EFFECT OF SULPHUR AND PHOSPHORUS ON THE GROWTH AND YIELD OF SOYBEAN

(*Glycine max* L.)

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by

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CERTIFICATE

This is to certify that the thesis entitled **EFFECT OF SULPHUR AND PHOSPHORUS ON THE GROWTH AND YIELD OF SOYBEAN (*Glycine max* L.)** 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 (MS)** in **SOIL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **MOHAMMAD NAYEM AHAMED**, Reg. no. **11-04625** 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.

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Dated : June, 2018
Place : Dhaka, Bangladesh

Dedicated To

My beloved parents & my respected supervisor

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The Author

EFFECT OF SULPHUR AND PHOSPHORUS ON THE GROWTH AND YIELD OF SOYBEAN (*Glycine max L.*)

ABSTRACT

The experiment was conducted during the period from January, 2018 to May 2018 to study the effect of sulphur and phosphorus on the growth, yield and nutrient component of BARI Soybean-6 (*Glycine max L.)*. In this experiment, the treatment consisted of four Levels of sulphur viz. 0, 20, 40 and 60 kg S ha^{-1} and four levels of phosphorus viz. 0, 40, 60 and 80 kg P ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters. The highest plant height (44.68 cm and 61.90 cm at 30 DAS and 60 DAS respectively) was found from P_3S_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) combination treatment. The maximum number of leaves $plant^{-1}$ from the individual treatment of S and P were found at S_3 (60 kg S ha^{-1}) and P_3 (80 kg P ha^{-1}) treatment whereas the maximum number of leaves $plant^{-1}$ (10.26 and 17.20 at 30 DAS and 60 DAS respectively) was found in P_3S_3 treatment. The highest values of seeds pod^{-1} (3.61), seeds $plant^{-1}$ (59.24), weight of 100 seed (13.50 g) observed in S_3. Grain yield of soybean was influenced significantly due to the application of phosphorus and sulphur. The highest grain yield (1.96 t ha^{-1}) was found in where 60 kg S ha^{-1} (S_3) was applied and the lowest was recorded in P_0 treatment. The highest seed yield (2.08 t ha^{-1}) was observed from S_3P_3 treatment combination. The combined use of 40 kg S ha^{-1} and 60 kg P ha^{-1} along with recommended doses of other fertilizer would be beneficial to increase the seed yield of soybean variety BARI soybean-6.

TABLE OF CONTENT

TABLE OF CONTENT

TABLE OF CONTENT

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Soybean (*Glycine max*) is the most important crops in the world for its seed legume having 25% contribution of the global edible oil and fill up about two-thirds protein concentrate for livestock feeding in the world. Soybean also act as a protein source for poultry and fish feeding. In Bangladesh there has been a big opportunity to cultivate soybean locally which could meet 40 percent of its soybean oil demand. The country's total demand for edible oil is around 13 lakh metric tons per year.

In Bangladesh about 70 percent of soybean farmers are cultivating variety “Shohag”, which was officially released in 1990; its average yield is 1.8-2 ton per hectare. Bangladesh Agricultural Research Institute (BARI) developed two variety of Soybean named BARI Soybean-5 and BARI Soybean-6. These two varieties are popular and planted by 30 percent of soybean farmers, but it supply constraints limit their impact in the field and overall yields remain flat, which in turn hinders growth of this subsector. Given normal weather conditions, soybean production is expected to increase 1.96 percent to 156 thousand metric ton. The production of soybean increases by greater interest of farmer in planting soybeans will drive an increase in planted area of 1.23 percent, to a total of 82 thousand hectares. Soybean cultivation is available in poor soil and competing crops limit area which competes with crops like Boro Season rice and ground nut in the river basin islands (charland) of the southern coastal part of the country.

Soybean, like many other legumes, is capable to fix and utilize atmospheric nitrogen through a symbiotic relationship with *Rhizobium japonicum*. *Rhizobia* are minor component of the soil micro flora and while not restricted to rhizosphere soil, reach their maximum numbers in association with plant roots (Reicosky *et* al, 1985).

The most of the countries where agriculture is today well developed have used fertilizers but it has become clear of their essential role in modern farming only in the last 60 years. The heavy uses of fertilizers in cultivation of different crop varieties which have arisen rapidly in Bangladesh causes soil toxicity, soil pollution results loosing soil fertility and soil productivity.

Soybean requires high amount of phosphorus than nitrogen because it has ability to fix atmospheric nitrogen by root-nodules. For proper growth and development of leguminous and oil seed crops N, P, S play a vital role. For normal growth and development of plants phosphorus plays a major role. Because Phosphorus is used for photosynthesis and produce ATP which contains phosphorus as part of its structure. They transfer energy by formation and translocation of carbohydrates, fatty acids, and without it plant can't complete their production cycles as expected. In the soybean seeds Phosphorus enters the composition of nucleo-proteins, which are basic components of the cell nucleus and of phosphatides. Phosphate occurs better nodulation, rooting and higher nitrogen-fixing capacity by plants.

Sulphur is a macro nutrient element which is recognized as fourth major plant nutrient after N, P, K. The deficiency of sulphur causes yellowing of leaves by affecting protein synthesis, structure, and chlorophyll production, as well as inhibit plant growth. Sulphur is essential for proper growth and development of crops followed by oil content in oil seeds crops. Sulphur founds in some amino acids, the building blocks of proteins. 90% of Sulphur absorbed by plants to use for that functions. Sulphur reduce soil pH where limited rainfall and little limestone will have high pH levels and make the soil favorable for plant growth. Sulphur is uptaken by plant as SO_4^{2-} and the most of the S exist in the organic matter and are concentrated in the plow layer or topsoil. The Sulphur in organic matter converted into sulphate form by the soil microbes and become available for plants. The conversion of sulphate from organic sulphur occurs most rapidly in warm, moist and well-drained soil. Sulphur is used for synthesis of other metabolites including coenzyme -A, thiamin, biotin or vitamin B_1 and glutathione. The major function of sulphur is stimulating seed formation and promoting nodule formation on the roots of leguminous plants.

The interaction of different elements is quite important among the various plant growth factors. Higher P and S demands of pulses and oilseeds have a definite bearing on their interrelationships. P and S interactions in soils of poor fertility may be more important (Aulakh et al., 1990; Marok and Dev, 1980).The interaction of P and S is quite expected in soil and plant system as both of these are adsorbed on similar sites on soil colloids and show similar composition of precipitation production with Ca, Fe and Al. This study deals with the effects of applied phosphorus and sulphur on the growth and nutrient content by BARI soybean-6 studied under SAU farm.

The above background keeping in mind the present piece of research work was done by applying S and P in soybean to get the following objectives:

1. To find out effective doses of sulphur and phosphorus combination on growth, yield and nutrient component of soybean

2. To determine the effect of sulphur and phosphorus on growth, yield contributing characters and yield of soybean

CHAPTER II
REVIEW OF LITERATURE

Soybean is an excellent leguminous crop where it is the source of oil and protein as well as having ability to fix atmospheric nitrogen at their root nodules. So that it requires low amount of nitrogen where it is more responsive to Phosphorus and Sulphur application. Phosphorus helps carbohydrate synthesis, root system development, and fruit and seed formation of plant (Brady, 1996). The information regarding the growth, development and nutrient content of Soybean in response to P and S are scarcely available in Bangladesh. However, in this paper the research work carried out Bangladesh and abroad on these aspects and the available literature related to the present field of study have been reviewed.

2.1 Effects of Phosphorus:

Barman *et al.* (2015) conducted a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka 1207, during the *kharif* season of 2014 to study the effects of Phosphorus and Zinc on the concentrations of N, P, K, S and Zn in mungbean stover and seed (BARI mug 6). Four levels of phosphorus (P) (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (Zn) (0, 1.5 and 3 kg Zn ha^{-1}) were used in the study. The results revealed that The N, P, K and S concentration of mungbean plant increased significantly from control to P_2Zn_2 (20 kg P ha^{-1} + 3 kg Zn ha^{-1}) treatment combination and again decreased with increasing phosphorus more than 20 kg P ha^{-1}. Application of phosphorus and zinc increase organic carbon, N, P, K and S status of postharvest soil significantly.

Habibullah *et al.* (2014) conducted a field experiment at Agronomy Farm in Sher-e-Bangla Agricultural University, Dhaka-1207, during Kharif season, 2012 to evaluate the performance of phosphorus level on growth, yield and quality of BARI MUNG-6. Randomized completely block designed (RCBD) was laid out to determine this experiment with three replications. Phosphorus fertilizer was applied at four treatments like as P_0, control; P_1, 15 kg ha^{-1} P_2, 20 kg ha^{-1}; P_3, 25 kg ha^{-1} respectively. Highest plant height (cm), no. of branches per plant, no. of pods per plant, pod length (cm), no. of grain per pod, weight of 1000 grain (g), grain yield (t ha^{-1}) and Stover yield (t ha^{-1}) were counted in 20 kg ha^{-1} level of phosphorus, whereas minimum was showed in control application of phosphorus fertilizer. Significant variation on concentration of N, P, K and S was found at 20 kg ha^{-1} application of phosphorus, whereas minimum was observed with control treatment in both stover and grain yield.

Ali *et al*. (2014) conducted a field experiment to the efficient supply of nutrients is important to ensure proficient crop production. Adequate supply of Phosphorus is essential at early stage of crop growth when the limited root system is not yet capable of absorbing the Phosphorus reserves of the soil. Increasing levels of phosphorus enhanced the plant growth, yield parameters like, nodules per plant, dry weight of nodules, and number of pods per plant, number of grains per pod, 1000-grain weight, straw yield and ultimately final crop yield of mungbean.

Akhter *et al.* (2009) conducted a field experiment at Agronomy Farm in Sher-e-Bangla Agricultural University, Dhaka-1207 during Rabi season of 2008-09 to study the role of phosphorus and sulphur on the growth, yield and oil content of soybean. Four level of phosphorus and sulphur was used in the study. She reported that a significant variation was observed on the grain yield of soybean when different doses of phosphorus were applied. The highest grain yield of soybean (2.046 t ha^{-1}) was recorded in P_2 (30 kg P ha^{-1}) treatment.

Ryan *et al.* (2008) reported that the legumes response towards phosphorus fertilizer (50-200 kg P_2O_5 ha^{-1}) reduced when P (range of 2.7 to 6.2 mg P kg^{-1}) availability in soil were increased. The yield of legumes were not affected by the residues of P_2O_5 fertilizer (50-200 kg ha^{-1}), but the yield of legumes were affected significantly by the direct phosphorus fertilization (15-60 kg P_2O_5 ha^{-1} $year^{-1}$). When available phosphorus levels is at or above the critical threshold (6-7 mg kg^{-1} P-Olsen) plant don't responds towards P fertilizer. Fertilization at the level of 15-20 kg P ha^{-1} $year^{-1}$ is needed to preserve soil fertility so that sufficient P to plant can be provided.

