GROWTH AND YIELD RESPONSE OF BLACKGRAM TO RHIZOBIUM INOCULATION AND FERTILIZATION

BY

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REG. NO. : 00982

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

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2008

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This is to certify that the thesis entitled "**Growth and Yield Response of Blackgram to *Rhizobium* Inoculation and Fertilization**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in Agronomy**, embodies the result of a piece of bonafide research work carried out by **Shah Mohammad Jalal Uddin**, Registration number **00982** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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ACKNOWLEDGEMENTS

All praises are due to Almighty Allah, the Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully.

The author likes to express his deepest sense of appreciation to his respected supervisor Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing.

The author also expresses his gratefulness to respected Co-Supervisor, Prof. Dr. A. K. M. Ruhul Amin, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his pedagogic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author expresses his sincere respect to the Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Agronomy, SAU, for their valuable suggestions, instuctions, cordial help and encouragement during the period of the study.

The author expresses his sincere appreciation to his parents, brother, sisters, and friends for their sacrifice, inspiration, help and encouragement throughout the study period.

ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007to study the effect of inoculation and fertilization on the growth and yield of blackgram. The treatments of the experiment were as T_1: Control (No inoculation and fertilization), T_2: 20 kg N ha^{-1}, T_3: 40 kg P_2O_5 ha^{-1}, T_4: 30 kg K_2O ha^{-1}, T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_8: *Rhizobium* inoculation, T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}, T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}, T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}, T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}. The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Results obtained from the experiment revealed that a package of Rhizobium inoculant along with N, P_2O_5 and K_2O at the rate of 20 kg ha^{-1}, 40 kg ha^{-1} and 30 kg ha^{-1} respectively improved the growth characters like plant height, leaves $plant^{-1}$, dry weight $plant^{-1}$, nodules $plant^{-1}$, CGR, RGR and yield characters like flower $plant^{-1}$, pods $plant^{-1}$, pod length, seeds pod^{-1} and 1000 seed weight. Eventually the seed yield was maximized (1.48 t ha^{-1}) and verified with higher value of harvest index (25.90 %). Seed yield was 47.83 % higher than that of control plot where as no Rhizobium inoculant and fertilizer were given.

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Chapter 1

INTRODUCTION

Lentil, blackgram, mungbean, chickpea, grasspea and cowpea are very important pulse crops among the various types that grown in Bangladesh. Pulse crops are important food crops because it provides a cheap source of easily digestible dietary protein which complements the stable rice diet in the country. According to FAO (1999) a minimum intake of pulse by a human should be 80 g per head per day, whereas it is only 14.19 g in Bangladesh (BBS, 2007).

Blackgram (*Vigna mungo* L.) is one of the most important pulses in Bangladesh with good digestibility, flavor, and high protein content among the pulse crop. Its grain contains 59.6% carbohydrates, 24% protein, 10.9% moisture, 3.2% mineral and 1.4% fat (Kaul, 1982). It valued for its high digestibility and freedom from flatulence effect (Fary, 2002). Blackgram is used for human food (vegetable diets), green manure, a cover crop, forage, silage, hay and chicken pasture (Munro and Small, 1997). Beside that blackgram potential as a dual-purpose crop for early season forage production follows by seed production should be examined (Imrie, 2005). Blackgram is sown on most soil but it can grow on heavier soils (pH 5.5-7.5). This crop improves soil fertility by fixing atmospheric nitrogen through the symbiotic relationship between the host blackgram roots and a soil bacterium called *Rhizobium*. Blackgram is the most important pulse crop although not in terms of area (70,784 ha) and production (20,826 t) but its consumption is quite high as a common pulse in Bangladesh (BBS, 2007).

The average yield of blackgram is 0.72 t ha^{-1} (BBS, 2007) which is very poor in comparison to blackgram growing countries in the world. There are many reasons of low yield of blackgram. Blackgram has been pushed down the marginal land with management due to the increased area of boro rice, wheat and maize. The land is very poor in nutrient contents and as well as having lower *Rhizobium* population. All these factors are responsible for low yield of blackgram.

Organisms like *Rhizobium/Bradyrhzobium* have been identified as economic bio-fertilizer to legume crops. In Bangladesh, pulse crop inoculation with *Rhizobium* increased 57% effective nodule, 77% dry matter production, 64% grain yield and 40% hay yield over unionculated control (Chanda *et al.*, 1991). So, inoculation of *Rhizobium* to blackgram is one way approach of elevating yield and to improve nitrogen status of the soils of the country.

Pulse crop like blackgram requires a starter dose of fertilizer as basal to get support of the seedling initially before nodules start functioning. Application of nitrogenous fertilizers becomes helpful in increasing the yield (Patel *et al.*, 1984 and Ardeshana *et al.*, 1993). As a component of protein nitrogen is most useful for pulse crops (BARC, 1997). Nitrogen plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most important element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anon., 1972). An adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa and Roan, 1981). Again, excessive application of nitrogen is not only uneconomical, but it can prolong the growing period and delay crop maturity. Excessive nitrogen application also causes physiological disorder for the plants (Obreza and Vavrina, 1993). Phosphorus is another important essential macro element for the normal growth and development of plant. It requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Deficiency of phosphorus restricts the plant growth and remains plants in immature (Hossain, 1990). Potassium plays a remarkable role in plant physiological process. It is an essential constituent of different plant substances. Potassium deficiency causes yield reduction by limiting plant growth. It influences nutrient uptake by promoting root growth and nodulation. On the other hand nutrient availability in a soil depends on some factors of which balance fertilizer is the important one. The optimum proportion fertilizer enhances the growth and development of a crop as well as ensuring the availability of other essential nutrients for the plant.

The farmers of Bangladesh generally grow blackgram as a mixed crop or by one ploughing but use almost no fertilizer. But there is a generous scope of increasing the yield of blackgram per unit area of our country with improved management practices and by using proper combination of organic and inorganic fertilizer. The farmers of our country hardly use fertilizer due to their poor socio-economic condition; as a result the yield becomes low. Adequate supply of chemical fertilizer or bio-fertilizer is essential for normal growth and yield of a crop especially blackgram.

