EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF BLACK GRAM

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EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF BLACK GRAM

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CERTIFICATE

This is to certify that the thesis entitled, "***EFFECT OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF BLACK GRAM***" submitted to the ***DEPARTMENT OF SOIL SCIENCE***, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE (M.S.)*** in ***SOIL SCIENCE*** embodies the result of a piece of *bona fide* research work carried out by ***MD. SHADEKUL ISLAM*** Registration No. 17-08180 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 by him.

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Dedicated

TO

MY

BELOVED

PARENTS

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EFFECT OF NITROGEN AND SULPHUR ON THE GROURTH AND YIELD OF BLACKGRAM

ABSTRACT

The experiment was conducted at experimental plot of Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka with a view to finding out the optimum dose of Nitrogen and Sulphur for maximizing the growth and yield of Black gram and their interactions on of Nitrogen and Sulphur fertilization for proper growth and yield of Black gram. The experiment consisted of treatment N_0 (no nitrogen) N_1 (nitrogen @ 10 kg ha^{-1}) N_2 (nitrogen @ 20 kg ha^{-1}) N_3 (nitrogen @ 30 kg ha^{-1}) and S_0 (no sulphur), S_1 (sulphur @ 5 kg ha^{-1}), S_2 (sulphur @ 10 kg ha^{-1}). The experiment was laid out in a two factor randomized complete block design with three replications. Growth characters, yield contributing characters and yield of blackgram were significantly influenced by nitrogen, sulphur and their interaction. At vegetative growth stage, application of nitrogen @ 30 kg ha^{-1} combined with sulphur @ 10 kg ha^{-1} produced the highest plant height (34.00 cm), number of leaves $plant^{-1}$ (28.28), dry matter weight (23.12 g) and number of branches $plant^{-1}$ (6.15) at harvest. The highest number of pods $plant^{-1}$ (64.80), number of seeds pod^{-1} (5.46), pod length (4.52 cm), 1000-seed weight (36.49 g), seed yield (1.68 t ha^{-1}), stover yield (2.03 t ha^{-1}), biological yield (3.71 t ha^{-1}) and harvest index (45.39 %) were found in nitrogen @ 10 kg ha^{-1}. The highest seed yield (1.68 t ha^{-1}) was obtained in nitrogen @ 30 kg $ha^{-1}$and the lowest seed yield (.81 t ha^{-1}) was obtained in no nitrogen application. The application sulphur @ 10 kg ha^{-1} showed superiority in terms of the highest number of pods $plant^{-1}$ (54.75), number of seeds pod^{-1} (5.13), pod length (4.05 cm), 1000-seed weight (33.87 g), seed yield (1.40 t ha^{-1}), stover yield (1.80 t ha^{-1}), biological yield (3.20 t ha^{-1}) and harvest index (43.51 %). In case of interaction, the highest seed yield (1.81 t ha^{-1}) was recorded in nitrogen @ 30 kg ha^{-1} when combined with sulphur @ 10 kg ha^{-1}. It can be concluded that the nitrogen @ 30 kg ha^{-1} appears to be promising fertilizer in terms of seed yield when combined with sulphur @ 10 kg ha^{-1}.

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ABBREVIATIONS USED

BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
NAA	National Archery Association
DAS	Days After Sowing
CLAM	Computational Linguistics Application Mediator
MH	Medical History
BAU	Bangladesh Agricultural University
PSB	Phosphate Solubilizing Bacteria
SAU	Sher-e-Bangla Agricultural University
RMN	Recommended Mineral Nitrogen
DAE	Department of Agricultural Extension
AEZ	Agro-Ecological Zone
UNDP	United Nations Development Programme
SRDI	Soil Resource Development Institute
TSP	Triple Super Phosphate
MP	Muriate of Potash
ANOVA	Analysis of Variance
DMRT	Duncan's Multiple Range Test
LSD	Least Significance Difference
DAT	Date After Transplanting

CHAPTER I

INTRODUCTION

Blackgram (*Vigna mungo L*) is one of the important pulse crops grown throughout Bangladesh. Proper fertilization is essential to improve the productivity of blackgram. It can meet its nitrogen requirements by symbiotic fixation of atmospheric nitrogen (Thakur and Negi, 1985; Nandal, et al., 1987). Blackgram is very much responsive to sulphur application (Aulakh, et at., 1997). Hence, the present investigation was undertaken to find out the response of blackgram to different levels of nitrogen and sulphur application.

A huge amount of foreign currency is expended every year to meet the national shortfall, as available of pulses in Bangladesh is about 12 g/head/day against the balanced nutritional requirement of 45 g/head/day (Anonymous, 1998). So there is no alternative to increase pulse production through adaption of modern technologies. Blackgram *(Vigna mungo* L.) one of the major pulse crop, stands fourth both in acreage and production in Bangladesh.

Generally legumes are rich in sulphur containing amino acids (methionine and cysteine). However, blackgram, especially contains higher percentage of methionine compared to other food legumes (Tsou and Hsu, 1978). Seeds of blackgram are used for human consumption as pulse soup. Green plants, matured plant parts and husk of blackgram are also used as animal feed. Blackgram is a short duration crop and matured within 70-80 days and it can easily fit well into an intensive cropping pattern thereby increasing total productivity. As a leguminous crop, blackgram fixes up atmospheric nitrogen for its growth and development and also improve soil fertility and productivity. Crop growth and yield depend on its growth characters like leaf area index, dry matter production and partitioning etc. These growth characters are greatly influenced by environmental factors (i.e. temperature, photoperiod etc.) variety and cultural practices (i.e. seeding date and rate, spacing etc.). Time of sowing determines time of flowering and it has great influence on dry matter accumulation, seed set and seed yield (Sofield*et at.al*, 1977). There are three varieties of blackgram developed by BARI which may be sown in both Kharif-1 (February-March) and Kharif-ll (August-September) seasons while BINA has developed one variety which is photosensitive and may be grown only in Kharif-ll season. But the magnitude of sowing time in the respective season is still to be known for different varieties in Jamalpur region. Therefore, the experiment was undertaken to know whether long range of sowing time in Kharif-ll could have any effect on the growth and seed yield of blackgram varieties under the agro-climatic conditions of Jamalpur in Bangladesh

Sulphur (S) is an essential plant nutrient plays a key role in sustaining higher production of pulse crop, is required in the formation of protein, vitamins and enzymes and it is a constituent of amino acids, *viz.*, cystine, cystein and methionine. Besides, it involves in various metabolic and enzymatic processincluding photosynthesis, respiration and legume-rhizobium symbiotic nitrogen fixation (Srinivasa Rao *et al.* 2001).Sulphur is one of the essential plant nutrients and its contribution in increasing the crop yields is well documented. Application of sulphur as gypsum increased plant height, dry matter production, leaf area index and straw yield of green gram (Singh *et al.,* 1994). Sulphur application through gypsum significantly increased the growth and yield of greengram (Balasubramanian and Ramamoorthy, 1999). Pandey and Singh (2001) reported that highest grain and straw yield of greengram was obtained by application of sulphur. The growth and yield potential of blackgram can be improved by optimum dose of sulphur through gypsum. Generally, a soil with less than 22 kg ha^{-1} of available sulphur is said to be deficient in sulphur. 'S' deficiency have been reported over 70 countries worldwide, of which India is one. Tamil Nadu is one of the agriculturally important states with very little documents on sulphur status. It has been found that 80% of the sample obtained from 15 benchmark clay soil in Cuddalore district were reported to be 'S' deficient (Balasubramanian *et al.,* 1990). Sulphur assumes greater significance in increasing growth and yield of pulses, as far as blackgram is concerned no work have been done earlier with regard sources and level of sulphur on growth and yield of rice fallow blackgram. Keeping this, the present experiment was planned to study the effect of sulphur and nitrogen on the growth and yield of blacgram. The main objectives of the study are;

i. To find out the optimum dose of nitrogen and sulphur for maximizing the growth and yield of black gram;
ii. To observe the interaction effect of nitrogen and sulphur fertilization for proper growth and yield of black gram.

1.

CHAPTER II

REVIEW OF LITERATURE

Blackgram is an important pulse crop in Bangladesh. In Bangladesh blackgram is generally grown without fertilizer management. However there are evidences that the yield of blackgram can be increased substantially by the use of nitrogen and sulphur. Information on application of nitrogen and sulphur fertilizer of pulse related to the study are reviewed and presented in the following heads.

2.1 Effect on growth parameters

2.1.1 Plant height

Khan and Prakash (2014) conducted a field experiment to study the effect of *rhizobial* inoculation on growth, yield, nutrient uptake and economics of summer blackgram in relation to zinc and molybdenum. Result data revealed that the *Rhizobium* culture significantly increased plant height than without inoculation.

Malik *et al.* (2014) conducted an experiment to synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata*). The maximum significant ($p<0.05$) increase in plant height was observed by the combined application of compost, *Rhizobium* and nitrogen compared to other treatments.

A field experiment was conducted by Marko *et al.* (2013) to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium*+ PSB (phosphate solubilizing bacteria) performed the best with respect to all the parameters. The treatment interactions were found to be significant in case of plant height. The highest plant height (25.01 cm) was produced in *Rhizobium* + PSB combination.

Achakzai *et al.* (2012) conducted a study to evaluate the growth response of mungbean cultivars subjected to different management of applied N fertilizer. The different N fertilizers exerted significant on plant height of mungbean. The plants of 20 kg h^{-1} N gained maximum height (36.81 cm), whereas the shortest plant height (29.64 cm) obtained in plots either receiving no fertilizer.

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean affected by foliar application of urea and bio-organic fertilizers. They found that foliar application of urea and organic manure substantially improved the plant height.

Asaduzzaman (2008) found that plant height of mungbean was significantly increased by the application of Nitrogen fertilizer at 30 kg ha^{-1}.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram. There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (pods per plant and number of seeds per pod) of greengram augmented significantly due to foliar nutrition. The foliar application of 2% diammonium phosphate + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield attributes.

Oad and Buriro (2005) conducted a research to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.25 cm whereas the lowest one was recorded from the control treatment (no fertilizer).

In a pot experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Masud (2003) observed the highest plant height with the application of 30 kg N ha^{-1}while Ghosh (2004) found the highest plant height at applying 25 kg N ha^{-1}.

Saini and Thakur (1996) stated that nitrogen at 30 and 40 kg ha^{-1} significantly increased the plant height of blackgram compared with no nitrogen.

Jamro *et al*. (1995) observed that application of 90 kg N ha^{-1} significantly increased the plant height of blackgram.

Quah and Jaafar (1994) noted that plant height of mungbean was significantly increased by the application of nitrogen fertilizer at 50 kg ha^{-1}.

In a study Suhartatik (1991) observed that increased application of NPK fertilizers significantly increased the plant height of mungbean.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increase in plant height of mungbean.

Trung and Yoshida (1983) conducted a field trial on mungbean in nutrient soil containing 0-100 ppm N in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulfate. They observed that maximum plant height was obtained by 25 ppm N at all the stages of development.

Yein *et al.* (1981) conducted a field experiment on nitrogen in combination with phosphorus fertilizer to blackgram. They revealed that application of 40 kg N ha^{-1} increased plant height.

2.1.2 Leaf area $plant^{-1}$

Mondal *et al.* (2014) conducted a field experiments with mungbean in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India. They found that leaf area $plant^{-1}$ of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS.

Achakzai *et al.* (2012) conducted a study was to evaluate the growth response of mungbean cultivars subjected to different management of applied N fertilizer. The plants grown with 80 kg h^{-1} N treatment numerically attained maximum leaf area (33.19 cm^2). Whereas, the minimum leaf area (24.36 cm^2) recorded for treatment receiving no added fertilizer (T_1).

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean affected by foliar application of urea and bio-organic fertilizers. They found that foliar application of urea and organic manure substantially improved leaf area $plant^{-1}$.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean. They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher number of leaves $plant^{-1}$.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that number of leaves plant^{-1} was significantly affected by varying level of nitrogen.

Srivastava and Verma (1982) showed that N application at the rate of 15kg ha^{-1} increased the number of green leaves in greengram plants.

2.1.3 Nodules plant^{-1}

Khan and Prakash (2014) conducted a field experiment to study the effect of *rhizobial* inoculation on growth, yield, nutrient uptake and economics of summer blackgram in relation to zinc and molybdenum. Result data revealed that the seed inoculation with *Rhizobium* culture significantly increased number of nodules plant^{-1}.

Malik *et al.* (2014) conducted an experiment on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbeanand found that the combined application of *Rhizobium*, compost and 75% of the recommended mineral nitrogen (RMN) gave maximum number of nodules and dry weight.

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean and mungbean response to fertilization and found that mungbean grown without fertilizer produced the highest nodules plant^{-1}.

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean and found that foliar application of urea and organic manure substantially improved number and dry weight of nodule.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium*and *Azotobacter*inoculation on growth and yield of mungbean varieties. The highest number of effective nodules per plant (34.9) was recorded in combined application of *Bradyrhizobium* and *Azotobacter* inoculants and the lowest (23.10) was found in uninoculated control. The use of' *Bradyrhizobium* inoculants alone gave the second highest number of nodule plant^{-1} in F_2 (31.2 plant^{-1}) followed by *Azotobacter* inoculants (29.8 plant^{-1}) and application of 20 kg N ha^{-1} (25.1 plant^{-1}).

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculation at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on BINA Mung-2. *Bradyrhizobium* inoculation and observed that nitrogen negatively affected on nodulation.

Maldal and Ray (1999) observed in a field experiment where mungbean cv. B 105, B1 and Hooghly local were untreated, seed inoculated with *Rhizobium* and 20, 30 or 40 kg N ha^{-1} as urea were given. They opinioned that nodulation was greatest with inoculation in B 105.

Provorov *et al.* (1998) observed that seed inoculation of mungbean with Strain CLAM 1901 of *Bradyrhizobium* increased number of root nodules by 24 %,herbage by 46.6%, seed mass by 39.2%, 1000-seeds weight by 16% and seed N by 30%. These results were equivalent to applying 120 kg N ha^{-1}.

Tripathi *et al*. (1994) conducted an experiment regarding soybean, mungbean and groundnut grown on a clay soil in 1985 and 1986. Five N treatments were applied through 2 sources: No N sources (control), 20 N kg ha^{-1}, *Rhizobium* seed inoculum alone, inoculum + 10 kg N ha^{-1}, and inoculum + 20 kg N ha^{-1}. The combination of inoculants + 20 kg N ha^{-1} gave the highest crop yield and the maximum number of root nodules. Soybeans and groundnuts gave comparatively higher yields than blackgram and mungbean.

Santos *et al.* (1993) observed on mungbean cv. Berken, grown in pots in podzolic soil using 7 level of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1} as NH_4NO_3. They noted that nodule number increased strongly, between flowering and maturity; in plants grown at 100 kg ha^{-1}, suggesting a delay in nodulation occurred. Poor nodulation and depletion of soil N as indicated by the low N concentration in the young mature leaves at the maturity stages. Plants grown at 400 and 500 kg ha^{-1} N failed to nodulation.

Hoque and Barrow (1993) conducted field trials at various locations in Bangladesh and found that the, inoculants markedly increased nodule number and nodule dry weight of soybean, lentil and mungbean compared to uninoculated control and urea-N treatments.

Murakami *et al*. (1990) reported that without N fertilizer, N fixation started at 12 days after sowing (DAS) increased rapidly at 34 DAS (flowering) to reach a peak at 45 DAS had a secondary peak at 60 DAS and then decreased until the plant died (83 DAS). With N fertilizer, N fixation started at 14 DAS, increased slowly to reach a much lower peak at 50 DAS and then decreased. Nodulation was greatly decreased by applied N, but fixation per unit nodule weight was similar in both N treatments. The percentage N derived from the air of 78 mungbean cultivar was 0-100% at 33 DAS and 760% in all cultivars at 60 DAS. The author suggested that these cultivars might respond more to applied N than high fixing cultivars.