Rahman *et al.* (2008) conducted a field experiment during *kharif* season, 2005 at Soil Science Division, Bangladesh Agricultural Research Institute to study the effect of phosphorus (P), molybdenum (Mo) and *Rhizobium* inoculation on the yield and yield contributing characters of mungbean (*Vigna radiata*) on a silty clay loam soil. The experiment was laid out in RCBD with four replications. Ten treatments were formulated with the combination of 4 levels of P (0, 20, 40, 60 kg ha^{-1}) and 2 levels of Mo (1.0, 1.5 kg ha^{-1}) having a common *Rhizobium*

Aulakh *et al.* (2003) reported that the availability of low native soil phosphorus coupled with poor utilization efficiency of phosphorus which is added to the soil is a major constraint that limiting the soybean productivity. He also found that the high cost of it limits the use of p fertilization while sufficient P is not provided due to the incapability of releasing P by organic inputs which results low P concentration and the optimum growth of crops are prohibited.

Gurkirpal *et al.* (2001) cited that after application of the fertilizers on soybean plots the growth attributes and grain yield have significantly increased. When he applied NPK, Zn with the combination of 90:80:60:25 and found that the highest number of pods per plant (68.9) and seed yield (24.8 q ha^{-1}) were obtained at that level of fertilizer combination.

And also found that the treatment with NPK at the combination of 90:60:30 produced the highest 100-grain weight in soybean (16.6 g).

Khamparia (1996) did an experiment with the trials at R.A.R.S., Sagar (M.P.) and found that taller plants with abundant growth and root nodulation were produced where phosphorus was supplied at an increment doses and get more pods plant^{-1} and dry weight as compared with control. Biological yield, grain, straw, grain straw ratio and harvest index are increased with the enhancement doses of phosphorus.

A field experiment was conducted by Sharma et al. (2002) in Rajasthan, India during 1997 - 1998 in the rainy season to find out the effects of 3 levels of phosphorus application (30, 60 and 90 kg ha^{-1}) and 3 phosphorus sources. Higher yield, yield component and dry matter was produces at 60 kg ha^{-1} of P_2O_5 compared to 30 kg ha^{-1} of P_2O_5.

Patel and Sastri (1999) found that growth rate, dry matter production and yield of soybean increased with the increasing of supply of N and P. Bothe et al (2000) determined the effects of phosphorus fertilizer (0, 25, 50. and 75 kg P_2O_5 ha^{-1}), at spacing (30 x 10, 20 x. 10 and 30 x 5 cm) and P-solubilizes on the yield of soybean and yield components of a soybean-fenugreek cropping system were experimented during 1995 at Pune, Maharashtra, India. All parameters of yield increased with increasing rate of application of phosphorus fertilizer. At the level of 75 kg ha^{-1} of phosphorus recorded the 71.20 cm, 57.46 g and 49.50 q ha^{-1} (while application rate of phosphorus at 25 kg ha^{-1} recorded 42.83 q ha^{-1} seed yield was the highest value) which was the highest values for plant height, dry matter per plant and straw yield respectively.

2.2 Effect of Sulphur:

Hosmath *et al.* (2014) carried out a field experiment at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad India. To identify the optimum S dose the treatments accommodated of four level of S (0, 10, 20, 30 and 40 kg ha^{-1}). The pooled data showed the significantly increased of soybean yield with the application of S @20 kg ha^{-1} (2534 kg ha^{-1}) compared to application of S @ 30 kg ha^{-1} (2376 kg ha^{-1}) and application of S @ 10 kg ha^{-1} (2226 kg ha^{-1})

Akter *et al.* (2013) conducted a field experiment at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh to determine 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. The significant increase of growth and yield of soybean was showed by the different levels of sulphur application. In case of S, the positive response was observed only upto 20 kg sulphur ha^{-1}. The highest value of number of pods $plant^{-1}$ (30.07), number of seeds $plant^{-1}$ (84.94), thousands seed weight (94.61 g) and highest grain yield (2.29 t ha^{-1}) were observed at the application rate of sulphur @ 20 kg S ha^{-1}.

Yadav *et al*. (2013) conducted a field experiment to evaluate the effect of phosphorus and sulphur on content, uptake and quality of summer soybean at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh. The result showed S level @ 30 kg ha^{-1} results highest content and uptake in grain and stover significantly.

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

A field experiment was conducted by Farhad *et al*. (2010) 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 experiment included four levels of K (0, 20, 40 and 70 kg K ha^{-1}) and four levels of S (0, 10, 20 and 40 kg S ha^{-1}) Application of S @ 20 kg ha^{-1} produced the highest plant height, seed yield, 1000-seed weight and straw yield.

Manchanda *et al.* 2006 conducted a field experiment in Ludhiana, Punjab, India. during 2003-04 on a loamy sand soil deficient in available S (7.37 mg kg^{-1} soil) to study the effects of S fertilizer (0. 7.5, 15.0 and 30 kg S ha^{-1} as gypsum) on the yield and nutrition status of crops under a soybean (cv. SL 295)-wheat (cv. PBW 343) system. 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^{-1} respectively. The total biological yield of these crops also increased significantly with S application. However, the harvest index of both crops was not significantly affected. The availability of Zn, Cu, Fe and Mn in soil, and the concentrations and uptake of these nutrients for both crops increased significantly due to S application.

A pot culture experiment was conducted by Arunageeta *et al.* (2006) at a glasshouse in the Department of Agricultural Microbiology, Tamil Nadu, India, on a clay loam soil with four levels of S as 0, 7.5, 15 and 30 kg hain 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}.

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 soybean cultivars by enhancing their growth.

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_8compared 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}.

Sangale *et al.* (2004) conducted a field experiment during 2003-04 in kharif season and found that the effects of the sources of S fertilizers (SSP, elemental S and gypsum) and fertilizer application rate (0.10 and 20 kg ha^{-1}) on the yield of seed, quality and uptake of S of soybean cv. JS 335 which grown on deep black soil in Marathwada the region of Maharashtra, India. SSP and gypsum were applied at the sowing time whereas elemental sulphur was given 15 days before sowing. The highest yield was found at 20 kg ha^{-1} of sulphur application.

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}.

Mohan and Sharma (1991) reported that application of sulfur @ 75kg ha^{-1} significantly increased the primary and secondary branches per plant. The plant height were significantly increased when S applied @ kg ha^{-1}.

Saran and Girl (1990) reported from a couple of experiments that the number of branches $plant^{-1}$ significantly increased with 60 kg ha^{-1} of S. Number of pods influenced the plant growth and attributes. They found that the application of S @ 60 kg ha^{-1} results significantly increased of height and primary branches $plant^{-1}$, number of seeds $plant^{-1}$, number of leaves $plant^{-1}$and 1000 seed weight and seed *weight* $plant^{-1}$ increased with 30 kg ha^{-1} of S.

A field experiment was conducted during 1993-94 and 1994-95 in Punjab by Jayesh *et al*. (2000), to evaluate the response of gobhi sarson (B. napus subsp. oleifera var. annua (*B. napus* var. *oleifera*) cv. GSL I and soybean (C. max) cv. PK 416 in sequential cropping to combinations of P at levels of 30, 60, 90 kg ha^{-1} and S fertilizers at levels of 0, 20 and 40 kg ha^{-1}. The application patterns of P were residual, direct and cumulative. When P applied in the direct application showed the highest yield. Both crops grown under residual phosphorus application had less yield compared to those grown under direct phosphorus. When P was applied in a direct method @ 60 kg P ha^{-1} results higher yields of both crops in the cropping system. Application of phosphorus to soybean alone gave higher agronomic efficiency than application to gobhi sarson. When phosphorus was applied @ 60 kg P ha^{-1} produced lower physiological efficiency than application of 30+30 kg P ha^{-1} to both the crops. Both crops responded to S application only upto 20 kg ha^{-1}.

In this chapter includes a brief description of the methods and materials that were used in the experiment. This section discuss about soil of the experimented field, variety of soybean, land preparation, experimental design, treatments cultural operations collection of soil and plant samples etc. and analytical methods followed in the experiment to study the effects of nitrogen and phosphorus with or without *Rhizobium* inoculation on the growth, yield and nodulation of soybean.

CHAPTER III
METHODS AND MATERIALS

3.1 Soil description of experimented area

The Research work was done to study the effects of sulphur and phosphorus fertilization on growth, yieldand yield contributing characters of soybean at Sher-e-Bangla Agricultural University Farm, Dhaka 1207 during rabi Season 2017-18. In the figure 1, following map showed the specific location of experimental site. The experimental location situated at $23^{0}77$ N and $90^{0}33$ E longitude with an elevation of 1 meter from sea level.

3.2 Description of soil

Soil of the experimented field belongs to the Tejgaon series under the Agro ecological Zone, AEZ-28 (Madhupur Tract). In this series soil types are in general is Deep Terrace Soils.

A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was oven-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. The morphological characteristics of the experimental field and initial physical and chemical characteristics of the soil are presented in Table 3.1, 3.2 and 3.3 respectively.