Hence, the present study was done to maximize the seed yield of blackgram with using inoculation of *Rhizobium* inoculant and inorganic fertilizer. Considering the above facts the investigation was undertaken with the following objectives:

i. To study the growth and yield response of blackgram to the application of bio-fertilizer and inorganic fertilizer and

ii. To determine the package of fertilization of blacgram to maximize its growth and yield.

Chapter 2

REVIEW OF LITERATURE

Blackgram is an important pulse crop in Bangladesh and in many countries of the world. The crop has been receiving less important in cultivation in the cereal dominating cropping system of Bangladesh. Based on this a very few research work related to growth, yield and development of blackgram have been carried out in our country. *Rhizobium* inoculation and fertilization is one of the apparatus to improve the yield status of this crop. However, some of the important and informative works and research findings related to the *Rhizobium* inoculation and inorganic fertilization so far been done at home and abroad on this crop and other pulse crop have been reviewed in this chapter under the following headings-

2.1 Effect of *Rhizobium*

Khurana and Poonam (1993) conducted an experiment with *Rhizobium* strains (LMR-107, KM-1, M-10, GMBS-1 and MO-5) and *Vigna radiata* cv. ML 207 and P 516. Under field condition seed inoculation with *Rhizobium* strain increased plant growth and seed yield by 21.5% and 35.1% over uninocultated control in 1988 and 1989, respectively.

Sattar and Ahmed (1995) conducted a field experiment on mungbean inoculation with *Rhizobium* inoculation and observed that *Rhizobium* inoculation increased plant growth and yield compared to control.

Upadhyay *et al.* (1999) found that seed yield of mungbean was higher when the seeds were inoculated with *Rhizobium* (2.02 vs. 1.87 t ha^{-1}).

Srivastav and Poi (2000) conducted field experiments to determine the symbiotic efficiencies of greengram (*V. radiata*) and blackgram (*V. mungo*) after inoculation with a native Bradyrhizobium strain and the residual effects of 7 *Bradyrhizobium* strains (NG-13/1, M-10, Kuthi AR-1, Jca-1, Caj-3, NK-4 and Caj6/1) in neutral pH soil, in Mohanpur, West Bengal, India. Symbiotic variations of greengram and blackgram were observed due to the host and inoculant strains. Inoculation with M-10 strain in greengram resulted in the highest dry matter production and nitrogen fixation, while NK-4 inoculation into blackgram resulted in the highest nitrogen uptake and grain yield.

A field experiment was conducted in Vamban, Tamil Nadu, India by Nagarajan and Balachandar (2001) during the kharif season of 1998 to study the effects of organic amendments on the nodulation and yield of blackgram cv. Vamban 1. In general, seed inoculation of *Rhizobium* and application of organic amendments enhanced biomass, root nodulation, and grain yield. Biodigested slurry at 5 t ha^{-1} + *Rhizobium* gave the greatest plant height (42.7 and 53.7 cm for blackgram and greengram, respectively), nodule number (23.3 and 24.0), nodule weight (45.3 and 42.3 mg), and grain yield (758.3 and 732.0 kg ha^{-1}).

The nodulation characteristics of 8 varieties of blackgram (*Vigna mungo*) were studied by Reddy and Mallaiah (2001). *Rhizobium* sp. was isolated from the T-9 cultivar of the crop. The effect of three different methods of *Rhizobium* inoculation on the nodulation of blackgram was studied. The initiation of nodulation was early and the numbers of nodules formed were more in the seed inoculation method than in soil inoculation or seedling inoculation methods. Three isolates of *Rhizobium*, viz. VM isolate, AH isolate and SG isolates, isolated respectively from blackgram, *Arachis hypogaea* and *Sesbania grandiflora*, were used to study their effect on nodulation and nitrogen content of blackgram cultivar T-9. In plants inoculated with the VM isolate, nodules appeared 12 days after sowing, and a maximum of 84 nodules plant^{-1} were found during the reproductive stage of the crop. The nitrogen content of the nodules at the reproductive stage was 4.5%. The nitrogen content of the shoot was 1.9% at the vegetative stage (25-day-old plants), 3.0% at the reproductive stage (45-day-old plants) and 1.0% at the harvesting stage. The nitrogen content of the fresh seeds was 5.78% in the inoculated plants, while that in uninoculated controls was only 2.72%.

An experiment was conducted by Sriramachandrasekharan and Vaiyapuri (2003) to study the effect of carbofuran in association with *Rhizobium* on the nodulation, growth, and yield of blackgram cv. ADT 3. Irrespective of the levels of carbofuran, *Rhizobium*-inoculated blackgram showed better growth and higher pod yield (50.3 g) and stover yield pot^{-1} (81.1 g) than the uninoculated crop.

Kumari and Nair (2003) conducted a study to isolate efficient native strains of *Rhizobium* or *Bradyrhizobium* spp. and to develop suitable package of practices recommendations for their efficient use. The initial isolation of *Bradyrhizobium* spp. was done from seven different locations in Kerala, India, where the soil was generally acidic in nature. A total of 26 isolates (13 each from blackgram (*Vigna mungo*) and greengram (*V. radiata*) were obtained and were screened for nodulation efficiency. It was also repeated under amended soil conditions using sterilized soil and application of FYM at 20 tonnes ha^{-1}. The selected isolates were further evaluated under field (Vellayani and Kayamkulam) conditions along with a package of practices recommendation (POP) developed by the Kerala Agricultural University. The extent of root nodulation, plant growth and yield were more in blackgram and greengram where *Bradyrhizobium* inoculation was done along with the POP recommendation.

Manivannan *et al.* (2003) conducted a field experiments during 1999/2000 in Tamil Nadu, India to investigate the effect of foliar application of Microsol B (NPK with chelated micronutrients) with and without *Rhizobium* seed inoculation on the productivity of blackgram. The treatments consisted of foliar application of DAP at 30 and 45 days after sowing (DAS), Microsol B at 15, 30 and 45 DAS with and without *Rhizobium* seed treatment and an untreated control. *Rhizobium* seed treatment and foliar application of Microsol B recorded markedly higher leaf area index, dry matter production, crop yield, net assimilation rate, crop growth rate and relative growth rate in both years.