2.1.4 Dry matter weight plant^{-1}

A field experiment was conducted Marko *et al.* (2013) to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of dry matter production plant^{-1}. The highest dry matter production plant^{-1} (39.84 g) was produced in *Rhizobium* + PSB.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean. They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher dry matter production.

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) significantly improved dry matter accumulation of mungbean.

Yakadri *et al.* (2002) studied the effect of nitrogen and phosphorus on crop growth and yield of greengram. Application of nitrogen at 20 kg ha^{-1} and phosphorous 60 kg ha^{-1} resulted in the significant increase in dry matter content in above ground part.

Santos *et al.* (1993)carried out an experiment on mungbean cv. Berken grown in pots in podzolic soil with 7 level of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1}), applied as NH_4NO_3 and noted that application of N up to 200 kg ha^{-1} increased the total dry matter, higher rates decreased it.

Chowdhury and Rosario (1992) studied the effects of 0, 30, 60 or 90 kg N ha^{-1} on the growth and yield performance of mungbean at Los Banos, Philippines in 1988. They observed that N @ 30 kg ha^{-1} showed significant difference in dry matter yield of mungbean up to a certain level (60 kg N ha^{-1}).

Leelavathi *et al* (1991) reported that different management of nitrogen showed significantly increased dry matter production of blackgram up to 60 kg N ha^{-1}.

Agbenin *et al.* (1991) found that applied N significantly increased growth components, dry matter yield and nutrient uptake of blackgram over the control.

Yein (1982) carried out two year field experiment in Assam. India on mungbean *(Vigna radiata)* and reported that combined application of nitrogen and phosphorus significantly increased the dry weight of the plants.

2.2 Effect on yield attributing characters

2.2.1 Branches $plant^{-1}$

Khan and Prakash (2014) conducted a field experiment to study the effect of *rhizobial* inoculation on growth, yield, nutrient uptake and economics of summer blackgram in relation to zinc and molybdenum. Result data revealed that the *Rhizobium* culture significantly increased number of primary and secondary branches $plant^{-1}$ than without inoculation.

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of branches $plant^{-1}$. The maximum branches $plant^{-1}$ (10.43) was produced in *Rhizobium* + PSB.

Achakzai *et al.* (2012) conducted a study to evaluate the growth response of mungbean cultivars subjected to different management of applied N fertilizer. Results regarding branches $plant^{-1}$ exhibited that there was a significant difference among various treatments of N fertilizer when compared it with their control treatment (no fertilizer). The plants of T_6 (100 kg h^{-1} N) produced the maximum number of branches $plant^{-1}$ (3.83), whereas minimum recorded for (3.17) in no fertilizer use.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vignaradiata*L.).They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly more number of branches (1.67) $plant^{-1}$.

Malik *et al.* (2003) conducted a study to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that number of branches $plant^{-1}$ was found to be significantly higher by 25 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer. They reported that increased branches with increasing N rates.

2.2.2 Pods $plant^{-1}$

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean and mungbean response to fertilization and they found that mungbean grown without fertilizer produced the highest number of pods plant $^{-1}$.

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of pods $plant^{-1}$. The maximum number of pods $plant^{-1}$ (39.02) was produced in *Rhizobium* + PSB.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium*and *Azotobacter*inoculation on growth and yield of mungbean varieties. The highest number of pods $plant^{-1}$ (20.5) was found in F_4 *(Bradyrhizobium +zotobacter).* The use of *Bradyrhizobium,*or *Azotobacter* inoculants alone also recorded higher number of pods $plant^{-1}$over controland 20 kg ha^{-1} N.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vignaradiata*L.). They found that application of 20 kg ha^{-1} N as basal + 20 kg ha^{-1} N with one weeding at vegetative stage showed significantly higher pods plant $^{-1}$.

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest values for number of pods plant $^{-1}$ (38.3).

Kulsum (2003) reported that different level of nitrogen showed significantly increased pods plant $^{-1}$ of blackgram up to N 60 kg ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that the number of pods plant $^{-1}$ increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) and observed that the number of pods plant $^{-1}$ was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N.

Jamro *et al* (1995) reported that application of 90 kg N ha^{-1} to blackgram resulted in appreciable improvement in the number of pods per plant.

Singh *et al*. (1993) reported increased pod yield greengram up to N 20kg ha^{-1} and P 40 kg ha^{-1}.

Tank *et al*. (1992) observed when mungbean was fertilized with 20 kg N along with level of 40 kg P_2O_5 ha^{-1} increased seed yield significantly over the unfertilized control. They also reported that mungbean fertilized with 20 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} significantly increased the number of pods plant $^{-1}$.

Basu and Bandyopadhyay (1990) conducted a field trail during the Kharif season in west Bengal where *Vignaradiata* was inoculated with *Rhizobium* strain M-10 or Jca_1 and grown in presence of 0-40 kg N ha^{-1}. Inoculation increased number of pods plant $^{-1}$ and seeds pod^{-1} and N uptake. Jca_1 was superior to M-10. Number of pods plant $^{-}$

^{1}and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

Patel and Parmar (1986) conducted an experiment on the response of greengram to varying level of nitrogen and phosphorus. They observed that increasing N application to rainfedmungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of pods plant $^{-1}$.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N level (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. In that experiment, it was found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods plant $^{-1}$.

2.2.3 Length of pod

Mondal *et al.* (2014) conducted a field experiments with mungbean in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India. They found that pod length of mungbean was significantly increased by the split application of nitrogen fertilizer at 21 DAS.

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest pod length was obtained at 150 kg ha^{-1} urea.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium*and *Azotobacter*inoculation on growth and yield of mungbean varieties. Pod length of mungbean increased significantly due to use of bacterial fertilizers. The longest pod (34.1cm) was found in F_4 (*Bradyrhizobium + Azotobacter)*. The pod length found due to *Azotobacter* (F_3) inoculants was comparable to those found in F_2 (*Bradyrhizobium*), F_5 (20 kg N ha^{-1}) and F_1 (control).

2.2.4 Seeds pod^{-1}

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizertreatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of seeds pod^{-1}. The maximum number of seeds pod^{-1} (8.95) was produced in *Rhizobium* + PSB.

Sheikh *et al.* (2012) an investigation was initiated to work out the effect of *Rhizobium* culture and phosphate solubilizing bacteria (PSB) with nitrogen and phosphorus applications on the performance of blackgram Cv-T9. The results revealed that the seeds pod^{-1}were influenced by the *Rhizobium* and Phosphate Solubilizing Bacteria (PSB) along with nitrogen and phosphorus applied @10 kg ha^{-1} and 25 kg ha^{-1}, respectively; implying the application of dual doses of biofertilizers helpful in combination with inorganic nutrient application in the enhancement of seeds pod^{-1} of blackgram.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium*and *Azotobacter*inoculation on growth and yield of mungbean varieties. The highest number of seeds pod^{-1} was produced in F_4 (*Bradyrhizobium* + *Azotobacter*). The use of *Bradyrhizobium*(F_2) or *Azotobacter*(F_3) alone or 20 kg Nha^{-1} (F_5) and control (F_1) recorded statistically identical number of seeds plant^{-1}.

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2 % foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest seeds pod^{-1}(7.67).

Malik *et al*. (2003) investigated the effect of varying level of nitrogen (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 during 2001. It was found that number seeds pod^{-1}was significantly affected by varying level of nitrogen and phosphorous.

Quah and Jaafar (1994) noted that seed yield of mungbean increased significantly by the application of nitrogen fertilizer at 50 kg ha^{-1}.

Patel and Parmar (1986) conducted an experiment on the response of greengram to varying level of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of seeds pod^{-1}.

2.2.5 Weight of 1000 seeds

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of weight of 1000 seed. The highest 1000 seed weight (56.40 g) was produced in *Rhizobium* + PSB.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculation on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on 1000 seed weight of Mungbean. The highest 1000 seed weight (34.1 g) was produced in F_4 (*Bradyrhizobium*+ *Azotobacter*) followed by F_2 (33.1 g) and F_3 (30.8 g), F_5 (30.0 g) and the lowest 1000 seed weight (29.4g) was found in control (F_1).

Srinivas*et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and observed 1000-seeds weight increased with increasing rates of N up to 40 kg ha^{-1}.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen level on the yield and yield components of mungbean at the agronomic research station, Farooqabad in Pakistan during the year of 2000 and 2001. They revealed that with the application of NPK at the rate of 50-50-0 kg ha^{-1} significantly affected the 1000 grains weight.

Patel *et al.* (1991) found that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in 1000 seed weight of blackgram.

Bali *et al.* (1991) conducted a field trail on mungbean in kharif season on silty clay loam soil. They revealed that 1000 seeds weight increased with 40 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5.

Basu and Bandyopadhyay (1990) conducted a field trail during the Kharif season in west Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or Jca_1 and grown in presence of 0-40 kg N ha^{-1}. Inoculation increased number of pods $plant^{-1}$ and seeds $plant^{-1}$ and N uptake. Jca_1 was superior to M-10. 1000 seedsweight and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increases in 1000 seeds weight of mungbean.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N level (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. They observed that application of 40 kg P_2O_5 ha^{-1} along with 20 kg N ha^{-1} significantly increased the 1000 seed weight of mungbean.

2.2.6 Seed yield

Khan and Prakash (2014) conducted a field experiment study the effect of *rhizobial* inoculation on growth, yield, nutrient uptake and economics of summer blackgram in relation to zinc and molybdenum. Result data revealed that the *Rhizobium* culture significantly increased seed yield than without inoculation.

Hossain *et al.* (2014) conducted an experiment to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculums *Bradyrhizobium*(1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI mung-5 and BARI mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher seed yield than BARI Mung-5.

Malik *et al.* (2014) conducted an experiment on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbeanand found that the combined application of *Rhizobium*, compost and 75% of the recommended mineral nitrogen (RMN) gave maximum grain yield $plant^{-1}$.

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* + PSB performed the best with respect to all these parameters. The treatment interactions were found to be significant in case of grain yield per hectare. The findings elude that 60 kg S/ha with dual biofertilizers may be applied to achieve maximum productivity and economical gain from blackgram cv. JU-2.

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest seed yield and pod length was obtained at 150 kgha^{-1} urea.

Akbar *et al.* (2013) conducted an experiment on the interactive effect of cobalt and nitrogen on growth, nodulation, yield and protein content of field grown pea and observed that the highest seed yield in the treatment the 60 kg N ha^{-1} and 10 g Co ha^{-1}.

Sheikh *et al.* (2012) an investigation was initiated to work out the effect of *Rhizobium* culture and phosphate solubilizing bacteria (PSB) with nitrogen and phosphorus applications on the performance of blackgram Cv-T9. The results revealed that all the attributes under study were highly influenced by the *Rhizobium* and Phosphate Solublizing Bacteria (PSB) along with nitrogen and phosphorus applied @10 kg ha^{-1} and 25 kg ha^{-1}, respectively; implying the application of dual doses of biofertilizers helpful in combination with inorganic nutrient application in overall enhancement of yield of blackgram.

Sadeghipour *et al. (*2010) conducted an experiment on the production of mungbean by nitrogen and phosphorus fertilizer application and they found that the maximum seed yield was obtained when 90 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} was applied.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean. They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher seed yield ha^{-1} (1982.05 kg).

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) gave significantly maximum seed yield $plant^{-1}$ (1.53 g).

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest grain yield (9.66 q ha^{-1}).

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher grain yield (1.63 t ha^{-1}) compared to cv. Pusa 105.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram. There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (number of pods per plant and number of seeds per pod) of greengram augmented significantly due to foliar nutrition. The foliar application of urea + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield. The highest grain yield of 1529 kg ha^{-1} was recorded with this treatment.

A field study conducted by Sharma and Sharma (2006) for two years at the Indian Agricultural Research Institute, New Delhi on a sandy clay loam soil showed that the application of NP increased the total grain production of a rice-wheat-mungbean cropping system by 0.5-0.6 t ha^{-1}, NK by 0.3-0.5 t ha^{-1} and NPK by 0.8-0.9 t ha^{-1}

compared to N alone, indicating that the balanced use of primary nutrients was more advantageous than their imbalanced application.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording the highest seed yield of 1205.2 kg ha^{-1}.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculation and different level of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied.

Mozumder*et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculation at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2. *Bradyrhizobium* inoculation increased dry matter production, nodulation, pod production, seed yield and harvest index and observed that increase of nitrogen fertilizer increased seed yield up to 40 kg N ha^{-1} and straw yield up to 60 kg N ha^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that a fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that grain yield increased with increasing rates of up to 40 kg N ha^{-1} only.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen level on mungbean at the agronomic research station, Farooqabad in

Pakistan. They revealed that seed inoculation + 50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Kamal *et al.* (2001) conducted an experiment at the BARI farm during rainy season for 2000-2001 to determine the effect of various level of fertilizer and weeding of mungbean. Superior grain yield (1430kg ha^{-1}) was found when fertilized @ 20-60-30 NPK kg $ha^{-1}$with two hand weeding at 20 and 30 DAE were used. This was followed by that obtained (1368 kg ha^{-1}) by using inoculum + 60-30 PK kg ha^{-1} with two hand weeding at 20 and 30 DAE. This result showed that application of fertilizer @ 20-60-30 kg ha^{-1} combine with two hands weeding at 20 and 30 DAE was economical for yield as well as quality seed production of mungbean.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India where mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmer's practices, while the highest yield was obtained by the fertilizer application (0.77 t ha^{-1}).

Karle and Pawar (1998) examined the effect of varying level of N and P fertilizers on summer mungbean. They reported higher seed yield in mungbean with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Mozumder (1998) conducted a field trail at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March, 1994 to June, 1994 to study the effects of five nitrogen level on two varieties of summer mungbean and reported that nitrogen produced negative effect on nodule production and starter dose of nitrogen (40 kg ha^{-1}) gave the maximum seed yield (1607 kg ha^{-1}).

Saini and Thakur (1996) stated that application of 30 kg ha^{-1} N significantly increased the grain yield $plant^{-1}$blackgram.

Bhalu *et al.* (1995) observed that seed yield of blackgram increased with up to 20 kg N and 40 kg P_2O_5.

Yadav *et al*. (1994) reported that higher seed yield of blackgram with 20 kg ha^{-1} N, 40 kg ha^{-1} P and 40 kg K ha^{-1}.

Singh *et al*. (1993) reported increased seed yield of blackgram with N 20 kg ha^{-1} and P 40 kg ha^{-1}.

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

Leelavathi *et al.* (1991) reported that different management of nitrogen showed significant difference in dry matter production of blackgram up to a certain level of 60 kg N ha^{-1}.

Upadhayay *et al*. (1991) reported that N application markedly increased the seed yield of blackgram in nitrogen deficient sandy loam soil

A field experiments was conducted by Sarkar and Banik (1991) to study the effect of N and P on yield of mungbean. Results showed that application of N along with P significantly increased the seed yield of mungbean. The maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_2O_5 ha^{-1}.

Arya and Kalra (1988) reported that application of N at the rate of 50 kg ha^{-1} along with 50 kg P ha^{-1} increased mungbean yield. Another experimental result from field experiments conducted by Mahadkar and Saraf (1988) of mungbean revealed that the application of N with P and K at 20:25 kg ha^{-1} gave higher seed yield.

Pongkao and Inthong (1988) applied N at the rate of 0-60 kg ha^{-1} on mungbean and reported that application of 15 kg N ha^{-1} was found to be superior giving 23% higher seed yield over the control. However 60 kg N ha^{-1} tended to produced seed yield which was at par of 15 kg N ha^{1}.

