EFFECT OF SULPHUR AND MOLYBDENUM ON THE GROWTH, YIELD AND OIL CONTENT OF BARI SOYBEAN-5

RIZWAN AHMED RIZVI

DEPARTMENT OF SOIL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

RIZWAN AHMED RIZVI

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APPROVED BY:

Prof. Mst. Afrose Jahan
Supervisor

Prof. Dr. Alok Kumar Paul
Co-Supervisor

Dr. Mohammad Issak
Chairman
Examination Committee

DEDICATED

TO

MY BELOVED PARENTS

DEPARTMENT OF SOIL SCIENCE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'Effect of Sulphur and Molybdenum on the Growth, Yield and Oil Content of BARI Soybean-5'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Soil Science**, embodies the result of a piece of bonafide research work carried out by **Rizwan Ahmed Rizvi**, Registration number: **08-03153** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Prof. Mst. Afrose Jahan
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

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The Author

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ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2013 to April, 2014 to study the effect of sulphur and molybdenum on growth, yield and oil content of BARI soybean 5. The experiment comprised of two factors-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} and S_3: 40 kg S ha^{-1}; Factors B: Levels of molybdenum (3 levels)- Mo_0: 0 kg Mo ha^{-1} (control), Mo_1: 1.0 kg Mo ha^{-1} and Mo_2: 1.5 kg Mo ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. For sulphur, the highest seed yield (2.00 t ha^{-1}) was observed from S_2 and the lowest (1.60 t ha^{-1}) from S_0. The highest oil content (21.52%) was observed from S_2 and the lowest (16.78%) from S_0.The maximum concentration in seed for N (2.80%), P (0.407%), K (0.574%), S (0.327%) and Mo (0.0143%) was found from S_2, while the minimum concentration in seed for N (1.67%), P (0.350%), K (0.447%), S (0.268%) and Mo (0.0112%) from S_0. In case of molybdenum, the highest seed yield (1.93 t ha^{-1}) was recorded from Mo_2, whereas the lowest yield (1.70 ha^{-1}) from Mo_0. The highest oil content (20.64%) was recorded from Mo_2, whereas the lowest oil content (18.21%) from Mo_0. The maximum concentration in seed for N (2.61%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from Mo_2 (1.5 kg Mo ha^{-1}) and the minimum concentration in seed for N (2.18%), P (0.349%), K (0.485%), S (0.286%) and Mo (0.0121%) was recorded from Mo_0. For the interaction effect of sulphur and molybdenum, the highest seeds yield (2.21 t ha^{-1}) was found from S_2Mo_2, while the lowest seeds yield (1.56 t ha^{-1}) from S_0Mo_0. The highest oil content (23.57%) was found from S_2Mo_2, while the lowest (16.25%) from S_0Mo_0. The maximum concentration in seed for N (0.261%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from S_2Mo_2, whereas the minimum for N (1.52%), P (0.334%), K (0.433%), S (0.261%) and Mo (0.0108%) from S_0Mo_0. It may be concluded that application of 20 kg S ha^{-1} & 1.5 kg Mo ha^{-1} can be more beneficial for the farmers to get maximum yield.

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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 about 90.19 million hectare of land and annual production is approximately 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*. 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.

On an average, about 8-10% of the protein intake in Bangladesh diet originates from animal sources (Begum, 1989) and the rest can be met from plant sources especially from the pulse crops like soybean. Soybean is originating from the hot areas of South-East Asia, but more than 50% of its production today comes from the United States and South America. Per hectare yield of soybean in Bangladesh is only 1.2 t ha^{-1} (BARI, 2007) as compared to other soybean producing countries of the world like USA with seed yield of 3.5 t ha^{-1} (James *et al*., 1999). Yield of soybean is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz., unavailability of seeds of high yielding varieties with indicative quality, delayed sowing, fertilizer management especially micronutrients, disease and insect infestation, modern cultivation and improper or limited irrigation facilities. Among different factor micronutrients especially sulphur and molybdenum application are also the most important factor.

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 and Shrivastava *et al*., 2000). 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.

Molybdenum is an essential micronutrient and required for the formation of the nitrate reductase enzyme and in legume is directly involved in symbiotic nitrogen fixation (Williams and Fraustoda Silva 2002; Roy *et al.*, 2006). It is an important co-factors components of key enzymes of assimilatory nitrogen metabolism, nitrogen fixation, nitrate uptake (Gupta and Lipsett, 1981; Campbell, 1999). Application of molybdenum into the soils has increased the contents of potassium, phosphorus and crude protein (Anonymous, 2005). Molybdenum is required for growth of most biological organisms including plants (Graham and Stangoulis, 2005). Moreover, Mo is an element that is translocated with low mobility inside plants, which is the main reason for its low utilization by plant organs during the period of starvation (Gupta and Lipsett, 1981). Molybdenum has a positive effect on yield quality and nodules forming in legume crops and molybdenum increased plant height, number of branches and pods plant^{-1}, number of seeds plant^{-1} and seeds yield (Togay *et al*., 2008). Effects of molybdenum and boron on legumes have been reported by many scientists (Bhuiyan *et al*., 1998; Verma *et al*., 1988; Tiwari *et al*., 1989; Zaman *et al*., 1996).

Under the above perspective and above all situation the present experiment was conducted with different levels of sulphur and molybdenum on BARI soybean 5 with the following objectives:

a. To find the effect of sulphur and molybdenum on growth, yield and oil content of BARI soybean 5; and
b. To assess the concentration of different nutrients in seeds and stover due to the application of different levels of sulphur and molybdenum.

CHAPTER II

REVIEW OF LITERATURE

Soybean is one of the leading oil and protein containing crops of the world and as well as Bangladesh. The crop has conventional less attention by the researchers on various aspects because normally it grows with minimum care or management practices. Based on this a very few research have been carried out in our country. 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 molybdenum play an important role in improving soybean growth and yield. But research works related to sulphur and molybdenum fertilizer are limited in Bangladesh context. However, some of the important and informative works and research findings related to the sulphur and molybdenum 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 grain 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 effect of phosphorus and sulphur on content, 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.

The field experiment was conducted by Pable and Patil (2011) to study 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 grain 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 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 S levels 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 Molybdenum on plant growth, yield attributing characters and yield

Liu Peng *et al*. (2005) carried out experiment in pot culture with three cultivars (Zheehun no. 3, Zheehum of Mo and/or B sufficiently increased the absorption of Mo and B by soybean. High supply of Mo enhanced Mo absorption and content. Combined application of proper Mo and B levels led to more Mo absorption by soybean and hence higher Mo content, than single application of proper Mo level at early stage but less at later stage. The Mo absorbed by soybean mainly accumulated in seeds.

Meschede *et al*. (2004) conducted a field experiment in Brazil, during 2000-2001 to investigate the effect of Mo and Co as foliar application and seed treatment on grain yield, seed protein content and agronomic traits of soybean cv. BRS 133. The treatments consisted of combination of seed treatment with and without Mo and Co (Comol; 12% Mo and 2% Co) and foliar application at different stages at development with the following commercial products; Comol at V_4 stage, Bas-Citrus (10% N, 4% Zn, 3.7% S, 3% Mn and 0.5% B) at V_4 stage, A control without Mo and Co application was included. The seed treatment with Mo and Co increased the seed protein content and grain yield.

Masto *et al.* (2004) conducted a pot experiment during rabi season 1999-2000 in Hyderabad using soybean as the test crop. The treatment used in the study consisted of two levels of liming (0 and 3.5 tons ha^{-1} based on lime requirement), two levels of P (0 and 10 mg P kg^{-1}) and three levels of Mo (0, 0.25 and 0.5 mg Mo kg^{-1}). It was observed that liming at 3.5 tons ha^{-1} and phosphorus applied at 10 mg P kg^{-1}, both combine with 0.5 mg Mo kg^{-1} resulted to maximum values of phosphorus and molybdenum better than all other treatments and control.

Mahapatra (2003) carried out a field experiment to evaluated the performance of soybean as influenced by S and Mo. The experiment comprised four levels of sulphur and molybdenum viz. 0, 6, 12, 18 kg S ha^{-1} and 0, 1, 2, 3 kg Mo ha^{-1} as gypsum and ammonium molybdate, respectively. Highest biological yield and most of the yield attributes were obtained for the treatment combination of 12 kg

S ha^{-1} and 2 kg Mo ha^{-1} Grain yield was found to be significantly and positively correlated with effective pod and seed $plant^{-1}$.

Billore and Joshp (2000) conducted a field experiment to study direct and residual effect of integrated micronutrient application on soybean-wheat cropping system. The seed treatment with sodium molybdate @ 4 g Mo kg^{-1} seed was found most remunerative in soybean-wheat cropping system.

Sfredo *et al.* (1997) assessed the effectiveness of products containing trace elements applied to the seed on yield and protein contain of soybean seeds. They found that application of Mo significantly increased seed yield up to 0.48 t ha^{-1} and increased seed protein content by up to 60 g kg^{-1}.

Bukhoriev (1997) conducted a field trails on dark soil low in B and Mo, irrigated soybean were given no trace elements or 1 kg B at sowing and/or 50 g Mo as an ammonium molybdate seed treatment. Application of B + Mo increased the number and weight of nodules ha^{-1} by 24 and 29% respectively. Applying either B or Mo gave smaller increases. Seed yields were 2.60 t ha-1 in the control, 2.72 t with B, 2.76 t with Mo and 2.95 t with B + Mo. Seed protein content and protein yield were highest with the application of B + Mo.

Razmjoo and Henderlong (1997) conducted a field experiment and revealed that plant K, Mg and Ca contents and yield were not significantly affected by Mo application. Combination of K, S, B and Mo fertilizer had variable effects and the effect was dependent on the combination of fertilizer sources and levels.

Dwivedi *et al.* (1996) carried out a field experiment to study the influence of phosphorus and molybdenum application on nutrient status in various plant parts of soybean. The reported that 1.0 kg Mo ha^{-1} enhanced the absorption of all the nutrients and their accumulation in various plant parts including seed.

Srivastava and Ahlaeat (1995) observed that molybdenum application at 0.5 kg ha^{-1} significantly increased nodule number, pod $plant^{-1}$ and 1000-grain weight. Application of Mo increased N uptake.

Gupta and Vyas (1994) conducted a field trails at kota, Rajasthan to determine the effect of phosphorus, zinc and molybdenum on the yield and quality of soybean. They applied 0, 40, 80 kg P_2O_5 ha^{-1} as superphosphate, 0, 15, 30 kg $ZnSO_4$ ha^{-1} and 0, 0.5 kg Na2MoO4 ha^{-1} and reported that seed yield was highest by the application of Mo with 40 kg P_2O_5 and 15 kg $ZnSO_4$ ha^{-1}. Seed protein content was increased by P, Zn and Mo application while oil content was increased by Zn application only.

Kumar *et al.* (1993) reported that seed yield of lentil increased with increasing Mo and P rates and was highest with the combine application of Mo and P at the highest 2 ppm Mo and 50 P rates. P and Mo concentration and uptake in seed and straw increased with increasing Mo and P rates.

Haque and Bundu (1980) observed that inoculation with Rhizobium-N Mo and mulch increased the number and weight of nodules of soybean compared with the control. Seed yield was increased by all treatment, notably 360 and 279% for N + Mo + inoculation and for N + inoculation, respectively, seed protein content was also increased by all treatment, especially 18.6% by N + Mo + inoculation and 16.8% by inoculation + mulch.

