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

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CERTIFICATE

This is to certify that the thesis entitled, ***"EFFECT OF PHOSPHORUS AND MOLYBDENUM ON GROWTH AND YIELD OF SOYBEAN (Glycine max L.)"*** *submitted to the Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of Master of Science in Soil Science, embodies the result of a piece of bona fide research work carried out by* ***MST. AFROZA KHATUN,*** *Registration No.* ***19-10046*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021
Place: Dhaka, Bangladesh

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh from December 2019 to April 2020 to evaluate the effect of phosphorus and molybdenum on growth and yield of soybean (*Glycine max* L.). The experiment comprised of two factors: Factor A: Levels of phosphorous: P_0: 0 kg P_2O_5 ha^{-1}, P_1: 30 kg P_2O_5 ha^{-1}, P_2: 60 kg P_2O_5 ha^{-1} and Factor B: Levels of molybdenum: Mo_0: 0 kg Mo ha^{-1}, Mo_1: 1 kg Mo ha^{-1}, Mo_2: 1.5 kg Mo ha^{-1}. The two factors experiment comprised of nine treatments combination was laid out in Randomized Complete Block Design (RCBD) with three replications. Individual application of different levels of phosphorus and molybdenum fertilization showed significant effect on growth and yield contributes studied. For phosphorus application, growth parameter viz. plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ increased significantly up to 30 kg P_2O_5 ha^{-1} fertilization and yield parameter viz. pod length, 100 seed weight, number of pods $plant^{-1}$, number of seeds pod^{-1}, seed yield, stover yield, biological yield and harvest index also significantly increased in P_1 (30 kg P_2O_5 ha^{-1}) treatment. The highest seed yield (2.44 t ha^{-1}) was found from P_1 (30 kg P_2O_5 ha^{-1}) treatment and lowest yield (1.20 t ha^{-1}) was obtained from P_0 (control) treatment. In case of molybdenum, growth parameter and yield contributing characters were also significantly increased up to Mo_2 (1.5 kg Mo ha^{-1}) treatment. The highest seed yield (2.38 t ha^{-1}) was obtained from Mo_2 (1.5 kg Mo ha^{-1}) treatment and lowest yield (1.23 t ha^{-1}) was found from Mo_0 (control) treatment. Combined application of phosphorus (30 kg P_2O_5 ha^{-1}) and molybdenum (1.5 kg Mo ha^{-1}) showed significant variation on all parameters of soybean. The combined application of 30 kg P_2O_5 ha^{-1} and 1.5 kg Mo ha^{-1} may be considered for getting higher yield of soybean.

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LIST OF ACRONYMS

Abbreviation	Elaboration
AEZ	Agro -Ecological Zone
Agril.	Agriculture
FAO	Food and Agriculture Organization
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
Cm	Centi-meter
CV	Coefficient of variance
cv.	Cultivar
DAS	Days after sowing
Df	Degrees of freedom
et al.	and others
G	Gram (s)
HI	Harvest index
i.e.	That is
IFDC	International Fertilizer Development Centre
J.	Journal
Kg	Kilogram (s)
MS	Master of Science
m^2	Square meter
Pod^{-1}	Per pod
$Plant^{-1}$	Per plant
Sci.	Science
SE	Standard error
$t\ ha^{-1}$	Ton per hectare
viz.	Namely
%	Percentage
@	At the rate of
^0C	Degree centigrade

CHAPTER I
INTRODUCTION

Soybean (*Glycine max* L. Merrill) is a leguminous crop, which belongs to the family Fabaceae. It is rich in high quality protein (40-45%), oil (19-22%) and other nutrients like calcium, iron and glycines. It is a good source of isoflavones (Kumar, 2007). Together protein and soybean oil content account for 56% of dry soybean by weight, remainder consists of 30% carbohydrate, 9% water, 5% ash. Soybean comprises approximately 8% seed coat or hull, 90% cotyledons and 2% hypocotyls axis. Soybean has a very good adaptability towards a wide range of soils and climate. The origin of soybean is reported to be eastern Asia or China. Globally, soybean has ranked first amongst various oilseed crops, contributing approximately 25% to the world's total oil and fat production. Worldwide, the total annual production of soybean is 365.79 million tons from an area of land totaling 130.90 million hectares (FAOSTAT, 2017). In Bangladesh, soybean is cultivated mainly as pulse crops. The cultivation of soybean in Bangladesh (mainly in Noakhali and feni) started in 1978. Soybean area and production levels for marketing year (FY 2018/2019-July to June) in Bangladesh are projected to increase to 80,000 hectare and 152,000 tonnes respectively. In Bangladesh, total annual production is 96,921 tons from a cultivated area of 62,870 hectares (FAOSTAT, 2017). Among oilseeds in Bangladesh, in fiscal year (FY) 2016-17, soybeans are the fourth ranked crop in terms of total planted area at 9.82% of total oilseed planted area. 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, disease and insect infestation, modern cultivation and improper or limited irrigation facilities. 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. Phosphorus and molybdenum plays an important role for growth and yield contributing characters of soybean.

Phosphorus plays an important role in an array of cellular processes, including maintenance of membrane structure, synthethsis of biomolycules and formation of high-energy molecules. It also helps in cell division, enzyme activation/inactivation and carbohydrate metabolism (Razaq *et al.,* 2017). The most obvious effect of phosphorus is on the plant root system. It promotes early root formation and thus formation of lateral fibrous and healthy roots, which is very important for nodule formation and fixing atmospheric nitrogen. Phosphorus application significantly increases dry matter production as well as yield and yield contributing characters of soybean. Phosphorus has beneficial effects on both nodulation and nitrogen fixation capacity of soybean.

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. Molybdenum is required for growth of most biological organisms including plants (Graham and Stangoulis, 2005). Moreover, molybdenum 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). From many research papers it was found that phosphorus and molybdenum favours each other in absorption from soil by the plant and has synergistic role in metabolism. Both the elements have great role in nitrogen fixation process. So it is necessary to examine the effects of different levels of those nutrients and assess their best combination in terms of enhanced nitrogen fixation and productivity of soybean.

Under the above perspectives and above all situation the present experiment was conducted with different levels of phosphorus and molybdenum on soybean with the following objectives:

1. To evaluate the performance of phosphorus and molybdenum on growth and yield of soybean.
2. To determine the optimum doses of phosphorus and molybdenum for the proper growth and development of soybean.

CHAPTER II

REVIEW AND LITERATURE

Soybean is well recognized oil and protein containing crop. It has conventional less attention by the researchers. On various aspects of production technology because normally this crop grows with minimum care or minimum agronomic management practices. For that a very few research have been carried out in our country. However, researches in home and abroad trying to maximize the yield of soybean with different management practices especially on NPK fertilizer, spacing, variety, weeding etc, but not other macro and micro nutrients. Phosphorus and molybdenum play an important role in improving soybean growth and yield. But this research works related to phosphorus and molybdenum so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1 Effect of phosphorus on growth and yield contributing characters of soybean

Bhattacharjee *et al.* (2013) conducted an experiment at Experimental Research Farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema to evaluate the effect of phosphorus, sulphur and cobalt (viz. 30, 60 and 90 kg P_2O_5 ha^{-1}) and their interaction of growth and yield of soybean in acidic soil of Northeast India. Application of different levels of phosphorus showed significant effect on yield and yield attributes studied. In case of phosphorus, the positive response was observed only up to 60 kg P_2O_5 ha^{-1}. Application of phosphorus 60 kg P ha^{-1} gave rise to the plant highest number of pods $plant^{-1}$ (43.5), number of seeds $plant^{-1}$ (28.2) and highest produced seed yield (2.50 t ha^{-1}).

Qasim Shahid *et al.* (2009) conducted a field experiment at Ayub Agricultural Research Institute (AARI) Faisalabad to evaluate the effect of different phosphorus levels viz. 0, 25, 50, 75 and 100 kg ha^{-1} and inoculation with *Rhizobium japonicum* and seed inoculation on yield of soybean. Application of different levels of P showed a positive result in 100 kg P_2O_5 ha^{-1} gave highest number of branches (4.94), number of pods $plant^{-1}$ (42.68), number of seeds pod^{-1} (2.74) and oil content 19.35%.

Sanjeev *et al.* (2005) conducted a study in Haryana, India, during the rainy season to assess the effects of nitrogen and phosphorus fertilizers on the nutrient uptake and yield of soybean. Treatments comprised: 0, 20, 40 and 60kg N ha^{-1}, and 0, 40, 60 and 80 kg

P ha^{-1}. P content in seed and Stover increased with increasing N and P rates up to 60 kg ha^{-1} and 80 kg ha^{-1}, respectively. Of the total nutrients accumulated by the crop, the seeds and the remaining by stover retained 87.1% of N and 68.1% of P. Maximum uptakes P in seeds, Mover and in the whole plant were recorded upon treatment with 80 kg P ha^{-1}. Soybean seed yield was highest with 80 kg P ha^{-1} treatment (22.82 q ha^{-1}), followed by 60 kg ha^{-1} (22.58 q ha^{-1}), and were significantly superior to the 20 kg P ha^{-1} and control treatments.

Runia, (2018) conducted a field experiment, at the research farm of Sher-e-Bangla Agricultural University, Dhaka, during January to April, 2018 to study the influence of biofertilizer and phosphorus level on growth, nodulation and yield of soybean. The experiment consists of two factors- factor A: Biofertilizer level-2; i) Control (without biofertilzer) (B_0) and ii) Biofertilizer (B_1); factor B: P levels-5; i) Control (no phosphorus) (P_0), ii) 25% less TSP than recommended dose (P_1), iii) Recommended dose of TSP (P_2), iv) 25% higher TSP than recommended dose (P_3) and 50% higher TSP than recommended dose (P_4). In case of phosphorus all parameter observed that plant height (54.55 cm), number of branches plant^{-1} (3.07), pod length (3.96 cm), number of pods plant^{-1} (49.27), 100 seed weight (8.03 g), seed yield (3613 kg ha^{-1}) and stover yield (4073 kg ha^{-1}) were from 25 % TSP in this experiment.

Bothe *et al.* (2000) evaluated the effects of P fertilizer (0, 25, 50. and 75 kg P_2O_5 ha^{-1}). Spacing (30 x 10, 20 x. 10 and 30 x 5 cm) and P-solubilizers on the yield and yield components of a soybean- fenugreek cropping system were evaluated during 1995 at Pune, Maharashtra, India. All yield parameters increased with increasing levels of P fertilizer. Phosphorus at 75 kg P_2O_5 ha^{-1} recorded the highest values for plant height (71.20 cm), dry matter per plant (57.46 g) and straw yield (49.50 q ha^{-1}, while P at 25 kg ha^{-1} recorded the highest seed yield (42.83 q ha^{-1}).

Khanam *et al*. (2014) showed the effect of phosphorus and potassium fertilization level on the growth and yield of soybean. The treatments were phosphorus (viz., 0,100, 175 and 250 kg TSP ha^{-1}) and potassium (i.e., 0, 60, 120 and 180 kg MoP ha^{-1}). Individual application of different levels of phosphorus and potassium showed significant effect of growth and yield attributing studied. In case of phosphorus the highest (3.01 t ha^{-1}) seed yield was found from 175 kg TSP ha^{-1} and other parameter such as, leaf area index, numbers of nodule plant^{-1} (9.99), numbers of filled pod plant^{-1} (51.14), numbers of seed pod^{-1} (2.98), pod length (3.05 cm), 1000-seed weight (106.2 g), seed yield (3.01 t ha^{-1}), stover yield (3.21 t ha^{-1}), biological yield (6.22 t ha^{-1}) and harvest index (48.54 %) increased significantly up to 175 kg TSP ha^{-1} among phosphorus fertilization.

Morshed *et al*. (2008) conducted an experiment evaluate to the influence of phosphorus (P) on growth and yield of soybean (*Glycine max* L.). The treatments were: control (P_1) and with the application of 50% (P_2), 75 % (P_3), 100 % (P_4), 125 % (P_5) and 150 % (P_6) of the BARC recommended dose of P. Among all treatments, P_5 treatment (11.25 kg P ha^{-1}) showed maximum growth and yield, which was 84.73% higher than that of control. The application of P at 11.25 kg ha^{-1} at 25% higher over BARC recommendation produced the highest seed yield of soybean (7.50 g plant^{-1}). So, for better yield of soybean in silty clay loam soil of Jahangir nagar University farm, application of P should be increased 25 % higher over BARC recommendation.

Noori *et al.* (2015) experimented that the use of fertilizer is considered to be one of the most important factors to increase crop yield. Phosphorous has been shown to be an essential element and its application has been shown to be important for growth, development and yield of soybean. Phosphorus deficiency has been shown to be an important fertility problem limiting legume production in the tropics. Under low P status, P fertilizer application to legume and its management are important in attaining high yields in soybean. The results showed that applying P to dose 50 kg ha^{-1} increase the growth, 100 seed weight (15. 87g), seed yield 2.01 t ha^{-1}, stover yield (4.87 t ha^{-1}) and quality of soybean seeds in all variables.

Ramasamy *et al.* (2000) reported that P application at 80 kg ha^{-1} recorded significantly higher number of pods per plant and was on a par with 60 kg ha^{-1}. P at 80 kg ha^{-1} recorded the highest grain yield of 1133 and 1396 kg ha^{-1} in summer and kharif, respectively, which was on a par with 60 kg ha^{-1}.

Timotiwu *et al.* (2017) conducted a research with soybean, the effect of P and application of B their response on growth, yield and quality of soybean seeds. This research was conducted at field land and the Laboratory of Seeds and Plant Breeding, Faculty of Agriculture, University of Lampung from November 2016 to April 2017. This treatment was arranged in a 6 × 2 factorial consisting of six doses of P_2O_5 (0, 50, 100, 150, 200, 250 kg ha^{-1}) and two concentration of B (0 and 5 ppm). The results showed that applying P to dose 250 kg ha^{-1} increase the growth, yield and quality of soybean seeds in all variables.

