

Organic matter in post harvest soil showed statistically significant variation due to different levels of sulphur. The highest organic matter in post harvest soil (1.54%) was recorded from S_3 (40 kg S ha^{-1}), which was statistically similar with S_2 (20 kg S ha^{-1}), whereas the lowest organic matter (1.38%) was observed from S_0 (0 kg S ha^{-1}) treatment (Table 11).

Different levels of boron varied significantly in terms of organic matter in post harvest soil. The highest organic matter in post harvest soil (1.55%) was found from B_2 (1.5 kg B ha^{-1}) which was statistically similar (1.52%) with B_1 (1.0 kg B ha^{-1}), while the lowest organic matter (1.36%) from B_0 (0 kg B ha^{-1}) treatment (Table 12).

Statistically significant variation was recorded on organic matter in post harvest soil due to the interaction effect of different levels of sulphur and boron. The highest organic matter in post harvest soil (1.66%) was observed from S_2B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}), which was statistically similar with S_3B_1 again the lowest organic matter in post harvest soil (1.30%) was recorded from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 13).

4.12 Available sulphur

Different levels of sulphur showed statistically significant variation in terms of available sulphur in post harvest soil. The highest available sulphur in post harvest soil (7.71 ppm) was found from S_3 (40 kg S ha^{-1}), while the lowest available sulphur (3.70 ppm) was found from S_0 (0 kg S ha^{-1}) treatment (Table 11).

Significant variation was recorded for available sulphur in post harvest soil due to different levels of boron. The highest available sulphur in post harvest soil (6.82 ppm) was recorded from B_2 (1.5 kg B ha^{-1}) which was statistically similar (6.63 ppm) with B_1 (1.0 kg B ha^{-1}), whereas the lowest available sulphur (5.58 ppm) from B_0 (0 kg B ha^{-1}) treatment (Table 12).

Interaction effect of different levels of sulphur and boron showed significant variation on available sulphur in post harvest soil. The highest available sulphur in post harvest soil (9.11 ppm) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}), whereas the lowest available sulphur in post harvest soil (3.12 ppm) was attained from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 13).

4.13 Available Boron

Statistically significant variation was recorded due to different levels of sulphur sin terms of available boron in post harvest soil. The highest available boron in post harvest soil (0.372 ppm) was recorded from S_3 (40 kg S ha^{-1}), while, the lowest available boron (0.229 ppm) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 11).

Different levels of boron showed statistically significant variation in terms of available boron in post harvest soil. The highest available boron in post harvest soil (0.393 ppm) was observed from B_2 (1.5 kg B ha^{-1}) which was statistically similar with by B_1 (1.0 kg B ha^{-1}), while the lowest available boron (0.215 ppm) from B_0 (0 kg B ha^{-1}) treatment (Table 12).

Available boron in post harvest soil showed significant variation due to the interaction effect of different levels of sulphur and boron. The highest available boron in post harvest soil (0.465 ppm) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}), which was statistically similar with whereas the lowest available boron in post harvest soil (0.21 ppm) was recorded from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 13).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November, 2016 to April 2017 to Influence of sulphur and boron on the growth, yield and oil content of BARI Soybean-6 (*Glycine max L.)*. In this experiment, the treatment consisted of four Levels of sulphur viz. S_0: 0 kg S ha^{-1} (control), S_1: 10 kg S ha^{-1}, S_2: 20 kg S ha^{-1}, S_3: 40 kg S ha^{-1} and three levels of boron viz. B_0: 0 kg B ha^{-1} (control), B_1: 1.0 kg B ha^{-1}, B_2: 2 kg B ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters.

Plant height of BARI soybean 6 showed statistically significant variation due to different levels of sulphur at 60 days after sowing (DAS) and at harvest. The tallest plant (27.89 and 31.81 cm, respectively) was recorded from S_3 (40 kg S ha^{-1}). Insignificant variation was recorded in terms of number of branches $plant^{-1}$ of BARI soybean 6 due to different levels of sulphur. The maximum number of branches $plant^{-1}$ (3.28) was observed from S_3 (40 kg S ha^{-1}). Statistically significant variation was recorded due to different levels of sulphur in terms of pod length of BARI soybean 6. The longest pod (4.22 cm) was observed from S_3 (40 kg S ha^{-1}). Different levels of sulphur showed statistically significant variation on number of pods $plant^{-1}$ of BARI soybean 5. The maximum number of pods $plant^{-1}$