Subbian and Ramiah (1982) observed that redgram (*Cajanus cajan*) CV-3 with and without rhizobial inoculation and seed treated with 1% sodium molybdate were grown with 0, 25 and 50 kg P_2O_5 ha^{-1} . Phosphorus affected the growth and yield of the crop significantly but rhizobial inoculation and soil or seed treatment with sodium molybdate did not affect.

Ibupoto and Kotecki (1994) observed that application of Mo or Mo + B to soybean increased the number of seeds plant and seed yield. They also observed that application of 1 kg B ha^{-1} to peas and soybeans and treating seeds with the equivalent of 50 gm ammonium molybdate increased nodule weight, atmospheric N-fixation and seed yield.

Chowdhury and Das (1998) observed that P, S and Mo application significantly increased the canopy, nodule count, yield of rain fed black gram, yield of succeeding safflower and reduced splash loss and conserved more soil water.

Bhuiyan *et al*. (1998) conducted a field experiment on grey terrace soil of Gajipur to observe the effect of rhizobial inoculam, Mo and B on the nodulation, yield and agronomic performances of chickpea. *Rhizobiom inoculam* along with phosphorus, potash, boron and molybdenum gave significantly higher nodule number, nodule weight, stover yield and seed yield.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from December 2013 to April 2014 to study the effect of sulphur and molybdenum on the growth, yield and oil content of BARI soybean 5. 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 (Anon., 1989).

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 Shallow 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 silty-clay with pH and Catayan 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, 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 5 was used as the test crops. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. BARI collected some lines from Taiwan and among the variety 'RANSOM' produced the highest yield in regional trial. In 2002, this line is released as variety BARI soybean 5, which was recommended by the national seed board. The life cycle of this variety ranges from 90-100 days. Maximum seed yield is 1.6-2.0 t ha^{-1}.

3.5 Land preparation

The land was irrigated before ploughing. After having 'zoe' 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 19th and 23th December 2013, 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 (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 molybdenum (3 levels)

i) Mo_0: 0 kg Mo ha^{-1} (control)

ii) Mo_1: 1.0 kg Mo ha^{-1}

iii) Mo_2: 1.5 kg Mo ha^{-1}

There were in total 12 (4×3) treatment combinations such as S_0Mo_0, S_0Mo_1, S_0Mo_2, S_1Mo_0, S_1Mo_1, S_1Mo_2, S_2Mo_0, S_2Mo_1, S_2Mo_2, S_3Mo_0, S_3Mo_1 and S_3Mo_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 boric acid were applied at the rate of 60, 175, 120 and 10 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation (BARI, 2011). Sulphur and molybdenum 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 three blocks. The 12 treatment combinations were assigned in the each plot of each block. 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 December 23, 2013 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm and plant to plant 5-6 cm.

3.10 Intercultural operations

3.10.1 Thinning

Seeds started germination within four days after sowing (DAS). Thinning was at 23 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was provided two times at 25 DAS and 55 DAS for all experimental plots equally. The crop field was weeded at 23 DAS and 52 DAS.

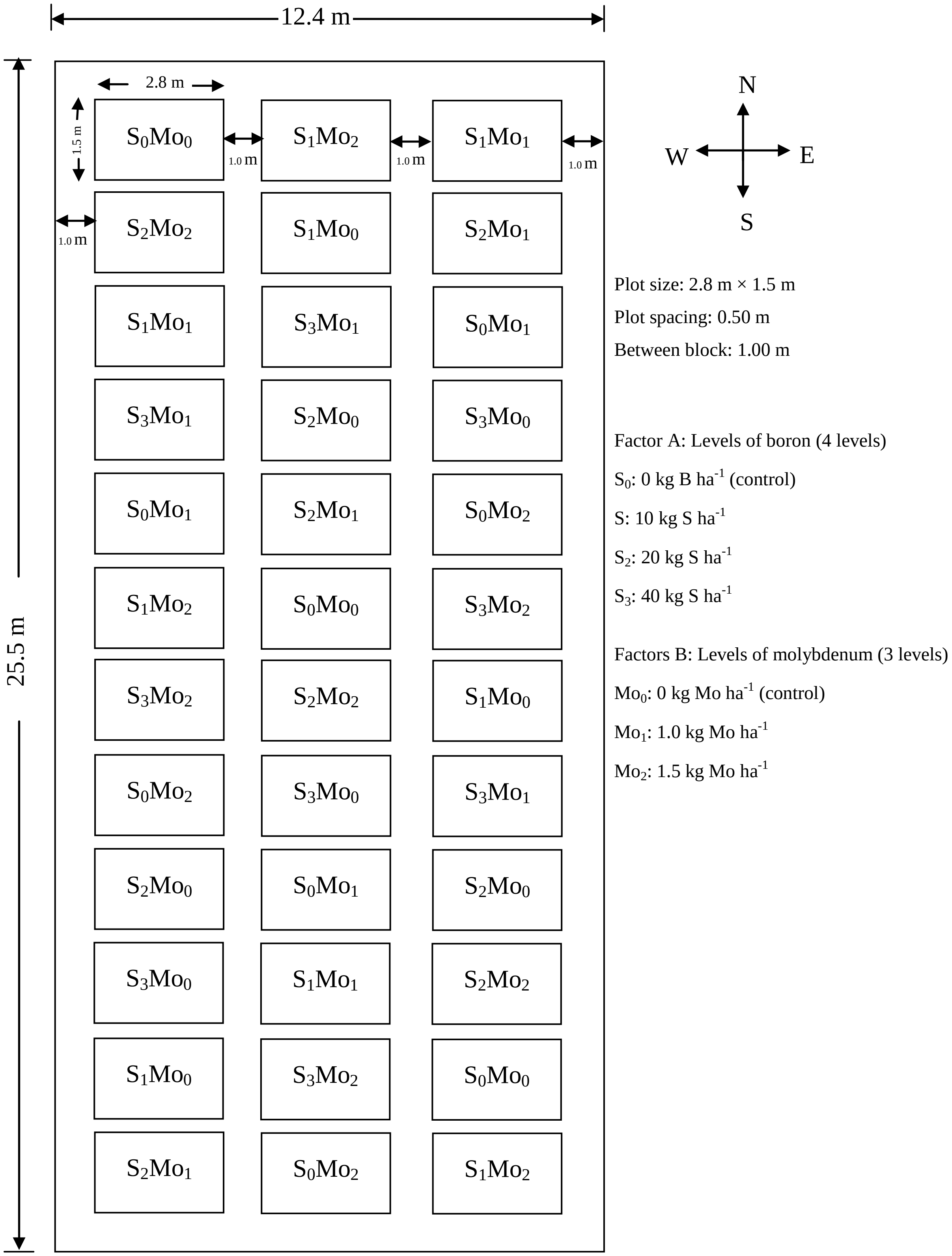


Figure 1. Layout of the experimental plot

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 sprayed at the rate of 1 mm with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

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 10 days started from 30 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. Days required from sowing to harvest
iv. Number of pods plant^{-1}
v. Pod length (cm)
vi. Number of seeds pod^{-1}
vii. Weight of 100 seeds (g)
viii. Seed yield hectare^{-1}
ix. Stover yield hectare^{-1}
x. N, P, K, S and Mo concentration of seeds and stover sample
xi. pH, organic matter, available S and Mo in post harvest soil

3.14 Procedure of data collection

3.14.1 Plant height

The plant height was measured at 30, 40, 50, 60 DAS and at harvest 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 30, 40, 50, 60 DAS and at harvest

3.14.3 Days required from sowing to harvest

Each plant of the experiment plot was kept under close observation to count days to harvest of soybean. Total number of days from the date of sowing to the harvest was recorded.

3.14.4 Pod length

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

3.14.5 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.

3.14.6 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.

3.14.7 Weight of 100 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).

3.14.8 Seed yield hectare^{-1}

The seeds 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 the yield in t ha^{-1}.

3.14.9 Stover yield hectare^{-1}

The stover collected from 4.2 (2.8 m ×1.5 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.14.10 Oil content in seed

The oil content of sesame seed was determined by Folch method (Folch, *et al.*, 1957). One gram sesame seed was taken in a mortar. The seeds were completely ground with a pestle. Thirty milliliter Folch 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 and stover samples

3.15.1 Collection of samples

Seeds and stover samples were collected after threshing and 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 Mo.

3.15.2 Preparation of samples

The samples were dried in an oven at 70^0C for 72 hours and then ground by a grinding machine to pass through a 20-mesh sieve. The seeds and stover samples were analyzed for N, P, K, S and Mo 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 and the volume was made up to the mark with de-ionized water. A 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 Mo

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, B and Mo were determined from this digest.

3.15.5 Determination of P, K, S and Mo from samples

3.15.5.1 Phosphorus

Phosphorus was digested from the plant sample (seeds and stover) with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.,* 1954). Phosphorus in the digest was determined by using 1 ml for seeds sample and 2 ml for stover 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 seeds and 10 ml for the stover were taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbance 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 $CaCl_2$ (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 S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wave lengths (Hunter, 1984).

3.15.5.4 Molybdenum

For Mo, the extractant of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1984). Molybdenum 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 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, crushed and 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 Mo 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

Sulphur content was determined from the digest of the soil samples with $CaCl_2$ (0.15%) solution as described by (Page *et al.*, 1982). The digested S was determined by developing turbidity by adding acid soil solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wave lengths (Hunter, 1984).

3.17.4 Available Molybdenum

Available Mo content was determined by extracting the soil with $BaCl_2$ solution as described by Page *et al*., 1982. The digested Zn was determined by developing turbidity by adding $BaCl_2$ solution. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

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 molybdenum on 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).