Yadav *et al*. (2013) conducted a field experiment during summer season at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh to effect of phosphorus and sulphur on growth and yield of summer soybean. Result of the experiment revealed that an application of phosphorus 60 kg ha^{-1} recorded significantly higher plant height (49.56 cm), branch $plant^{-1}$ (5.83), plant spread (36.78 cm), pods $plant^{-1}$ (58.78), seeds pod^{-1} (3.04), test weight (149.22 g), seed yield (2675 kg ha^{-1}), and stover yield (2980 kg ha^{-1}) over control.

Akter *et al.* (2013) conducted an experiment, at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from December 2008 to April 2009 to evaluate the effect of P (viz.0, 15, 30, 50 kg P_2O_5 ha^{-1}) and S (viz. 0, 10, 20, 40 kg S ha^{-1}) and their interaction on the growth and yield of soybean (*Glycine max* L.). Individual application of different levels of phosphorus and sulphur showed significant effect on yield and yield attributes studied. In case of phosphorus number of leaves $plant^{-1}$ (48.12), numbers of pods $plant^{-1}$ (27.73), number of seeds $plant^{-1}$ (80.21), thousand seed weight (93.57 g), grain yield (2.04 t ha^{-1}), stover yield (2.93 t ha^{-1}) and biological yield (4.96 t ha^{-1}) increased significantly up to 30 kg P ha^{-1}. The combined application of 30 kg phosphorus ha^{-1} and 20 kg sulphur ha^{-1} may be considered to be optimum for getting higher yield of soybean.

Malik *et al.* (2006) reported that soybean requires no N fertilizers, but more P as it plays a vital role in getting higher yield with better grain quality. They studied different aspects of soybean growth and yield applying different phosphorus treatments namely: control T_1, 0 kg P ha^{-1} (T_2), 30 kg (T_3), 60 kg (T_4), 90kg (T_5) and 120 kg (T_6). All the P (T_2-T_6) treatments are inoculated with *Rhizobium.* Maximum grain yield (2.53 t ha^{-1}) was recorded from T_5 90 kg P ha^{-1}.

Landge *et al*. (2002) conducted a field experiment and observed a progressive increased in yield and yield contributing characters of soybean with the application of P fertilizer in combination with Rhizobium.

Sharma *et al.* (2002) evaluated the experiment, to know the effect of levels and source of phosphorus under the effect of farm yard manure on growth determinants and productivity of soybean (*Glycine max* L. Merrill) and observed that P 60 kg ha^{-1} produced better yield, dry matter and yield components compared to 30 kg ha^{-1}.

Thirumurugan *et al*. (2002) conducted a field experiment to study the influence of zinc, phosphorus and phosphobacteria on seed quality of soybean. The highest protein content due to the P application were obtain with 60 (40.24 and 40.86%) kg ha^{-1} + phosphobacteria 2 kg ha^{-1}. Phosphorus treatment had no significant effect of oil content of soybean.

Kumar *et al.* (2014) conducted an experiment, effects of phosphorus and varieties of growth parameter and yield of soybean (*Glycine max* L). The treatment consisted of four levels of phosphorus (P_0 = control, P_1 = 30kg P_2O_5 ha^{-1}, P_2 = 60kg P_2O_5 ha^{-1}, P_3 = 90 kg P_2O_5 ha^{-1}) and three varieties. Application of phosphorus significantly influenced the plant height, number of branches per plant, fresh weight of plant, dry weight of plant, seed yield and stover. The highest seed yield was recorded with the application of phosphorus at 60 kg P_2O_5 ha^{-1} which remained at par with 90 kg P_2O_5 ha^{-1}, but significantly higher stover 1.8 t ha^{-1} yield was observed at 90 kg P_2O_5 ha^{-1}.

Begum *et al.* (2015) observed that effect of nitrogen and phosphorus on the growth and yield performance of soybean. Seed yield varied significantly due to phosphorus application. The results revealed that the highest seed yield (2.09 t ha^{-1}) obtained from 54 kg P ha^{-1} whereas, the lowest (1.30 t ha^{-1}) obtained from control treatment.

Sonar and Bhakare (2004) studied a field experiment in Rahuri, Maharastra. Soybean was supplied with 0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}. Applied of P increased grain and straw yield, P uptake and soil available. They reported that P gave the highest grain and straw soybean yields (32.1 and 64.9 q ha^{-1}, respectively), P uptake in grain and straw (12.9 and 14.6 q ha^{-1}, respectively) and soil available P (14.6 kg ha^{-1}) were recorded from the 100 kg P_2O_5 ha^{-1} treatment. The results showed that inorganic forms of P contribute to increased P availability and uptake in soybean and increased yields.

Singh and Bajpai (1990) reported that the grain yield of soybean increased significantly with increasing phosphorus levels up to 60 kg P_2O_5 ha^{-1}. The response in respect of per kg of applied phosphorus to grain yield (8.2 kg grain/ kg P_2O_5 ha^{-1}) was highest up to 60 kg P_2O_5 ha^{-1}, with a further addition of 40 kg P_2O_5 ha^{-1} the grain yield per kg of phosphorus (3.5 kg grain/ kg P_2O_5) declined.

Upadhay *et al*. (1988) revealed that leaf area index of soybean increased with P level up to 69 kg P_2O_5 ha^{-1} from 40 days after sowing to reproductive stage. Total dry matter at harvest was maximum with 69 kg P_2O_5 ha^{-1} although was equal with that of 46 kg P_2O_5 ha^{-1}. The grain and straw yields increased significantly with increasing levels of phosphorus up to 40 and 69 kg P_2O_5 ha^{-1}, respectively. The increase in yield is attributed to the higher dry matter per plant and leaf area index with phosphorus application.

Gosh and Gosh (1988) showed that the statistically significant positive correlation obtained between fertilizer P and supply parameters (SP) values suggests that SP may be a suitable index for predicting fertilizer P uptake by plants.

Khandaker *et al*. (1985) reported that the dry matter yield of above ground parts during 30 to 60 days of growth and the number of nodules $plant^{-1}$ at 40 days of growth were significantly increased in black gram (*Vigna mungo*) by P application. The percentage of increase by application of phosphorus at @ 30 kg P_2O_5 ha^{-1} over control was 51 and 45 for the grain and straw yields, respectively.

Kumar and Singh (1980) investigated that the application of P increased the P concentration. The concentration of P in 45 and 110 days gave significant positive correlation with P uptake and grain yield of soybean.

2.2 Effect of molybdenum on growth and yield contributing characters of soybean

Ansary (2014) conducted an experiment at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. Bangladesh during the period from December, 2013 to April 2014 to study the effect of potassium and molybdenum on the growth, yield and oil content of BARI soybean -5. The experiment comprised of two factors; Factor A: Levels of potassium (4 levels) – K_0: 0 kg K_2O ha^{-1} (control); K_1: 30 kg K_2O ha^{-1}, K_2: 40 kg K_2O ha^{-1}, K_3: 50 kg K_2O ha^{-1} and Factors B: Levels of molybdenum (3 levels)- Mo_0: 0 kg Mo ha^{-1} (control), Mo_1: 1.0 kg Mo ha^{-1}, Mo_2: 1.5 kg Mo ha^{-1}. In case of molybdenum, the longest plant height (64.50 cm), number of leaves (25.91), pod length (5.43 cm) the highest seed yield (2.11 t ha^{-1}) was recorded from Mo_2, whereas the lowest seed yield (1.58 t ha^{-1}) from Mo_0. The highest oil content (23.89%) was recorded from Mo_2, whereas the lowest oil content (21.10%) from Mo_0.

Biswas *et al*. (2012) carried out at Bangladesh Agricultural University Farm, Mymensingh to study the growth and yield of soybean cv. Shohag in relation to different levels of added sulphur (0, 6, 12 and 18 kg S ha^{-1}) and molybdenum (0, 1, 2 and 3 kg Mo ha^{-1}). The results indicated that single and combined effect of different levels of sulphur and molybdenum had significant effect on growth and yield of soybean. In case of molybdenum the maximum number of effective pod plant^{-1} (39.67), pod length (3.85 cm), grain and stover yield (1773 and 2767 kg ha^{-1} respectively) and harvest index (39.05%) were obtained by the application of 2 kg Mo ha^{-1}.

Mahapatra (2003) carried out a field experiment to evaluate 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}.

Jabbar *et al*. (2014) conducted a study to evaluate the effect of molybdenum and pre-inoculation of *Azospirillum* on biological nitrogen fixation, yield and yield contributing characters of soybean plants. A total of eight treatments were used in this study including control, 1.0 kg of Mo ha^{-1}, 1.5 kg of Mo ha^{-1}, 10.0 kg of Mo ha^{-1}, *Azospirillum brasilense, A. brasilense* + 1.0 kg of Mo ha^{-1}, *A. brasilense* + 1.5 kg of Mo ha^{-1} and *A.brasilense* + 10.0 kg of Mo ha^{-1}. The result showed that the bacterial inoculation in combination with 1.0 kg Mo ha^{-1} significantly contributed to increase weight of nodules (9.8 mg), plant dry weight (68.8 g), total nitrogen content (6%), 100 seed weight (13.2 g) and pod weight (47.5 g). Application of 1.0 kg of Mo ha^{-1} in association with *A. brasilense* produced significantly high yield (27.3 g plant^{-1}) compared to control which produced only 8.1 g plant^{-1}, thus indicating the potential of this treatment to be used for soybean in large scale.

Rizvi (2014) reported that 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}. In case of molybdenum the tallest plant (61.85 cm), number of branches $plant^{-1}$ (3.42), longest pod (4.93 cm), maximum number of pods $plant^{-1}$ (36.26), number of seeds pod^{-1} (3.31), 100 seeds weight (13.61 g), seed yield (1.93 t ha^{-1}), stover yield (2.48 t ha^{-1}) were obtained by application of 1.5 kg Mo ha^{-1}.

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}.

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. *Rhizobium inoculam* along with phosphorus, potash, boron and molybdenum gave significantly higher nodule number, nodule weight, stover yield and seed yield (2.14 t ha^{-1}).

Zahoor *et al*. (2013) conducted a field experiment to evaluate the response of soybean to micronutrients viz. iron (Fe), molybdenum (Mo) and cobalt (Co). Results indicated that iron applied at the rate of 400 g ha^{-1} and molybdenum 20 g ha^{-1} had a significant effect on shoot length, shoot dry weight, number of nodules $plant^{-1}$, nodules fresh weight and thousand seed weight. The highest seed yield 42.28% over control, dry matter yield, seed nitrogen and seed protein content was recorded by combined application of Fe at the rate of 400 g ha^{-1} and Mo 20 g ha^{-1}.

Dozet *et al.* (2016) reported that the effect of preceding crops nitrogen fertilization, cobalt and molybdenum application on yield and quality of soybean grain. The experimental field trial was designed as corn – soybean – wheat crop rotation and performed in four replications. The application of trace elements cobalt and molybdenum with microbiological nitrogen significantly percentage of protein in the grain (37.66%), highest seed yield (2.31 t ha^{-1}), grain yield (3.05 t ha^{-1}) compared to the variant without cobalt and molybdenum (38.22 %). However, significantly increase in soybean yields was 1.77%.

Khandkar *et al*. (2013) conducted an experiment to evaluate the effect of micronutrients, organics and biofertilizers on growth and yield of soybean.

Recommended dose of fertilizer (RDF) + 1 g ammonium molybdate kg^{-1} seed + Rhizobium + phosphate solubilizing bacteria (PSB) as compared to others nutrient management treatments. Similarly, highest yield were recorded with the application of RDF + 1 g ammonium molybdate kg^{-1} seed + Rhizobium + PSB during the investigation**.** Among all various nutrients management treatments, molybdenum had positive effects on plant height (62.47cm), nodules $plant^{-1}$ (54.00), pods $plant^{-1}$ (67.00), number of seeds pod^{-1} (2.44), 100 seed weight (10.08 cm) and seed yield (844 kg ha^{-1}) of soybean.

Elkhatib *et al*. (2007) conducted two field trials, in two successive growing seasons of 2006 and 2007. To study the combination effects of seed inoculation, nitrogen fertilization with (0, 48, 96 kg N ha^{-1}) and foliar molybdenum application (0 and 30 g Mo l^{-1} as sodium molybdate). The inoculated treatments and Mo fertilization increased Plant fresh weight and pods green yield by 16.04 and 26.16 %; and 23.0 and 45.86% in the first and second seasons respectively. In case of Mo fertilizer showed that highest result 6.52 t ha^{-1} in Mo_1.

Ibupoto and Kotecki (1994) observed that application of Mo or Mo + B to soybean increased the number of seeds plant and seed yield. They 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.

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.

Bukhoriev (1997) noted that application of B + Mo in soybean increased number and weight of nodules $plant^{-1}$ by 24 and 29% respectively, active symbiotic potential by 63%, maximum leat area by 23% and photosynthetic potential by 19%. Applying either

B or Mo gave smaller increases. Seed yields were 2.6 t ha^{-1} in the control, 2.72 t ha^{-1} with Mo and 2.95 t ha^{-1} with B + Mo. Seed protein content and yield were highest with B + Mo.

Dabarajan and Palaniappan (1995) carried out field trails to determine the effect of zinc and molybdenum on yield and nutrition of soybean with soil application of 2.5 or 5.0 kg Zn as $ZnSO_4$, 5.0 kg Zn + 0.5% $ZnSO_4$ foliar spray after sowing, 0.5 or 1.0 kg Mo as Na_2MoO_4, 10 t FYM, dust equal to that in 2.5 and 5.0 kg $ZnSO_4$, 2.5 kg Zn + 0.5 kg Mo + 10 t ha FYM or 20 kg N + 80 kg P_2O_5 + 40 kg K_2O ha^{-1} alone; all trace element treatments also received basal NPK. In both years a combination of Zn + Mo + FYM gave the highest seed yields.