To evaluate the response of summer mungbean cultivars *Binamoog-2* and *Kanti* to *Bradyrhizobium* inoculation and N application an experiment was conducted by Mozumder *et al.* (2005). Results showed that the highest seed yield (1461 kg/ha) were obtained in the treatment with 40 kg N/ha along with *Bradyrhizobium* inoculation. The highest straw yield (4702 kg/ha) was obtained in the treatment with 60 kg N/ha with *Bradyrhizobium* inoculation.

2.2 Effect of NPK fertilizer

Yien *et al.* (1981) conducted an experiment with nitrogen and phosphorus fertilizers to mungbean and reported highest number of pods plant^{-1} from 50 kg and 75 kg per hectare, respectively. Combined application of nitrogen and phosphorus significantly increased the dry weight of plants. Combination with 20 kg P ha^{-1} resulted in significant increase in the seed yield.

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.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N levels (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 per plant. 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.

Raju and Verma (1984) carried out a field experiment during summer season of 1979 and 1980 to study the response of mungbean var. Pusa Baishaki to varying levels of nitrogen (15, 30, 45 and 60 kg N ha^{-1}) in the presence and absence of seed inoculation with *Rhizobium*. They found that maximum dry matter weight per plant was obtained by the application of 60 kg N ha^{-1} inoculated with *Rhizobium*.

Patel and Parmer (1986) conducted an experiment of the response of green gram to varying levels 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 pods per plant.

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. They also stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in plant growth and seed yield of mungbean. They also stated that application of nitrogen, phosphorus and potassium fertilizers combinedly resulted in significant increases in 1000 seed weight.

Salimullah *et al.* (1987) reported that the yield contributing characters and yield was highest with the application of 50 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} in summer mungbean.

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. Results from field experiments conducted by Mahadkar and Saraf (1988) during summer season of mungbean showed that the application of N with P and K at 20:25 kg ha^{-1} gave higher seed yield.

Hamid (1988) conducted a field experiment to investigate the effect of nitrogen and carbon on the growth and yield performance of mungbean (*Vigna radiata* L. wilczek) and reported that the plant height of mungbean cv. Mubarik was found to be increased at 40 kg N ha^{-1}.

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}.

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

Chowdhury and Rosario (1992) studied the effect of 0, 30, 60 or 90 kg N ha^{-1} levels on the rate of growth and yield performance of blackgram at los Banos, Philippines in 1988. They observed that N above the rate of 30 kg N ha^{-1} reduced the dry matter yield. Leelavathi *et al.* (1991) showed significant increase in seed yield of blackgram with 60 kg N ha^{-1}.

Patel *et al.* (1992) conducted a field trial to evaluate the response of mungbean to sulphur fertilization under different levels 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 and found that plant growth with highest doses. Seed yield was 1.2 and 1.24 t ha^{-1} in Gujrarat 2 K 851, respectively with 20 kg N + 40 kg P ha^{-1}.

Phimsirkul (1992) conducted a field trial on mungbean variety, U- Thong I grown in different soils under varying N levels. Results revealed that there was no effect of N fertilizer when mungbean was grown in Mab Bon soil. However, seed yield of mungbean was increased when the crop received N at 30 kg ha^{-1}.

Tank *et al.* (1992) found that mungbean 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 per plant.

Ardeshna *et al.* (1993) conducted a field experiment on clay soil during the rainy season of 1990 to study the response of mungbean to nitrogen. They observed that seed yield increased with application of nitrogen fertilizer up to 20 kg N ha^{-1} in combination with phosphorus fertilizer up to 40 kg P_2O_5 ha^{-1}.

Mishra (1993) carried out a field experiment on farmer's field during the rainy seasons of 1986-87 at Sidhi, Madhya Pradesh where 3 blackgram (*Vigna mungo*) cultivars was given 0, 20, 40 and 60 kg P_2O_5 ha^{-1} and reported that 0, 20, 40 and 60 kg P_2O_5 ha^{-1} gave mean seed yields of 592, 655, 751 and 846 kg ha^{-1}, respectively.

Singh *et al.* (1993) examined the effects of varying levels of N on mungbean cv. MH-85-61. They found that nitrogen application at the rate of 30 kg N resulted in the highest seed yield in mungbean.

Ali *et al.* (1995) carried out field trials at Mianchannu in 1992 and Layyah in 1993 on sandy loam soils low in OM, N and P and *V. mungo* was given no fertilizers or 50 kg N, 50 kg N + 50, 75, 100 or 125 kg P_2O_5 or 50 kg N + 125 kg P_2O_5 + 50 kg K_2O ha^{-1}. NPK gave the highest number of pods $plant^{-1}$ (23.03-23.75) and seed yield (1080-1082 kg ha^{-1}) but was not significantly better than 50 kg N + 75 kg P_2O_5, which gave the highest 1000-seed weight (49.30 and 42.75 g in the 2 trials, respectively). Straw yields did not differ significantly among the treatments.

Bachchhav *et al.* (1994) conducted a field experiment during the summer season with green gram cv. Phule-M. They observed that among nitrogen fertilizers rates (0-45 kg N ha^{-1}) seed yield increased with 30 kg N ha^{-1}

Bhalu *et al.* (1995) conducted a field experiment during the rainy season of 1990 at Junagadh, Gujarat with blackgram (*Vigna mungo*) and seed was inoculated with *Rhizobium* or not inoculated and given 10, 20 or 30 kg N and 20, 40 or 60 kg P_2O_5 ha^{-1}. Seed inoculation increased seed yield (471 vs. 434 kg ha^{-1}). Seed yield increased with up to 20 kg N (464 kg) and 40 kg P_2O_5 (475 kg). N and P uptakes and seed protein content increased with increasing N and P rates. Net return was the highest with seed inoculation.

Kaneria and Patel (1995) conducted a field experiment on a Vertisol in Gujarat, India with mungbean cv. K 581 using 0 or 20 kg N ha^{-1} levels. They found that application of 20 kg N ha^{-1} significantly increased the seed yield (1.14 ton ha^{-1}) when compared with that of control (1.08 ton ha^{-1}).