Vidhate and Jana (1986) explored the response of blackgram to nitrogen fertilization. They observed that an increase in the dose of N fertilizer increased the grain yield. Higher percent of grain yield increased when equal dose of 25 kg ha^{-1} N applied at sowing and at flowering.

An experiment was conducted by Trung and Yoshida (1983) using 0-100 ppm N as treatment in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulphate. They found that seed yield of mungbean increased with the increase in N up to 50 ppm.

2.2.7 Stover yield

Khan and Prakash (2014) conducted a field experiment study the effect of *rhizobial* inoculation on growth, yield, nutrient uptake and economics of summer blackgram in relation to zinc and molybdenum. Result data revealed that the *Rhizobium* culture significantly increased stover yield than without inoculation.

Hossain *et al.* (2014) conducted an experiment to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculums *Bradyrhizobium* (1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI mung-5 and BARI mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher stover yield than BARI Mung-5.

Nazmun*et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculation on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on stover yield of Mungbean. The highest (3754 kg ha^{-1}) and the lowest stover yield (2644 kg ha^{-1}) was found in F_4 (*Bradyrhizobium*+*Azotobacter*) and in control (F_4), respectively.

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Stover yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender*et al*. (2002) in Hisar, Haryana, India during the summer and reported that straw yield increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and stated that the stover yield increased with increasing N up to 40 kg ha^{-1}.

2.2.8 Biological yield

Hossain *et al.* (2014) found that nitrogen and *Bradyrhizobium* inoculants showed significant increase the biological yield of Mungbean. The *Bradyrhizobium* inoculated plants showed the highest seed yield (876 kg ha^{-1}) which was statistically superior to other treatments. The lowest seed yield (716 kg ha^{-1}) was showed in non-inoculated plant.

Malik *et al.* (2014) found that biological yield increased by the addition of compost, mineral N and *Rhizobium* inoculation. Lowest number of biological yield was recorded in control while it was being nourished by recommended mineral NPK fertilizers.

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India. Cultivar Pusa Vishal recorded higher biological (3.66 1.63 t ha^{-1}) compared to cv. Pusa 105.

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T_{44}. Biological yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect biological yield.

Results of an experiment conducted by Sardana and Verma (1987) in Delhi, India and stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in biological yield of mungbean.

2.2.9 Harvest index

Marko *et al.* (2013) a field experiment were conducted to study the effect of sulphur and biofertilizers on growth, yield and quality of blackgram. Amongst the biofertilizer treatments, *Rhizobium* performed the best with respect to all these parameters. The treatments were found to be significant in case of harvest index. The maximum harvest index (39.24) was in *Rhizobium* application.

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculation at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2 *Bradyrhizobium* inoculation and observed that nitrogen negatively affected on harvest index.

In a field experiment carried out by Mozumder (1998) at the Agronomy field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994 studied with five nitrogen level (0. 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer mungbean *viz*. BINA Mung-2 and Kanti, results revealed that nitrogen produced negative effect of harvest index. Harvest index (%) was decreased by higher nitrogen level.

From the above literature reviewed it may be concluded that legume crops may itself be able to fix atmospheric nitrogen but supplemental use of nitrogen (at vegetative stage @ 20-40 kg ha^{-1}) and sulphur may increase the yield of blackgram.. So additional application of nitrogen and sulphur as a source of nutrient might be helpful for increasing the growth, yield and yield attributes of blackgram.

CHAPTER III

MATERIALS AND METHODS

In Bangladesh, black gram is being grown in a very limited scale, but a good deal of interest has been generated for raising this crop due to its demand in food. Nitrogen and sulphur has an effect on growth and yield of black gram. So, this experiment has undertaken to find out optimum doses of nitrogen and sulphur for exploiting the growth and yield potential blackgram.

3.1 Experimental Site

The experiment was conducted at the Agronomy Farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from January 2018 to April 2018. The location of the site in 23° 74 N latitude and 90° 35 E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

Table 1. Morphological Characteristics of experimental field

Morphological Features	**Characteristics**
Location	Sher-e Bangla Agril. University Farm, Dhaka
AEZ No. and name	AEZ-28, Modhupur Tract
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 2. Physical and chemical properties of the experimental soil

Soil properties	Value
A. Physicalproperties	
1. Particle size analysis ofsoil.	
% Sand	29.04
% Silt	41.80
% Clay	29.16
2. Soiltexture	Clay
B. Chemicalproperties	
1. SoilpH	
2. Organic carbon(%)	
3. Organic matter(%)	
4. Total N(%)	
5. C : Nratio	
6. Available P(ppm)	
7. Exchangeable K (me/100gsoil)	
8. Available S(ppm)	

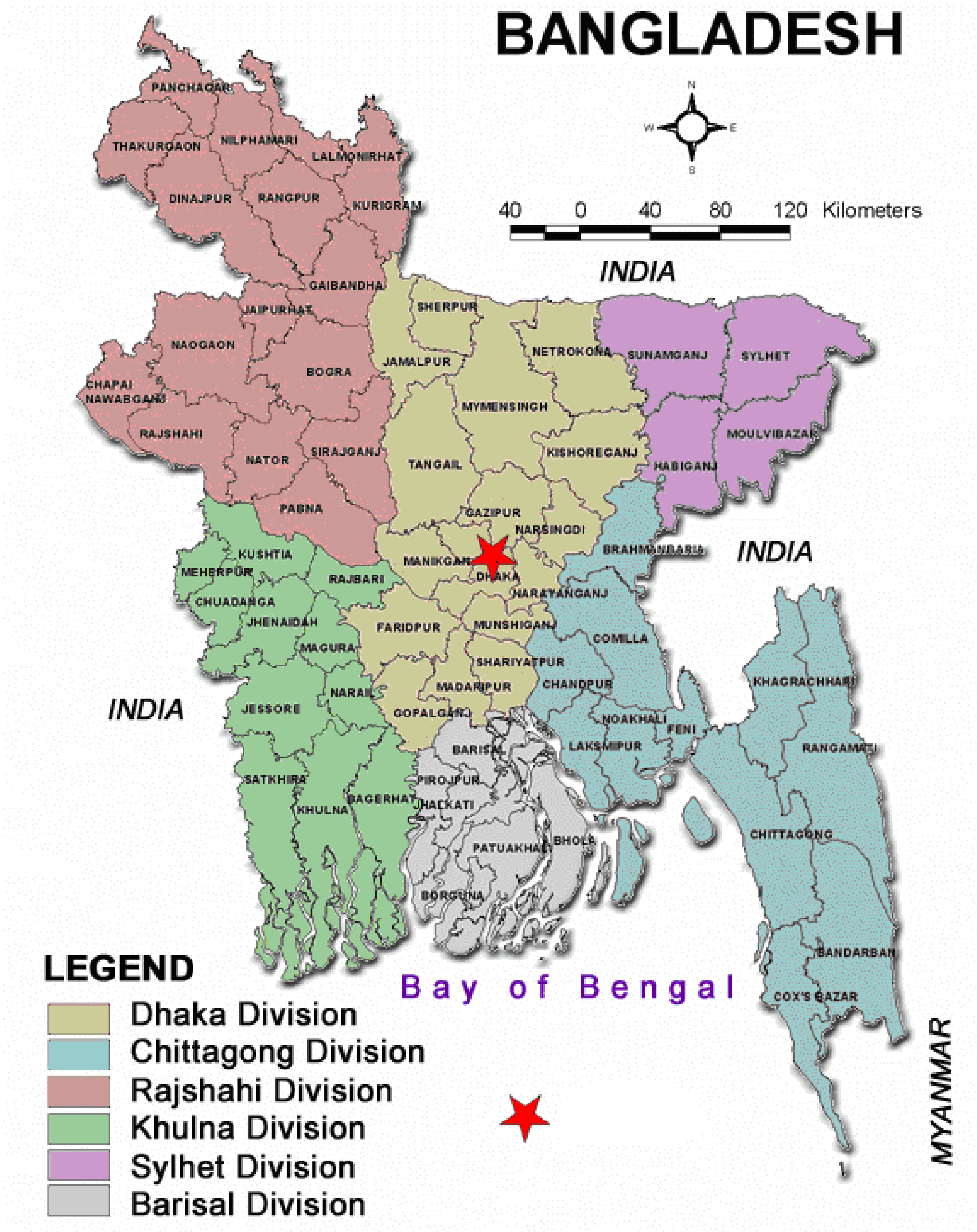

Fig.1. Map showing the experimental site under study

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). There was no rainfall during the growing period except the month of October (208mm). The average monthly maximum and minimum temperature were 29.45°C and 13.86°C respectively during the experimental period. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity, rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented in appendix I.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Farmgate, Dhaka have been presented in appendix II**.**

The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988) are given below -

AEZ No. 28

Soil series - Tejgaon

General soil: - Deep Red Brown Terrace Soil.

3.4 Plant materials

BARI Mash-2 was used as planting material. BARI Mash-2 was released and developed by BARI in 1996. Plant height of the cultivar ranges from 33 to 35 cm. Average yield of this cultivar is about 1.4-1.5 t ha^{-1}. The seeds of BARI Mash-2 for the experiment were collected from BARI, Joydepur, Gazipur. The seeds were drum-shaped and blackish and free from mixture of other seeds, weed seeds and extraneous materials.

3.5 Experimental design and layout

The two factors experiment was laid out following Randomized Complete Block

Design (RCBD) with three replications. An area of 24m * 10m was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments were allotted at random. Thus there were 36 unit plots altogether in the experiment. The size of each plot was 1.5 x 2 m. The spacing was plant to plant 10 cm and row to row 30 cm. A layout of the experiment has been shown in Fig. 1.

Treatment of the experiment

The experiment was designed to study the effect of nitrogen and sulphur on the growth and yield of black gram. The experiment consisted of two factors are as follows.

Factor A: Nitrogen (N), four levels

N_0 =Control

N_1 = Nitrogen @ 10kg ha^{-1}

N_2 = Nitrogen @ 20kg ha^{-1}

N_3 = Nitrogen @ 30kg ha^{-1}

Factor B : Sulphur (S), three levels

S_0 =Control

S_1 = Sulphur @ 5kg ha^{-1}

S_2 = Sulphur@ 10kg ha^{-1}

Treatment combination: Twelve treatment combinations

N_0S_0	N_1S_0	N_2S_0	N_3S_0
N_0S_1	N_1S_1	N_2S_1	N_3S_1
N_0S_2	N_1S_2	N_2S_2	N_3S_2

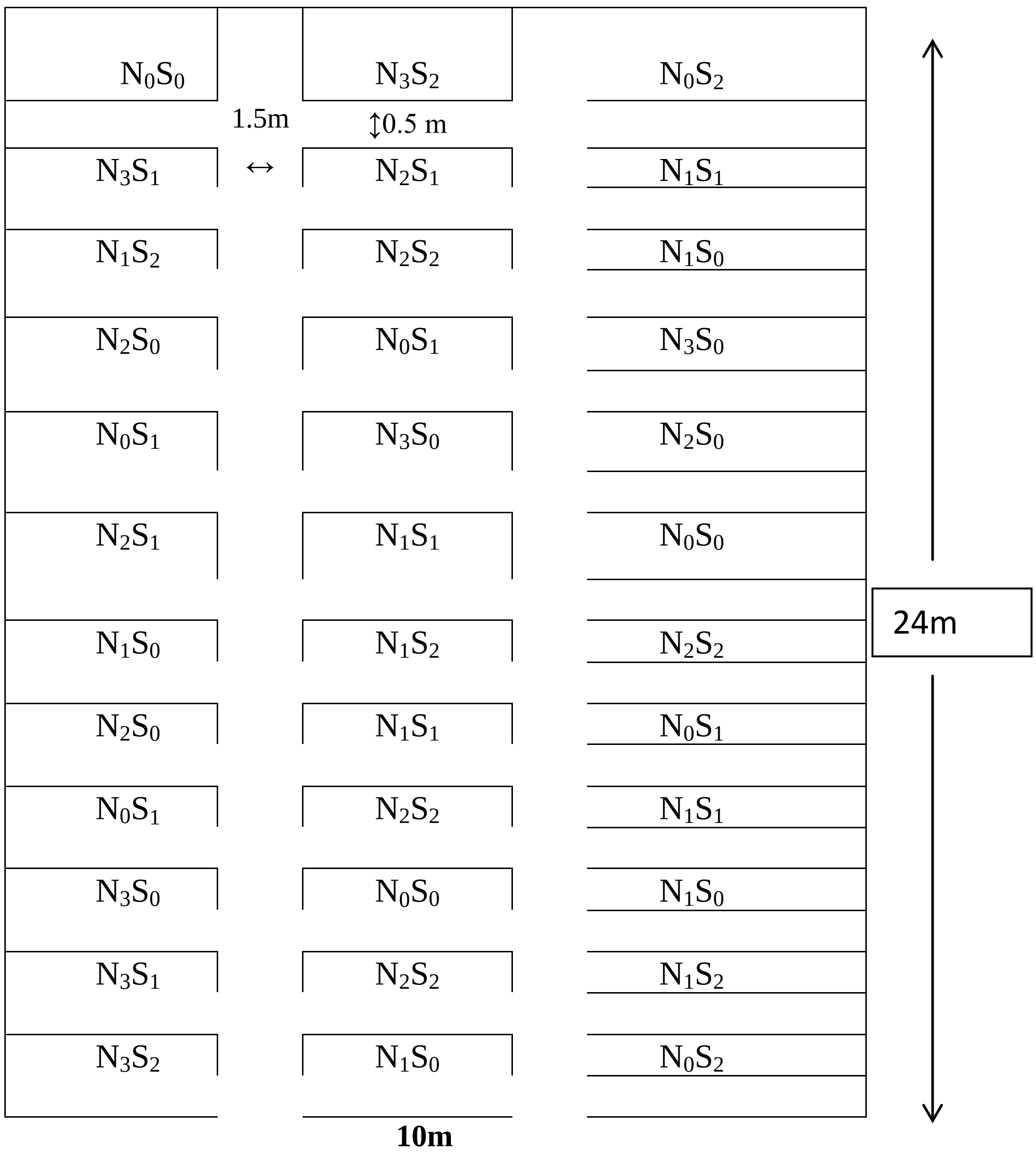

Fig. 2 **Layout of the experiment**

3.6 Land preparation

The land which was selected to conduct as experiment field was opened 3 January, 2018 with the help of a power tiller and then it was kept open to sun for 7 days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made until good tilth.

3.7 Application of fertilizers

The P K and Zn fertilizer were applied at the rate of 1, .5 and .5 kg/bigha according to

Fertilizer Recommendation Guide (BARC, 1997) through Triple super phosphate (TSP), Muriate of potash (MP) and Zinc oxide, respectively. One third (1/3) of whole amount of Urea and full amount of MP, TSP and Zinc oxide were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after sowing (DAS) and 40 DAS respectively.

3.8 Seed sowing

Seeds were sown at the rate of 35 kg ha^{-1} in the furrow on 10 January, 2018 and the furrows were covered with the soils soon after seeding. Row to row distance is 30 cm and in rows seed to seed distance 10 cm were maintained.

3.9 Intercultural operations

3.9.1 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.9.2 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and other two were given at 30 DAS and 45 DAS, respectively.

3.9.3 Plant protection measures

The crop was infested by insects. Those were effectively and timely controlled by applying insecticides Diazinon 50 EC @ 2 ml L^{-1} two times with one week interval.

3.10 Harvesting and sampling

The crop was harvested plot wise when about 80% of the pods became mature at 78 DAS. Samples were collected from different places of each plot leaving undisturbed very small in the center. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.11 Threshing

The crop was 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.