Amadi (1994) conducted a field experiment in Baghdad to investigate the influence of five levels of molybdenum (0, 0.16, 0.36, 0.48 and 0.64 kg ha^{-1}) as ammonium molybdate on the growth of soybean at the condition of alkali soil of Iraq. He showed that a significant increase in weight of seeds $plant^{-1}$ and total crop yield mean while, the height of plant, protein and oil percentage insignificant increased. A high positive correlation was found, between the accumulation of Mo, N, P and K in the seed, followed by leaves and stems of the plant and the level of molybdenum application.

Aghatise and Tayo (1994) reported that application of Mo to soybean increased leaf number and area, plant height, number of branches per plant, number of nodules per plant compared with the control. At final harvest 0.2 and 0.4 kg Mo pot^{-1} increased seed dry weight by 29 and 10%, respectively.

Ali *et al.* (1993) observed that soybean cv. Clark was supplied with the equivalent of 0, 30 or 60 kg P $feddan^{-1}$ plus 0, 5 or 10 ppm Mo. The highest dry matter yield pot^{-1}, number of nodules and N and Mo uptake pot^{-1} came from the rates of 10 ppm Mo + 60kg P $feddan^{-1}$ (1 feddan = 0.42 ha).

Olufajo and Adu (1991) conducted a field experiment on soybean (cv. Samsoy) inoculated with *Bradyrhizobium japonicum* and Mo application @270 g Mo ha^{-1} and reported that increased nodulation on soybean.

Chhonker and Chandel (1991) conducted a field experiment on calcareous and showed that the separate basal application of 4.0 ppm Fe and 0.5 ppm Mo increased the nitrogenase activity and nitrogen fixation of soybean (*Glycine max* L.). They aslo showed that combined application of 4.0 ppm Fe with 0.5 ppm Mo resulted in the maximum nitrogen uptake by plant.

Dwivedi *et al*. (1990) conducted a field experiment on an acid soil in soybean and wheat crop sequence. They observed that Mo alone or in mixture of micronutrients increased significantly the yield of grain and straw of soybean and wheat.

Nayak *et al.* (1989) reported that seed treatment with molybdenum exerted a significant influence on growth, yield and yield attributes. It also improved the protein content of seeds significantly.

Chandel *et al*. (1989) conducted a field experiment with soybean and observed that Mo @ 0.5 kg ha^{-1} gave the maximum pods/plant of soybean. 1 kg Mo ha^{-1} increased the seed yield significantly over the control. They also reported that Mo @ 0.5 and 1.0 kg ha^{-1} significantly increased the protein content in grain, grain yield and quality of soybean.

2.3 Interaction effect of phosphorus and molybdenum on growth and yield contributing characters of soybean:

Dwivedi *et al*. (1997) conducted a field experiment during the rainy season of 1990-91 at Jabalpur, Madhay Pradesh to study the effect of applied phosphorus 0, 60, 80, 100, 120 kg P_2O_5 ha^{-1} and molybdenum 0, 0.5, 1.0, 1.5 kg Mo ha^{-1}, respectively. Applying 80 kg P_2O_5 and 1.0 kg Mo ha^{-1} gave significantly higher chlorophyll contents in the leaf during flowering and pod filling stage compared with all other treatments.

Pal *et al*. (1988) reported that a field experiment to determine the response of soybean to the application of P, K and Mo at four locations in the Nigerian savanna. Soybean was grown at factorial combinations of four rates of P (0, 13-2, 26-4 and 39-6 kg P ha^{-1}) and two rates of K (0 or 41-5 kg K ha^{-1}), but in subsequent years two or three rates of Mo (0, 0-5 or 1-0 kg ammonium molybdate ha^{-1}) were included in a randomized complete block design with three replications at all locations. Whereas P x Mo interaction effects were significant in three trials only, highest yields were recorded due to application of 26-4 or 39-6 kg P ha^{-1} in combination with 0-5 kg ammonium molybdate ha^{-1}.

Zakaria *et al*. (2014) conducted an experiment during the two successive growing summer seasons of 2013 and 2014 in sandy soil. To study the effect of spraying aqueous solutions of iron (Fe) at 20mg L^{-1} and seed treatment with Mo at 0.5 g kg^{-1} seeds and three levels of phosphorus (0, 15 and 30 kg P_2O_5 fed^{-1}) as single super phosphate on seeds yield and yield components of soybean (*Glycine max* L.). Results of interaction between seed treatment with molybdenum and foliar application of iron and combined with different levels of phosphorus showed significant increase on pod weight $plant^{-1}$ (28.30 g), number of pods $plant^{-1}$ (46), weight of 100-seed (14.22 g), seed yield (1.25 ton/fed.) and biological yield (2.97ton/fed) . Their maximum inoculating of soybean seeds with Mo at 0.5 g kg^{-1} seeds or spraying the plants by Fe at 20 mg L^{-1} with 30 kg P_2O_5 fed^{-1} treatment, whereas the lowest values for these traits were obtained by untreated plants (control treatments). The result indicate that the highest seed weight by 56.25% over control.

Aziz *et al*. (2012) reported that the effect of added phosphorus levels (30, 60 kg p fed^{-1}) with the addition of boron at (2.6 ppm) and molybdenum at (5.10 ppm) and without addition beside the control on growth and mineral content and root nodules in soybean plants. The molybdenum, nitrogen and phosphorus uptake increased directly proportional to the result of increased rate of addition of phosphorus and molybdenum. P-uptake increased with increasing the rate of either P or Mo, the percentages of increase at 30kg P fed^{-1} increased from 91% at 0 ppm Mo to 140% at 5 ppm Mo and 145% at 10 ppm Mo. The corresponding values at 60kg P fed^{-1} were 131%, 159% and 177% at 0, 5 and 10 ppm Mo, respectively. From the results that application of Mo combined with P enhanced nodules formation.

Khan (2004) conducted a field experiment in soil science field laboratory, Bangladesh Agricultural University, Mymensingh. An experiment to evaluate the effect of phosphorus and molybdenum on the nodulation, growth and yield of *Bradyrhizobium* inoculated Soybean (*Glycine max* L.).This experiment had 7 treatment with 3 replication. The result was recorded that the combine effect of P and Mo showed the highest number of pods $plant^{-1}$ (38.66), highest seed yield (2833 kg ha^{-1}) and stover yield (3833 kg ha^{-1}) were obtained in T_5 (*Bradyrhizobium* + $P_{25}Mo_{1.5}$). Application of phosphorus and molybdenum alone or in combination exerted positive effects on growth and yield and nutrient content and uptake by *Bradyrhizobium* inoculated soybean.

Umar *et al*. (2011) carried out an experiment that to evaluate the effects of phosphorus, micronutrients and *rhizobia* inoculation on growth and yield of soybean (*Glycine max* L.) on a fallowed soil. The treatments consisted of Macronutrients-P, K, S, Ca, and Mg, and Micronutrients- Mn, Zn, Cu, Co, B, and Mo; were arranged in randomized complete block design and replicated three times. The interaction effect of macronutrient + micronutrient showed the highest yield 1.61 t ha^{-1} and other parameter like plant height (54.20 cm), root length (48.38 cm), number of leaves $plant^{-1}$ (39) and 100 grain weight (11.70 g).

Rahman *et al*. (2005) conducted an experiment 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. There was 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 inoculant*. P and Mo application at the rate of 40 and 1.0 kg ha^{-1} respectively, significantly increased yield and yield contributing characters of mungbean compared to soybean plant. Highest stover (26.67 g $plant^{-1}$) and grain yield (14.61 g $plant^{-1}$) were obtained with P (40 kg ha^{-1}), Mo (1.0 kg ha^{-1}) and *Rhizobium* inoculation. Combined application of *Rhizobium inoculant* along with 40 kg P and 1.0 kg Mo ha^{-1} was considered to be the suitable combination of fertilizer for mungbean cultivation in silty clay loam soils.

Singh *et al*. (2002) conducted an experiment to study the effect of sulphate and molybdate application on yield and biochemical constituents of soybean (*Glycine max* L. Merrill). They used 0, 20, 40 and 60 mg S kg^{-1} and 0.0, 0.5, 1.0 and 1.5 mg kg^{-1} soil as sodium molybdate on soybean. Sulpher up to 60 mg kg^{-1} increased 1000 seed weight grains yield $plant^{-1}$, proteins and oil contents. The highest was obtained with 40 mg S kg^{-1} soil. S + Mo application up to 40 mg S kg^{-1} + 1.0 mg kg^{-1} increased the number of pods $plant^{-1}$ (24.56), 1000 seed weight (18.22 g), grain yield (2.11 t ha^{-1}), proteins and oil content.

Vargas and Rahmirez (1989) conducted a field experiment with 0 or 80 kg N + 100 kg P_2O_5 and reported that plant dry weight ranged from 129.0 g/10 plant without fertilizer or inoculation to 350.5 g with 30 kg N + inoculation. They also observed that nodule dry weight was greatest with and without inoculation. They also observed that soybean pod dry weight yield at harvest ranged from 332 g/ 10 plants without fertilizer or inoculation to 658.7 g with 30 kg N + P_2O_5 + Mo with inoculation. Pod yield ranged from 1.44 t ha^{-1} with fertilizer or inoculation to 6.58 t with 30 kg N + P_2O_5 + Mo with inoculation. They concluded that seed inoculation with low N rates and adequate P and Mo are necessary to increase soybean yields.

Hossain *et al*. (2005) conducted a field experiment to evaluate the effect of added P, Mo and *Bradyrhizobium* inoculant on nodulation, yield and yield contributing characters of two soybean cultivars, Pb-1 and G-2. The rates of P, Mo and *Bradyrhizobium* inoculant were 40 kg P ha^{-1}, 1 kg Mo ha^{-1} and 15 g inoculant kg^{-1} seed, respectively. Between two varieties, the G-2 showed higher nodulation, number of pods and seeds $plant^{-1}$ compared to Pb-1 variety. On the other hand, variety Pb-1 gave significantly higher 100-seed weight, seed and stover yields of soybean. The combine application of P and Mo with *Bradyrhizobium* inoculation further increased the nodulation and yield of soybean varieties.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted during the period from December 2019 to April 2020 to study the effect of phosphorus and molybdenum on growth and yield of soybean (*Glycine max* L.). This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2019 to April 2020. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2020) at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2011). The location of the experimental site has been shown in Appendix I.

3.2 Soil characteristics

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The experimental plot was also high land, having pH 5.6. The physicochemical properties and nutrient status of soil of the experimental plots are given in Appendix II.

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 III.

3.4 Planting material

In the experiment, planting material used as BARI soybean-5 that was developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Land preparation

The land was irrigated before ploughing. After having 'joe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 1st December and 05th December, 2019, 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: Phosphorus (3 levels)

P_0 = 0 kg P_2O_5 ha^{-1}

P_1 = 30 kg P_2O_5 ha^{-1}

P_2 = 60 kg P_2O_5 ha^{-1}

Factor B: Molybdenum (3 levels)

Mo_0 = 0 kg Mo ha^{-1}

Mo_1 = 1 kg Mo ha^{-1}

Mo_2 = 1.5 kg Mo ha^{-1}

There were total 9 (3×3) treatment combinations as: P_0Mo_0, P_0Mo_1, P_0Mo_2, P_1Mo_0, P_1Mo_1, P_1Mo_2, P_2Mo_0, P_2Mo_1, P_2Mo_2.

3.7 Experimental design and layout

The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. An area of 24 × 8 m was divided into three blocks. The 9 treatment combinations were assigned in the each plot of each block. The size of the each unit plot was 2m × 2m. The space between two blocks and two plots were 0.75 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

The layout of the design of experiments was as follows:

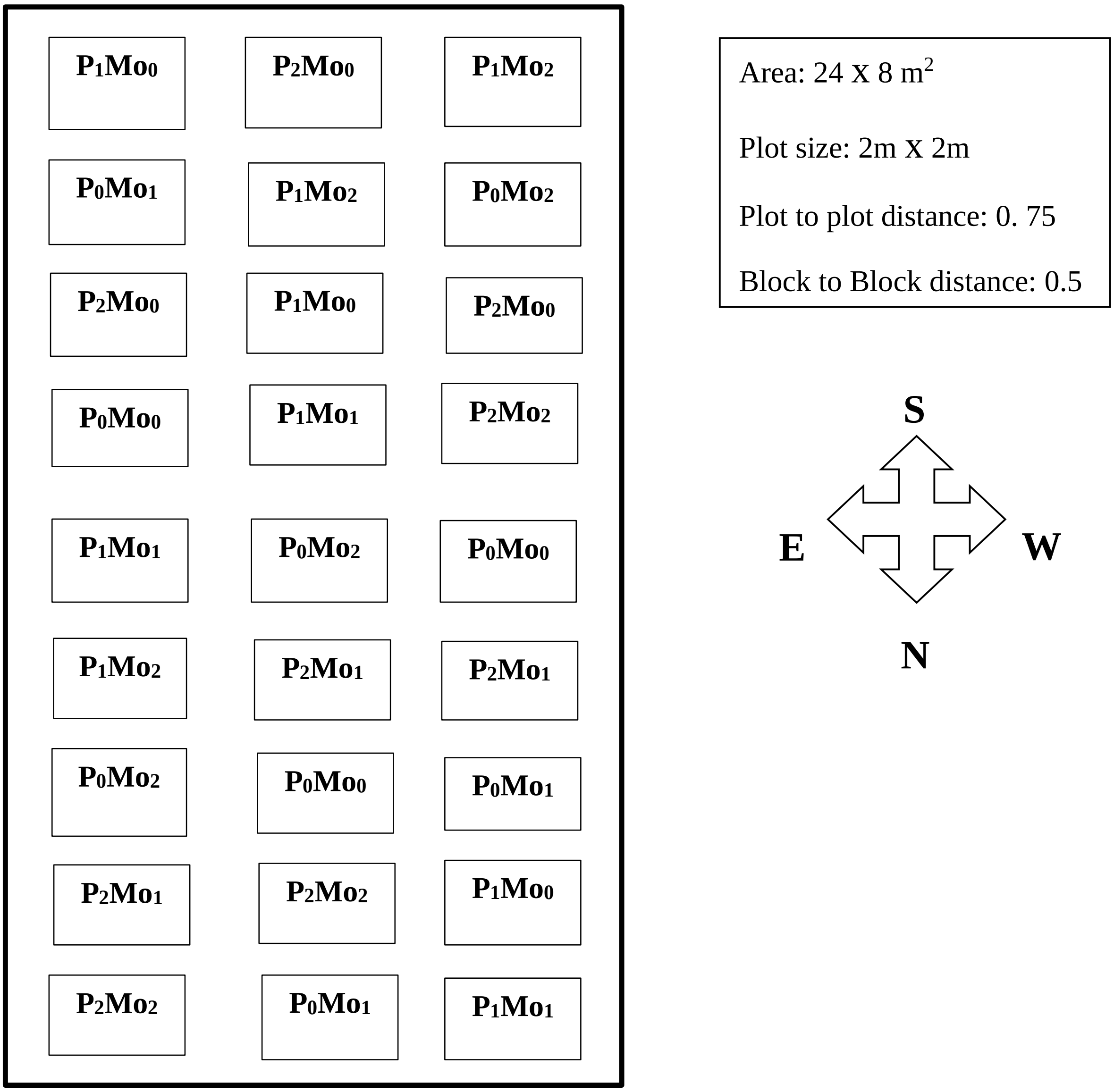

Figure 1: Field layout of the experiment

3.8 Fertilizer application

Recommended doses of N, K, Zn and B (20 kg N ha^{-1} from urea, 40 kg K ha^{-1} from MoP, 1 kg Zn ha^{-1} from ZnO and 1 kg B ha^{-1} from boric acid) respectively. The whole amount of MoP, ZnO, Boric acid and half amount of urea fertilizer were used as basal dose during final land preparation. The remaining half of urea was top dressed after 20 days of germination. The required amount of phosphorus and molybdenum were applied at the land preparation time as per treatment combination after field layout of experiment and were mixed properly through hand spading.

3.9 Seed collection

The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute (BARI), 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} (BARI, 2002). The variety is resistant to yellow mosaic virus.

3.10 Sowing of seeds in the field

The seeds of soybean were sown on December 08, 2019 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. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with soil.

3.11 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.11.1 Thinning

At 15 DAS, excess plants were thinned out and maintained plant to plant distance 10 cm.

3.11.2 Weeding

The crop was weeded trice. First weeding was done at 25 days after sowing (DAS), second weeding was done at 45 DAS and last weeding was done at 60 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.11.3 Irrigation

Irrigation was done at 30 DAS after sowing (pre-flowering) stage and then at 60 DAS (pod formation stages) as per recommendation (BARI, 2011). Proper drainage system was also made for draining out excess water.

3.11.4 Plant protections

The soybean plants were infested by cutworms (*Agrotis ipsilon*) at early growth stage which were controlled by applying Darsban 20 EC @ 5ml/L of water. Diseased or off type plants were uprooted as and when required.

3.12 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.13 Sampling and harvesting

Maturity of crop was determined when 95 % of the pods become brown in color. Five sample plants were collected from each plot before harvesting for taking yield attributes data. The plants of central 1 m^2 area were harvested by placing quadrates at random for recording yield data. Harvesting was done on 02 April, 2020. The harvested crops from each plot were tied up into bundles separately, tagged and brought to the clean threshing floor. The same procedure was followed for sample plant.

3.13.1 Threshing

The crop bundles were sun dried for seven days by spreading them on the threshing floor. Seeds were separated from the stover by hand machine and rubbing.

3.13.2 Drying

Seeds and stover were cleaned and dried in the sun for four consecutive days. After proper drying of seeds to a moisture content of 12 % were kept in polythene bags. Moisture contents were determined by moisture meter.

3.13.3 Cleaning and weighing

Dried seeds and stover was weighed plot wise. After that the weights were converted into t ha^{-1}.

3.14 Data collection

Five plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those five selected plants.

The following data were collected –

I. Plant height (cm)
II. Number of leaves $plant^{-1}$
III. Number of branches $plant^{-1}$
IV. Number of pods $plant^{-1}$
V. Pod length (cm)

VI. Number of seeds pod^{-1}
VII. Weight of 100 seeds (gm)
VIII. Seed yield (t ha^{-1})
IX. Stover yield (t ha^{-1})
X. Biological yield (t ha^{-1})
XI. Harvest index (%)

3.15 Procedure of data collection:

3.15.1. Plant height (cm)

The height of soybean plants was recorded at 30, 45, 60, 75 DAS and at harvest. The heights of five preselected sample plants were measured from the ground level to the tip of the shoot. Then the data was averaged and expressed in cm.

3.15.2. Number of leaves plant^{-1}

Number of leaves plant^{-1} was taken at 30, 45, 60 and 75 DAS. Leaves were present on five preselected sample plants were counted and averaged them to have number of leaves plant^{-1}.

3.15.3. Number of branches plant^{-1}

Total branch number was taken at 45, 60, 75, 90 DAS and at harvest. All the branches present on five preselected sample plants were counted and averaged them to have number of branches plant^{-1}.

3.15.4. Pod length (cm)

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

3.15.5. 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 5 plants selected at random from the inner rows of each plot.

3.15.6. Number of seeds pod^{-1}

The number of seeds pod^{-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.

3.15.7. Weight of 100 seeds (gm)

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 (gm).

3.15.8. Seed yield (t ha^{-1})

The seed collected from 4 (2m × 2m) square meter of each plot was cleaned. The weight of seeds was taken and converted the yield in t ha^{-1}.

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

The stover collected from (2m × 2m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.15.10. Biological yield (t ha^{-1})

The summation of seed yield and above ground straw yield was the biological yield. The biological yield was calculated with the following formula-

Biological yield= Seed yield + Stover yield

3.15.11. Harvest index

The harvest index (%) was calculated with the following formula-

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

Here, Biological yield = Seed yield + straw yield

3.16. Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different levels of phosphorus and molybdenum on soybean. The mean values of all the characters were calculated and analysis of variance was performed by Statistix 10 data. The significance of the difference among the treatment means was estimated by 5% level of significant.

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of phosphorus and molybdenum on growth and yield of soybean. The findings of the experiment have been presented and discussed with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Growth parameters of soybean

4.1.1 Plant height (cm)

Effect of phosphorus level

Plant height of soybean showed statistically significant variation due to different levels of phosphorus at 30, 45, 60, 75 DAS (days after sowing) and at harvest. At 30, 45, 60, 75 DAS and at harvest, the tallest plant (13.80, 23.93, 40.83, 53.47 and 58.83 cm respectively) was recorded from P_1 (30 kg P_2O_5 ha^{-1}) which was statistically different from (12.23, 21.50, 37.17, 49.40 and 52.93 cm) P_2 (60 kg P_2O_5 ha^{-1}) except at 45 DAS (21.50 cm). The shortest plant (10.13, 15.07, 26.43, 44.03 and 49.70 cm, respectively) was found from P_0 (control) treatment (Figure 2). Soybean requires a large amount of phosphorus during growth and development. Plant height increased with increasing levels of phosphorus up to maximum level of P application. The increased plant height may be due to favorable effects of phosphorus on the vegetative growth of soybean plant. Bothe *et al.* (2000) recorded the highest value of plant height (71.20 cm) at 75 kg P_2O_5 ha^{-1} and also recorded that all yield parameters increased with increasing levels of P fertilizer.

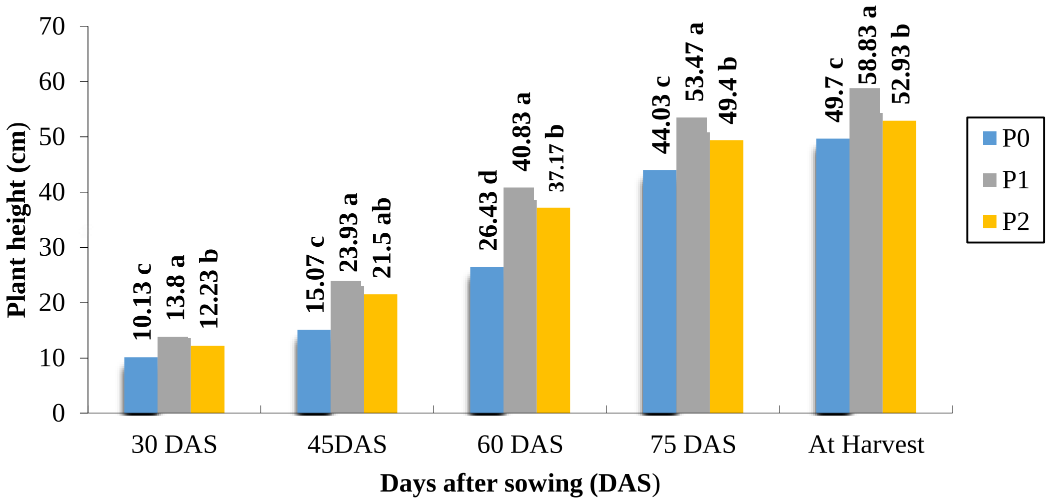

Figure 2. Effect of different levels of phosphorus on plant height (cm) of soybean

Effect of molybdenum level

Different levels of molybdenum significantly influenced the plant height of soybean at 30, 45, 60, 75 DAS (days after sowing) and at harvest. At 30, 45, 60, 75 and at harvest, the tallest plant (13.27, 23.03, 39.67, 49.83 and 54.60 cm, respectively) was found from Mo_2 (1.5 kg Mo ha^{-1}) which was statistically different from (11.77, 19.47, 34.20, 44.63 and 52.13 cm, respectively) with Mo_1 (1.0 Mo ha^{-1}), while the shortest plant (18.24, 29.21, 48.61, 60.28 and 63.29 cm, respectively) was observed from Mo_0 (0 kg Mo ha^{-1}) treatment (Figure 3). Rizvi (2014) recorded the maximum plant height (61.85 cm) from 1.5 kg Mo ha^{-1}.

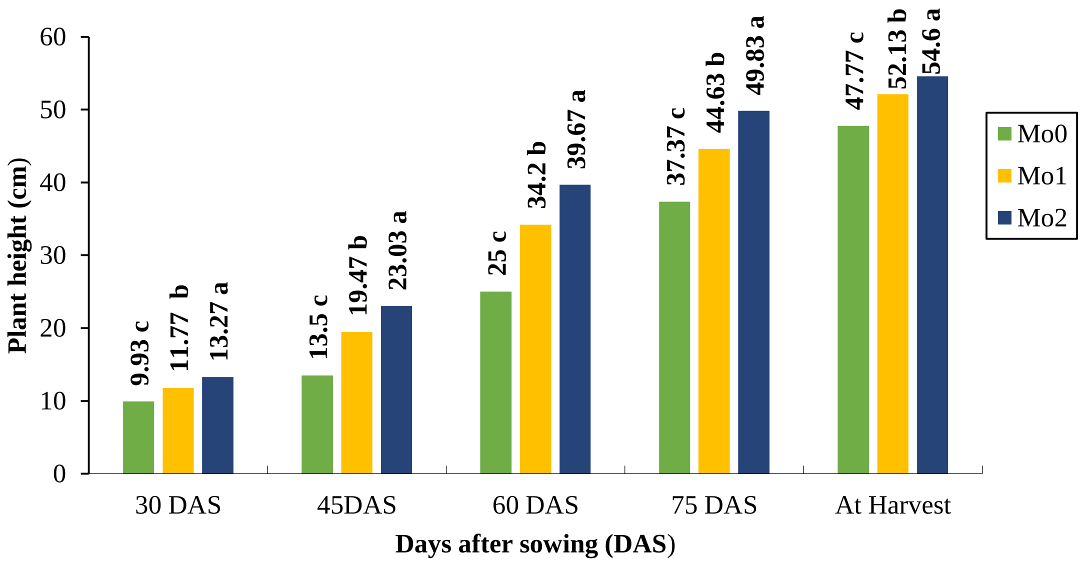

Figure 3. Effect of different levels of molybdenum on plant height (cm) of soybean

Combined effect of phosphorus and molybdenum

Interaction effect of different levels of phosphorus and molybdenum showed statistically significant variation on plant height of soybean at 30, 45, 60, 75 DAS and at harvest. At 30, 45, 60, 75 DAS and at harvest, the tallest plant (13.17, 25.37, 42.23, 54.51 and 64.63 cm respectively) were recorded from P_1Mo_2 (30 kg P_2O_5 ha^{-1} + 1.5 kg Mo ha^{-1}) treatment which were in some cases statistically identical and some cases different from (12.87, 22.23, 38.33, 53.87 and 62.13 cm) P_2Mo_2 (60 kg P_2O_5 ha^{-1} + 1.5 kg Mo ha^{-1}). Whereas, the shortest plant (9.93, 14.9, 27.30, 40.80 and 48.37 cm, respectively) was found from P_0Mo_0 (control) treatment combination (Table 1). Umar *et al*. (2011) reported that the interaction effect of macronutrient + micronutrient showed the highest plant height (54.20 cm).