Table 3.1 Morphological characteristics of experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University
AEZ No. and name	AEZ-28, Madhupur Tract
General soil type	Shallow Red Brown Terrace Soil
Soil series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	Medium high land

Table 3.2 Physical characteristics of the initial soil of the experimental field

%Sand(2-0.02 mm)	31.20
%Silt(0.02-0.002 mm)	36.88
%Clay(<0.002 mm)	31.92
Textural Class	Clay Loam

Table 3.3 Chemical characteristics of the initial soil of the experimental field

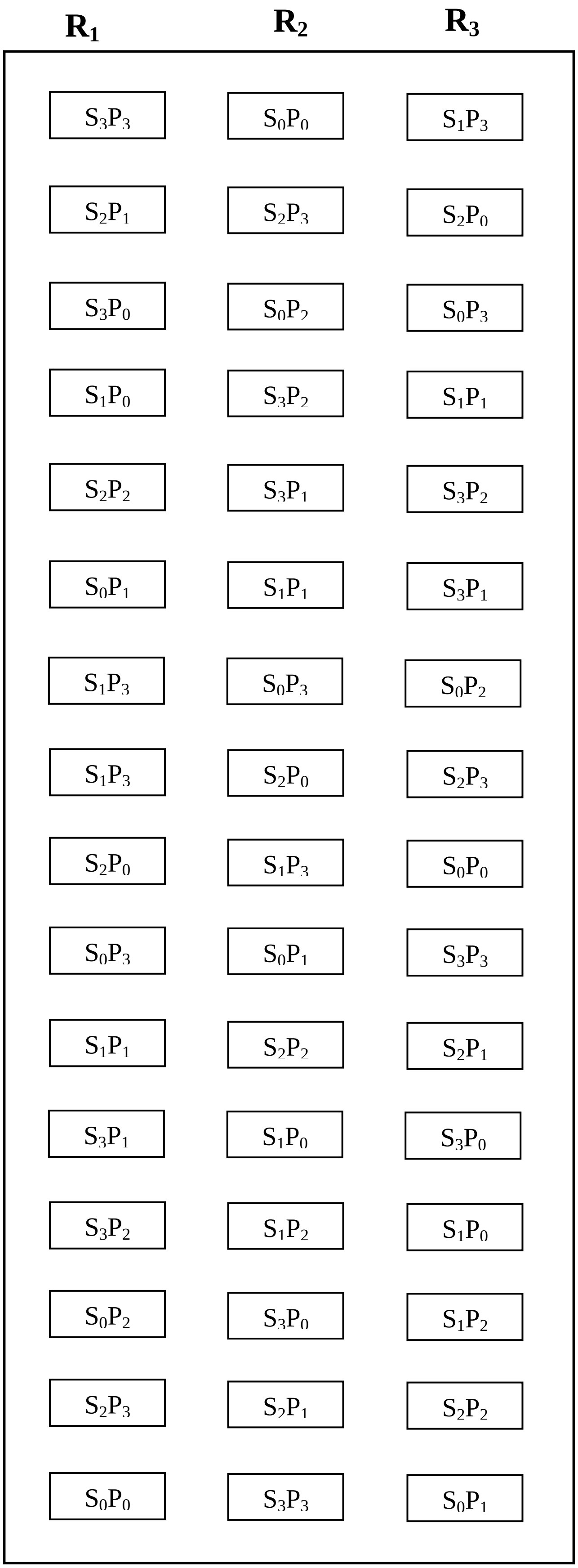
pH	6.48
Organic Matter(%)	0.86
Total N(%)	0.079
Available P (ppm)	15
Exchangeable K (ppm)	0.12
Available S (ppm)	0.119

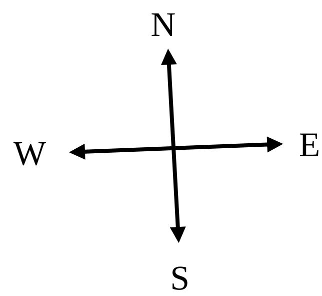
3.3 Description of Soybean Variety

In the experiment BARI soybean-6, a high yielding variety, was as cultivated as test crop. This Variety was released in 2009 by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. It is generally 50-55 cm long having 50-55 capsule per plant and 2-3 seed per capsules. On an average 100g seed weight is around 10-12 g. The duration of life cycle of this variety is 100-110 days. Generally planted in both rabi and kharif season throughout the country. Mid December to Mid January is suitable time for sowing in Rabi season and in kharif season, July suitable time for sowing. The yield of BARI Soybean-6 is 1.80-2.10 t/ha which is higher than BARI Soybean-5. BARI Soybean-6 is resistance to yellow mosaic virus. Vigorous, healthy and well matured seed was selected to sow in the experimented field.

3.4 Preparation of the field

The selected plot for the experiment plot was opened by power tiller driven rotovator on the 20th December, 2017. Afterwards several times the land was ploughed and cross-ploughed followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the following section (Fig 1).





Each Plot Area: 3 m X 1.5 m = 4.5 m^2

Plot to Plot Distance: 0.75 m

Plot distance from border: 0.5 m

Length of field: 25m

Breadth of field: 11 m

Fig 1: Layout of experimental field

3.5 Treatments

Fertilizer treatments consisted of 4 levels of S (0, 20, 40 and 60 kg ha^{-1}) and 4 levels of P (0, 40, 60 and 80 kg ha^{-1}). There were 16 treatment combinations designed as RCBD. The following treatments combinations will be comprised for the experiment.

Rate of Sulphur:

S_0: 0 kg N ha^{-1}

S_1: 20 kg N ha^{-1}

S_2: 40 kg N ha^{-1}

S_3: 60 kg N ha^{-1}

Rate of Phosphorus:

P_0: 0 kg P ha^{-1}

P_1: 40 kg P ha^{-1}

P_2: 60 kg P ha^{-1}

P_3: 80 kg P ha^{-1}

Combined Treatment

I. S_0P_0: Control (no S and P fertilizer);

II. S_1P_0: (20 kg S ha^{-1} + 0 kg P ha^{-1})

III. S_2P_0: (40 kg S ha^{-1} + 0 kg P ha^{-1})

IV. S_3P_0: (60 kg S ha^{-1} + 0 kg P ha^{-1})

V. S_0P_1: (0 kg S ha^{-1} + 40 kg P ha^{-1})

VI. S_0P_2: (0 kg S ha^{-1} + 60 kg P ha^{-1})

VII. S_0P_3: (0 kg S ha^{-1} + 80 kg P ha^{-1})

VIII. S_1P_0: (0 kg S ha^{-1} + 40 kg P ha^{-1})

IX. S_1P_2: (20 kg S ha^{-1} + 60 kg P ha^{-1})

X. S_1P_3: (20 kg S ha^{-1} + 80 kg P ha^{-1})

XI. S_2P_1: (40 kg S ha^{-1} + 40 kg P ha^{-1})

XII. S_2P_2: (40 kg S ha^{-1} + 60 kg P ha^{-1})

XIII. S_2P_3: (40 kg S ha^{-1} + 80 kg P ha^{-1})
XIV. S_3P_1: (60 kg S ha^{-1} + 40 kg P ha^{-1})
XV. S_3P_2: (60 kg S ha^{-1} + 60 kg P ha^{-1})
XVI. S_3P_3: (60 kg S ha^{-1} + 80 kg P ha^{-1})

3.6 Application of fertilizers:

Recommended doses of N, K, Zn and B (40 kg K ha^{-1} from MoP, 2 kg Zn ha^{-1} from ZnO and 1 kg B ha^{-1} from boric acid, respectively) were applied. The whole amounts of TSP, ZnO, boric acid and half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 22 days of germination. The required amounts of P (from TSP) and S (from gypsum) were applied at a time as per treatment combination after field lay out of the experiment and were mixed properly through hand spading.

3.7 Seed sowing

Soybean seeds were sown on the 12 January, 2018 in lines following the recommended line to line distance of 30 cm and plant to plant distance of *5* cm.

3.8 Weeding and thinning

Weeds of different types were controlled manually and removed from the field. The weeding and thinning were done after 25 days of sowing, on February 6, 2018. Care was taken to maintain constant plant population per plot.

3.9 Irrigation

Irrigation was given at three times. The first irrigation was given in the field on January 22, 2018 at ten days after sowing (DAS) through irrigation channel. Second irrigation was given in the field on March 08, 2018 at 45 days after sowing (DAS) before flowering. The third irrigation was given at the stage of pod formation (70 DAS) on April 23, 2018.

3.10 Pest Management

To rescue the plant from the infested Cutworm at the seedling stage and application of Dursban-25EC @ 2.5ml $Litr^{-1}$ was done twice on February 5 and 8, 2018. Special care was taken to protect the crop from birds especially after sowing and germination stages.

3.11 Harvesting

The crop was harvested at maturity on 6th May 2018. The harvested crop of each individual plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in ton ha^{-1}.

3.12 Collection of soil samples

The initial soil sample was collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. The samples were oven -dried, ground and sieved through a 2 mm (10 mesh) sieve and kept for analysis.

3.13 Collection of data

Five (5) plants from each plot were selected at random and were tagged for the data collection. Data collections were done on the following parameters:

Plant height (cm)

Number of leaves $plant^{-1}$

Number of primary branches plant^{-1}

Number of pods plant^{-1}

Number of seeds plant^{-1}

Hundred seed weight (g)

Number of nodule plant^{-1}

Grain yield (t ha^{-1})

Stover yield (t ha^{-1})

3.13.1 Plant height

The plant height was measured from the ground level to the top of the plant. 5 plants were selected randomly from each plot at the ripening stage. Plant height was measured and averaged.

3.13.2 Number of leaves plant^{-1}

Numbers of leaves were counted at the maximum vegetative stage. 5 plants were selected randomly from each plot and number of leaves were counted and averaged.

3.13.3 Number of primary branches plant^{-1}

5 plants were selected randomly from each plot at the maximum vegetative stage. Number of primary branches were counted and averaged.

3.13.4 Number of pods plant^{-1}

Pods were counted at the ripening stage. 5 plants were selected randomly from each plot. Number of pods were counted and averaged.

3.13.5 Number of seeds plant $^{-1}$

It was done after harvesting. 5 plants were selected randomly from each plot. At first, number of seeds plant^{-1} were counted and averaged. Then it was multiplied with number of pods plant^{-1} and averaged.

3.13.6 Hundred seed weight

Hundred seed of soybean were counted randomly and then weighed plot wise.

3.13.7 Number of Nodule plant^{-1}

5 plants were selected randomly from each plot at maximum vegetative stage. Number of nodule plant^{-1} were counted and averaged.

3.13.8 Grain yield

Grains obtained from 1m^2 area from the center of each unit plot was dried, weighed carefully and then converted into t ha-^{1}.

3.13.9 Stover yield

Stover remained after collection of grain (1m^2 of each individual plot) was dried, weighed carefully and the yield was expressed in t ha^{-1}.

3.14 Chemical analysis of soil samples

a) Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

b) Sulphur

Sulphur content in the digest was determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049)

c) Nitrogen

Plant samples were digested with 30% H_2O_2, cone. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson. 1973).

3.15. Soil sample analysis

a) Organic carbon

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973) from the samples collected before sowing and also after harvesting the crop.

b) Organic matter

The organic matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950).

c) Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl Method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4:$CuSO_4.5H_2O$Selenium powder in the ratio 100: 10: 1, respectively). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

d) Available Phosphorous

Available phosphorous was extracted from the soil by Bray-I method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectro-photometer (LKB Novaspec, 1949).

e) Available Sulphur

Available sulphur was extracted from the soil with $Ca(H_2PO_4)_2.H_2O$ (Fox *et al.*,1964). Sulphur in the extract was determined by the Turbidimetric Method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec. 4049).

f) Soil pH

Soil pH was determined by pH meter.