Sharma *et al.* (1995) carried out a field trial in the monsoon season of 1991 at Gwalior, Madhya Pradesh with blackgram (*Vigna mungo*) cv. JU-2 treated with 0, 15 or 30 kg N, 0, 30 or 60 kg P_2O_5 and 0 or 60 kg S ha^{-1}. Application of N and P, either alone or with S, increased Mn, Zn, Cu and Fe contents in seeds and straw and the available Mn and Zn content in soil. Application of 30 kg N + 60 kg P_2O_5 + 60 kg S ha^{-1} gave the highest trace element content in blackgram. Soil available Cu content decreased with increasing N and P applications but increased with S application. Soil available Fe increased with increasing N and P applications and decreased with increasing S applications.

In a field experiment conducted by Satyanarayanamma *et al.* (1996), five mungbean cultivars were sprayed with 2% urea at pre-flowering, flowering, pod development or at all the combinations or at combination of two of three growth stages. They reported that spraying urea at flowering and pod development stages produced the highest seed yield.

Trivedi (1996) conducted a field trials in the rainy seasons of 1990-91 at Gwalior, Madhya Pradesh, India with *P. mungo* (*Vigna mungo*) cv. Jawahar Urd-2 and was given 0-30 kg N, 0-60 kg P_2O_5 and 0 or 60 kg S ha^{-1}. Seed yield, net returns and N, P and S contents in seed increased with rate of N, P and S applications.

Trivedi *et al.* (1997) carried a field experiment to study the effect of nitrogen, phosphorus and sulfur on yield and nutrient uptake of blackgram (*Vigna mungo*) at Gwalior, Madhya Pradesh during the 1990-91 kharif (monsoon) seasons. Application of 30 kg N, 60 kg P_2O_5 and 60 kg S ha^{-1} increased yield, net profit and nutrient uptake.

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

Tomar (1998) conducted a field experiment in Madhya Pradesh, India, during the rainy season of 1994-95 and 1995-96 to evaluate the effect of phosphate solubilizing-bacteria and farmyard manure on the yield of blackgram (*Vigna mungo*) under different fertility levels. Yield and yield components of cv. RU 2 increased significantly with the application of N, P and K at 20, 26.20 and 16.66 kg ha^{-1}, respectively. Phosphate-solubilizing bacteria inoculation at 10 g kg^{-1} seed and farmyard manure at 5 t ha^{-1} both singly and in combination gave a significant increase in yield and its attributes compared with the control. Application of phosphate-solubilizing bacteria combined with farmyard manure gave the grain and straw yields of 819 and 1200 kg ha^{-1}, respectively. Application of N, P, and K at 20, 26.20 and 16.66 kg ha^{-1}, respectively, phosphate-solubilizing bacteria inoculation with farmyard manure gave the highest grain yield (1001 kg ha^{-1}).

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India. 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 ton ha^{-1}).

Gunjkar *et al.* (1999) carried out an experiment on blackgram (*Vigna mungo*) at Parbhani during kharif (monsoon) 1994 and reported that blackgram gave seed yields of 658, 870 and 921 kg ha^{-1} with 0, 25 and 50 kg N ha^{-1}, and 768, 800, 836 and 863 kg ha^{-1} with 0, 25, 50 and 75 kg P_2O_5 ha^{-1}, respectively.

An investigation was conducted by Singh *et al.* (2002) to study the effect of N, P and K application on seed yield and nutrient uptake by blackgram at Central Agricultural University, Imphal, Manipur, India during 1998 and 1999. In the grain yield, response of blackgram to the various treatments combinations of N (0 and 15 kg ha^{-1}), P (0, 30 and 60 kg ha^{-1}) and K (0 and 20 kg ha^{-1}), the highest yield was obtained from the application of 15:60:20 kg $N:P_2O_5:K_2O$ ha^{-1} which was at par with control and this might be due to higher values of organic carbon, N, P_2O_5 and K_2O in the soil. The total uptake of nutrients by blackgram was associated with higher biomass production.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on mungbean at the agronomic research station, Farooqabad in Pakistan. They reported that various yield components like 1000 grain weight were affected significantly with 50-50-0 NPK kg ha^{-1} application. Again they revealed that seed inoculation + 50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods per plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P was than followed by a decrease with further increase in N.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in leaf area ratios indicating better partitioning of leaf dry matter.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels 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 in 2001. They observed that number of flowers per plant was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds per pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Patel and Thakur (2003) conducted a field experiment with blackgram, comprising of 4 P levels (0, 30, 60 and 90 kg ha^{-1}) with and without phosphate solubilizing bacteria (PSB; 5 kg ha^{-1}) and farmyard manure (FYM; 1 t ha^{-1}) during the rainy season of 1997 and 1998 in Raigarh, Madhya Pradesh, India. The soil was sandy loam in texture, slightly acidic in reaction, with low available N and P and medium available K. Yield attributes and yield were significantly affected by P, PSB and FYM applications. Application of 60 kg P ha^{-1} significantly increased the number of pods $plant^{-1}$, 100-seed weight and seed yield of blackgram over 30 kg P ha^{-1} and the control, but found at par with 30 kg P ha^{-1} for seeds pod^{-1} during both the years. Application of 60 kg P ha^{-1} recorded 10.4 and 69.3% higher yield over 30 kg Pha^{-1} and the control, respectively. Application of PSB and FYM resulted in significantly the highest pod length, pods $plant^{-1}$ and seeds pod^{-1} during 1997, and appreciably increased 100-seed weight and seed yield during both years. An increasing trend in harvest index was observed with increasing levels of P and application of PSB and FYM.

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 T44. Plant growth and grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

A field experiment was conducted by Poonkodi (2004) during 2000-01 in Tamil Nadu, India to investigate the effect of P and pressmud on nutrient uptake of blackgram and on the postharvest soil nutrient status. The treatments were T_1: control; T_2: recommended P rate (RDP) at 100% as single superphosphate (SSP); T_3: RDP at 100% as diammonium phosphate (DAP); T_4: pressmud at 6.25 t/ha; T_5: RDP at 100% as SSP + PM; T_6: RDP at 100% as DAP + PM; T_7: RDP at 75% as

SSP + PM; T_8: RDP at 75% as DAP + PM; T_9: RDP at 50% as SSP + PM; and T_{10}: RDP at 50% as DAP + PM. T_5 produced the highest available N (167.7 kg ha^{-1}), while the lowest (155.9 kg ha^{-1}) was obtained under the control. The available P and K values showed similar patterns with that of the available N. The application of P as SSP or DAP at 75% + PM showed similar efficacy as RDP at 100% as DAP or SSP + PM in increasing the crop nutrient uptake and postharvest N status.

Khan *et al*. (2004) carried out a study to determine the effect of different levels of phosphorus on the yield components of mungbean cv. NM-98 in D.I. Khan, Pakistan in 2000. Treatments comprised of 0, 20, 40, 60, 80, and 100 kg P/ha. The increase in phosphorus levels decreased the days to flowering and increased the branches per plant, number of pods per plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774 kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

Nadeem *et al*. (2004) studied the response of mungbean cv. NM-98 to seed inoculation and different levels 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 growth of plant and yield. The maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Singh and Singh (2004) conducted a field experiments on a soil deficient in S and medium in P with blackgram (*Phaseolus mungo*) as the test crop sulphur phosphorus interaction. The treatments were taken in factorial combination of three levels of S (0, 30, and 60 kg ha^{-1}) and four levels of P (0, 30, 60 and 90 kg ha^{-1}) applied through gypsum ($CaSO_4.2H_2O$) and triple superphosphate, respectively. A uniform dose of N was applied with the treatments. The grain, straw and total dry matter yield increased with the application of S and P individually, but decreased when S and P were applied in different combinations. Sulphur application increased S and P content in seed as well as in straw. Total P content increased with applied P and decreased with S application. Applied S increased and P decreased the protein content in grains. Changes in N: S ratio in grain was affected by S and P application.

Bhat *et al.* (2005) conducted a study during the summer of 2004 in Uttar Pradesh. India, to examine the effects of phosphorus levels on green gram. Four phosphorus rates (0, 30, 60 and 90 kg/ha) were used. All the phosphorus rates increased the seed yield significantly over the control. The highest seed yield was observed with 90 kg P/ha, which was at par with 60 kg P/ha, and both were significantly superior to 30 kg P/ha. Likewise, 60 kg P/ha significantly improved the yield attributes except seed weight compared to the control. For the phosphorus rates, the stover yield followed the trend observed in seed yield.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly influenced the crop parameters. The 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.25, germination of 90.50%, prolonged days taken to maturity, long pods of 5.02 cm, seed weight per plant of 10.53 g, seed index of 3.52 g and the highest seed yield of 1205.2 kg/ha.

Raman and Venkataramana (2006) carried out a field experiment during February to May 2002 in Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of green gram (*V. radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate (DAP) at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA, DAP + NAA, DAP + Penshibao, DAP + Zn chelate, DAP + Penshibao + NAA, and DAP + NAA + Zn chelate. Crop nutrient uptake, yield and its attributes (plant height, number of pods per plant and number of seeds per pod) of green gram augmented significantly due to foliar nutrition. The foliar application of DAP + NAA + Penshibao was significantly superior to other treatments in increasing the values of N, P and K uptakes, yield attributes and yield. The highest grain yield of 1529 kg/ha was recorded with this treatment.

Tickoo *et al.* (2006) conducted an experiment with mungbean cultivars Pusa 105 and Pusa Vishal sown at 22.5 and 30 cm spacing, and supplied with 36-46 and 58-46 kg NP ha^{-1} in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t/ha, respectively) compared to cv. Pusa 105. NP rates had no significant effects on both the biological and grain yield of the crop. Row spacing at 22.5 cm resulted in higher grain yields in both crops than 30 cm.

To evaluate the interactive effects of irrigation and phosphorus on green gram (*V. radiata* cv. NM-54) Malik *et al*. (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 with five phosphorus doses 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) in a split plot design with four replications. Phosphorus application at 40 kg P_2O_5 ha^{-1} influenced the crop positively, while rates below and above this rate resulted in non-significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective. The rest of the combinations remained statistically non-significant to each other. It may be concluded that green gram can be successfully grown with phosphorus at 40 kg P_2O_5 ha^{-1}.

Nigamananda and Elamathi (2007) conducted an experiment in Uttar Pradesh, India during 2005-06 to evaluate the effect of N application time as basal and as DAP or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of green gram cv. K-851. The recommended rate of N:P:K (20:50:20 kg/ha) as basal was used as a control. Treatments included: 1/2 basal N + foliar N as urea or DAP at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea or DAP; and 1/2 basal N + 1/2 foliar spraying as urea or DAP + 40 ppm NAA. Results showed that 2% foliar spray as DAP and NAA, applied at 35 DAS, resulted in the highest values for number of pods/plant (38.3), seeds/pod, flower number, fertility coefficient, grain yield (9.66 q/ha).

2.3 Effect of Rhizobium and NPK fertilizers

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi seed was inoculated with *Rhizobium* or not inoculated and given 0-60 kg P_2O_5 ha^{-1}. They found that seed inoculation influenced plant growth and seed yield of the crop.

Jayakumar *et al.* (1997) carried out a pot culture experiment where blackgram (*Vigna mungo*) plants were raised from: uninoculated seeds; uninoculated seeds with 250 g pot^{-1} coir-pith compost applied at 15 and 45 days after sowing; *Rhizobium*-inoculated, lime-pretreated seeds; and *Rhizobium*-inoculated seeds + lime-pretreatment with 250 g pot^{-1} coir-pith compost. Application of coir-pith compost increased root length more than shoot length of plants compared to controls. It is suggested that coir-pith compost improved the growth of blackgram by increasing the rate and activity of nodulation and increasing the availability of P and K. *Rhizobium* inoculation with lime seed pelleting increased both root and shoot lengths by 45%. *Rhizobium* inoculation, lime pretreatment and coir-pith compost synergistically increased the dry weight of plants and number of nodules $plant^{-1}$ compared to controls.

Singha and Sarma (2001) conducted an experiment in India on blackgram cv. T-9 to study the effect of different levels of P fertilization and *Rhizobium* inoculation of seeds on yield and nutrient uptake. Application of P significantly increased the grain and straw yield and N, P and K uptake. P at 45 kg ha^{-1} produced the highest grain and straw yield with the application of 25 and 35 kg P ha^{-1}. N uptake increased from 20 to 30 kg ha^{-1} with application of 25 to 45 kg P ha^{-1}, respectively. *Rhizobium* inoculation significantly increased the number (2.2%) and mass (9.5%) of root nodules $plant^{-1}$ compared to the control indicating increased efficiency of the crop to fix the atmospheric N.