Table 1: Combined effect of phosphorus and molybdenum on plant height (cm) of soybean at different DAS

Treatment	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
P_0Mo_0	9.93 f	14.90 g	27.30 f	40.80 c	48.37 f
P_0Mo_1	11.27 de	18.07 ef	30.30 def	48.73 abc	52.07 ef
P_0Mo_2	12.00 cd	18.97 de	31.73 de	47.73 abc	54.10 de
P_1Mo_0	10.50 ef	17.10 f	29.80 ef	50.93 ab	49.60 f
P_1Mo_1	12.13 bc	20.13 cd	33.93 cd	53.23 ab	56.70 cd
P_1Mo_2	13.17 a	25.37 a	42.23 a	54.51 a	64.63 a
P_2Mo_0	10.73 ef	17.67 ef	30.23 def	44.73 bc	50.53 ef
P_2Mo_1	12.47 abc	21.00 bc	35.63 bc	53.23 ab	59.27 bc
P_2Mo_2	12.87 ab	22.23 b	38.33 b	53.87 ab	62.13 ab
Level of significance	*	*	*	*	*
CV %	7.43	6.15	9.86	7.45	8.47

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

*Significant at 5% probability level

4.1.2 Number of leaves plant^{-1}

Effect of phosphorus level

Significant variation was observed in the number of leaves plant^{-1} of soybean when different doses of phosphorus were applied (Figure 4). The highest number of leaves plant^{-1} (12.87, 15.9, 39.2, 59.33 respectively) was recorded in P_1 (30 kg P_2O_5 ha^{-1}) treatment which was statistically similar and in some cases different with (11.60, 13.73, 35.77 and 55.67 respectively) P_2 (60 kg P_2O_5 ha^{-1}) treatment. The lowest number of leaves plant^{-1} (9.77, 12.67, 31.83 and 51.90 respectively) was recorded in the P_0 treatment where no phosphorus was applied. The increased number of leaves plant^{-1} may be due to favorable effects of phosphorus on the vegetative growth and accumulation of growth materials that helped proper growth and development of the soybean plant. Akter *et al.* (2013) recorded the highest number of leaves plant^{-1} (48.12) at 30 kg P_2O_5 ha^{-1} and also recorded that all yield parameters increased with increasing levels of P fertilizer.

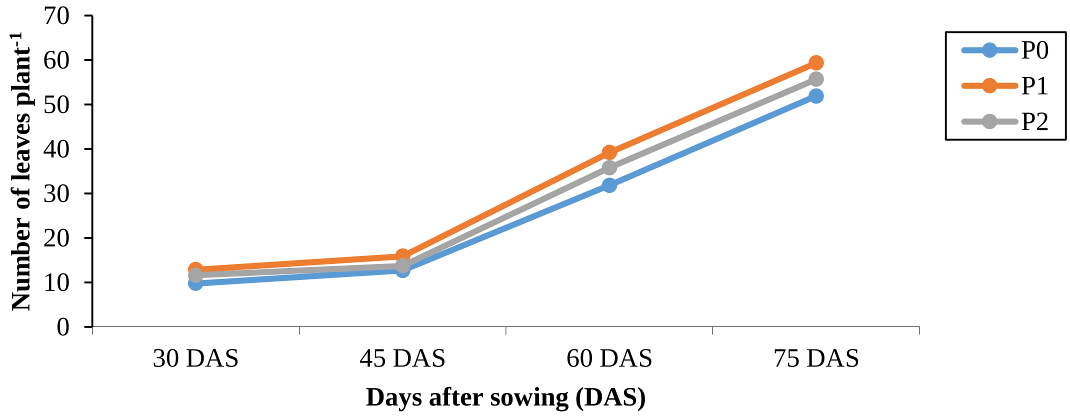

Figure 4. Effect of different levels of phosphorus on number of leaves plant^{-1} of soybean

Effect of molybdenum level

Number of leaves plant^{-1} of soybean varied significantly due to different levels of molybdenum, highest number of leaves was counted (12.27, 15.1, 37.23 and 56.73

respectively) in Mo_2 (1.5 kg Mo ha^{-1}) treatment which was statistically different with Mo_1 (1 kg Mo ha^{-1}) treatment. The lowest number of leaves $plant^{-1}$ (8.80, 11.77, 29.23 and 47.8 respectively) was recorded in Mo_0 (0 kg Mo ha^{-1}) treatment. Ansary (2014) reported that maximum number of leaves (25.91) was found from 1.5 kg Mo ha^{-1} that was significantly increased by highest level of molybdenum used in field.

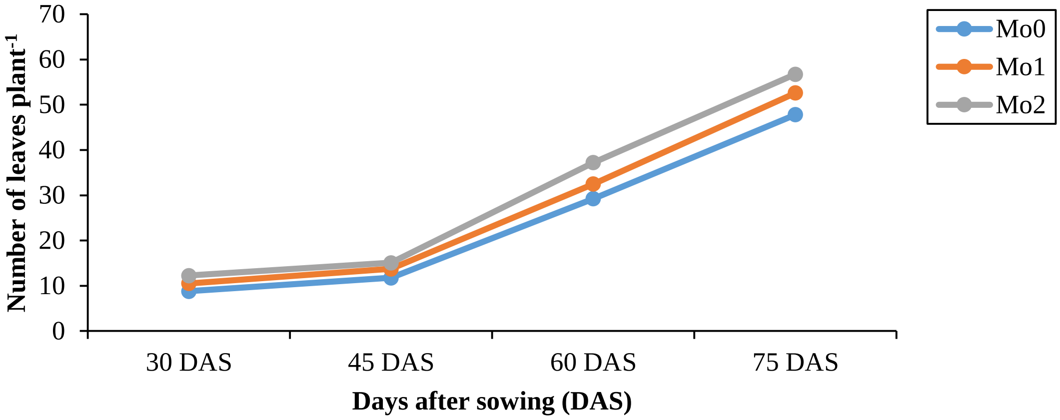

Figure 5. Effect of different levels of molybdenum on number of leaves $plant^{-1}$ of soybean

Combined effect of phosphorus and molybdenum

Interaction effect of different levels of phosphorus and molybdenum fertilizer on number of leaves in soybean showed (Table 2) significant variation at different days. The highest number of leaves $plant^{-1}$ (11.50, 15.7, 38.63 and 59.37 respectively) was recorded from P_1Mo_2 (30 kg P_2O_5 ha^{-1} +1.5 kg Mo ha^{-1}) treatment. Lowest number of leaves $plant^{-1}$ (9.53, 12.8, 32.2 and 53.3 respectively) was enumerated from P_0Mo_0 (control) treatment.

Table 2: Combined effect of phosphorus and molybdenum on number of leaves plant^{-1} at different DAS

Treatment	Number of leaves plant^{-1}			
	30 DAS	45 DAS	60 DAS	75 DAS
P_0Mo_0	9.53 g	12.80 g	32.20 g	53.30 g
P_0Mo_1	10.33 df	13.93 f	35.97 de	56.50 de
P_0Mo_2	10.70 cd	14.30 df	36.50 cde	57.13 cd
P_1Mo_0	9.77 fg	12.87 g	34.67 f	54.76 f
P_1Mo_1	10.90 bc	14.73 cd	37.00 bcd	57.57 bcd
P_1Mo_2	11.50 a	15.70 a	38.63 a	59.37a
P_2Mo_0	10.13 ef	13.50 f	35.40 ef	55.70 ef
P_2Mo_1	11.13 ab	15.03 bc	37.60 abc	58.23 abc
P_2Mo_2	11.37 a	15.33 ab	38.07 ab	58.87 ab
Level of significance	*	*	*	*
CV %	11.38	9.28	8.12	8.82

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

*Significant at 5% probability level

4.1.3 Number of branches plant^{-1}

Effect of phosphorus level

Phosphorus had a significant influence on the number of primary branches plant^{-1} of soybean when different doses of phosphorus were applied at different DAS (Figure 6). The highest number of primary branches plant^{-1} (3.85) was recorded in P_1 (30 kg P_2O_5 ha^{-1}) treatment all over the growth period whereas, statistically different with (3.49) P_2 (60 kg P_2O_5 ha^{-1}) treatment. The lowest number of primary branches plant^{-1} (2.52) was recorded in the P_0 (control) treatment where no phosphorus was applied. The increased number of primary branches plant^{-1} may be due to favorable effects of phosphorus on the vegetative growth and accumulation of growth materials that helped proper growth and development of the soybean plant. Phosphorus is not only essential for plant growth; its availability has been noted to affect the functioning of the biological nitrogen fixation system. Qasim Shahid *et al*. (2009) found highest number of branches (4.94) from 100 kg P_2O_5 ha^{-1}.

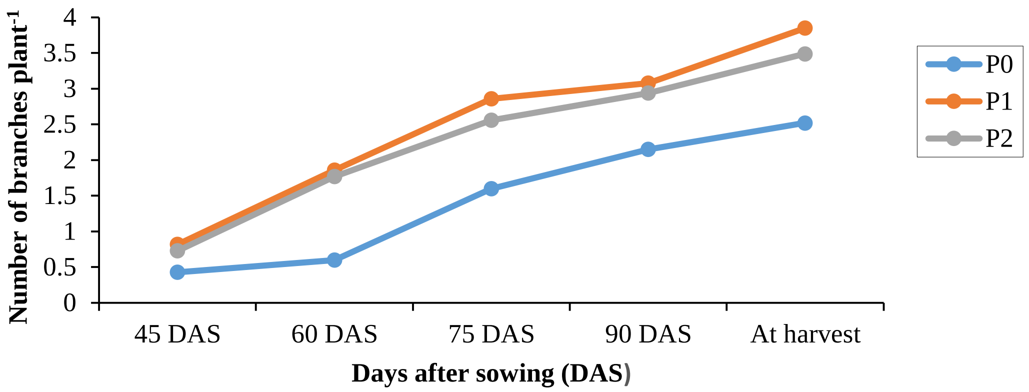

Figure 6. Effect of different levels of phosphorous on number of branches plant^{-1} of soybean

Effect of molybdenum level

Different doses of molybdenum fertilizer showed (Figure 7) significant variations in respect of number of primary branches plant^{-1} at different DAS. Among the different doses of molybdenum Mo_2 (1.5 kg Mo ha^{-1}) showed the highest number of primary branches plant^{-1} (3.62) all over the growth period which was statistically different (2.89) with the Mo_1 (1 kg Mo ha^{-1}) treatment. On the contrary, the lowest number of primary branches plant^{-1} (2.33) was recorded in the Mo_0 treatment where no molybdenum fertilizer was applied. The increased number of primary branches plant^{-1} may be due to positive effects of molybdenum on the vegetative growth and accumulation of growth promoting substances that helped proper growth and development of the soybean plant. Rizvi (2014) examined that maximum branches plant^{-1} (3.42) was obtained from 1.5 kg Mo ha^{-1}.

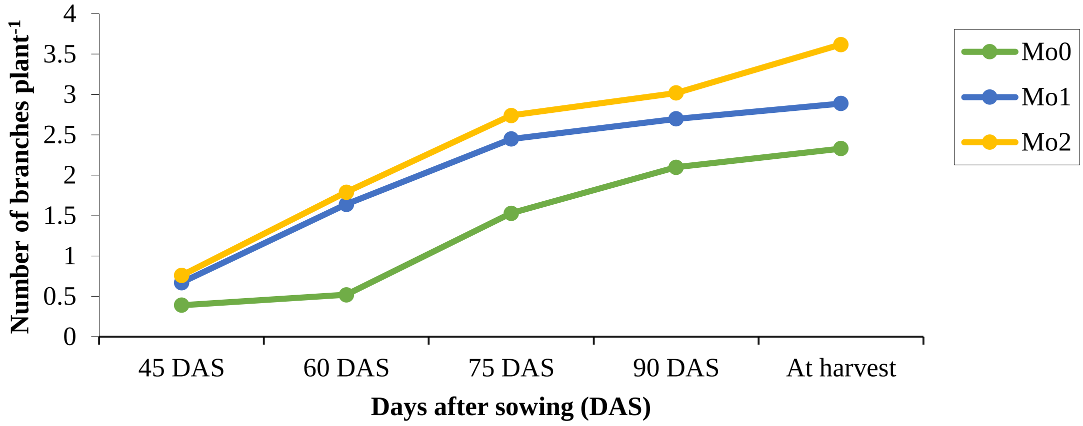

Figure 7. Effect of different levels of molybdenum on number of branches plant^{-1} of soybean

Combined effect of phosphorus and molybdenum

Combined effect of different levels of P and Mo application on number of branches plant^{-1} was also significant at different DAS (Table 3). At 45 DAS, maximum number of branches (0.88) was recorded from P_1Mo_2 which was statistically similar with P_2Mo_2 (0.82) and minimum branches plant^{-1} (0.31) was observed from P_0Mo_0. At 60 DAS, maximum number of branches (1.95) was obtained from P_1Mo_2 which was statistically similar with P_2Mo_2 (1.77) and the minimum (0.55) was recorded from P_0Mo_0 which was statistically similar with P_1Mo_0 (0.99). At 75 DAS, maximum number of branches plant^{-1} (3.00) was recorded from P_1Mo_2 which was statistically identical to P_2Mo_2 (2.85) treatment and the minimum (1.63) was obtained from P_0Mo_0 which was statistically different from (2.07) P_1Mo_0 treatment. At 90 DAS, maximum number of branches (3.60) was recorded from P_1Mo_2, which was statistically identical to P_2Mo_2 (3.46) and the minimum (2.13) was obtained from P_0Mo_0 which was statistically identical P_1Mo_0 (2.51). At harvest, the maximum number of branches plant^{-1} (4.73) was recorded from P_1Mo_2, which was statistically similar with P_2Mo_2 (4.46) and the minimum (2.60) was observed from P_0Mo_0 treatment, which were statistically different from all other treatments.