3.12 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.13 Recording of data

The data were recorded on the following parameters

a. Plant height (cm)

b. Leaf area plant $^{-1}$ (cm^2)

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

d. Dry weight plant^{-1} (g)

e. Nodules plant^{-1} (no.)

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

g. Pod length (cm)

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

i. 1000 seed weight (g)

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

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

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

m. Harvest index (%)

3.14 Procedure of recording data

i. Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 25, 40, 55 and harvest time.

ii. Leaf area plant^{-1} (cm^2)

Leaf area was measured by destructing method using CL-202 Leaf Area Meter (USA). All the leaves of the sampled plants were collected and measured leaf area and expressed in cm^2. Then the mean was calculated.

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. Dry weight plant^{-1}(g)

Ten plants were collected randomly from each plot at 25, 40, 55 and at harvest. The sample plants were oven dried for 72 hours at 70°C and then dry weight plant^{-1} was determined.

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

The 10 plants plot^{-1} from second line was uprooted and total number of nodules from ten plants was counted at 25, 40, 55 and at harvest and at harvest and the mean value determined**.**

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

Pods plant^{-1} was counted from the 10 selected plant sample and then the average pod number was calculated.

vii. Pod length (cm)

Length of pod was measured by meter scale from 20 pods of plants and then the average seed number was calculated.

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

Seeds pod^{-1} was counted from 20 selected pods of plants and then the average seed number was calculated.

vii. 1000 seed weight (g)

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

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

Seed yield was recorded on the basis of total harvested seeds plot^{-1} and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 12% moisture content.

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

After separation of seeds from plant, the straw and shell harvested area was sun dried and the weight was recorded and then converted into 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 = seed yield + Stover yield.

xi. Harvest index (%)

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

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

Here, Biological yield = Seed yield + stover yield

3.15 Data analysis technique

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 at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

Results obtained from the study of effect of nitrogen and sulphur on the growth and yield of black gram are presented and discussed in this chapter.

4.1 Growth Performance

4.1.1 Plant height at different days after sowing

4.1.1.1 Effect of nitrogen

Results revealed that plant height was significantly influenced by different levels of nitrogen at all dates of sampling. Plant height in all the nitrogen increased progressively with the advancement of time from 25 up to harvesting. Application of N_3 (nitrogen @ 30 kg ha^{-1}) was observed to produce the tallest plant at all dates of sampling . The highest plant height (31.85 cm) was recorded at harvest, and the shortest plant height (18.70 cm) was found in no nitrogen at harvest. (Fig.1, Appendix III). Variation in plant height among the treatment was mainly due to absorption of available nutrient.

4.1.1.2 Effect of sulphur

Plant height was significantly influenced by different levels of sulphur respective of growth stages. It was found that treatment S_2 (sulphur @ 10 kg ha^{-1}) produced the highest plant height (27.87 cm) at harvest. The shortest plant (24.40 cm) was obtained from treatment no sulphur application at harvest (Fig.2, Appendix IV). This trend of plant stature was observed at all dates of sampling.

4.1.1.3 Interaction effect of nitrogen and sulpher

The effect of interaction between different levels of nitrogen and sulphur on plant height at 25, 40, 55 and at harvest was significant. At harvest the tallest plant (34.00cm) was recorded in the combination of N_3 x S_2 (nitrogen @ 30 kg ha^{-1} x sulphur @ 10 kg ha^{-1} and the shortest one was recorded in the combination of no nitrogen and no sulphur (Table 1).

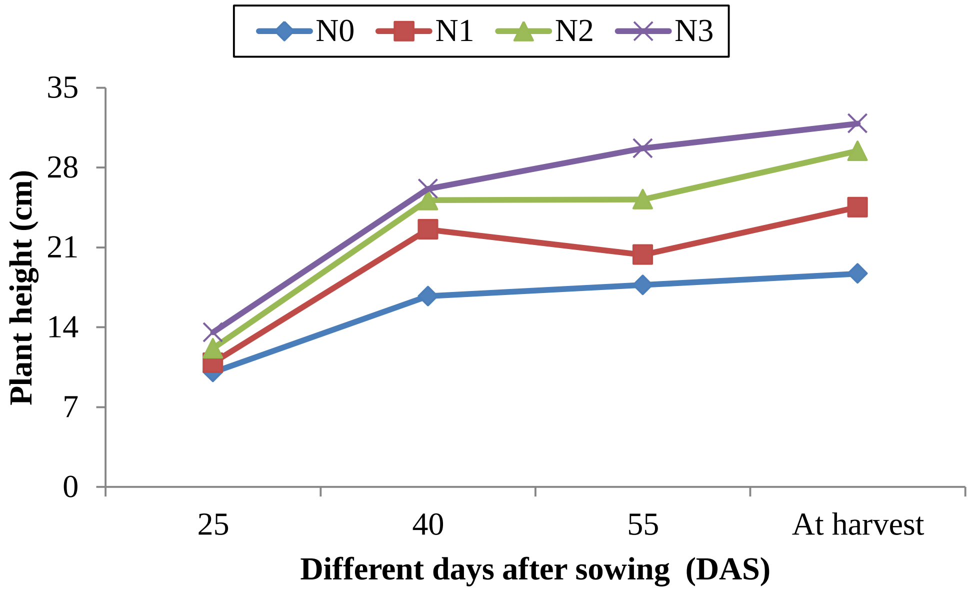

Figure 1. Effect of different levels of nitrogen on the plant height of blackgram at different days after sowing (LSD $_{(0.05)}$ = 1.34, 2.43, 2.52 and 2.57 at 25, 40, 55 DAS and harvest respectively)

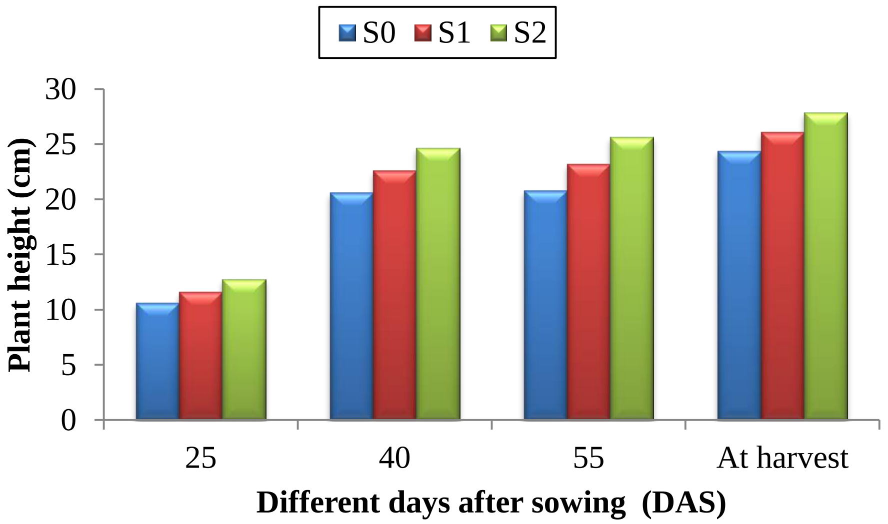

Figure 2. Effect of different levels of sulphur on the plant height of blackgram at different days after sowing (LSD $_{(0.05)}$ =1.16, 2.10, 2.19 and 2.22 at 25, 40, 55 DAS and harvest respectively)

Table 1. Interaction effect of nitrogen and sulphur on the plant height of blackgram at different days after sowing

Treatment combinations	Plant height (cm) at different days after sowing (DAS)			
	25	40	55	At harvest
N_0S_0	9.14 e	13.46 d	16.24 e	16.65 f
N_0S_1	9.92 de	16.06 d	17.86 e	18.84 f
N_0S_2	11.12 c-e	20.63 c	19.05 de	20.62 ef
N_1S_0	10.23 c-e	20.80 c	18.24 e	23.53 de
N_1S_1	10.82 c-e	22.84 bc	19.45 de	24.19 de
N_1S_2	11.62 b-d	24.08 a-c	23.35 cd	25.85 cd
N_2S_0	10.67 c-e	23.62 a-c	23.21 cd	27.87 b-d
N_2S_1	11.94 b-d	25.10 ab	25.19 c	29.50 bc
N_2S_2	13.84 ab	26.71 ab	27.24 bc	31.01 ab
N_3S_0	12.49 abc	24.64 a-c	25.58 c	29.55 bc
N_3S_1	13.75 ab	26.48 ab	30.38 ab	32.00 ab
N_3S_2	14.44 a	27.30 a	33.07 a	34.00 a
LSD $_{(0.05)}$	**2.32**	**4.21**	**4.37**	**4.45**
CV (%)	**11.75**	**10.97**	**11.11**	**10.04**

4.1.2 Number of leaves plant^{-1}

4.1.2.1 Effect of nitrogen

Significant differences were observed for producing number of leaves plant^{-1} due to different levels of nitrogen at all days after sowing. The tiller production was increased with the advancement of time from 25 to harvesting. The highest number of leaves plant^{-1}(25.16) was recorded in treatment nitrogen @ 30 kg ha^{-1} at harvest. The lowest number of leaves plant^{-1} (12.82) was found in no nitrogen application (Fig.3, Appendix V).

4.1.2.2 Effect of sulphur

Significant differences were observed for producing number of leaves plant^{-1} due to sulphur application at all days after sowing. The leaves production was increased with the advancement of time from 25 to harvesting. The highest number of leaves plant^{-1} (20.72) was recorded in the application of sulphur @ 10 kg ha^{-1}. The lowest number of total leaves plant^{-1} (16.54) was found in the no sulphur application at harvest. (Fig.4, Appendix VI).

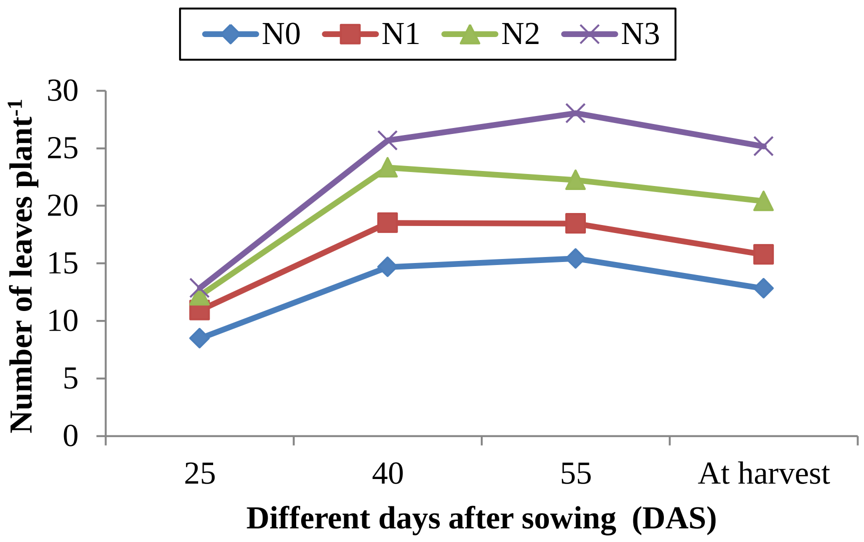

Figure 3. Effect of different levels of nitrogen on the number of leaves plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ =1.23, 2.29, 2.62 and 1.89 at 25, 40, 55 DAS and harvest respectively)

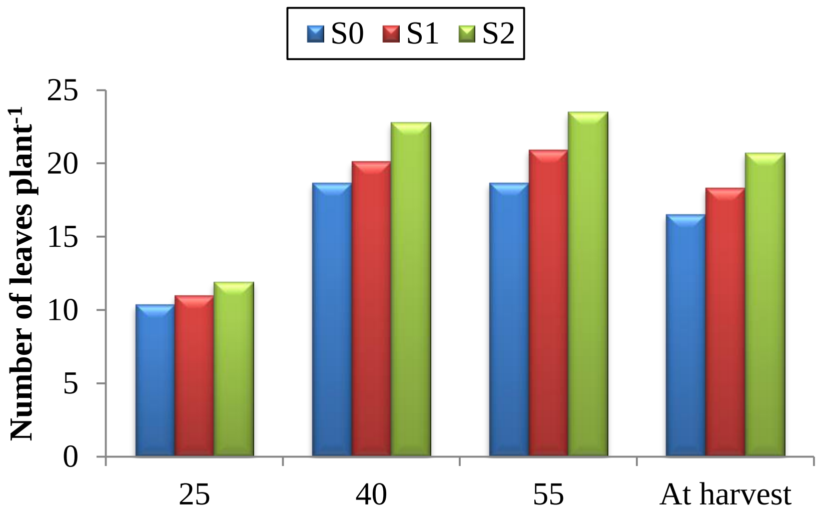

Figure 4. Effect of different levels of sulphur on the number of leaves plant^{-1}of blackgram at different days after sowing (LSD $_{(0.05)}$ =1.06, 1.99, 2.27 and 1.64 at 25, 40, 55 DAS and harvest respectively)

Table 2. Interaction effect of nitrogen and sulphur on the number of leaves plant^{-1} of blackgram at different days after sowing

Treatment combinations	Number of leaves plant^{-1}at different days after sowing (DAS)			
	25	**40**	**55**	**At harvest**
N_0S_0	6.84 e	12.83 d	13.81 h	11.60 h
N_0S_1	9.36d	13.88 cd	14.48 gh	12.35 gh
N_0S_2	9.22 d	17.32 c	17.98 e-h	14.52gh
N_1S_0	10.23 cd	16.41 cd	17.26 f-h	14.22 gh
N_1S_1	11.04 b-d	17.40 c	18.39 e-g	15.19 fg
N_1S_2	11.49 bc	21.73 b	19.73 d-f	17.88 ef
N_2S_0	11.79 bc	21.67 b	20.28 c-f	18.59 de
N_2S_1	12.16 bc	23.09 ab	22.17 c-e	20.41 c-e
N_2S_2	12.65 ab	25.19 ab	24.29 bc	22.22 bc
N_3S_0	12.72 ab	23.78 ab	23.38 cd	21.76 cd
N_3S_1	11.49 bc	26.22 a	28.73 ab	25.43 ab
N_3S_2	14.36 a	27.01 a	32.02 a	28.28 a
LSD $_{(0.05)}$	2.13	3.97	4.53	3.28
CV (%)	11.31	11.42	12.71	10.45

4.1.2.3. Interaction effect nitrogen and sulphur

Combine application nitrogen and sulphur exhibit significant influence on leaves production at all sampling dates (Appendix IV). The highest number of leaves plant^{-1} (28.28) was found in the interaction between N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) and the lowest leaves plant $^{-1}$ (11.60) was found in the interaction between no nitrogen and no sulphur application at harvest.

4.1.3 Dry matter production hill^{-1}

4.1.3.1 Effect of nitrogen

Significant differences were observed for producing dry matter hill^{-1} due to nitrogen at all days after sowing. The dry matter production was increased with the advancement of time from 25 to harvesting. The highest dry matter hill^{-1} (20.89 g) was recorded in nitrogen @ 30 kg ha^{-1} and the lowest (11.90) in at harvest. (Fig.5, Appendix VII).

