EFFECT OF CALCIUM (Ca) AND SULPHUR (S) ON THE MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF MUNG BEAN (*Vigna radiata* L.)

MD. HASAN BASRI

DEPARTMENT OF AGRICULTURAL BOTANY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

DECEMBER, 2018

EFFECT OF CALCIUM (Ca) AND SULPHUR (S) ON THE MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF MUNG BEAN (*Vigna radiata L.*)

BY

MD. HASAN BASRI
REGISTRATION NO. 17-08247

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRICULTURAL BOTANY
SEMESTER: JULY-DECEMBER, 2018

Approved by

Dr. Md. Ashabul Hoque	**Dr. Mohammad Mahbub Islam**
Professor	Professor
Supervisor	**Co-supervisor**

Assoc. Prof. Dr. Kamrun Nahar
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar,Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF CALCIUM (Ca) AND SULPHUR (S) ON THE MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF MUNG BEAN (*Vigna radiata* L.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY,** embodies the result of a piece of bonafide research work carried out by **MD. HASAN BASRI,** Registration No. **17-08247** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Dr. Md. Ashabul Hoque
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka.
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to The Almighty Allah Rabbul Al-Amin for His gracious kindness and infinite mercy in all the endeavors the author to let him successfully complete the research work and the thesis leading to Master of Science.

The author is proud to express his deepest gratitude, deep sense of respect and immense indebtedness to his research supervisor ***Dr. Md. Ashabul Hoque****, Professor, Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, for his constant supervision, valuable suggestions, scholastic guidance, continuous inspiration, constructive comments, extending generous help and encouragement during his research work and guidance in preparation of manuscript of the thesis.*

The author sincerely expresses his heartiest respect, deepest sense of gratitude and profound appreciation to his co-supervisor ***Dr. Mohammad Mahbub Islam****, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice during the research period and preparing the thesis.*

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operations and inspirations throughout the course of this study and research work.

The author feels proud to express his sincere appreciation and gratitude to all of his friends specially Md. Hasibul Hasan Rabbi, student of Department of Agronomy, Sher-e-Bangla Agricultural University, for his help and encouragement.

The author is deeply indebted to his father and to his respected mother, brothers, sisters and relatives for their moral support, encouragement and love with cordial understanding.

Last but not least the author appreciates the assistance rendered by the staffs of the department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, who have helped him during the period of study.

December, 2018 **The Author**

EFFECT OF CALCIUM (Ca) AND SULPHUR (S) ON THE MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF MUNG BEAN (*Vigna radiata* L.)

BY

MD. HASAN BASRI

ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January, 2018 to July, 2018 to find out the effect of Calcium (Ca) and Sulphur (S) on the morpho-physiological characters and yield of mung bean. BARI mug-6, high yielding variety was used in this experiment as the test crop. The tallest plant was recorded as 34.05 cm, 47.42 cm and 52.27 cm from T_6 (100 ppm Ca +100 ppm S), T_1 (100 ppm Ca) and T_5 (100 ppm Ca +50 ppm S) at 30 DAS, 45 DAS and 60 DAS respectively. The highest number of leaves per plant (6.67, 8 and 9.07 respectively) were recorded from the treatment of T_5 (100 ppm Ca + 50 ppm S), T_1 (100 ppm Ca) and T_1 (100 ppm Ca). The highest number of branches per plant (0.80, 1.20 and 1.60 respectively) were observed from $T_{5,}$ T_2 and T_2. The highest days to flowering (32.3) was observed from T_0. The highest SPAD values at 30 DAS was 49.50 for T_5, at 45 DAS was 69.88 for T_2 and at 60 DAS 72.74 for T_2. The highest leaf area (132.49 cm^2) was obtained from T_3 (50 ppm S). The highest number of flowers per plant (40.36) was observed from T_7 (200 ppm Ca + 50 ppm S). The highest number of pods per plant (28.33) was observed from T_7 (200 ppm Ca + 50 ppm S). T_7 (200 ppm Ca + 50 ppm S) treated plants took the minimum number of days to first ripening of fruit and to 50 % maturity of fruit and T_5 (100 ppm Ca + 50 ppm S) treated plants to 100 % maturity of fruit 49.33, 67.00 and 70.66 days respectively. The highest no. of fertile seed was observed as 145.40 for T_0. The highest weight of 1000 seeds (51g) was recorded from T_5 (100 ppm Ca + 50 ppm S). The highest seed yield 1615.13 kg/ha was gathered from T_5 (100 ppm Ca + 50 ppm S). Whereas the minimum yield 1041.31 kg/ha given by T_0 (no treatment) which was statistically similar with 1122 kg/ha of T_3 (50 ppm S). The highest harvest index 62.86% was gathered from T_8 (200 ppm Ca + 100 ppm S) which was statistically similar to 61.65% recorded from T_5 (100 ppm Ca + 50 ppm S). Whereas the minimum harvest index 51.04% given by T_1 (100 ppm Ca) . It can be concluded from the above study that application of the treatment T_5 (100 ppm Ca+ 50 ppm S) was found to be the most suitable combination for the higher performances of mung bean.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATION AND ACRONYMS

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

CHAPTER 1

INTRODUCTION

Mung bean [*Vigna radiata* (L.) Wilczek] is also known as green gram, golden gram, oregon pea, chickasano pea, chiroko or simply mung (Duke, 1983). It is synonymous with *Phaseolus aureus* Roxb. The crop is said to have originated from India and must have been derived from var. sublobata which occurs wild throughout India and Burma (Aykroyd and Doughty, 1964). From there it has spread to South and East Asia, East and Central Africa, the West Indies and the United States. Mung bean is grown on more than 6 million ha worldwide (about 8.5% of global pulse area). The cultivation of the crop extends across a wide range of latitudes (40°N or S) in regions where the average diurnal temperatures during the growing season are higher than about 20°C. Concentrated mainly in South, East and Southeast Asia, annual production is around 3 million t of grain (5% of global pulse production). It is grown three seasons a year covering 42,577 ha with an average yield of 0.87 t/ha in Bangladesh (BBS, 2016). Mung bean is a major seed legume among the pulses in Asia. It ranks the second position in case of acreage and production in Bangladesh. The green plants are used as animal feed and the residues as manure. The crop is potentially useful in improving cropping systems as catch crop due to its rapid growth and early maturing characteristics.

Mung bean is an annual, 0.3 to 1.5 m tall, erect or sub erect plant, sometimes slightly twining at the tips. It is deep rooted, much branched with long petioles. The leaves are alternate, trifoliate, and dark or light green, the leaflets ovate and vary from 5 to 12cm wide and 2 to 10cm long. The inflorescence is an axillary raceme with a peduncle 2 to 13 cm long. The flower is yellow and the keel petal is spirally coiled with a horn-like appendage. Pods are 6 to 10cm long, slender, short and hairy. Seeds are globose, weight 15 to 85 mg, mostly green but sometimes yellow, tawny brown, black or mottled and germination is epigeal. It is very early maturing crop, Special features include high yield; good nutritive value, the earliness and drought resistant features, the reasonable cost of production and the ability to stimulate striga. (Sehrawat *et al.,* 2013)

As a whole, mung bean could be considered as an inevitable component of sustainable agriculture. It is a good source of protein and various important micro-nutrients. It contains 59.9% carbohydrate, 24.5% protein and 75 mg calcium, 8.5 mg iron, 49 mg β-carotene per 100g of split dal (Afzal *et al.*, 2004). Mung bean is used as whole or split seeds as Dal (Soup) but in other countries sprouted seeds are widely used as vegetables. It is considered as poor man's meat containing almost triple amount of protein as compared to rice. It has good digestibility and flavor. It synthesizes N in symbiosis with Rhizobia and enriches the soil. It fixes atmospheric N that improves the fertility status of soil and can fix N in soil by 63-342 kg ha^{-1} per season (Anjum *et al*., 2006). The importance of pulses is very much pertinent for food and improving the farm family income in order to ensure food security, nutritional security and economic security. The recommendation of fertilizer for soils and crops is a dynamic process and the management of fertilizers is one of the important crop production factors that greatly affect the growth, development and yield of mung bean (Duke,1983). Sulphur is an important macro-nutrient element, next to NPK that has a profound effect on pulse crops. Sulphur plays an inseparable role for synthesis of amino-acids like cystine, cysteine, methionine, hormone and vitamins. The application of sulfur increases the concentration as well as total uptake of N, P, K, Ca, S, Zn and B at different stages of crop growth (Agrawal *et al*., 2000). Lack of S causes retardation of terminal growth and root development. S deficiency induced chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004). Calcium plays an important role in plant growth and development. It is implicated in the movement of cellular organelles such as the spindle apparatus and secretory vesicles, and may play a key role in integrating plant cell metabolism (Jaleel *et al*., 2007). The cells of fibrous tissue need more calcium because it is required to bind the polysaccharides that form the middle lamella in the cell plates that arise between daughter cells.

Adequate Ca^{2+} levels are necessary for the membrane to function normally. Most of the interest in calcium in plants has centered on its role in the cytoplasm in controlling developmental process. Free calcium in the apoplast may also influence plant growth (Lawlor, 2002). Mung bean represents a cheap source of carbohydrates and high-quality protein, folate and iron. Mung bean, a warm-season leguminous species, has a short life cycle (approximately 60 days) and is mainly cultivated on small farms in South, East, and Southeast Asia (Kang *et al*., 2014). Although sporadic research works regarding response of mung bean to phosphorus and zinc were done but the influence of phosphorus and zinc on the yield of mung bean and their effect on seed quality and yield are still scantly. In Bangladesh, many experiments have been conducted on nutrient requirements of mung bean but reports are very few on the Calcium and Sulphur fertilizer requirement and on the combined effects of these elements on mung bean. Considering the above facts, the present study is aimed at:

Objectives:

1. To observe the effect of Ca on the morpho-physiological characters and yield of mung bean.
2. To observe the effect of S on the morpho-physiological characters and yield of mung bean.
3. To observe the combined effect of Ca and S on the morpho-physiological characters and yield of mung bean.

CHAPTER 2

REVIEW OF LITERATURE

Mung bean is an important pulse crop in Bangladesh and as well as many countries of the world although the crop has conventional less attention by the researchers because it grows in fallow land or as intercropped without or minimum care or management practices. Although Calcium and Sulphur and variety of mung bean play an important role in improving yield but research works related to Calcium and Sulphur and variety on mung bean are limited and not conclusive in context of Bangladesh. However, some of the important and informative works and research findings related to Calcium and Sulphur and variety on mung bean so far been done at home and abroad have been reviewed in this chapter under the following headings.

2.1 Effect of Calcium on morpho-physiology and yield of mung bean

Singh *et al.* (2018) showed that Ca is a renowned secondary messenger and plays important role in cell metabolism and in the nutrient's absorption across the cell membranes of pulse crops.

Singh *et al.* (2018) explained the Ca has also proven to improve the photosynthetic electron transport, activities of key enzymes of Calvin cycle, and antioxidant capacity of stressed plants.