Table 3: Combined effect of phosphorus and molybdenum on number of branches plant^{-1} at different DAS

Treatment	Number of Branches plant^{-1}				
	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
P_0Mo_0	0.31 f	0.55 g	1.63 f	2.13 e	2.60 f
P_0Mo_1	0.50 de	1.39 de	2.33 de	3.11 bc	3.27 cd
P_0Mo_2	0.56 cd	1.46 cde	2.37 cd	3.18 abc	3.53 c
P_1Mo_0	0.41 ef	0.99 f	2.07 e	2.51 de	2.89 e
P_1Mo_1	0.67 bc	1.55 bcd	2.45 cd	3.30 ab	3.87 b
P_1Mo_2	0.88 a	1.95 a	3.00 a	3.60 a	4.73 a
P_2Mo_0	0.45 ef	1.22 ef	2.19 de	2.75 cd	3.00 de
P_2Mo_1	0.75 ab	1.69 abc	2.66 bc	3.37 ab	4.10 b
P_2Mo_2	0.82 a	1.77 ab	2.85 ab	3.46 ab	4.46 a
Level of significance	*	*	*	*	*
CV %	7.38	7.14	9.21	5.18	8.67

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

*Significant at 5% probability level

4.2 Yield contributing characters of soybean

4.2.1 Number of pods plant^{-1}

Effect of phosphorus level on number of pods plant^{-1}

The number of filled pods plant^{-1} was the highest in the P_1 (30 kg P_2O_5 ha^{-1}) treatment which was significantly higher than those of other treatments (Table 4). The maximum number of pods plant^{-1} of soybean (42.40) was recorded from P_1 (30 kg P_2O_5 ha^{-1}) and whereas, the lowest (25.00) was observed from P_0 (control) treatment. The increased number of pods plant^{-1} may be due to favorable effects of phosphorus on the vegetative growth and accumulation of materials that helped proper growth and development of the soybean pod. Bhattacharjee *et al.* (2013) showed highest (43.5) pod in soybean plant by application of 60 kg P_2O_5 ha^{-1}.

Table 4: Effect of different levels of phosphorus on yield contributing characters of soybean

Treatment	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)	100 seed weight (gm)
P_0	25.00 c	2.40 b	3.20 c	9.33 b
P_1	42.40 a	3.83 a	4.17 a	14.53 a
P_2	39.10 b	3.60 a	3.77 b	13.30 a
Level of significance	*	*	*	*
CV	8.94	7.69	10.84	7.56

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

*Significant at 5% probability level

Effect of molybdenum level on number of pods $plant^{-1}$

Number of pods $plant^{-1}$ of soybean varied significantly due to different levels of molybdenum. The maximum number of pods $plant^{-1}$ (41.97) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which was statistically similar (40.17) with Mo_1 (1.0 kg Mo ha^{-1}), while the minimum number (25.43) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 5). Biswas *et al.* (2012) also found the similar effect of molybdenum were the highest (39.67) pod in soybean plant was obtained by using 2 kg Mo ha^{-1}.

Table 5: Effect of different levels of molybdenum on yield contributing characters of soybean

Treatment	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	Pod length (cm)	100 seed weight (gm)
Mo_0	25.43 b	2.10 c	3.20 b	8.70 c
Mo_1	40.17 a	3.40 b	3.63 ab	13.20 b
Mo_2	41.97 a	3.80 a	4.03 a	14.27 a
Level of significance	*	*	*	*
CV	8.16	7.72	8.00	9.05

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

*Significant at 5% probability level

Combined effect of phosphorus and molybdenum on number of pods $plant^{-1}$

Significant variation was found in the number of pods $plant^{-1}$ of soybean when different doses of phosphorus and molybdenum were applied (Table 6). The highest number of pods $plant^{-1}$ (44.40) was recorded in P_1Mo_2 treatment. The lowest number of pods $plant^{-1}$ (23.90) was recorded in the P_0Mo_0 treatment where no fertilizers were applied. This result was supported by the findings of Zakaria *et al*. (2014) who reported that significant increase pods $plant^{-1}$ (46) due to application of P (30 kg P_2O_5 ha^{-1}) + Mo (0.5 g kg^{-1} seeds) treatment.

Table 6: Combined effect of phosphorus and molybdenum on yield contributing characters of soybean

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	100 seed weight (gm)
P_0Mo_0	23.90 g	2.13 g	3.30 g	9.67 f
P_0Mo_1	33.50 e	2.67 de	3.73 e	11.70 cd
P_0Mo_2	34.87 de	2.87 d	3.93 d	12.30 c
P_1Mo_0	26.67 g	2.33 fg	3.43 fg	10.57 e
P_1Mo_1	36.73 cd	3.20 c	4.13 c	13.17 b
P_1Mo_2	44.40 a	3.80 a	4.73 a	15.27 a
P_2Mo_0	30.13 f	2.47 ef	3.57 ef	11.03 de
P_2Mo_1	39.20 bc	3.40 bc	4.30 c	13.87 b
P_2Mo_2	41.33 b	3.60 ab	4.50 b	14.63 a
Level of significance	*	*	*	*
CV %	9.80	8.85	8.48	7.25

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

*Significant at 5% probability level

4.2.2 Number of seeds pod $^{-1}$

Effect of phosphorus level

Different levels of phosphorus showed statistically significant variation on number of seeds pod^{-1} of soybean (Table 4). The maximum number of seeds pod^{-1} (3.83) was found from P_1 (30 kg P_2O_5 ha^{-1}), which was statistically similar (3.60) with P_2 (60 kg P_2O_5 ha^{-1}), while the minimum number (2.40) was recorded from P_0 (control) treatment (Table 4). Qasim shahid *et al*. (2009) was found maximum seeds pod^{-1} (2.74) from 100 kg P_2O_5 application in field.

Effect of molybdenum level

Number of seeds pod^{-1} of soybean varied significantly due to different levels of molybdenum. The maximum number of seeds pod^{-1} (3.80) was recorded from Mo_2 (1.5 kg Mo ha^{-1}), which was significantly different (3.40) from Mo_1 (1 kg Mo ha^{-1}) and minimum seeds pod^{-1} (2.10) was found from Mo_0 treatment where no molybdenum was used (Table 5). Khander *et al.* (2013) found that maximum number of seeds pod^{-1} (2.44) was recorded from (RDF + ammonium molybdate kg^{-1} seed + *Rhizobium*) treatment. They also suggested that organic and inorganic fertilizer along with micronutrients create the favorable soil condition resulting improved availability of nutrients and final reflection on yield attributes of soybean production.

Combined effect of phosphorus and molybdenum

Different levels of phosphorus and molybdenum showed statistically significant variation on number of seeds pod^{-1} of soybean. The maximum number of seeds pod^{-1} (3.80) was found from P_1Mo_2 (30 kg P_2O_5 ha^{-1} + 1.5 kg Mo ha^{-1}) which was statistically identical to (3.60) and statistically different from (3.40) in P_2Mo_2 and P_2Mo_1 treatment. The minimum number (2.13) was recorded from P_0Mo_0 (control) treatment (Table 6).

4.2.3 Pod length (cm)

Effect of phosphorus level

Statistically significant variation was recorded due to different levels of phosphorus in terms of pod length of soybean. The longest pod (4.17 cm) was observed from P_1 (30 kg P_2O_5 ha^{-1}), which was statistically different (3.77 cm) from P_2 (60 kg P_2O_5 ha^{-1}), while the shortest pod (3.20 cm) was found from P_0 (0 kg P_2O_5 ha^{-1}) treatment (Table 4). Khanam *et al*. (2014) showed the longest pod length (3.05 cm) from P_2 (175 kg TSP ha^{-1}) treatment by application of soybean.

Effect of molybdenum level

Different levels of molybdenum significantly influence the pod length of soybean (Table 5). The longest pod (4.03 cm) was recorded from Mo_2 (1.5 kg Mo ha^{-1}) which was statistically identical (3.63 cm) with Mo_1 (1 kg Mo ha^{-1}) and the shortest pod (3.20 cm) from Mo_0 (0 kg Mo ha^{-1}) treatment (Table 5). Ansary (2014) found that pod length of soybean varied significantly by using molybdenum fertilizer. In his experiment he showed the longest pod (5.43 cm) from 1.5 kg Mo ha^{-1}.

Combined effect of phosphorus and molybdenum

Pod length of soybean varied significantly due to the interaction effect of different levels of phosphorus and molybdenum. Numerically the longest pod (4.73 cm) was recorded from P_1Mo_2, which was second highest but statistically different (4.50 cm) in P_2Mo_2 treatment combination. The shortest pod (3.30 cm) was found from P_0Mo_0 (control) treatment (Table 6). Zakaria *et al*. (2014) reported that application of different levels of phosphorus and molybdenum showed significant effect on pod length of soybean.

4.2.4 Weight of 100 seed (gm)

Effect of phosphorus level

Weight of 100 seeds of soybean statistically varied due to different levels of phosphorus application (Table 4). The highest weight of 100 seeds (14.53) was recorded from P_1 (30 kg P_2O_5 ha^{-1}) treatment, which was statistically similar (13.30) with P_2 (60 kg P_2O_5 ha^{-1}) treatment. Lowest weight of 100 seeds (9.33 g) was found from P_0 (where no phosphorus used) treatment. Noori *et al.* (2015) reported that the highest 100 seed weight (15. 87g) was observed in 50 kg P ha^{-1} whereas, lowest from control (0 kg P ha^{-1}) treatment.

Effect of molybdenum level

Significant differences of 100 seed weight were also noted with different Mo treatments (Table 5). As for different treatments concerned the application of 1.5 kg Mo ha^{-1} resulted (14.27 g) in maximum 100 seed weight which was statistically different (13.20 g) from 1 kg Mo ha^{-1} and minimum (8.70 g) seed weight was recorded in plots where no molybdenum fertilizer was applied. Jabbar *et al.* (2014) observed the highest weight of 100 seed (13.2 g) by application of 1 kg Mo ha^{-1} significantly increase of 100 grain weight.

Combined effect of phosphorus and molybdenum

Statistically significant variation was recorded in terms of weight of 100 seeds of soybean due to different levels of phosphorus and molybdenum. The highest weight of 100 seeds (15.27 g) was found from P_1Mo_2 which was statistically similar (14.63 g) with P_2Mo_2 treatment and the lowest weight was found (9.67 g) from P_0Mo_0 (control) treatment (Table 6). Zakaria *et al.* (2014) showed that weight of 100-seed (14.22 g) from (30 kg P_2O_5 fed^{-1} + Mo 0.5 kg + Fe 20 mg L^{-1}) treatment in soybean.

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

Effect of phosphorus level

The highest seed yield (2.44 t ha^{-1}) was produced when the crop was fertilized with 30 kg P_2O_5 ha^{-1} (P_1) and the lowest (1.20 t ha^{-1}) was recorded in the treatment of 0 kg P_2O_5 ha^{-1} (P_1) (Figure 8). 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. Begum *et al.* (2015) observed that seed yield varied significantly due to phosphorus application. The results revealed that the highest seed yield (2.09 t ha^{-1}) obtained from 54 kg P ha^{-1} whereas, the lowest (1.30 t ha^{-1}) obtained from control treatment.

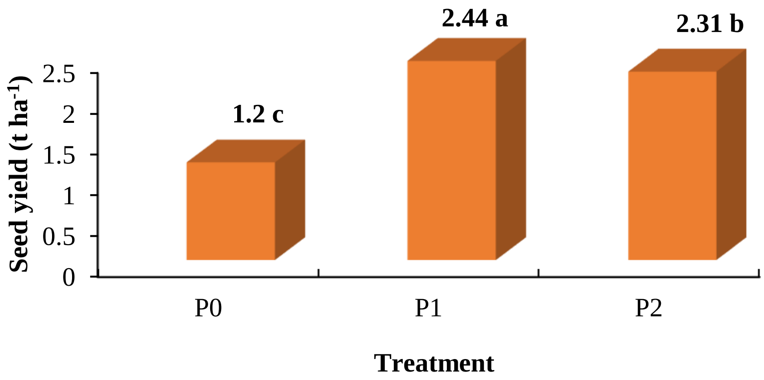

Figure 8. Effect of different levels of phosphorus on seed yield (t ha^{-1}) of soybean

Effect of molybdenum level

Seed yield of soybean varied significantly with different level of molybdenum application (Figure 9). The maximum yield of soybean (2.38 t ha^{-1}) was recorded from Mo_2, which was statistically similar with Mo_1 (2.25 t ha^{-1}) and the minimum (1.23 t ha^{-1}) yield was observed in Mo_0 treatment. Biswas *et al*. (2012) found highest seed yield 1773 kg ha^{-1} from the application of 2 kg Mo ha^{-1}. Chhonker and Chandel (1991) also reported that Mo increased the nitrogenase activity and nitrogen fixation of soybean.

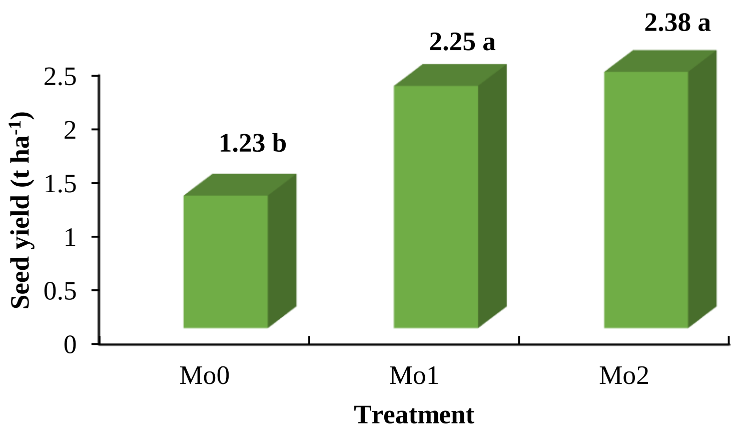

Figure 9. Effect of different levels of molybdenum on seed yield (t ha^{-1}) of soybean

Combined effect of phosphorus and molybdenum

The interaction effect of phosphorus and molybdenum on soybean yield was significant. The highest seed yield (2.47 t ha^{-1}) was produced when the crop was fertilized with P_1Mo_2 treatment which was followed by P_2Mo_2 (2.38 t ha^{-1}) and P_2Mo_1 (2.31 t ha^{-1}) treatment. The lowest (1.18 t ha^{-1}) seed yield was recorded in the treatment of P_0Mo_0 (control). Khan (2004) found similar result in their experiment where they reported that combination of P and Mo fertilizers the highest seed yield (2833 kg ha^{-1}) was obtained in T_5 (*Bradyrhizobium* + $P_{25}Mo_{1.5}$). Application of phosphorus and molybdenum alone or in combination exerted positive effects on growth and yield and nutrient content and uptake by *Bradyrhizobium* inoculated soybean.