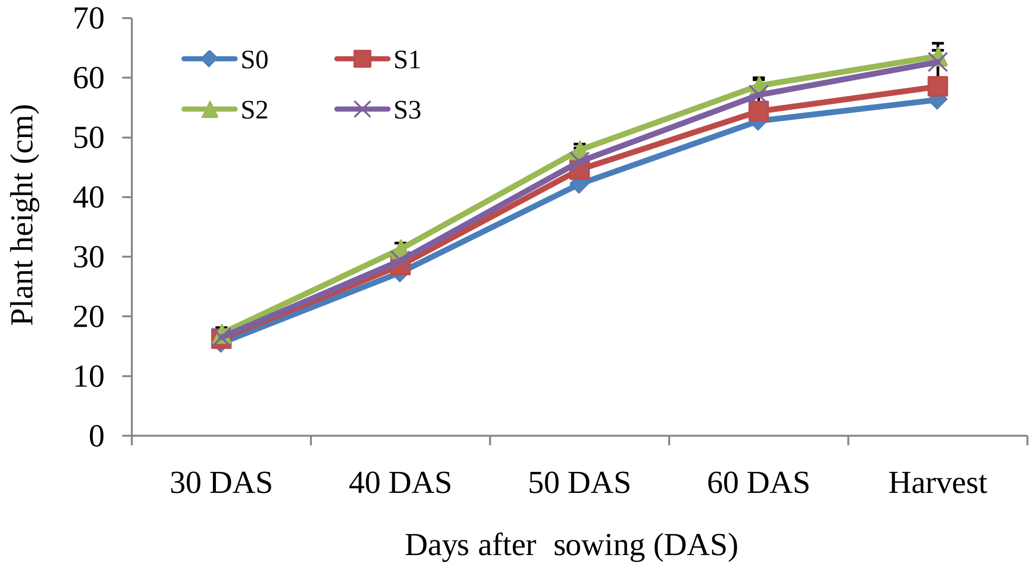
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of sulphur and molybdenum on growth, yield and oil content of BARI soybean 5. Data on different growth parameter, yield, oil content, nutrient concentration in pods & stover, and characteristics of post harvest soil was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-VIII. 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

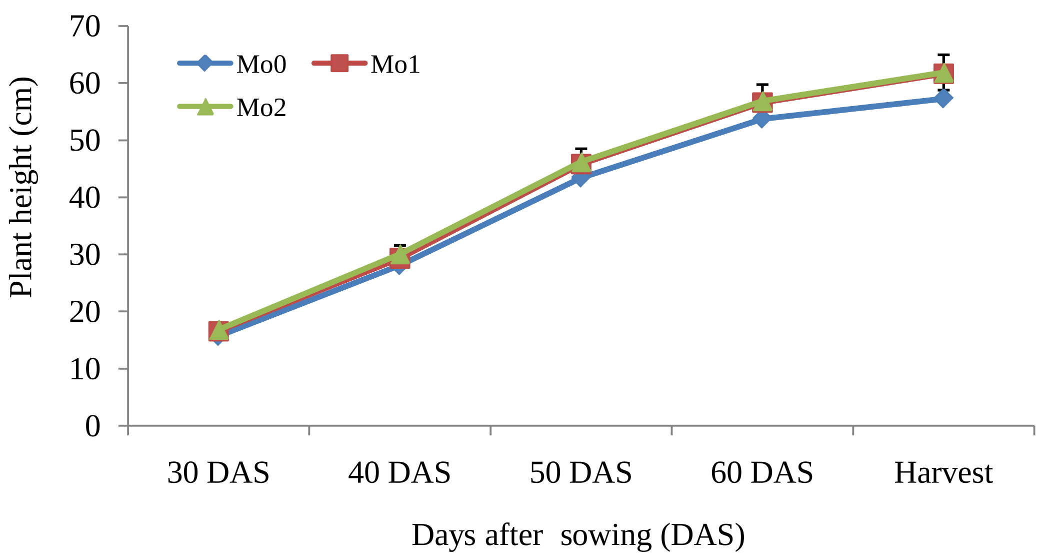
Plant height of BARI soybean 5 showed statistically significant variation due to different levels of sulphur at 30, 40, 50, 60 days after sowing (DAS) and at harvest (Appendix III). Data revealed that at 30, 40, 50, 60 and at harvest, the tallest plant (17.12, 31.29, 47.86, 58.66 and 63.58 cm, respectively) was recorded from S_2 (20 kg S ha^{-1}), which were statistically similar (16.49, 29.38, 45.92, 57.13 and 62.63 cm, respectively) with S_3 (40 kg S ha^{-1}), whereas the shortest plant (15.58, 27.36, 42.19, 52.75 and 56.27 cm, respectively) was found from S_0 (0 kg S ha^{-1}) treatment (Figure 2). Among 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.



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}

Figure 2. Effect of different levels of sulphur on plant height of BARI soybean 5. Vertical bars represent LSD value.



Mo_0: 0 kg Mo ha^{-1} (control) Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

Figure 3. Effect of different levels of molybdenum on plant

Different levels of molybdenum differed significantly in terms of plant height of BARI soybean 5 at 30, 40, 50, 60 DAS and at harvest (Appendix III). At 30, 40, 50, 60 DAS and at harvest, the tallest plant (16.82, 30.05, 46.18, 56.88 and 61.85 cm, respectively) was found from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically identical (16.58, 29.33, 45.83, 56.59 and 61.62, respectively) with Mo_1 (1.0 Mo ha^{-1}), while the shortest plant (15.69, 28.08, 43.42, 53.74 and 57.28 cm, respectively) was observed from Mo_0 (0 kg Mo ha^{-1}) treatment (Figure 3). Mahapatra (2003) recorded plant height was highest with 2 kg Mo ha^{-1}.

Interaction effect of different levels of sulphur and molybdenum showed statistically significant variation on plant height of BARI soybean 5 at 30, 40, 50, 60 DAS and at harvest (Appendix III). At 30, 40, 50, 60 DAS and at harvest, the tallest plant (18.67, 33.32, 51.51, 61.83 and 68.06 cm, respectively) was recorded from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}) and the shortest plant (14.58, 26.55, 41.56, 51.30 and 52.68 cm, respectively) was observed from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 1).

4.2 Number of branches plant^{-1}

Statistically significant variation was recorded in terms of number of branches plant^{-1} of BARI soybean 5 due to different levels of sulphur at 30, 40, 50, 60 days after sowing (DAS) and at harvest (Appendix IV). At 30, 40, 50, 60 and at harvest, the maximum number of branches plant^{-1} (5.47, 11.04, 14.22, 19.11 and 20.00, respectively) was observed from S_2 (20 kg S ha^{-1}), which were statistically similar (5.40, 10.36, 13.73, 18.67 and 19.53, respectively) with S_3 (40 kg S ha^{-1}), while the minimum number of branches plant^{-1} (4.49, 8.09, 12.33, 15.27 and 16.38, respectively) was recorded from S_0 (0 kg S ha^{-1}) treatment (Figure 4). Farhad *et al*. (2010) reported that application of sulphur @ 20 kg ha^{-1} produced the maximum number of branches plant^{-1}.

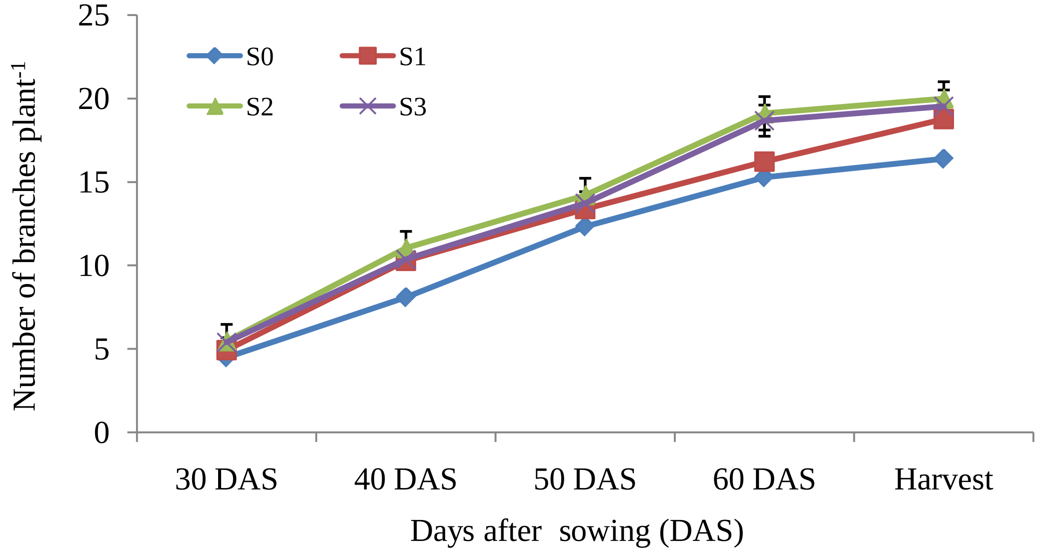
Table 1. Interaction effect of sulphur and molybdenum on plant height at different days after sowing (DAS) of BARI soybean 5

Sulphur × molybdenum	Plant height (cm) at				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
S_0Mo_0	14.58 d	26.55 d	41.56 d	51.30 c	52.68 e
S_0Mo_1	16.14 bc	27.04 cd	42.60 d	53.10 bc	57.62 de
S_0Mo_2	16.03 bcd	28.50 bcd	42.39 d	53.84 bc	58.50 cd
S_1Mo_0	16.25 bc	28.20 bcd	43.94 cd	53.34 bc	57.44 de
S_1Mo_1	16.14 bc	28.30 bcd	44.60 cd	55.12 bc	59.60 cd
S_1Mo_2	16.39 bc	29.24 bc	45.27 bcd	54.77 bc	58.52 cd
S_2Mo_0	15.41 cd	28.18 bcd	42.98 d	53.19 bc	57.03 de
S_2Mo_1	17.29 b	32.37 a	48.91 ab	60.95 a	65.64 ab
S_2Mo_2	18.67 a	33.32 a	51.71 a	61.83 a	68.06 a
S_3Mo_0	16.53 bc	29.41 bc	45.18 bcd	57.14 ab	61.96 bcd
S_3Mo_1	16.76 bc	29.62 b	47.21 bc	57.20 ab	63.63 abc
S_3Mo_2	16.18 bc	29.13 bc	45.36 bcd	57.05 ab	62.31 bcd
$LSD_{(0.05)}$	1.386	2.214	3.654	4.618	4.872
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	5.00	4.48	6.78	4.89	6.78

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}

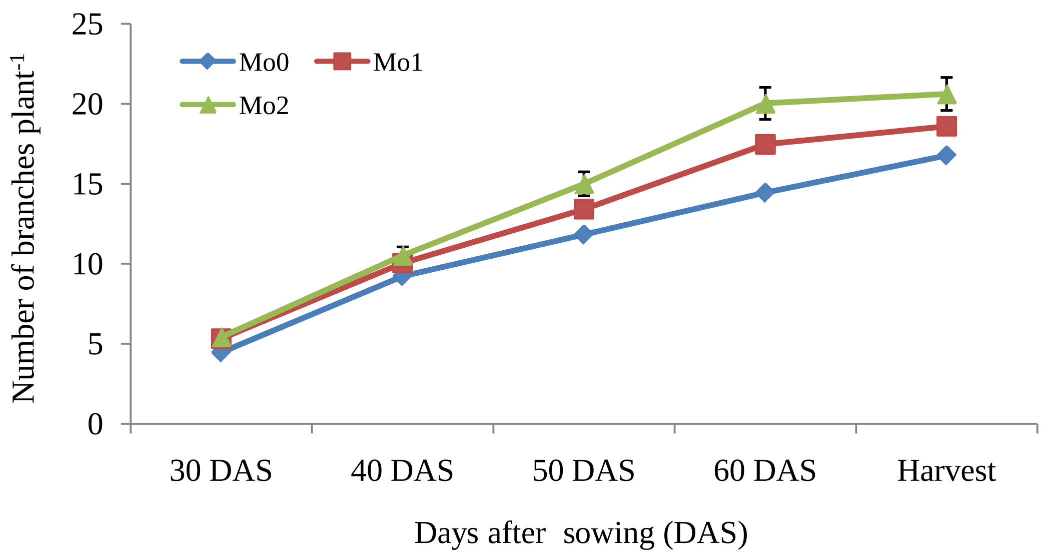
Mo_0: 0 kg Mo ha^{-1} (control)
Mo_1: 1.0 kg Mo ha^{-1}
Mo_2: 1.5 kg Mo ha^{-1}



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}

Figure 4. Effect of different levels of sulphur on number of branches plant^{-1} of BARI soybean 5. Vertical bars represent LSD value.