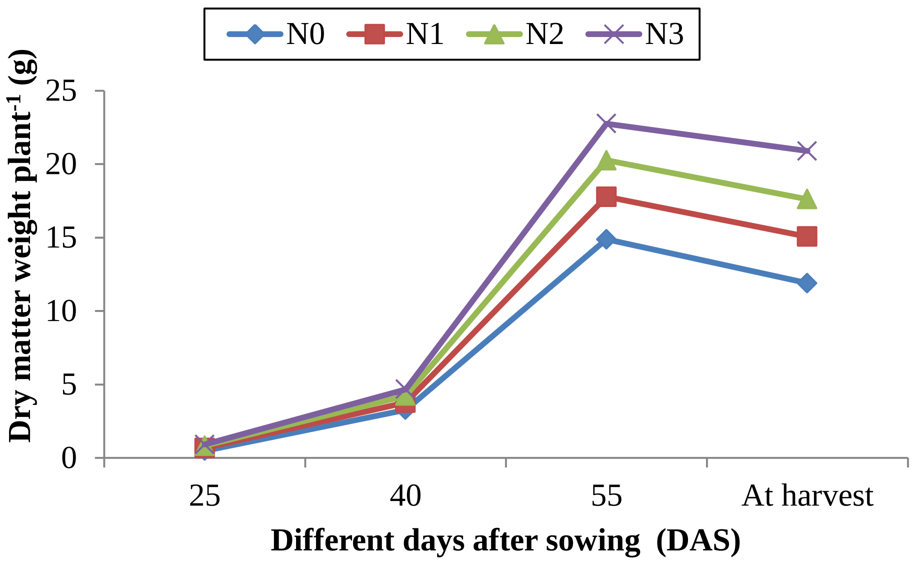

Figure 5. Effect of different levels of nitrogen on the dry matter weight plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ =0.08, 0.40, 1.73 and 1.71 at 25, 40, 55 DAS and harvest respectively).

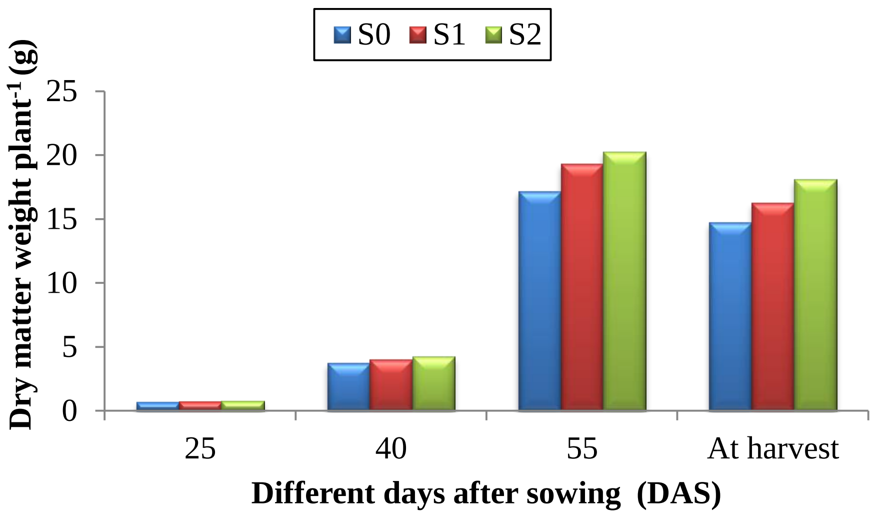

Figure 6. Effect of different levels of sulphur on the dry matter weight plant^{-1}of blackgram at different days after sowing (LSD $_{(0.05)}$ =0.07, 0.35, 1.49 and 1.48 at 25, 40, 55 DAS and harvest respectively).

4.1.3.2 Effect of sulphur

The results showed that the dry matter production had significant at all the days after sowing due to application of sulphur. The results showed that treatment sulphur @ 10 kg ha^{-1} produced the highest dry matter (18.10 g). The dry matter increased with increasing days after transplanting up to harvesting due to application of different levels of sulphur. The highest dry matter production occurred due to the absorption available nutrient. The lowest dry matter production occurred due to lack of proper nutrient uptake (Fig 6, Appendix VIII).

4.1.3.3 Effect of interaction of nitrogen and sulphur

The results showed that the dry matter production had significant at all the days after sowing due to application of nitrogen and sulphur. The results showed that interaction between treatment N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) the highest dry matter $hill^{-1}$ (23.12 g) (Table 3). The dry matter production $hill^{-1}$ increased with increasing days after sowing due to interaction between nitrogen and the application of different levels of sulphur. The highest dry matter production occurred due to the absorption of more nutrient, moisture and also for availability. The lowest dry matter production occurred due to lack of proper nutrient uptake.

4.1.4 Number of branches $plant^{-1}$

4.1.4.1 Effect of nitrogen

The number of branches $plant^{-1}$ had significant effect on different level of nitrogen at all days after sowing by nitrogen application. The results indicated that nitrogen @ 30 kg ha^{-1} produced the highest branches (5.73) at harvesting. The lowest branches $plant^{-1}$ (3.68) was recorded at harvest in no nitrogen treatment (Fig.7, Appendix IX).

Table 3. Interaction effect of nitrogen and sulphur on the dry matter weight $plant^{-1}$ of blackgram at different days after sowing

Treatment combinations	Dry matter weight $plant^{-1}$(g)at different days after sowing (DAS)			
	25	40	55	At harvest
N_0S_0	0.44 g	3.04 g	13.48 f	11.05 g
N_0S_1	0.49 fg	3.30fg	15.15 f	11.21 g
N_0S_2	0.56e-g	3.50 e-g	16.00 ef	13.44 e-g
N_1S_0	0.61ef	3.60 d-g	15.27 f	13.29 fg
N_1S_1	0.67de	3.70 d-g	18.74 de	15.14 d-f
N_1S_2	0.76 cd	4.01 b-e	19.33 cd	16.76 cd
N_2S_0	0.79 b-d	3.83 c-f	18.99 c-e	16.33 c-e
N_2S_1	0.85a-c	4.25 a-d	20.04 cd	17.42 cd
N_2S_2	0.87a-c	4.62ab	21.74 a-c	19.06 bc
N_3S_0	0.90 ab	4.46 a-c	20.95 b-d	18.30 bc
N_3S_1	0.93 a	4.72 a	23.30 ab	21.25 ab
N_3S_2	0.91ab	4.86 a	24.00 a	23.12 a
LSD $_{(0.05)}$	0.13	0.69	2.99	2.96
CV (%)	10.16	10.23	9.33	10.67

Table 4. Interaction effect of nitrogen and sulphur on the number of Branches plant^{-1} of blackgram at different days after sowing

Treatment combinations	Dry matter weight plant^{-1}(g)at different days after sowing (DAS)		
	40	55	At harvest
N_0S_0	2.67de	2.74 h	3.52 h
N_0S_1	2.85 c-e	2.85gh	3.68 gh
N_0S_2	2.62 e	2.95gh	3.86gh
N_1S_0	2.49 e	2.93gh	4.08 f-h
N_1S_1	2.85 c-e	3.38 f-h	4.27 e-g
N_1S_2	3.23 b-d	3.55 e-g	4.74d-f
N_2S_0	2.89 c-e	3.80ef	4.37 e-g
N_2S_1	3.42bc	4.10 de	4.84 c-e
N_2S_2	3.58b	5.13bc	5.52 a-c
N_3S_0	3.31 bc	4.62 cd	5.31 b-d
N_3S_1	3.68b	5.57 b	5.73ab
N_3S_2	4.56 a	6.70 a	6.15 a
LSD $_{(0.05)}$	**0.59**	**0.72**	**0.75**
CV (%)	**10.95**	**10.61**	**9.45**

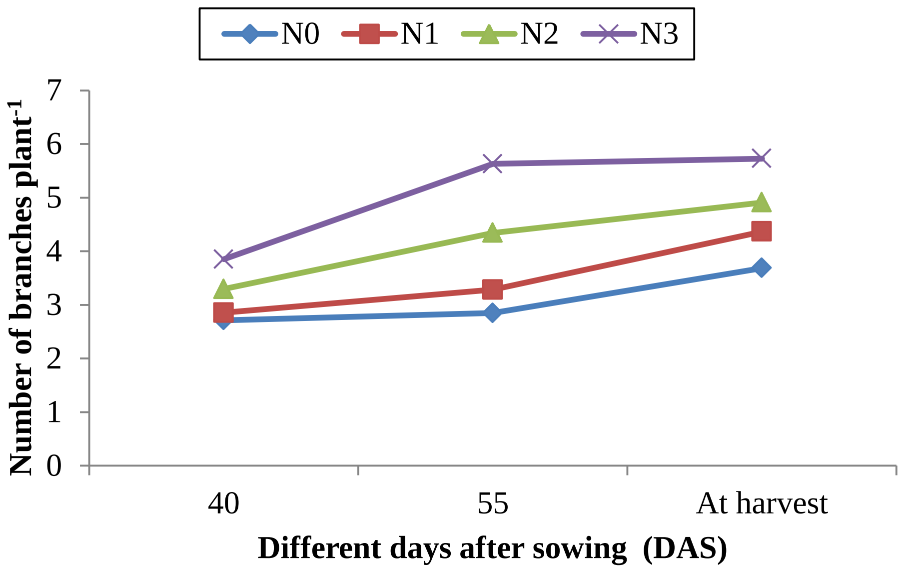

Figure 7. Effect of different levels of nitrogen on the number of branches plant^{-1} of blackgram at different days after sowing (LSD $_{(0.05)}$ =0.34, 0.42 and 0.43 at 40, 55 DAS and harvest respectively)

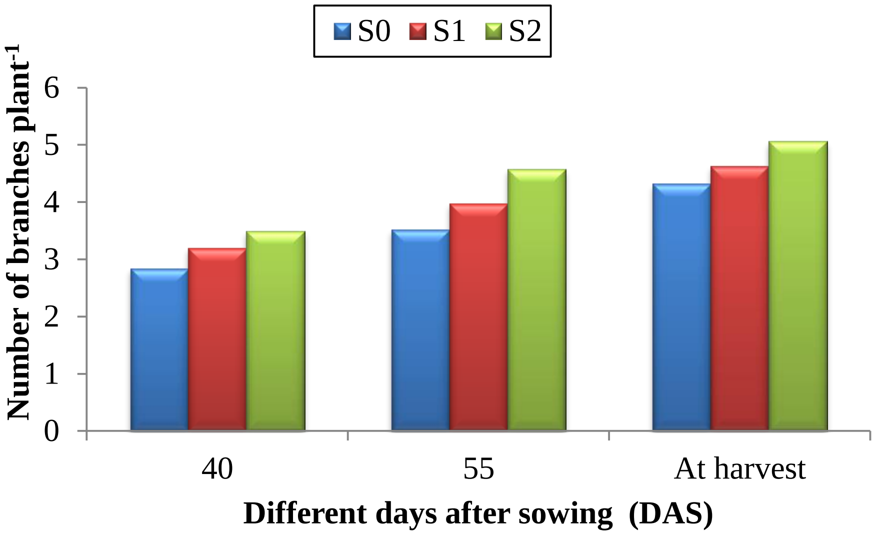

Figure 8. Effect of different levels of sulphur on the number of branches plant^{-1}of blackgram at different days after sowing (LSD $_{(0.05)}$ =0.29, 0.36 and 0.37 at 40, 55 DAS and harvest,respectively).

4.1.4.2 Effect of sulphur

Different levels of sulphur had significant effect on branches plant^{-1} at the all after sowing. It was observed that was the highest branches plant^{-1} (5.06) in sulphur @ 10 kg ha^{-1}. The lowest branches plant^{-1} (4.32) was recorded in treatment S_0 (no sulphur) (Fig.8, Appendix X).

4.1.4.3 Effect of interaction of nitrogen and sulphur

The interaction between different level of nitrogen and sulphur had significant effect on the branches plant^{-1}. The result indicated that highest (6.15) branches plant^{-1} was found between the interaction of N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}). The lowest branches plant^{-1} (3.52) was produced from the interaction between no nitrogen and no sulphur application (Table 4).

4.2 Yield and yield contributing characters

4.2.1 Number of pod pant^{-1}

4.2.1.1 Effect of nitrogen

It was found that the number of pod plant^{-1} at maturity was significantly influenced by nitrogen application. The highest number of pod plant^{-1} (64.80) was recorded from application of nitrogen @ 30 kg ha^{-1} and the lowest (33.81) was found in no nitrogen

(Fig. 09, Appendix XI). These differences might be due to variation in the genetic make-up and the absorption capacity of nutrient of the blackgram.

4.2.1.2 Effect of sulphur

The number of pod plant^{-1} was significantly influenced by different level of sulphur. It was found that the application sulphur @ 10 kg ha^{-1} produced the highest number of pod plant^{-1} (54.75) (Fig. 10, Appendix XII). The shortest plant (45.24) was obtained from S_0 (no sulphur). It might be due to lack of nutrient in the field.

4.2.1.3 Effect of interaction of nitrogen and sulphur

The effect of interaction of nitrogen and sulphur had significant influence on the number of pod plant^{-1}(Table 5). It was found that interaction N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) produced the highest number of pod plant^{-1} (68.70). The shortest number of pod plant^{-1} (30.33) was recorded from the interaction no nitrogen and no sulphur application.

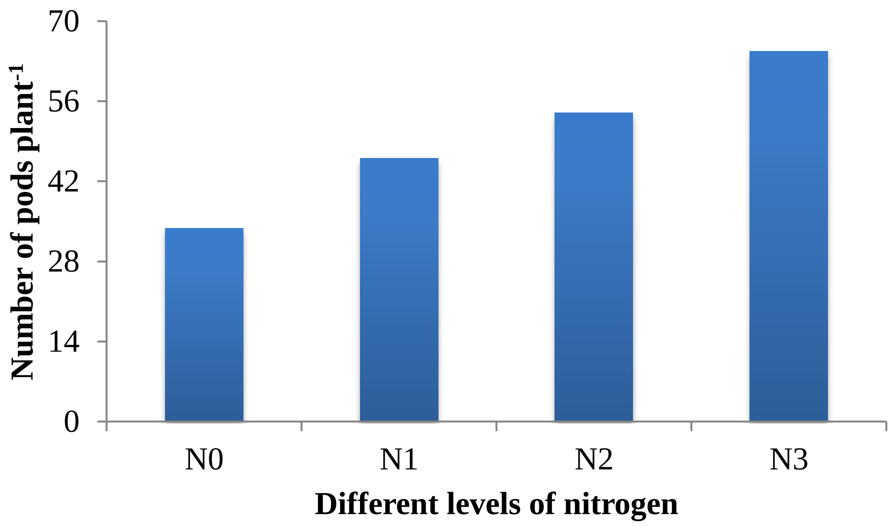

Figure 9. Effect of different levels of nitrogen on the number of pods plant^{-1} of blackgram (LSD $_{(0.05)}$ =4.49)

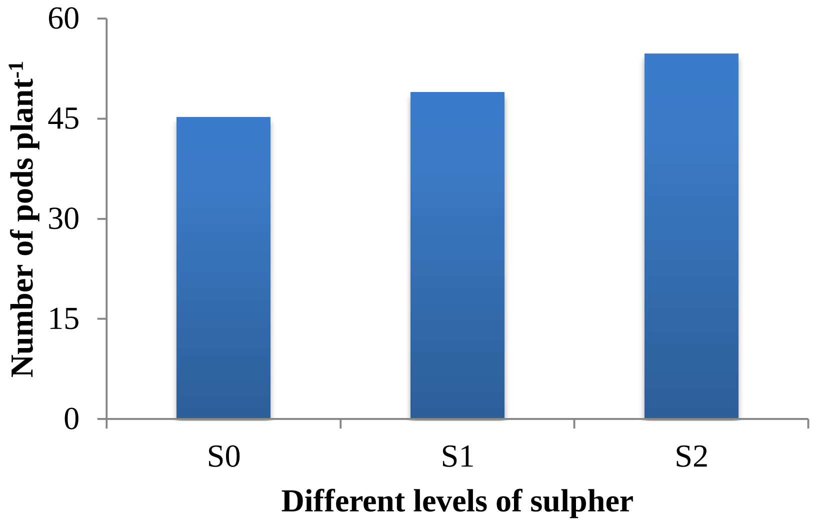

Figure 10. Effect of different levels of sulphur on the number of pods plant^{-1} of blackgram (LSD $_{(0.05)}$ =3.89

4.2.2 Number of seeds pod^{-1}

4.2.2.1 Effect of nitrogen

Different levels of nitrogen showed significant variation on the number of seed pod^{-1} (Fig. 11, Appendix XI). From the experimental results it was found that application of treatment nitrogen @ 30 kg ha^{-1} (5.46). The lowest number of total seeds pod^{-1} (4.13) was recorded in no nitrogen.