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

Effect of phosphorus level

Stover yield of soybean varied significantly with different levels of P application (Figure 10). Numerically the maximum stover yield of soybean (3.07 t ha^{-1}) was recorded from P_1 (30 kg P_2O_5 ha^{-1}) which was statistically similar with P_2 (2.86 t ha^{-1}) while, the minimum (1.74 t ha^{-1}) was found from P_0 (control) treatment. These results are similar to Akter *et al.* (2013) who reported that the highest stover yield (2.93 t ha^{-1}) was observed from 30 kg P_2O_5 ha^{-1} treatment.

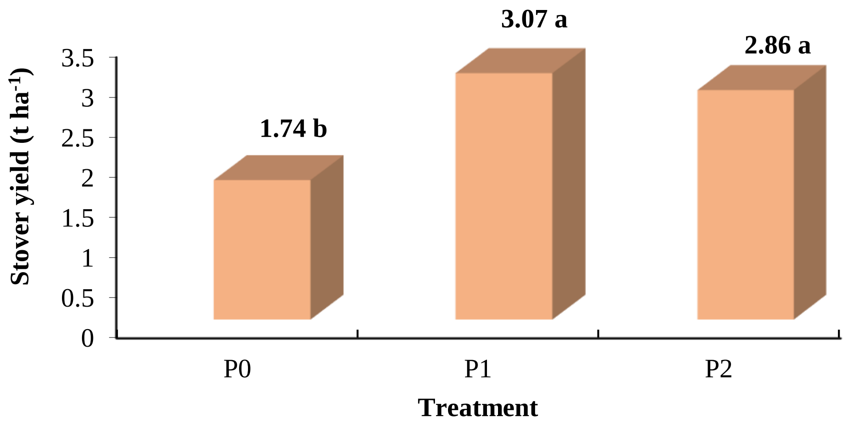

Figure 10. Effect of different levels of phosphorus on stover yield (t ha^{-1}) of soybean

Effect of molybdenum level

Stover yield of soybean varied significantly with different levels of molybdenum application (Figure 11). The maximum (3.06 t ha^{-1}) stover yield was recorded from Mo_2 whereas, the minimum (1.78 t ha^{-1}) was obtained from Mo_0, which was statistically different from Mo_1 (2.88 t ha^{-1}) treatment. Biswas *et al.* (2012) obtained maximum stover yield (2767 kg ha^{-1}) from 2 kg Mo ha^{-1}. Molybdenum application can play a vital role in increasing soybean yield through its effect on the plant.

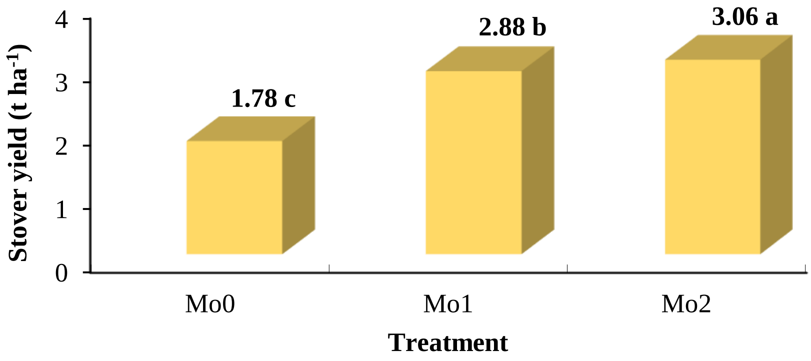

Figure 11. Effect of different levels of molybdenum on stover yield (t ha^{-1}) of soybean

Combined effect of phosphorus and molybdenum

Different levels of phosphorus and molybdenum significantly influenced the stover yield (t ha^{-1}) of soybean. The highest stover yield (3.07 t ha^{-1}) was found from P_1Mo_2 (30 kg ha^{-1} P_2O_5 + 1.5 kg ha^{-1} Mo), which was statistically identical (2.95 t ha^{-1}) with P_2Mo_2 (60 kg ha^{-1} P_2O_5 + 1.5 kg ha^{-1} Mo), whereas the lowest stover yield (1.77 t ha^{-1}) from P_0Mo_0 (control) treatment (Table 7). Khan (2004) found the similar result in their experiment combination of P and Mo fertilizers where the highest stover yield (3833 kg ha^{-1}) was obtained in T_5 (*Bradyrhizobium* + $P_{25}Mo_{1.5}$).

4.2.7 Biological yield (t ha^{-1})

Effect of phosphorus level

Biological yield of soybean varied significantly with different level of P application (Figure 12).The maximum biological yield of soybean (5.52 t ha^{-1}) was recorded from P_1 which was statistically different from P_2 (5.18 t ha^{-1}) and the minimum (2.94 t ha^{-1}) was recorded in P_0 treatment where no phosphorus was applied. Khanam *et al*. (2014) observed biological yield varied significantly due to phosphorus application. The results revealed that the highest biological yield (6.22 t ha^{-1}) obtained from 175 kg TSP ha^{-1} whereas, the lowest (5.00 t ha^{-1}) obtained from control treatment.

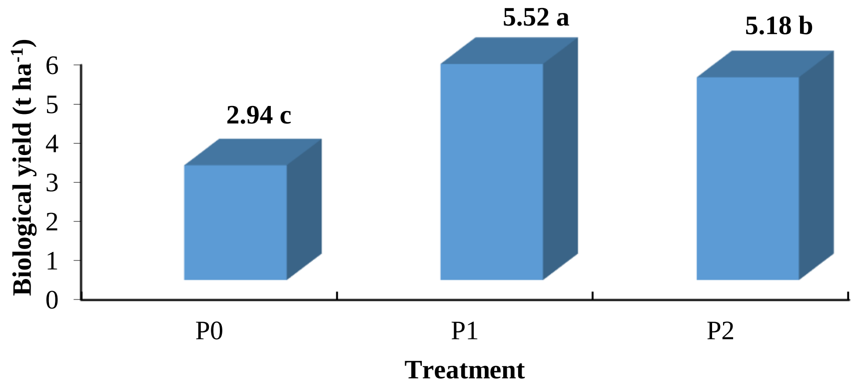

Figure 12. Effect of different levels of phosphorus on biological yield (t ha^{-1}) of soybean

Effect of molybdenum level

Different level of molybdenum application (Figure 13) showed the different result in biological yield. The maximum biological yield (5.44 t ha^{-1}) was recorded in Mo_2 where the level of molybdenum was 1.5 kg ha^{-1}. The lowest (3.03 t ha^{-1}) was found from Mo_0 treatment, which was statistically different from Mo_1 (5.12 t ha^{-1}) treatment. Generally biological yield increased with increasing rate of fertilizer application.

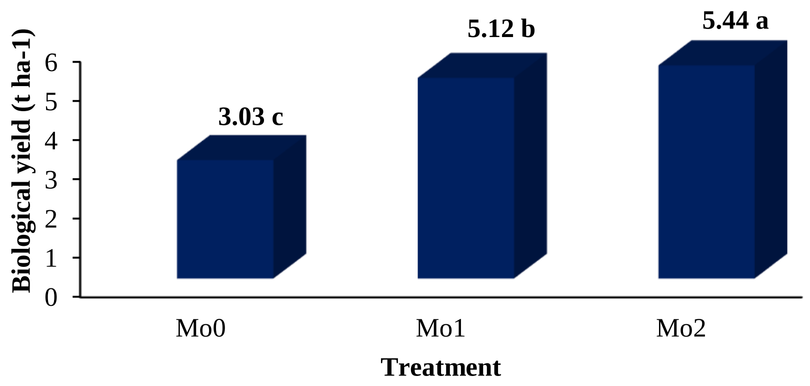

Figure 13. Effect of different levels of molybdenum on biological yield (t ha^{-1}) of soybean

Combined effect of phosphorus and molybdenum

Combined effect of P and Mo application had significant effect on biological yield of soybean (Table 7). The highest biological yield (5.55 t ha^{-1}) was recorded from P_1Mo_2 which was statistically identical to P_2Mo_2 (5.33 t ha^{-1}) and different from P_1Mo_2 (5.21 t ha^{-1}) while, the lowest (2.97 t ha^{-1}) was found from P_0Mo_0 treatment. Zakaria *et al.*

(2014) showed that significantly effect of biological yield (2.97 ton/fed) was observed in (30 kg P_2O_5 fed^{-1} + Mo 0.5 kg + Fe 20 mg L^{-1}) treatment in soybean plant.

Table 7: Combined effect of phosphorus and molybdenum on yield of soybean

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_0Mo_0	1.18 g	1.77 h	2.97 h	39.83 d
P_0Mo_1	1.72 e	2.32 e	4.04 e	42.69 bc
P_0Mo_2	1.92 d	2.54 d	4.46 d	43.10 abc
P_1Mo_0	1.43 f	2.01 g	3.44 g	41.51 cd
P_1Mo_1	2.21 c	2.80 c	5.01 c	44.07 ab
P_1Mo_2	2.47 a	3.07 a	5.55 a	44.78 a
P_2Mo_0	1.56 f	2.16 f	3.72 f	41.83 c
P_2Mo_1	2.31 bc	2.90 bc	5.21 bc	44.31 ab
P_2Mo_2	2.38 ab	2.95 ab	5.33 ab	44.41 ab
Level of significance	*	*	*	*
CV %	7.81	8.04	7.15	7.56

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

*Significant at 5% probability level

4.2.8 Harvest index (%)

Effect of phosphorus level

Harvest index of soybean varied significantly with different level of P application (Figure 14).The maximum HI of soybean (44.71 %) was recorded from P_1 which was statistically similar to P_2 (44.30 %) and the minimum HI (40.83 %) was found from P_0 treatment. Khanam *et al*. (2014) also found significant effect of phosphorus fertilizer. The highest harvest index (48.54 %) was calculated by using 175 kg TSP ha^{-1} in her experiment.

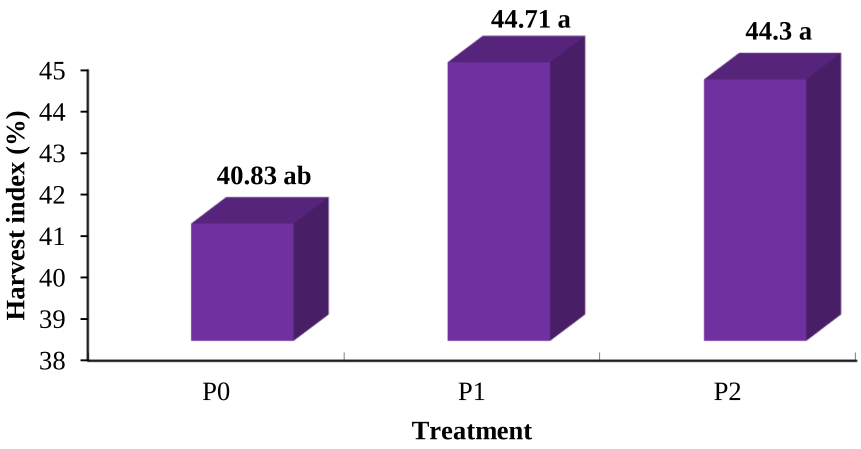

Figure 14. Effect of different levels of phosphorus on harvest index (%) of Soybean

Effect of molybdenum level

Different level of molybdenum application showed different result in harvest index (Figure 15). The maximum HI of soybean (43.84 %) was recorded in Mo_2 (1.5 kg ha^{-1}) which was highly significant and the lowest (41.24 %) was found in control treatment. Biswas *et al*. (2012) observed highest harvest index (39.05%) the application of 2 kg Mo ha^{-1}.

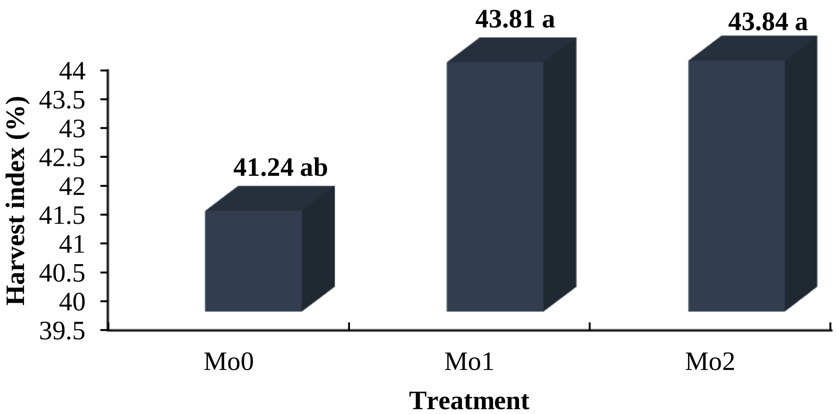

Figure 15. Effect of different levels of molybdenum on harvest index (%) of soybean

Combined effect of phosphorus and molybdenum

Harvest index of soybean influenced significantly with different level of phosphorus and molybdenum application (Table 7).The maximum harvest index values (44.78 %) was recorded in P_1Mo_2 which was statistically similar (44.41 %) with P_2Mo_2, P_2Mo_1, P_1Mo_1 and P_0Mo_2 treatments. The lowest harvest index (39.83 %) was recorded from P_0Mo_0 treatment.