Mo_0: 0 kg Mo ha^{-1} (control) Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

Figure 5. Effect of different levels of molybdenum on number

Number of branches plant^{-1} of BARI soybean 5 varied significantly due to different levels of molybdenum at 30, 40, 50, 60 DAS and at harvest (Appendix IV). At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches plant^{-1} (5.43, 10.53, 15.00, 20.03 and 20.62, respectively) was attained from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (5.32, 10.05, 13.42, 17.47 and 18.60, respectively) with Mo_1 (1.0 Mo ha^{-1}) and the minimum number (4.47, 9.23, 11.83, 14.45 and 16.78, respectively) was observed from Mo_0 (0 kg Mo ha^{-1}) treatment (Figure 5).

Number of branches plant^{-1} of BARI soybean 5 at 30, 40, 50, 60 DAS and at harvest showed statistically significant differences due to the interaction effect of different levels of sulphur and molybdenum (Appendix IV). At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches plant^{-1} (5.93, 12.40, 16.93, 22.13 and 22.60, respectively) was recorded from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), while the minimum number (4.13, 7.60, 10.47, 12.93 and 15.20, respectively) from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 2).

4.3 Days required for sowing to harvest

Days required for sowing to harvest of BARI soybean 5 showed statistically significant variation due to different levels of sulphur (Appendix V). The minimum days required for sowing to harvest (91.00) was found from S_2 (20 kg S ha^{-1}), which was closely followed (94.33 and 94.44) by S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), while the maximum days required for sowing to harvest (97.56) was observed from S_0 (0 kg S ha^{-1}) treatment (Figure 6).

Different levels of molybdenum varied significantly in terms of days required for sowing to harvest of BARI soybean 5 (Appendix V). The minimum days required for sowing to harvest (92.83) was observed from Mo_2 (1.5 kg Mo ha^{-1}), whereas the maximum days required for sowing to harvest (95.67) was recorded from Mo_0 (0 kg Mo ha^{-1}) which were statistically similar (94.50) with Mo_1 (1.0 kg Mo ha^{-1}) treatment (Figure 7).

Table 2. Interaction effect of sulphur and molybdenum at different days after sowing (DAS) on number of branches plant^{-1} of BARI soybean 5

Sulphur × molybdenum	Number of branches plant^{-1} at				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
S_0Mo_0	4.13 e	7.60 g	10.47 e	12.93 h	15.20 d
S_0Mo_1	4.53 cd	7.93 fg	12.67 cd	14.60 fgh	15.60 d
S_0Mo_2	4.80 c	8.73 ef	13.87 bc	18.27 cde	18.33 bcd
S_1Mo_0	4.40 de	10.13 c	12.67 cd	14.07 gh	16.80 cd
S_1Mo_1	5.20 b	10.47 c	13.40 bcd	16.60 def	18.93 bc
S_1Mo_2	5.20 b	10.20 c	14.07 bc	18.00 cde	20.53 ab
S_2Mo_0	4.67 cd	9.20 de	11.73 de	14.53 fgh	16.73 cd
S_2Mo_1	5.80 a	11.53 b	14.00 bc	19.67 bc	20.67 ab
S_2Mo_2	5.93 a	12.40 a	16.93 a	22.13 a	22.60 a
S_3Mo_0	4.67 cd	10.00 cd	12.47 cd	16.27 efg	18.40 bcd
S_3Mo_1	5.73 a	10.27 c	13.60 bcd	19.00 bcd	19.20 bc
S_3Mo_2	5.80 a	10.80 bc	15.13 ab	20.73 b	21.00 ab
$LSD_{(0.05)}$	0.339	0.865	1.857	2.275	2.868
Level of significance	0.05	0.01	0.05	0.05	0.05
CV(%)	5.94	5.14	8.17	7.76	9.07

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

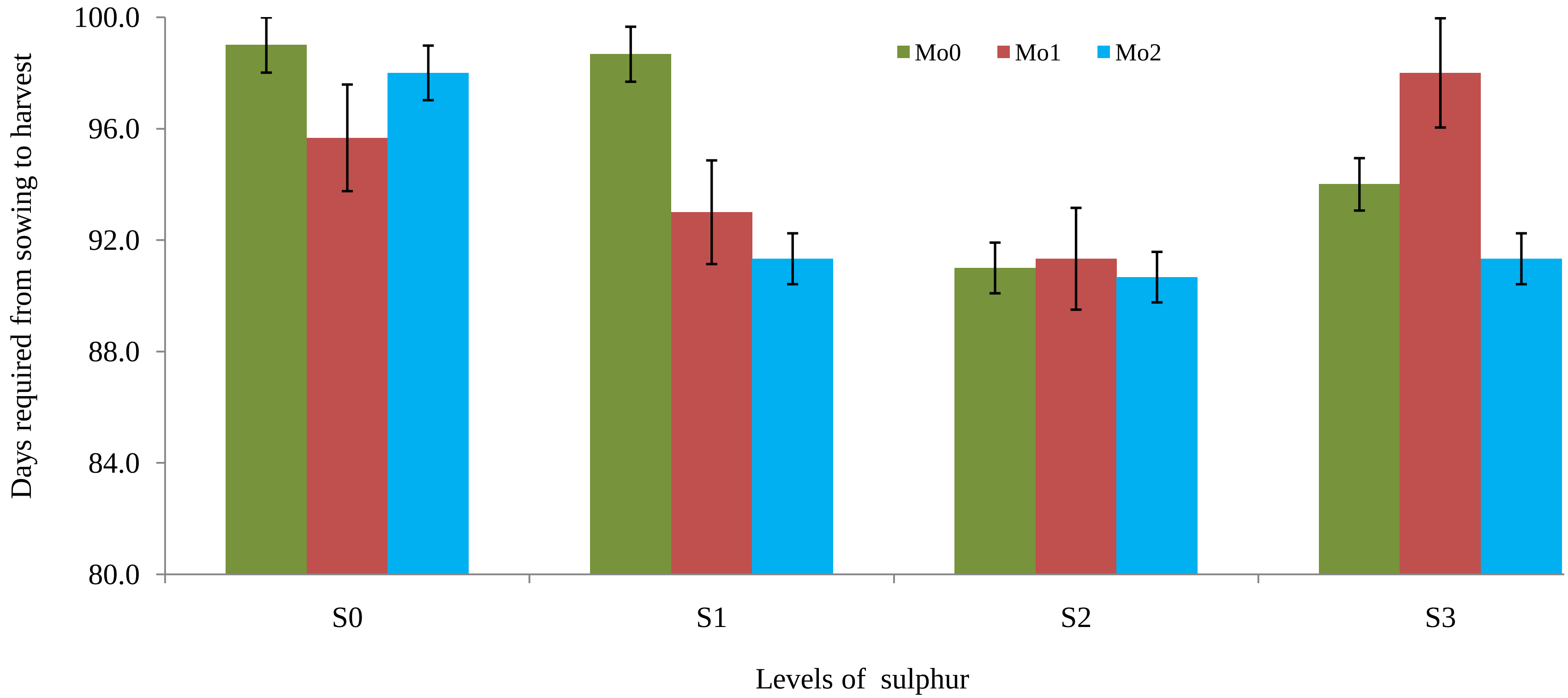
Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and molybdenum on days required for sowing to harvest of BARI soybean 5 (Appendix V). The minimum days required for sowing to harvest (90.67) was found from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), again the maximum days required for sowing to harvest pod (99.00) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Figure 8).

4.4 Pod length

Statistically significant variation was recorded due to different levels of sulphur in terms of pod length of BARI soybean 5 (Appendix V). The longest pod (4.79 cm) was observed from S_2 (20 kg S ha^{-1}), which were statistically identical (4.71 cm and 4.59 cm) with S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), while the shortest pod (4.25 cm) was found from S_0 (0 kg S ha^{-1}) treatment (Table 3). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes.

Different levels of molybdenum varied significantly in terms of pod length of BARI soybean 5 (Appendix V). The longest pod (4.93 cm) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (4.75 cm) with Mo_1 (1.0 kg Mo ha^{-1}) and the shortest pod (4.08 cm) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 3). Mahapatra (2003) recorded longest pod with 2 kg Mo ha^{-1}.

Pod length of BARI soybean 5 showed statistically significant variation due to the interaction effect of different levels of sulphur and molybdenum (Appendix V). The longest pod (5.35 cm) was recorded from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), whereas the shortest pod (3.69) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 4).



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1} Mo_0: 0 kg Mo ha^{-1} (control) Mo_1: 1.0 kg Mo ha^{-1}

S_2: 20 kg S ha^{-1} S_3: 40 kg S ha^{-1} Mo_2: 1.5 kg Mo ha^{-1}

Figure 8. Interaction effect of different levels of sulphur and molybdenum on days required from sowing to harvest of BARI soybean 5. Vertical bars represent LSD value.

Table 3. Effect of sulphur and molybdenum on yield contributing characters and yield of BARI soybean 5

Sulphur and molybdenum	Pod length (cm)	Number of seeds pod^{-1}	Weight of 100 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0	4.25 b	2.91 c	12.49 b	1.60 c	2.13 c
S_1	4.59 a	3.10 b	12.94 b	1.79 b	2.34 b
S_2	4.79 a	3.27 a	13.96 a	2.00 a	2.56 a
S_3	4.71 a	3.19 ab	13.77 a	1.96 a	2.54 a
$LSD_{(0.05)}$	0.245	0.135	0.563	0.128	0.120
Level of significance	0.01	0.01	0.01	0.01	0.01
Mo_0	4.08 b	2.86 c	12.70 b	1.70 b	2.24 b
Mo_1	4.75 a	3.18 b	13.56 a	1.89 a	2.46 a
Mo_2	4.93 a	3.31 a	13.61 a	1.93 a	2.48 a
$LSD_{(0.05)}$	0.213	0.117	0.487	0.110	0.104
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.49	4.38	5.33	7.15	5.16

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

Table 4. Interaction effect of sulphur and molybdenum on yield contributing characters and yield of BARI soybean 5

Sulphur × molybdenum	Pod length (cm)	Number of seeds pod^{-1}	Weight of 100 seeds (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0Mo_0	3.69 e	2.77 f	11.78 e	1.56 f	2.07 e
S_0Mo_1	4.45 cd	2.93 def	12.76 de	1.60 ef	2.17 de
S_0Mo_2	4.61 cd	3.03 de	12.94 cd	1.65 def	2.17 de
S_1Mo_0	4.36 d	2.90 def	12.73 de	1.69 cdef	2.23 cde
S_1Mo_1	4.52 cd	3.10 cd	13.16 cd	1.82 bcde	2.37 bcd
S_1Mo_2	4.89 bc	3.30 bc	12.94 cd	1.86 bcd	2.43 bc
S_2Mo_0	3.89 e	2.80 ef	12.65 de	1.63 def	2.17 de
S_2Mo_1	5.14 ab	3.40 ab	14.37 ab	2.17 a	2.73 a
S_2Mo_2	5.35 a	3.60 a	14.85 a	2.21 a	2.77 a
S_3Mo_0	4.37 d	2.97 def	13.63 bcd	1.90 bc	2.50 b
S_3Mo_1	4.88 bc	3.30 bc	13.97 abc	1.98 ab	2.57 ab
S_3Mo_2	4.89 bc	3.30 bc	13.70 bcd	1.99 ab	2.57 ab
$LSD_{(0.05)}$	0.425	0.233	0.974	0.221	0.207
Level of significance	0.05	0.05	0.05	0.05	0.01
CV(%)	5.49	4.38	5.33	7.15	5.16