4.2.2.2 Effect of sulphur

The results showed that the number of total seeds pod^{-1} had significant due to application of different level of sulphur (Fig. 12, Appendix XII). It was found that sulphur @ 10 kg ha^{-1} produced the highest number of total seeds pod^{-1} (5.13). The highest number of total seeds pod^{-1} occurred due to the absorption of more nutrient, moisture and also for availability of more sunlight. It was also observed that the treatment S_0 (no sulphur) produced the lowest number of total seeds pod^{-1} (4.67).

4.2.2.3 Effect of interaction of nitrogen and sulphur

Number of total seeds pod^{-1} was significantly influenced by the interaction of nitrogen and sulphur (Table 5). It was observed that combination of nitrogen @ 30 kg ha^{-1} and sulphur @ 10 kg ha^{-1} produced the highest (5.56) number of seeds pod^{-1}. The lowest number of total seeds pod^{-1} (3.86) was recorded from the interaction $N_0 \times S_0$ (no nitrogen and sulphur).

4.2.3 Pod length

4.2.3.1 Effect of nitrogen

Nitrogen had significant effect on pod length (Fig. 13, Appendix XI). The results indicated that nitrogen @ 30 kg ha^{-1} produced the highest pod length (4.52 cm). The probable reasons of difference in producing the pod length were mainly genetic makeup of the variety and nitrogen availability. The lowest pod length (3.71 cm) was recorded in treatment N_0.

4.2.3.2 Effect of sulphur

Different levels of sulphur had significant effect on the pod length (Fig. 14, Appendix XII). It was found that sulphur @ 10 kg ha^{-1} produced the highest pod length (4.05 cm). Probably this treatment provided adequate nutrients to the plants and as a result produced the highest length of pod. The lowest length of pod (3.97 cm) was obtained in S_0 (no sulphur).

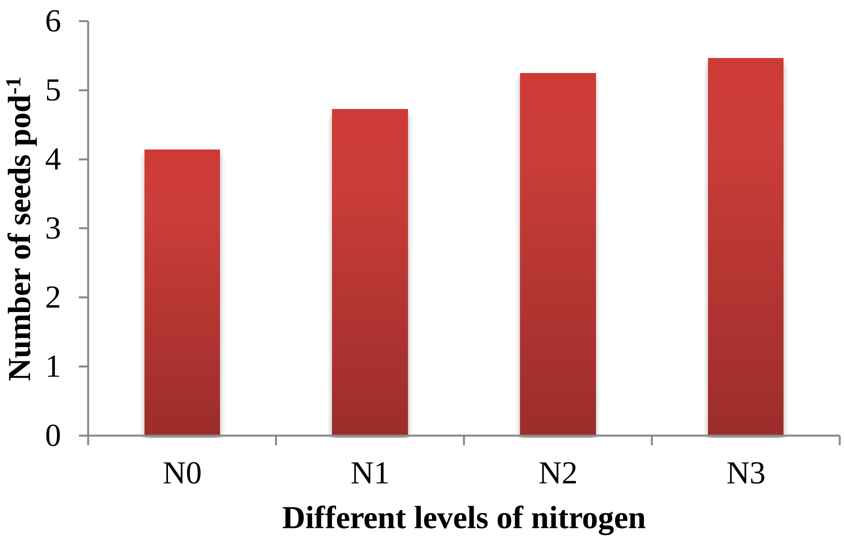

Figure 11. Effect of different levels of nitrogen on the number of seeds pod^{-1} of blackgram (LSD $_{(0.05)}$=0.47)

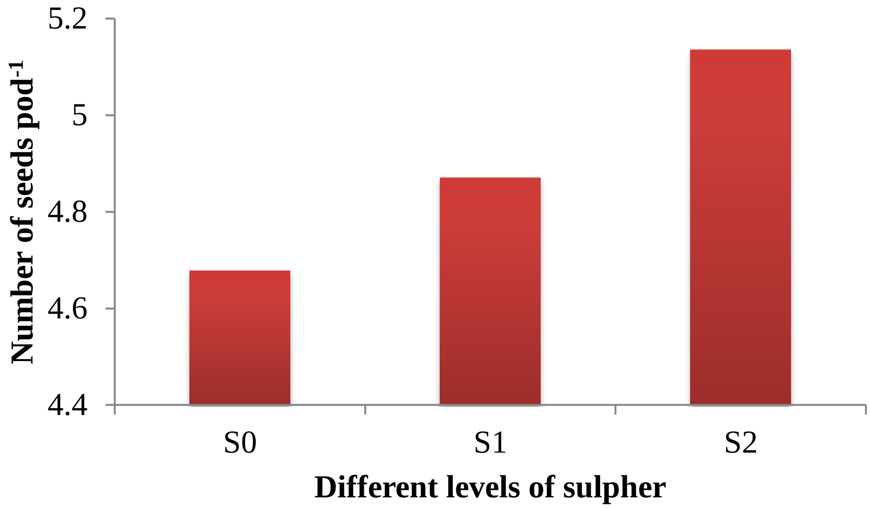

Figure 12. Effect of different levels of sulphur on the number of seeds pod^{-1} of blackgram (LSD $_{(0.05)}$ =0.41)

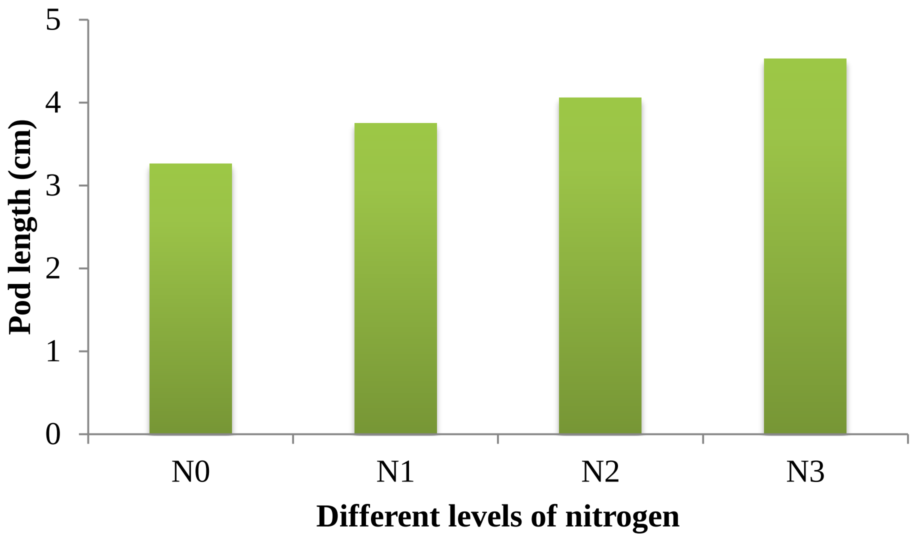

Figure 13. Effect of different levels of nitrogen on the pod length of blackgram (LSD $_{(0.05)}$ =0.35).

4.2.2.3 Effect of interaction of nitrogen and sulphur

Pod length was significant due to the interaction of nitrogen and sulphur (Table 5). The highest length of pod (4.62 cm) was found in N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) (Table 6). The lowest length of pod (3.86 cm) was recorded from N_0 x S_0.

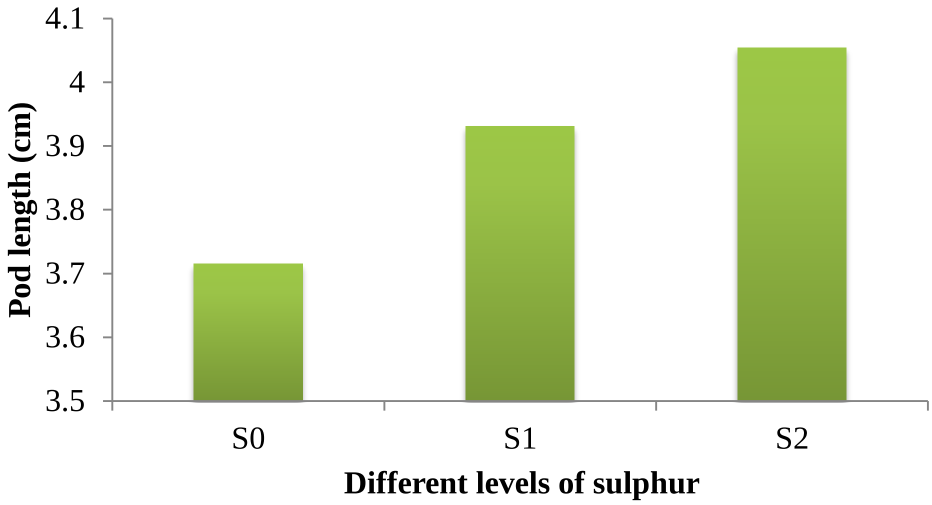

Figure 14. Effect of different levels of sulphur on the pod length of blackgram (LSD $_{(0.05)}$=0.31)

Table 5. Interaction effect of nitrogen and sulphur on the yield contributing characters of blackgram

Treatment combinations	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	Weight of 1000-grain (g)
N_0S_0	30.33 h	3.86 d	3.11 f	25.33 d
N_0S_1	31.96 gh	4.11d	3.26 ef	28.71 cd
N_0S_2	39.13 fg	4.44 cd	3.42 d-f	29.36 cd
N_1S_0	43.32 ef	4.45 cd	3.53 d-f	30.44 bc
N_1S_1	45.74 d-f	4.63 b-d	3.79 c-e	31.39 bc
N_1S_2	49.05 de	5.11 a-c	3.94 b-d	32.61 a-c
N_2S_0	48.51 de	5.07 a-c	3.80 c-e	32.42 a-c
N_2S_1	51.33 cd	5.25 a-c	4.14 a-c	34.68 ab
N_2S_2	62.13 ab	5.43 ab	4.24 a-c	36.47 a
N_3S_0	58.81 bc	5.33 ab	4.42ab	35.35 ab
N_3S_1	66.88 a	5.49 a	4.53ab	36.69 a
N_3S_2	68.70 a	5.57 a	4.62 a	37.44 a
LSD $_{(0.05)}$	**7.77**	**0.82**	**0.61**	**5.05**
CV (%)	**9.24**	**9.91**	**9.23**	**9.16**

4.2.4 1000-seed weight

4.2.4.1 Effect of nitrogen

Different levels of nitrogen had significant effect on 1000-seed weight (Fig. 15, Appendix XI). It was found that treatment N_3 (nitrogen @ 30 kg ha^{-1}) produced the highest 1000-grain weight (36.49 g). The lowest 1000-seed weight (27.80 g) was recorded in no nitrogen. The differences in 1000- seed weight might be due to differences in grain size which is the genetic character and availability of nutrient in the field of blackgram.

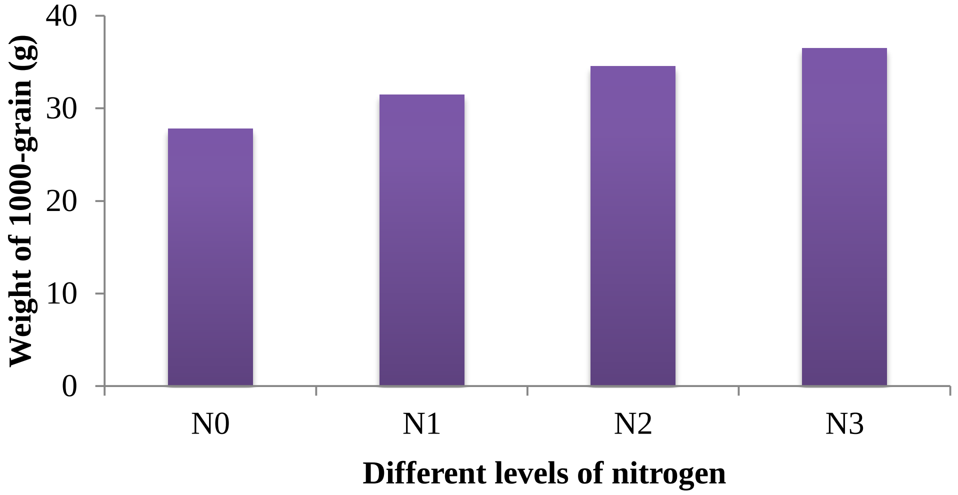

Figure 15. Effect of different levels of nitrogen on the weight of 1000-grain of blackgram (LSD $_{(0.05)}$=2.92)

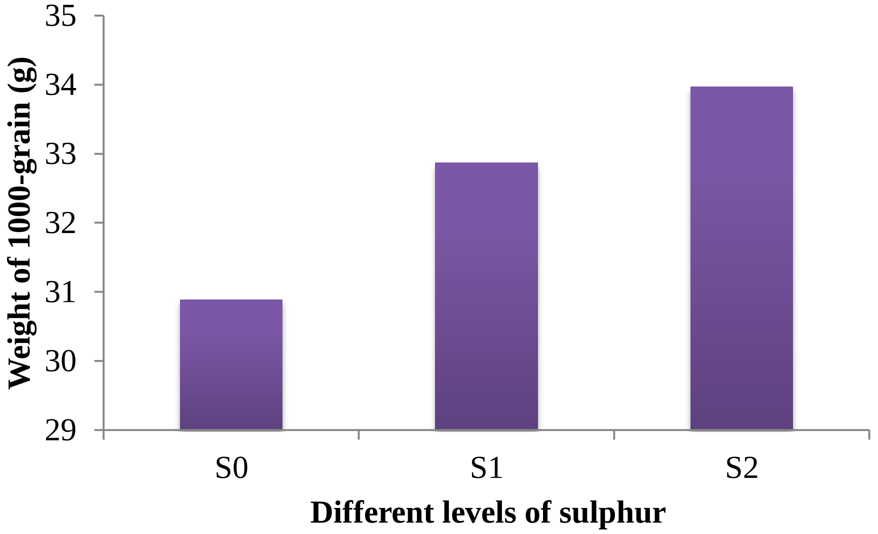

Figure 16. Effect of different levels of sulphur on the weight of 1000-grainof blackgram (LSD $_{(0.05)}$=2.53)

4.2.4.2 Effect of sulphur

1000-seed weight was significantly influenced by application of sulphur (Fig. 16, Appendix XII). The results revealed that treatment S_2 (sulphur @ 10 kg ha^{-1}) produced the highest seed weight (33.97 g). The lowest (30.89 g) seed weight was found in treatment S_0 (no sulphur).

4.2.4.3 Effect of nitrogen and sulphur

The effect of interaction between nitrogen and sulphur had significant effect on 1000-seed weight. The highest (37.44) 1000-seed weight was found in the interaction between the N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) and the lowest (25.33 g) 1000-seed weight was found in the interaction between N_0 x S_0 (Table 5).

4.2.5 Seed yield

4.2.5.1 Effect of nitrogen

Different levels of nitrogen had highly significant effect on seed yield (Fig. 17, Appendix XI). The results obtained indicated that the application of nitrogen @ 30 kg ha^{-1} produced the highest seed yield (1.68 t ha^{-1}). The lowest seed yield (.81 t ha^{-1}) was recorded from no nitrogen application. The highest seed yield from the application of nitrogen @ 30 kg ha^{-1} was due to the highest pod length, the highest 1000-seed weight.

4.2.5.2 Effect of sulphur

Application of different levels of sulphur had highly significant effect on seed yield (Fig. 18, Appendix XII). The results showed that treatment S_2 (sulphur @ 10 kg ha^{-1}) produced the highest seed yield (1.41 t ha^{-1}). The lowest (1.13 t ha^{-1}) seed yield was found in treatment S_0 (no sulphur). Application of S_2 (sulphur @ 10 kg ha^{-1} improved the yield contributing characters of blackgram.

