GROWTH AND YIELD RESPONSE TO MUNGBEAN UNDER DIFFERENT LEVELS OF SULFUR AND POTASSIUM FERTILIZER APPLICATION

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CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD RESPONSE OF MUNGBEAN UNDER DIFFERENT LEVELS TO SULFUR AND POTASSIUM FERTILIZER APPLICATION"*** submitted to the Department of ***Agronomy*** Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (MS)** in ***AGRONOMY***, embodies the result of a piece of bona fide research work carried out by ***FALGUNI KARMOKAR***, ***Registration No. 18-09159*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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GROWTH AND YIELD RESPONSE TO MUNGBEAN UNDER DIFFERENT LEVELS OF SULFUR AND POTASSIUM FERTILIZER APPLICATION

ABSTRACT

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during March to June, 2019 to study the effect of different levels of sulfur and potassium fertilizer application on the growth and yield of BARI Mung-6. In this experiment, the treatment consisted of 2 factors. Factor A: sulfur levels (4) *viz*. S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1} and Factor B: potassium level (4) *viz*. K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications and each replication had 16 unit plots. BARI Mung-6 seeds were sown at the rate of 40 kg ha^{-1} in furrows. Data on different yield contributing characters and yield were recorded and statistically analyzed for evaluating the treatments effect to find out the suitable levels of sulfur and potassium fertilizer application for the highest yield of mungbean. In case of different level of sulfur fertilizer application, the highest number of branches $plant^{-1}$ (3.55), pods $plant^{-1}$ (14.72), seeds pod^{-1} (9.74), 1000 seeds weight (51.27 g), seed yield (1.24 t ha^{-1}), stover yield (2.35 t ha^{-1}) and biological yield (3.59 t ha^{-1}) were observed in S_2 (6 kg S ha^{-1}) treatment. In case of different level of potassium fertilizer application, the highest number of branches $plant^{-1}$ (3.57), pods $plant^{-1}$ (14.20), seeds pod^{-1} (9.65), 1000 seeds weight (51.16 g), seed yield (1.24 t ha^{-1}), stover yield (2.36 t ha^{-1}) and biological yield (3.6 t ha^{-1}) were observed in K_2 (40 kg K ha^{-1}) treatment. In case of the combined effect, the highest number of branches $plant^{-1}$ (4.73), pods $plant^{-1}$ (16.47), seeds pod^{-1} (10.87), 1000 seeds weight (56 g), seed yield (1.51 t ha^{-1}), stover yield (2.92 t ha^{-1}) and biological yield (4.43 t ha^{-1}) were observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination and the corresponding lowest value was observed in control treatment.

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LIST OF ABBREVIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAE	=	Department of Agricultural Extension
DAS	=	Days after sowing
^0C	=	Degree Celsius
et al	=	And others
FAO	=	Food and Agriculture Organization
G	=	gram(s)
ha^{-1}	=	Per hectare
HI	=	Harvest Index
Kg	=	Kilogram
Max.	=	Maximum
mg	=	Milligram
Min.	=	Minimum
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NS	=	Not significant
%	=	Percent
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
TSP	=	Triple Super Phosphate
Wt.	=	Weight

CHAPTER I
INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the most important short durated pulse crop in Bangladesh and other South Asian countries. It belongs to the family of Leguminosae. Mungbean, also known as green gram or golden gram, is used as a foodstuff in both savory and sweet dishes. Its seed is more palatable, nutritive, digestible and non-flatulent than other pulses (Anjum *et al*., 2006). It not only plays an important role in human diet but also in improving the soil fertility by fixing the atmospheric nitrogen (Nadeem *et al*., 2004) through symbiotic relationship with Rhizobia. It can fix N in soil by 63-342 kg ha^{-1} per season (Kaisher *et al*., 2010). Mungbean contains 59.9% carbohydrate, 24.5% protein, 75 mg calcium, 8.5 mg iron and 49 mg β-carotene per 100g of split dal (Afzal *et al*., 2004). The foliage and stems using as fodder for livestock. Hence, on the nutritional point of view, mungbean is perhaps the best crop of all other pulses (Khan, 1981 and Kaul, 1982). The total production of pulses is only 0.65 million tons in Bangladesh against the requirement of 2.7 million tons i.e., shortage is almost 80% of the total requirement which is mostly due to low yield (MoA, 2005). In Bangladesh per capita consumption of pulses is only 14.72 g (BBS, 2012) as against 45.0 g recommended by World Health Organization. For maintaining the supply of this level, pulse production should be increased urgently to meet up the demand. Among all other pulses, mungbean ranks third in area and production but first in market price. The total production of mungbean in Bangladesh in 2011-12 was 19,972 metric tons from an area of 20,117 hectares with average yield is about 0.98 tons ha^{-1} (BBS, 2012). So, the importance of pulse production is very much topical for food and improving the farm-family income in order to ensure food security, nutritional security and economic security.

Mungbean is highly responsive to fertilizers and manures. 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 mungbean (Hoque *et al*., 2004; Singh *et al*., 2013). The crop has a marked response to nitrogen, phosphorus and potassium. These nutrients play a key role in plant physiological process. A balanced supply of essential nutrients is indispensable for optimum plant growth. Continuous use of large amount of N, P, K, S and B are expected to influence not only the availability of other nutrients to plants because of possible interaction between them but also the buildup of some of the nutrients creating imbalances in soils and plants leading to decrease fertilizer use efficiency (Nayyar and Chhibbam, 1992).

Among the essential plant nutrients, potassium is the third macronutrient required for plant growth, after nitrogen and phosphorus (Abbas *et al*., 2011) and also plays a vital role as macronutrient in plant growth and sustainable crop production (Baligar *et al.*, 2001). Potassium plays a remarkable role in plant physiological processes. Potassium is not only a constituent of the plant structure but it also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism and enzyme activation. Several physiological processes depend on K such as stomatal regulation and photosynthesis (Hasanuzzaman *et al.*, 2018). It influences nutrient uptake by promoting root growth and nodulation. Sangakara (1990) carried out a field experiment to study the effects of 0-120 kg K_2O ha^{-1} on growth, yield parameters and seed quality of mungbean and reported that K application increased plant growth rate, flowers/plant, percent pod set seeds/pod, 1000 seed weight and yield/plant. Its adequate supply during growth period improves the water relations of plant and photosynthesis (Garg *et al.*, 2005), maintains turgor pressure of cell which is necessary for cell expansion, helps in osmotic-regulation of plant cell, assists in opening and closing of stomata (Yang, *et al*., 2004), activates more than 60 enzymes (Bukhsh, *et al*., 2012), synthesizes the protein, creates resistance against the pest attack and diseases and enhances the mungbean yield (Ali *et al.*, 2010).

Moreover, sulphur plays as an important macro nutrient element, next to NPK that has a profound effect on pulse crops. In broad sense, the functions of nitrogen and sulphur are similar and they are synergistic. Sulfur plays a remarkable role in protein metabolism and it is required for the synthesis of proteins, vitamins and chlorophyll. The S containing amino acids such as Methionine (21% S) and Cysteine (27%) which are essential components for proteins (Kumar *et al*., 2012). 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. The deficiency of S induces chlorosis in young leaves and decreases seed yield by 45% (BARI, 2004).

However, inadequate application of fertilizer is one of the major constrains to low productivity of mungbean (Jackson, 2010). Farmers have a wrong view that mungbean does not need fertilizers. It is noted that a standard levels of potassium and sulfur give better yield of mungbean. So, there is an adequate scope of increasing the yield of mungbean by using balanced fertilization including both potassium and sulfur containing fertilizers. For these reasons, the study was undertaken with the following objectives:

i) To evaluate the effect of different levels of sulfur on the growth and yield of mungbean.
ii) To determine the effect of different levels of potassium on growth and yield of mungbean and
iii) To evaluate the interaction effect of sulfur and potassium on growth and yield of mungbean.

CHAPTER II
REVIEW OF LITERATURE

Mungbean is greatly influenced by sulfur and potassium application. Following review of literature includes reports as studied by several investigators who were engaged in understanding the problems that may help in the explanation and interpretation of results of the present investigation. In this chapter, an attempt has been made to review the available information in home and abroad regarding the effect of K and S on the growth and yield of mungbean.

2.1 Effect of sulfur on growth, yield and yield attributes

Parmar *et al.* (2021) concluded that an application of 60 kg P_2O_5, 20 kg S ha^{-1} and seed inoculation of PSB recorded significantly higher number of branches $plant^{-1}$, number of pods $plant^{-1}$, seeds pod^{-1}, seed yield (kg ha^{-1}) and stover yield (kg ha^{-1}) while protein content was remained unaffected

Laxmi *et al.* (2020) evaluated that the yield of mungbean was increased with the increasing dose of sulfur significantly up to 30 kg ha^{-1}. However, increasing doses of boron were not found significant on yield. The maximum yield was found with T4 -30 kg S ha^{-1} + 0 kg B ha^{-1} (12.171 mg/pot). Uptake of available nutrients N, P, K, S and B increased significantly up to 30 kg S ha^{-1}.

Phogat *et al.* (2020) stated that combined application of phosphorus and sulfur showed synergistic effect on seed and stover yield of black gram with increasing levels of phosphorus and sulfur up to highest level as both the nutrients mutually help absorption and utilization by black gram probably due to balanced nutrition. The seed and stover yield were 955.50 and 2398.30 kg ha^{-1} with combined application of phosphorus 60 kg and sulfur 30 kg ha^{-1}. The yield attributes of black gram viz., plant height, number of pods $plant^{-1}$ and 100 seeds weight also increased significantly with increasing levels of phosphorus and sulfur up to highest level and the optimum values were recorded with combined application of phosphorus 60 kg and sulfur 30 kg ha^{-1}.

Patel *et al.* (2020) investigated the effect of sulphur (0,10, 20 and 30 kg/ha) and three levels of boron (0,1 and 2 kg/ha) on growth and yield of mungbean as test crop. The results indicated that the crop responded significantly to sulphur and boron in respect of growth and yield such as plant height, number of branches/plant, pods/plant, pod length, number of seeds/pod, test weight, seed yield, straw yield. In the combination of sulphur and boron, all the parameters were significant by influence. Maximum seed yield was recorded in treatment combination of 30 kg S ha^{-1} and 2 kg B ha^{-1}.

Thakor *et al.* (2020) concluded that green gram variety GM-7 with sulfur application 20 kg/ ha along with a full recommended dose of fertilizer (20:40:00 NPK kg/ha) improve the nutrient status of soil and it also maintains the fertility status of soil because green gram is considering a soil restoring crop.

Krishna *et al.* (2019) conducted a field trial to study mungbean crop performance and production potential under sulfur fertilization with recommended dose of NPK whereby, 17 treatments were replicated thrice. The maximum plant height (51.2 cm), seed yield plant-^{1} (5.7 g) and pods $plant^{-1}$ (16.0) were recorded under (T15:100% RD of NPK+S). T15:100% RD of NPK+S was found significantly superior to other treatments and recorded maximum grain yield (1524 Kg ha^{-1}). T15:100% RD of NPK+S was significantly superior to all treatments except T16:125% RD of NPK+S and recorded maximum stover yield (2696 Kg ha^{-1}). T15:100% RD of NPK+S recorded significantly superior harvest index followed by T14:75% RD of NPK+S and T16:125% RD of NPK+S. The maximum production efficiency (25.4 $Kgday^{-1}$ ha-^{1}) was recorded in T15:100% RD of NPK+S which was at par with T16:125% RD of NPK+S and significantly higher compared to all other treatments.

Dharwe *et al.* (2019) mentioned that sulfur has pivotal role in synthesis of vitamin (biotin and thiamine) and sulfur containing amino acids like cysteine, cystine and methionine, besides glutathione and improves nodulation in legumes. Saini (2017) observed that 40 kg S ha^{-1} as gypsum + 0.5% $FeSO_4$ foliar spray showed highest yield (716.67 kg ha^{-1}) in green gram.

Marko *et al.* (2014) carried out an experiment to evaluate the effect of sulphur and biofertilizers on nutrient contents and uptake of blackgram. The nutrient contents in grain and straw viz., N, P, K and S deviated significantly due to sulphur levels and biofertilizers as well as their interactions. The highest sulphur level (60 kg/ha) and dual biofertilizers (Rhizobium+PSB) resulted in almost significantly higher N, P, K and S contents and their uptake of blackgram. The highest uptake of nutrients by blackgram producing a total biomass up to 31.36 q/ha with highest S level was 99.56 kg N, 11.70 kg P, 52.07 kg K and 5.41 kg S/ha. Similarly, under dual biofertilizers, the corresponding uptake values were 101.61 kg N, 10.62 kg P, 53.20 kg K and 5.57 kg S/ha.

2.2 Effect of potassium on growth, yield and yield attributes

Gadi *et al.* (2020) observed that 60 kg P_2O_5 ha^{-1} resulted significantly higher plant height, number of branches per plant, number of pods per plant, grain yield, stover yield, nutrient content and nutrient uptake as compared to other levels of phosphorus. Application of potassium also significantly enhanced the growth, yield attributes, yield, nutrient content and uptake by green gram. Application of 60 kg P_2O_5 ha-1 increased the seed yield by 19.1% and stover yield by 46.1% over control. Application of 60 kg K_2O ha-1 increased the seed yield to the extent of 18.3% and stover yield up to 14.5% over control.

Sekhar *et al.* (2020) concluded that N (20Kg/ha) with K(20Kg/ha) was found to be the best treatment for obtaining higher growth and yield attributes viz., plant height (46.47 cm) at 60 DAS, dry weight (16.930 g) at 60 DAS, Crop Growth Rate (9.78 g m-^{2} day^{-1}) at 60 DAS, number of branches/plant (5.88) at 60 DAS, number of nodules/plant (30.89) at 45 DAS, number of pods/plant (16.33) and test weight (40.33 g) were obtained with green gram.

Bagadkar *et al.* (2020) mentioned that growth traits viz., plant height (cm), number of branches plant^{-1}, dry matter plant^{-1} (gm) and chlorophyll content index were found significantly superior in the treatment with application of RDF + 40 kg K_2O ha^{-1} than rest of graded potassium level treatments. However, the yield and quality contributing attributes i.e., pod length (cm), Number of pods plant^{-1}, Number of seeds pod-1, Weight of seeds plant^{-1}, 1000 seed wt (g) seed yield kg ha^{-1}, Straw yield kg ha^{-1}, Biological yield kg ha^{-1} and Protein content (%) were registered significantly superior in the treatment with application of RDF + 40 kg K_2O ha^{-1} than other graded potassium level treatments.

Ghule *et al.* (2020) concluded that the application of 100% of RDF (20: 40 N, P2O5 kg/ha) was found beneficial in increasing the yield, nutrient content (%) and uptake of

NPK by summer green gram. Among the potassium levels application of 20 K_2O kg ha^{-1} was found maximum yield, nutrient content (%) and uptake of NPK of summer green gram.

Sachan *et al.* (2020) stated that treatment 100% NPK+ PM @ 5 t/ha recorded maximum plant height (65.61 cm), number of leaves (26.0 per plant), number of branches (13.27 per plant) and leaf area (113.0 cm2) followed by 100 % NPK + FYM @ 12 t/ha and PM @ 5 t/ha. Treatment 100% NPK+ PM @ 5 t/ha also recorded significantly higher maximum yield (1.83 t/ha), stover yield (2.99 t/ ha) and production efficiency (13.94 kg/day/ha). The above findings concluded that the combination of 100 % NPK (200 kg/ha) along with poultry manure @ 5 t/ha is the optimum dose of organic and inorganic fertilizers to enhance the growth and yield of mung bean.

Quddus *et al.* (2019) conducted a research to understand the effects of potassium (K) on mungbean productivity, quality, nutrient content and nutrient uptake and how this element can help to manage soil fertility. The treatments were T1 = Control, T2 = 30 kg K ha-^{1}, T3= 40 kg K ha-^{1}, T4= 50 kg K ha-^{1}, T5= 60 kg K ha-^{1} and T6= 70 kg K ha-^{1} along with the blanket dose of N15 P20 S10 Zn2 B1.5 kg ha-^{1}. Results revealed that application of different levels of potassium showed significant effects on the plant height, number of pods per plant, number of seeds per pod and 1000 seeds weight which were influenced to obtain higher yield of mungbean. The highest average seed yield (1476 kg ha-^{1}) and highest yield increment (39.5%) of mungbean were produced from the treatment T5. Most of the cases the highest nutrient (N, P, K, S, Zn and B) content was obtained in T5 treatment. The highest K uptake by mungbean, maximum nodulation, the highest protein content in seed and maximum apparent K recovery efficiency (54.8%) however, recorded from the treatment receiving of 60 kg K ha-^{1}.

Amrutsagar *et al.* (2019) observed that inclusion of K in fertilization schedule gave 9.5% higher yield in kharif blackgram and robi sorghum crops. K from 30 to 60 kg K_2O ha^{-1} showed significant grain and stover yield.

Sindhu *et al.* (2019) concluded that increasing amount of potassium results higher plant growth and yielding parameters. Application of potassium in the form of K_2SO_4 at 40 kg ha^{-1} increases the growth characters of green gram.

Krishna *et al.* (2019) reported that application of 100% RD of NPK + S showed the highest results in case of seed yield of mungbean. Bansal *et al.* (2018) observed a significant increase in rice productivity (ranging from 6 to 15%) due to K fertilizer application.

Hussain *et al*. (2016) conducted a research work to evaluate the performance of two mungbean varieties (Mung-06 and NM-92) against five potassium levels ([control, without K], 50, 75, 100 and 125 kg ha^{-1}). Mungbean variety NM-92 showed better performance than Mung-06 with seed germination (11.93 m^{-2}), plant height (44.40 cm), branches $plant^{-1}$ (12.79), pods $plant^{-1}$ (48.40), seeds $plant^{-1}$ (281.42), seed weight $plant^{-1}$ (15.22 g), seed index (37.14 g), seed yield (1802 kg ha^{-1}), biological yield (4371.68 kg ha^{-1}) and harvest index (41.71%). On the other hand, variety Mung-06 ranked 2nd with for the studied traits. The effect of potash levels on mungbean indicated that the mungbean crop fertilized with 125 kg ha^{-1} potash in addition to recommended rates of N and P, had higher number of seeds germinated (3.50 m^{-2}), plant height (45.50 cm), branches $plant^{-1}$ (13.22), pods $plant^{-1}$ (49.60), seeds plant-^{1} (290.44), seed weight $plant^{-1}$ (15.55 g), seed index (39.27 g), seed yield (1869.90 kg ha^{-1}), biological yield (4826.40 kg ha^{-1}) and harvest index (38.74%) followed by the plots supplied with 100 kg ha^{-1} potash.

Buriro *et al*. (2015) evaluated growth and yield response of two mungbean (Mung-06 and NM-92) varieties to different application rates of potassium under field condition. Plants were fertilized with five K (00, 50, 75, 100 and 125 kg ha^{-1}) levels. The data obtained from the study indicated that there was significant effect of potassium levels on growth, yield and yield components of both varieties. Compared to Mung-06, the variety NM-92 performed well by displaying maximum seed germination, taller plants with more branches, pods, seeds and biological yield. In addition to the recommended rates of nitrogen and phosphorus, the K applied @ 125 kg ha^{-1} significantly increased seed germination, plant height, number of branches per plant, number of pods, seed index and biological yield (kg ha^{-1}) as well. The difference between 125 and 100 kg K ha^{-1} rates for mjority of the growth and yield parameters under study remained non-significant. However, the plants given 75, 50 and 00 kg K ha-^{1} ranked 3rd, 4th and 5th, respectively for all the recorded yield parameters. It is, therefore, concluded that 100 kg K ha^{-1} can be the effective rate for achieving economically higher mungbean yield.

2.3 Interaction effect of sulfur and potassium on growth, yield and yield attributes

Mazed *et al*. (2015) stated that the growth and yield of mungbean are significantly influenced by potassium (K) and sulfur (S). Four levels of K (0, 15, 25 and 35 kg ha^{-1}) and three levels of S (0, 3 and 6 kg ha-1) were used in the study. The results reveald that grain and stover yield of mungbean increased with increasing levels of K and S. The maximum significant grain and stover yield were obtained with the treatment combinations K2S2 (25 kg K ha-1 + 6 kg S ha-1) and the same treatments combinations showed the highest plant height, number of branch plant-1 and the yield attributes like number of pods plant-1, number of grains pod-1, weight of 1000 seeds.

Thesiya *et al.* (2013) carried out a research during the kharif season of the year 2003 to study the effect of potassium and sulphur on the growth and yield of mungbean (*Vigna radiata* L.) under rainfed condition. There was a significant effect of potash and sulphur levels on plant height, number of branches per plant, number of pods per plant, length of pod, 100-grain weight, straw yield and grain yield. Significantly the highest grain yield (9.17 q ha^{-1}) and stover (18.28 q ha^{-1}) yield was recorded with 40 kg K_2O ha^{-1}. Application of sulfur at 30 kg S ha^{-1}gave significantly the highest grain (9.19 q ha^{-1}) and stover (18.06 q ha^{-1}) yield. Combined application of 20 kg K_2O ha^{-1} and 30 kg S ha^{-1} showed the significant result in respect of yield attributes and yield.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the effect of sulfur and potassium on the growth and yield of BARI Mung-6. Materials used and methodologies followed in the present investigation have been described in this chapter

3.1 Experimental period

The experiment was conducted during the period from March to June-2019 in Kharif-I season

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Appendix-II). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.3 Soil

The soil texture was silty clay with pH 5.6. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from

March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix- III.

3.5 Plant materials

VARIETY: BARI Mung-6	
Main Features of the Variety	
Developed by	Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh
Method of development/origin	Introduced from AVRDC
Year of release	2003
Main characteristics	Plant height 40-45 cm, photo insensitive and can be grown in Kharif-I, Kharif-II and late Rabi, after flowering stage plant growth become stunted, leaf and seed color deep green and leaf broad, seed large shaped with smooth seed coat, pods matured at a same stage. Grain large, 1000 seed weight 51-52 g, after wheat harvest sowing up to April first week, It is sowing also Kharif-2 and Rabi season, crop duration 55-58 days.
Planting season and time	Last February to mid-March (Kharif-1); First August to last September (Kharif-II).
Yield	1.6-2.0 t/ha
Resistance/tolerance	Tolerant to *Cercospora* leaf spot and yellow mosaic virus

3.6 Treatments used in the study

There were two fertilizers used for sources of sulfur and potassium in the experiment namely Muriate of Potash and Gypsum as variables of the experiment mentioned below:

Factor A. Rates of sulfur (4 levels):

1. S_0 = No sulfur (Control)
2. S_1 = 3 kg S ha^{-1}
3. S_2 = 6 kg S ha^{-1}
4. S_3 = 12 kg S ha^{-1}

Factor B. Rates of potassium (4 levels):

1. K_0 = No potassium (Control)
2. K_1 = 20 kg K ha^{-1}
3. K_2 = 40 kg K ha^{-1}
4. K_3 = 60 kg K ha^{-1}

Treatment combination: There were sixteen combinations of treatment considered for the experimentation as below:

S_0K_0, S_0K_1, S_0K_2, S_0K_3, S_1K_0, S_1K_1, S_1K_2, S_1K_3, S_2K_0, S_2K_1, S_2K_2, S_2K_3, S_3K_0, S_3K_1, S_3K_2 and S_3K_3

3.7 Design and layout of experimental site

The experiment was laid out in a Randomized Complete Block Design (RCBD). There were 16 treatment combinations and replicated in 3 times. Total number of plots in the study were 48. The unit plot size was 3.24 m^2 (1.8 m x 1.8 m). There was a gap of 0.75 m between the replication to replication and between plot to plot was 0.5m. The layout of the experimental field has been presented in Appendix IV.

3.8 Land preparation

The experimental land was opened with a power tiller on 24^{th} March 2019. Ploughing and cross ploughing were done with power tiller followed by laddering. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental plot was partitioned into the unit plots. Land preparation was completed on 28^{th} March, 2019 and was ready for sowing seeds.

3.9 Application of fertilizers

The fertilizers were applied as basal dose at final land preparation. Urea and TSP, were applied at 40 kg ha^{-1} and 80 kg ha^{-1}, respectively. The MoP and gypsum were applied as per treatment wise in all plots at 7 days after sowing (Krishi Projukti Hatboi, BARI, 2019). All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.10 Seed sowing

Seeds were sown at the rate of 40 kg ha^{-1} in the furrow on 29^{th} March, 2019 and the furrows were covered with the soils soon after seeding. The line to line distance was maintained with by 30 cm continuous sowing of seeds in the line.

3.11 Seed germination percentages (%)

Seed germination occurred from 3^{rd} day after sowing. On the 5^{th} day the percentage of germination was more than 85% and on the 6^{th} day nearly all baby plants (seedlings) came out of the soil.

3.12 Intercultural operations

3.12.1 Thinning

Thinning (as required places) was done to maintain 10 cm (approximately) plant to plant distance after 15 days of germination.

3.12.2 Weed control

Weed control was done twice at the experimental period. 1^{st} weeding was done on 15^{th} April, 2019 (16 DAS) and 2^{nd} weeding was done on 4^{th} May, 2019 (35 DAS).

3.12.3 Irrigation and drainage

Pre-sowing irrigation was given to ensure the maximum germination percentage. During the whole experimental period, there was a rain in earlier part and at the middle of the growing period. So, no irrigation was required but it was essential to drain the water from the field.

3.12.4 Tagging of the plot

Tagging of the plots was done on 16^{th} April, 2019.

3.13 Harvesting and make sampling

The crop was harvested at 65 DAS by hand pulling. The crop was harvested plot wise when about 80% of the pods became matured. The pods were harvested from prefixed 1 m^2 area. Before harvesting 5 plants were selected randomly from each plot and pods from the selected 5 plants were collected at each harvesting time for recording data. The pods from the rest of the plants of prefixed 1 m^2 area were collected at each harvest of plots and were bagged separately, tagged and brought to the threshing floor for yield data. The stover data was taken from the plants of the same area after sun–drying.

3.14 Threshing

The bundles of these samples were sun dried for three days by placing them on the open threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks.

3.15 Seed drying, cleaning and weighing

After threshing seeds collected were dried for three days. Then those dried seeds were cleaned in proper way and weighed in a electrical balance.

3.16 Data collection

The data were recorded on the following parameters

i) Plant height (cm)
ii) Number of leaves plant^{-1}
iii) Total dry matter weight plant^{-1} (g)
iv) Branches plant^{-1} (no.)
v) Pods plant^{-1} (no.)
vi) Seeds pod^{-1} (no.)
vii) 1000-seed weight (g)
viii) Seed yield (t ha^{-1})
ix) Stover yield (t ha^{-1})
x) Biological yield (t ha^{-1}) and
xi) Harvest index (%)

3.17 Procedure of recording data

i. Plant height (cm)

The height of the selected five plants was measured from the ground level to the tip of the plant at 25, 35, 45 and 55 DAS.

ii. Number of leaves plant^{-1}

The number of leaves of five selected plants was measured at 25, 35, 45 and 55 DAS.

iii. Branches plant^{-1} (no.)

The branches plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants then the average data were recorded.

iv. Total dry matter weight plant^{-1}(g)

Five plants were collected randomly from each plot at 25, 35, 45 and 55 DAS. The sample plants were oven dried for 72 hours at 70°C and then dry matter content plant^{-1} was determined.

v. Pods plant^{-1} (no.)

Pods plant^{-1} was counted from the 5 selected plant sample and then the average pod number was calculated.

vi. Seeds pod^{-1} (no.)

Seeds pod^{-1} was counted from 5 pods of each 3 plants, and then the average seed number was calculated.

vii. 1000-seed weight (g)

1000-grains were counted which were taken from the grain sample of each plot separately, then weighted in an electrical balance and data were recorded.

viii. Seed yield (kg ha^{-1})

Seed yield was recorded on the basis of grains collected from prefixed 1m^2 area and was expressed in terms of yield (t ha^{-1}). Grain yield was adjusted to 12% moisture content.

ix. Stover yield (kg ha^{-1})

After separation seeds from the plant, the left pats of the plant is known as stover. Stover obtained from each individual plot was dried, weighed carefully and the yield expressed in t ha^{-1}.

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

The summation of seed yield and above ground stover yield was the biological yield. Biological yield =Grain yield + Stover yield.

xi. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula.

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

Here, Biological yield = Grain yield + stover yield

3.18 Technique of data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10. Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

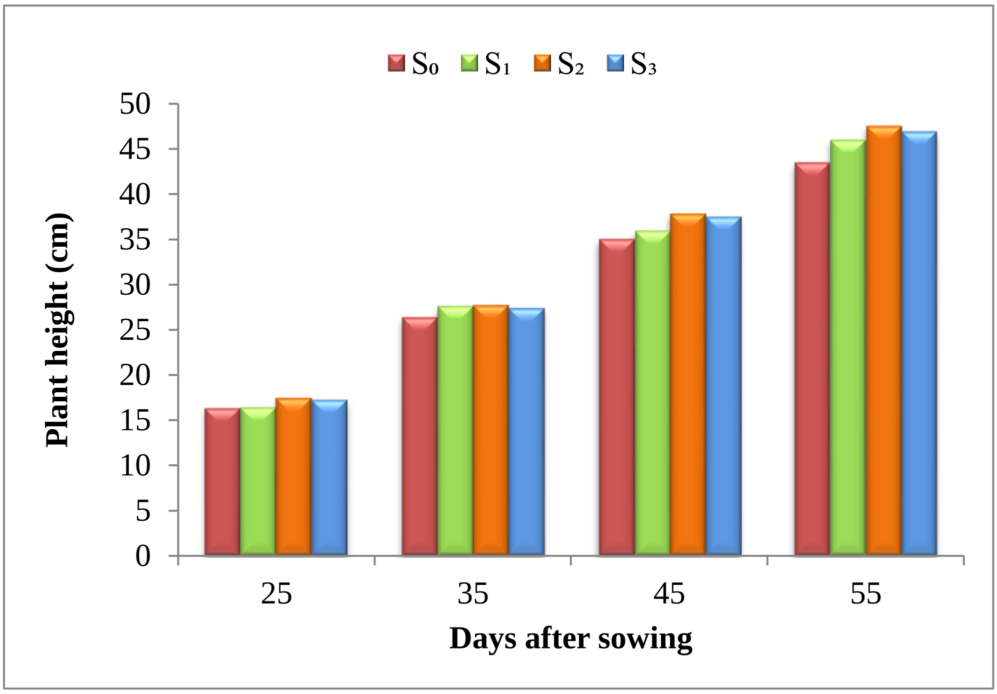
CHAPTER IV
RESULTS AND DISCUSSION

The data on different growth, yield contributing characters and yield were recorded to know the effect of sulfur and potassium on the growth and yield of BARI Mung-6. The results have been presented and discussed and possible explanation have been given under the following headings:

4.1 Plant height

Effect of sulfur

Different level of sulfur fertilizer application showed significant variation in respect of plant height at different days after sowing. (Fig. 4.1 & Appendix V). From the experiment result revealed that the highest plant height (17.47, 27.73, 37.83 and 47.5 cm, at 25, 35, 45 and 55 DAS respectively) was observed in S_2 (6 kg S ha^{-1}) treatment where the lowest plant height (16.3, 26.35, 34.99 and 43.45 cm at 25, 35, 45 and 55 DAS, respectively) was observed in S_0 (control) treatment. The result might be due to sulphur is involved in chlorophyll formation which enhance vegetative growth resulting increase in plant height. Sulfur helps in cell division, enlargement and elongation of cell that results improvement of plant growth parameters. These findings are similar with Saini A. K. (2017).

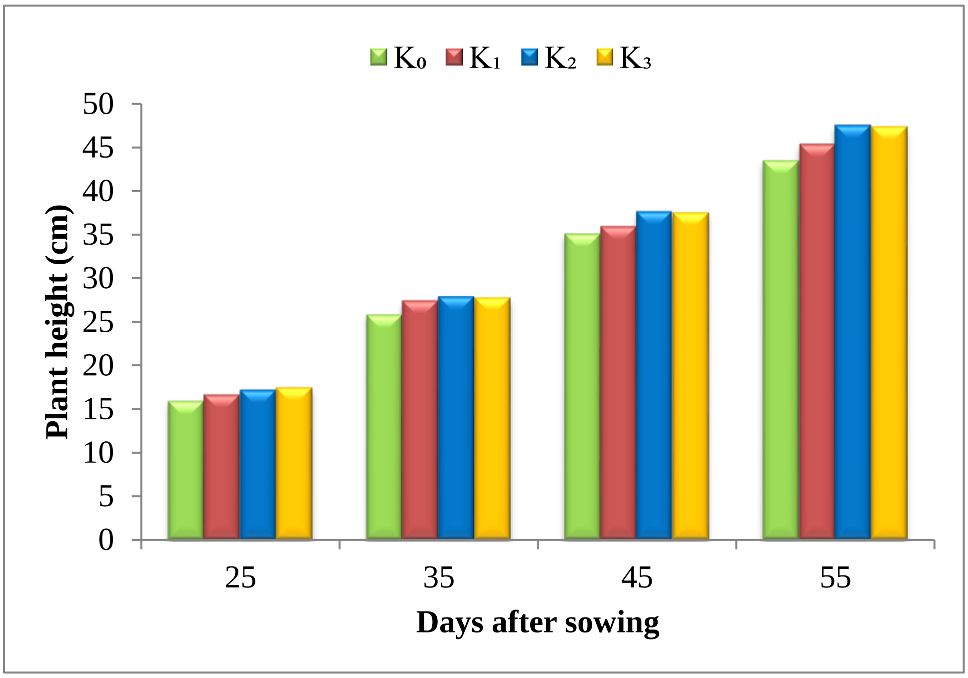


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.1 Effect of different levels of sulfur on plant height of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.62, 0.96, 0.77 and 1.22 at 25, 35, 45 and 55 DAS respectively).

Effect of potassium

Different level of potassium fertilizer application showed significant variation in respect of plant height at various days after sowing (Fig. 4.2 & Appendix V). From the experiment result revealed that the highest plant height (17.4 cm at 25 DAS) was observed in K_3 treatment. At 35, 45 and 55 DAS the highest plant height (27.99, 37.67, 47.54 cm) was observed in K_2 (40 kg K ha^{-1}) treatment. whereas the lowest plant height (16.03, 25.89, 35.15 and 43.53 cm at 25, 35, 45 and 55 DAS, respectively) was observed in the K_0 treatment (no potassium was applied). This result is similar with the findings of Thesiya *et al.* (2013) who found significant increase in plant height of mungbean due to the application of potassium.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.2 Effect of different levels of potassium on plant height (cm) of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.62, 0.96, 0.77 and 1.22 at 25, 35, 45 and 55 DAS respectively).

Combined effect of sulfur and potassium

Combination between sulfur and potassium showed significant effect on plant height at different growth stage of mungbean ((Table 4.1 & Appendix V). From the experiment result revealed that the highest plant height (18.4 cm) at 25 DAS was found in S_2K_3 (6 kg S ha^{-1} + 60 kg K ha^{-1}) treatment combination and at 35 DAS highest plant height (18.4 cm) was found in S_3K_2 (12 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. The highest plant height (40 and 50.01 cm at 45 and 55 DAS, respectively) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. Whereas, the lowest plant height (15.41, 24.07, 34.56 and 42.54 cm at 25, 35, 45 and 55 DAS. respectively) was observed in S_0K_0 (no sulfur + no potassium).

Table 4.1. Combined effect of sulfur and potassium on plant height at different days after sowing

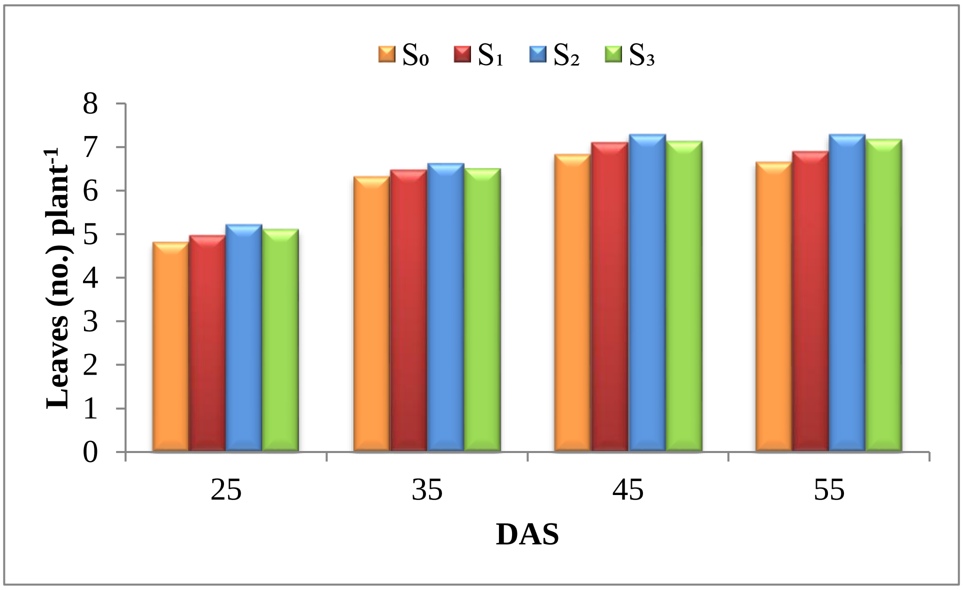
Treatment combinations	Plant height (cm)			
	25 DAS	35 DAS	45 DAS	55 DAS
S_0K_0	15.41 e	24.07 c	34.56 f	42.54 h
S_0K_1	16.83 a-e	27.65 ab	34.76 f	43.51 gh
S_0K_2	16.47 de	26.79 ab	35.3 ef	43.64 gh
S_0K_3	16.51 c-e	26.9 ab	35.33 ef	44.09 e-h
S_1K_0	16.39 e	27.09 ab	34.7 f	43.71 gh
S_1K_1	15.95 e	27.62 ab	35.48 ef	45.55 d-h
S_1K_2	16.45 de	27.7 ab	36.46 d-f	47.2 a-f
S_1K_3	16.57 c-e	27.95 ab	36.99 c-e	47.41 a-e
S_2K_0	16.21 e	26.05 bc	35.98 ef	43.92 f-h
S_2K_1	16.95 a-e	27.69 ab	36.17 ef	46.37 b-g
S_2K_2	18.31 ab	28.55 ab	40.00 a	50.01 a
S_2K_3	18.4 a	28.62 ab	39.17 ab	49.68 ab
S_3K_0	16.11 e	26.37 abc	35.35 ef	43.93 f-h
S_3K_1	16.61 b-e	26.61 abc	37.24 bcde	46.11 c-g
S_3K_2	18.17 a-c	28.93 a	38.9 a-c	49.31 a-c
S_3K_3	18.11 a-d	27.53 ab	38.34 a-d	48.17 a-d
LSD (0.05)	1.7	2.62	2.1	3.36
CV (%)	3.32	3.16	1.89	2.40

Note-S_0 = Control, S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}
K_0 = Control, K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

4.2 Number of leaves plant^{-1}

Effect of sulfur

Application of sulfur at different level showed significant variation in respect of number of leaves of mungbean at different days after sowing. (Fig. 4.3 & Appendix VI). From the experiment result revealed that the highest number of leaves (5.22, 6.62, 7.28 and 7.47 at 25, 35, 45 and 55 DAS respectively) was observed in S_2 (6 kg S ha^{-1}) treatment. where the lowest number of leaves (4.82, 6.32, 6.83 and 6.92 at 25, 35, 45 and 55 DAS, respectively) was observed in S_0 (control) treatment. Sulfur fertilization gave highest number of leaves might be due to optimum supply of nutrients which increased the leaf number, leaf length and breadth Amrutsagar *et al.* (2019).

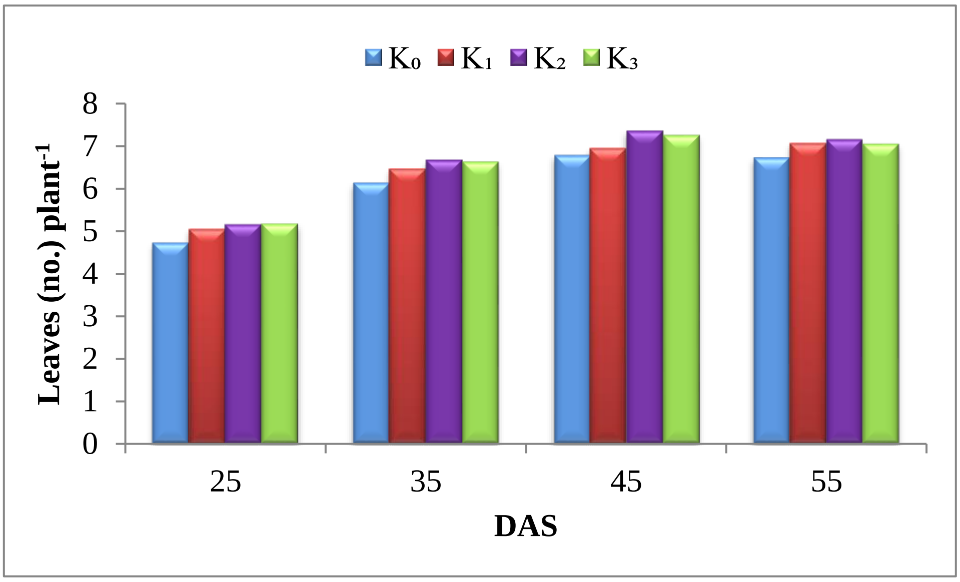


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.3 Effect of different levels of sulfur on number of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.21, 0.24, 0.27 and 0.27at 25, 35, 45 and 55 DAS respectively).

Effect of potassium

Application of different level of potassium showed significant variation in respect of number of leaves of mungbean at different days after sowing. (Fig. 4.4 & Appendix VI). From the experiment result revealed that the highest number of leaves (5.17 at 25 DAS) was observed in K_3 treatment. At 35, 45 and 55 DAS, respectively the highest number of leaves (6.67, 7.35 and 7.48) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest number of leaves (4.73, 6.13, 6.78 and 6.77 at 25, 35, 45 and 55 DAS, respectively) was observed in the K_0 treatment where no potassium was applied.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.4 Effect of different levels of potassium on number of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.21, 0.24, 0.27 and 0.27at 25, 35, 45 and 55 DAS respectively).

Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on number of leaves at different growth stages of mungbean (Table 4.2 & Appendix VI). From the experiment result revealed that the highest number of leaves (5.4) at 25 DAS was observed in S_3K_2 (12 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination, at 35 DAS the highest number of leaves plant^{-1} (7) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. At 45 and 55 DAS, respectively the highest number of leaves (7.60 and 7.67) was observed in S_2K_3 (6 kg S ha^{-1} + 60 kg K ha^{-1}), whereas, on the other hand, the lowest number of leaves (4.33, 5.87, 6.6 and 6.33 at 25, 35, 45 and 55 DAS. respectively) was observed in S_0K_0 (no sulfur + no potassium).

Table 4.2. Combined effect of sulfur and potassium on number of leaves of at different days after sowing

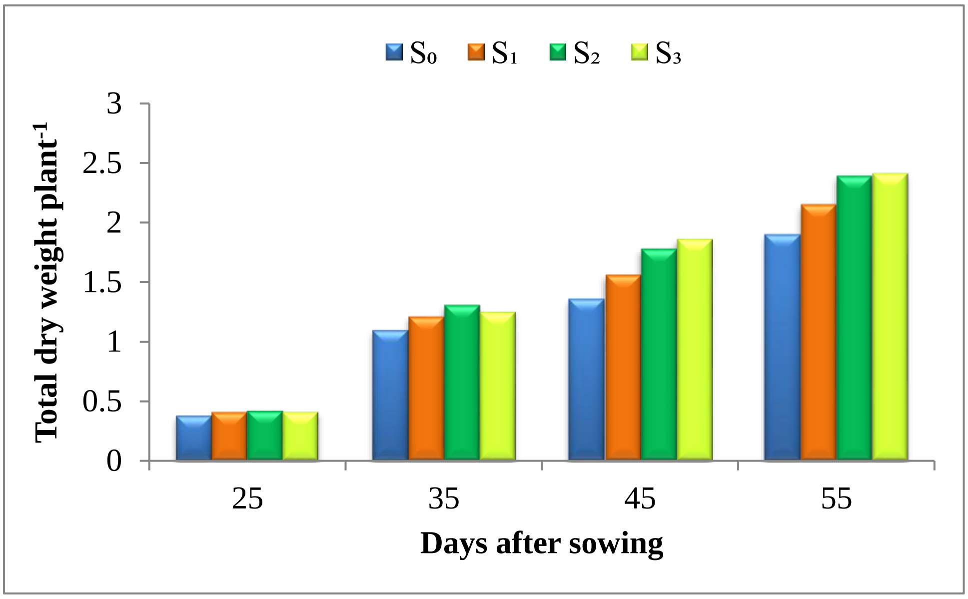
Treatment combinations	No. of leaves plant^{-1}			
	25 DAS	35 DAS	45 DAS	55 DAS
S_0K_0	4.33 c	5.87 d	6.60 e	6.33 d
S_0K_1	4.80 bc	6.33 b-d	6.67 de	6.60 cd
S_0K_2	4.93 ab	6.13 cd	7.07 a-e	7.00 a-d
S_0K_3	4.87 a-c	6.20 b-d	6.80 b-e	6.67 b-d
S_1K_0	5.07 ab	6.40 a-d	6.73 c-e	6.73 b-d
S_1K_1	5.00 ab	6.47 a-d	7.00 a-e	7.00 a-d
S_1K_2	5.20 ab	6.53 a-c	7.13 a-e	7.00 a-d
S_1K_3	4.93 ab	6.47 a-d	6.93 a-e	6.87 a-d
S_2K_0	4.93 ab	6.40 a-d	7.00 a-e	6.87 a-d
S_2K_1	5.00 ab	6.53 ac	7.33 a-d	7.33 a-c
S_2K_2	5.33 ab	7.00 a	7.47 ab	7.40 ab
S_2K_3	5.33 ab	6.73 a-c	7.60 a	7.53 a
S_3K_0	4.93 ab	6.60 a-c	7.00 a-e	7.00 a-d
S_3K_1	5.07 ab	6.53 a-c	7.40 ac	7.33 a-c
S_3K_2	5.4 a	6.8 ab	7.47 ab	7.20 a-c
S_3K_3	5.27 ab	6.6 abc	7.13 a-e	7.13 a-c
LSD $_{(0.05)}$	0.59	0.66	0.73	0.74
CV (%)	3.84	3.35	3.37	3.46

Note - S_0 = Control, S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}
K_0 = Control, K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

4.3 Total dry weight plant^{-1}

Effect of sulfur

Application of different level of sulfur fertilizer showed significant effect in respect of total dry weight plant^{-1} of mungbean at different days after sowing ((Fig. 4.5 & Appendix VII). From the experiment result revealed that the highest total dry weight (0.42 and 1.31 g at 25 and 35 DAS) was observed in S_2 (6 kg S ha^{-1}) treatment. At 45 and 55 DAS, the highest total dry weight (1.86 and 2.41 g, respectively) was observed in S_3 (12 kg S ha^{-1}) treatment. On the other hand, the lowest total dry weight (0.38, 1.1, 1.36 and 1.9 g, at 25, 35, 45 and 55 DAS respectively) was observed in S_0 (control) treatment.

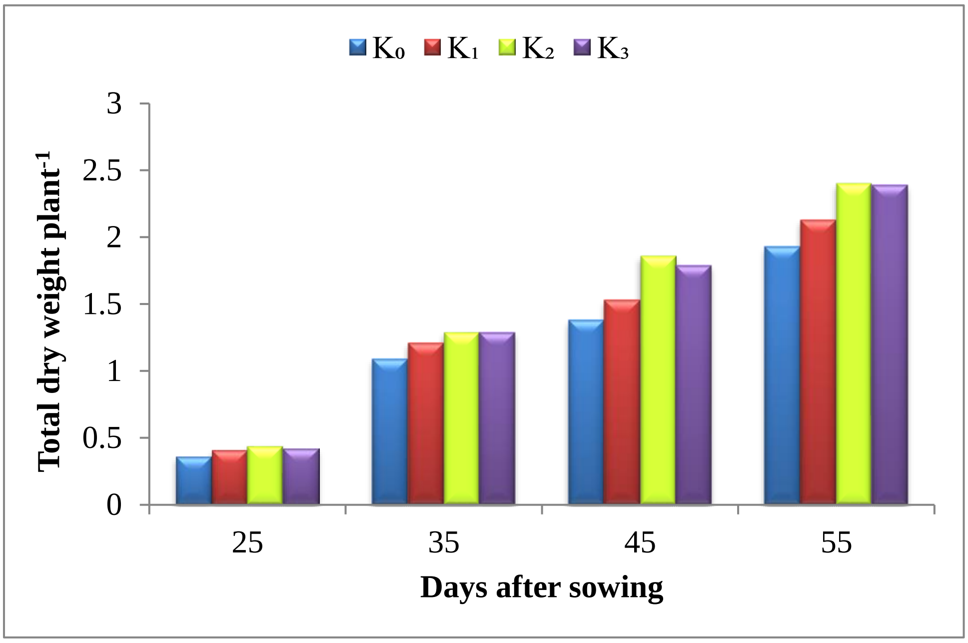


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.5 Effect of different levels of sulfur on total dry weight of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.03, 0.08, 0.06 and 0.03 at 25, 35, 45 and 55 DAS respectively).

Effect of potassium

Application of different level of potassium fertilizer showed significant effect in respect of total dry weight plant^{-1} of mungbean at different days after sowing (Fig. 4.6 & Appendix VII). From the experiment result revealed that the highest total dry weight (0.44, 1.29, 1.86 and 2.4 g at 25, 35, 45 and 55 DAS, respectively) was observed in K_2 (40 kg K ha^{-1}) treatment. This result clearly indicates that total dry weight increased gradually with increasing levels of sulfur. On the other hand, the lowest total dry weight (0.36, 1.09, 1.38 and 1.93 g at 25, 35, 45 and 55 DAS, respectively) was observed in the K_0 treatment where no potassium was applied.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.6 Effect of different levels of potassium on total dry weight of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.03, 0.08, 0.06 and 0.03 at 25, 35, 45 and 55 DAS respectively).

Combined effect of sulfur and potassium

Combined effect of sulfur and showed significant effect on total dry weight at different growth stages of mungbean (Table 4.3 & Appendix VII). The highest total dry weight (0.47, 1.4 and 2.24 g at 25, 35 and 45 DAS, respectively) was observed in S_2K_3 (6 kg S ha^{-1} + 60 kg K ha^{-1}) treatment combination. At 55 DAS highest total dry weight (2.75 g) was found in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest total dry weight (0.32, 1.06, 1.32 and 1.77 g at 25, 35, 45 and 55 DAS. respectively) was observed in S_0K_0 (no sulfur + no potassium).

Table 4.3. Combined effect of sulfur and potassium on total dry weight of mungbean at different days after sowing

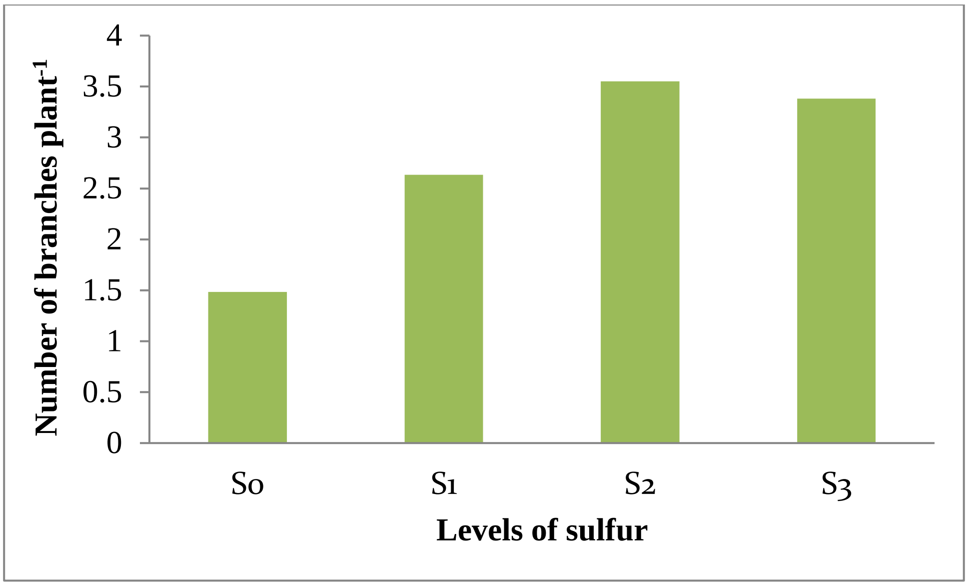
Treatment combinations	Total dry weight plant^{-1} (g)			
	25 DAS	35 DAS	45 DAS	55 DAS
S_0K_0	0.32 c	1.06 e	1.32 h	1.77 h
S_0K_1	0.38 bc	1.09 e	1.41 gh	1.95 fg
S_0K_2	0.39 bc	1.12 c-e	1.41 gh	1.99 f
S_0K_3	0.37 bc	1.06 e	1.39 gh	2.00 f
S_1K_0	0.39 bc	1.1 de	1.35 h	1.9 g
S_1K_1	0.41 ab	1.15 b-e	1.55 e-g	2.15 e
S_1K_2	0.42 ab	1.36 ab	1.45 f-h	2.16 e
S_1K_3	0.41 ab	1.22 a-e	1.77 d	2.31 d
S_2K_0	0.38 bc	1.11 de	1.39 gh	1.94 fg
S_2K_1	0.43 ab	1.26 a-e	1.61 d-f	2.16 e
S_2K_2	0.46 a	1.40 a	2.21 ab	2.75 a
S_2K_3	0.47 a	1.40 a	2.24 a	2.72 ab
S_3K_0	0.42 ab	1.13 c-e	1.39 h	1.99 f
S_3K_1	0.43 ab	1.35 a-c	1.66 de	2.32 d
S_3K_2	0.42 ab	1.37 ab	2.06 bc	2.66 bc
S_3K_3	0.41 ab	1.32 a-d	2.04 c	2.59 c
LSD $_{(0.05)}$	0.07	0.22	0.17	0.09
CV (%)	5.95	6.03	3.36	1.32

Note - S_0 = Control, S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}
K_0 = Control, K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

4.4 Number of branches plant^{-1}

Effect of sulfur

Different level of sulfur fertilizer showed significant variation in respect of number of branches plant^{-1} of mungbean (Fig. 4.7 & Appendix VIII). From the experiment result revealed that the highest number of branches plant^{-1} (3.55) was observed in S_2 treatment. Where the lowest number of branches plant^{-1} (1.44) was measured in S_0 treatment. Increase in growth and straw yield can be ascribed to cell division, enlargement and elongation resulting in overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the effect of sulphur application. This result is almost similar with Parmar *et al.* (2021).

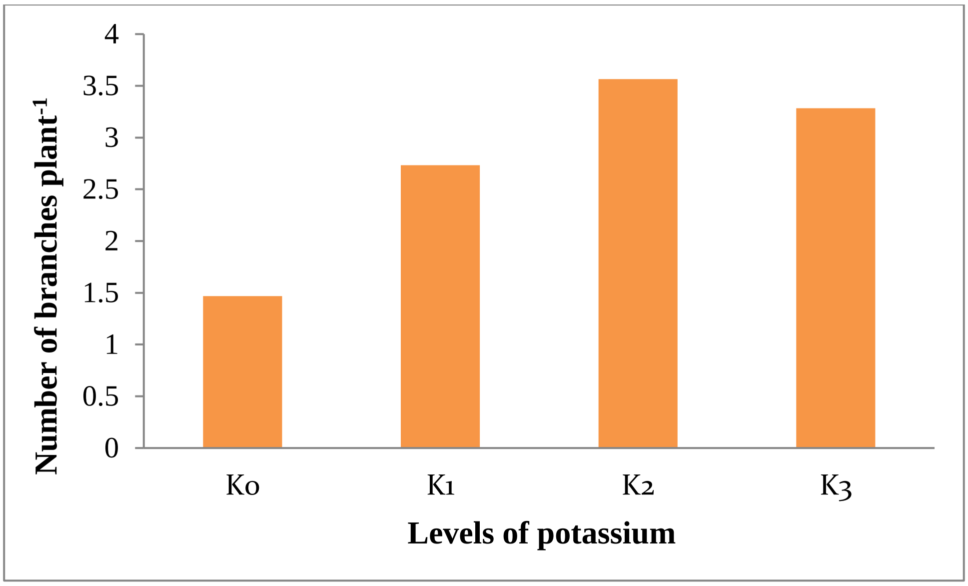


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.7 Effect of different levels of sulfur on number of branches $plant^{-1}$ of mungbean (LSD $_{(0.05)}$ = 0.13 at 55 DAS).

Effect of potassium

Different level of potassium fertilizer showed significant variation in respect of number of branches $plant^{-1}$ of mungbean (Fig. 4.8 & Appendix VIII). From the experiment result revealed that the highest number of branches $plant^{-1}$ (3.57) was observed in K_2 treatment. It may be due to K application increased the availability of nitrogen and phosphorus which resulted in better plant growth and more number of branches per plant. On the other hand, the lowest number of branches (1.47) was observed in the K_0 treatment where no potassium was applied (Fig. 4.8). Potassium enhances cell division, improves growth, thus increases number of branches. Similar results were obtained by Sindhu *et al.* (2019).



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.8 Effect of different levels of potassium on number of branches $plant^{-1}$ of mungbean ($LSD_{(0.05)}$ = 0.13 at 55 DAS).

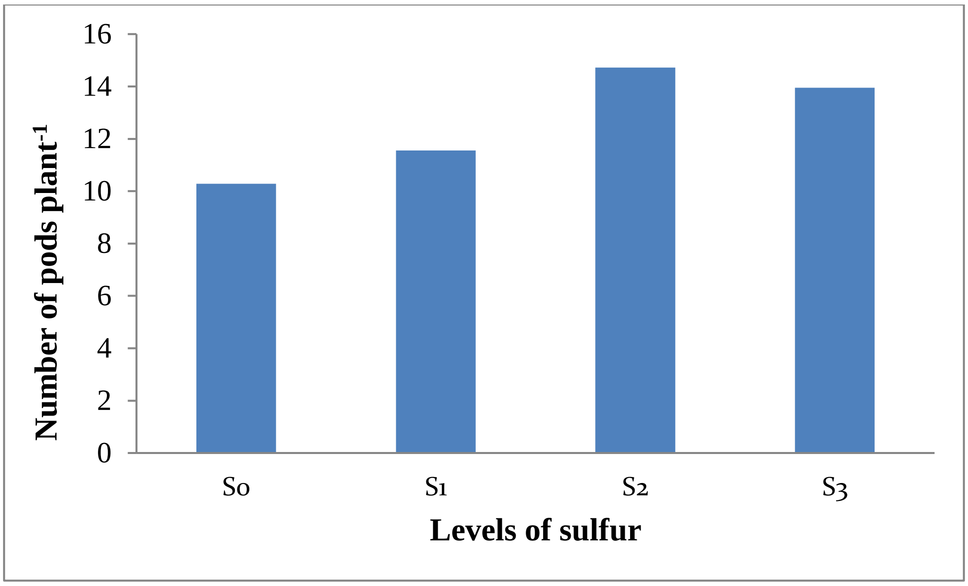
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on number of branches $plant^{-1}$ of mungbean (Table 4.4 & Appendix VIII). From the experiment result revealed that the highest number of branches $plant^{-1}$ (4.73) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination which was statistically similar with S_2K_3 treatment combination. On the other hand, the lowest number of branches (1.07) was observed in S_0K_0 (no sulfur + no potassium) treatment combination.

4.5 Number of pods $plant^{-1}$

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of number of pods $plant^{-1}$ (Fig. 4.9 & Appendix IX). From the experiment result revealed that the highest number of pods $plant^{-1}$ (14.72) was recorded in S_2 (6 kg S ha^{-1}) treatment where the lowest number of pods $plant^{-1}$ (10.29) was measured in S_0 (control) treatment.

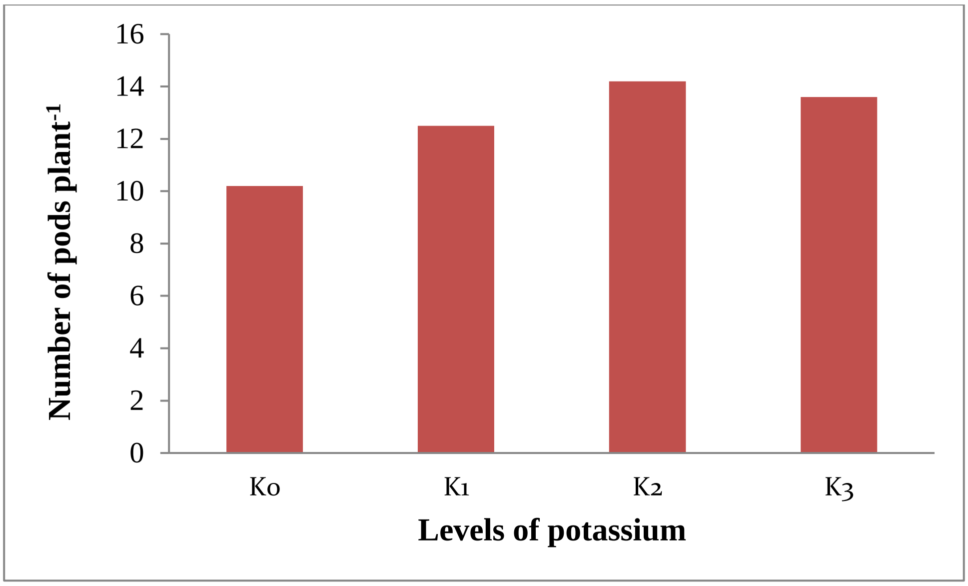


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.9 Effect of different levels of sulfur on number of pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.42).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of number of pods plant^{-1} (Fig. 4.10 & Appendix IX). From the experiment result showed that the highest number of pods plant^{-1} (14.20) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest number of pods plant^{-1} (10.2) was observed in the K_0 treatment where no potassium was applied. Similar findings were recorded by Ali *et al*. (2007) who studied the effect of different K levels and reported that the number of pods per plant was influenced significantly by K application. The minimum number of pods where no potash was applied might have been due to less availability of N and P and stunted growth.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.10 Effect of different levels of potassium on number of pods $plant^{-1}$ of mungbean (LSD $_{(0.05)}$ 0.42).

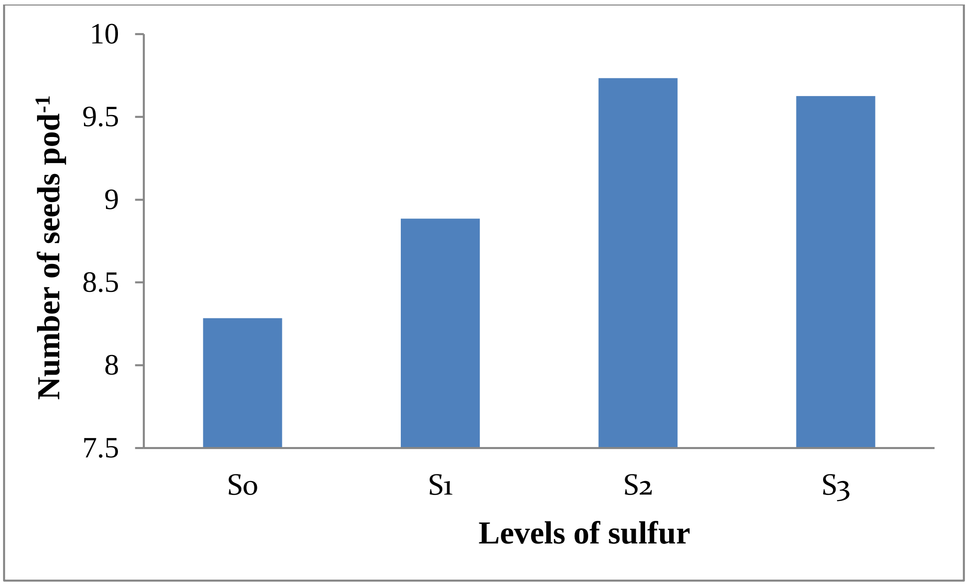
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on number of pods $plant^{-1}$ of mungbean (Table 4.4 & Appendix IX). From the experiment result revealed that the highest number of pods $plant^{-1}$(16.47) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination which was statistically similar with S_3K_2, S_2K_3 and S_3K_3 treatment combination. On the other hand, the lowest number of pods $plant^{-1}$ (9) was observed in S_0K_0 (no sulfur + no potassium) which was statistically similar with S_0K_1 treatment combination.

4.6 Number of seeds pod^{-1}

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of number of seeds pod^{-1} (Fig. 4.11 & Appendix X). The highest number of seeds pod^{-1} (9.74) was recorded in S_2 (6 kg S ha^{-1}) treatment which was statistically similar with S_3 treatment. Where the lowest number of seeds pod^{-1} (8.28) was observed in S_0 (control).

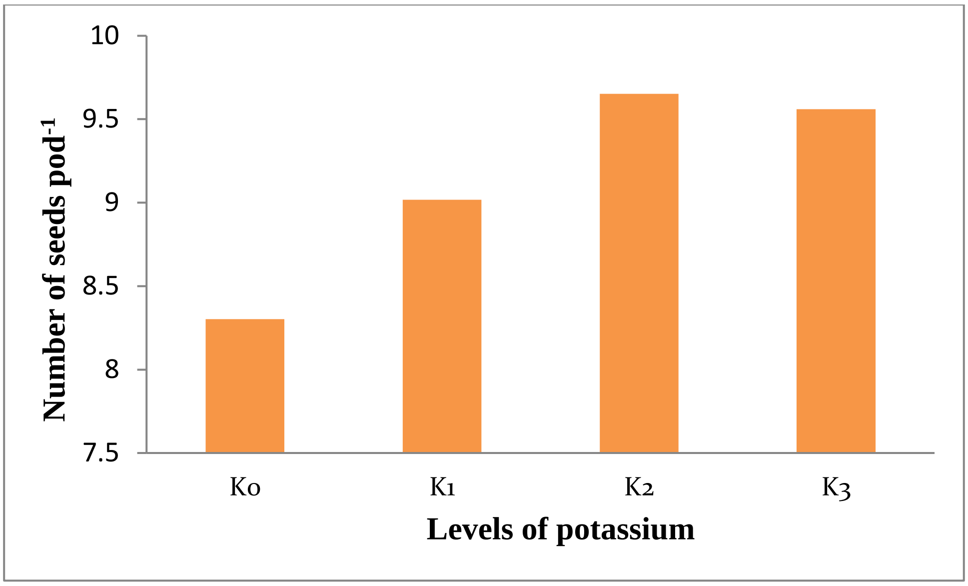


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.11 Effect of different levels of sulfur on number of seeds pod^{-1} of mungbean (LSD $_{(0.05)}$ = 0.17).

Effect of sulfur

Application of different level of potassium fertilizer showed significant variation in respect of number of seeds pod^{-1} (Fig. 4.12 & Appendix X). From the experiment result revealed that the highest number of seeds pod^{-1} (9.65) was observed in K_2 (40 kg K ha^{-1}) treatment which was statistically similar with K_3 treatment. On the other hand, the lowest number of seeds pod^{-1} (8.30) was observed in the K_0 treatment where no potassium was applied.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.12 Effect of different levels of potassium on number of seeds pod^{-1} of mungbean (LSD $_{(0.05)}$ = 0.17).

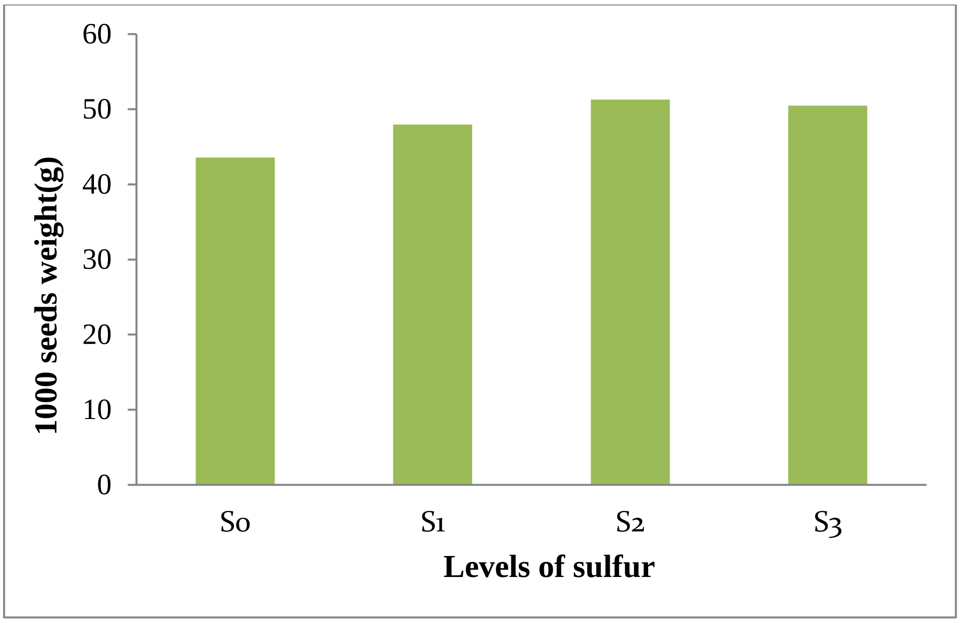
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on number of seeds pod^{-1} of mungbean (Table 4.4 & Appendix X). From the experiment result revealed that the highest number of seeds pod^{-1} (10.87) was observed in S_2K_2 (6kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest number of seeds pod^{-1} (7.6) was observed in S_0K_0 (no sulfur + no potassium) treatment combination.

4.7 1000 seeds weight (g)

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of 1000 seeds weight of mungbean (Fig. 4.13 & Appendix XI). From the experiment result revealed that the highest 1000 seeds weight (51.27 g) was observed in S_2 (6 kg S ha^{-1}) treatment where the lowest 1000 seeds weight (43.57 g) was measured in S_0 (control). The increase in 1000-seed weight may be due to sulphur, which increases the seed weight and size.

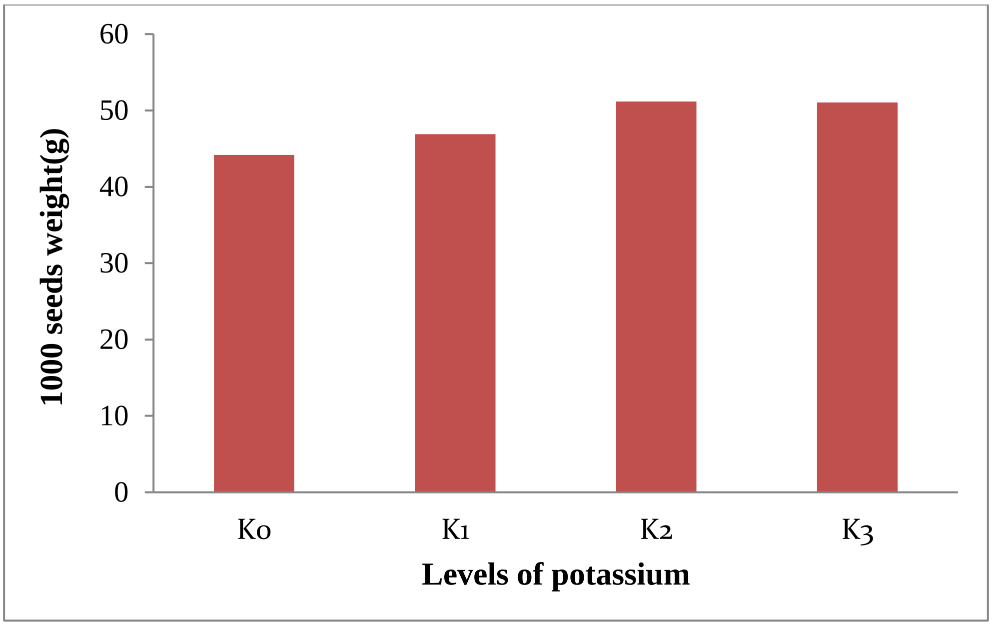


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.13 Effect of different levels of sulfur on 1000 seeds weight of mungbean (LSD $_{(0.05)}$ = 0.96).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of 1000 seeds weight of mungbean (Fig. 4.14 & Appendix XI). From the experiment result revealed that the highest 1000 seeds weight (51.16 g) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest 1000 seeds weight (44.17 g) was observed in the K_0 treatment where no potassium was applied (Fig. 4.14). Quddus *et al*. (2019) found that 1000 seeds weight significantly affected by highest amount of potassium fertilizer application.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.14 Effect of different levels of potassium on 1000 seeds weight (g) of mungbean (LSD $_{(0.05)}$ = 0.96).

Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on 1000 seeds weight of mungbean (Table 4.4 & Appendix XI). From the experiment result revealed that the highest 1000 seeds weight (56 g) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination which was statistically similar with S_3K_2 and S_2K_3 treatment combination. On the other hand, the lowest 1000 seeds weight (41.53 g) was observed in S_0K_0 (no sulfur + no potassium).

Table 4.4. Combined effect of sulfur and potassium on no. of branches, no. of pods, no. of seeds and 1000 seeds weight

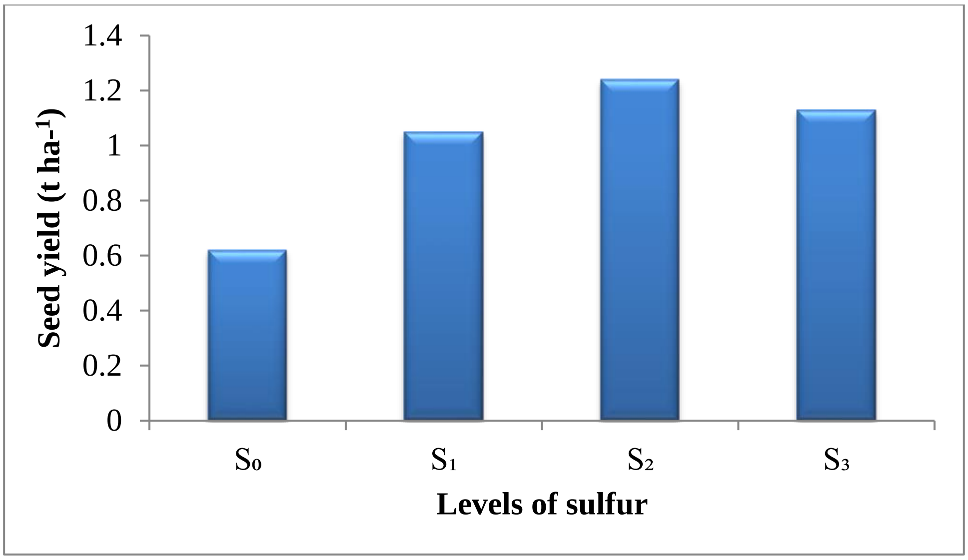
Treatment combinations	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seeds wt. (g)
S_0K_0	1.07g	9 g	7.6 i	41.53i
S_0K_1	1.33f	10.67e	8.27h	43.60h
S_0K_2	2.2e	10.8d	8.67fg	44.25f-h
S_0K_3	1.33f	10.67de	8.6gh	44.88f-h
S_1K_0	1.33f	9.47fg	8.27h	43.77gh
S_1K_1	2.8d	11.2d	9.0ef	47.40de
S_1K_2	3.2c	13.4b	9.07de	49.13d
S_1K_3	3.20c	12.13c	9.20de	51.53c
S_2K_0	1.47f	12.4c	8.67fg	45.70ef
S_2K_1	3.40c	14.2b	9.40d	49.13d
S_2K_2	4.73a	16.47a	10.87a	56 a
S_2K_3	4.6a	15.8a	10.0c	54.23ab
S_3K_0	2.0e	9.93ef	8.67fg	45.67e-g
S_3K_1	3.40c	13.93b	9.4d	47.43de
S_3K_2	4.13b	16.13a	10.c	55.27ab
S_3K_3	4.0b	15.80a	10.44b	53.5b
LSD (0.05)	0.26	0.83	0.35	1.91
CV (%)	5.62	3.96	2.27	2.38

Note - S_0 = Control, S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}
K_0 = Control, K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

4.8 Seed yield

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of seed yield (t ha^{-1}) of mungbean. (Fig. 4.15 & Appendix XII). From the experiment result revealed that the highest seed yield (1.24 t ha^{-1}) was observed in S_2 (6 kg S ha^{-1}) treatment where the lowest seed yield (0.62 t ha^{-1}) was measured in S_0 (control) treatment. The process of tissue differentiation from somatic to reproductive meristematic activity and development of floral primordial might have increased with increasing sulphur levels resulting higher grain yield. These results are almost similar with the results obtained by Patel *et al.* (2020).

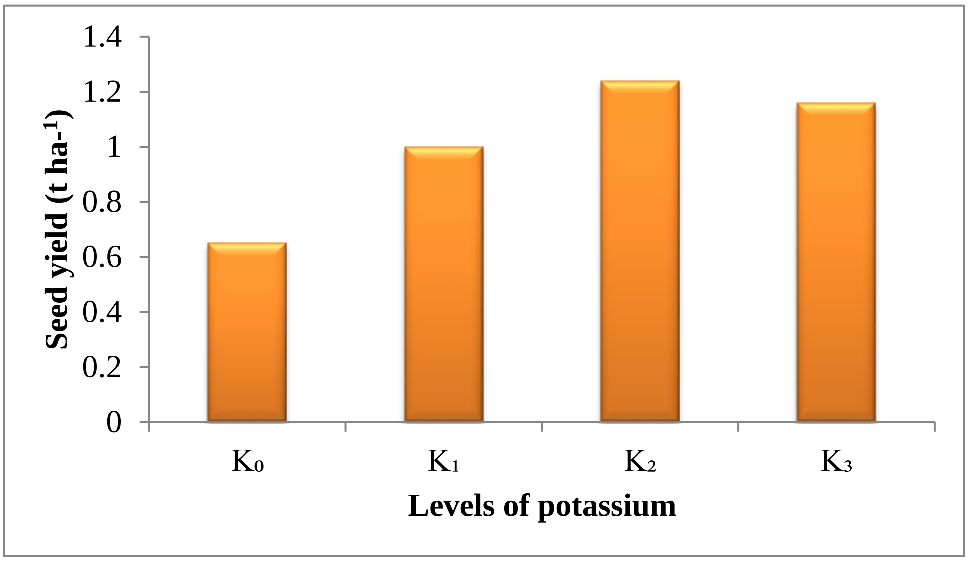


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.15 Effect of different levels of sulfur on seed yield of mungbean (LSD $_{(0.05)}$ = 0.03).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of seed yield (t ha^{-1}) of mungbean (Fig. 4.16 & Appendix XII). From the experiment result revealed that the highest seed yield (1.24 t ha^{-1}) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest seed yield (0.65 t ha^{-1}) was observed in the K_0 treatment where no potassium was applied. Potassium enhances the process of cell division and elongation and that reflects positive growth in plants. The findings are almost similar with the results recorded by Amrutsagar *et al.*, (2019).



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.16 Effect of different levels of potassium on seed yield of mungbean (LSD $_{(0.05)}$ = 0.03).

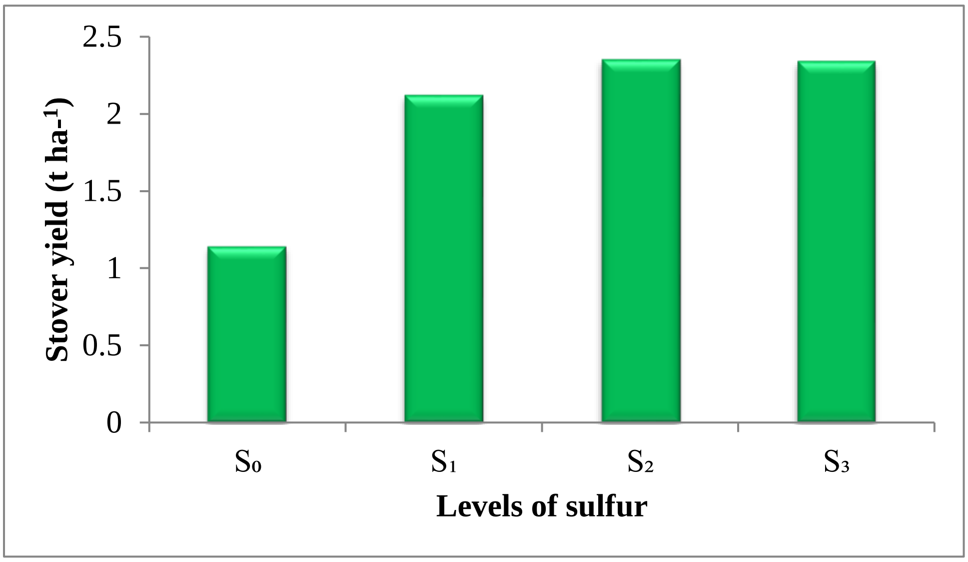
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on seed yield (t ha^{-1}) of mungbean (Table 4.5 & Appendix XII). From the experiment result revealed that the highest seed yield (1.51 t ha^{-1}) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest seed yield (0.52 t ha^{-1}) was observed in S_0K_0 (no sulfur + no potassium) treatment combination.

4.9 Stover yield

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of stover yield (t ha^{-1}) of mungbean. (Fig. 4.17 & Appendix XIII). The highest stover yield (2.35 t ha^{-1}) was recorded in S_2 (6 kg S ha^{-1}) treatment where the lowest stover yield (1.14 t ha^{-1}) was measured in S_0 (control). The results are almost agreement with the findings of Phogat *et al.* (2020). He found significant increases in stover yield of mungbean due to application of S.

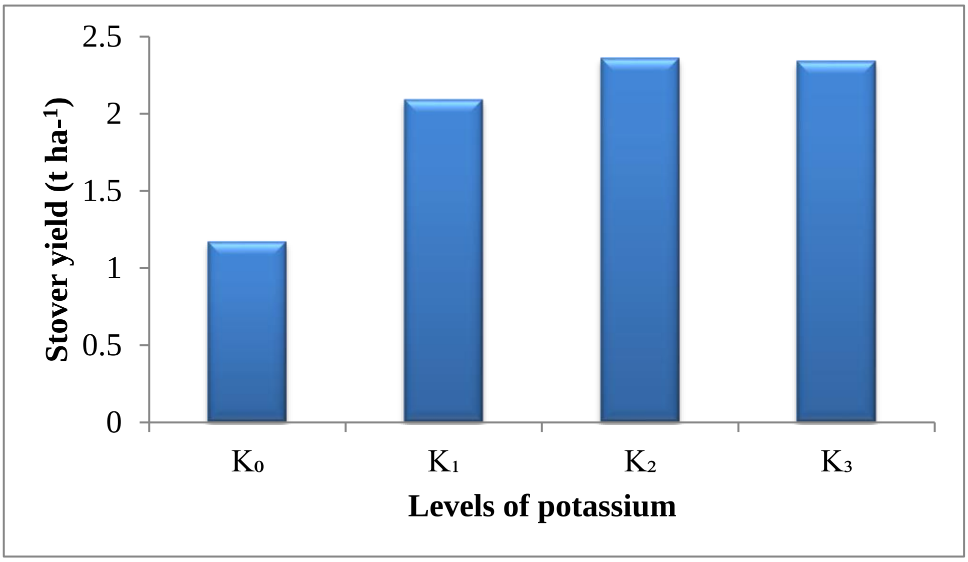


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.17 Effect of different levels of sulfur on stover yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.03).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of stover yield (t ha^{-1}) of mungbean (Fig. 4.18 & Appendix XIII). From the experiment result revealed that the highest stover yield (2.36 t ha^{-1}) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest stover yield (1.17 t ha^{-1}) was observed in the K_0 treatment where no potassium was applied.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.18 Effect of different levels of potassium on stover yield of mungbean (LSD $_{(0.05)}$ = 0.03).

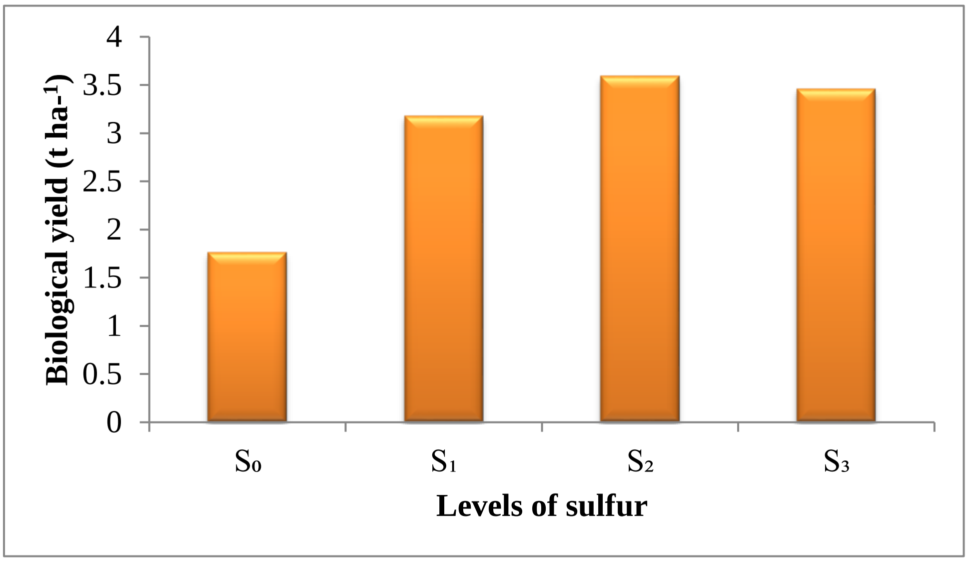
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on stover yield (t ha^{-1}) of mungbean (Table 4.5 & Appendix XIII). The highest stover yield (2.92 t ha^{-1}) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest stover yield (0.97 t ha^{-1}) was observed in S_0K_0 (no sulfur + no potassium) treatment combination.

4.10 Biological yield

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of biological yield (t ha^{-1}) of mungbean (Fig. 4.19 Appendix XIV). From the experiment result revealed that the highest biological yield (3.59 t ha^{-1}) was recorded in S_2 (6 kg S ha^{-1}) treatment where the lowest biological yield (1.76 t ha^{-1}) was measured in S_0 (control).

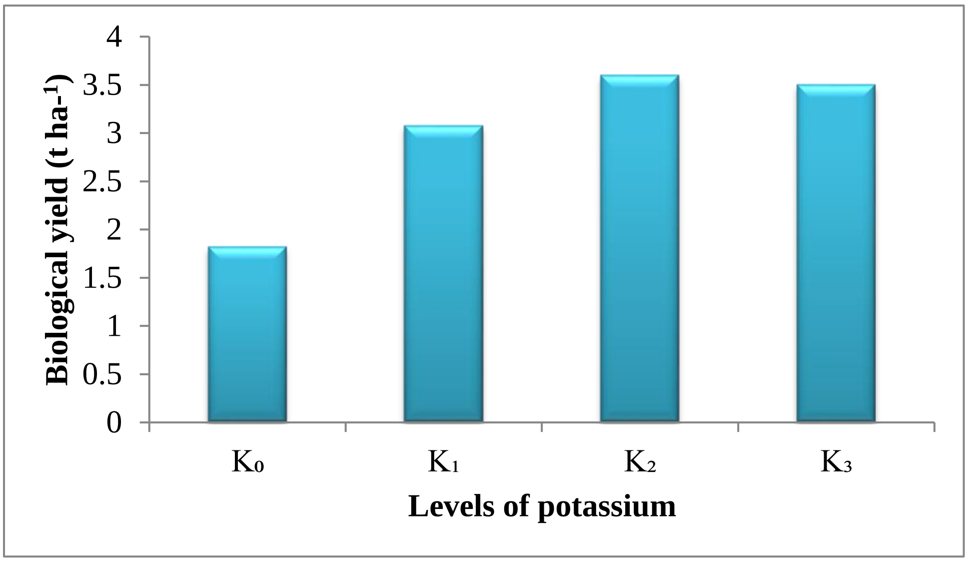


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.19 Effect of different levels of sulfur on biological yield of mungbean (LSD $_{(0.05)}$ = 0.04).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of biological yield (t ha^{-1}) of mungbean (Fig. 4.20 & Appendix XIV). From the experiment result revealed that the highest biological yield (3.6 t ha^{-1}) was observed in K_2 (40 kg K ha^{-1}) treatment. On the other hand, the lowest biological yield (1.82 t ha^{-1}) was observed in the K_0 treatment where no potassium was applied.



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.20 Effect of different levels of potassium on biological yield of mungbean (LSD $_{(0.05)}$ = 0.04).

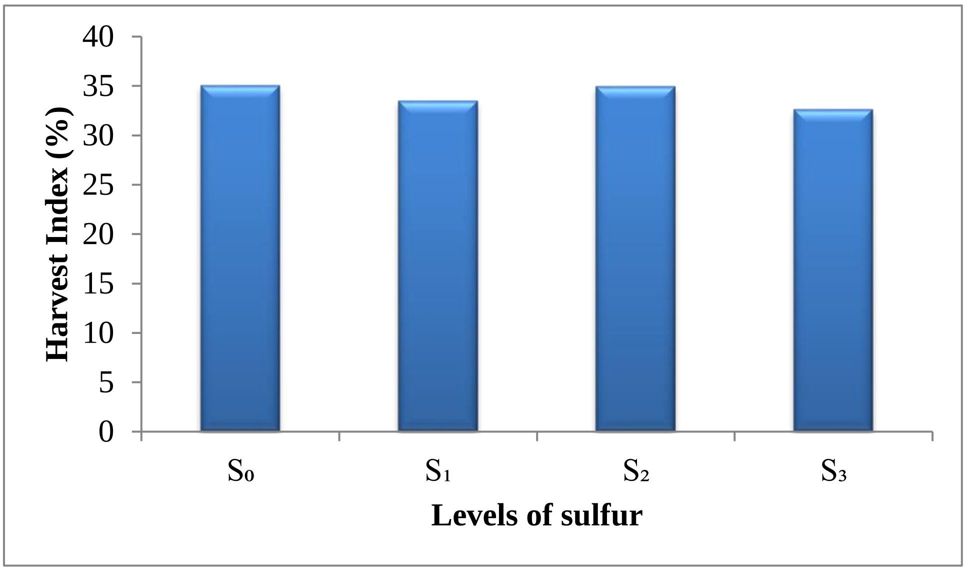
Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on biological yield (t ha^{-1}) of mungbean (Table 4.5 & Appendix XIV). The highest biological yield (4.43 t ha^{-1}) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest biological yield (1.48 t ha^{-1}) was observed in S_0K_0 (no sulfur + no potassium) treatment combination.

4.11 Harvest Index

Effect of sulfur

Application of different level of sulfur fertilizer showed significant variation in respect of harvest index (%) of mungbean (Fig. 4.21 & Appendix XV). From the experiment result revealed that the highest harvest index (35.06 %) was recorded in S_0 (control) treatment where the lowest harvest index (32.62 %) was observed in S_3 (12 kg S ha^{-1}) treatment.

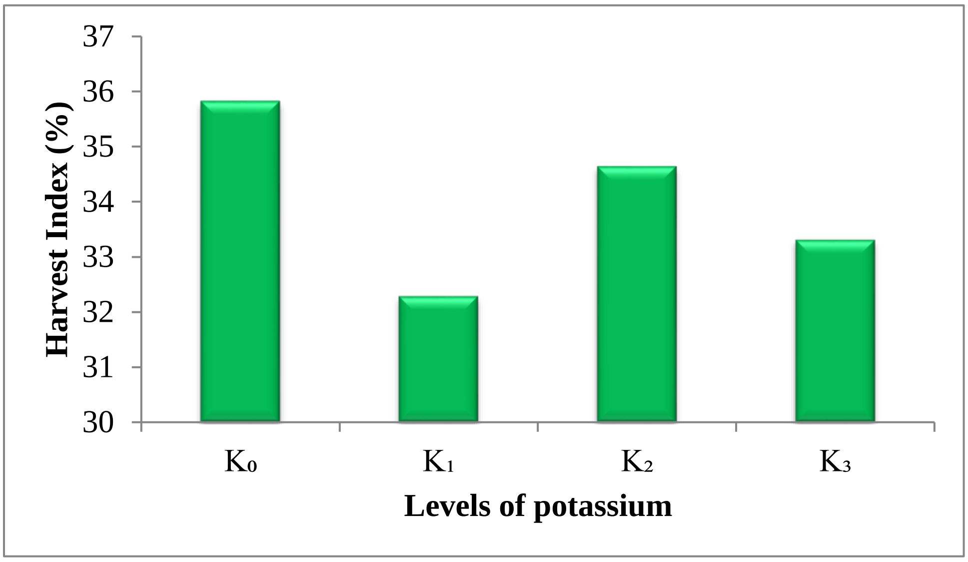


S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}

Fig. 4.21 Effect of different levels of sulfur on harvest index of mungbean (LSD $_{(0.05)}$ = 0.72).

Effect of potassium

Application of different level of potassium fertilizer showed significant variation in respect of harvest index (%) of mungbean (Fig. 4.22 & Appendix XV). From the experiment result revealed that the highest harvest index (35.82 %) was observed in K_0 (control) treatment. On the other hand, the lowest harvest index (32.29 %) was observed in the K_1(20 kg K ha^{-1}).



K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

Fig. 4.22 Effect of different levels of potassium on harvest index (%) of mungbean (LSD $_{(0.05)}$ = 0.72).

Combined effect of sulfur and potassium

Combined effect of sulfur and potassium showed significant effect on harvest index (%) of mungbean (Table 4.5 & Appendix XV). From the experiment result revealed that the highest harvest index (37.5%) was observed in S_0K_2 (no sulfur + 40 kg K ha^{-1}) treatment combination. On the other hand, the lowest harvest index (28.01 %) was observed in S_3K_1(12 kg S ha^{-1} + 20 kg K ha^{-1}) treatment combination.

Table 4.5 Combined effect of sulfur and potassium combinations on seed yield, stover yield, biological yield and harvest index

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
S_0K_0	0.52 h	0.97 h	1.48 i	34.93 b-d
S_0K_1	0.67 g	1.16 g	1.71 h	36.52 ab
S_0K_2	0.76 f	1.17 g	1.82 g	37.5 a
S_0K_3	0.66 g	1.28 f	2.03 f	34.33 cd
S_1K_0	0.55 h	1.17 g	1.84 g	32.29 e
S_1K_1	1.25 cd	2.34 e	3.6 d	34.83 b-d
S_1K_2	1.21 d	2.5 c	3.81 c	33.46 de
S_1K_3	0.97 e	2.48 c	3.45 e	28.59 f
S_2K_0	0.66 g	1.27 f	2.03 f	36.01 a-c
S_2K_1	1.31 c	2.41 de	3.62 d	34.5 cd
S_2K_2	1.51 a	2.92 a	4.43 a	34.11 c-e
S_2K_3	1.47 ab	2.81 b	4.3 b	33.94 de
S_3K_0	0.75 f	1.26 f	1.92 g	37.03 a
S_3K_1	0.97 e	2.43 cd	3.4 e	28.01 f
S_3K_2	1.49 a	2.85 ab	4.32 b	34.61 b-d
S_3K_3	1.42 b	2.8 b	4.22 b	33.6 de
LSD $_{(0.05)}$	0.07	0.07	0.1	1.97
CV (%)	2.37	1.24	1.13	1.91

Note - S_0 = Control, S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1}
K_0 = Control, K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during March to June, 2019 to study the effect of different levels of sulfur and potassium on the growth and yield of BARI Mung-6. In this experiment, the treatment consisted of 2 factors. Factor A: sulfur levels (4) *viz*. S_0 = No sulfur (Control), S_1 = 3 kg S ha^{-1}, S_2 = 6 kg S ha^{-1}, S_3 = 12 kg S ha^{-1} and Factor B: potassium level (4) *viz*. K_0 = No potassium (Control), K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) with three replications and each replication had 16 unit plots. BARI Mung-6 seeds were sown at the rate of 40 kg ha^{-1} in furrows. Data on different yield contributing characters and yield were recorded and statistically analyzed for evaluating the treatments effect to find out the suitable levels of sulfur and potassium fertilizer application for the highest yield of mungbean.

In this research work, it was observed that growth, yield and yield contributing characters were significantly affected due to the different levels of sulfur fertilizer application. From the experiment result revealed that the highest plant height (17.47, 27.73, 37.83 and 47.5 cm, at 25, 35, 45 and 55 DAS respectively), number of leaves (5.22, 6.62, 7.28 and 7.47 at 25, 35, 45 and 55 DAS respectively) were observed in S_2 (6 kg S ha^{-1}) treatment, the highest total dry weight (0.42 and 1.31 g at 25 and 35 DAS) was observed in S_2 (6 kg S ha^{-1}) treatment. At 45 and 55 DAS, the highest total dry weight (1.86 and 2.41 g, respectively) was observed in S_3 (12 kg S ha^{-1}) treatment. The highest number of branches plant^{-1} (3.55), pods plant^{-1} (14.72), seeds pod^{-1} (9.74), 1000 seeds weight (51.27 g), seed yield (1.24 t ha^{-1}), stover yield (2.35 t ha^{-1}), biological yield (3.59 t ha^{-1}) were observed in S_2 (6 kg S ha^{-1}) treatment, and the highest harvest index (35.06 %) was observed in S_0 (control) treatment. Whereas the lowest plant height (16.3, 26.35, 34.99 and 43.45 cm at 25, 35, 45 and 55 DAS, respectively), number of leaves (4.82, 6.32, 6.83 and 6.92 at 25, 35, 45 and 55 DAS, respectively), total dry weight (0.38, 1.1, 1.36 and 1.9 g, at 25, 35, 45 and 55 DAS respectively), number of branches plant^{-1} (1.44), pods plant^{-1}(10.29), seeds pod^{-1} (8.28), 1000 seeds weight (43.57 g), seed yield (0.62 t ha^{-1}), stover yield (1.14 t ha^{-1})

and biological yield (1.76 t ha^{-1}) were measured in S_0 (control) treatment and the lowest harvest index (32.62 %) was observed in S_3 (12 kg S ha^{-1}) treatment.

In this research work, it was observed that growth, yield and yield contributing characters were significantly affected due to the different levels of potassium fertilizer application. From the experiment result revealed that the, the highest plant height (17.4 cm at 25 DAS) was observed in K_3 treatment. At 35, 45 and 55 DAS the highest plant height (27.99, 37.67, 47.54 cm) was observed in K_2 (40 kg K ha^{-1}) treatment, the highest number of leaves (5.17 at 25 DAS) was observed in K_3 treatment. At 35, 45 and 55 DAS, respectively the highest number of leaves (6.67, 7.35 and 7.48) was observed in K_2 (40 kg K ha^{-1}) treatment, the highest total dry weight (0.44, 1.29, 1.86 and 2.4 g at 25, 35, 45 and 55 DAS, respectively), branches $plant^{-1}$ (3.57), pods $plant^{-1}$ (14.20), seeds pod^{-1} (9.65), 1000 seeds weight (51.16 g), seed yield (1.24 t ha^{-1}), stover yield (2.36 t ha^{-1}), and biological yield (3.6 t ha^{-1}) were observed in K_2 (40 kg K ha^{-1}) treatment. The highest harvest index (35.82 %) was observed in K_0 (control) treatment. Whereas the lowest plant height (16.03, 25.89, 35.15 and 43.53 cm at 25, 35, 45 and 55 DAS, respectively), number of leaves (4.73, 6.13, 6.78 and 6.77 at 25, 35, 45 and 55 DAS, respectively), total dry weight (0.36, 1.09, 1.38 and 1.93 g at 25, 35, 45 and 55 DAS, respectively), number of branches (1.47), pods $plant^{-1}$ (10.2), seeds pod^{-1} (8.30), 1000 seeds weight (44.17 g), seed yield (0.65 t ha^{-1}), stover yield (1.17 t ha^{-1}), and biological yield (1.82 t ha^{-1}) were observed in the K_0 treatment and the lowest harvest index (32.29 %) was observed in the K_1(20 kg K ha^{-1}) treatment.

Combined effect of sulfur and potassium showed significant effect on growth, yield and yield contributing characters of mungbean. The highest plant height (18.4 cm) at 25 DAS was found in S_2K_3 (6 kg S ha^{-1} + 60 kg K ha^{-1}) treatment combination and at 35 DAS highest plant height (18.4 cm) was found in S_3K_2 (12 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination, The highest plant height (40 and 50.01 cm at 45 and 55 DAS, respectively) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}), treatment combination. the highest number of leaves (5.4) at 25 DAS was observed in S_3K_2 (12 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination, at 35 DAS the highest number of leaves (7) was observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. At 45 and 55 DAS, respectively the highest number of leaves (7.60 and 7.67) was observed in S_2K_3 (6 kg S ha^{-1} + 60 kg K ha^{-1}). The highest total dry weight (0.47, 1.4 and 2.24 g at 25, 35 and 45 DAS, respectively) was observed in S_2K_3 (6 kg S ha^{-1} +

60 kg K ha^{-1}) treatment combination. At 55 DAS highest total dry weight (2.75 g) was found in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. The highest number of branches $plant^{-1}$ (4.73), pods $plant^{-1}$(16.47), seeds pod^{-1} (10.87), 1000 seeds weight (56 g), seed yield (1.51 t ha^{-1}), stover yield (2.92 t ha^{-1}), biological yield (4.43 t ha^{-1}) were observed in S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination and the highest harvest index (37.5%) was observed in S_0K_2 (no sulfur + 40 kg K ha^{-1}) treatment combination. Whereas, the lowest plant height (15.41, 24.07, 34.56 and 42.54 cm at 25, 35, 45 and 55 DAS. respectively), number of leaves (4.33, 5.87, 6.6 and 6.33 at 25, 35, 45 and 55 DAS. respectively), total dry weight (0.32, 1.06, 1.32 and 1.77 g at 25, 35, 45 and 55 DAS. respectively), number of branches (1.07), pods $plant^{-1}$ (9), seeds pod^{-1} (7.6), 1000 seeds weight (41.53 g), seed yield (0.52 t ha^{-1}), stover yield (0.97 t ha^{-1}) and biological yield (1.48 t ha^{-1}) were observed in S_0K_0 (no sulfur + no potassium) treatment combination and the lowest harvest index (28.01 %) was observed in S_3K_1 (12 kg S ha^{-1} + 20 kg K ha^{-1}) treatment combination.

Conclusion

From the above findings it can be concluded that, most of the growth, yield and yield contributing characteristics of mungbean gave the best performance which was achieved from S_2 treatment (6 kg S ha^{-1}). Again, Different level of potassium fertilizer application K_2 (40 kg K ha^{-1}) treatment showed the best performance regarding most of the yield and yield contributing characteristics of mungbean. In case of combined effect, S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination gave the best result in producing highest number of branches $plant^{-1}$ (4.73), pods $plant^{-1}$(16.47), seeds pod^{-1} (10.87) and 1000 seeds weight (56 g), which ultimately influences seed yield. The highest seed yield 1.51 t ha^{-1} was obtained from the application of 6 kg S ha^{-1} sulfur along with 40 kg K ha^{-1} potassium fertilizer as S_2K_2 (6 kg S ha^{-1} + 40 kg K ha^{-1}) treatment combination. So, this treatment combination (S_2K_2) can be treated as the best treatment combination under the present study.

Recommendation

However, to reach a specific conclusion and recommendation, more research work on mungbean under these treatment variables should be done in different Agro-ecological zones of Bangladesh to fit in cropping system for rich diet and improve the soil health.

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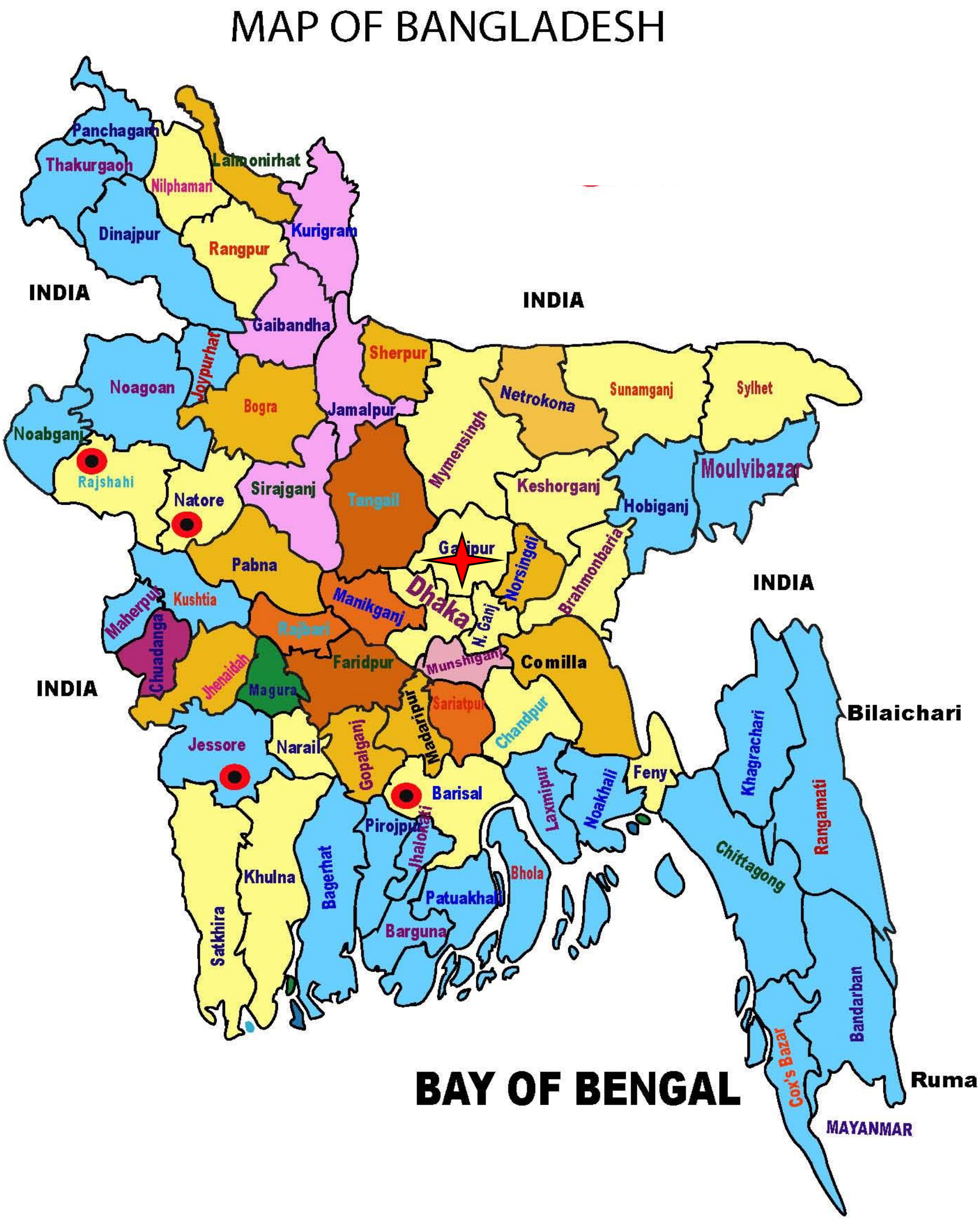
APPENDICES

Appendix I. Map of Bangladesh showing the experimental site under study



Appendix II. Characteristics of Agronomy Farm soil is analysed by Soi Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

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

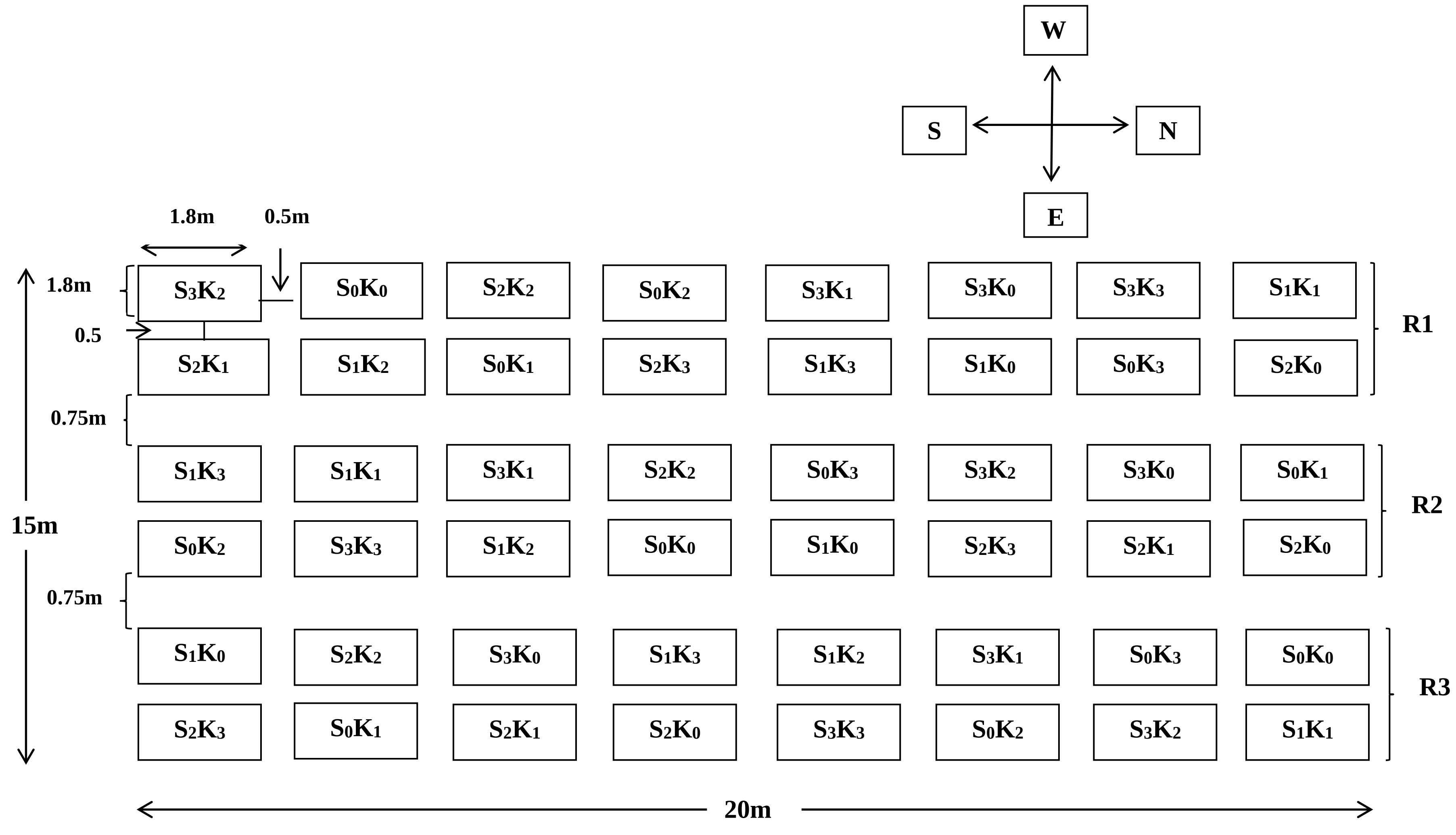
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from March, 2019 to June, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	March	35.20	21.00	52.44	20.4
	April	34	24	54	225.1
	May	37	28	61	259.3
	June	39	29	67	273.6

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

Appendix IV. Layout of the experimental field



Appendix V. Response of sulfur and potassium on plant height

	Plant height at 25 DAS				Plant height at 35 DAS			
Source	**DF**	**SS**	**MS**	**F**	**DF**	**SS**	**MS**	**F**
Replication	2	3.0362	1.51811		2	8.8833	4.4417	
Sulfur	3	13.1754	4.39179	14.01**	3	13.9058	4.6353	6.25**
Potassium	3	15.5155	5.17183	16.50**	3	31.9412	10.6471	14.35**
Sulfur × Potassium	9	8.7707	0.97452	3.11**	9	16.3241	1.8138	2.44*
Error	30	9.4030	0.31343		30	22.2559	0.7419	
Total	47	49.9008			47	93.3104		
Grand Mean	16.841				27.257			
	Plant height at 45 DAS				**Plant height at 55 DAS**			
Source	**DF**	**SS**	**MS**	**F**	**DF**	**SS**	**MS**	**F**
Replication	2	2.245	1.1225		2	2.156	1.0778	
Sulfur	3	63.793	21.2644	44.43**	3	114.314	38.1045	31.32**
Potassium	3	53.340	17.7801	37.15**	3	127.831	42.6105	35.02**
Sulfur × Potassium	9	17.572	1.9525	4.08**	9	28.616	3.1796	2.61*
Error	30	14.359	0.4786		30	36.500	1.2167	
Total	47	151.309			47	309.417		
Grand Mean	36.545				45.946			

**Significant at 1% level of probability
*Significant at 5% level of probability

Appendix VI. Response of sulfur and potassium on number of leaves

Number of leaves 25 DAS					Number of leaves 35 DAS			
Source	**DF**	**SS**	**MS**	**F**	**DF**	**SS**	**MS**	**F**
Replication	2	0.21500	0.10750		2	0.10500	0.05250	
Sulfur	3	1.45667	0.48556	13.03**	3	2.14333	0.71444	15.15**
Potassium	3	1.07000	0.35667	9.57**	3	0.55000	0.18333	3.89*
Sulfur × Potassium	9	0.51000	0.05667	1.52^{NS}	9	0.55667	0.06185	1.31^{NS}
Error	30	1.11833	0.03728		30	1.41500	0.04717	
Total	47	4.37000			47	4.77000		
Grand Mean	5.0250				6.4750			
Number of leaves 45 DAS					**Number of leaves 55 DAS**			
Source	**DF**	**SS**	**MS**	**F**	**DF**	**SS**	**MS**	**F**
Replication	2	0.21167	0.10583		2	0.8000	0.04000	
Sulfur	3	2.48000	0.82667	14.52**	3	2.88667	0.96222	16.40**
Potassium	3	1.24667	0.41556	7.30**	3	1.20667	0.40222	6.86**
Sulfur × Potassium	9	0.42000	0.04667	0.82^{NS}	9	0.54667	0.06074	1.04^{NS}
Error	30	1.70833	0.05694		30	1.76000	0.05867	
Total	47	6.06667			47	6.48000		
Grand Mean	7.0833				7.2208			

**Significant at 1% level of probability
*Significant at 5% level of probability
NS= not significance

Appendix VII. Response of sulfur and potassium on total dry weight $plant^{-1}$

Source	Total dry weight 25 DAP				Total dry weight 35 DAP			
	DF	SS	MS	F	DF	SS	MS	F
Replication	2	0.00115	0.00057		2	0.00568	0.00284	
Sulfur	3	0.03500	0.01167	19.84**	3	0.34642	0.11547	21.36**
Potassium	3	0.01476	0.00492	8.37**	3	0.28059	0.09353	17.30**
Sulfur × Potassium	9	0.00986	0.00110	1.86^{NS}	9	0.10680	0.01187	2.19^{NS}
Error	30	0.01764	0.00059		30	0.16221	0.00541	
Total	47	0.07841			47	0.90170		
Grand Mean	0.4075				1.2199			

Source	Total dry weight 45 DAP				Total dry weight 55 DAP			
	DF	SS	MS	F	DF	SS	MS	F
Replication	2	0.00207	0.00104		2	0.00097	0.00049	
Sulfur	3	1.79642	0.59881	197.60**	3	1.82006	0.60669	710.78**
Potassium	3	1.81971	0.60657	200.16**	3	2.08787	0.69596	815.37**
Sulfur × Potassium	9	1.05907	0.11767	38.83**	9	0.63684	0.07076	82.90**
Error	30	0.09091	0.00303		30	0.02561	0.00085	
Total	47	4.76819			47	4.57135		
Grand Mean	1.6402				2.2102			

**Significant at 1% level of probability
NS= not significance

Appendix VIII. Response of sulfur and potassium on number of branch plant^{-1}

Number of branchplant^{-1}				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.0381	0.0191	
Potassium	3	31.9183	10.6394	441.29**
Sulfur	3	31.1080	10.3693	430.09**
Potassium × Sulfur	9	7.2789	0.8088	33.55**
Error	30	0.7233	0.0241	
Total	47	71.0665		
Grand Mean	2.7619			

**Significant at 1% level of probability

Appendix IX. Response of sulfur and potassium on number of pods plant^{-1}

No. of pods plant^{-1}				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.500	0.2500	
Potassium	3	153.105	51.0352	204.14**
Sulfur	3	111.930	37.3100	149.24**
Potassium × Sulfur	9	21.984	2.4427	9.77**
Error	30	7.500	0.2500	
Total	47	295.020		
Grand Mean	12.625			

**Significant at 1% level of probability

Appendix X. Response of sulfur and potassium on seed pod^{-1}

No of seed pod^{-1}				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.0417	0.02083	
Sulfur	3	16.6576	5.55253	128.96**
Potassium	3	13.8714	4.62381	107.39**
Sulfur × Potassium	9	2.9686	0.32984	7.66**
Error	30	1.2917	0.04306	
Total	47	34.8309		
Grand Mean	9.1327			

**Significant at 1% level of probability

Appendix XI. Response of sulfur and potassium on 1000 seeds wt

1000 seeds weight				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	1.125	0.563	
Potassium	3	432.313	144.104	109.34**
Sulfur	3	416.871	138.957	105.44**
Potassium × Sulfur	9	91.814	10.202	7.74**
Error	30	39.538	1.318	
Total	47	981.660		
Grand Mean	48.314			

**Significant at 1% level of probability

Appendix XII. Response of sulfur and potassium seed yield

Seed yield				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.00084	0.00042	
Sulfur	3	2.40325	0.80108	1399.18**
Potassium	3	2.67136	0.89045	1555.27**
Sulfur × Potassium	9	0.89561	0.09951	173.81**
Error	30	0.01718	0.00057	
Total	47	5.98823		
Grand Mean	1.0108			

**Significant at 1% level of probability

Appendix XIII. Response of sulfur and potassium on stover yield

Stover yield				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.0004	0.00022	
Sulfur	3	11.8561	3.95205	6532.68**
Potassium	3	11.3830	3.79433	6271.97**
Sulfur × Potassium	9	2.5281	0.28090	464.32**
Error	30	0.0181	0.00060	
Total	47	25.7858		
Grand Mean	1.9884			

**Significant at 1% level of probability

Appendix XIV. Response of sulfur and potassium on biological yield

Biological yield				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.0004	0.00021	
Sulfur	3	25.6211	8.54037	7486.72**
Potassium	3	24.0581	8.01937	7030.00**
Sulfur × Potassium	9	5.7006	0.63340	555.25**
Error	30	0.0342	0.00114	
Total	47	55.4144		
Grand Mean	2.9991			

*Significant at 1% level of probability

Appendix XV. Response of sulfur and potassium on harvest index

Harvest index				
Source	**DF**	**SS**	**MS**	**F**
Replication	2	0.748	0.3738	
Sulfur	3	85.283	28.4278	67.60**
Potassium	3	50.110	16.7034	39.72**
Sulfur × Potassium	9	172.126	19.1252	45.48**
Error	30	12.616	0.4205	
Total	47	320.884		
Grand Mean	34.015			

*Significant at 1% level of probability