(28.12) was recorded from S_3 (40 kg S ha^{-1}). Different levels of sulphur showed statistically significant variation on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (4.28) was found from S_3 (40 kg S ha^{-1}). Weight of 1000 seeds of BARI soybean 6 varied significantly due to different levels of sulphur under the present trial. The highest weight of 1000 seeds (123.70 g) was observed from S_1 (10 kg S ha^{-1}). Seed yield $hectare^{-1}$ of soybean varied significantly due to different levels of sulphur. The highest seed yield (1.93 t ha^{-1}) was observed from S_3 (40 kg S ha^{-1}). Oil content of seeds of BARI soybean 6 varied significantly due to different levels of sulphur. The highest oil content (26.27%) was observed from S_3 (40 kg S ha^{-1}). Insignificant variation was found for N, P, K, S and B concentration in seeds due different levels of sulphur. The maximum concentration in seeds for N (2.86%), P (0.431%), K (0.601%), S (0.35%) and B (0.0183%) was found from S_3 (40 kg S ha^{-1}). The highest pH in post harvest soil (6.90) was observed from S_3 (40 kg S ha^{-1}). The highest organic matter in post harvest soil (1.54%) was recorded from S_3 (40 kg S ha^{-1}). The highest available sulphur in post harvest soil (7.71 ppm) was found from S_3 (40 kg S ha^{-1}). The highest available boron in post harvest soil (0.372 ppm) was recorded from S_3 (40 kg S ha^{-1}).

Different levels of boron differed significantly in terms of plant height of BARI soybean 6 at 60 DAS and at harvest. At 60 DAS and at harvest, the tallest plant (28.38 and 33.12 cm, respectively) was found from B_2 (2.00 kg B ha^{-1}). Number of branches $plant^{-1}$ of BARI soybean 6 was not varied significantly due to different levels of boron. The maximum number of branches $plant^{-1}$ (3.60) was attained from B_2 (2 kg B ha^{-1}). Different levels of boron varied significantly in terms of pod length of soybean. The longest pod (4.35 cm) was recorded from B_2 (2 kg B ha^{-1}). Number of pods $plant^{-1}$ soybean varied significantly due to different levels of boron. The maximum number of pods $plant^{-1}$ (29.51) was recorded from B_2 (2 kg B ha^{-1}). Number of seeds pod^{-1} of soybean was not varied significantly due to different levels of boron. The maximum number of seeds pod^{-1} (4.46) was recorded from B_2 (2 kg B ha^{-1}). The highest weight of 1000 seeds (133.90 g) was found from B_2 (2 kg B ha^{-1}). Levels of boron varied significantly in terms of seed yield $hectare^{-1}$ of BARI soybean 6. The highest seed yield (1.85 t ha^{-1}) was recorded from B_2 (2 kg B ha^{-1}). The lowest seed yield (1.76 t ha^{-1}) from B_0 (0 kg B ha^{-1}). Levels of boron varied significantly in terms of oil content of BARI soybean 6. The highest oil content (23.65%) was recorded from B_2 (1.5 kg B ha^{-1}). N, P, K, S and B concentration in seeds showed insignificant variation due to different levels of boron. The maximum concentration in seeds for N (2.67%), P (0.426%), K (0.577%), S (0.339%) and B (0.0178%) was observed from B_2 (1.5 kg B ha^{-1}). The highest pH in post harvest soil (6.92) was recorded from B_2 (1.5 kg B ha^{-1}). The highest organic matter in post harvest soil (1.55%) was found from B_2 (1.5 kg B ha^{-1}). The highest available sulphur in post harvest soil (6.82 ppm) was recorded from B_2 (1.5 kg B ha^{-1}). The highest available boron in post harvest soil (0.393 ppm) was observed from B_2 (1.5 kg B ha^{-1})