Kader and Lindberg (2010) explained Calcium (Ca) enriched growth condition could be another approach in regulates cytoplasmic streaming, cell division and elongation, photomorphogenesis and its protective role against environmental stresses.

Khan *et al.* (2010) reported that addition of calcium in the NaCl and Ni containing medium, enhanced plant growth.

Saidi *et al.* (2009) based on duration and intensity of heat stress, release of Ca^{2+} ions and its expression pattern vary (calcium signatures) calcium availability in cytosol during early hours of heat stress significantly reduced activation level of small HSP promoter and negatively influenced acquired thermo-tolerance.

Jaleel *et al.* (2007) reviewed that calcium plays an important role in plant growth and development. It is implicated in the movement of cellular organelles such as the spindle apparatus and secretory vesicles may play a key role in integrating plant cell metabolism.

Tuteja and Mahajan (2007) found that calcium is an essential plant macro-nutrient which is taken up by roots and delivered to shoot via xylem to regulate many physiological and metabolic processes.

Misra and Gupta (2006) reported that proline and glycine betaine levels in roots and shoots increased in mung bean (tolerant) cultivar 'T 44' subjected to NaCl stress at seedling stage, increase was seen with a supply of 5 mM $CaCl_2$ to 200 mM NaCl and calcium ions play a key role in osmo protection and effects of Na-and Ca^{2+} are thus harmonizing the accretion of osmolytes.

Lawlor (2002) showed the cells of fibrous tissue need more calcium because it is required to bind the polysaccharides that form the middle lamella in the cell plates that arise between daughter cells. Adequate Ca^{2+} levels are necessary for the membrane to function normally. Most of the interest in calcium in plants has centered on its role in the cytoplasm in controlling developmental process. Free calcium in the apoplast may also influence plant growth.

Yang *et al.* (2001) reported alleviation effect of Ca on Al toxicity for morphological growth of mung bean seedling. Treatments with Calcium increased root length (4%), seedling height (5%), fresh weight (15%) and dry weight (5%).

2.2 Effect of Sulphur on morpho-physiology and yield of mung bean

A field experiment was conducted by Sipai *et al.* (2016) for four consecutive years at Centers of Excellence for Research on Organic Farming S. D. Agricultural University, Bhachau, Kutch, to study the effect of P, S and Rhizobium on yield, yield attributes and nodulation of Mung bean. The experiment consisting of three levels of phosphorus, three levels of Sulphur (0, 20, 40 kg ha^{-1}) and two levels of Rhizobium, total 18 treatment combinations with three replications were comprised in factorial randomized block design. Application of 40 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} along with Rhizobium inoculation significantly increased the yields, yield attributes and nodulation of Mung bean as compared to control, but it remained at par with 20 kg P and 20 kg S ha^{-1}.

Mazed *et al.* (2015) carried out a field experiment at the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh to study the growth and yield of Mung bean as influenced by potassium (K) and Sulphur (S). Four levels of K and three levels of S (0, 3 and 6 kg ha^{-1}) were used in the study. The results revealed that grain and Stover yield of mung bean increased with increasing levels of S. The maximum significant grain and Stover yield were obtained with the treatment combinations K_2S_2 (25 kg K ha^{-1} +6 kg S ha^{-1}) and the same treatments combinations gave the highest plant height, number of branch $plant^{-1}$, yield attributes like number of pods $plant^{-1}$, number of grains pod^{-1}, weight of 1000 seeds.

Ram & Katiyar (2013) carried out a field experiment was conducted under Instructional Farm of N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.), to evaluate the influence of Sulphur and zinc on mung bean for two consecutive summer seasons. The experiment was conducted with four levels of Sulphur (0, 20, 40 and 60 kg S ha^{-1}) and four levels of zinc (0, 5, 7.5 and 10 kg Zn ha^{-1}). The results revealed that application of 40 kg S ha and 10 kg Zn ha^{-1} significantly increased the plant height, number of branches plant, number of nodules plant^{-1}, number of pods plant^{-1}, number of seeds/pod, seed yield, protein content (%) and test weight was non-significant. The control (0 kg S × 0 kg Zn ha^{-1}) had the poorest performance in respect of yield and protein content of mung bean seed. The increasing dose of zinc increased the seed yield with increasing dose of Sulphur up to 40 kg S ha^{-1}. The highest seed yield (13.69 and 14.40 q ha^{-1}) was observed in combination with 40 kg S ha^{-1} and 10 kg Zn ha^{-1} which was significantly superior over rest of the combinations except 60 kg S ha^{-1} and 10 kg Zn ha^{-1}. The minimum seed yield (9.56 and 10.06 q ha^{-1}) was achieved with treatment having 20 kg S ha^{-1} and 5 kg Zn ha^{-1} and least was in control.

Surendra Ram and Katiyar (2013) showed all the higher doses of Sulphur significantly superior over control enhancing the seed and straw yield production of summer green gram. The lowest average value of seed yield and straw yield were recorded in control treatment. The seed yield 2.47, 8.11 and 7.52% and straw yield 13.93, 26.59 and 22.09% increased of summer green gram due to 10, 20 and 40kg S/ha.

A field experiment was conducted by Tripathi *et al.* (2012) to find out the effect of rhizobial strains and Sulphur (S) levels (15, 30 and 45 kg ha^{-1}) on mung bean cultivars (SML-668, Pusa Vishal, and HUM-1). Application of 45 kg S ha^{-1} recorded higher plant height, primary branches, green tri-foliates, leaf area index, dry matter accumulation, nodule numbers and nodule dry weight, increased days to maturity, number of pod and higher grain and straw yield as compared to cultivars Pusa Vishal and S application at 15 and 30 kg ha^{-1}, respectively. Nodule number was highest in HUM-1 × MO5 and application of 45 kg S ha^{-1} in Pusa Vishal and HUM-1.

Yadav (2007) conducted an experiment to find out the effects of phosphorus and Sulphur (0, 20, 40 and 60 kg ha^{-1}) on the growth and yield of green gram cv. RMG-62 in a field experiment conducted in Rajasthan, India during the Kharif seasons.

Plant height, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed yield, Stover yield and biological yield increased with increasing rates of phosphorus and Sulphur up to 40 kg ha^{-1} and decreased thereafter.

Srinivasarao *et al.* (2004) conducted an experiment with available Sulphur (S) extracted in five extractants, crop response to S application and use efficient use of S by mung bean and urdbean on different soil types of pulse growing regions of India. Among extractants tested, 1 N NHO Ac extracted higher S followed by Morgan's reagent, 0.001 N HCl, 0.15% $CaCl_4$, and 1% NaCl. Response of urdbean was in higher magnitude as compared to mung bean to 20 mg S/kg^2. In both the crops, larger response was obtained in Inceptisols followed by Vertisols-1 and lower response was found in Alfisols. Larger utilization of native soil S in case of Alfisols by both the crops resulted in lower levels of response to added fertilizer S. Owing to high degree of correlation with plant response, 0.15% CaCl and Morgan's reagent can be used as soil test methods for assessing the available S supply and predicting the crop response to applied S on these soils.

A field trial was conducted by Siag and Yadav (2003) during Kharif seasons under irrigated conditions to study the response of mung bean cv. MUM-2 to Sulphur (applied as gypsum) with different application methods in sandy loam soil of Rajasthan, India. Treatments comprised: two Sulphur rates (20 and 40 kg ha^{-1}) and three application methods as basal, side dressing at 25 days after sowing (DAS) and half as basal + half as side dressing at 25 DAS, along with a control (no Sulphur). The number of pods plant-1 increased with increasing Sulphur rates. Basal dose of 40 kg S ha^{-1} recorded the highest number of pods (34.2). Plant heights, number of seeds pod^{-1} and 1000-seed weight were not influenced by different treatments in any year. Grain yield obtained at basal dose of 20 kg S ha^{-1} (973 kg ha^{-1}) was 42.9% higher than that of the control treatment (681 kg/ha). Grain yield was highest with a basal dose of 40 kg S ha^{-1} (1095 kg ha^{-1}), but did not differ significantly from 20 kg S ha^{-1}.

A side dressing of 20 kg S ha^{-1} at 25 DAS did not increase grain yield over the control.

Nita *et al.* (2002) conducted an experiment to find out the effects of K and S at 0, 20 and 40 kg ha^{-1}, applied singly or in combination, on the growth and productive attributes of mung bean as well as on the fertility of the soil were determined in a field experiment conducted in West Bengal, India during the summer of 1998-99. Leaf area index, seed yield, protein yield, harvest index and net production value increased with increasing rates of K and S. Similarly, the status of N and P in soil decreased with increasing rates of K and S.

The effects of phosphorus (30, 60 and 90 kg ha^{-1}), Sulphur (0, 10, 20 and 30 kg ha^{-1}) and Rhizobium inoculation on the protein and S-containing amino acids of green gram (V. radiata) were determined in a field experiment conducted by Shahi *et al.* (2002) in Allahabad, Uttar Pradesh, India. Application of P and S, and inoculation with Rhizobium enhanced the protein content in the grains of green gram, with 60 kg P ha^{-1} and 30 kg S ha^{-1} resulting in the highest increase in the protein content. Rhizobium inoculation also significantly increased the protein content in the grains of the crop. The S-containing amino acids were highest at 30 kg S ha^{-1}. The methionine, cystine and cysteine content of the grains were highest with the application of 30 kg S ha^{-1}, which was similar with the application of 20 kg S ha^{-1}.

Pandey and Singh (2001) conducted an experiment with P_2O_5 the rate of 0, 25 or 50 kg ha^{-1} and S at 0, 20 and 40 kg ha^{-1} were applied as basal in Pura, Jammu and Kashmir, India. Mung bean responded significantly to the addition of P and S. The highest seed grain and Stover yields were obtained at 50 kg P and 40 kg S ha^{-1}. The protein and Sulphur-containing amino acid contents of the grains linearly increased with increasing rates of phosphorus and Sulphur. The highest protein and Sulphur-containing amino acid contents were observed at 50kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} and the lowest contents were observed in the control, during both the years.

In generally, Sulphur is also essential for synthesis of vitamin (biotin and thiamine), Sulphur containing amino acids (cystine, cysteine and methionine) and promotes nodulation in legumes. According to Pandey and Singh (2001) reported that highest grain and straw yield of green gram was obtained by application of Sulphur.

Summer mung bean was grown in the field of India for two years with the application of elemental Sulphur (0, 15, 30 and 45 kg ha^{-1}) by Singh *et al.* (1997). Sulphur application significantly improved plant biomass, nodule number and weight, seed grain and Stover yield, nitrogen and Sulphur uptake, the optimum application rate being 30 kg ha^{-1}. Application of Sulphur up to 15 kg ha^{-1} increased the population of total bacteria and Azotobacter. However, addition of Sulphur decreased the population of fungi and actinomycetes.

Trivedi *et al.* (1997) carried out a field experiment to study the effects of nitrogen, phosphorus and Sulphur on yield and nutrient uptake of black gram (*Vigna mungo*) at Gwalior, Madhya Pradesh, India in Kharif (monsoon) seasons. Application of 30 kg N, 60 kg P_2O_5 and 60 kg S ha^{-1} increased yield, net profit and nutrient uptake.