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 December, 2019 to April, 2020 to study the effect of phosphorus and molybdenum on growth and yield of soybean. The experiment was comprised of two factors- Factor A: levels of phosphorus (3 levels): P_0 = 0 kg P ha^{-1}, P_1 =30 kg P ha^{-1}, P_2 = 60 kg P ha^{-1}; Factor B: levels of molybdenum (3 levels): Mo_0 = 0 kg Mo ha^{-1}, Mo_1 = 1 kg Mo ha^{-1}, Mo_2 = 1.5 kg Mo ha^{-1}. The experiment was laid out two factors randomized complete block design (RCBD) with three replications and nine treatments having unit plot size 2m x 2m (4m^2). Area of experimental field was 24 x 8 m which was divided into three blocks. Data on different growth parameter and yield contributing characters were recorded and statistically significant variation was recorded for all the studied characters.

For phosphorous fertilizer, at 30, 45, 60, 75 DAS and at harvest, the tallest plant (13.80, 23.93, 40.83, 53.47 and 58.83 cm, respectively) was recorded from P_1 treatment. Whereas the shortest plant (10.13, 15.07, 26.43, 44.03 and 49.70 cm, respectively) was recorded from P_0 treatment. At 30, 45, 60 and 75 DAS, the maximum number of leaves plant^{-1} (12.87, 15.90, 39.20 and 59.33 respectively) was found from P_1 treatment and minimum number of leaves plant^{-1} (9.77, 12.67, 31.83 and 51.90 respectively) was recorded from P_0 treatment. The more number of branches (0.82, 1.86, 2.86, 3.08 and 3.85) was found at 45, 60, 75, 90 DAS and at harvest, from P_1 treatment, whereas less number of branches (0.43, 0.60, 1.60, 2.15 and 2.52 respectively) was found from P_0 treatment. The maximum number of pods plant^{-1} (42.40) was found from P_1 and minimum number of pods plant^{-1} (25.43) was found from P_0 treatment. The more number of seeds pod^{-1} (3.83) from P_1 treatment, whereas less number of seeds pod^{-1} (2.40) was from P_0 treatment. The longest pod (4.17 cm) length was observed from P_1 treatment and shortest pod length (3.20 cm) from P_0 treatment. The highest weight of 100 seeds (14.53 gm) was observed from P_1 treatment, while the lowest weight of 100 seeds (9.33) was observed from P_0 treatment. The highest seed yield (2.44 t ha^{-1}) was attained from P_1 treatment and lowest seed yield (1.23 t ha^{-1}) was attained from P_0 treatment. The maximum stover yield (3.07 t ha^{-1}) was found from P_1, whereas minimum stover yield (1.78 t ha^{-1}) was from P_0 treatment. The highest biological yield

(5.52 t ha^{-1}) was recorded from P_1 treatment, while lowest biological yield (3.03 t ha^{-1}) was recorded from P_0 treatment. The highest harvest index (44.71 %) found from P_1, whereas lowest harvest index (40.83 %) was found from P_0 treatment.

In case of molybdenum fertilizer, at 30, 45, 60, 75 DAS at harvest, the tallest plant (13.27, 23.03, 39.67, 49.83 and 54.60 cm, respectively) was found from Mo_2, while the shortest plant (9.93, 13.50, 25.00, 37.37 and 47.77 cm, respectively) was found from Mo_0 treatment. At 30, 45, 60 and 75 DAS, the maximum number of leaves $plant^{-1}$ (12.27, 15.10, 37.23 and 56.73 respectively) was counted from Mo_2, while minimum number of leaves $plant^{-1}$ (8.80, 11.77, 29.23 and 47.80 respectively) was counted from Mo_0 treatment. The more number of branches $plant^{-1}$ (0.76, 1.79, 2.74, 3.02 and 3.62 respectively) was counted from Mo_2, whereas less number of branches $plant^{-1}$ (0.39, 0.52, 1.53, 2.10 and 2.33 respectively) was from Mo_0 treatment, at time followed 45, 60, 75, 90 DAS and at harvest. The highest number of pods $plant^{-1}$ (41.97) was counted from Mo_2, while lowest number of pods $plant^{-1}$ (25.00) was from Mo_0 treatment. The more number of seeds pod^{-1} (3.80) was recorded from Mo_2, where less number of seeds pod^{-1} (2.10) was found from Mo_0 treatment. The longest pod length (4.03 cm) was found from Mo_2, whereas shortest pod length (3.20 cm) was from Mo_0 treatment. The highest weight of 100 seeds (14.27 gm) was recorded from Mo_2, while lowest weight of 100 seeds (8.70 g) was from Mo_0 treatment. The maximum seed yield (2.38 t ha^{-1}) was recorded from Mo_2 and minimum seed yield (1.20 t ha^{-1}) was from Mo_0 treatment. The highest stover yield (3.05 t ha^{-1}) was observed from Mo_2, where lowest stover yield (1.74 t ha^{-1}) was from Mo_0 treatment. The maximum biological yield (5.44 t ha^{-1}) was found from Mo_2, whereas minimum biological yield (2.94 t ha^{-1}) was from Mo_0 treatment. Most harvest index (44.29 %) was recorded from Mo_2, while low harvest index (41.24 %) was from Mo_0 treatment.

Due to the interaction effect of different levels of phosphorus and molybdenum at 30, 45, 60, 75 DAS and at harvest, the tallest plant (13.17, 25.37, 42.23, 54.51 and 64.63 cm) was recorded from P_1Mo_2 and shortest plant (9.93, 14.90, 27.30, 40.80 and 48.37 cm) was recorded from P_0Mo_0 treatment. Maximum number of leaves (11.50, 15.70, 38.63 and 59.37 no. respectively) at 30, 45, 60 and 75 DAS was counted in P_1Mo_2 treatment, while minimum number of leaves (9.53, 12.80, 32.20 and 53.30 no. respectively) was counted from P_0Mo_0 treatment. At 45, 60, 75, 90 and at harvest, more number of branches $plant^{-1}$ (0.88, 1.95, 3.00, 3.60 and 4.73 respectively) was observed from P_1Mo_2, whereas less number of branches plant^{-1} (0.31, 0.55, 1.63, 2.13 and 2.60 respectively) was observed from P_0Mo_0 treatment. Statistically significant variation was recorded due to different levels of P and Mo in the highest number of pods plant^{-1} (44.40) was observed from P_1Mo_2 and lowest number of pods (23.90) plant^{-1} was from P_0Mo_0 treatment. The more number of seeds pod^{-1} (3.80) was attained from P_1Mo_2, where less number of seeds pod^{-1} (2.13) was attained from P_0Mo_0 treatment. The longest pod length (4.73 cm) was observed from P_1Mo_2 and shortest pod length (3.30 cm) was from P_0Mo_0 treatment. The highest weight of 100 seeds (15.27 g) was found from P_1Mo_2, while lowest weight of 100 seeds (9.67 gm) was found from P_0Mo_0 that was significantly variation of different levels of P and Mo application. Seed yield of soybean was influenced significantly due to application of P and Mo. The highest seed yield (2.47 t ha^{-1}) was found from P_1Mo_2 (30 kg P ha^{-1} + 1.5 kg P ha^{-1}) which was significantly similar (2.38 t ha^{-1}) to P_2Mo_2 (60 kg P ha^{-1} + 1.5 kg Mo ha^{-1}) and lowest yield (1.18 t ha^{-1}) was observed from P_0Mo_0 (control). The highest stover yield (3.07 t ha^{-1}) was found from P_1Mo_2 (30 kg P ha^{-1} + 1.5 kg Mo ha^{-1}) and lowest stover yield (1.77 t ha^{-1}) from P_0Mo_0 (control) treatment. The highest biological yield (5.55 t ha^{-1}) was recorded from P_1Mo_2 and lowest biological yield (2.97 t ha^{-1}) from P_0Mo_0 (control). Harvest index of soybean had non-significant with different level of phosphorus and molybdenum application. The maximum harvest index values (44.78 %) were recorded in P_1Mo_2 (30 kg P ha^{-1} + 1.5 kg Mo ha^{-1}) treatment.

Considering the above results, it may be summarized that all growth parameters and yield contributing parameters of soybean were significantly correlated with phosphorus and molybdenum application under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Recommendation: Considering the situation of the present experiment and further studies in the following ideas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh.
2. The results are required to substantiate further with different varieties of soybean.
3. It needs to conduct more experiments with phosphorus and molybdenum to assess the morphological characters, yield and seed quality of soybean.

However, to reach a specific conclusion and recommendation, more research work of soybean should be done in different areas of Bangladesh.

CHAPTER VI

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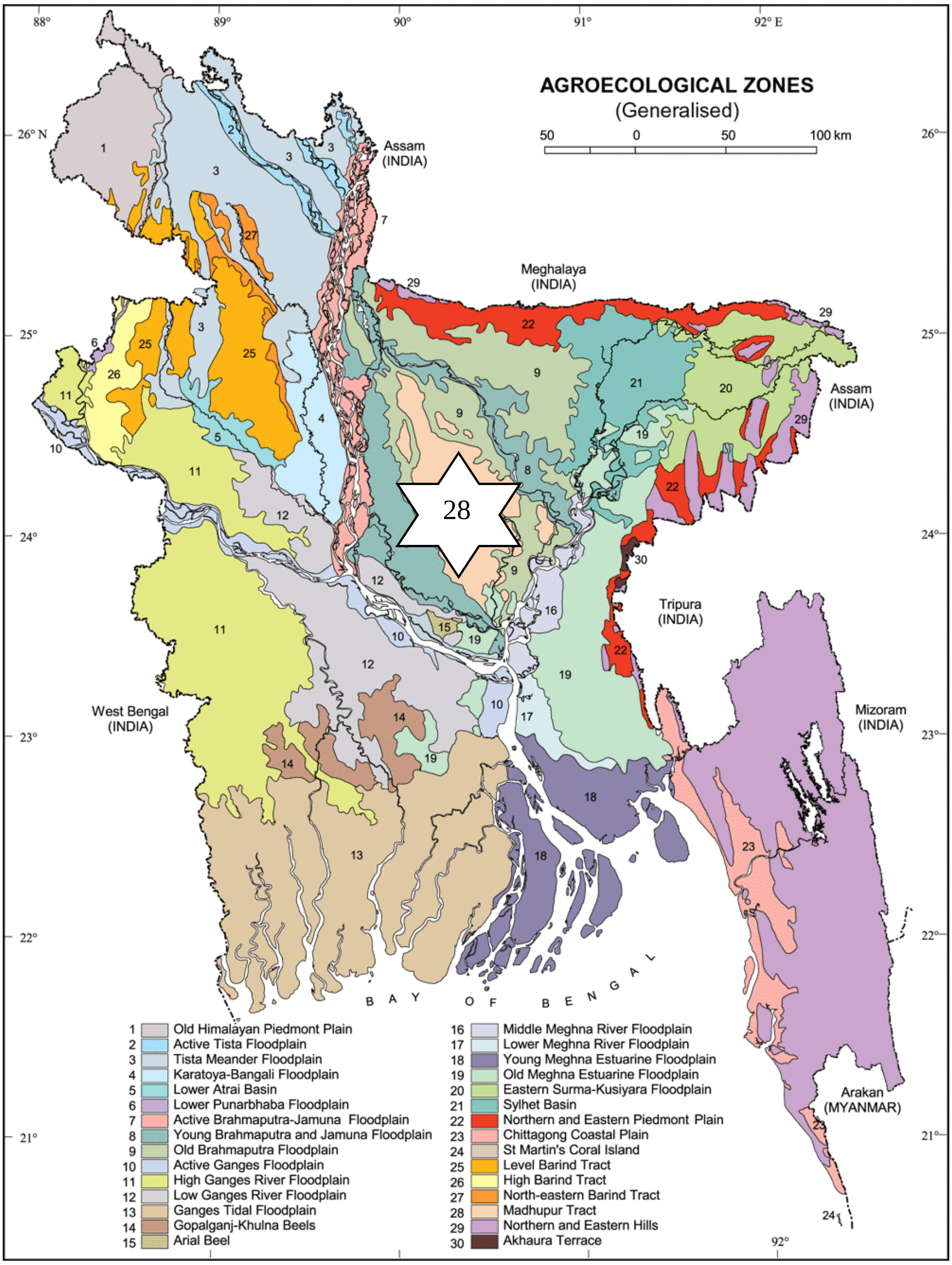
CHAPTER VII

APPENDICES

Appendix I: Map showing the experimental site under study



Experimental area under the study

Appendix II: Characteristics of soil of experimental field

A. Morphological characteristics of 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

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

B: Physico-chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
Sand%	25
Silt%	45
Clay%	30
Textural Classes	Silty -Clay
pH	5.6
Organic carbon (%)	0.43
Organic matter (%)	0.76
Total N (%)	0.03
Available P (ppm)	23.00
Exchangeable K (meq/100g soil)	0.1

Appendix III. Monthly average of relative humidity, air temperature and total rainfall of experimental site during the period from December 2019 to April 2020, SAU

Month	Average RH%	Average temperature (^{0}C)		Total Average Rainfall(mm)
		Min.	Max.	
December, 2019	74	15.5	19.3	5
January, 2020	76	15	18.5	21
February, 2020	59	18	21.6	1
March, 2020	57	18.5	26.4	30
April, 2020	55	19	31.4	25

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207

PLATES

Plate 1: Field view of experimental plot

Plate 2: Pod bearing stage of soybean plant

Plate 3: Pictorial view of laboratory activities during experiment