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

4.5 Number of pods plant^{-1}

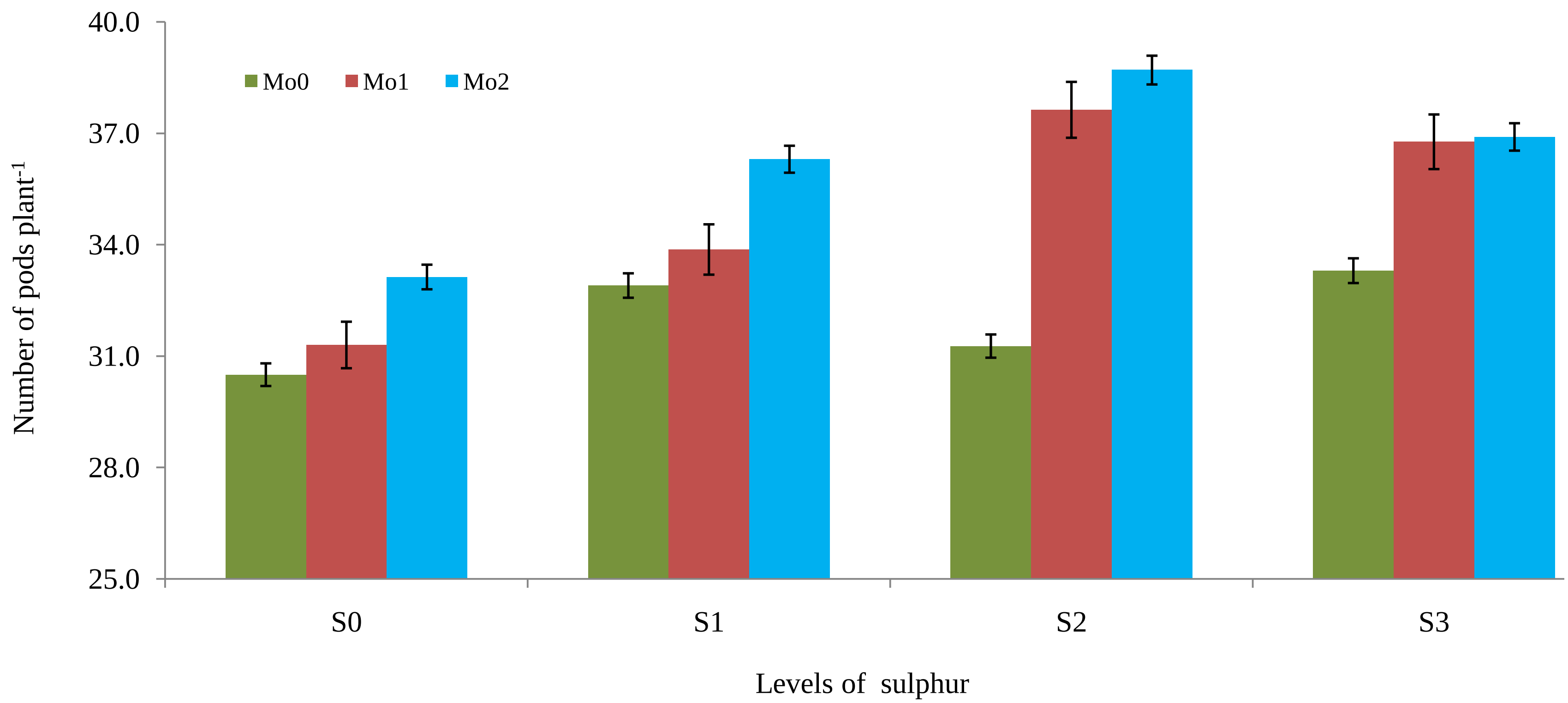
Different levels of sulphur showed statistically significant variation on number of pods plant^{-1} of BARI soybean 5 (Appendix V). The maximum number of pods plant^{-1} (35.87) was recorded from S_2 (20 kg S ha^{-1}), which were statistically identical (35.66 and 34.36) with S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), whereas the minimum number (31.64) was attained from S_0 (0 kg S ha^{-1}) treatment (Figure 9). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes.

Number of pods plant^{-1} BARI soybean 5 varied significantly due to different levels of molybdenum (Appendix V). The maximum number of pods plant^{-1} (36.26) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (34.89) with Mo_1 (1.0 kg Mo ha^{-1}), while the minimum number (31.99) from Mo_0 (0 kg Mo ha^{-1}) treatment (Figure 10). Srivastava and Ahlaeat (1995) observed that molybdenum application at 0.5 kg ha^{-1} significantly increased pod plant^{-1}.

Interaction effect of different levels of sulphur and molybdenum varied significantly in terms of number of pods plant^{-1} of BARI soybean 5 (Appendix V). The maximum number of pods plant^{-1} (38.70) was found from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}) and the minimum number (30.50) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Figure 11).

4.6 Number of seeds pod^{-1}

Different levels of sulphur showed statistically significant variation on number of seeds pod^{-1} of BARI soybean 5 (Appendix V). The maximum number of seeds pod^{-1} (3.27) was found from S_2 (20 kg S ha^{-1}), which were statistically identical (3.19) with S_3 (40 kg S ha^{-1}) and closely followed (3.10) by S_1 (10 kg S ha^{-1}), while the minimum number (2.91) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 3). 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.



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1} Mo_0: 0 kg Mo ha^{-1} (control) Mo_1: 1.0 kg Mo ha^{-1}

S_2: 20 kg S ha^{-1} S_3: 40 kg S ha^{-1} Mo_2: 1.5 kg Mo ha^{-1}

Figure 11. Interaction effect of different levels of sulphur and molybdenum on number of pods plant^{-1} of BARI soybean 5. Vertical bars represent LSD value.

Number of seeds pod^{-1} BARI soybean 5 varied significantly due to different levels of molybdenum (Appendix V). The maximum number of seeds pod^{-1} (3.31) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which were closely followed (3.18) by Mo_1 (1.0 kg Mo ha^{-1}), while the minimum number (2.86) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 3).

Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and molybdenum on number of seeds pod^{-1} of BARI soybean 5 (Appendix V). The maximum number of seeds pod^{-1} (3.60) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}) and the minimum number (2.77) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 4).

4.7 Weight of 100 seeds

Weight of 100 seeds of BARI soybean 5 varied significantly due to different levels of sulphur under the present trial (Appendix V). The highest weight of 100 seeds (13.96 g) was observed from S_2 (20 kg S ha^{-1}), which were statistically identical (13.77 g) with S_3 (40 kg S ha^{-1}) and closely followed (12.94 g) by S_1 (10 kg S ha^{-1}), while the lowest weight (12.49 g) was attained from S_0 (0 kg S ha^{-1}) treatment (Table 3). Akter *et al*. (2013) reported that application of different levels of sulphur showed significant effect on yield attributes. 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 100 seeds of BARI soybean 5 due to different levels of molybdenum (Appendix V). The highest weight of 100 seeds (13.61 g) was found from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (13.56 g) with Mo_1 (1.0 kg Mo ha^{-1}), again the lowest weight (12.70 g) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 3). Srivastava and Ahlaeat (1995) observed that molybdenum application at 0.5 kg ha^{-1} significantly increased 1000-grain weight.

Interaction effect of different levels of sulphur and molybdenum showed statistically significant variation in terms of weight of 100 seeds of BARI soybean 5 (Appendix V). The highest weight of 100 seeds (14.85 g) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), whereas the lowest weight (11.78 g) from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 4).

4.8 Seed yield hectare^{-1}

Seed yield hectare^{-1} of BARI soybean 5 varied significantly due to different levels of sulphur (Appendix V). The highest seed yield (2.00 t ha^{-1}) was observed from S_2 (20 kg S ha^{-1}), which were statistically identical (1.96 t ha^{-1}) with S_3 (40 kg S ha^{-1}) and closely followed (1.79 t ha^{-1}) by S_1 (10 kg S ha^{-1}). On the other hand, the lowest seed yield (1.60 t ha^{-1}) was observed from S_0 (0 kg S ha^{-1}) treatment (Table 3). 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.

Levels of molybdenum varied significantly in terms of seed yield hectare^{-1} of BARI soybean 5 (Appendix V). The highest seed yield (1.93 t ha^{-1}) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (1.89 t ha^{-1}) with Mo_1 (1.0 kg Mo ha^{-1}), whereas the lowest seed yield (1.70 t ha^{-1}) from Mo_0 (0 kg Mo ha^{-1}) (Table 3). Sfredo *et al.* (1997) found that application of Mo significantly increased seed yield up to 0.48 t ha^{-1}.

Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and molybdenum on seed yield hectare of BARI soybean 5 (Appendix V). The highest seed yield (2.21 t ha^{-1}) was found from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), while the lowest seed yield (1.56 t ha^{-1}) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 4).

4.9 Stover yield hectare^{-1}

Different levels of sulphur varied significantly on stover yield hectare^{-1} of BARI soybean 5 (Appendix V). The highest stover yield (2.56 t ha^{-1}) was found from S_2 (20 kg S ha^{-1}), which were statistically identical (2.54 t ha^{-1}) with S_3 (40 kg S ha^{-1}) and closely followed (2.34 t ha^{-1}) by S_1 (10 kg S ha^{-1}), whereas the lowest stover yield (2.13 t ha^{-1}) from S_0 (0 kg S ha^{-1}) treatment (Table 3). Farhad *et al*. (2010) reported that application of of sulphur @ 20 kg ha^{-1} produced the highest straw yield.

Stover yield hectare^{-1} of BARI soybean 5 varied significantly due to different levels of molybdenum (Appendix V). The highest stover yield (2.48 t ha^{-1}) was observed from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (2.46 t ha^{-1}) with Mo_1 (1.0 kg Mo ha^{-1}), while the lowest stover yield (2.24 t ha^{-1}) was recorded from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 3).

Interaction effect of different levels of sulphur and molybdenum showed statistically significant variation in terms of stover yield hectare of BARI soybean 5 (Appendix V). The highest stover yield (2.77 t ha^{-1}) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}) and the lowest stover yield (2.07 t ha^{-1}) from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 4).

4.10 Oil content in seeds

Oil content of seeds of BARI soybean 5 varied significantly due to different levels of sulphur (Appendix V). The highest oil content (21.52%) was observed from S_2 (20 kg S ha^{-1}), which were statistically identical (20.98%) with S_3 (40 kg S ha^{-1}) and closely followed (19.31%) by S_1 (10 kg S ha^{-1}). On the other hand, the lowest oil content (16.78%) was observed from S_0 (0 kg S ha^{-1}) treatment (Figure 12).

Levels of molybdenum varied significantly in terms of oil content of BARI soybean 5 (Appendix V). The highest oil content (20.64%) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which were statistically similar (21.10%) with Mo_1 (1.0 kg Mo ha^{-1}), whereas the lowest oil content (18.21%) from Mo_0 (0 kg Mo ha^{-1}) treatment (Figure 13).