3.15 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatments was estimated by the least significant difference (LSD) test at 5% and 1% level of probability and DMRT was calculated (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

4.1 Effect of sulphur on plant height of soybean

Sulphur application at different level results significant variation in respect of plant height (Table 4.1). Among the different fertilizer doses S_3 (60 kg S ha^{-1}) showed the highest plant height (40.76 cm and 56.60 cm at 30 DAS and 60 DAS respectively).It was also observed that height of plant increased with increasing levels of sulphur application. These findings are similar to those of Gosh *et al.*(1997) who reported that sulphur @ 40kg ha^{-1} enhanced the plant height. Similar results were also found by Chaubey *et al.* (2000) in groundnut and Dubey *et al.*(1997) in linseed. Shortest plant was obtained from control condition. The result is similar to Tabatabai (1986) who reported that lack of sulphur reduces plant height. The lowest height was found at control condition. It was further noticed that plant height of soybean increased as the level of S was increased.

Table 4.1: Effect of sulphur on plant height of soybean

Treatment	Plant height (cm) at 30 DAS	Plant Height (cm) At 60 DAS
S_0	34.14^c	49.76^d
S_1	$37.62b^b$	52.41^c
S_2	38.94^b	54.06^b
S_3	40.76^a	56.60^a
$LSD_{0.05}$	0.69	0.35
CV	7.53	8.63

4.2 Effect of phosphorus on plant height of soybean

Different phosphorus level showed significant results on plant height of soybean (Table 4.2). Significant variation was observed on the plant height of soybean when the field was fertilized with 4 levels of P dose (eg. 0, 40, 60 and 80 kg P ha^{-1}). Among the different doses of phosphorus, P_3 (80 kg P ha^{-1}) showed the highest plant height (40.782 cm) at 30 DAS which was statistically similar with P_2 (60 kg P ha^{-1}) treatment. At 60 DAS from the Table 4.2 also showed that the tallest plant was found in P_3 (80 kg P ha^{-1}) treatment which was significant. On the other hand, the lowest plant height (33.59 cm and 49.17 cm at 30 DAS and 60 DAS respectively) was observed in the P_0 treatment where no phosphorus was applied. Plant height increased with increasing levels of phosphorus up to maximum level of P application. The results are similar to those of Bothe *et al.* (2000) who reported that the application of P @ 75 kg ha^{-1} enhanced the plant height at highest value. Maurya and Rathi (2000) also found the positive effect of P on the plant height of soybean.

Table 4.2: Effect of phosphorus on plant height of soybean

Treatment	Plant height (cm) at 30 DAS	Plant height (cm) At 60 DAS
P_0	33.59^c	49.17^d
P_1	37.30^b	52.16^c
P_2	39.79^a	54.91^b
P_3	40.78^a	56.60^a
$LSD_{0.05}$	0.69	0.35
CV	7.53	10.63

4.3 Effects on plant height of soybean by combined application of sulphur and phosphorus

Combined application of different doses of sulphur and phosphorus fertilizers had significant effect on the plant height of soybean (Table 4.3 and Fig 2). At 30 DAS, the highest plant height (44.68cm) was recorded with S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1})

which was statistically similar with the S_3P_2 (60 kg S ha^{-1} + 60 kg P ha^{-1}) treatment. At 60 DAS, the highest plant height (61.90 cm) was recorded with S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) treatment. On the other hand the lowest plant height (30.28 cm and 46.55 cm at 30 DAS and 60 DAS respectively) was observed in the S_0P_0 treatment (no sulphur and no phosphorus). The highest plant height may be clue to the positive effects of sulphur and phosphorus on the vegetative growth of soybean. Tomar *et al.* (2004) also found the positive interaction effect of P and S on the plant height of soybean. The highest plant height may be due to the positive effects of phosphorus and sulphur on the vegetative growth and accumulation of growth materials. Further it could be seen (Table 4.3) that the interaction effect of increased levels of phosphorus and sulphur increased plant height also.

Table 4.3: Interaction effects of sulphur and phosphorus on plant height of soybean

Treatment	Plant height (cm) at 30 DAS	Plant Height (cm) At 60 DAS
S_0P_0	30.28^{h}	46.55^{j}
S_0P_1	33.71^{fg}	49.02^{h-j}
S_0P_2	35.95^{e-g}	51.16^{f-h}
S_0P_3	36.63^{d-g}	52.33^{e-g}
S_1P_0	33.16^{gh}	48.43^{ij}
S_1P_1	37.81^{c-f}	52.48^{e-g}
S_1P_2	39.44^{b-d}	53.30^{d-f}
S_1P_3	40.40^{bc}	55.44^{cd}
S_2P_0	34.72^{e-g}	50.27^{g-i}
S_2P_1	37.94^{c-f}	53.03^{d-f}
S_2P_2	41.40^{b}	56.40^{bc}
S_2P_3	41.41^{b}	56.72^{bc}
S_3P_0	36.22^{e-g}	51.43^{f-h}
S_3P_1	39.78^{b-d}	54.30^{c-e}
S_3P_2	42.37^{ab}	58.77^{b}
S_3P_3	44.68^{a}	61.90^{a}
$LSD_{0.05}$	2.32	1.77
CV	12.53	14.63

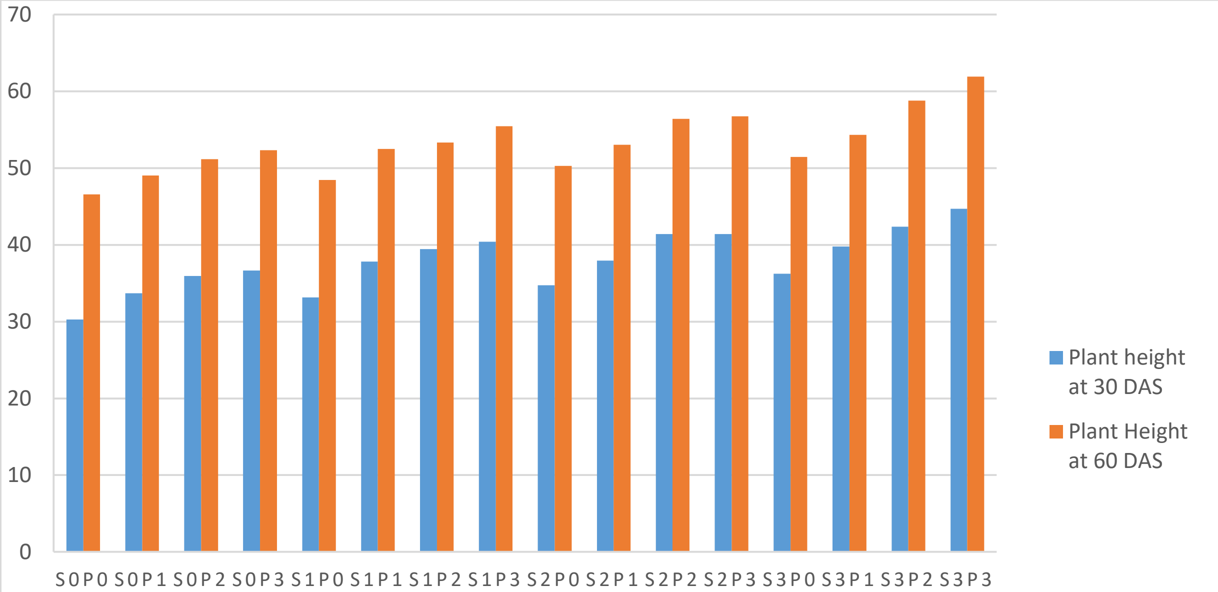


Fig 2: Interaction effects of combined application of sulphur and phosphorus on plant height of soybean

4.4 Effect of sulphur on leaves Number plant^{-1}of soybean

The response of number of leaves plant^{-1} of soybean with the application of different dose of sulphur application was represented in Table 4.4. From the Table 4.4 it was clearly showed the significant variations in respect of number of leaves plant at different S levels. The highest number of leaves plant^{-1} was recorded in the treatment of S_3 (60 kg S ha^{-1}) as 8.98 and 14.80 at 30 DAS and 60 DAS respectively. On the contrary, the lowest number of leaves plant^{-1} (6.32 and 10.36) was recorded in the S_0 (control) treatment. The increased number of leaves plant^{-1} may be due to favorable effects of sulphur on the vegetative growth and accumulation of growth promoting materials that helped proper growth and development of the soybean plant. Saran and Gin (1990) also found similar results with the application of 60 kg S ha^{-1}.

Table 4.4: Effect of sulphur on leaves Number plant^{-1}of soybean

Treatment	Leaves Number plant^{-1} at 30 DAS	Leaves Number plant^{-1} At 60 DAS
S_0	6.32^{c}	10.36^{d}
S_1	7.43^{b}	12.20^{c}
S_2	8.13^{b}	13.78^{b}
S_3	8.98^{a}	14.80^{a}
$LSD_{0.05}$	0.72	0.33
CV	8.14	12.60

4.5 Effect of phosphorus on leaves Number plant^{-1}of soybean

In the Table 4.5, significant variation was observed in the number of leaves plant^{-1} of soybean when different doses of phosphorus were applied. Treatment P_3 (80 kg P ha^{-1}) showed the highest number of leaves plant^{-1} was 8.80and 14.90at 30 DAS and 60 DAS respectively and which was statistically similar with P_2 (60 kg P ha^{-1}) treatment. The lowest number of leavesplant^{-1} (6.03 and 9.64 at 30 DAS and 60 DAS respectively) was recorded in the P_0 treatment where no phosphorus was applied. From the Table 4.5 showed increased dose of P application results increased the number of leaves plant^{-1}.

Table 4.5: Effect of phosphorus on leaves Number plant^{-1}of soybean

Treatment	Leaves Number plant^{-1} at 30 DAS	Leaves Number plant^{-1} At 60 DAS
P_0	6.03^{c}	9.64^{c}
P_1	7.58^{b}	12.43^{b}
P_2	8.45^{a}	14.16^{a}
P_3	8.80^{a}	14.90^{a}
$LSD_{0.05}$	0.79	1.83
CV	10.14	16.36

4.6 Combined effects of sulphur and phosphorus on leaves number plant^{-1} of soybean

Interaction effect of different doses of phosphorus and sulphur fertilizers on the number of leaves plant^{-1} of soybean was represented in table 4.8 and fig 2 which showed significant variation. Treatment combination of P_3S_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) results the highest number of leaves plant^{-1}was recorded as 12.53 and 17.20 at 30 DAS and 60 DAS respectively. At 30 DAS, S_3P_2 (60 kg S ha^{-1} + 60 kg P ha^{-1}), S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) and S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}) treatment and at 60 DAS S_3P_2 and S_2P_3 treatment showed statistically similar results with the treatment combination of $S_3P_3$the contrary, the lowest number of leaves plant^{-1}(4.87 and 7.38 at 30 DAS and 60 DAS respectively) was recorded in the S_0P_0 treatment (control) combination. The highest number of leaves plant^{-1} may be due to the fact that, the combined effect of both phosphorus and sulphur played positive effect on the growth and development of soybean plant.