Bhattacharyya and Pal (2001) conducted a field experiment on summer green gram and showed that *Rhizobium* inoculation and application of P significantly influenced the number of nodules per plant, dry matter accumulation in the shoot, crop growth rate and plant height. Maximum growth was obtained in *Rhizobium* treatments combined with P at 40 kg/ha.

Tomar *et al.* (2001) conducted a field experiment at the G.B. Pant University Research Station, Ujhani, Uttar Pradesh, India, during *kharif* 1994-95 to study the effect of *Rhizobium*, vesicular arbuscular mycorrhiza (VAM, *Glomus caledonium*) and phosphate solubilizing bacteria (PSB, *Pseudomonas striata* strain P-27) inoculation, with and without P, on blackgram (*Vigna mungo*) seed yield. Phosphorus application in soil with medium P content (5.4 mg kg^{-1}) increased nodulation, grain yield, N and P in plant and grain over no phosphorus control. Forty kilograms of P_2O_5 each hectare recorded an increase of 20.6% in nodule dry weight, significant increases of 0.35 g kg^{-1} in N concentration and 1.28 g kg^{-1} in P concentration of plant over 20 kg P_2O_5 ha^{-1}. Similar significant increases of 0.59 g kg^{-1} in grain yield and 0.54 and 0.23 g kg^{-1} in N and P concentrations of the grain, respectively, over 20 kg P_2O_5 ha^{-1} were also obtained with higher dose. Inoculation of *Rhizobium* + VAM + PSB at all the stages of plant growth recorded maximum increases in all the parameters studied. *Rhizobium* gave the highest and 21.0% more nodule number, 34.7% more nodule dry mass, 0.73 g kg^{-1} more N in grain and 4.2% higher grain yield over PSB.

The effects of P and biofertilizers as seed inoculants (*Rhizobium* and the phosphate-solubilizing bacterium (PSB) *Bacillus megaterium* var. *phosphaticum*), singly or in combination, on the performance of blackgram cv. T-9 were studied by Tanwar *et al*. (2002) in Udaipur, Rajasthan, India during the kharif season of 1996. P as diammonium phosphate was applied during sowing. The application of 60 kg P_2O_5 ha^{-1} increased the dry matter production $plant^{-1}$ at 60 days after sowing (DAS) and at harvest, and number of primary branches $plant^{-1}$ by 52.8, 18.8 and 37.9% over the control, respectively. Seed inoculation with *Rhizobium* and PSB either singly or in combination enhanced dry matter production, number of branches $plant^{-1}$, number of nodules $plant^{-1}$, number of pods $plant^{-1}$ and number of seeds pod^{-1}. However, the inoculation of both biofertilizers was more effective than the inoculation of either of the biofertilizers. *Rhizobium* and PSB were equally effective when applied alone. The application of 40 and 60 kg P_2O_5 ha^{-1} resulted in the highest number of pods $plant^{-1}$. The highest grain, straw and biological yields were obtained with 60 kg P_2O_5 ha^{-1} (39.0, 29.7 and 31.28% increase over the control, respectively). The interaction between P rate and biofertilizers was significant with regard to the number of nodules and seed yield. The inoculation of both biofertilizers along with the application of 60 kg P_2O_5 gave the highest number of nodules $plant^{-1}$ (40.5) and seed yield.

Tanwar *et al.* (2003) conducted a field study in Rajasthan, India during kharif 1996 to investigate the effect of P (0, 20, 40 and 60 kg ha^{-1}) and biofertilizers (*Rhizobium* sp. and *Bacillus megaterium* var. *phosphaticum*) on the nutrient content and uptake of blackgram. The biofertilizers were applied singly or in combination. The crop yield, N and P contents, and N and P uptake increased with increasing P rate up to 80 kg ha^{-1}. Inoculation with the combination of the biofertilizers resulted in higher yield, N and P content, N and P uptake of the grain and straw compared to no inoculation and individual inoculation.

Dost *et al.* (2004) carried out a field experiment on mung bean cv. *NM-92* and revealed that the maximum number of pods (17.0) were recorded at 80 kg P_2O_5/ha + *Rhizobium* inoculum and the number of grains per pod increased only with an increase of P levels. The maximum grains per pod (10.9) were recorded at 80 kg P_2O_5/ha followed by 10.83 at 65 kg P_2O_5/ha and the highest grain yield (1018 kg/ha) was with 65 kg P_2O_5/ha + *Rhizobium* inoculum.

Chapter 3

MATERIALS AND METHODS

An investigation was made at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of *Rhizobium* inoculation and fertilization growth on yield contributing characters and yield of blackgram. This chapter includes materials and methods that were used in conducting the experiment. The details have been presented below under the following headings -

3.1 Experimental site

The experimental site of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh is situated in $23^{0}74'$N latitude and $90^{0}35$ E longitude (Anon., 1989).

3.2 Climate

The climate of the experimental field was sub-tropical and was characterized by temperature and heavy rainfall during karif season (April-September) and scanty rainfall during rabi season (October-March) associated with moderately low temperature. Maximum and minimum temperatures were varied from 31.4° C to 34.7° C and 19.6° C to 25.9° C respectively; relative humidity from 54 % to 70 % ; total rainfall from 11 mm to 185 mm and sunshine hour from 6.4 to 8.2. Meteorological data like temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Sher-e-Bangla Nagar and presented in Appendix II.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was shallow red brown terrace soil. The selected experimental plot was medium high land and the soil series was Tejgaon (FAO, 1988). The soil characteristics under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix II.

3.4 Planting material

The variety BARI mash-3 was used as the test crop. The seeds were collected from the Pulse Seed Division of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. BARI mash-3 is a recommended variety of blackgram. It grows both in kharif and rabi season. Life cycle of this variety ranges from 65 to 70 days. Maximum seed yield is 1.5-1.6 ton/ha.

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on March 22, 2007 and March 30, 2007, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The treatments of the experiment were as follows:

T_1: Control (No inoculation and fertilization)

T_2: 20 kg N ha^{-1}

T_3: only 40 kg P_2O_5 ha^{-1}

T_4: 30 kg K_2O ha^{-1}

T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_8: *Rhizobium* inoculation

T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}

T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}

T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}

T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_{14}:*Rhizobium* inoculation +20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

3.7 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each block was divided into 14 plots where 14 treatments were allotted at random. There were 42 unit plots altogether in the experiment. The size of the each unit plot was 4.0 m × 2.5 m. The distance maintained between two blocks and two plots were 1.5 m and 0.75 m, respectively.

3.8 Fertilizer application

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium respectively. Nitrogen, phosphorous, and potassium was applied in the experiment as per treatment variables.

3.9 Seed inoculation

The quantity of seed required for each plot was weighted and was kept in polythene packets. Respective packets were made ready to mix thoroughly with *Rhizobium* inoculants at the rate of 30 g kg^{-1} seed. In the process, the amount of seed in each packet was mixed thoroughly with *Rhizobium*.

3.10 Sowing of seeds in the field

The seeds of blackgram were sown on April 04, 2007. Seeds were treated with Bavistin before sowing to control the seed borne disease. The seeds were sown continuously in the furrows having a depth of 2-3 cm having row to row distance as 30 cm.

3.11 Intercultural operations

3.11.1 Thinning

Seeds were germinated four days after sowing (DAS). Thinning was done two times; first thinning was done at 8 days after sowing and second at 15 days after sowing to maintain plant to plant distance as 10 cm.

3.11.2 Irrigation and weeding

Irrigation was done according to crop requirement. The crop field was weeded twice; first weeding was done at 15 DAS and the second at 30 DAS.

3.11.3 Protection against insect and pest

At early stage of growth worms (*Agrotis ipsilon*) and virus vectors (jassid) attacked the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Dimacron 50EC was sprayed at the rate of 1litre/ha.

3.12 Crop sampling and data collection

Ten plants from each treatment were randomly sellected to record the growth data of blackgram at 10 days interval started from 25 DAS to 55 DAS. Yield components and yield data were taken at harvest stage.

3.13 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to black in color. The matured pods were collected by hand picking from a pre demarcated area of 6 m^2 at the centre of each plot.

3.14 Data collection

The following data were recorded

1. Growth characters

    i. Plant height (cm)

    ii. Number of leaves $plant^{-1}$

    iii. Above ground dry matter (g) $plant^{-1}$

    iv. Crop Growth Rate (CGR)

    v. Relative Growth Rate (RGR)

    vi. Number of nodule $plant^{-1}$

2. Yield components

    i. Pods $plant^{-1}$

    ii. Pod length (cm)

    iii. Seeds pod^{-1}

    vii. 1000- seed weight (g)

3. Yield and harvest index

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

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

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

iv. Harvest index (%)

3.15 Procedure of data collection

3.15.1 Plant height (cm)

The heights of plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.15.2 Leaves $plant^{-1}$

The leaves (trifoliate) were counted from selected plants. The average number of leaves per plant was determined.

3.15.3 Above ground dry weight $plant^{-1}$

Ten plants including stem, leaves and pods were oven dried at 70^0C for 72 hours until constant weight than transferred into desicator and allowed to cool down at room temperature and final weight was taken and converted into dry weight $plant^{-1}$.

3.15.4 Nodules $plant^{-1}$

The number of nodules in each plant was recorded from randomly 10 selected plants at the time of flower initiation and mean volume was determined.

3.15.5. Estimated growth parameter

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula-

$$CGR = \frac{1}{GA} \times \frac{W_2\text{-}W_1}{T_2T_1} \quad g\ m^{-2}\ day^{-1}$$

Where,

GA = Ground area (m^2)

W_1 = Dry weight at time T_1 (g)

W_2 = Dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

Relative Growth Rate (RGR):

Relative growth rate was calculated using the following formula

$$RGR = \frac{LnW_2 - LnW_1}{(T_2 - T_1)} \quad g\ g^{-1}\ day^{-1}$$

Where,

W_1 = Dry weight at time T_1 (g)

W_2 = Dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

Ln = Natural logarithm.

3.15.6 Flowers plant^{-1}

Number of flowers of selected plants from each plot was counted and the mean number of flower and was expressed as per plant basis.

3.15.7 Pods plant^{-1}

Number of total pods of ten selected plants from each plot was counted and the mean number was expressed as per plant basis.

3.15.8 Pod length

Pod length was taken from the selected 10 pods in each plot and the mean length was expressed in per pod basis.

3.15.9 Seeds pods^{-1}

The number of seeds was counted from randomly selected 10 pods from each plot at the harvest and averaged them to have number of seeds pod^{-1}.

3.15.10 Weight of 1000-seed

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

3.15.11 Seed yield hectare^{-1}

The seeds collected from 6.0 m^2 of each plot were sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.15.12 Stover yield hectare^{-1}

The stover collected from 6.0 m^2 of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.15.13 Biological yield

Biological yield was measured by adding seed yield and stover yield.

$$\text{Biological yield} = \text{Seed yield} + \text{Stover yield}$$

3.15.14 Harvest index

The harvest index was calculated by using the following formula

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

3.16 Statistical analysis

The data obtained for different parameters were statistically analyzed by using MSTAT software. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

The major objective of the present study was to find out a way of improving the yield of blackgram through inoculation and fertilization. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix III-IX. In this chapter, the results have been presented along with discussion. The presented results were compared with the results of other scientists in respect of their treatment variables.