4.2.5.3 Effect of interaction of nitrogen and sulphur

The variation due to interaction of nitrogen and sulphur was significant in respect of seed yield (Table 6). The highest seed yield (1.81 t ha^{-1}) was produced by the combination of N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}). The lowest seed yield (.68 t ha^{-1}) was produced by N_0 x S_0 (no nitrogen and no sulphur).

4.2.6 Stover yield

4.2.6.1 Effect of nitrogen

Nitrogen had significant influence on stover yield (Fig. 19, Appendix XI). The treatment N_3 (nitrogen @ 30 kg ha^{-1}) produced the highest stover yield (2.03 t ha^{-1}) (Table. 4). The lowest stover yield (1.38 t ha^{-1}) was produced by N_0.

4.2.6.2 Effect of sulphur

The effect of sulphur at different levels on stover yield was significant (Fig. 20, Appendix XII). It was found that the treatment S_2 (sulphur @ 10 kg ha^{-1}) produced the highest stover yield (1.80 t ha^{-1}). The lowest (1.51 t ha^{-1}) stover yield was observed in treatment S_0 (no sulphur). Application of different levels of sulphur influenced the vegetative growth in terms of plant height and number of total branches $plant^{-1}$ which resulted in differences of stover yield (Table 6).

4.2.6.3 Effect of interaction of nitrogen and sulphur

The interaction of nitrogen and sulphur showed significant effect on stover yield. Interaction between N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) resulted in the highest (2.27 t ha^{-1}) stover yield. The lowest stover yield (1.31 t ha^{-1}) was found in N_0 x S_0 (Table 6).

4.2.7 Biological yield

4.2.7.1 Effect of nitrogen

Nitrogen had statistically significant effect on biological yield (Fig. 21, Appendix XI). The results indicated that nitrogen @ 30 kg ha^{-1} produced the highest biological yield (3.71 t ha^{-1}). The lowest biological yield (2.19 t ha^{-1}) was found in no application of nitrogen.

4.2.7.2 Effect of sulphur

Sulphur application at different levels had statistically significant effect on biological yield (Fig. 22, Appendix XII). The results suggested that the S_2 (sulphur @ 10 kg ha^{-1}) produced the highest biological yield (3.20 t ha^{-1}) (Table. 6). The lowest (2.65 t ha^{-1}) biological yield was found in treatment S_0 (no sulphur).

4.2.7.3 Effect of interaction of nitrogen and sulphur

Nitrogen and sulphur had statistically significant effect on biological yield. The results indicated that interaction of N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) produced the highest biological yield (4.08 t ha^{-1}) (Table. 6). The lowest biological yield (1.99 t ha^{-1}) was found in N_0 with S_0 (no sulphur).

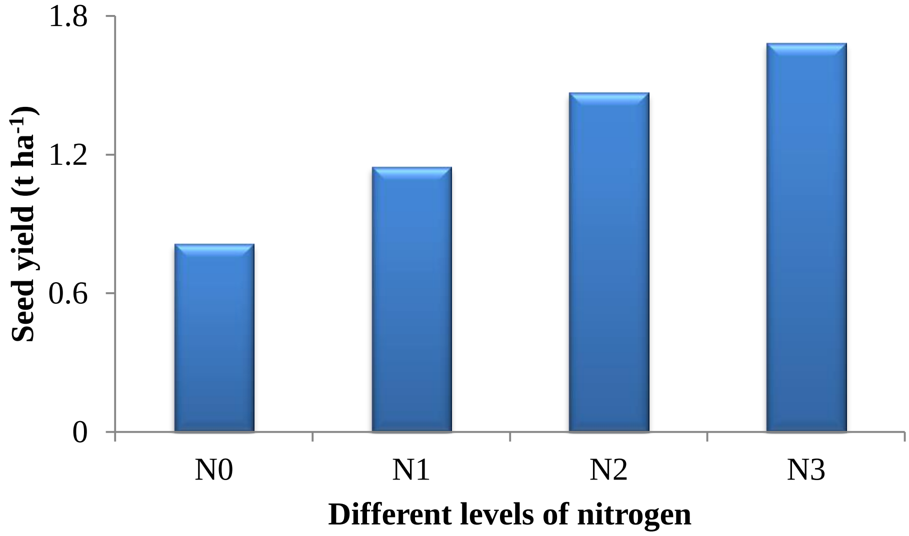

Figure 17. Effect of different levels of nitrogen on the seed yield of blackgram (LSD $_{(0.05)}$=0.10)

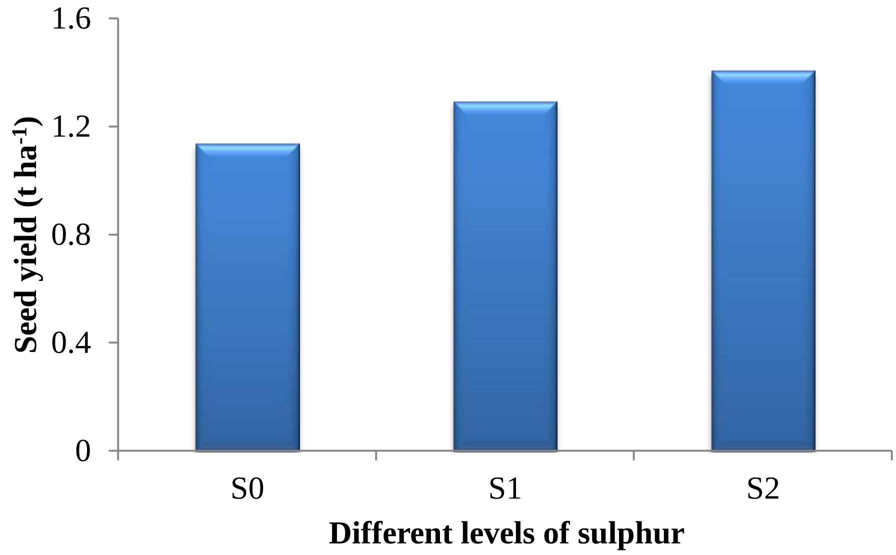

Figure 18. Effect of different levels of sulphur on the seed yield of blackgram (LSD $_{(0.05)}$=0.08).

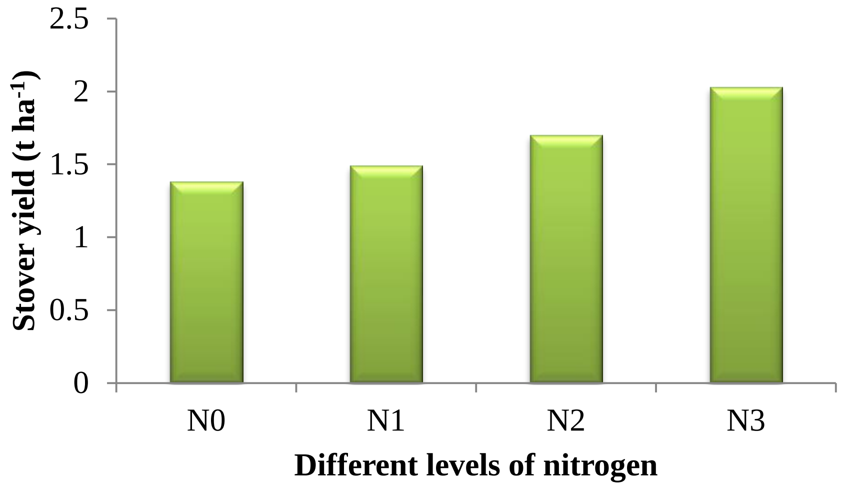

Figure 19. Effect of different levels of nitrogen on the stover yield of blackgram (LSD $_{(0.05)}$ =0.15)

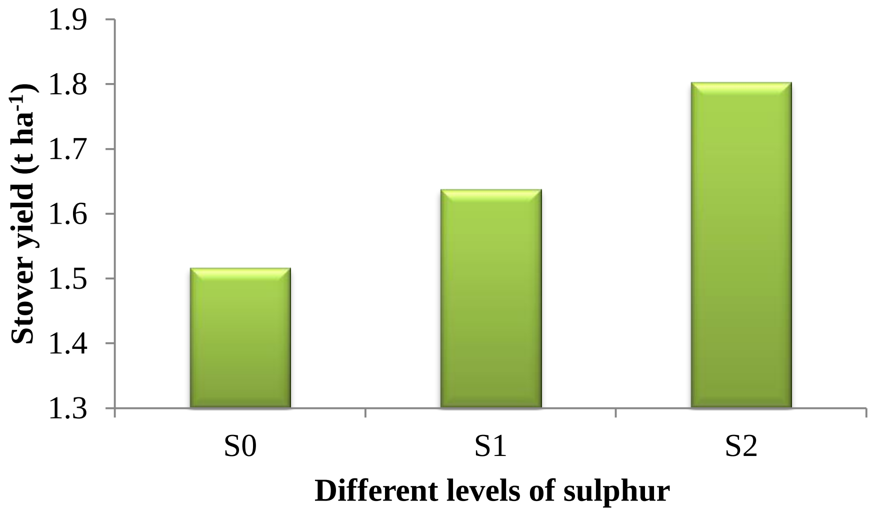

Figure 20. Effect of different levels of sulphur on the stover yield of blackgram (LSD $_{(0.05)}$ =0.13)

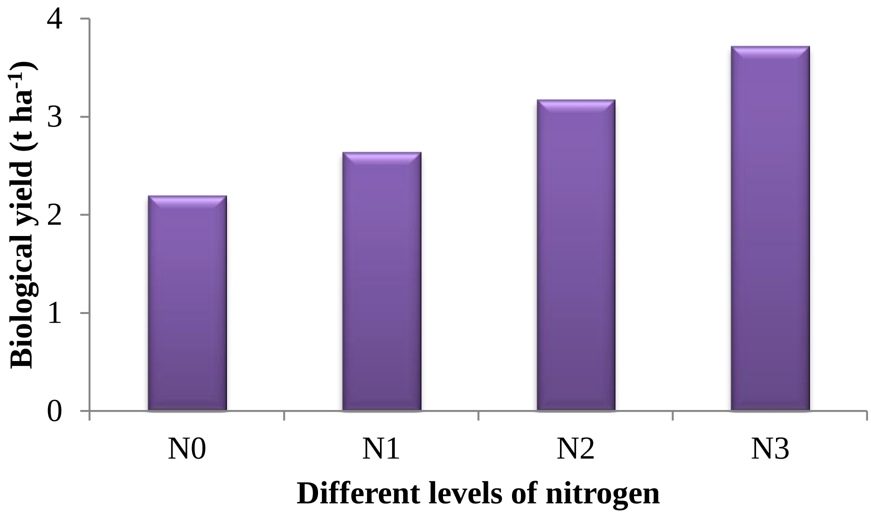

Figure 21. Effect of different levels of nitrogen on the biological yield of blackgram (LSD $_{(0.05)}$=0.28)

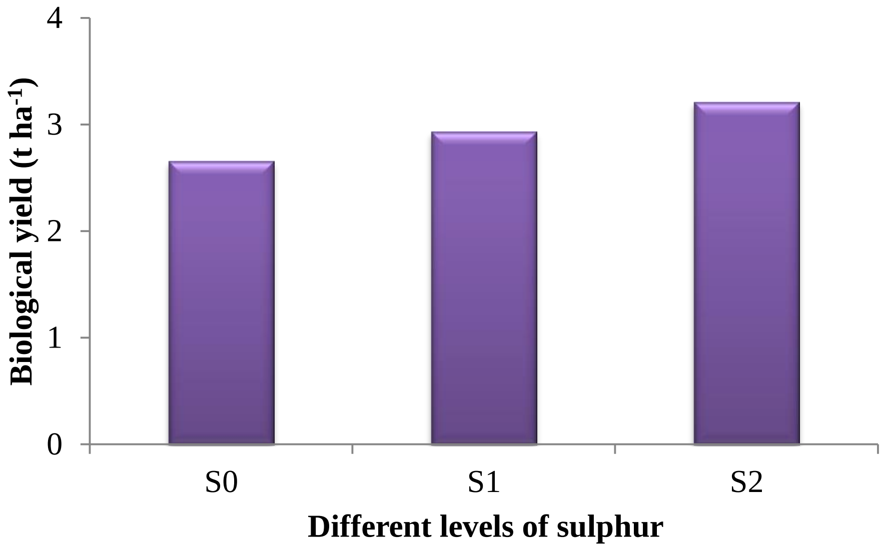

Figure 22. Effect of different levels of sulphur on the biological yield of blackgram (LSD $_{(0.05)}$ =0.24)

4.2.8 Harvest index (%)

4.2.8.1 Effect of nitrogen

Nitrogen had statistically significant effect on harvest index. (Fig. 23, Appendix XI). The results indicated that the N_3 (nitrogen @ 30 kg ha^{-1}) produced the highest harvest index (45.39%). The lowest harvest index (37.00) produced by N_0.

4.2.8.2 Effect of sulphur

Different level of sulphur application showed no significant influence on harvest index (Fig. 24, Appendix XII). Apparently, the highest harvest index (43.51%) was found in the treatment S_2 (sulphur @ 10 kg ha^{-1}). The lowest (42.13 %) harvest index was observed in treatment S_0 (no sulphur).

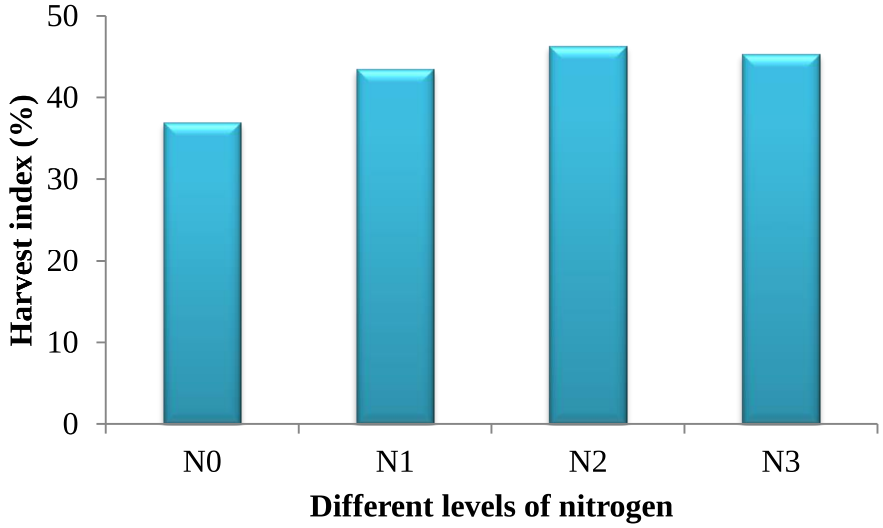

Figure 23. Effect of different levels of nitrogen on the harvest index of blackgram (LSD $_{(0.05)}$=4.14).