4.7 Effect of sulphur on primary branch number plant^{-1}of soybean

Different doses of sulphur fertilizer showed significant variations in respect of number of primary branches plant^{-1} (table 4.6). Among the different doses of sulphur. S_3 (60 kg S ha^{-1}) showed the highest number of primary branches plant^{-1} (3.55 and 7.19at 30 DAS and 60 DAS respectively) and at 60 DAS S_2 (40 kg S ha^{-1}) treatment showed statistically similar result. The increased number of primary branches plant^{-1} may be due to positive effects of sulphur on the vegetative growth and accumulation of growth promoting substances that helped proper growth and development of the soybean plant. Mohanti *et al.* (2004) found similar results with the application of 30 kg S ha^{-1}.Dubey *et al.* (1997) reported that sulphur increased the number of primary branches per plant of linseed up to 40 kg S ha^{-1}. Similar findings were obtained by Ohosh *et al.* (1997).

Table 4.6: Effect of sulphur on primary branch number plant^{-1} of soybean

Treatment	Branch Number plant^{-1} at 30 DAS	Branch Number plant^{-1} At 60 DAS
S_0	2.48^{d}	6.53^{b}
S_1	3.00^{c}	6.72^{ab}
S_2	3.30^{b}	6.77^{ab}
S_3	3.55^{a}	7.19^{a}
$LSD_{0.05}$	0.21	0.25
CV	16.53	12.08

4.8 Effect of phosphorus on primary branch number plant^{-1} of soybean

From the Table 4.7 application of different level of phosphorus had a positive effect on the number of primary branches plant^{-1} of soybean. The highest number of primary branches plant^{-1} was recorded as 3.55 at 30 DAS in P_2 (60 kg P ha^{-1} which was statistically similar with the P_3 (40 kg P ha^{-1}) treatment. At 60 DAS, the highest number of primary branch plant^{-1} (7.05) was also recorded in P_2 treatment but no significant variation was observed at different level of P application. The lowest number of primary branches plant^{-1} (2.38 and 6.55 at 30 DAS and 60 DAS respectively) was recorded in the P_0 treatment where no phosphorus was applied.

Table 4.7: Effect of phosphorus on primary branch number plant^{-1} of soybean

Treatment	Branch number plant^{-1} at 30 DAS	Branch number plant^{-1} At 60 DAS
P_0	2.38^{c}	6.55^{a}
P_1	3.03^{b}	6.77^{a}
P_2	3.55^{a}	7.05^{a}
P_3	3.36^{a}	6.85^{a}
$LSD_{0.05}$	0.189	NS
CV	16.53	8.08

4.9 Combined effects of sulphur and phosphorus on primary branch number plant^{-1} of soybean

The interaction effect of different doses of phosphorus and sulphur application on the number of primary branches plant^{-1} of soybean was significant (Table 4.3 and fig 3). The highest number of primary branches plant^{-1} (4.00) was recorded at 30 DAS with the treatment combination of S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) which was statistically similar with S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}) and S_1P_3 (20 kg S ha^{-1} + 80 kg P ha^{-1}) treatment combinations. At 60 DAS, the highest number of primary branches plant^{-1} (7.53) was recorded with the treatment combination of S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) and there had less significant variation response to S and P combination treatment. The lowest number of primary branches plant^{-1} (1.66 and 6.20 at 30 DAS and 60 DAS respectively) was recorded in the S_0P_0 treatment (control) combination. The highest number of primary branches plant^{-1} may be due to the fact that. The combined effect of both phosphorus and sulphur played positive effect on the growth and development of soybean plant.

Table 4.8: Interaction effects of sulphur and phosphorus on primary branch number plant^{-1} and leaves number plant^{-1} of soybean

Treatment	Branch Number plant^{-1} at 30 DAS	Branch Number plant^{-1} At 60 DAS	Leaves Number plant^{-1} at 30 DAS	Leaves Number plant^{-1} At 60 DAS
S_0P_0	1.66^{i}	6.20^{b}	4.867^{g}	7.38^{i}
S_0P_1	2.40^{gh}	6.36^{b}	6.33^{e-g}	10.33^{h}
S_0P_2	2.86^{fg}	6.86^{ab}	6.67^{d-f}	11.60
S_0P_3	3.00^{d-f}	6.71^{ab}	7.40^{c-e}	12.13^{fg}
S_1P_0	2.13^{hi}	6.23^{b}	5.47^{fg}	7.98^{i}
S_1P_1	3.20^{c-f}	6.86^{ab}	7.67^{b-e}	12.53^{e-g}
S_1P_2	3.21^{c-f}	6.56^{ab}	8.20^{b-d}	13.73^{c-f}
S_1P_3	3.46^{a-d}	6.93^{ab}	8.40^{bc}	14.56^{b-d}
S_2P_0	2.73^{e-g}	6.73^{ab}	6.40^{ef}	11.40^{gh}
S_2P_1	3.20^{c-f}	6.86^{ab}	8.00^{b-d}	12.86^{d-g}
S_2P_2	3.53^{a-d}	7.26^{ab}	9.00^{a-c}	15.13^{bc}
S_2P_3	3.73^{a-c}	6.23^{b}	9.13^{ab}	15.73^{ab}
S_3P_0	3.00^{d-f}	7.05^{ab}	7.40^{c-e}	11.80^{gh}
S_3P_1	3.33^{b-e}	7.00^{ab}	8.33^{bc}	14.00^{c-e}
S_3P_2	3.86^{ab}	7.20^{ab}	9.93^{a}	16.20^{ab}
S_3P_3	4.00^{a}	7.53^{a}	12.53^{a}	17.20^{a}
$LSD_{0.05}$	0.59	0.69	1.64	1.45
CV	16.14	14.36	15.39	12.08

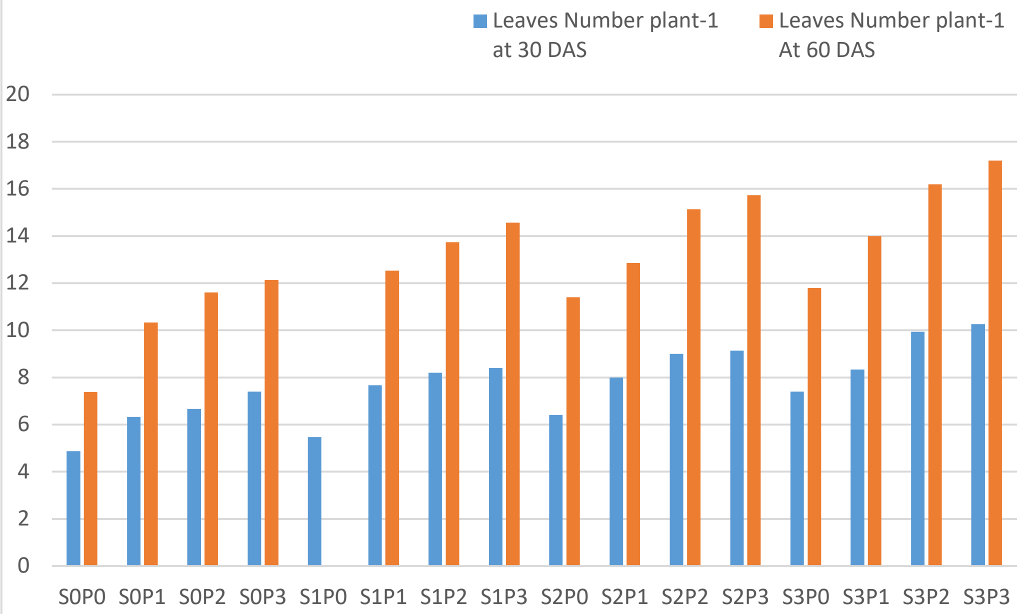


Fig 3: Interaction effects of sulphur and phosphorus on leaves number plant^{-1} of soybean

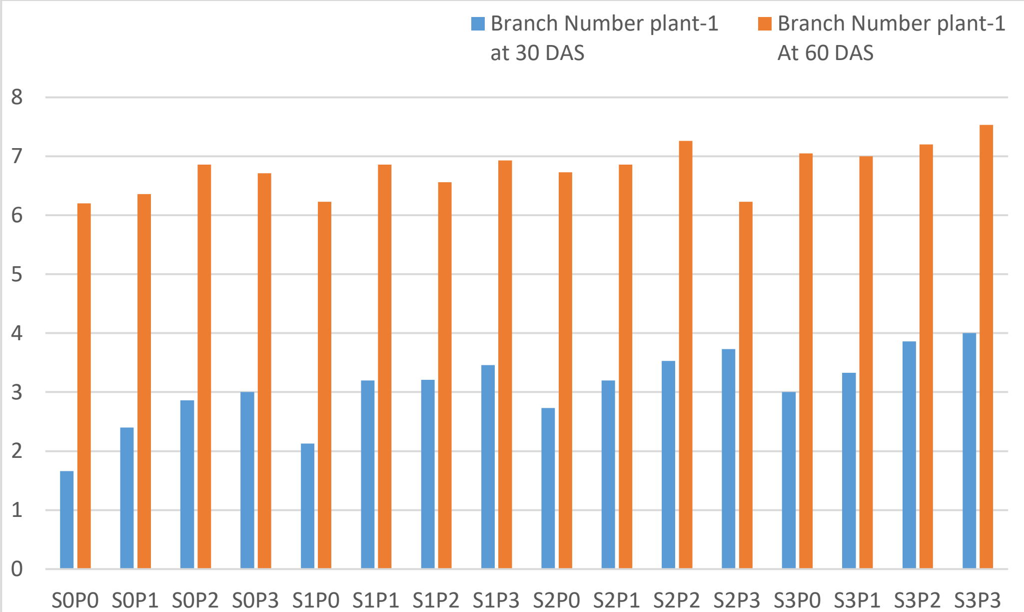


Fig 4: Interaction effects of sulphur and phosphorus on primary branch number plant^{-1} of soybean

4.10 Effect of sulphur on pod length plant^{-1} of soybean

The different level of S application had a significant effect on pod length plant^{-1}of soybean (table 4.9). The largest pods (3.92 cm) was recorded in S_3 (60 kg S ha^{-1}) treatment which was statistically similar with S_2 (40 kg S ha^{-1}). The smallest pods (3.45 cm) was recorded in S_0 where no S was applied. The increased number of primary branches plant^{-1} may be due to positive effects of sulphur on the vegetative growth and accumulation of growth promoting substances that helped proper growth and development of the soybean plant.