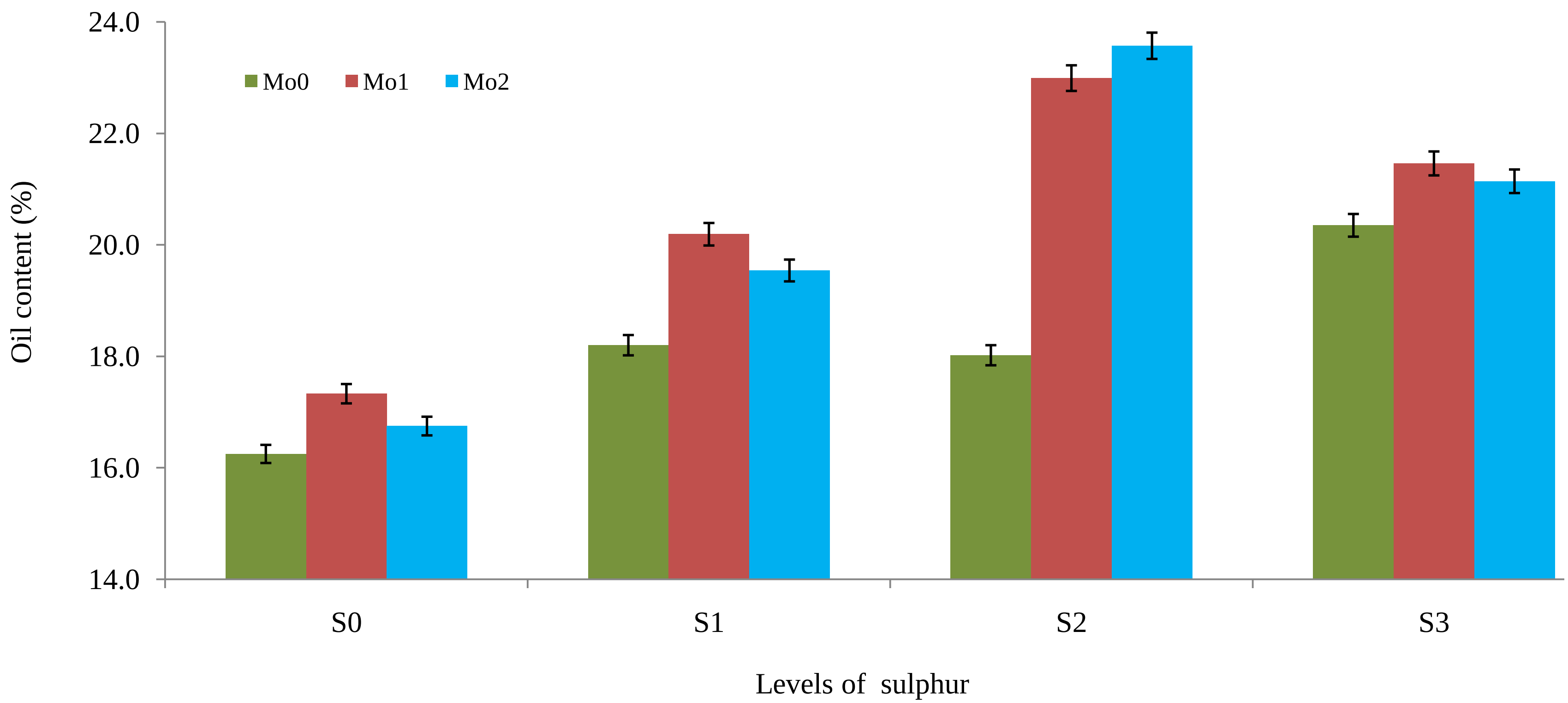
Statistically significant variation was recorded due to the interaction effect of different levels of sulphur and molybdenum on oil content of BARI soybean 5 (Appendix V). The highest oil content (23.57%) was found from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), while the lowest oil content (16.25%) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Figure 14).

4.11 N, P, K, S and Mo concentration in seeds

Significant variation was found for N, P, K, S and Mo concentration in seeds due different levels of sulphur (Appendix VI). The maximum concentration in seeds for N (2.80%), P (0.407%), K (0.574%), S (0.327%) and Mo (0.0143%) was found from S_2 (20 kg S ha^{-1}), while the minimum (1.67%), P (0.350%), K (0.447%), S (0.268%) and Mo (0.0112%) was found from S_0 (0 kg S ha^{-1}) treatment (Table 5).

N, P, K, S and Mo concentration in seeds showed statistically significant variation due to different levels of molybdenum (Appendix VI). The maximum concentration in seeds for N (2.61%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from Mo_2 (1.5 kg Mo ha^{-1}) and the minimum concentration in seeds for N (2.18%), P (0.349%), K (0.485%), S (0.286%) and Mo (0.0121%) was recorded from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 5).

Statistically significant variation was recorded due to the interaction effect of sulphur and molybdenum in terms of N, P, K, S and Mo concentration in pod (Appendix VI). The maximum concentration in seeds for N (0.261%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), whereas the minimum concentration in seeds for N (1.52%), P (0.334%), K (0.433%), S (0.261%) and Mo (0.0108%) from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 6).



S_0: 0 kg S ha^{-1} (control) S_1: 10 kg S ha^{-1} Mo_0: 0 kg Mo ha^{-1} (control) Mo_1: 1.0 kg Mo ha^{-1}

S_2: 20 kg S ha^{-1} S_3: 40 kg S ha^{-1} Mo_2: 1.5 kg Mo ha^{-1}

Figure 14. Interaction effect of different levels of sulphur and molybdenum on oil content of BARI soybean 5. Vertical bars represent LSD value.

Table 5. Effect of sulphur and molybdenum on N, P, K, S and Mo concentration in seeds of BARI soybean 5

Sulphur and molybdenum	Concentration (%) in seeds				
	N	P	K	S	Mo
S_0	1.67 c	0.350 c	0.447 c	0.268 c	0.0112 c
S_1	2.46 b	0.373 bc	0.515 b	0.299 b	0.0129 b
S_2	2.80 a	0.407 a	0.574 a	0.327 a	0.0143 a
S_3	2.68 a	0.392 ab	0.560 a	0.320 a	0.0140 a
$LSD_{(0.05)}$	0.131	0.031	0.031	0.010	0.0010
Level of significance	0.01	0.01	0.01	0.01	0.01
Mo_0	2.18 c	0.349 b	0.485 b	0.286 b	0.0121 b
Mo_1	2.41 b	0.391 a	0.536 a	0.309 a	0.0134 a
Mo_2	2.61 a	0.402 a	0.550 a	0.316 a	0.0138 a
$LSD_{(0.05)}$	0.114	0.027	0.027	0.008	0.0008
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.66	6.22	6.17	4.95	6.17

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

Table 6. Interaction effect of sulphur and molybdenum on N, P, K, S and Mo concentration in seeds of BARI soybean 5

Sulphur × molybdenum	Concentration (%) in seeds				
	N	P	K	S	Mo
S_0Mo_0	1.52 g	0.334 d	0.433 f	0.261 f	0.0108 f
S_0Mo_1	1.67 fg	0.353 cd	0.447 f	0.267 ef	0.0112 ef
S_0Mo_2	1.81 f	0.363 cd	0.462 f	0.275 ef	0.0116 ef
S_1Mo_0	2.23 e	0.364 cd	0.485 def	0.285 de	0.0121 def
S_1Mo_1	2.44 de	0.366 cd	0.521 cde	0.302 cd	0.0130 cde
S_1Mo_2	2.69 bc	0.389 bcd	0.538 cde	0.310 bc	0.0135 bcd
S_2Mo_0	2.45 cde	0.337 d	0.481 ef	0.283 e	0.0120 def
S_2Mo_1	2.88 ab	0.435 ab	0.613 ab	0.345 a	0.0153 ab
S_2Mo_2	3.06 a	0.450 a	0.628 a	0.352 a	0.0157 a
S_3Mo_0	2.52 cd	0.362 cd	0.543 cd	0.312 bc	0.0136 bcd
S_3Mo_1	2.65 bcd	0.408 abc	0.564 bc	0.322 b	0.0141 abc
S_3Mo_2	2.87 ab	0.407 abc	0.572 bc	0.326 b	0.0143 abc
$LSD_{(0.05)}$	0.227	0.054	0.054	0.017	0.002
Level of significance	0.05	0.05	0.05	0.05	0.05
CV(%)	5.66	6.22	6.17	4.95	6.17

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

4.12 N, P, K, S and Mo concentration in stover

N, P, K, S and Mo concentration in stover showed statistically significant variation due different levels of sulphur (Appendix VII). The maximum concentration in stover for N (1.90%), P (0.252%), K (1.64%), S (0.274%) and Mo (0.0142%) was observed from S_2 (20 kg S ha^{-1}), whereas the minimum concentration in stover for N (1.60%), P (0.176%), K (1.20%), S (0.233%) and Mo (0.0117%) was found from S_0 (0 kg S ha^{-1}) treatment (Table 7).

Statistically significant variation was recorded in terms of N, P, K, S and Mo concentration due to different levels of molybdenum (Appendix VII). The maximum concentration in stover for N (1.88%), P (0.248%), K (1.64%), S (0.271%) and Mo (0.0140%) was recorded from Mo_2 (1.5 kg Mo ha^{-1}), while the minimum concentration in stover for N (1.61%), P (0.176%), K (1.28%), S (0.231%) and Mo (0.0123%) was observed from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 7).

Interaction effect of sulphur and molybdenum showed statistically significant variation in terms of N, P, K, S and Mo concentration in stover (Appendix VII). The maximum concentration in stover for N (2.11%), P (0.325%), K (2.00%), S (0.305%) and Mo (0.0160%) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), again the minimum concentration in stover for N (1.54%), P (0.141%), K (1.16%), S (0.203%) and Mo (0.0109%) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 8).

4.13 pH

Different levels of sulphur showed statistically significant variation in terms of pH in post harvest soil (Appendix VIII). The highest pH in post harvest soil (6.86) was observed from S_2 (20 kg S ha^{-1}), which was statistically identical (6.77 and 6.75) with S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), while the lowest pH (6.52) was found from S_0 (0 kg S ha^{-1}) treatment (Table 9).