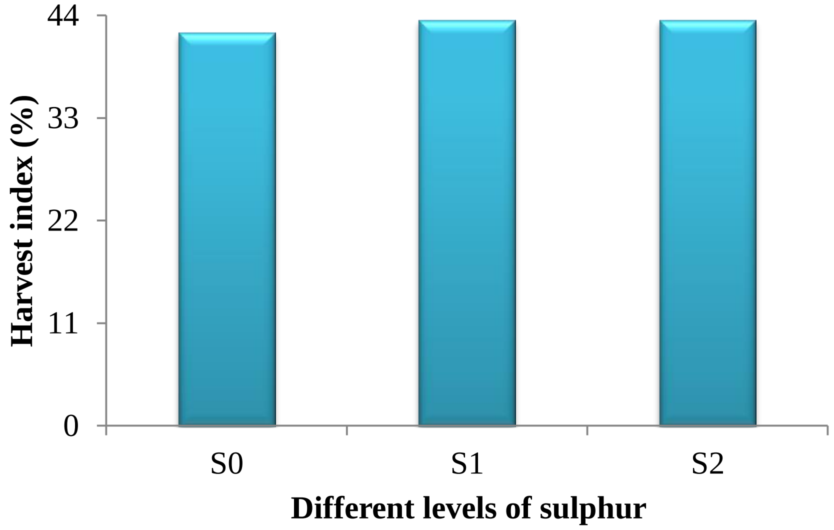

Figure 24. Effect of different levels of sulphur on the harvest index plant^{-1} of blackgram (LSD $_{(0.05)}$ =NS)

4.2.8.3 Effect of interaction of nitrogen and sulphur

The effect of interaction of nitrogen and sulphur on harvest index was significant (Table 6). Interaction between N_3 (nitrogen @ 30 kg ha^{-1}) x S_2 (sulphur @ 10 kg ha^{-1}) produced the highest harvest index (44.44 %). The lowest harvest index (34.18%) was found in the interaction between N_0 x S_0 (Table. 6).

Table 6. Interaction effect of nitrogen and sulphur on the yield characters of blackgram

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0S_0	0.68 j	1.31 g	1.99 g	34.18 d
N_0S_1	0.83ij	1.39fg	2.21fg	37.39 cd
N_0S_2	0.94 hi	1.45 e-g	2.39 e-g	39.42 b-d
N_1S_0	1.04 gh	1.41e-g	2.45 e-g	42.60 a-c
N_1S_1	1.13 fg	1.48 e-g	2.61ef	43.33 a-c
N_1S_2	1.27 ef	1.59 d-f	2.86 de	44.53 a-c
N_2S_0	1.32 de	1.54 e-g	2.86 de	46.22 ab
N_2S_1	1.48 cd	1.66 c-e	3.15 cd	47.15 a
N_2S_2	1.60bc	1.91 bc	3.51 bc	45.66 ab
N_3S_0	1.51 c	1.81 b-d	3.31 b-d	45.51 ab
N_3S_1	1.73 ab	2.02ab	3.75ab	46.21 ab
N_3S_2	1.81 a	2.27 a	4.08 a	44.44 a-c
LSD $_{(0.05)}$	**0.17**	**0.26**	**0.48**	**7.17**
CV (%)	**7.93**	**9.32**	**9.73**	**9.84**

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at experimental plot of Agronomy farm of Sher -e-Bangla Agricultural University in Dhaka city. It is situated at $23^0 77'$ N latitude and $90^0 33'$ E longitude at an altitude of 8.2 meter above the sea level with a view to finding out the optimum dose of Nitrogen and Sulphur for maximizing the growth and yield of Black gram and their interactions on of Nitrogen and Sulphur fertilization for proper growth and yield of Black gram. The experiment consisted of treatment N_0 (no nitrogen) N_1 (nitrogen @ 10 kg ha^{-1}) N_2 (nitrogen @ 20 kg ha^{-1}) N_3 (nitrogen @ 30 kg ha^{-1}) and S_0 (no sulphur), S_1 (sulphur @ 5 kg ha^{-1}), S_2 (sulphur @ 10 kg ha^{-1}). The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year. The average rainfall is 218 mm per annum and average maximum and minimum temperature are 29.45^0C and 13.86^0C respectively. The experimental site is medium high land in Agro-Ecological Zone of Madhupur Tract (AEZ no. 28). The experiment was laid out in a two factor randomized complete block design with three replications. The size of each unit plot was 1.5 m × 2.0 m. The space between two replications was 1 m and that from plot to plot was 50 cm. At the time of final land preparation, respective unit of plots were fertilized with different levels of poultry manure and inorganic fertilizers according to treatments. The amount of nitrogen, phosphorus, potassium, sulphur and zinc required for each unit was applied in the form of triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively. Urea was applied in three equal splits. The first split of urea and full dose of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation. The second split of urea was top dressed at 30 DAT and third split of urea at 45DAT. Seeds of blackgram are sowing at 10^{th} January, 2018. Necessary intercultural operations were done. Growth parameters were recorded from 25 DAT at 15-day intervals up to harvesting. The crop was harvested at proper maturity, sample were randomly selected (excluding border side) from each unit plot for recording data on yield components. The collected data were analyzed statistically using the "analysis of variance" technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

Results obtained from growth parameters showed that different levels of nitrogen had significant effect on plant height, number of leaves plant^{-1} total dry matter production and number of branches plant^{-1} during 25 to harvest. Application of nitrogen @ 30 kg ha^{-1} produced the tallest plant (31.85 cm), number of leaves plant^{-1} (25.16), dry matter weight (20.89), number of branches plant^{-1}(5.72) at harvest. On the other hand, the shortest plant height (18.70 cm), number of leaves plant^{-1} (12.82), dry matter weight (11.90 g), the number of branches plant^{-1} (3.78) at harvest were recorded no nitrogen application. The effect of different levels of sulphur on growth parameters were found significant. The application of sulphur @ 10 kg ha^{-1} showed superiority in terms of the highest plant height (27.87 cm),), number of leaves plant^{-1} (20.72), dry matter weight (18.10), number of branches plant^{-1} (5.06) at harvest. The treatment S_0 (no sulphur) gave the lowest values for the same parameters. There was a significant variation in plant height, number of leaves plant^{-1}, dry matter weight, number of branches plant^{-1} due to the interaction of nitrogen @ 30 kg ha^{-1} and sulphur @ 10 kg ha^{-1}. Seed yield and most of the yield contributing characters were significantly influenced by nitrogen. The highest number of pod plant^{-1}, number seed pod^{-1}, pod length, 1000-seed weight, seed yield, stover yield, biological yield and harvest index were recorded in nitrogen @ 30 kg ha^{-1}. At the same time, application no nitrogen was given the lowest of all parameters. The effect of different levels of sulphur on yield and yield contributing characters were found significant. The application sulphur @ 10 kg ha^{-1} showed superiority in terms of the highest number of pod plant^{-1} (54.75), number seed pod^{-1} (5.13), pod length (4.05 cm), 1000-seed weight (33.87 g), seed yield (1.40 t ha^{-1}), stover yield (1.80 t ha^{-1}), biological yield (3.20 t ha^{-1}) and harvest index (43.51 %). The treatment no sulphur application gave the lowest values for the same parameters. There was a significant variation in highest number of pod plant^{-1}, number seed pod^{-1}, pod length, 1000-seed weight, seed yield, stover yield, biological yield and harvest index due to the interaction of nitrogen and sulphur. The highest values of these parameters were recorded in the interaction between nitrogen @ 30 kg ha^{-1} and sulphur @ 10 kg ha^{-1}.

According to the results obtained from the experiment, nitrogen @ 30 kg ha^{-1} performed well considering most of the growth and yield contributing characters. Among the different levels of sulphur, sulphur @ 10 kg ha^{-1} showed the best performance. Nitrogen @ 30 kg ha^{-1} combined with sulphur @ 10 kg ha^{-1} showed better performance in respect of seeed yield. Finally, it can be concluded that nitrogen @ 30 kg ha^{-1} coupled with sulphur @ 10 kg ha^{-1} appeared as the promising practice in blackgram cultivation in terms of growth and seed yield.

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APPENDISES

Appendix I. Morphological, physical and chemical characteristics of the experimental field

A. Morphological characteristics of the soil

Constitutions	Characteristies
Location	Agronomy Field Laboratory, SAU, Dhaka
Soil tract	Old Brahmaputra Alluvium
Land type	Medium high land
General soil type	Deep Red Brown Terrace Soil
Soil series	Tejgaon
Parent material	Brahmaputra river-brone deposits
Agro-ecological zone	Modhupur Tract (AEZ-28)
Topography	Fairly level
Flood level	Dark grey
Soil colour	Above flood level
Drainage	Moderate

B. Physical properties of the initial soil (0-15 cm depth)

Constitution	Results
% sand (0.2-0.02 nun)	32
% silt (0.02-0.002 mm)	60
% clay (< 0.002) mm	08
Textural class	Silt loam
Bulk density	1.35
Porosity(%	46.67

C. Chemical characteristics of the initial soil (0-15 cm depth)

Constituents	Results**
Ph	6.50
OM (%)	1.29
Total N (%)	0.10
Available P (ppm)	16.72
Exchangeable K (me%)	0.12
Available S (ppm)	14.2

**Results obtained from mechanical analysis of the initial soil sample done in the Department of Soil Science, SAU, Dhaka.

Appendix II. Distribution of monthly temperature, relative humidity, sunshine hour and rainfall of the experimental site during the crop growth period

Year	Month	*Air temperature			**Rainfall (mm)	*Relative humidity (%)	**Sunshine (hrs)
		Maxi.	Mini.	Aver.			
	June	32.7	26.2	29.5	388.8	84	149.5
	July	31.6	26.5	29.1	522.7	87	101.8
	August	33.2	26.8	30.0	97.6	81	179.6
2016	September	32.0	26.1	29.1	408.6	87	125.6
	October	32.4	24.2	28.3	31.7	84	200.9
	November	29.5	18.1	23.4	1.0	81	204.8
	December	27.5	14.6	21.1	0.0	81.4	180.30

* Monthly total

**Monthly average

Source: Weather Yard, Department of Irrigation and Water Management, Sher-e-Bangla Agricultural University, Dhaka.

Appendix III. Effect of different levels of nitrogen on the plant height of blackgram at different days after sowing

Treatment	Plant height at different days after Sowing			
	25	40	55	At harvest
N_0	10.06 c	16.72 c	17.71 d	18.70 c
N_1	10.89 bc	22.57 b	20.35 c	24.52 b
N_2	12.15 b	25.14 a	25.21 b	29.46 a
N_3	13.56 a	26.14 a	29.68 a	31.85 a
$LSD_{(0.05)}$	1.34	2.43	2.52	2.57
CV (%)	11.75	10.97	11.11	10.04

Appendix IV. Effect of different levels of sulphur on the plant height of blackgram at different days after sowing

Treatment	Plant height at different days after Sowing			
	25	40	55	At harvest
S_0	10.63 b	20.63 b	20.82 c	24.40 b
S_1	11.61 ab	22.62 ab	23.22 b	26.13 ab
S_2	12.76 a	24.68 a	25.68 a	27.87 a
$LSD_{(0.05)}$	1.16	2.10	2.19	2.22
CV (%)	11.75	10.97	11.11	10.04

Appendix V. Effect of different levels of nitrogen on the number of leaves plant^{-1} of blackgram at different days after sowing

Treatment	Number of leaves Plant^{-1} at different days after Sowing			
	25	40	55	At harvest
N_0	8.472 c	14.68 d	15.42 d	12.82 d
N_1	10.92 b	18.51 c	18.46 c	15.76 c
N_2	12.20 a	23.32 b	22.24 b	20.41 b
N_3	12.86 a	25.67 a	28.04 a	25.16 a
$LSD_{(0.05)}$	1.23	2.29	2.62	1.89
CV (%)	11.31	11.42	12.71	10.45

Appendix VI. Effect of different levels of sulphur on the number of leaves plant^{-1} of blackgram at different days after sowing

Treatment	Number of leaves Plant^{-1} at different days after Sowing			
	25	40	55	At harvest
S_0	10.39 b	18.67 b	18.68 b	16.54 c
S_1	11.01 ab	20.15 b	20.94 b	18.34 b
S_2	11.93 a	22.81 a	23.51 a	20.72 a
$LSD_{(0.05)}$	1.06	1.99	2.27	1.64
CV (%)	11.31	11.42	12.71	10.45

Appendix VII. Effect of different levels of nitrogen on the dry matter weight of blackgram at different days after sowing

Treatment	Dry matter weight at different days after Sowing			
	25	40	55	At harvest
N_0	0.4978 d	3.280 d	14.88 d	11.90 d
N_1	0.6811 c	3.769 c	17.78 c	15.07 c
N_2	0.8356 b	4.236 b	20.26 b	17.61 b
N_3	0.9133 a	4.680 a	22.75 a	20.89 a
$LSD_{(0.05)}$	0.08	0.40	1.73	1.71
CV (%)	10.16	10.23	9.33	10.67

Appendix VIII. Effect of different levels of sulphur on the dry matter weight of blackgram at different days after sowing

Treatment	Dry weight matter at different days after Sowing			
	25	40	55	At harvest
S_0	0.6842 b	3.733 b	17.17 b	14.74 c
S_1	0.7375 ab	3.993 ab	19.31 a	16.26 b
S_2	0.7742 a	4.247 a	20.27 a	18.10 a
LSD $_{(0.05)}$	0.07	0.35	1.49	1.48
CV (%)	10.16	10.23	9.33	10.67

Appendix IX. Effect of different levels of nitrogen on the number branches plant^{-1} of blackgram at different days after sowing

Treatment	Number of branches plant^{-1} at different days after Sowing		
	40	55	At harvest
N_0	2.713 c	2.847 d	3.688 d
N_1	2.853 c	3.283 c	4.366 c
N_2	3.297 b	4.344 b	4.909 b
N_3	3.850 a	5.630 a	5.729 a
LSD $_{(0.05)}$	0.34	0.42	0.43
CV (%)	10.95	10.61	9.45

Appendix X. Effect of different levels of sulphur on the number branches plant^{-1} of blackgram at different days after sowing

Treatment	Number of branches plant^{-1} at different days after Sowing		
	40	55	At harvest
S_0	2.841 c	3.520 c	4.321 b
S_1	3.199 b	3.976 b	4.632 b
S_2	3.495 a	4.582 a	5.066 a
LSD $_{(0.05)}$	0.29	0.36	0.37
CV (%)	10.95	10.61	9.45

Appendix XI. Effect of different levels of nitrogen on the Pod plant^{-1}, no. of seed pod^{-1}, Pod length, 1000-seed weight, seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield(t ha^{-1}) and harvest index (%0) of blackgram

Variety	Pod Plant^{-1}	No. of seed pod^{-1}	Pod length	1000 grain wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	HI (%)
N_0	33.81 d	4.137 c	3.263 c	27.80 c	0.815 d	1.382 c	2.198 d	37.00 b
N_1	46.03 c	4.729 b	3.752 b	31.48 b	1.149 c	1.491 c	2.640 c	43.49 a
N_2	53.99 b	5.249 a	4.059 b	34.53 a	1.469 b	1.703 b	3.172 b	46.34 a
N_3	64.80 a	5.464 a	4.526 a	36.49 a	1.684 a	2.032 a	3.717 a	45.39 a
LSD $_{(0.05)}$	4.49	0.47	0.35	2.92	0.10	0.15	0.28	4.14
CV (%)	9.24	9.91	9.23	9.16	7.93	9.32	9.73	9.84

Appendix XII. Effect of different levels of sulphur on the Pod plant^{-1}, no. of seed pod^{-1}, Pod length, 1000-seed weight, seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield(t ha^{-1}) and harvest index (%) of blackgram

Variety	Pod Plant^{-1}	No. of seed pod^{-1}	Pod length	1000 grain wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	HI (%)
S_0	45.24 b	4.678 b	3.715 b	30.89 b	1.138 c	1.517 b	2.655 c	42.13
S_1	48.98 b	4.871 ab	3.931 ab	32.87 ab	1.293 b	1.638 b	2.931 b	43.52
S_2	54.75 a	5.136 a	4.054 a	33.97 a	1.407 a	1.803 a	3.209 a	43.51
LSD $_{(0.05)}$	3.89	0.41	0.31	2.53	0.08	0.13	0.24	NS
CV (%)	9.24	9.91	9.23	9.16	7.93	9.32	9.73	9.84