Trivedi (1996) conducted a field trial in the rainy seasons at Gwalior, Madhya Pradesh, India with Vigna mungo cv. Jawahar Urd-2 and was given 0-30 kg N, 0 60 kg P_2O_5 and 0 or 60 kg S ha^{-1}. Seed yield, net returns and N, P and S contents in seed increased with increasing rates of N, P and S applications.

Singh *et al.* (1997) have findings of the higher level of S (40 kg S/ha) tended to decreased 0.54% and 0.43% in seed and straw yield of summer green gram over 20kg S/ha level. However, this reduction in seed yield and straw yield of summer green gram were statistically non-significant.

In a field experiment conducted by Tiwari and Chaplot (1995) during the summer seasons at Udaipur, Rajasthan and they studied the effects of irrigation regimes (irrigation water: cumulative pan evaporation ratios, IW: CPE of 0.5, 0.7, 0.9 or 1.1) and application of 0-150 kg elemental S ha^{-1} on mung bean. Irrigation at 0.9 IW: CPE ratio, at par with 1.1, gave 59.8 and 29.5% higher yield than at 0.5 and 0.7 IW: CPE ratio, respectively. Seed yield of mung bean increased significantly with an increase in Sulphur rate up to 100 kg ha^{-1}.

Sharma *et al.* (1995) carried out a field trial in the monsoon season at Gwalior, Madhya Pradesh with Vigna mungo cv. JU-2 treated with 0, 15 or 30 kg N, 0, 30 or 60 kg P_2O_5 and 0 or 60 kg S ha^{-1}. Application of N and P, either alone or with S, increased Mn, Zn, Cu and Fe contents in seeds and straw and the available Mn and Zn content in soil. Application of 30 kg N + 60 kg P_2O_5 + 60 kg S ha^{-1} gave the highest trace element content. Soil available Cu content decreased with increasing N and P applications but increased with S application. Soil available Fe increased with increasing N and P applications and decreased with increasing S applications.

Patel *et al.* (1992) conducted a field trial to evaluate the response of mungbean with Sulphur fertilization under different levels of nitrogen and phosphorus. Green gram cv. Gujrarat 2 and K 851 were given 10 kg N + 20 kg P ha^{-1}, 20kg N + 40 kg P ha^{-1} and 0, 10, 20 or 30 kg S ha^{-1} as gypsum and found that plant growth with highest doses. Seed yield with 20 kg N + 40 kg P ha^{-1} was 1.2 and 1.24 t ha^{-1} in Gujrarat 2 and K 851, respectively.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to find out the effect of Calcium (Ca) and Sulphur (S) on the morpho-physiological characters and yield of mungbean. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from February to July, 2018.

3.1.2 Experimental location

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and it was located in 24.09°N latitude and 90.26°E longitudes. As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level (Appendix- Ⅰ).

3.1.3 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 5.7 and 1.13%, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Appendix II.

3.1.4 Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the rabi from November to February and the kharif-I, pre-monsoon period or hot season from March to April and the kharif-II monsoon period from May to October. During the experimental period the maximum temperature (36°C), highest relative humidity (80%) and highest rainfall (373.1 mm) was recorded in the month of July 2018, whereas the minimum temperature (20°C), minimum relative humidity (65%) and no rainfall was recorded for the month of January 2018 considering 200 mm average rainfall per year (Appendix III).

3.2 Experimental details

3.2.1 Treatments of the experiment

The experiment comprised of 9 treatments; Ca and S standard solution from $(NH_4)_2SO_4$ and $Ca(NO_3)_2$ was prepared as the treatment ppm requirement (using 95% isopropyl alcohol). The experiment will consist of the following treatments:

T_0= No treatment

T_1= 100 ppm Ca

T_2= 200 ppm Ca

T_3= 50 ppm S

T_4= 100 ppm S

T_5= 100 ppm Ca + 50 ppm S

T_6= 100 ppm Ca +100 ppm S

T_7= 200 ppm Ca + 50 ppm S

T_8= 200 ppm Ca + 100 ppm S

3.2.2 Planting material

Mung bean (*Vigna radiata L*), BARI mung-6 (high yielding variety) was selected as plant material. Seed of the crop will be collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.2.3 Land preparation

The land was opened on the 12th March, 2018 with the tractor drawn disc plough. Ploughed soil was brought into desirable tilth by cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on the 16th and 22nd March, 2018, respectively. Experimental land was divided into unit plots following experimental design.

3.2.4 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum and boric acid were used as a source of nitrogen (N), phosphorous (P), potassium (K), sulphur (S) and boron (B), respectively. Urea, TSP, MoP, gypsum and boric acid were applied at the rate of 120, 133, 62, 90 and 1 kg ha^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation. All of the fertilizers were applied during final land preparation.

3.2.5 Experimental design and layout

The experiment will be laid out in a Randomized Complete Block Design (RCBD) with three (3) replications (Appendix-Ⅸ).

Number of treatments: 9

Number of Replication: 3

Total Number of plots: 27

Plot size: 3m×1.5m

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of mung bean were sown on March 23, 2018 in solid rows in the furrows having a depth of 2-3 cm with maintaining row to row distance 30 cm and plant to plant 10 cm.

3.3.2 Intercultural operations

3.3.2.1 Intercultural operations

Seeds started germination of 4 Days after sowing (DAS). Thinning was done two times; first thinning was done at 10 DAS and second was done at 18 DAS to maintain optimum plant population in each plot.

3.3.2.2 Irrigation, drainage and weeding

Irrigation was provided before 15 and 30 DAS for optimizing the vegetative growth of mung bean for the all experimental plots equally. Proper drain also made for drained out excess water from irrigation and also rainfall from the experimental plot. The crop field was weeded at 15 and 30 DAS by hand weeding.

3.3.2.3 Plant protection measures

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 ml with 1-liter water to 5 decimal lands for two times at 15 days interval after seedlings germination to control the insects. Before sowing seeds were treated with Bavistin 50 WP to protect seed borne disease.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height (cm) at 30, 45 and 60 days, number of leaves/plant (at 30, 45 and 60 days), no. of branch/plant (at 30, 45 and 60 days), days to first flowering, days to first pod setting, spade value (at 30, 45 and 60 days), leaf Area Index (at 30, 45 and 60 days), no. of flowers/plant, no. of pods/plant, days to first ripening of fruit, days to 50 % maturity of fruit, days to 100 % maturity of fruit, no. of fruits/plant, no. of fertile seed/plant, no. of infertile seed/plant, thousand seed weight, seed yield, biological yield and harvest Index were recorded.

3.5 Harvest and post-harvest operations

Harvesting was done when 90% of the pods became brown to black in color. The matured pods were collected by hand picking from each plot.

3.6 Data collection

The following data were recorded:

1) Plant height (cm) at 30, 45 and 60 DAS.

2) Number of leaves/plant (at 30, 45 and 60 DAS).

3) No. of branch/plant (at 30, 45 and 60 DAS).

4) Days to first flowering

5) Days to first pod setting

6) SPAD value (at 30, 45 and 60 DAS)

7) Leaf Area Index (at 30, 45 and 60 DAS)

8) No. of flowers/plant

9) No. of pods/plant

10) Days to first ripening of fruit

11) Days to 50 % maturity of fruit

12) Days to 100 % maturity of fruit

13) No. of fruits/plant

14) No. of fertile seed/plant

15) No. of infertile seed/plant

16) Thousand seed weight (g)

17) Seed yield (kg ha^{-1})

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

19) Harvest index (%)

3.7 Procedure of data collection

3.7.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 30, 45 and 60 DAS (at harvest). Data were recorded from 5 plants from each plot and average plant height plant-1 was recorded as per treatment. The height was measured from the ground level to the tip of the plant by a meter scale.

3.7.2 Number of leaves $plant^{-1}$

The number of leaves $plant^{-1}$ was counted at 30, 45 and 60 DAS (at harvest). Data were recorded from 5 plants from each plot and average Number of leaves $plant^{-1}$ was recorded as per treatment.

3.7.3 No. of branch $plant^{-1}$

The number of branch $plant^{-1}$ was counted at 30, 45 and 60 DAS (at harvest). Data were recorded from 5 plants from each plot and average Number of branch $plant^{-1}$ was recorded as per treatment.

3.7.4 Days to first flowering

Days to 1^{st} flowering were recorded by counting the number of days required to start flower initiation of mung bean plant in each plot.

3.7.5 Days to first pod setting

Days to first pod setting were recorded by counting the number of days required to start pod setting initiation of mung bean plant in each plot.

3.7.6 SPAD value

The SPAD meter is a hand-held device that is widely used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations. Chlorophyll content of leaf was determined from plant samples by using an automatic SPAD meter. Starting from 30 DAS were recorded at 30, 45 and 60 DAS. Data were recorded from 5 plants from each plot.

3.7.7 Leaf area index

Since the crop yield is to be assessed per unit ground area instead of per plant, the leaf area existing on unit ground area was proposed by Watson (1952). Leaf area index is the ratio of leaf area to ground area occupied by crop plant. Leaf area index plant was calculated by using the following formula.

$$\text{Leaf area index} = \text{Leaf area plant}^{-1}\ (cm^2)/\text{Ground area plant}^{-1}\ (cm^2)$$

3.7.8 Number of flowers plant^{-1}

The number of flowers per plant was observed and counted from each plot and average number of flowers per plant was recorded as per treatment.

3.7.9 Number of pods plant^{-1}

The number of pods per plant was observed and counted from each plot and average number of pods per plant was recorded as per treatment.

3.7.10 Days to first ripening of fruit

Days to first ripening of fruit were recorded by counting the number of days required to maturity of mung bean plant in each plot.

3.7.11 Days to 50 % maturity of fruit

Days to first 50 % maturity of fruit were recorded by counting the number of days required to maturity of mug bean plant in each plot.

3.7.12 Days to 100 % maturity of fruit

Days to first 100 % maturity of fruit were recorded by counting the number of days required to maturity of mung bean plant in each plot.

3.7.13 No. of fruits plant^{-1}

Numbers of total fruits of 5 plants from each plot were counted and the mean numbers were expressed as plant-1 basis.

3.7.14 No. of fertile seed plant^{-1}

The number of fertile seeds per plant was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 5 pods from each plot.

3.7.15 No. of infertile seed plant^{-1}

The number of infertile seeds per plant was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 5 plants from each plot.

3.7.16 Thousand seed weight (g)

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

3.7.17 Seed yield (kg ha^{-1})

The seeds collected from 4.5 (3 m × 1.5 m) square meter of each plot were sun dried properly. The weight of seeds was taken and converted the yield in kg/ha.

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

The sum of grain yield and Stover yield is regarded as biological yield. Biological yield was determined by the using the following formula:

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

3.7.19 Harvest index (%)

Harvest index (HI) was calculated by using the following formula:

HI = (Grain yield kg ha^{-1}/Biological yield kg ha^{-1}) × 100

3.8 Statistical analysis

The data obtained for different parameters were analyzed to find out the effect of calcium and Sulphur to mung bean variety BARI mug-6. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment means was estimated by the Least Significant difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprised presentation and discussion of the results obtained from the study on the effect of Calcium (Ca) and Sulphur (S) on the morpho-physiological characters and yield of mung bean. The analyses of variance (ANOVA) of the data on different morpho-physiological parameters and yield of mungbean are presented in Appendix VI-VIII. The results have been presented and discussed in the different tables and graphs and possible interpretations are given under the following headings.

4.1 Plant height (cm)

Mung bean plant height at 30, 45 and 60 DAS showed statistically not significant due to the effect of Calcium (Ca) and Sulphur. Effect of Calcium and Sulphur showed no significant differences on plant height at 30, 45 and 60 DAS. At 30 DAS, the tallest 34.05 cm plant was recorded from T_6 (100 ppm Ca +100 ppm S) which is statistically similar to 34.04 cm recorded from T_1 (100 ppm Ca) and 33.97 cm recorded from T_7 (200 ppm Ca + 50 ppm S) and the smallest plant 30.36 cm was recorded from T_0 (Control). At 45 DAS, the tallest plant 47.42 cm was recorded from T_1 (100 ppm Ca) similar 47.06 cm to T_5 (100 ppm Ca +50 ppm S) and the smallest plant 42.14 cm was recorded from T_0 (control). At 60 DAS, the tallest plant 52.27 cm was recorded T_5 (100 ppm Ca +50 ppm S) similar to 51.61 cm recorded from T_1 (100 ppm Ca) and the smallest plant 45.11 cm was recorded from T_0 (control). It was observed that plant height increased gradually with the increment of Calcium and Sulphur combined doses. This might be due to higher availability of Calcium and Sulphur and their uptake that progressively enhanced the vegetative growth of the plant. This result is similar with the findings of some other researchers, e.g. Suhartatik (1991) revealed that application of Ca significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of mug bean over control.

Table 1. Effect of calcium and Sulphur on plant height (cm) of mung bean

Treatments	Plant height (cm)		
	30 DAS	**45 DAS**	**60 DAS**
T_0	30.36 b	42.14 b	45.11 b
T_1	34.04 a	47.42 a	51.61 a
T_2	32.79 a	46.48 ab	50.55 a
T_3	33.86 a	45.82 ab	49.86 a
T_4	32.63 ab	45.77 ab	50.05 a
T_5	32.89 a	47.06 a	52.27 a
T_6	34.05 a	46.13 ab	49.98 a
T_7	33.97 a	46.57 ab	50.85 a
T_8	33.25 a	45.78 ab	49.91 a
CV (%)	4.17	5.91	4.82
LSD	2.36	4.65	4.13

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.) (T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.2 Number of leaves plant^{-1}

Effect of Calcium and Sulphur don't show significant differences on number of leaves per plant at 30, 45 but at 60 DAS it shows significant difference (Table 2). At 30 DAS, the maximum number of leaves per plant (6.67) was recorded from the treatment T_5 (100 ppm Ca + 50 ppm S) which was statistically similar to 6.00 recorded from T_3 (50 ppm S) and 5.67 recorded from T_1 (100 ppm Ca) and the minimum number of leaves per plant 4.67 was recorded from T_0 (control),T_2 (200 ppm Ca), T_7(200 ppm Ca + 50 ppm S) and T_8(200 ppm Ca + 100 ppm S). At 45 DAS, the maximum number of leaves per plant (8.00) was recorded from the treatment T_1 (100 ppm Ca) which was statistically similar to 7.80 recorded from T_2 (200 ppm Ca) and 7.67 recorded from T_0 (control). The minimum number of leaves per plant 6.40 was recorded from T_3 (50 ppm S), T_7 (200 ppm Ca + 50 ppm S) and T_8 (200 ppm Ca + 100 ppm S). The maximum number of leaves per plant (9.07) was recorded from the treatment of T_1 (100 ppm Ca) at 60 DAS which was statistically similar to 8.80 recorded from T_2 (200 ppm Ca) and the minimum number of leaves per plant was 7.00 recorded from T_4 (100 ppm S). Some previous studies reported that BARI Mung-6 performed better than other available varieties of mug bean with greater number of leaves per plant.

Table 2. Effect of Calcium and Sulphur on No. of leaves per plant of mung bean

Treatments	No. of leaves per plant		
	30 DAS	**45 DAS**	**60 DAS**
T_0	4.67 a	7.67 a	7.80 bc
T_1	5.67 a	8.00 a	9.07 a
T_2	4.67 a	7.80 a	8.80 ab
T_3	6.00 a	6.40 a	7.07 c
T_4	5.00 a	7.53 a	7.00 c
T_5	6.67 a	6.73 a	7.53 c
T_6	5.33 a	6.47 a	7.27 c
T_7	4.67 a	6.40 a	7.27 c
T_8	4.67 a	6.40 a	7.27 c
CV (%)	12.99	17.23	8.64
LSD	1.22	2.08	1.13

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.)

(T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.3 No. of branch/plant

Number of branches per plant of mung bean at 30, 45 and at 60 DAS showed statistically significant variation due to Calcium and Sulphur. At 30 DAS the maximum number of branches per plant 0.80 was observed from T_5 (100 ppm Ca + 50 ppm S) which was statistically similar 0.73 to T_1 at 30 DAS. The maximum number of branches per plant was recorded from T_1 and T_2 (1.20) which was statistically similar to T_0 (1.07) and T_5 and T_6 (1.0667). The smallest number of branches was recorded from T_4 (0.33) at 45 DAS. The maximum number of branches per plant was recorded from T_2 (1.60) which was statistically similar to T_1 (1.47) and the smallest number of branches was recorded from T_4 (0.40) at 60 DAS. Tahir *et al.* (2013) reported that Sulphur at 4 kg ha^{-1} significantly increased number of branches per plant.

Table 3. Effect of Calcium and Sulphur on No. of branches per plant of mung bean

Treatments	No. of branches per plant		
	30 DAS	45 DAS	60 DAS
T_0	0.53 ab	1.07 ab	1.27 abc
T_1	0.73 a	1.2 a	1.47 ab
T_2	0.60 ab	1.2 a	1.60 a
T_3	0.53 ab	0.8 abc	0.87 bcd
T_4	0.27 b	0.33 c	0.40 d
T_5	0.80 a	1.07 ab	1.27 abc
T_6	0.60 a	1.07 ab	1.33 abc
T_7	0.47 ab	0.67 abc	0.73 cd
T_8	0.33 b	0.53 ab	0.73 cd
CV (%)	39.28	40.37	38.93
LSD	0.379	0.61	0.71

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.) (T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.4 Days to first flowering

Days to first flowering of mung bean showed statistically significant variation due to Calcium and Sulphur. The maximum days to flowering (32.3) was observed from T_0 (control) which was statistically similar (31.3) to T_2 and followed (31.3) by T_7 and the minimum days to flowering (29.7) was observed from T_6 (Table 4).

4.5 Days to first pod setting

Days to first pod setting of mung bean showed statistically significant variation due to Calcium and Sulphur. The maximum days to pod setting (36.7) was observed from T_0 which was statistically similar (36.0) to T_8 and followed (35.3) by T_4 and the minimum days to pod setting (34.0) was observed from T_6 (Table 4).

Table 4. Effect of Calcium and Sulphur on days to first flowering and days to first pod setting of mug bean.

Treatments	Days to first flowering	Days to first pod setting
T_0	32.3 a	36.7 a
T_1	30.7 c	35.0 bcd
T_2	31.3 bc	35.3 bc
T_3	30.7 c	34.7 cd
T_4	31.0 c	35.3 bc
T_5	31.0 c	34.7 cd
T_6	29.7 d	34.0 d
T_7	31.3 bc	35.0 bcd
T_8	32.0 ab	36.0 ab
CV (%)	1.86	2.05
LSD	0.99	1.23

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.) (T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.6 SPAD value

SPAD (Soil Plant Analysis Development) meter reading was analyzed and presented in order to having an idea about relative leaf chlorophyll content per unit leaf area of the mug bean. Measurement of Chlorophyll content using SPAD value of leaf was significantly affected at different stages of crop growth starting from 30 DAS were recorded at 30, 45 and 60 DAS. Data were recorded from 5 plants from each plot. The SPAD value of mug bean showed statistically significant variation due to Calcium and Sulphur. The maximum SPAD value at 30 DAS was 49.50 was recorded form T_5 (100 ppm Ca +50 ppm S) which was statistically similar to 47.91 recorded from T_3 (50 ppm S) and 47.04 from T_6 (100 ppm Ca +100 ppm S), at 45 DAS the maximum SPAD value of mug bean was recorded 69.88 from T_2 (200 ppm Ca) which was statistically similar to 69.85 obtained from T_3 (50 ppm S) and 68.41 from T_1 (100 ppm Ca) and at 60 DAS the maximum SPAD value of mungbean was 72.74 recorded from T_2 (200 ppm Ca) which was statistically similar to 72.61 recorded from T_3 (50 ppm S) and 71.57 from T_1 (control) (Table 5). It seems from the results that combined effect of Calcium and Sulphur significantly increased the SPAD value than sole use of any fertilizer. Actually, Calcium help increase the micro nutrient content of soil, thus reducing the bulk density and decreasing compaction. Thus, plants get a suitable growing environment which promotes better growth and development. Which supports the information SPAD value mirrors crop quality and crop yield by providing an indication of the amount of chlorophyll present in plant leaves, Konikaminolta, (2009).

Table 5. Effect of Calcium and Sulphur on SPAD value of mug bean

Treatments	SPAD value		
	30 DAS	**45 DAS**	**60 DAS**
T_0	45.91 ab	65.89 b	71.50 a
T_1	45.21 ab	68.41 ab	71.57 a
T_2	46.76 ab	69.88 a	72.74 a
T_3	47.91 ab	69.85 a	72.61 a
T_4	45.95 ab	68.15 ab	70.44 a
T_5	49.50 a	65.99 b	69.31 a
T_6	47.04 ab	66.39 ab	71.10 a
T_7	44.16 b	66.80 ab	70.08 a
T_8	44.41 ab	66.26	68.77 a
CV (%)	6.63	3.14	3.88
LSD	5.27	3.63	4.70

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.)

(T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.7 Leaf Area Index (LAI)

T_7 (200 ppm Ca + 50 ppm S) showing Sulphur has significant effect on LAI of mug bean in early growth period (Figure 1). Leaf area production at 60 DAS influenced by Calcium and Sulphur was significant. The maximum leaf area (132.49 cm^2) was obtained from T_3 (50 ppm S). The minimum leaf area (124.06 cm^2) was recorded from T_4 (100 ppm S) showing Calcium has no significant effect on LAI of mug bean in growth prior to harvest. (Figure 2)

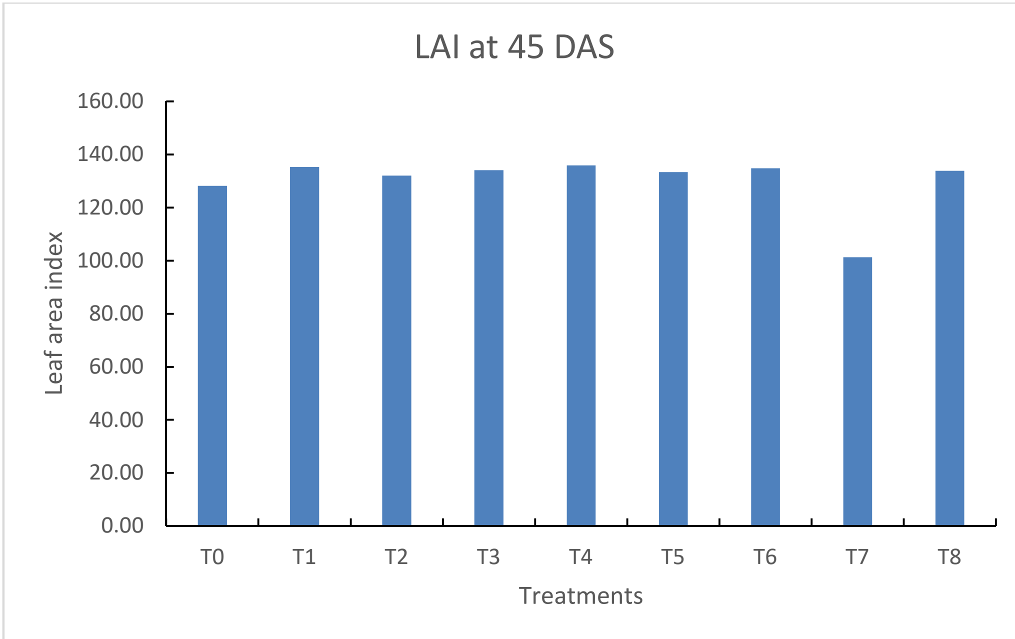


Figure 1. Effect of Calcium and Sulphur combination treatment on LAI of mung bean at 45 DAS

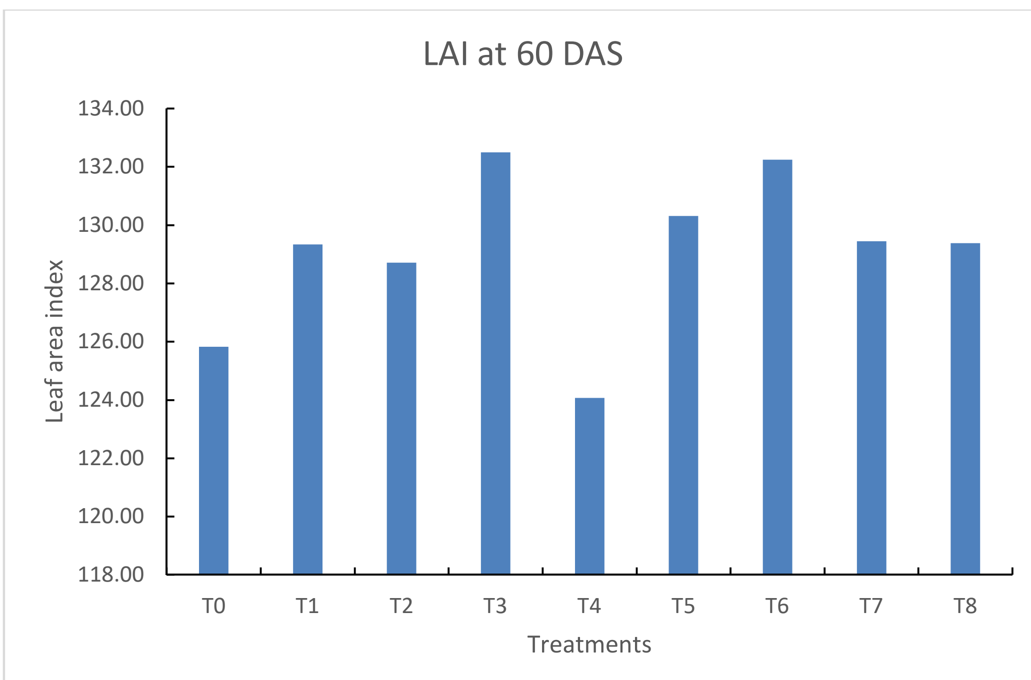


Figure 2. Effect of Calcium and Sulphur combination treatment on LAI of mung bean at 60 DAS

4.8 Number of flowers plant^{-1}

The variations in respect of number of flowers per plant due to the effects of different levels of Calcium and Sulphur were found to be statistically significant. The maximum number of flowers per plant (40.36) was observed from T_7. T_4 treated plants produced the minimum number of flowers per plant (30.06). Number of flowers per plant showed significant variation due to the effects of different levels of Calcium and Sulphur (Table. 6). The highest number of flowers per plant (40.36) was obtained from T_7 which was statistically similar to T_6 (34.80) and T_5 (34.33). The lowest number of flowers per plant (30.06) was found when the plants were raised without Calcium and with Sulphur T_4 (100 ppm S). The combined effect of different doses of Calcium and Sulphur showed a statistically significant effect on number of flowers per plant of mug bean (Table 6).

4.9 No. of pods plant^{-1}

The variations in respect of number of pods per plant due to the effects of different levels of Calcium and Sulphur were found to be statistically significant. The maximum number of pods per plant (19.67) was observed from T_3 (50 ppm S) which was statistically similar to T_5 (19.33). T_4 (100 ppm S) treated plants produced the minimum number of flowers per plant (16.67). Number of pods per plant showed significant variation due to the effects of different levels of Calcium and Sulphur (Table. 6).

Table 6. Effect of Calcium and Sulphur on number of flowers/plant and number of pods/plant of mung bean

Treatments	No. of flowers per plant	No. of pods per plant
T_0	32.93 b	18.00 b
T_1	33.66 b	19.00 b
T_2	32.26 b	19.00 b
T_3	33.00 b	19.67 b
T_4	30.06 b	16.67 b
T_5	34.33 ab	19.33 b
T_6	34.80 ab	19.33 b
T_7	40.36 a	28.33 a
T_8	31.46 b	18.33 b
CV (%)	11.25	23.94
LSD	6.50	8.10

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.

4.10 Days to first ripening of fruit, days to 50 % maturity of fruit and days to 100 % maturity of fruit

The variations in respect of days to first ripening of fruit, days to 50 % maturity of fruit and days to 100 % maturity of fruit due to the effects of different levels of Calcium and Sulphur were found to be statistically significant. T_7 treated plants took the minimum number of days 48.67 to first ripening of fruit and days to 50 % maturity of fruit 65.67 and days to 100 % maturity of fruit 70.66 for T_5 treated plants took the minimum number of days. Maximum days taken by T_0 (no treatment) as

51.67 and 68.33 and T_8 as 73.33 from days to first ripening of fruit, days to 50 % maturity of fruit and days to 100% maturity of fruit of mungbean . (Table 7)

Table 7. Effect of Calcium and Sulphur on Days to first ripening of fruit, days to 50 % maturity of fruit and days to 100% maturity of fruit of mung bean

Treatments	Days to first ripening of fruit	Days to 50 % maturity of fruit	Days to 100 % maturity of fruit
T_0	51.67 a	68.33 a	73.33 ab
T_1	50.33 b	67.33 a	72.00 abc
T_2	50.33 b	67.00 ab	71.00 bc
T_3	49.67 bc	67.33 a	71.66 abc
T_4	50.33 b	67.00 ab	71.66 abc
T_5	49.33 cd	67.00 ab	70.66 c
T_6	49.33 cd	67.67 a	73.00 abc
T_7	48.67 d	65.67 b	71.66 abc
T_8	50.33 b	68.00 a	73.66 a
CV(%)	1.15	1.18	2.02
LSD	0.99	1.36	2.49

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.) (T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S.)

4.11 No. of fertile seed/plant and No. of infertile seed/plant

The variations in respect of No. of fertile seed/plant and No. of infertile seed/plant due to the effects of different levels of Calcium and Sulphur were found to be statistically significant. The maximum No. of fertile seed for treated plant was observed as 145.40 for T_0 and the minimum No. of infertile seed as 3.4 (Figure 3).

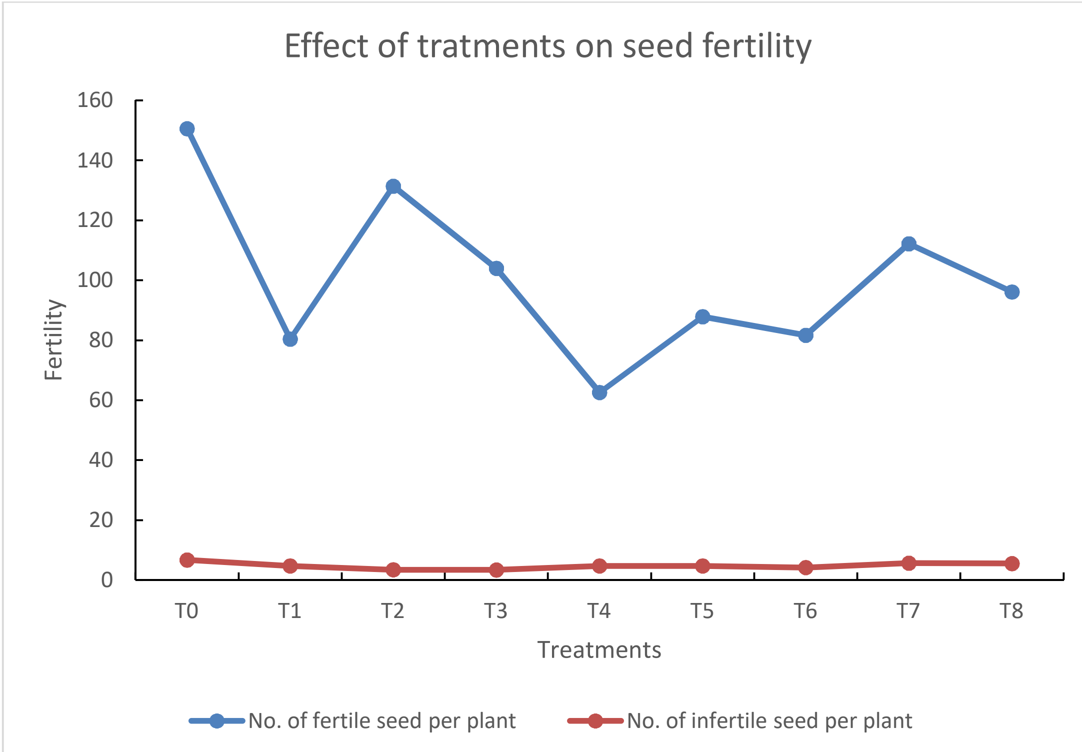


Figure 3. Effect of Calcium and Sulphur on No. of fertile seed/plant and No. of infertile seed/plant of mung bean

(T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S. CV=Coefficient of variance.)

4.12 Weight of 1000 seeds

Weight of 1000 seeds of mung bean showed statistically significant variation due to Calcium and Sulphur combination treatment (Table 8). The highest weight of 1000 seeds (51 g) were recorded from T_5 and T_6, while the lowest weight of 1000 seeds (46 g) were found from T_0 of no treatment (Table 8). Dey and Basu (2009) reported that yield components i.e. 1000-seed weight increased with increasing rates of Sulphur.

4.13 Seed yield (kg ha^{-1})

Seed yield per plot of mung bean showed statistically significant variation due to Calcium and Sulphur combination treatment (Table 8). The highest seed yield per plot was recorded as 1615.13 kg/ha from T_5 of the treatment combination of 100 ppm Ca + 50 ppm S, where the minimum yield was obtained from T_1 of 100 ppm Ca as 1041.31 kg/ha (Table 8). Tripathi *et al.* (2012) reported that application of 45 kg S ha^{-1} recorded higher grain yields as compared to control.

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

Effect of Calcium and Sulphur as treatment on mung bean showed significant variation on biological yield. The highest biological yield 2.62 t/ha was gathered from T_5 of the treatment combination of 100 ppm Ca + 50 ppm S which is statistically similar with 2.31 t/ha T_2. Whereas the minimum biological yield given by 1.82 t/ha of T_8 (200 ppm Ca + 100 ppm S) which is statistically similar with T_5 1.96 t/ha (Table 8).

4.15 Harvest index (%)

Harvest index indicates the higher translocation ability of current assimilates towards reproductive organs of the plant. The effect of Calcium and Sulphur as individual treatment on mung bean showed significant variation on harvest index than the combined treatment of Calcium and Sulphur. The highest harvest index 62.86% was gathered from T_8 which is statistically similar to 61.65% recorded from T_0. Whereas the minimum harvest index is 51.04% given by T_1 (Table 8).

Table 8. Effect of Calcium and Sulphur on thousand seeds weight, seed yield, biological yield and harvest index of mug bean

Treatments	Thousand seed weight (g)	Seed yield ($kgha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
T_0	46 c	1041.31 f	1.96 de	57.24 abcde
T_1	48.66 b	1246.63 cd	2.04 bcde	51.04 e
T_2	49.33 ab	1305.31 bc	2.31 ab	56.51 abcde
T_3	48.33 b	1122 ef	2.25 bcd	55.41 bcde
T_4	49.66 ab	1158.63 de	2.16 bcde	53.64 cde
T_5	51 a	1615.13 a	2.62 a	61.65 ab
T_6	51 a	1158.63 de	1.98 cde	58.52 abcd
T_7	50 ab	1349.31 b	2.27 bc	59.44 abc
T_8	49.66 ab	1144 def	1.82 e	62.86 a
CV (%)	3.41	29.21	2.296	29.97
LSD	1.77	112.79	0.31	7.38

(In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.)

(T_0= No treatment, T_1= 100 ppm Ca, T_2= 200 ppm Ca, T_3= 50 ppm S, T_4= 100 ppm S, T_5= 100 ppm Ca + 50 ppm S, T_6= 100 ppm Ca +100 ppm S, T_7= 200 ppm Ca + 50 ppm S, T_8= 200 ppm Ca + 100 ppm S.)

From the experiment it was found that, at 30 DAS the tallest 34.05 cm plant was recorded from T_6 (100 ppm Ca +100 ppm S) and the smallest plant 30.36 cm was recorded from T_0 (Control). It was observed that plant height increased gradually with the increment of Calcium and Sulphur combined doses. This might be due to higher availability of Calcium and Sulphur and their uptake that progressively enhanced the vegetative growth of the plant. Yang *et al*. (2001) reported alleviation effect of different ratio of Al to Ca on Al toxicity for morphological growth of mug bean seedling. Treatments with Al and Ca increased root length (4%), seedling height (5%), fresh weight (15%) and dry weight (5%). The maximum number of leaves per plant (6.67) was recorded from the treatment T_5 (100 ppm Ca + 50 ppm S) which was statistically similar to 6.00 recorded from T_3 (50 ppm S) and 5.67 recorded from T_1 (100 ppm Ca) and the minimum number of leaves per plant 4.67 was recorded from $T_{0,}$ T_2, T_7 and T_8 at 30 DAS. Number of leaves/plants were also increased to promote growth. Prasad and Srivastava (2001) studied the yielding ability in mug bean. Maximum number of leaves, leaf area and dry weight accumulation were recorded between 30-60 DAS. Calcium promotes growth while higher concentrations of Sulphur reduces the number of leaves. The maximum number of branches per plant 0.80 was observed from T_5 (100 ppm Ca + 50 ppm S) which was statistically similar 0.73 to T_1 at 30 DAS. The maximum number of branches per plant was recorded from T_1 and T_2 (1.20) which was statistically similar to T_0 (1.07) and T_5 and T_6 (1.0667). SPAD (Soil Plant Analysis Development) meter reading was analyzed and presented in order to having an idea about relative leaf chlorophyll content per unit leaf area of the mug bean. The maximum SPAD value at 30 DAS was 49.50 was recorded form T_5 (100 ppm Ca +50 ppm S) which is statistically similar to 47.91 recorded from T_3 (50 ppm S) and 47.04 from T_6 (100 ppm Ca +100 ppm S). The highest yield 1615.13 kg/ha. was gathered from T_5 of the treatment combination of 100 ppm Ca + 50 ppm S which is statistically similar with T_7 (1349.31 kg/ha) of 200 ppm Ca +50ppm S. Whereas the minimum yield given by T_0 (1041.31 kg/ha) of no treatment which is statistically similar with 1122 kg/ha of T_3 (50 ppm S). Mehta and Singh (1981) studied the response of green gram to sulphur application of elemental S increased yield by 75%. Thandapani (1989) reported that N, P, K, Ca and Mg in green gram at different growth stages increased the seed yield.

CHAPTER 5

SUMMARY

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January to July, 2018 to find out the effect of Calcium (Ca) and Sulphur (S) on the morpho-physiological characters and yield of mug bean. Mug bean (*Vigna radiata* L.) variety of BARI mug-6; high yielding variety was used in this experiment as the test crop. Data on different yield contributing characters and yield were recorded to find out the optimum levels of Calcium (Ca) and Sulphur (S) for higher yield of mung bean.

Different plant and yield parameters were significantly influenced by different interaction effect of Calcium and Sulphur showed significant differences on plant height at 30, 45 and 60 DAS. The tallest plant 34.05 cm was recorded at 30 DAS from T_6 (100 ppm Ca +100 ppm S) which is statistically similar to 34.04 cm of T_1(100 ppm Ca), at 45 DAS 47.42 cm from T_1 (100 ppm Ca) similar to 47.06 cm from T_5 (100 ppm Ca +50 ppm S) and at 60 DAS 52.27 cm fromT_5 (100 ppm Ca +5 ppm S) similar to 51.61 cm from T_1 (100 ppm Ca). The maximum number of leaves per plant (6.67, 8 and 9.07 respectively) were recorded from the treatment of T_5 (100 ppm Ca + 50 ppm S), T_1 (100 ppm Ca) and T_1(100 ppm Ca). The maximum number of branches per plant 0.80, 1.20 and 1.60 was observed from $T_{5,}$ T_1 and T_2 respectively. The minimum days to flowering (29.7) was observed from $T_{6.}$ The maximum days to flowering (32.3) was observed from T_0 which is statistically similar (32.0) to T_8 and followed (31.3) by T_7. The maximum SPAD value at 30 DAS was 49.50 for T_5, at 45 DAS was 69.88 for T_2 and at 60 DAS T_2. The maximum leaf area (132.49 cm^2) was obtained from T_3 (50 ppm S). The maximum number of flowers per plant (40.36) was observed from T_7 (200 ppm Ca + 50 ppm S). The maximum number of pods per plant (28.33) was observed from T_7 (200 ppm Ca + 50 ppm S). $T_{7,}$ T_7 and T_5 treated

plants took the minimum number of days to first ripening of fruit, days to 50 % maturity of fruit and days to 100 % maturity of fruit 48.67, 65.67 and 70.66 days respectively. The maximum no. of fertile seed of no treated plant was observed as 145.40 for T_0. The highest weight of 1000 seeds (51g) were recorded from T_5 and T_6. The highest yield 1615.13 kg/ha. was gathered from T_5 of the treatment combination of 100 ppm Ca + 50 ppm S which is statistically similar with T_7 (1349.31 kg/ha) of 200 ppm Ca +50ppm S. Whereas the minimum yield given by T_0 (1041.31 kg/ha) of no treatment which is statistically similar with 1122 kg/ha of T_3 (50 ppm S). The highest biological yield 2.62 t/ha was gathered from T_5 of the treatment combination of 100 ppm Ca + 50 ppm S which is statistically similar with 2.31 t/ha of T_2(200 ppm Ca). Whereas the minimum biological yield is 1.82 t/ha given by T_8 of (200 ppm Ca + 100 ppm S) which is statistically similar with 1.96 t/ha of $T_{0(}$control treatment). The highest harvest index 62.86% was gathered from T_8(200 ppm Ca + 100 ppm S) which is statistically similar to 61.65% recorded from T5 of the treatment combination of 100 ppm Ca + 50 ppm S. Whereas the minimum harvest index is 51.04% given by T_1 of 100 ppm Ca.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The results in this study indicated that the plants performed better for the different parameters from different treatments. It can be therefore, concluded from the above study that having better performances of T_5 (100 ppm Ca + 50 ppm S) treatment than other treatments in maximum important parameters without some parameters it is decided that T_5 (100 ppm Ca + 50 ppm S) treatment is the best treatment combination for morpho-physiological characters and yield of mung bean.

Based on the results of the present study, the following recommendation may be drawn: -

1. Application of 100 ppm Ca + 50 ppm S was the most suitable combination for higher performances of mug bean in Deep Red Brown Terrace Soils of Bangladesh and in Tejgaon series under AEZ No. 28 to get better growth and yield of mung bean and also to maintain soil fertility and productivity compared to their individual applications.
2. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.
3. This experiment was an individual one conducted in this, BARI mug-6 high yielding variety. For proper fertilizer recommendation, further regional trials should be conducted.

4. However, to reach a specific conclusion and recommendation, more research work on mug bean should be done in different agro-ecological zones of Bangladesh.

REFERENCES

Agrawal, M.M., Verma, B.S. and Kumar, C. (2000). Effect of phosphorus and sulphur on yield, N, P and S content and uptake by sunflower (*Helianthus annuus*). *Indian J. Agron.* **45**: 184-187.

Anjum, M.S., Ahmed, Z.I. and Rauf, C.A. (2006). Effect of *Rhizobium* inoculation and nitrogen fertilizer on yield and yield components of mung bean. *Intl. J. Agri. Biol*. **8**: 238-240.

Aykroyd, W.R. and Doughty, J. (1964). *Legumes in Human Nutrition*. FAO Nutritional Studies No. 19. Food and Agriculture Organization of the United Nations, Rome.

BARI (Bangladesh Agricultural Research Institute). (2004). Annual Report for 2003-04. Mung bean in Bangladesh. BARI, Gazipur. p. 28.

BBS. (2018). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of Peoples Republic of Bangladesh, Dhaka. Bangladesh. p. 79.

Duke, J.A. (1982). Handbook of Legumes of World Economic Importance. *Starch.* **34**(10): 358.

Gomez. K.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hossain, D. and Solaiman, A.R.M. (2004). Performances of mung bean varieties as affected by Rhizobium inoculants. *Bulletin Inst. Tropic. Agric.* **27**: 35-43.

Islam, M.K., Islam, S.M.A., Harun-or-Rashid, M., Hossain, A.F.M.G.F. and Alom, M.M. (2006). Effect of biofertilizer and plant growth regulators on growth of summer mung bean. *Intl. J. Bot.* **2**(1): 36-41.

Jaleel, C.A., Gopi, R., Manivannan, P. and Panneerselvam, R. (2007). Antioxidative potentials as a protective mechanism in *catharanthus roseus* (L.) G.Don. Plants under salinity stress. *Turkish J. bot.* **31**(3): 245–251.

Kader, M.A. and Lindberg, S. (2010). Cytosolic calcium and pH signaling in plants under salinity stress. *Plant Signal. Behav.* **5**(3): 233–238.

Kang, Y.J., Kim, S.K., Kim, M.Y., Lestari, P. and Kim, K.H. (2014). Genome sequence of mung bean and insights into evolution within Vigna species. *Nat. Commun*. **5**: 5443.

Khan, M.N., Siddiqui, M., Mohammad, F. and Naeem, M. (2010). Calcium chloride and gibberellic acid protect linseed (*Linum usitatissimum* L.) from NaCl stress by inducing antioxidative defence system and osmoprotectant accumulation. *Acta Physiologiae Plantarum*. **32**: 121-132.

Lawlor, D.W. (2002). Limitation to photosynthesis in water stressed leaves: Stomata vs. metabolism and the role of ATP. *Ann. Bot.* **89**: 1–15.

Mazed, H.E.M.K., Moonmoon, J.F., Haque, M.N., Pulok, M.A.I. and Rahman, M.H. (2015). Growth and yield of Mung bean as influenced by potassium and sulphur. *Annals Bio. Res*. **6**(1): 6-10

Misra, N. and Gupta, A. (2006). Interactive Effects of Sodium and Calcium on Proline Metabolism in Salt Tolerant Green Gram Cultivar. *American J. Plant Physio*. **1**: 10.

Mohammad, D. and Hossain, I. (2003). Seed treatment with biofertilizer in controlling foot and root rot of mung bean. *Pakistan J. Plant Patho*. **2**(2): 91-96.

Nita, C., Mondal, S.S., Arup, G., Brahmachari, K. and Pal, A.K. (2002). Effect of potassium and sulphur on mung bean in relation to growth, productivity and fertility buildup of soil. *J. Intl. Acad.* **6**(3): 266-271.

Pandey, S.P. and Singh, R.S. (2001). Responses of phosphorus and sulphur on yield and quality of summer moong. *Crop Res. Hisar*. **22**(2): 206-209.

Patel, L.R., Salvi, N.M. and Patel, R.H. (1992). Response of green gram (*Phaseolus vulgaris*) varieties to sulphur fertilization under different levels of nitrogen and phosphorus. *Indian J. Agron.* **37**(4): 831-833.

Prasad, S. and Srivastava, J.P. (2001). Physiological analysis of yielding ability in mung bean. *Indian J. Pulse Res*., **12** (1): 49-56.

Quaderi, R.S., Islam, S.M.A., Hossain, A.F.M.G.F., Hoque, M.M. and Haque, M.S. (2006). Influence of seed treatment with indole acitic acid on mung bean cultivation. *Intl. J. Bot*. **2**(1): 42-47.

Rahman, M.M., Bakr, M.A., Mia, M.F., Idris, K.M., Gowda, C.L.L., Kumar, J., Deb, U.K., Malek, M.A. and Sobhan, A. (2000). Legumes in Bangladesh: Legumes in rice and wheat cropping systems of the indo-gangetic plain - constraints and opportunities. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India. pp. 5-34.

Rahman, M.S., Eunus, M. and Awal, M.A. (2005). Dry matter production and partitioning of mung bean (*Vigna radiata* I.) varieties as influenced by sowing date and planting method in summer. *Bangladesh J. Training Dev.* **15**(1/2): 193-199.

Ram, S. and Katiyar, T.P.S. (2013). Effect of sulphur and zinc on the seed yield and protein content of summer mung bean under arid climate. *Intl. J. Sci. Nat.* **4**(3): 563-566.

Saidi, Y., Finka, A. and Goloubinoff, P. (2010). Heat perception and signaling in plants: A tortuous path to thermotolerance. *The New phytologist*. **190**: 556-565.

Shahi, D.K., Sharma, A. and Lal, S. (2002). Improving protein quality of green gram through use of Rhizobium inoculation, phosphorus and sulphur. *J. Res. Birsa Agril. Univ*. **14**(2): 171-174.

Shamsuzzaman, A.M.M., Alam, M.S., Mondal, G. and Ahamed, K.U. (2004). Growth and yield response of summer mung bean to irrigation frequency. *J. Agric. Rural Dev.* **2**(1): 95-100.

Sharma, S.C., Tiwari, H.O. and Tiwari, R.J. (1995). Effect of nitrogen, phosphorus and sulphur on the micronutrient content of black gram. *Crop Res. Hisar*. **9**(1): 54-58.

Sehrawat, N. Jaiwal, P.K. Yadav, M. Bhat K.V. and Sairam. R.K. (2013). Salinity stress restraining mung bean (*Vigna radiata* L. Wilczek) production: Gateway for genetic improvement. *Intl J. Agri. Crop Sci,* **6** (9): 505-509.

Siag, R.K. and Yadav, B.S. (2003). Effect of levels and methods of Sulphur application on growth and yield of mung bean. *Indian J. Pulses Res.* **16**(2): 159-160.

Singh, J.P., Farafdar, J.C. and Gupta, B.R. (1997). Sulphur fertilization for increased production of summer Moong. *J. Indian Soc. Soil Sci.* **45**(3): 526-528.

Singh, R., Parihar, P. and Prasad, S.M. (2018). Simultaneous exposure of sulphur and calcium hinder as toxicity: up-regulation of growth, mineral nutrients uptake and antioxidants system. *J. Eco. Env.* **10**.1016.

Sipai, A.H. and Jat, J.R. (2016). Effect of phosphorus, sulphur and bio-fertilizer on growth, yield and nodulation in mungbean on loamy sand soils of kutch. *J. Plant Physiol. Patho*. **4**: 2.

Srinivasrao, C., Arakalagud, G., Ali, M. and Singh, R.N. (2004). Sulphur fractions, distribution, and their relationships with soil properties in different soil types of major pulse-growing regions of India. *Comm. Soil Sci. Plant Analysis.* **20**(19): 2757-2769.

Suhatatik, E. (1991). Residual effect of lime and organic fertilizer on mung bean (Vigna radiata L.) on red yellow podzolic soil. *In Semi. of Food Crops Res.* Balittan, Bogor, Indonesia. **2**: 267-275.

Tiwari, R.C. and Chaplot, P.C. (1995). Effect of irrigation schedules and Sulphur levels on summer mung bean. *Indian J. Pulses Res.* **8**(2): 149-151.

Thandapani, V. (1989). Nutrient content of nitrogen, phosphorus, potassium, calcium and magnesium in green gram [*Vigna radiata* (L.) Wilczek] at different growth stages in relation to yield. *Madras agric. J.,* **72** (6): 305-310

Tripathi, P.K., Singh, M.K, Singh, J.P. and Singh, O.N. (2012). Effect of rhizobial strains and sulphur nutrition on mung bean (*Vigna radiata* L.) cultivars under dryland agro-ecosystem of Indo-Gangetic plain. *African J. Agril. Res*. **7**: 34-42.

Trivedi, S.K., Singh, V. and Shinde, C.P. (1997). Effect of nitrogen, phosphorus and sulphur on yield and chemical composition of black gram (*Phaseolus mungo*). *Gujarat Agric. Univ. Res. J.* **22**(2): 46-50.

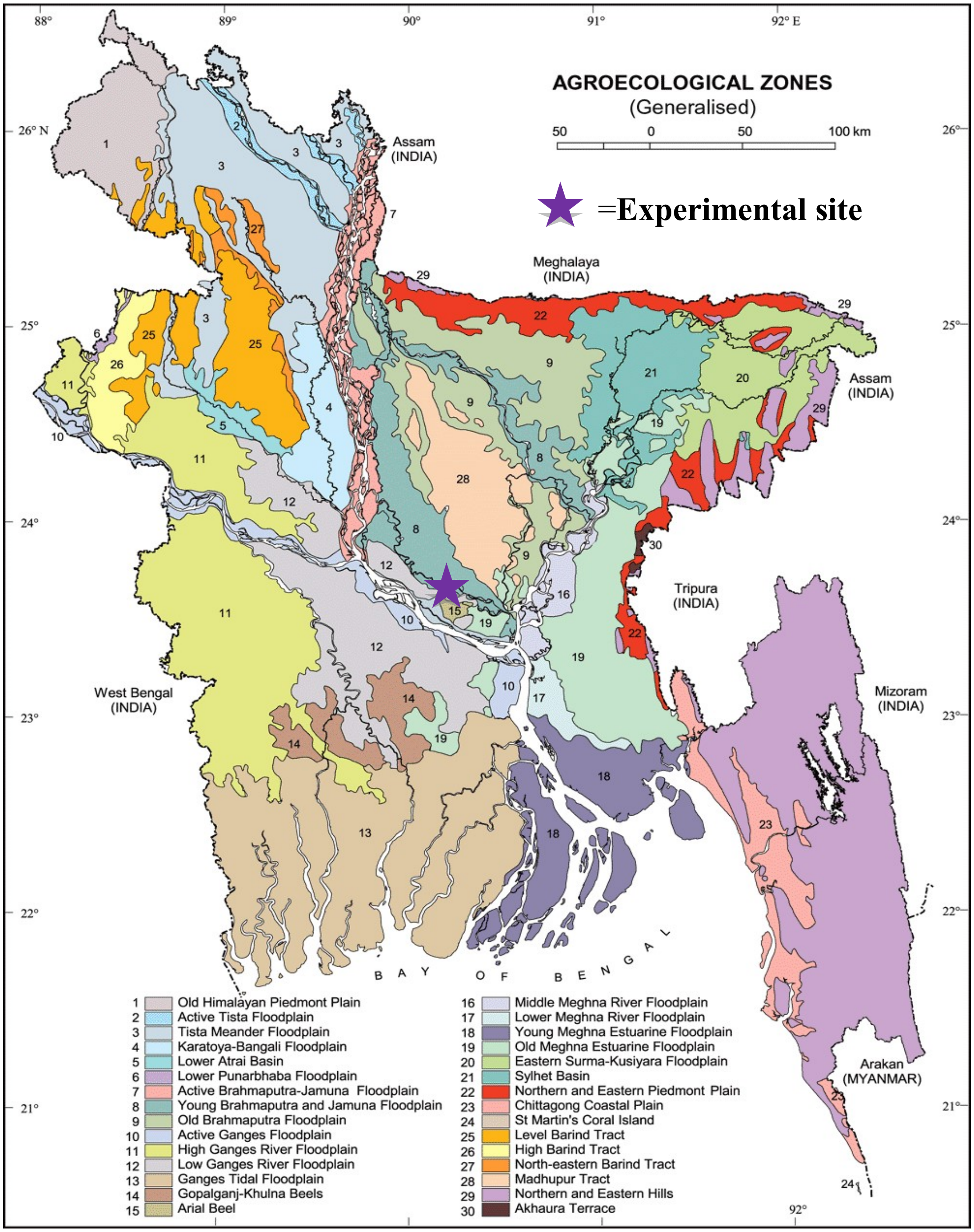
Tuteja, N. and Mahajan, S. (2007). Calcium Signaling Network in Plants. *Plant Sig. Behav.* **2**(2): 79-85.

Yadav, S.S. (2007). Growth and yield of green gram (*Vigna radiata L.*) as influenced by phosphorus and sulphur fertilization. *Haryana J. Agron.* **20**(1/2): 10-12.

Yang, Y.H., Chen, S.M. and Abdullaha, B.A. (2001). Alleviation effect of different ratios of Al to Ca on Al toxicity for morphological growth of mung bean seedling. *J. Plant Nutrition*. **24**(3): 573-583.

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from February, 2018 to May, 2018

Year	Month	Air temperature (^0C) Maximum	Minimum	Relative humidity (%)	Total rainfall (mm)
2018	February	28.10	11.83	58.18	00
	March	25.00	13.46	69.53	35
	April	29.20	18.8	69	110
	May	33.30	19.9	66	119

Source : Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on plant height of mung bean as influenced by Calcium and Sulphur

Source of variation	df	Mean square of plant height at different days after transplanting		
		30 DAS	45 DAS	60 DAS
Treatment	8	4.11787*	6.95176*	12.217*
Error	18	1.90037	7.35926	5.8200
Total	26	6.0178	14.310	18.037
CV		4.17	5.91	4.82
Grand mean		33.096	45.919	50.33

*Significant at 5% level of significance

Appendix V. Analysis of variance of the data on no. of leaves plant^{-1} of mung bean as influenced by Calcium and Sulphur

Source of variation	df	Mean square of no. of leaves plant^{-1} at different days after transplanting		
		30 DAS	45 DAS	60 DAS
Treatment	8	0.44000*	1.42000*	1.71148*
Error	18	0.50815	1.47259	0.44000
Total	26	0.5481	2.8925	2.151
CV		12.99	17.23	8.64
Grand mean		5.4889	7.0444	7.6741

*Significant at 5% level of significance

Appendix VI. Analysis of variance of the data on no. of branches plant^{-1} of mung bean as influenced by Calcium and Sulphur

Source of variation	df	Mean square of no. of branches plant^{-1} at different days after transplanting		
		30 DAS	**45 DAS**	**60 DAS**
Treatment	8	0.11037*	0.29259*	0.48815*
Error	18	0.04889	0.12889	0.17481
Total	26	0.1592	0.4213	0.6629
CV		39.28	40.73	1.0741
Grand mean		0.5630	0.8815	38.93

*Significant at 5% level of significance

Appendix VII. Analysis of variance of the data on SPAD value of mung bean as influenced by Calcium and Sulphur

Source of variation	df	Mean square of SPAD at different days after transplanting		
		30 DAS	**45 DAS**	**60 DAS**
Treatment	8	8.71451*	7.71849*	5.66500*
Error	18	9.44311	4.49134	7.56853
Total	26	18.1575	12.2098	13.2335
CV		46.316	67.513	70.900
Grand mean		6.63	3.14	3.88

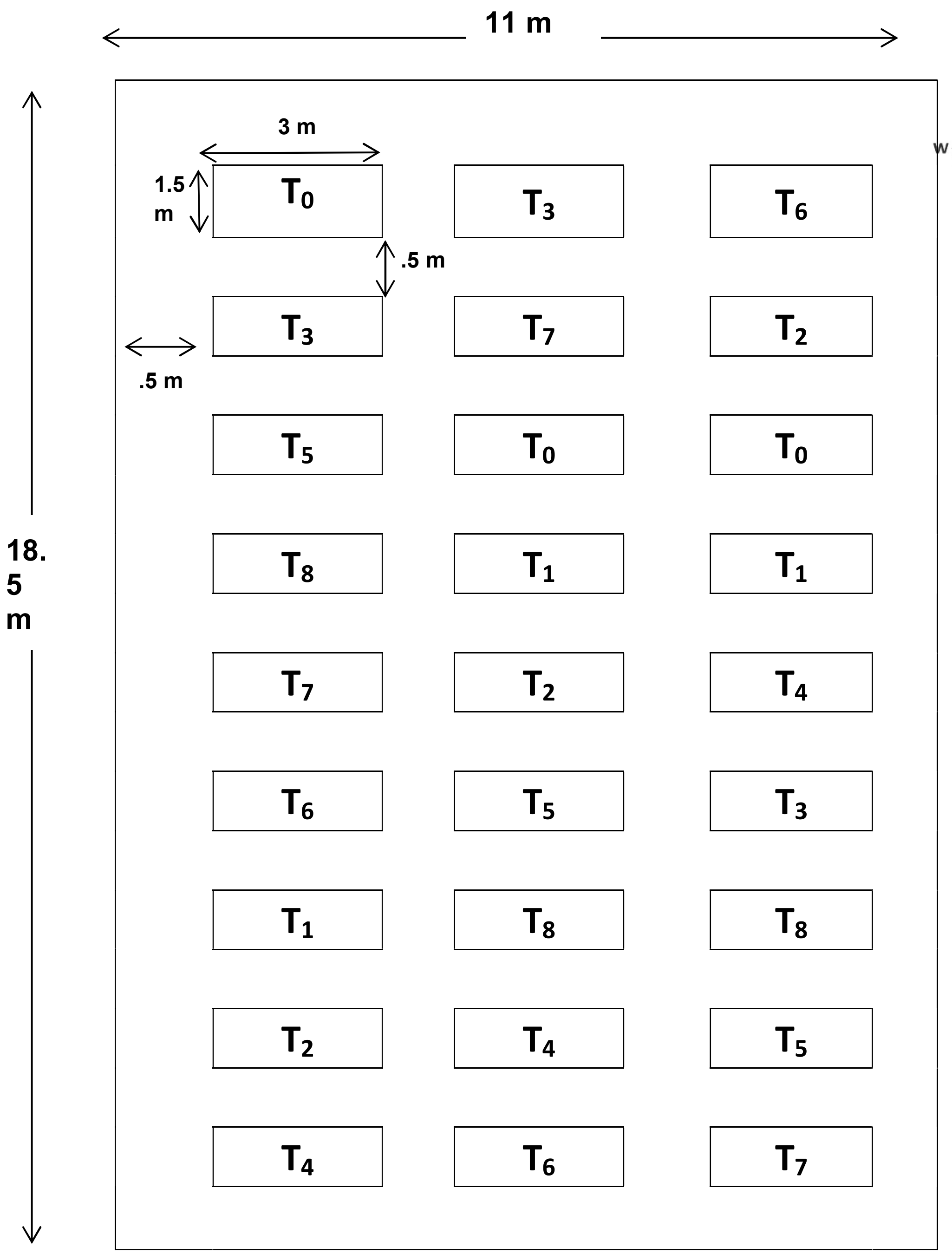
*Significant at 5% level of significance

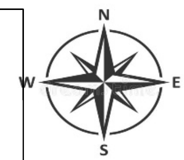
Appendix VIII. Analysis of variance of the data on Interaction effect of Calcium and Sulphur on thousand seed weight, seed Yield/plot, biological yield/plot and harvest Index of mung bean

Source of variation	df	Mean square of			
		Thousand seed weight	Seed Yield/plot	Biological yield/plot	Harvest Index
Treatment		7.03704*	2886.15*	7.12037*	29.6080*
Error		1.07407	4323.59	1.81481	18.5254
Total		8.1144	7209.74	8.93518	48.1334
CV		3.41	29.21	2.296	29.97
Grand mean		49.296	225.07	2.2963	14.450

*Significant at 5% level of significance

Appendix IX: Layout of the experimental design





Plot size= (3× 1.5) m^2

Plot spacing- 0.5 m

Treatment:

T_0- No treatment

T_1- 100 ppm Ca

T_2- 200 ppm Ca

T_3- 50 ppm S

T_4- 100 ppm S

T_5- 100 ppm Ca + 50 ppm S

PLATES

Plate 1. Collected seed of BARI mung 6

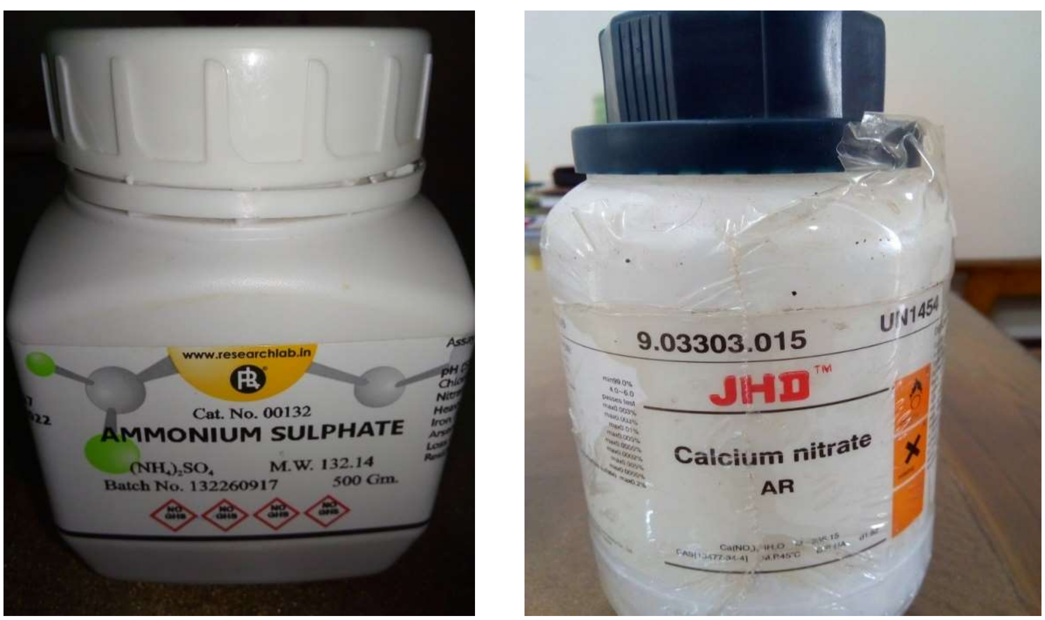


Plate 2. Chemicals used for experiment as treatment

Plate 3. Fertilizer application

Plate 4. Seed sowing

Plate 5. Field inspection by supervisor Prof. Dr. Ashabul Haque

Plate 6. Intercultural operations(weeding and thining)

A **B**

C

Plate 7. Data Collection {A. Plant height; B. SPAD value; C. Leaf Area Index (LAI)}

Plate 8. Signboard of the experiment