4.11 Effect of phosphorus on pod length plant^{-1} of soybean

The different level of phosphorus application had a significant effect on pod length plant^{-1} of soybean (table 4.10). The largest pods (3.92 cm) was recorded in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg S ha^{-1}). The smallest pods (3.40 cm) was recorded in P_0 where no P was applied. The increased number of primary branches plant^{-1} may be due to positive effects of sulphur on the vegetative growth and accumulation of growth promoting substances that helped proper growth and development of the soybean plant.

4.12 Combined effect of sulphur and phosphorus on pod length plant^{-1} of soybean

The interaction effect of different doses of phosphorus and sulphur application on the number of primary branches plant^{-1} of soybean was significant (Table 4.13). The largest pod plant^{-1} (4.28 cm) was recorded with the treatment combination of S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) which was statistically similar with S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) and S_3P_2 (60 kg S ha^{-1} + 60 kg P ha^{-1}) treatment combinations. The lowest number of primary branches plant^{-1} (3.23 cm) was recorded in the S_0P_0 treatment (control) combination. The highest number of primary branches plant^{-1} may be due to the fact that. The combined effect of both phosphorus and sulphur played positive effect on the growth and development of soybean plant.

4.13 Effect of sulphur on pods plant^{-1} of soybean

The response of number of pods plant^{-1} of soybean with the application of different level of sulphur was represented in table 4.9. Among the different doses of fertilizers. S_3 (60kg S ha^{-1}) showed the highest number of pods plant^{-1} (19.44) which had no significant variation except S_0 (zero S application) treatment. The increased number of pods plant^{-1}may he due to favorable effects of sulphur on the vegetative growth and accumulation of growth materials that helped proper growth and development of the soybean pod. Sriram Chandra sekharan *et al.* (2004) found similar results with the application of 30 kg S ha^{-1} in the presence of *Bradyrhizobium* inoculation. Arunageeta *et al.* (2006) observed that the highest number of pods plant^{-1} was obtained with the application of 30 kg S ha^{-1}.

4.14 Effect of phosphorus on pods plant^{-1} of soybean

In the table 4.10 showed positive effect on pods plant^{-1} of soybean when different doses of phosphorus were applied. The highest number of pods plant^{-1} (18.91) was recorded in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg P ha^{-1}) and P_1 (40 kg P ha^{-1}) treatment. The lowest number of pods plant^{-1}(15.38) was recorded in the P_0 (no phosphorus application) treatment. These findings are similar to those of Reddy and Gajendragiri (1989) who reported that phosphorus @ 20 kg P ha^{-1} increased the pod yield of soybean. Similar results were also found by Jana *et al.* (1990) and Singh and Bajpai (1990) in soybean.

4.15 Combined effect of sulphur and phosphorus on pods plant^{-1} of soybean

The interaction effect of different doses of P and S fertilizers on the number of pods plant^{-1} of soybean represented in table 4.13 which showed less significant variation. The highest number of pods plant^{-1} (21.03) was recorded with the treatment combination of S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) which was less statistically dissimilar and only showed significantly variation with control (S_0P_0). The lowest number of pods plant^{-1}(12.15) was recorded in the S_0P_0 treatment (control) combination. The number of pods plant^{-1} was increased with the increased application of sulphur and phosphorus. Majumdar *et al.* (2001) found that combined application of P and S @ 60 kg P_2O_5 ha^{-1} and 40kg S ha^{-1} increased the number of pods plant^{-1}The highest number of pods plant^{-1}may be due to the fact that, the combined effect of both phosphorus and sulphur had positive effect on the vegetative growth and accumulation of growth promoting materials that helped proper growth and development of the soybean pod.

4.16 Effect of sulphur on seeds pod^{-1} of soybean

The positive effect of the number of seeds pod^{-1} of soybean with the application of different level of sulphur was represented in table 4.9. Among the different doses of fertilizers, S_3 (60 kg S ha^{-1}) showed the highest number of seeds pod^{-1} (3.61) which are statistically similar with S_2 (40 kg S ha^{-1}) and S_1 (20 kg S ha^{-1}) treatment. The increased number of seeds pod^{-1}may be due to favorable effects of sulphur on the vegetative growth and accumulation of growth materials that helped proper growth and development of the soybean pod.

4.17 Effect of phosphorus on seeds pod^{-1} of soybean

In the table 4.10 showed positive effect on seeds pod^{-1} of soybean when different doses of phosphorus were applied. The highest number of seeds pod^{-1}(3.80) was recorded in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg P ha^{-1}). The lowest number of seeds pod^{-1} (3.33) was recorded in the P_0 (no phosphorus application) treatment.

4.18 Combined effect of sulphur and phosphorus on seeds pod^{-1} of soybean

The interaction effect of different doses of P and S fertilizers on the number of seeds pod^{-1} of soybean represented in table 4.13 which showed less significant variation. The highest number of seeds pod^{-1} (4.06) was recorded with the treatment combination of S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) which was statistically similar with S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}), S_3P_2 (40 kg S ha^{-1} + 80 kg P ha^{-1}), S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}), S_1P_3 (20 kg S ha^{-1} + 80 kg P ha^{-1}), S_2P_1 (40 kg S ha^{-1} + 40 kg P ha^{-1}) and S_1P_2 (20 kg S ha^{-1} + 60 kg P ha^{-1}) treatment combination. The lowest number of seeds pod^{-1} (3.00) was recorded in the S_0P_0 treatment (control) combination. The number of seeds pod^{-1} was increased with the increased application of sulphur and phosphorus. Majumdar *et al.* (2001) found that combined application of P and S @ 60 kg P_2O_5 ha^{-1} and 40kg S ha^{-1} increased the number of seeds pod^{-1} The highest number of pods plant^{-1} may be due to the fact that, the combined effect of both phosphorus and sulphur had positive effect on the vegetative growth and accumulation of growth promoting materials that helped proper growth and development of the soybean pod.

4.19 Effect of sulphur on seeds plant^{-1} of soybean

Different doses of sulphur fertilizer showed significant variations in respect of number of seeds plant^{-1} was represented in table 4.9. Among the different doses of fertilizers, S_3(60 kg S ha^{-1}) showed the highest number of seeds plant^{-1} (59.24) which was statistically similar with S_2 (40 kg S ha^{-1}) and S_1 (20 kg S ha^{-1}) treatments. It was also observed that the lowest number of seeds plant^{-1}(49.17) was recorded in the S_0 (sulphur fertilizer application) treatment. The increased number of seeds plant^{-1} may be due to the favorable effects of sulphur on the vegetative growth and accumulation of growth promoting materials that helped in obtaining the highest number of seeds plant' of soybean. The present studies are in accordance with the findings of Dubey *et al*. (1997) who reported that seeds capsule^{-1} of linseed increased significantly due to increased levels of sulphur. Saran and Gin (1990) also found similar results with the application of 60 kg S ha^{-1}.

4.20 Effect of phosphorus on seeds plant^{-1} of soybean

Significant variation was observed in the number of seeds plant^{-1} of soybean when different doses of phosphorus were applied was represented in Table 4.10. The highest number of seeds plant^{-1} (61.03) was recorded in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg P ha^{-1}) treatment. The lowest number of seeds plant^{-1} (48.18) was recorded in the P0 treatment where no phosphorus was applied. The number of seeds plant^{-1} increased with increasing levels of phosphorus up to certain level. The result confirms with the findings of Jana *et al.*(1990).

4.21 Combined effect of sulphur and phosphorus on seeds plant^{-1} of soybean

The combined effect of different doses of P and S fertilizers on the number of seeds plant^{-1} of soybean represented in table 4.13. The highest number of seeds plant^{-1} (65.60) was recorded with the treatment combination of S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) which showed significant variation with S_0P_0 (no S and fertilizer application), S_0P_1 (0 kg S ha^{-1} + 40 kg P ha^{-1}) and S_1P_0 (20 kg S ha^{-1} + 0 kg P ha^{-1}) treatment combination and rest of treatment combination results statistically similar. The lowest number of seeds plant' (41.40) was recorded in the S_0P_0 treatment (control) combination. The present studies are in accordance with the findings of Tomar *et al.* (2004) and Majumdar *et al.* (2001) who reported that seeds plant^{-1} of soybean increased significantly due to combined application of increased levels of phosphorus and sulphur. Optimum fertilizer doses increased the vegetative growth and development of soybean that lead to the formation of the highest number of seeds plant^{-1}

Table 4.9: Effect of sulphur on pod length plant^{-1}, pods plant^{-1}, seeds pod^{-1} and seeds plant^{-1} of soybean

Treatment	Pod length plant^{-1}(cm)	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}
S_0	3.45^{c}	15.62^{b}	3.27^{b}	49.17^{b}
S_1	3.63^{b}	17.23^{ab}	3.67^{a}	54.59^{a}
S_2	3.76^{ab}	17.96^{ab}	3.70^{a}	58.44^{a}
S_3	3.92^{a}	19.44^{a}	3.61^{a}	59.24^{a}
$LSD_{0.05}$	0.0186	0.6181	0.6181	0.1103
CV	1.24	8.62	7.58	2.73

Table 4.10: Effect of phosphorus on pod length plant^{-1}, pods plant^{-1}, seeds pod^{-1} and seeds plant^{-1} of soybean

Treatment	Pod length plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}
P_0	3.40^{c}	15.38^{b}	3.33^{b}	48.18^{c}
P_1	3.64^{b}	17.23^{ab}	3.41^{b}	54.52^{b}
P_2	3.80^{a}	18.72^{a}	3.70^{a}	57.70^{ab}
P_3	3.92^{a}	18.91^{a}	3.80^{a}	61.03^{a}
CV	1.24	8.62	7.58	2.73
$LSD_{0.05}$	0.02	0.62	0.62	0.11

4.22 Effect of sulphur on 100 seeds weight of soybean

Different doses of sulphur fertilizer showed significant variations in respect of the weight of 100 seed (Table 4.11). Among the different doses of S fertilizer. S_3 (60 kg S ha^{-1}) showed the highest weight of 100 seed (13.50 g) which is statistically similar with S_2 (40 kg S ha^{-1}). On the other hand, the lowest weight of 100 seed (11.00 g) was recorded in the S (no sulphur fertilizer) treatment. The increased grain weight may be due to the positive effects of sulphur on the vegetative growth and accumulation of growth promoting materials that helped proper growth and development of the soybean grain. These results are in agreement with the findings of Hemantarajan and Trivedi (1997), Agrawal and Mishra (1994) who reported that S application increased 1000-seed weight of soybean. Saran and Gin (1990) also found similar results with the application of 60 kg S ha^{-1}.