Table 7. Effect of sulphur and molybdenum on N, P, K, S and Mo concentration in stover of BARI soybean 5

Sulphur and molybdenum	Concentration (%) in stover				
	N	P	K	S	Mo
S_0	1.60 c	0.176 c	1.20 b	0.233 c	0.0117 b
S_1	1.71 b	0.217 b	1.56 a	0.255 b	0.0131 a
S_2	1.90 a	0.252 a	1.64 a	0.274 a	0.0142 a
S_3	1.85 a	0.244 ab	1.58 a	0.267 a	0.0138 a
$LSD_{(0.05)}$	0.082	0.031	0.107	0.010	0.0010
Level of significance	0.01	0.01	0.01	0.01	0.01
Mo_0	1.61 c	0.176 b	1.28 b	0.231 b	0.0123 b
Mo_1	1.81 b	0.244 a	1.56 a	0.269 a	0.0133 a
Mo_2	1.88 a	0.248 a	1.64 a	0.271 a	0.0140 a
$LSD_{(0.05)}$	0.071	0.027	0.093	0.008	0.0008
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	4.67	12.92	7.32	7.67	8.23

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}

Mo_0: 0 kg Mo ha^{-1} (control)
Mo_1: 1.0 kg Mo ha^{-1}
Mo_2: 1.5 kg Mo ha^{-1}

Table 8. Interaction effect of sulphur and molybdenum on N, P, K, S and Mo concentration in stover of BARI soybean 5

Sulphur × molybdenum	Concentration (%) in stover				
	N	P	K	S	Mo
S_0Mo_0	1.54 f	0.141 ef	1.16 g	0.203 d	0.0109 e
S_0Mo_1	1.59 ef	0.195 de	1.19 g	0.237 c	0.0117 de
S_0Mo_2	1.67 def	0.191 def	1.24 fg	0.259 b	0.0126 cde
S_1Mo_0	1.61 ef	0.211 d	1.39 ef	0.258 b	0.0134 bcd
S_1Mo_1	1.71 de	0.211 d	1.60 cd	0.250 bc	0.0126 cde
S_1Mo_2	1.82 cd	0.229 cd	1.70 bc	0.258 b	0.0134 bcd
S_2Mo_0	1.55 f	0.137 f	1.09 g	0.218 d	0.0116 de
S_2Mo_1	2.04 ab	0.295 ab	1.82 ab	0.299 a	0.0149 ab
S_2Mo_2	2.11 a	0.325 a	2.00 a	0.305 a	0.0160 a
S_3Mo_0	1.73 de	0.213 d	1.49 de	0.247 bc	0.0134 bcd
S_3Mo_1	1.89 bc	0.274 abc	1.65 bcd	0.291 a	0.0140 bc
S_3Mo_2	1.92 bc	0.246 bcd	1.61 cd	0.264 b	0.0140 bc
$LSD_{(0.05)}$	0.142	0.054	0.186	0.017	0.002
Level of significance	0.01	0.01	0.01	0.01	0.05
CV(%)	4.67	12.92	7.32	7.67	8.23

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}

Mo_0: 0 kg Mo ha^{-1} (control)
Mo_1: 1.0 kg Mo ha^{-1}
Mo_2: 1.5 kg Mo ha^{-1}

Table 9. Effect of sulphur and molybdenum on pH, organic matter, available S and Mo of post harvest soil of BARI soybean 5

Sulphur and molybdenum	pH	Organic matter (%)	Available S (ppm)	Available Mo (ppm)
S_0	6.52 b	1.34 b	3.66 c	0.249 c
S_1	6.75 a	1.41 ab	6.57 b	0.280 b
S_2	6.86 a	1.50 a	7.66 a	0.332 a
S_3	6.77 a	1.48 a	7.28 a	0.298 b
$LSD_{(0.05)}$	0.186	0.120	0.604	0.031
Level of significance	0.01	0.05	0.01	0.01
Mo_0	6.46 b	1.32 b	5.53 b	0.174 b
Mo_1	6.84 a	1.51 a	6.58 a	0.344 a
Mo_2	6.88 a	1.47 a	6.77 a	0.352 a
$LSD_{(0.05)}$	0.161	0.104	0.523	0.027
Level of significance	0.01	0.01	0.01	0.01
CV(%)	4.84	8.48	9.82	10.51

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

Statistically significant variation was recorded for pH in post harvest soil due to different levels of molybdenum (Appendix VIII). The highest pH in post harvest soil (6.88) was recorded from Mo_2 (1.5 kg B ha^{-1}) which was statistically similar (6.84) with Mo_1 (1.0 kg Mo ha^{-1}), whereas the lowest pH (6.46) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 9).

Interaction effect of different levels of sulphur and molybdenum showed significant variation on pH in post harvest soil (Appendix VIII). The highest pH in post harvest soil (7.17) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}) and the lowest pH in post harvest soil (6.43) was found from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 10).

4.14 Organic matter

Organic matter in post harvest soil showed statistically significant variation due to different levels of sulphur (Appendix VIII). The highest organic matter in post harvest soil (1.51%) was recorded from S_2 (20 kg S ha^{-1}), which was statistically identical (1.48% and 1.41%) with S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), whereas the lowest organic matter (1.34%) was observed from S_0 (0 kg S ha^{-1}) treatment (Table 9).

Different levels of molybdenum varied significantly in terms of organic matter in post harvest soil (Appendix VIII). The highest organic matter in post harvest soil (1.51%) was found from Mo_2 (1.5 kg B ha^{-1}) which was statistically similar (1.47%) with Mo_1 (1.0 kg Mo ha^{-1}), while the lowest organic matter (1.32%) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 9).

Statistically significant variation was recorded on organic matter in post harvest soil due to the interaction effect of different levels of sulphur and molybdenum (Appendix VIII). The highest organic matter in post harvest soil (1.62%) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), again the lowest organic matter in post harvest soil (1.34%) was recorded from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 10).

Table 10. Interaction effect of sulphur and molybdenum on pH, organic matter, available S and Mo of post harvest soil of BARI soybean 5

Sulphur × molybdenum	pH	Organic matter (%)	Available S (ppm)	Available Mo (ppm)
S_0Mo_0	6.43 e	1.34 d	3.08 f	0.167 d
S_0Mo_1	6.58 bcde	1.35 cd	3.98 f	0.283 c
S_0Mo_2	6.56 bcde	1.34 cd	3.93 f	0.296 bc
S_1Mo_0	6.55 cde	1.29 d	6.23de	0.167 d
S_1Mo_1	6.85 abcd	1.49 abcd	6.58 cde	0.334 bc
S_1Mo_2	6.87 abc	1.44 abcd	6.90 cd	0.339 bc
S_2Mo_0	6.35 e	1.26 d	5.67 e	0.161 d
S_2Mo_1	7.05 a	1.61 ab	8.25 ab	0.410 a
S_2Mo_2	7.17 a	1.62 a	9.07 a	0.425 a
S_3Mo_0	6.51 de	1.39 bcd	7.15 bcd	0.199 d
S_3Mo_1	6.89 abc	1.58 abc	7.51 bc	0.348 b
S_3Mo_2	6.92 ab	1.49 abcd	7.19 bcd	0.347 b
$LSD_{(0.05)}$	0.321	0.207	1.047	0.054
Level of significance	0.05	0.05	0.01	0.01
CV(%)	4.84	8.48	9.82	10.51

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}

Mo_0: 0 kg Mo ha^{-1} (control)

Mo_1: 1.0 kg Mo ha^{-1}

Mo_2: 1.5 kg Mo ha^{-1}

4.15 Available sulphur

Different levels of sulphur showed statistically significant variation in terms of available sulphur in post harvest soil (Appendix VIII). The highest available sulphur in post harvest soil (7.66 ppm) was found from S_2 (20 kg S ha^{-1}), which was statistically identical (7.28 ppm) with S_3 (40 kg S ha^{-1}) and closely followed (6.57 ppm) by S_1 (10 kg S ha^{-1}), while the lowest available sulphur (3.66 ppm) was found from S_0 (0 kg S ha^{-1}) treatment (Table 9).

Significant variation was recorded for available sulphur in post harvest soil due to different levels of molybdenum (Appendix VIII). The highest available sulphur in post harvest soil (6.77 ppm) was recorded from Mo_2 (1.5 kg B ha^{-1}) which was statistically similar (6.58 ppm) with Mo_1 (1.0 kg Mo ha^{-1}), whereas the lowest available sulphur (5.53 ppm) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 9).

Interaction effect of different levels of sulphur and molybdenum showed significant variation on available sulphur in post harvest soil (Appendix VIII). The highest available sulphur in post harvest soil (9.07 ppm) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), whereas the lowest available sulphur in post harvest soil (3.08 ppm) was attained from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 10).

4.16 Available Molybdenum

Statistically significant variation was recorded due to different levels of sulphur in terms of available molybdenum in post harvest soil (Appendix VIII). The highest available molybdenum in post harvest soil (0.332 ppm) was recorded from S_2 (20 kg S ha^{-1}), which was closely followed (0.298 ppm and 0.280 ppm) by S_3 (40 kg S ha^{-1}) and S_1 (10 kg S ha^{-1}), while, the lowest available molybdenum (0.249 ppm) was recorded from S_0 (0 kg S ha^{-1}) treatment (Table 9).

Different levels of molybdenum showed statistically significant variation in terms of available molybdenum in post harvest soil (Appendix VIII). The highest available molybdenum in post harvest soil (0.352 ppm) was observed from Mo_2 (1.5 kg B ha^{-1}) which was closely followed (0.344 ppm) by Mo_1 (1.0 kg Mo ha^{-1}), while the lowest available molybdenum (0.174 ppm) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 9).

Available molybdenum in post harvest soil showed significant variation due t o the interaction effect of different levels of sulphur and molybdenum (Appendix VIII). The highest available molybdenum in post harvest soil (0.425 ppm) was observed from S_2Mo_2 (20 kg S ha^{-1} and 1.5 kg Mo ha^{-1}), whereas the lowest available molybdenum in post harvest soil (0.167 ppm) was recorded from S_0Mo_0 (0 kg S ha^{-1} and 0 kg Mo ha^{-1}) treatment combination (Table 10).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2013 to April, 2014 to study the effect of sulphur and molybdenum on growth, yield and oil content of BARI soybean 5. The experiment comprised of two factors-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} and S_3: 40 kg S ha^{-1}; Factors B: Levels of molybdenum (3 levels)- Mo_0: 0 kg Mo ha^{-1} (control), Mo_1: 1.0 kg Mo ha^{-1} and Mo_2: 1.5 kg Mo ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameter, yield, oil content, nutrient concentration in seeds and stover and characteristics of post harvest soil was recorded and statistically significant variation was recorded for all the studied characters.

At 30, 40, 50, 60 DAS and at harvest, the tallest plant (17.12, 31.29, 47.86, 58.66 and 63.58 cm, respectively) was recorded from S_2, whereas the shortest plant 15.58, 27.36, 42.19, 52.75 and 56.27 cm, respectively) was found from S_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches $plant^{-1}$ (5.47, 11.04, 14.22, 19.11 and 20.00, respectively) was observed from S_2, while the minimum number of branches $plant^{-1}$ (4.49, 8.09, 12.33, 15.27 and 16.38, respectively) was recorded from S_0. The minimum days required for sowing to harvest (91.00) was found from S_2, while the maximum days required for sowing to harvest (97.56) was observed from S_0. The longest pod (4.79 cm) was observed from S_2, while the shortest pod (4.25 cm) was found from S_0. The maximum number of pods $plant^{-1}$ (35.87) was recorded from S_2, whereas the minimum number (31.64) was attained from S_0. The maximum number of seeds pod^{-1} (3.27) was found from S_2 and the minimum number (2.91) was recorded from S_0. The highest weight of 100 seeds (13.96 g) was observed from S_2, while the lowest weight (12.49 g) was attained from S_0. The highest seeds yield (2.00 t ha^{-1}) was observed from S_2 and the lowest (1.60 t ha^{-1}) was observed from S_0. The highest stover yield (2.56 t ha^{-1}) was found from S_2, whereas the lowest stover yield (2.13 t ha^{-1}) was recorded from S_0. The highest oil content (21.52%) was observed from S_2 and the lowest oil content (16.78%) was observed from S_0.