Interaction effect of different levels of sulphur and boron showed statistically significant variation on plant height of BARI soybean 6 at 60 DAS and at harvest. At 60 DAS and at harvest, the tallest plant (28.96 and 36.53 cm, respectively) was recorded from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}). The maximum number of branches $plant^{-1}$ (4.50) was recorded from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}). Pod length of soybean showed statistically significant variation due to the interaction effect of different levels of sulphur and boron. The longest pod (4.93 cm) was recorded from S_2B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}). Interaction effect of different levels of sulphur and boron varied significantly in terms of number of pods $plant^{-1}$ of BARI soybean 6 . The maximum number of pods $plant^{-1}$ (32.40) was found from S_3B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}). The maximum number of seeds pod^{-1} (5.17) was observed from S_2B_2 (40 kg S ha^{-1} and 2 kg B ha^{-1}). The highest weight of 1000 seeds (141.60 g) was observed from S_1B_2 (10 kg S ha^{-1} and 2 kg B ha^{-1}). The highest seed yield (1.99 t ha^{-1}) was found from S_2B_3 (40 kg S ha^{-1} and 2 kg B ha^{-1}), while the lowest seed yield (1.57 t ha^{-1}) was found from S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) treatment combination. The highest oil content (27.20%) was found from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}). The maximum concentration in seeds for N (3.13%), P (0.473%), K (0.655%), S (0.375%) and B (0.0197%) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}). The highest pH in post harvest soil (7.22) was observed from S_2B_3 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}). The highest organic matter in post harvest soil (1.66%) was observed from S_2B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}). The highest available sulphur in post harvest soil (9.11 ppm) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}). The highest available boron in post harvest soil (0.465 ppm) was observed from S_3B_2 (40 kg S ha^{-1} and 1.5 kg B ha^{-1}).

Considering the above results, it may be summarized that growth, seed yield, oil content and contributing parameters of Soybean are positively correlated with S and B application. Therefore, the present experimental results suggest that the combined use of 40 kg S/ha and 2 kg B/ha along with recommended doses of other fertilizer would be beneficial to increase the seed yield of soybean variety BARI soybean 6 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. The results are required to substantiate further with different varieties of soybean.
3. It needs to conduct more experiments with S and micronutrient B whether can regulate the morphological characters, yield and seed quality of BARI soybean- 6.

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APPENDICES

Appendix I: **Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

Source: SRDI

B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	1.00
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II: Analysis of variance of the data on Plant height , Number of branch and Number of pod per plant of soyabean as influenced by S and B

Sources of Variation	Degrees of freedom	Mean Square			
		Plant height		Number of branch	Number of pod per plant
		40 DAS	60 DAS		
Replication	2	39.571	39.571	35.98	3.22
Factor A	3	28.62*	28.62*	37.64^{NS}	1.712*
Factor B	2	59.57*	59.57*	169.33 ^{NS}	5.324*
AB	6	6.774*	6.774*	5.68*	0.525*
Error	22	1.8	1.8	7.27	0.286

*significant at 5% level of probability
NS- Non significant

Appendix III: Analysis of variance of the data on pod length, Number of seed per pod, thousand seed weight, yield and oil content of soyabean as influenced by S and B

Sources of Variation	**Degrees of freedom**	**Mean Square**				
		Pod length	**Seed per pod**	**Thousand seed weight**	**Yield (t/ha)**	**Oil content (%)**
Replication	2	0.922	3.528	101.14	0.006	9.284
Factor A	3	0.862*	3.451 ^{NS}	189.56*	0.121*	134.24*
Factor B	2	2.165*	4.382*	1224.8*	0.023*	26.12*
AB	6	0.172*	0.743*	134*	0.006*	0.869*
Error	22	0.032	0.24	25.535	0.001	1.799

*significant at 5% level of probability
NS- Non significant

Appendix IV: Analysis of variance of the data on N, P, K, S and B content of soyabean seed as influenced by S and B

Sources of Variation	Degrees of freedom	Mean Square				
		N	P	K	S	B
Replication	2	0.004	0.013	0.005	0.009	0.026
Factor A	3	2.419 NS	0.007 NS	0.032 NS	0.008 NS	0.02 NS
Factor B	2	0.585*	0.012 NS	0.016 NS	0.004 NS	0.024 NS
AB	6	0.017 *	0.001*	0.003*	0.001*	0.008*
Error	22	0.095	0.003	0.004	0.001	0.071

*significant at 5% level of probability

NS- Non significant

Appendix V: Analysis of variance of the data on pH, Organic matter (%),Available S (ppm), Available B content of post harvest soil of soyabean field as influenced by S and B

Sources of Variation	Degrees of freedom	Mean Square			
		pH	Organic matter (%)	Available S (ppm)	Available B (ppm)
Replication	2	0.425	0.139	0.428	0.036
Factor A	3	0.192*	0.048*	29.63*	0.012*
Factor B	2	0.65*	0.12*	5.35*	0.122*
AB	6	0.07*	0.022*	1.76*	0.003*
Error	22	0.33	0.083	0.331	0.001

*significant at 5% level of probability