4.23 Effect of phosphorus on 100 seeds weight of soybean

Grain yield of soybean response to different level of P application was represented in table 4.12.From the table 4.12, significant variation was observed on the weight of 100 seeds of soybean when different doses of phosphorus were applied. The highest seed weight of soybean (13.50gm/100 seeds) was obtained in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg P ha^{-1}) treatment. The lowest grain yield (10.9 g/100 seeds) was recorded in the P_0 (Zero P applied) treatment. It was also showed that the weight of seeds was increased upto 23.85% at the maximum dose of P compared to control (zero P application). The increased grain weight may be due to the favorable effects of phosphorus on the vegetative growth and accumulation of plant growth materials that helped proper growth and development of the soybean grain. The result confirms with the findings of Reddy and Gajendragiri (1989).

4.24 Combined effect of sulphur and phosphorus on weight of 100 seeds of soybean

From the table 4.13 it was obtained a positive effect of S and application on weight of 100 seeds of soybean. The interaction effect of different doses of P and S fertilizers on the weight of 100 seed of soybean results significantly increased of weight of seeds with the increased application of S and P (table 4.13). The highest weight of 1000 seed (14.66 g) was recorded with the treatment combination of S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) which was statistically similar with S_3P_2 (60 kg S ha^{-1} + 60 kg P ha^{-1}) S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) and S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}) treatment. On the other hand, the lowest weight of 1000 seed (10.00 g) was recorded in the P0S0 treatment (control treatment). The weight of 1000 seed increased with increasing level of phosphorus and sulphur up to optimum level due to the favorable effects of fertilizer on the yield attributes.

4.25 Effect of sulphur on grain yield of soybean

In the table 4.11, significant variation was observed on the grain yield of soybean when different doses of sulphur were applied. The highest grain yield of soybean (1.96 t ha^{-1}) was obtained in S_3 (80 kg P ha^{-1}) treatment which was statistically similar with S_2(60 kg S ha^{-1}) treatment. It was also observed that the lowest grain yield (1.55 t ha^{-1}) was found in the S_0 (Zero S application).Sriram Chandra sekharan *et al.* (2004) found similar results with the application of 30 kg S ha in the presence of *Bradyrhizohium* inoculation. Sangale *et al.* (2004) observed that application of S at 20 kg ha^{-1} gave highest secd yield. Mohanti *et al.* (2004) found similar results with the application of 30 kg S ha^{-1}. Tomar *et al.* (2000) reported that the highest seed yield (2257 kg ha^{-1}) was recorded with the application of 50 kg S ha^{-1} regardless of sources. The increased grain yield may be due to the positive effects of sulphur on the vegetative growth and accumulation of plant growth materials that helped proper growth and development of the soybean grain. From the table 4.11 it was clearly observed that the effect of sulphur application on grain yield of soybean is positive and the yield was increased 26.45% at the maximum level of sulphur application compared to control (Zero S application).

4.26 Effect of phosphorus on grain yield of soybean

The effect of phosphorus on grain yield of soybean was represented in table 4.12 which was showed positive relationship between phosphorus application and grain yield. Significant variation was observed on the grain yield of soybean when different doses of phosphorus were applied. The highest grain yield of soybean 2.08 t ha^{-1}) was recorded in P_3 (80 kg P ha^{-1}) treatment which was statistically similar with P_2 (60 kg P ha^{-1}) treatment. The lowest grain yield (1.55 t ha^{-1}) was recorded in the P_0 treatment where no phosphorus was applied. These results were similar with the findings of Maurya and Rathi (2000) who reported that grain yield was maximum with the application of 60 kg P ha^{-1}. The increased grain yield may be due to the positive effects of phosphorus on the vegetative growth and accumulation of plant growth materials that helped proper growth and development of the soybean grain.

4.27 Combined effect of sulphur and phosphorus on grain yield of soybean

The combined effect of different doses of sulphur and phosphorus on grain yield was represented in table 4.13. It was found a positive relationship between different level of S and P on grain yield of soybean. It was also observed that the combined effect of different doses of P and S fertilizers on the grain yield of soybean was significant (table 4.13). The highest grain yield of soybean (2.36t ha^{-1}) was recorded with the treatment combination of S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) which were statistically similar with S_3P_3 (60 kg S ha^{-1}+ 80 kg Pha^{-1}) and S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}). On the other hand, the lowest grain yield of soybean (1.36t ha^{-1}) was recorded in the P_0S_0 treatment (control) combination which was statistically similar with S_0P_1 (0 kg S ha^{-1} + 40 kg P ha^{-1}) and S_0P_2 (0 kg S ha^{-1} + 60 kg P ha^{-1}) treatment. The present studies are in accordance with the findings of Tomar *et al.* (2004) and Majumdar *et al.*(2001) who reported that grain yield of soybean increased significantly due to combined application of increased levels of phosphorus and sulphur. Grain yield increased with increasing level of phosphorus and sulphur up to optimum level due to the positive effect of fertilizers on the yield attributes.

4.28 Effect of sulphur on stover yield of soybean

Significant variations in respect of stover yield of soybean at different doses of sulphur fertilizer showed in Table 4.11. Among the different doses of S fertilizer, S_3 (60 kg S ha^{-1}) showed the highest stover yield of soybean (3.16 t ha^{-1}) which was statistically similar with S_2 (40 kg S ha^{-1}) and S_1 (20 kg S ha^{-1}) treatment. On the other hand, the lowest weight of stover yield of soybean (2.40 t ha^{-1}) was recorded in the S_0treatment where no S was applied. The findings for these characters agree with the results obtained by Tomar *et al.* (1995) who observed that straw yields of mustard increased with increased S rates.

4.29 Effect of phosphorus on stover yield of soybean

Significant variation was observed on the stover yield of soybean when different doses of phosphorus were applied (Table 4.12). The highest stover yield of soybean (3.21t ha^{-1}) was recorded in P_3 (80 kg P ha^{-1}), which was statistically similar with P_2(60 kg P ha^{-1}) treatment. On the other hand. the lowest stover yield (2.32 t ha^{-1}) was obtained in the control (Zero P application). The findings for these characters agree with the results obtained by Khandkar *et al. (1985)* and Sacchindanand *et al.* (1980) who observed that straw yields of soybean increased with the application of P @30 kg P_2O_5 ha^{-1}.

4.30 Combined effect of sulphur and phosphorus on stover yield of soybean

The combined effect of different doses of P and S fertilizers on the stover yield of soybean was represented in table 4.13. The interaction effect of P and S fertilizers on the stover yield of soybean showed significant variation and positive relation. The highest stover yield of soybean (3.70 t ha^{-1}) was observed in the treatment combination of S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) which was statistically similar with S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}), S_2P_2(40 kg S ha^{-1} + 60 kg P ha^{-1}) and S_1P_3(20 kg S ha^{-1} + 80 kg P ha^{-1}) treatment. The lowest stover yield of soybean (2.66t ha^{-1}) was recorded in the S_0P_0treatment (control) combination which was statistically similar with S_0P_1 (0 kg S ha^{-1} + 40 kg P ha^{-1}), S_0P_2 (0 kg S ha^{-1} + 60 kg P ha^{-1}), S_0P_3 (0 kg S ha^{-1} + 80 kg P ha^{-1})and S_1P_0 (20 kg S ha^{-1} + 0 kg P ha^{-1}). Tomar *et al.* (2004) and Majumdar *et al.* (2001) reported that straw yield of soybean increased significantly due to combined application of increased levels of phosphorus and sulphur.

Table 4.11: Effect of sulphur on 100 seeds wt., grain yield and stover yield of soybean

Treatment	100 seeds wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0	11.00^c	1.55^c	2.40^b
S_1	12.16^b	1.88^b	2.73^a
S_2	12.91^a	1.96^{ab}	2.99^a
S_3	13.50^a	1.96^a	3.16^a
$LSD_{0.05}$	0.2200	0.0553	0.1500
CV	4.35	7.35	13.01

Table 4.12: Effect of phosphorus on 100 seeds wt., grain yield and stover yield of soybean

Treatment	100 seeds wt. (g)	Yield (t ha^{-1})	Stover yield (t ha^{-1})
P_0	10.91^c	1.51^c	2.32^c
P_1	12.08^b	1.77^b	2.73^b
P_2	13.08^a	1.99^a	3.02^{ab}
P_3	13.50^a	2.08^a	3.21^a
$LSD_{0.05}$	0.2200	0.0553	0.1500
CV	4.35	7.35	13.01

Table 4.13: Effect of sulphur and phosphorus on pod length plant^{-1}, pods plant^{-1},seeds pod^{-1}, seeds plant^{-1}, 100 seeds wt., grain yield and stover yield of soybean

Treatment	Pod length plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	Seeds plant^{-1}	100 seeds wt. (g)	Yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0P_0	3.23^{i}	12.15^{b}	3.00^{e}	41.40^{e}	10.00^{i}	1.36^{g}	2.66^{f}
S_0P_1	3.45^{g-i}	16.33^{ab}	3.13^{d-e}	49.27^{c-e}	11.00^{g-i}	1.43^{fg}	2.43^{d-f}
S_0P_2	3.53^{e-i}	16.87^{ab}	3.40^{b-e}	51.40^{c-e}	11.33^{f-h}	1.63^{d-g}	2.60^{d-f}
S_0P_3	3.58^{d-i}	17.13^{ab}	3.53^{b-d}	54.60^{a-d}	11.67^{f-h}	1.76^{de}	2.60^{d-f}
S_1P_0	3.30^{hi}	15.73^{ab}	3.53^{b-d}	47.73^{ab}	10.67^{hi}	1.46^{fg}	2.26^{ef}
S_1P_1	3.64^{c-h}	17.33^{ab}	3.53^{b-d}	54.70^{a-d}	12.00^{e-h}	1.90^{b-d}	2.70^{d-e}
S_1P_2	3.72^{b-g}	17.70^{ab}	3.86^{ab}	56.87^{a-d}	12.66^{c-f}	2.06^{bc}	2.86^{c-e}
S_1P_3	3.86^{b-e}	18.17^{ab}	3.73^{a-c}	59.07^{a-d}	13.33^{b-d}	2.06^{bc}	3.10^{a-d}
S_2P_0	3.50^{f-i}	16.53^{ab}	3.33^{c-e}	50.96^{c-e}	11.33^{f-h}	1.53^{e-g}	2.53^{d-f}
S_2P_1	3.66^{c-h}	17.47^{ab}	3.60^{a-d}	56.67^{a-d}	12.33^{d-g}	1.90^{b-d}	2.73^{d-e}
S_2P_2	3.93^{b-d}	18.53^{ab}	3.80^{a-c}	60.53^{a-c}	13.66^{a-c}	2.10^{a-c}	3.06^{a-d}
S_2P_3	3.97^{a-c}	19.33^{a}	4.06^{a}	65.60^{a}	14.33^{ab}	2.36^{a}	3.70^{a}
S_3P_0	3.57^{e-i}	17.13^{ab}	3.46^{b-e}	52.63^{b-e}	11.66^{f-h}	1.70^{d-f}	2.50^{d-f}
S_3P_1	3.82^{b-f}	17.80^{ab}	3.40^{b-e}	57.47^{a-d}	13.00^{c-e}	1.86^{cd}	3.00^{b-d}
S_3P_2	4.02^{ab}	21.80^{a}	3.73^{a-c}	62.00^{a-c}	14.66^{a}	2.13^{bc}	3.63^{ab}
S_3P_3	4.28^{a}	21.03^{a}	3.86^{ab}	64.86^{ab}	14.66^{a}	2.16^{ab}	3.46^{a-c}
$LSD_{0.05}$	0.04	1.24	1.23	0.22	0.44	0.11	0.30
CV	1.24	8.62	2.73	7.58	4.35	7.35	13.01