The maximum concentration in seeds for N (2.80%), P (0.407%), K (0.574%), S (0.327%) and Mo (0.0143%) was found from S_2, while the minimum concentration in pod for (1.67%), P (0.350%), K (0.447%), S (0.268%) and Mo (0.0112%) was found from S_0. The maximum concentration in stover for N (1.90%), P (0.252%), K (1.64%), S (0.274%) and Mo (0.0142%) was observed from S_2, whereas the minimum concentration in stover for N (1.60%), P (0.176%), K (1.20%), S (0.233%) and Mo (0.0117%) was found from S_0. The highest pH in post harvest soil (6.86) was observed from S_2, while the lowest pH (6.52) was found from S_0. The highest organic matter in post harvest soil (1.50%) was recorded from S_2 and the lowest organic matter (1.34%) was observed from S_0. The highest available sulphur in post harvest soil (7.66 ppm) was found from S_2, while the lowest available sulphur (3.66 ppm) was found from S_2. The highest available molybdenum in post harvest soil (0.332 ppm) was recorded from S_2, and, the lowest available molybdenum (0.249 ppm) was recorded from S_0.

At 30, 40, 50, 60 DAS and at harvest, the tallest plant (16.82, 30.05, 46.18, 56.88 and 61.85 cm, respectively) was found from Mo_2, while the shortest plant (15.69, 28.08, 43.42, 53.74 and 57.28 cm, respectively) was observed from Mo_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches $plant^{-1}$ (5.43, 10.53, 15.00, 20.03 and 20.62, respectively) was attained from Mo_2 and the minimum number (4.47, 9.23, 11.83, 14.45 and 16.78, respectively) was observed from Mo_0. The minimum days required for sowing to harvest (92.83) was observed from Mo_2, whereas the maximum days required for sowing to harvest (95.67) from Mo_0. The longest pod (4.93 cm) was recorded from Mo_2 and the shortest pod (4.08 cm) from Mo_0. The maximum number of pods $plant^{-1}$ (36.26) was recorded from Mo_2, while the minimum number (31.99) from Mo_0. The maximum number of seeds pod^{-1} (3.31) was recorded from Mo_2, while the minimum number (2.86) from Mo_0. The highest weight of 100 seeds (13.61 g) was found from Mo_2, again the lowest weight (12.70 g) from Mo_0. The highest seeds yield (1.93 t ha^{-1}) was recorded from Mo_2, whereas the lowest yield (1.70 ha^{-1}) from Mo_0. The highest stover yield (2.48 t ha^{-1}) was observed from Mo_2, while the lowest stover yield (2.24 t ha^{-1}) was recorded from Mo_0. The highest oil content (20.64%) was recorded from Mo_2, whereas the lowest oil content (18.21%) from Mo_0.

The maximum concentration in seeds for N (2.61%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from Mo_2 (1.5 kg Mo ha^{-1}) and the minimum concentration in seeds for N (2.18%), P (0.349%), K (0.485%), S (0.286%) and Mo (0.0121%) was recorded from Mo_0. The maximum concentration in stover for N (1.88%), P (0.248%), K (1.64%), S (0.271%) and Mo (0.0140%) was recorded from Mo_2, while the minimum concentration in stover for N (1.61%), P (0.176%), K (1.28%), S (0.231%) and Mo (0.0123%) was observed from Mo_0. The highest pH in post harvest soil (6.88) was recorded from Mo_2, whereas the lowest pH (6.46) from Mo_0. The highest organic matter in post harvest soil (1.51%) was found from Mo_2, while the lowest organic matter (1.32%) from Mo_0. The highest available sulphur in post harvest soil (6.77 ppm) was recorded from Mo_2, whereas the lowest (5.53 ppm) from Mo_0. The highest available molybdenum in post harvest soil (0.352 ppm) was observed from Mo_2, while the lowest (0.174 ppm) from Mo_0.

At 30, 40, 50, 60 DAS and at harvest, the tallest plant (18.67, 33.32, 51.51, 61.83 and 68.06 cm, respectively) was recorded from S_2Mo_2 and the shortest plant (14.58, 26.55, 41.56, 51.30 and 52.68 cm, respectively) was observed from S_0Mo_0. At 30, 40, 50, 60 DAS and at harvest, the maximum number of branches $plant^{-1}$ (5.93, 12.40, 16.93, 22.13 and 22.60, respectively) was recorded from S_2Mo_2, while the minimum number (4.13, 7.60, 10.47, 12.93 and 15.20, respectively) was found from S_0Mo_0. The minimum days required for sowing to harvest (91.33) was found from S_2Mo_2, again the maximum days required for sowing to harvest pod (99.00) was found from S_0Mo_0. The longest pod (5.35 cm) was recorded from S_2Mo_2, whereas the shortest pod (3.69 cm) was found from S_0Mo_0. The maximum number of pods plant^{-1} (38.70) was found from S_2Mo_2 and the minimum number (30.50) was found from S_0Mo_0. The maximum number of seeds pod^{-1} (3.60) was observed from S_2Mo_2 and the minimum number (2.77) was found from S_0Mo_0. The highest weight of 100 seeds (14.85 g) was observed from S_2Mo_2, whereas the lowest weight (11.78 g) was attained from S_0Mo_0. The highest seeds yield (2.21 t ha^{-1}) was found from S_2Mo_2, while the lowest seeds yield (1.56 t ha^{-1}) was found from S_0Mo_0. The highest stover yield (2.77 t ha^{-1}) was observed from S_2Mo_2 and the lowest stover yield (2.07 t ha^{-1}) from S_0Mo_0. The highest oil content (23.57%) was found from S_2Mo_2, while the lowest oil content (16.25%) was found from S_0Mo_0.

The maximum concentration in seeds for N (0.261%), P (0.402%), K (0.550%), S (0.316%) and Mo (0.0138%) was observed from S_2Mo_2, whereas the minimum concentration in pod for N (1.52%), P (0.334%), K (0.433%), S (0.261%) and Mo (0.0108%) was found from S_0Mo_0. The maximum concentration in stover for N (2.11%), P (0.325%), K (2.00%), S (0.305%) and Mo (0.0160%) was observed from S_2Mo_2, again the minimum concentration in stover N (1.54%), P (0.141%), K (1.16%), S (0.203%) and Mo (0.0109%) was found from S_0Mo_0. The highest pH in post harvest soil (7.17) was observed from S_2Mo_2 and the lowest (6.43) was found from S_0Mo_0. The highest organic matter in post harvest soil (1.62%) was observed from S_2Mo_2, again the lowest (1.34%) was recorded from S_0Mo_0. The highest available sulphur in post harvest soil (9.07 ppm) was observed from S_2Mo_2, whereas the lowest (3.08 ppm) was attained from S_0Mo_0. The highest available molybdenum in post harvest soil (0.425 ppm) was observed from S_2Mo_2, whereas the lowest (0.167 ppm) was recorded from S_0Mo_0.

Conclusion

It may be concluded that application of 20 kg S ha^{-1} and 1.5 kg Mo ha^{-1} can be more beneficial for the farmers to get maximum yield from the cultivation of BARI soybean 5.

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

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

Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from December, 2013 to March, 2014

Month	*Air temperature (^{o}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2013	25.8	16.0	78	00
December, 2013	22.4	13.5	74	00
January, 2014	25.2	12.8	69	00
February, 2014	27.3	16.9	66	39
March, 2014	31.7	19.2	57	23

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix III. Analysis of variance of the data on plant height of BARI soybean 5 at different days after sowing (DAS) as influenced by different levels of sulphur and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAS	40 DAS	50 DAS	60 DAS	Harvest
Replication	2	0.461	1.119	0.377	1.478	0.031
Levels of sulphur (A)	3	3.626**	24.449**	51.125**	63.494**	106.807**
Levels of molybdenum (B)	2	4.230**	11.832**	27.207**	36.038**	79.689**
Interaction (A×B)	6	2.139*	4.957*	12.804*	13.230*	18.840*
Error	22	0.670	1.709	4.657	7.437	8.278

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of branches plant^{-1} of BARI soybean 5 at different days after sowing (DAS) as influenced by different levels of sulphur and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Number of branches plant^{-1} at				
		30 DAS	40 DAS	50 DAS	60 DAS	Harvest
Replication	2	0.041	0.084	0.970	3.453	0.583
Levels of sulphur (A)	3	1.868**	14.777**	5.773**	31.329**	23.327**
Levels of molybdenum (B)	2	3.341**	5.181**	30.083**	93.723**	44.123**
Interaction (A×B)	6	0.101*	1.549**	2.024*	3.971*	7.419*
Error	22	0.040	0.261	1.203	1.805	2.869

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on yield contributing characters, yield and oil content of BARI soybean 5 as influenced by different levels of sulphur and molybdenum

Source of variation	Degrees of freedom	Mean square			
		Days required from sowing to Harvest	Pod length (cm)	Number of pods plant^{-1}	Number of seeds pod^{-1}
Replication	2	0.583	0.045	0.055	0.007
Levels of sulphur (A)	3	64.519**	0.510**	33.963**	0.212**
Levels of molybdenum (B)	2	24.333*	2.435**	56.956**	0.649**
Interaction (A×B)	6	20.963**	0.221*	6.225*	0.053*
Error	22	5.492	0.063	4.091	0.019

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Contd'

Source of variation	Degrees of freedom	Mean square			
		Weight of 100 seeds (g)	Pod yield (t ha^{-1})	Stover yield (t ha^{-1})	Oil Content (%)
Replication	2	0.001	0.000	0.009	0.007
Levels of sulphur (A)	3	4.272**	0.297**	0.357**	40.973**
Levels of molybdenum (B)	2	3.188**	0.180**	0.212**	19.566**
Interaction (A×B)	6	0.754*	0.054*	0.058**	4.418*
Error	22	0.331	0.017	0.015	1.468

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on N, P, K, S and Mo concentrations in seeds of BARI soybean 5 as influenced by different levels of boron and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Concentration (%) in seeds				
		N	P	K	S	Mo
Replication	2	0.009	0.000	0.000	0.000	0.0001
Levels of sulphur (A)	3	2.324**	0.005**	0.029**	0.006**	0.0001**
Levels of molybdenum (B)	2	0.552**	0.009**	0.014**	0.003**	0.0001**
Interaction (A×B)	6	0.021*	0.002*	0.003*	0.001*	0.0001*
Error	22	0.018	0.001	0.001	0.000	0.0001

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on N, P, K, S and Mo concentrations in stover of BARI soybean 5 as influenced by different levels of sulphur and molybdenum

Source of variation	Degrees of freedom	Mean square				
		Concentration (%) in stover				
		N	P	K	S	Mo
Replication	2	0.000	0.001	0.012	0.000	0.0001
Levels of sulphur (A)	3	0.162**	0.011**	0.360**	0.003**	0.0001**
Levels of molybdenum (B)	2	0.240**	0.020**	0.418**	0.006**	0.0001**
Interaction (A×B)	6	0.040**	0.006**	0.127**	0.002**	0.0001*
Error	22	0.007	0.001	0.012	0.000	0.0001

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on pH, organic matter, available S and Mo of post harvest soil of BARI soybean 5 as influenced by different levels of sulphur and molybdenum

Source of variation	Degrees of freedom	Mean square			
		pH	Organic matter (%)	Available S (ppm)	Available Mo (ppm)
Replication	2	0.015	0.005	0.278	0.001
Levels of sulphur (A)	3	0.184**	0.046*	29.559**	0.001**
Levels of molybdenum (B)	2	0.655**	0.122**	5.326**	0.122**
Interaction (A×B)	6	0.071*	0.021*	1.778**	0.003**
Error	22	0.036	0.015	0.382	0.001

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability