EFFECT OF POTASSIUM AND SULPHUR ON GROWTH AND YIELD OF BARIMash-1

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CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF POTASSIUM AND SULPHUR ON GROWTH AND YIELD OF BARIMash-1"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE,** embodies the result of a piece of *bona fide* research work carried out by **MD. JIBON ISLAM, REGISTRATION NO. 09-03513** 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: **(Prof. Dr. Alok Kumar Paul)**

Place: Dhaka, Bangladesh **Supervisor**

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ABSTRACT

An experiment was conducted at the research Field of Sher-e-Bangla Agricultural University, Dhaka, during the period from February to June, 2014 to study the effect of potassium and sulphur on the growth and yield of BARIMash-1. The treatment consisted of four level of potassium viz. K_0 = 0 kg/ha, K_1 = 12 kg/ha, K_2 = 18 kg/ha, K_3 = 24 kg/ha and three different level of sulphur viz. S_0 = 0 kg/ha, S_1 = 5 kg/ha, S_2 = 10 kg/ha. The experiment was laid out in a randomized complete block design (RCBD) having three replications. Each replication had 12 unit plots to which the treatment combinations were assigned randomly. Seeds (v.BARIMash-1) were sown at the rate of 25 kg ha^{-1} in the furrow. Necessary intercultural operations were done as and when necessary. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed significant variation among the treatments in respect of the majority of the observed parameters and yield. Potassiun @ 24 kg ha^{-1} gave the highest plant height, length of pod, number of pods per plant, number of seeds per pod, thousand seed weight. The highest yield of seed (1505.00 kg ha^{-1}) was recorded in 24 kg ha^{-1}. Similarly, the highest number of pods per plant, number of seeds per pod, thousand seed weight, seed yield (1494 kg ha^{-1}) was recorded with 10 kg S ha^{-1}. The interaction between different levels of K and S was significant for almost all studied parameters and seed yield. The highest seed yield (1528 kg ha^{-1}) was recorded with the combination of 24 kg K and 10 kg S ha^{-1}. The yield components also attained the maximum results from the said treatment combination. Concentrations of N, P, K and S in blackgram stover were influenced significantly due to combined application of K and S. The highest concentrations were obtained with the combination of 24 kg ha^{-1} K and 10 kg ha^{-1} S application. As the tested crop responded linearly due to application of K and S, therefore further higher dose may be used for maximizing the yield of blackgram in the study area (AEZ-28).

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
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
ha^{-1}	=	Per hectare
g	=	gram (s)
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%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Black gram (*Vigna mungo* L.) is one of the most important pulse crops in Bangladesh. The cultivated black gram belongs to the family leguminoseae, sub-family Papilionceae. It is mainly a day neutral warm season crop commonly grown in semi-arid to sub-humid low land tropics and sub-tropices. Pulse originated in south and Southeast Asia but widely grown in India, Pakistan, Banagladesh, Myanmar, Thiland, Philippines, China and Indonesia. Different kinds of pulses are grown and consumed by the people of Bangladesh. Among them black gram locally known as maskalai and also known as urd, udid or mash is one of the important short duration pulse crop. It grows well in north or north-west part of Bangladesh, especially in Rajshahi and Chapai Nowabganj districts. The crop has its own importance due to high nutritional value of grains as human food and fodder as rich feed for cattle. The grains contain about 24 per cent protein on dry weight basis, which is more than twice than that of cereals (Thesiya *et al.,* 2013). It is a good green manure and erosion resisting cover crop. The crop also improves soil fertility by symbiotic fixation of atmospheric nitrogen in root nodules.

Bangladesh is a developing country and there is a serious nutritional problem in the cereal-based diet for her common people. Black gram is the cheapest source of protein for the poor and is called the poor men's meat (Main, 1976). Pluses contain a remarkable amount of proteins, minerals, vitamins and carbohydrates. Among the various pulses, black gram is an important one which contains approximately 25-28% protein, 4.5-5.5% ash, 0.5-1.5% fat, 3.5-4.5% fibre and 62-65% carbohydrate on dry weight basis (Kaul, 1982). It contains sulphur containing amino acids methionine and cysteine and also contains lysine, which are excellent component of balanced human nutrition. The dried seeds whole or split, are used to make dal, soups, curries and are added to various spiced or fried dishes. In spite of its various uses, its cultivation is decreasing day by day both in acreage and yield (BBS, 2005) which badly affects on human health. The daily consumption of pulses in Bangladesh is only 12.27 g per capita compared to 45.0g, recommended by Food and Agriculture Organization (FAO, 2003).

In Bangladesh, it is cultivated as black gram, which occupied a area of 62000 acres of land, and the total production of black gram were 24 thousands metric tons in Bangladesh in the year of 2009-2010. Thus the Average yield of black gram is 900 kg/ha (BBS, 2011). Black gram is an important pulse ranking the third both in acreage and production among the pulses (BBS, 2005). In Bangladesh it can be grown both in summer and winter seasons. Excessive growth with less number of pods and seeds occurs when the crop is grown in summer. It is generally recognized that pulses offer the most practical means of solving protein deficiency in Bangladesh but there is an acute shortage of grain legumes in relation to their requirements. Increase of pulse production is urgently needed to meet up the demand of the people to reduce import, to save foreign currency and to increase pulse consumption. Increase of pulse production can also minimize the scarcity of fodder because the whole plant or it's by products can be used as good animal feed.

Potassium plays a critical role in enzyme activation, water use efficiency, photosynthesis, transport of sugars, protein, and starch synthesis in plants (Ngatunga and Uriyo, 1984; Muchena and Kiome, 1995) is especially important in its interaction with nitrogen throughout the growing period. Adequate potassium in the field results in higher crop yields and higher nitrogen- use efficiency as it enhance nodulation and hence N_2 fixation (Drevon and Hartwig, 1997). Crops respond to higher potassium levels when nitrogen is sufficient, and greater yield response to nitrogen occurs when potassium is sufficient (Buttery *et al*. 1987), thus a complementary uptake for the plant growth and development. Therefore, contribution of N fixation in K nutrition of legumes is very important.

In recent years, sulphur deficiency has been aggravated in Bangladesh soils due to increase in cropping intensity, use of high-yielding varieties and addition of sulphur-free fertilizers. Sulphur is now recognized as the fourth major nutrients after N, P and K. On an average, crops absorb sulphur as much as they absorb phosphorus. The increasing concerns of sulphur deficiency suggest that S deserves greater attention than that it has received so far. According to Tandon (1995), black gram yielding 8.90 q/ha removes 70 kg N, 5.6 kg P, 50.1 kg K and 5.1 kg S/ha from the soil.

Potassium and sulphur play a vital role in the nutrition of plants. Infact these are the nutrients, which are deficient in the soils. Therefore application of potassium and sulphur fertilizers becomes important both from quality as well as production point of view. No systematic work has been done on the effect of potassium and sulphur on yield of black gram particularly in this region. Therefore, the present experiment was undertaken to study the effect of potassium and sulphur on the growth and yield of BARIMash-1. The present study was therefore, undertaken with the following objectives.

i. to find out the optimum dose of potassium for maximizing the growth and yield of black gram.

ii. to find out the optimum dose of sulphur for maximizing the growth and yield of black gram.

iii. to observe the interaction effect of potassium and sulphur fertilization for proper growth and yield of black gram.

CHAPTER 2
REVIEW OF LITERATURE

The growth and yield of black gram are influenced by potassium and sulphur. 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 BARIMash-1.

2.1 Effect of potassium on the growth and yield of blackgram

Zaki *et al.* (2013) conducted at El Rayyan region, Fayoum Governorate, Egypt, during the two successive winter seasons of 2010-11 and 2011-12 to study the effect of application of potassium fertilizer levels (0, 50 and 75 kg K O/faddan, one faddan = 0.42 ha) under skipping one irrigation (3^{rd} or 4^{th}) irrigation) on growth and yield of chickpea (*Cicer arietinum* L.) cv. Giza 3. The main findings of this study showed that skipping one irrigation or increasing potassium fertilizer levels led to significant reduction in all characters under study in both seasons (plant height, total dry weight /plant, number of branches/plant, number of capsules/plant, dry weight of capsules/plant and dry weight of leaves/plant at 115 days after sowing. Skipping the 3rd or 4th irrigation led to declined in weight of capsules/plant, seed yield/plant, shelling%, seed index, seed, straw and biological yields /faddan. Meanwhile, application of potassium induced stimulating effect on yield and its components under the present study and the rate of 75 Kg K_2O/faddan increased all characters under this study i.e. weight of capsules/plant, seed yield/plant, shelling % seed index, seed, straw and biological yields. It is clear from the results that skipping the 3rd or 4th irrigation led to reduction in protein and carbohydrate percentages compared with the control, while there was a significant increase in protein and carbohydrate percentages of chickpea seed due to application of potassium fertilization. The interaction between skipping irrigation and potassium fertilizer levels was significant in all characters under study and the best treatment was 75kg K_2O /faddan with normal irrigation.

Patil *et al*. (2011) studied the effect of potassium humate on growth and yield of soybean (Glycine max (L.) Merrill) cv. Mahamendal and black gram (*Phaseolus mungo* (L.)) cv. Local. For the study of growth and yield characters (seedling emergence, height of plants, root length, root nodules per plant, pods per plant and yield per acre) of soybean and black gram, Seeds were sown in field plot and potassium humate 5 kg per acre per dose was applied in two doses (first dose along with sowing and second 40 days after sowing) and water as control. Growth and yield characters of crop plants were noted after various periods from seed sowing. Results obtained during this investigation clearly showed that, potassium humate treated plants showed significantly increased results on growth and yield characters of soybean and black gram than control plants.

Hussain *et al.* (2011) carried out an experiment at the Department of Agronomy, University of Agriculture, Faisalabad during summer 2005. The objective was to find out the best level of potash fertilizer on growth and yield response of two mungbean **(***Vigna radiata* **L.)** cultivars (Niab Mung-92 and Chakwal Mung-06) to different levels of potassium. The experiment was laid out in Randomized Complete Block Design with factorial arrangements and replicated thrice. Treatments were comprised of five levels of potash fertilizer (0, 30, 60, 90,120 Kg ha-1). Different potassium levels significantly infiuenced the seed yield and yield contributing parameters except number of plants per plot. Maximum seed yield (753 Kg ha-1) was obtained with the application of 90 Kg potash per hectare. Genotype M-06 produced higher seed yield than that of NM-92. The interactive effect of mungbean varieties and Potassium level was found significant in parameter of protein contents (%). Maximum protein contents were observed in case of Mung-06 with application of 90 Kg potash per hectare. It is concluded that the application of potash fertilizer gave higher yield of mungbean cultivars under agro-climatic conditions of Faisalabad.

Jahan et al. (2009) conducted at the Agronomy Field Laboratory, University of Rajshahi to study the effects of potassium levels on the growth, yield and yield contributing characters of lentil. The experiment comprised of three varieties viz. BARImasur- 4, BARImasur-5 and BARImasur-6 and five potassium levels viz. 0, 15, 25, 35 and 45 Kg K ha^{-1}. The results revealed that among the three varieties, BARImasur-6 produced the highest seed yield (2.24 t ha-1) and BARImasur-4 produced the lowest seed yield (1.79 t ha^{-1}). Grain and stover yield of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. The highest grain yield (2.16 t ha^{-1}) was found at 35 kg K ha^{-1} and the lowest grain yield (1.61 t ha^{-1}) was exhibited from potassium control level and the highest stover yield (3.89 t ha^{-1}) was also found in 35 kg K ha^{-1} and the lowest (3.32 t ha^{-1}) was found in control potassium level. In case of interaction, the highest seed yield (2.58 t ha-1) was produced by BARImasur-6 with 35 kg K ha^{-1}. Therefore, fertilization of all the varieties with 35 kg K ha^{-1} appeared as the best rate of potassium in respect of grain and stover yield. It can be suggested that farmers may be used BARImasur-6 with 35 kg K ha-1 for better grain and stover production of lentil.

Asghar *et al.* (1994) investigated the effect of varying levels of potash application on the yield and quality characteristics of black gram on a sandy loam soil having 0.05% N, 8 and 130 ppm $P_{20}S$ and K_20, respectively. A uniform dose of 25 and 75 kg Nand P_20S ha^{-1} was used in all the treatments. The varying levels of potash were 0, 25, 50, 75, 100 and 125 kg K_20 ha^{-1}. The whole quantity of N, P and K in the form of urea, single super phosphate and potassium sulphate, respectively was side drilled just after seeding. The results revealed that application of 75 kg K_20 in addition to 25 and 75 kg N and P_20S ha^{-1} showed a significant increase in yield and improved seed protein contents of mash.

K^+ is highly mobile and can aid in balancing the anion charges within the plant. Potassium regulates the opening and closing of the plant stomata, thus helping to prevent water loss through transpiration and hence influencing growth and yield (Nziguheba, 1998). Research findings indicates that potassium application in corn and soyabean increased average yields of both crop when applied at the rate of 120 kg K ha^{-1} based on soil potassium test recommendations as compared with lower rates. The importance of potassium on increasing yields was also revealed in other crops rather than legumes. For example, Borges and Mallarino (2000); Turuko and Mohammed (2014) reported K removal in tubers ranged from 203 to 397 kg/ha and was directly proportional to tuber yield, that is, the more the plant absorbs K+ the more the yield it produce. Like nitrogen, the importance of potassium in legume production has to be considered and taken into action for proper yield.

2.2 Effect of sulphur on the growth and yield of blackgram

Marko *et al.* (2014) conducted during rainy seasons of 2010 and 2011 to study 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. The findings suggest that due to heavy withdrawal of nutrients by blackgram cv. JU-2, the succeeding crop must be nourished properly based on nutrients status of the soil.

Ganie *et al.* (2014) conducted during *Kharif* 2011 to study the effect of sulphur and boron application on nutrient content and uptake pattern of N, P, K, S and B in french bean. The experiment showed that increase in application of sulphur led to an increase in the concentration and in turn uptake of N, P, K, S and B in pods, seeds as well as stover up to 45 kg/ha. However, the increase in nutrient concentration and uptake parameters with the increase in sulphur from 30 kg/ha to 45 kg/ha showed no significant effect. Owing to boron application similar trend was followed in N, P, K, S and B concentration and uptake by the crop. The interaction effect between sulphur and boron significantly and synergistically increased N, P, K, S and B content and uptake of french bean at pod picking stage as well as harvesting stage. However, it was found that higher levels of sulphur and boron showed antagonistic effect on nutrient content and uptake of French bean at pod picking stage as well as harvesting stage. The study suggested that soil application of sulphur and boron in inceptisols of Kashmir valley increased the availability of primary nutrients in addition to sulphur and boron causing their absorption by french bean plant.

Mir *et al.* (2013) conducted at Allahabad Agricultural Institute Deemed University, Allahabad to study the effect of levels of phosphorus, sulphur and Phosphorus Solubilizing Bacteria (PSB) on growth, yield and nutrient content of blackgram for consecutive two years 2004 and 2005. The crop growth parameters viz., plant height, number of nodules and number of leaves per plant, yield and nutrient content increased significantly with the application of high levels of phosphorus, sulphur with or without bio-fertilizer inoculation. Application of 60 kg P_2O_5 ha^{-1} recorded maximum plant height (49.9 cm), number of leaves $plant^{-1}$ (50.8), number of nodules $plant^{-1}$ (27.8), haulm yield (28.9 q ha^{-1}), grain yield (8 q ha^{-1}) and phosphorus, sulphur and protein content of grain (0.356 %, 0.253% and 22.64%, respectively) as compared to lower levels. Application of Sulphur @ 40 kg ha^{-1} recorded maximum plant height (47.31 cm), number of leaves plant-1 (49.80), number of nodules plant-1 (25.58), haulm yield (28.80 q ha^{-1}), grain yield (7.92 q ha^{-1}) and phosphorus, sulphur and protein content (0.295 , 0.281 and 21.79%, respectively). Inoculation of blackgram seeds with phosphorus solubilizing bacteria recorded slightly high.

Surendra Ram and Katiyar (2013) conducted under Instructional Farm of N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.), to evaluate the influence of sulphur and zinc on mungbean for two consecutive summer seasons i.e. 2008- 09 and 2009-10. The experiment 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) was laid down in randomized block design with three replications. The summer mungbean variety "Narendra Moong-1" was sown during both the years. The results revealed that application of 40 Kg S ha^{-1} and 10 Kg Zn ha^{-1} significantly increased the plant height, number of branches plant-1, number of nodules plant-1, number of pods $plant^{-1}$, number of seeds pod^{-1}, seed yield, protein content (%) and test weight was non-significant. The control (0 Kg Sx0 Kg Zn ha-1) had the poorest performance in respect of yield and protein content of mungbean seed during both the years, respectively. The interaction effect between S x Zn on various parameters of summer mungbean was found significant and test weight was found non-significant during both the years. The interaction effect in seed yield was synergistic. 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} during 2008-09 and 2009-10, respectively. 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 the least was in control during both the years.

Islam (2012) conducted at two different locations (Barani Agricultural Research Institute Chakwal and farm field Talagang, district Chakwal) for two crop-growing seasons in northern rainfed Punjab, Pakistan to assess the yield and micronutrient uptake of chickpea (*Cicer arietinum*). The treatments were four combinations of two levels of sulfur (15 and 30 kg/ha) from two sources (gypsum and ammonium sulfate) and a no-sulphur (control). Application of sulfur resulted in a significant increase in seed yield up to 17% over control. Ammonium sulfate was a more efficient source of sulfur as compared to gypsum at both the locations. Sulfur application resulted in a significant increase in micronutrient uptake by plant; however effect of sulfur application on soil pH at the end of experiment was not significant. Availability of soil zinc and copper increased with sulfur application at the end of two year experiment. Tissue copper and iron and soil available copper and iron correlated negatively with soil pH. Sulfur should be applied to chickpea grown under rainfed conditions in order to increase seed yield, to improve nutritional composition of product and to enhance efficiency of other fertilizers.

Sulphur is a part of every living cell and is a constituent of two of the 21 amino acids which form proteins. Of all the macronutrients, sulphur is perhaps the nutrient which has attracted the most attention to soil science and plant nutrition due to its potential defensive characteristics to pests, good nutritive potentiality to crops and its relative immobility in the soil-plant system. The benefits from sulphur fertilisation of crops can be traced to its role in protein development, to improvement of nitrogen use, etc.This review highlights the prominent role of microbes in sulphur availability to crop plants as well as includes the mechanism of its uptake, translocation and assimilation. Moreover, it provides new insights leading us to revisit the hypothesis of sulphur significance in pulse cropping and regulatory mechanisms in sulphur assimilation (Khan and Mazid, 2011).

Rahman *et al*. (2008) conducted at Bangladesh Agricultural University, Mymensingh farm during 2004 boro season to evaluate the effect of S and Zn on rice (cv. BRRI dhan29). There were seven treatments viz. S_0Zn_0, $S_{10}Zn_0$, $S_{20}Zn_0$, $S_0Zn_{1.5}$, S_0Zn_3, $S_{10}Zn_{1.5}$ and $S_{20}Zn_3$. The subscripts of S and Zn represent the dose in kg ha^{-1}. The highest grain (5.76 t ha^{-1}) and straw (7.32 t ha^{-1}) yields were recorded with $S_{20}Zn_3$ treatment (100% recommended dose). The S_0Zn_0 (control) had the lowest grain yield with 4.35 t ha^{-1} as well as the lowest straw yield with 5.47 t ha^{-1}. Application of both S and Zn fertilizers significantly increased S and Zn contents as well as their uptake over control.

2.3 Combined effect of potassium and sulphur on the growth and yield of blackgram

Thesiya *et al*. (2013) conducted during the kharif season of the year 2003 to study the effect of potassium and sulphur on the growth and yield of black gram (*Vigna mungo* L. Hepper) 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 straw (18.28 q ha^{-1}) yield was recorded with 20 kg K_2O ha^{-1}, which was at par with 40 kg K_2O ha^{-1} in case of grain yield. Application of sulphur at 30 kg S ha^{-1} (S_2) registered significantly the highest grain (9.19 q ha^{-1}) and straw (18.06 q ha^{-1}) yield. Combined application of 20 kg K_2O ha^{-1} along with 30 kg S ha^{-1} recorded significant increase in respect of yield attributes and yield.

Mondal *et al*. (2005) carried out during *rabi* season in the Entisol soil with neutral reaction at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, during 1998 - 2000 under irrigated condition to evaluate the effect of potassium and sulphur on the productivity, nutrient uptake and quality improvement of chickpea. Highest seed yield of chickpea (l.38 t ha^{-1}) was obtained when the crop was treated with 25 kg K along with 40 kg S ha^{-1} which was closely followed (1.30 t ha^{-1})) with the application of 12.5 kg K and 40 kg S ha^{-1}. Increased uptake of nutrients by the crop was obtained with the treatment receiving higher dose of potassium (25 kg K ha^{-1}) along with higher dose of sulphur (40 kg S ha^{-1}). The experimental results also revealed that maximum protein content in the seeds of chickpea (23.25 %) was obtained with 25 kg Kha^{-1} (K_2) with 40 kg S ha^{-1} (S_2).

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Field of Sher-e-Bangla Agricultural University farm, Dhaka during the period from February to June, 2014 to study the effect of potassium and sulphur on the growth and yield of BARIMash-1. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1. Description of the experimental site

3.1.1. Site and soil

Geographically the experimental field was located at 23^0 77´ latitude and 90^0 33´ E longitudes at an altitude of 8.5 m above the mean sea level. The soil belonged to the Agro-ecological Zone – Modhupur Tract (AEZ 28) (Appendix I). The land topography was medium high and soil texture was silty clay loam with pH 5.80. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix I.

3.1.2. Climate and weather

The climate of the locality is subtropical, which is characterized by high temperature and heavy rainfall during *kharif* season (April-September) and scanty rainfall during *rabi* season (October-March) associated with moderately low temperature.

3.2. Planting materials

BARIMash-1

BARIMash-1 was developed by BARI and released by National Seed Board (NSB). The seeds of BARIMash-1 for the experiment were collected from Bangladesh Agriculture Research Institute (BARI) Joydepur, Gazipur.

3.3. Treatment

The experiment was consisted of the following two treatment factors:

Factor-A: level of potassium -4

K_0 = 0 kg/ha

K_1 = 12 kg/ha

K_2 = 18 kg/ha

K_3 = 24 kg/ha

Factor-B: level of Sulphur -3

S_0 = 0 kg/ha

S_1 = 5 kg/ha

S_2 = 10 kg/ha

3.4. Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) having three replications. Each replication had 12 unit plots to which the treatment combinations were assigned randomly. The unit plot size was 5.0 m^2 (2.5 m ×2m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5. Land preparation

The experimental land was opened with a power tiller on 5th February, 2014. Ploughing and cross ploughing were done with country plough followed by laddering. Land preparation was completed on 10th February, 2014 and was ready for sowing of seeds.

3.6. Fertilizer application

The fertilizers were applied as basal dose at final land preparation where Urea and TSP, were applied @ 40 kg $ha^{-1}$and 75 kg ha^{-1}, respectively and also MoP, and S were applied as per treatment in all plots. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.7. Sowing of seeds

Seeds were sown at the rate of 25 kg ha^{-1} in 30 cm a part furrows on 20 February, 2014 and the furrows were covered with the soils soon after seeding.

3.8. Germination of seeds

Seed germination occurred from 3rd day of sowing. On the 4th day the percentage of germination was more than 85% and on the 5th day nearly all seedlings sprouted out from the soil.

3.9. Intercultural operations

3.9.1. Weed control

Weeding was done once in all the unit plots with care at 15 DAS.

3.9.2. Thinning

Thinning was done at 20 days after sowing. Plant to plant distance was maintained at 15 cm.

3.9.3. Irrigation and drainage

Presowing irrigation was given to ensure the maximum germination percentage. During the whole experimental period, there was a shortage of rainfall in earlier part; however, it was heavier at the middle of the growing period. So it was essential to remove the excess water from the field at the middle of the growing period.

3.9.4. Pest control

The infestation of pod borer was successfully controlled by the application of Dimecrone 50 EC @ 1.00 L ha^{-1} to prevent pod borer infestation as and when required.

3.10. Determination of maturity

At the time when 80% of the pods turned black colour, the crop was considered to attain maturity.

3.11. Harvesting and sampling

The Mashkali pods were harvested from prefixed 1.0 m^2 area. Before harvesting ten plants were selected randomly from each plot and pods from the selected 10 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 in time plot wise and were bagged separately, tagged and brought to the threshing floor for yield data. The stover yield was taken from the plants of the same area by sun–drying.

3.12. Threshing

The pods were sun dried for three days by placing them on the open threshing floor. Seeds were separated from the pods by beating with bamboo sticks.

3.13. Drying, cleaning and weighing

The seeds collected by threshing were dried in the sun to reduce the seed moisture at safe moisture content level. The dried seeds were cleaned and weighed. The stovers were also sun dried and weighed.

3.14. Data collection

1. Plant height
2. Pod length
3. No. of pods plant^{-1}
4. No. of seeds pod^{-1}
5. 1000- seed weight
6. Seed yield
7. Stover yield

Plant height

The heights of the 10 selected plants were measured from the ground level to the tip of the plant at harvest time. Thereafter, average plant height was calculated.

Pod length

Pod length was measured in centimeter (cm) scale from randomly selected 10 pods. Mean value of three pod lengths were recorded as treatment wise.

Number of pods per plant

Number of pods per plant was counted from the 10 randomly selected plant samples thrice as biackgram pods matured asynchronously and then the average pod number was calculated.

Number of seeds per pod

Number of seeds per pod was counted from 10 randomly selected pods of plants and then the average seed number per pod was calculated.

1000-seed weight

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

Seed yield

Pods collected from plants of pre-demarkated central 1 m^2 area, were considered for taking yield data. Pods were collected thrice from that plants and the seeds collected from that pods were adjusted at 12 % moisture content by sun-drying. The weights of those seeds were taken and yield was expressed in ton per hectare.

Stover yield

Stover yield was determined from the central 1 m^2 area of each plot. After threshing, the plant parts were sun-dried and weight was taken Finally the yield was converted to ton per hectare.

3.15 Chemical analysis of plant samples

3.15.1 Collection and preparation of plant samples

Stover samples were collected after threshing for N, P, K and S analyses. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S. The stover samples were analyzed for N, P, K and S concentrations. The methods were as follows:

3.15.2 Digestion of plant samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^{0} C and then 2 ml 30% H_2O_2 was added therefore heating was continued at 360^{0} C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.15.3 Digestion of plant samples with nitric-perchloric acid for P, K and S

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest by using different standard methods.

3.15.4 Determination of P, K and S from plant samples

3.15.4.1 Phosphorus

Plant samples (stover) were digested by diacid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by using venadomolybdate method (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 5 ml for stover sample from 50 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.15.4.2 Potassium

One milli-liter of digested sample was taken and diluted to 20 ml volume to make desired concentration so that the flame photometer reading of samples was measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.15.4.3 Sulphur

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

3.16 Nutrient Uptake

After chemical analysis of straw and grain samples the nutrient contents were calculated and from the value of nutrient contents, nutrient uptakes were also calculated by following formula:

Nutrient uptake (kg/ha) = Nutrient content (%) × Yield (kg/ha)/100

3.17 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil sample of each plot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container for the determination of physical and chemical properties of soil.

3.18 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz.texture, organic matter, pH, total N and available P, K, and S contents. The soil samples were analyzed by the following standard methods as follows:

3.18.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of % sand, % silt and % clay to the Marshall's textural triangular co-ordinate following the USDA system.

3.18.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

3.18.3 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1934). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter,c content was multiplied by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.18.4 Total nitrogen

Total N content in soil weas determined following Micro Kjeldahl method. One gram of air dried ground soil sample was taken into micro Kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160 ^{0}C and then 2 ml H_2O_2 was added. After that heating was continued upto 360^0C until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digest weas used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask. After that 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10N-NaOH solutions was added in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.18.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity was measured colorimetrically at 660 nm wavelength and readings was calibrated with the standard P curve (Page *et al*. 1982).

3.18.6 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods Potassium in the extract was measured by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.18.7 Available sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*. 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by a spectrophotometer at 420 nm wavelength.

3.19 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test (Gomez & Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the experiment. The experiment was conducted to determine the effects of four levels of potassium and four levels of sulphur and their interaction effects on the growth and yield of blackgram. The growth and yield contributing characters such as plant height, pod length, thousand seed weight and yield as influenced by potassium and sulphur are presented in Tables (1-9). The results of each parameter have been adequately discussed with possible interpretations whenever necessary under the following headlines:

4.1 Plant height (cm)

The effects of potassium on the plant height of blackgram are presented in (Table1). The plant height was significantly influenced by different levels of potassium. Among the different doses of potassium, K_3 (24 kg ha^{-1}) showed the highest plant height (45.52 cm). On the other hand, the lowest plant height (40.48 cm) was observed in the K_0 treatment where no potassium was applied. The taller plants at the highest doses received more nutrients which might have encouraged more vegetative growth.

Sulphur showed statistically significant variation in respect of plant height when fertilizers in different doses were applied (Table 2). However, among the different doses of sulphur, S_2 (10 $kgha^{-1}$) showed the highest plant height (43.81 cm). The lowest plant height (41.73 cm) was observed in the S_0 treatment where no sulphur was applied.

Table 1. Effects of potassium on plant height, pod length and number of pods per plant of blackgram

Treatment	Plant height (cm)		Pod length (cm)		Number of pods per plant	
K_0	40.48	c	4.29	c	33.50	c
K_1	41.58	c	4.36	c	37.00	bc
K_2	43.41	b	4.51	b	39.93	b
K_3	45.52	a	4.82	a	45.24	a
LSD $_{(0.05)}$	1.759		0.14		4.41	
CV(%)	6.08		6.42		7.42	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 2. Effects of Sulphur on plant height pod length and number of pods plant^{-1} of blackgram

Treatment	Plant height (cm)		Pod length (cm)	Number of pods per plant	
S_0	41.73	b	4.41	36.05	b
S_1	42.69	ab	4.49	39.27	ab
S_2	43.81	a	4.59	41.43	a
LSD $_{(0.05)}$	1.378		0.1924	4.814	
CV(%)	6.08		6.42	7.42	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

The plant height of blackgram increased significantly due to interaction effect between potassium and sulphur (Table 3). The lowest plant height (39.75 cm) was observed in the treatment combination of K_0S_0 (no potassium and no Sulphur). On the other hand, the highest plant height (47.02 cm) was recorded with K_3S_2 treatment, which was statistically similar with K_1S_2, K_2S_0, K_2S_1, K_2S_2, K_3S_0 and K_3S_1.

4.2 Length of pod

There was significant variation in the length of pod in blackgram when different doses of potassium fertilizer were applied (Table 1). The longest pod (4.82 cm) was recorded in K_3 treatment (24 kg K ha^{-1}). The lowest length of pod $plant^{-1}$ (4.29 cm) was recorded in the K_0 treatment where no potassium fertilizer was applied. Optimum fertilizer dose might have increased the vegetative growth and development of blackgram that lead to the highest length of pod.

Application of Sulphur fertilizer at different doses showed no significant variation on length of pod (Table 2). Among the different fertilizer doses, S_2(10 kg S ha^{-1}) treatment showed the highest length of pod (4.59 cm). The lowest length of pod (4.41 cm) was recorded with S_0 treatment where no sulphur was applied.

Table 3. Interaction effects of potassium and Sulphur on the plant height, pod length and number of pod plant^{-1} of blackgram

Treatments	Plant height	Pod length	Number of pods plant^{-1}
K_0S_0	39.75 C	4.20 c	31.92 g
K_0S_1	40.42 Bc	4.31 bc	33.82 g
K_0S_2	41.27 Bc	4.36 bc	34.77 fg
K_1S_0	40.95 Bc	4.29 bc	34.47 fg
K_1S_1	41.52 Bc	4.37 bc	37.02 defg
K_1S_2	42.27 Abc	4.42 abc	39.51 cdef
K_2S_0	42.12 Abc	4.43 abc	36.07 efg
K_2S_1	43.42 Abc	4.48 abc	40.42 cde
K_2S_2	44.70 Abc	4.62 abc	43.32 abc
K_3S_0	44.12 Abc	4.71 abc	41.77 bcd
K_3S_1	45.42 Ab	4.81 ab	45.83 ab
K_3S_2	47.02 A	4.95 a	48.12 a
LSD $_{(0.05)}$	4.40	0.49	4.89
CV(%)	6.08	6.42	7.42

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

The Interaction effect of different doses of potassium and sulphur fertilizer on the length of pod were significant (Table 3). However, the highest length of pod (4.95 cm) was recorded with the treatment combinations of K_3S_2, which was statistically similar with K_1S_2, K_2S_0, K_2S_1, K_2S_2, K_3S_0 and K_3S_1. On the other hand, the lowest length of pod (4.20 cm) was found in K_0S_0 treatment.

4.3 Number of pods per plant

Number of pods per plant is one of the most important yield contributing characters for blackgram. Potassium showed a significant variation on the number of pods per plant (Table 1). The highest number of pods per plant (45.24) was recorded in K_3 and the lowest (35.50) in K_0 treatment.

However, there was significant variation in the number of pods per plant due to sulphur. Numerically maximum number of pods per plant (41.43) was obtained from S_2 treatment, which was statistically similar with S_1 treatment. On the other hand, the minimum (36.05) was obtained in S_0 treatment (Table 2).

Interaction effect between potassium and sulphur had a significant variation on the number of pods per plant. The highest number of pods per plant (48.12) was obtained from K_3S_2 treatment, which was statistically similar with K_2S_2 and K_3S_1 treatment combination. While the minimum (31.92) was obtained from K_0S_0 combination (Table 3).

4.4 Number of seeds per pod

The number of seeds per pod was significantly influenced by different levels of potassium. The highest number of seeds per pod (6.12) was recorded in K_3 and the minimum (4.76) in K_0 (Table 4).

There was significant variation in the number of seeds per pod due to the different level of sulphur application. The maximum number of seeds per pod (5.70) was obtained from S_2 treatment which was followed by S_1 and the minimum (4.97) was from S_0 treatment (Table 5).

The number of seeds per pod increased significantly due to interaction effect between K and S (Table 3). The highest number of seeds per pod (6.44) was obtained from K_3S_2 treatment, which was statistically similar with K_2S_1, K_2S_2, K_3S_0 and K_3S_1treatment. While the lowest (4.34) seeds per pod was recorded from K_0S_0 (Table 6).

Table 4 Effects of potassium on yield contributing characters and yield of blackgram

Treatments	Number of seeds per pod		1000- seed weight (g)		Seed yield (kg/ha)	
K_0	4.76	c	39.50	b	1415.00	c
K_1	4.94	c	39.92	ab	1457.00	b
K_2	5.52	b	40.04	ab	1479.00	ab
K_3	6.12	a	40.36	a	1505.00	a
LSD $_{(0.05)}$	0.39		0.84		35.18	
CV(%)	10.82		7.23		9.97	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 5. Effects of sulphur on yield contributing characters and yield of blackgram

Treatments	Number of seeds pod		1000- seed weight (g)		Seed yield (kg/ha)	
S_0	4.97	b	39.64	b	1427.0	b
S_1	5.34	ab	39.96	ab	1470.0	a
S_2	5.70	a	40.26	a	1494.0	a
LSD $_{(0.05)}$	0.54		0.56		40.57	
CV(%)	10.82		7.23		10.0	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 6. Interaction effects of potassium and sulphur on the yield contributing characters and yield of blackgram

Treatments	Number of seeds pod^{-1}		1000- seed weight (g)		Seed yield (kg/ha)	
K_0S_0	4.34	e	39.20	d	1378.00	f
K_0S_1	4.84	de	39.50	cd	1405.00	ef
K_0S_2	5.09	bcde	39.80	bcd	1461.00	bcd
K_1S_0	4.64	e	39.60	bcd	1418.00	def
K_1S_1	4.94	cde	40.00	bc	1468.00	bcd
K_1S_2	5.24	bcde	40.15	bc	1483.00	abc
K_2S_0	5.09	bcde	39.80	bcd	1438.00	cde
K_2S_1	5.44	abcde	40.10	bc	1493.00	ab
K_2S_2	6.04	abc	40.23	b	1504.00	ab
K_3S_0	5.79	abcd	39.95	bc	1473.00	bc
K_3S_1	6.14	ab	40.25	b	1512.00	ab
K_3S_2	6.44	a	40.88	a	1528.00	a
$LSD_{(0.05)}$	0.98		0.61		48.88	
CV(%)	10.82		7.23		9.97	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.5 1000 seed weight

Thousand seed weight of blackgram differed significantly due to level of potassium. The highest thousand seed weight (40.36 g) was obtained from K_3, which was statistically similar with K_2 and K_1. The minimum thousand seed weight (39.50 g) was obtained from K_0 (Table 4).

There was significant variation in the thousand seed weight due level of sulphur. The maximum thousand seed weight (40.26 g) was obtained from S_2 treatment which was followed by S_1 and the minimum (39.64 g) from S_0 (Table 5).

Interaction effect between potassium and sulphur had a significant variation on the thousand seed weight. The highest thousand seed weight (40.88 g) was obtained from K_3S_2 treatment while the lowest (39.20 g) from K_0S_0 combination (Table 6).

4.6 Yield of seed (kg ha^{-1})

Significant variation was observed on the seed yield of blackgram when different doses of potassium fertilizer were applied (Table 4). The highest yield of seed (1505.00 kg ha^{-1}) was recorded in K_3 (24 kgha^{-1}) which was statistically similar with

K_2 treatment. The lowest yield of seed (1415 kg ha^{-1}) was recorded in the K_0 treatment where no potassium fertilizer was applied.

The results of the single effects of different levels of sulphur have been shown in (Table 5). From the table it was apparent that S_2 (10 $kgha^{-1}$) treatment gave the highest yield (1494 kg ha^{-1}), which was statistically similar with S_1 treatment. On the contrary, the lowest yield of pod (1427.00 ha^{-1}) was observed with $S_{0,}$ where no sulphur was applied.

The interaction effect between potassium and sulphur fertilizer on the yield of blackgram were significant (Table 6). The highest yield of seed (1528 kg ha^{-1}) was recorded with the treatment combination of K_3S_2, which was statistically similar with K_1S_2, K_2S_1, K_2S_2, and K_3S_{1}.. On the other hand, the lowest yield of seed (1378 kg ha^{-1}) was found in K_0S_0 treatment combination (no potassium and no sulphur).

4.7 Nitrogen concentrations in stover of blackgram

Effect of K on N concentration of stover was significantly influenced due to application of potassium (Table 7). The highest N concentration in blackgram stover (0.798 %) was recorded in K_3 (24 kgha^{-1}), which showed similar result with K_2 (18 kgha^{-1}) treatment. Otherwise, the lowest N concentration in blackgram stover (0.682 %) was recorded in K_0 treatment where no potassium was applied.

Effect of S on N concentration of stover was significantly influenced by application of sulphur (Table 8). The highest N concentration in blackgram stover (0.815 %) was recorded in S_2 (10 kg ha^{-1}). The lowest N concentration in blackgram stover (0.655 %) was recorded in S_0 treatment where no sulphur was applied.

Nitrogen concentration in the stover of blackgram was significantly increased due to interaction effect of potassium and sulphur (Table 9). The highest concentration of N in the stover (0.883 %) was recorded in the treatment combination of $K_3S_{2.}$The lowest potassium concentration (0.577 %) in stover was found in $K_0S_{0.}$

Table 7. Effects of potassium on N, P, K and S content in stover in blackgram

Treatment	%N	%P	%K	%S
K_0	0.682 b	0.477	0.900 c	0.110 b
K_1	0.686 b	0.544	1.233 b	0.126 b
K_2	0.771 a	0.639	1.510 a	0.124 b
K_3	0.798 a	0.667	1.542 a	0.415 a
LSD $_{(0.05)}$	0.082	0.217	0.164	0.037
CV(%)	4.460	5.890	4.650	4.550

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 8. Effects sulphur on the N, P, K and S content of stover in blackgram

Treatments	%N	%P	%K	%S
S_0	0.655 b	0.510 a	1.208 b	0.124 b
S_1	0.733 ab	0.608 a	1.298 ab	0.152 b
S_2	0.815 a	0.627 a	1.383 a	0.306 a
LSD $_{(0.05)}$	0.111	0.294	0.157	0.035
CV(%)	4.46	5.89	4.65	4.55

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

Table 9. Interaction effects between potassium and sulphur on the N, P, K and S content of stover of blackgram

Treatments	%N		%P		%K		%S	
K_0S_0	0.577	e	0.386	d	0.707	f	0.062	f
K_0S_1	0.660	d	0.511	cd	0.960	e	0.123	d
K_0S_2	0.810	bc	0.535	cd	1.033	e	0.146	c
K_1S_0	0.693	d	0.558	bc	1.167	d	0.099	e
K_1S_1	0.817	bc	0.657	abc	1.190	d	0.125	d
K_1S_2	0.703	d	0.702	ab	1.343	c	0.154	bc
K_2S_0	0.680	d	0.568	bc	1.457	b	0.142	c
K_2S_1	0.770	c	0.671	abc	1.500	ab	0.124	d
K_2S_2	0.863	ab	0.510	cd	1.573	ab	0.167	b
K_3S_0	0.670	d	0.530	cd	1.503	ab	0.109	de
K_3S_1	0.683	d	0.593	bc	1.543	ab	0.122	d
K_3S_2	0.883	a	0.762	a	1.580	a	0.955	a
$LSD_{(0.05)}$	0.054		0.142		0.107		0.017	
CV(%)	4.460		5.890		4.650		4.550	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.8 Phosphorus concentrations in stover of blackgram

Effect of K on P concentration in the stover of blackgram was not significantly influenced by the application of potassium (Table 7). The highest P concentration in blackgram stover (0.667 %) was recorded in K_3 (24 kgha^{-1}), which showed similar result with K_2 (18 kgha^{-1}) treatment. Otherwise, the lowest P concentration in blackgram stover (0.477 %) was recorded in K_0 treatment where no potassium was applied.

Effect of sulphur on potassium concentration in stover was not significantly influenced by the application of sulphur (Table 8). The highest P concentration in blackgram stover (0.627 %) was recorded in S_2 (10 kg ha^{-1}). The lowest P concentration in blackgram stover (0.510 %) was recorded in S_0 treatment where no sulphur was applied.

Significant effect was observed due to intereaction (K × S) effect on the P concentration in stover of blackgram (Table 9). The highest concentration of P in the stover (0.762%) was recorded in the treatment combination of $K_3S_{2.}$The lowest P concentration (0.386 %) in stover was found in $K_0S_{0.}$

4.9 Potassium concentration in stover of blackgram

The effect of different doses of potassium fertilizer showed a statistically significant variation in the potassium concentration in stover (Table 7) of blackgram. The total K content of the stover varied from 0.90 % to 1.542 %. Among the different doses of potassium fertilizer, K_3 (24 kgha^{-1}) treatment showed the highest potassium concentration (1.542%) in stover, which was statistically similar with K_2 (18 kgha^{-1}) treatment. The lowest value 0.90 % was recorded in control treatment in K_0.

The effect of different doses of sulphur showed statistically significant variation in potassium concentration in stover (Table 8) of blackgram. K content of the stover varied from 1.383 % to 1.208 %. The highest K content (1.383 %) was observed in S_2 (10 kg ha^{-1}) treatment. The lowest value of K (1.208 %) was observed under control (S_0) treatment.

Significant variation on the potassium content in the stover of blackgram was seen due to interaction (K × S) effect (Table 9). The highest concentration of potassium in stover (1.580 %) was recorded in the treatment combination of K_3S_2 which was statistically similar with K_2S_1, K_2S_2, K_3S_0 and K_3S_1. On the other hand, the lowest potassium concentration (0.707 %) in stover was found in K_0S_0.

4.10 Sulphur concentration in stover blackgram

The effect of different doses of potassium fertilizer showed a statistically significant variation in the sulphur concentration in the stover (Table 7) of blackgram. S content of the stover varied from 0.11 % to 0.415 %. Among the different doses of potassium fertilizer, K_3 (24 $kgha^{-1}$) treatment showed the highest sulphur concentration (0.415 %) in stover which was followed by the lowest value 0.110 % was found in control treatment.

The effect of different doses of sulphur fertilizer showed a statistically significant variation in the sulphur concentration in the stover (Table 8) of blackgram. Sulphur content in the stover varied from 0.124 % to 0.306 %. The highest total S content (0.306 %) was observed in S_2 (10 kg/ha) treatment and the lowest value of 0.124 % was observed in control (S_0) treatment.

There was significant interaction effect (K × S) on the S content in the stover of blackgram (Table 9). The highest concentration of Sulphur in stover (0.955 %) was recorded in the treatment combination of K_3S_2. On the other hand, the lowest potassium concentration (0.062 %) in stover was found in $K_0S_{0.}$

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the research Field of Sher-e-Bangla Agricultural University, Dhaka during the period from February to June, 2015 to study the effect of potassium and sulphur on the growth and yield of BARI Maskali-1. In this experiment, the treatment consisted of four level of potassium viz. K_0 = 0 kg/ha, K_1 = 12 kg/ha, K_2 = 18 kg/ha, K_3 = 24 kg/ha, and three different level of sulphur viz. S_0 = 0 kg/ha, S_1 = 5 kg/ha, S_2 = 10 kg/ha. The experiment was laid out in a randomized complete block design (RCBD) having three replications. Each replication had 12 unit plots to which the treatment combinations were assigned randomly. The seeds of BARI maskali-1 variety were sown at the rate of 25 kg ha^{-1} in the furrow on 20 February, 2014. Necessary intercultural operations were done as and when necessary. The crop was harvest at its right stage of maturity on 17May, 2014.

Data on yield and yield components were collected. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation was observed among the treatments in respect majority of the observed parameters.

It was observed that the plant height was significantly influenced due to different doses of potassium. The tallest plant (45.52 cm) was obtained from K_3 (24 $kgha^{-1}$). Sulphur showed statistically significant variation in respect of plant height. The tallest plant (43.81 cm) was obtained from S_2 (10 $kgha^{-1}$) treatment.

Combined application of different doses of potassium and sulphur had significant effect on the plant height of blackgram (Table 1). The lowest plant height (39.75 cm) was observed in the treatment combination of K_0S_0 (no potassium and no sulphur).

There was significant variation in the length of pod in blackgram when different doses of potassium fertilizer were applied (Table 2). The highest length of pod (4.82 cm) was recorded in K_3 treatment. Application of sulphur fertilizer at different doses showed no significant variation on the length of pod. Never the less S_2 treatment (10 kg S ha^{-1}) showed the highest length of pod (4.59 cm). The interaction effect between potassium and sulphur resulted in significant variation in pod length. The highest length of pod (4.95 cm) was recorded with the treatment combinations of K_3S_2.

Potassium showed a significant variation on the number of pods per plant. The highest number of pods per plant (45.24) was recorded in K_3. There was significant variation in the number of pods per plant for S as well. Numerically the maximum number of pods per plant (41.43) was obtained from S_2 treatment. Interaction effect of different potassium and different level of sulphur had a significant variation on the number of pods per plant. The highest number of pods per plant (48.12) was obtained from K_3S_2 treatment.

The number of seeds per pod and thousand seed weight was significantly influenced by potassium. The highest number of seeds per pod (6.12) and thousand seed weight (40.36 g) was recorded in K_3. The number of seeds per pod and thousand seed weight of blackgram (BARI mung-5) were significantly influenced by sulphur. The maximum number of pods per plant and thousand seed weight were obtained from S_2 treatment. Interaction effect between different levels of potassium and sulphur had a significant variation on the number of seeds per pod and thousand seed weight. The highest number of seeds per pod and thousand seed weight were obtained from K_3S_2 treatment.

Significant variation was observed on the seed yield of seed of blackgram when different doses of potassium fertilizer were applied. The highest seed yield of (1505.00 kg ha^{-1}) was recorded in K_3 (24 kgha^{-1}). The lowest yield of seed (1415 kg ha^{-1}) was recorded in the K_0 treatment where no fertilizer was applied. Significant variation was observed on the yield of seed of blackgram when different doses of sulphur fertilizer were applied. The application of S @ 10kg $^{ha-1}$ gave the highest seed yield (1494.00 kg ha^{-1}). The lowest seed yield of (1427.00 ha^{-1}) was observed with $S_{0,}$ where no shuphur was applied. Interaction effect between K and S resulted in significant yield variation in blackgram. The highest yield of seed (1528 kg ha^{-1}) was recorded with the treatment combination of $K_3S_{2.}$ The lowest yield of seed (1378 kg ha^{-1}) was found in K_0S_0 treatment combination (no potassium and no sulphur).

Effect of K on N, K and S concentration in stover was significantly influenced by the application K and S. The highest N concentration in blackgram stover was 0.798 %. The highest concentration of P, K and S was o.667%, 1.542% and 0.415% respectively when the crop was fertilized with 24 kg K ha^{-1}. For S application, the highest concentration of N, P, K and S in the stover was recorded in 0.,815%, 0.627%, 1.383% and 0.306% respectively with 10 kg S ha^{-1}. The highest N concentration in blackgram stover (0.815%), total P content (0.627%), potassium (1.383 %) and Sulphur (0.306%) were recorded in S_2 (10 kg/ha).

Significant effect was also observed due to interaction (K × S) effect regarding N, P, K and S concentration in stover of blackgram. The highest concentration of N in the stover(0.883 %), phosphorus in stover (0.762%) and potassium in the stover (1.580%) and sulphur (0.955%) was recorded in the treatment combination of K_3S_2.

The effect of different doses of potassium fertilizer showed a statistically significant variation in the N, P, K and S concentration in post harvest soil. The K_3 (24 kg/ha) treatment showed the highest N concentration (0.099 %), P concentration (19.83 ppm) and potassium concentration (66.04 ppm) and Sulphur (23.82 ppm) in soil.

The effect of different doses of sulphur fertilizer showed a statistically significant variation in the N, P, K and S concentration in post harvest soil of blackgram field. The highest total N content (0.095 %), P concentration (18.57 ppm), potassium concentration (57.7 ppm) and Sulphur (23.91 ppm) were observed in S_2 (10 kg/ha) treatment.

Significant effect of combined application of different doses of potassium and sulphur fertilizer on the N, P, K and S concentration was observed in post harvest soil of blackgram field. The highest concentration of nitrogen in post harvest soil

(0.114%), concentration of P (22.78 ppm) and concentration of potassium (69.84 ppm) and sulphur (27.520%) were recorded in the treatment combination of K_2S_2.

It may be concluded from the above studies that blackgram responded significantly due to K and S application . The response was linear in nature . The highest seed yield was obtained with 24 kg ha^{-1} K and 10 kg ha^{-1} S.

Further higher doses may be used for maximizing the yield of the crop in the study area. (Deep Red Brown Terrace Soil under Madhupur Tract).

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APPENDIES

Appendix I: **Soil characteristics of the research plot of the Sher-e-Bangla Agricultural University are analyzed by Soil Resources Development Institute (SRDI) Farmgate Dhaka..**

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.80
Organic matter (%)	1.05
Total N (%)	0.06
Available P (µgm/gm soil)	42.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40