CHAPTER V
SUMMARY AND CONCLUSION

A field experiment was conducted at Agronomic Farm and laboratory of Sher-e-Bangla Agricultural University (Tejgaon series under AEZ No.28) during the rabi season of 2018. The objectives of the research works were to study the growth, yield and nutrient composition of soybean (*Glycine max*) as influenced by four doses of sulphur and four doses of phosphorus fertilizer. Experiments were conducted and were laid out in RCBD. The field experiment had 16 treatments each having three replications and the size of unit plot was 3 m x l.5 m. Fifteen plants were accommodated in each plot with the spacing of 50 cm x 40 cm. From each plot, 5 plants were randomly selected for collection of data on growth, yield and yield contributing characters. Laboratory experiment was conducted for measuring concentration of major nutrient content in plant as well as physical and nutrient composition of post-harvest soil. The soil was clay loam in texture having pH 6.5 and organic matter content of 0.86%, 0.079% total nitrogen, 9.88 ppm available P, and 0.119 ppm available Sulphur contents. The treatment combinations were: S_0P_0Control (no S and P fertilizer);S_1P_0 (20 kg S ha^{-1} + 0 kg P ha^{-1})S_2P_0 (40 kg S ha^{-1} + 0 kg P ha^{-1}); S_3P_0(60 kg S ha^{-1} + 0 kg P ha^{-1}); S_0P_1 (0 kg S ha^{-1} + 40 kg P ha^{-1});S_0P_2 (0 kg S ha^{-1} + 60 kg P ha^{-1}); S_0P_3 (0 kg S ha^{-1} + 80 kg P ha^{-1}); S_1P_0 (0 kg S ha^{-1} + 40 kg P ha^{-1}); S_1P_2 (20 kg S ha^{-1} + 60 kg P ha^{-1}); S_1P_3 (20 kg S ha^{-1} + 80 kg P ha^{-1}); S_2P_1 (40 kg S ha^{-1} + 40 kg P ha^{-1}); S_2P_2 (40 kg S ha^{-1} + 60 kg P ha^{-1}); S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}); S_3P_1 (60 kg S ha^{-1} + 40 kg P ha^{-1}); S_3P_2 (60 kg S ha^{-1} + 60 kg P ha^{-1}); S_3P_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}). Each plot received recommended doses of N, K. Zn and 13 (30 kg N ha^{-1} from urea, 40 kg K *h*a^{-1} from MP, 2 kg Zn ha^{-1} from ZnO and 1 kg B from Boric acid ha^{-1}, respectively). The elements P and S were applied in the form of TSP and Gypsum. The effect of different levels of sulphur and phosphorus individually was significant in relation to yield and yield attributes studied. Plant height was significantly affected by different levels of P and S. Plant height increased with increasing levels of P and S up to highest level. The individual application of phosphorus @ 80 kg ha^{-1} (P_3) produced the tallest plant, whereas application of S 60 kg ha^{-1} (S_3) produced the tallest plant. The highest plant height (44.68 cm and 44.68 cm at 30 DAS and 60 DAS respectively) was found from P_3S_3 (60 kg S ha^{-1} + 80 kg P ha^{-1}) combination treatment. The maximum number of leaves $plant^{-1}$from the individual treatment of S and P were found at S_3 (60 kg S ha^{-1}) and P_3 (80 kg P ha^{-1}) treatment whereas the maximum number of leaves $plant^{-1}$ (10.26 and 17.20 at 30 DAS and 60 DAS respectively) was found in P_3S_3 treatment. The effect of application of S and P fertilizer on primary branch $plant^{-1}$, number of pods $plant^{-1}$, pod length (cm), seeds pod^{-1}, seeds $plant^{-1}$, weight of 100 seed and seed weight $plant^{-1}$ were also positive and it was clearly showed that increased dose of S and P results significantly and upto its maximum level. Grain yield of soybean was influenced significantly due to the application of phosphorus and sulphur. Grain yield was increased with increasing dose of phosphorus and sulphur upto the maximum level. The highest grain yield was found 1.96 t ha^{-1} in where 60 kg S ha^{-1} (S_3) was applied and the lowest was recorded in P_0 treatment. The individual application of S in increasing dose results significantly on grain yield attributes of soybean. The highest amount of grain yield was recorded as2.08t ha^{-1} in P_3 (80 kg P ha^{-1}. The combined application of P and S had positive effect on grain yield of soybean. The highest grain yield of soybean was recorded as 2.36 t ha^{-1} in S_2P_3 treatment combination. The lowest yield (1.36 t ha^{-1}) was recorded in S_0P_0 treatment. Combined application of S_2P_3 (40 kg S ha^{-1} + 80 kg P ha^{-1}) produced more than 73.54% higher grain yield compared to control treatment.

Considering all the parameters studied the following conclusion may be drawn: Significantly higher growth and yield performance and major nutrient composition of soybean was observed by S_3P_3 treatment i.e., by the combined application of sulphur and phosphorus fertilizers @ 60 kg S ha^{-1} and 80 kg P ha^{-1}. In some cases the highest results obtained at S_2P_3 and S_2P_2 treatment combination i.e. @ 40 kg S ha^{-1} and 80 kg P ha^{-1} and @ 40 kg S ha^{-1} and 60 kg P ha^{-1} respectively which were very close to the results obtained by the S_3P_3 treatment. Considering the findings it is wise and economic to adopt S_2P_2 treatment i.e., by the combined application of phosphorus and sulphur fertilizers @ 40 kg S ha^{-1} and 60 kg P ha^{-1} and avoid the luxurious doses of phosphorus and Sulphur.

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APPENDICES

Appendix Table I: Monthly records of meteorological observation at the period of experiment (January, 2018 to May, 2018

Month	Temperature (°C)		Humidity (%)	Rainfall (mm)
	Minimum	Maximum		
January	25.40	12.70	46.80	7.70
February	28.10	15.50	37..45	28.90
March	32.40	20.50	38.12	65.80
April	33.70	23.6	42.23	156.30
May	32.90	24.5	59.14	339.40

Source: Weather Yard, Bangladesh Meteorological Department, Dhaka.

Appendix Table II. Summary of analysis of variance of plant height, number of branch and number of leaves of soybean at 30 DAS and 60 DAS as influenced by different level of Sulphur and phosphorus

Source of variation	Degree of freedom	Mean square					
		Plant height at 30 DAS	Plant height at 60 DAS	Branch no. at 30 DAS	Branch no. at 60 DAS	Leaves no. at 30DAS	Leaves no. at 60 DAS
Replication	2	3.712	21.841	0.98583	0.98583	8.1908	4.5400
Factor A	3	93.904**	98.880**	2.52667**	2.52667*	15.2733**	45.0710*
Factor B	3	123.091**	127.098**	3.16222**	3.16222**	18.2511**	65.7289**
AB	9	0.830**	3.768**	0.06667**	0.06667**	0.2815**	1.0706*
Error	30	2.937	0.753	0.02761	0.02761	0.2246	0.6621

Appendix Table III: Summary of analysis of variance of length of pods plant^{-1}, number of pods, plant^{-1}, seedspod^{-1}, and seeds plant^{-1} of soybean as influenced by different level of sulphur and phosphorus

Source of variation	Degree of freedom	Mean square			
		Length of pods plant^{-1}	Number of Pods plant^{-1}	seeds pod^{-1}	seeds plant^{-1}
Replication	2	3.712	21.841	0.98583	8.1908
Factor A	3	93.904*	98.880*	2.52667**	15.2733**
Factor B	3	123.091**	127.098*	3.16222*	18.2511**
AB	9	0.830*	3.768**	0.06667*	0.2815**
Error	30	2.937	0.753	0.02761	0.2246

Appendix Table IV: Summary of analysis of variance of weight of 100 seeds, grain yield and stover of soybean as influenced by different level of sulphur and phosphorus

Source of variation	Degree of freedom	Mean square		
		weight of100seeds	Grain yield	Stover yield
Replication	2	0.98583	3.712	21.841
Factor A	3	2.52667**	93.904**	98.880**
Factor B	3	3.16222*	123.091**	127.098**
AB	9	0.06667**	0.830**	3.768*
Error	30	0.02761	2.937	0.753

Appendix Table V: Summary of analysis of variance of N, P and S content in plant of soybean as influenced by different level of Sulphur and phosphorus

Source of variation	Degree of freedom	Mean square		
		N(%)	P(%)	S(%)
Replication	2	0.01597	3.712	21.841
Factor A	3	0.45427*	93.904*	98.880*
Factor B	3	0.59262*	123.091**	127.098*
AB	9	0.01459**	0.830*	3.768**
Error	30	0.00266	2.937	0.753

Appendix Table VI: Summary of analysis of variance of N, P and S content in post-harvest soil as influenced by different level of Sulphur and phosphorus

Source of variation	Degree of freedom	Mean square		
		N(%)	P(%)	S(%)
Replication	2	0.01484	0.00007	0.00034
Factor A	3	0.02711*	0.00132**	0.06364*
Factor B	3	0.02138*	0.02242*	0.00471**
AB	9	0.02091*	0.00049*	0.00058*
Error	30	0.01645	0.00001	0.00003