4.1 Growth characters

4.1.1 Plant height

Significant variation among the treatments was recorded in respect of plant height of blackgram at 25, 35, 45 and 55 DAS (Appendix III). Plant height varied from 16.90-33.81 cm, 28.20-47.79 cm, 39.71-70.29 cm and 49.05-81.03 cm at 25, 35, 45 and 55 DAS respectively (Table 1). At 25 DAS, the tallest plant (33.81 cm) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar to T_{13} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}), T_7 (20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}), T_{11} (*Rhizobium* inoculation + 30 kg K_2O ha^{-1}), T_{10} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}), T_9 (*Rhizobium* inoculation + 20 kg N ha^{-1}), T_{12} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}) and T_5 (20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}) with corresponding plant height of 33.33 cm, 30.72 cm, 30.42 cm, 28.62 cm, 28.13 cm, 28.04 cm and 26.24 cm respectively. The shortest plant (16.90 cm) was observed in T_1 (control) which was closely followed by T_8 (*Rhizobium* inoculation), T_3 (40 kg P_2O_5 ha^{-1}), T_2 (20 kg N ha^{-1}), T_4 (30 kg K_2O ha^{-1}), and T_6 (40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) having plant height of 20.29 cm, 21.67 cm, 22.62 cm, 23.13 cm and 23.81 cm respectively. At 35 DAS, the tallest plant (47.79 cm) was found from T_{14} which was statistically similar to T_{13} (46.36 cm), T_{11} (44.89 cm), T_{10} (43.51 cm), T_7 (42.85 cm) and T_9 (39.34 cm) while the shortest plant (28.20 cm) was recorded from T_1 which was statistically similar to T_8 (28.94 cm), T_6 (33.91 cm), T_3 (35.18 cm), T_4 (36.89 cm) and T_2 (36.99 cm). At 45 DAS, the tallest plant (70.29 cm) was recorded from T_{14} which was statistically similar to T_{13} (68.69 cm), T_{11} (64.40 cm), T_{10} (61.20 cm), T_7 (61.15 cm), T_5 (55.66 cm) and T_{12} (53.88 cm). The shortest plant (39.71 cm) was recorded from T_1 which was closely followed by T_8 (44.38 cm), T_3 (45.23 cm), T_6 (48.79 cm), T_2 (49.76 cm), T_9 (49.73 cm), T_4 (50.72 cm), T_{12} (53.88 cm) and T_5 (55.66 cm). At 55 DAS, the tallest plant (81.03 cm) was recorded from T_{14} which was statistically similar to T_{13} (80.45 cm), T_{11} (75.73 cm), T_7 (69.33 cm), T_{10} (69.28 cm), T_5 (63.32 cm) and T_{12} (62.87 cm) whereas the shortest plant (46.97 cm) was recorded from T_8 which was closely followed by T_1 (49.05 cm) and T_3 (52.42cm), T_4 (58.37 cm), T_9 (58.87 cm), T_6 (59.09 cm), T_2 (60.50 cm), T_{12} (62.87 cm), T_5 (63.32 cm).

Rhizobium inoculation along with recommended doses of chemical fertilizer was more effective for showing increased plant height. Any single chemical fertilizer or *Rhizobium* alone could not influence plant height. Urea seemed as an important fertilizer which helped in cell division and cell elongation of blackgram thus producing taller plants. But inoculation of *Rhizobium* along with other fertilizer except urea was found effective as like urea was given.This findings was supported by Dost *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996). Sattar and Ahmed (1995), Khurana and Poonam (1993), Salimullah *et al.* (1987) and Patel *et al.* (1984) in mungbean.

Table 1. Effect of *Rhizobium* inoculation and fertilization on the plant height of blackgram

Treatments	Plant height (cm)			
	25 DAS	35 DAS	45 DAS	55 DAS
T_1	16.90 e	28.20 f	39.71 d	49.05 d-e
T_2	22.62 b-e	36.99 c-f	49.76 b-d	60.50 b-e
T_3	21.67 c-e	35.18 d-f	45.23 cd	52.42 de
T_4	23.13 b-e	36.89 c-f	50.72 b-d	58.37 c-e
T_5	26.24 a-d	38.32 b-e	55.66 a-d	63.32 a-e
T_6	23.81 b-e	33.91 e-f	48.79 b-d	59.09 c-e
T_7	30.72 ab	42.85 a-e	61.15 a-c	69.33 a-d
T_8	20.29 d-e	28.94 f	44.38 cd	46.97 e
T_9	28.13 a-d	39.34 a-e	49.73 b-d	58.87 c-e
T_{10}	28.62 a-c	43.51 a-d	61.20 a-c	69.28 a-d
T_{11}	30.42 ab	44.89 a-c	64.40 ab	75.73 a-c
T_{12}	28.04 a-d	37.85 b-e	53.88 a-d	62.87 a-e
T_{13}	33.33 a	46.36 ab	68.69 a	80.45 ab
T_{14}	33.81 a	47.79 a	70.29 a	81.03 a
$S\overline{x}$	2.450	2.702	5.083	6.122
CV(%)	6.15	12.11	8.14	9.73

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)

T_2: 20 kg N ha^{-1}

T_3: 40 kg P_2O_5 ha^{-1}

T_4: 30 kg K_2O ha^{-1}

T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_8: *Rhizobium* inoculation

T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}

T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}

T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}

T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

4.1.2 Leaves plant^{-1}

Number of leaves plant^{-1} of blackgram showed statistically significant differences due to the different treatments at 25, 35, 45 and 55 DAS (Appendix IV). Number of leaves plant^{-1} was varied between 3.46-6.52, 9.37-12.83, 13.74-23.06 and 16.14-25.76 at 25, 35, 45 and 55 DAS, respectively (Table 2). At 25 DAS, the maximum number of leaves plant^{-1} (6.52) was obtained from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar (6.26, 5.45, 5.43 and 5.38) to T_{13} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}), T_7 (20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) and T_{11} (*Rhizobium* inoculation + 30 kg K_2O ha^{-1}) and T_{10} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}), respectively. The minimum number of leaves plant^{-1} (3.46) was found from T_1 (control) which was closely followed by T_8 (4.12), T_3 (4.24), T_6 (4.28), T_2 (4.59), T_5 (4.62) and T_4 (4.71). At 35 DAS, the maximum number of leaves plant^{-1} (12.83) was recorded from T_{14} which was statistically similar to T_{13} (12.63), T_7 (12.42), T_{11} (12.23), T_{10} (11.94), T_5 (11.59), T_2 (11.13), T_4 (10.74), T_9 (10.72), T_6 (10.59), and T_{12} (10.44). The minimum number of leaves plant^{-1} (9.37) was observed from T_1 which was closely followed by T_8 (9.63) and T_3 (9.69), T_{12} (10.44), T_6 (10.59), T_9 (10.72), T_4 (10.74), T_2 (11.13) and T_5 (11.59). At 45 DAS, the maximum number of leaves plant^{-1} (23.06) was recorded from T_{14} which was statistically similar with T_{13} (22.41), T_{11} (21.43), T_7 (20.53), T_5 (20.19), T_{10} (19.65), T_2 (18.41), T_{12} (18.28), T_4 (17.50) and T_9 (16.54). The minimum number of leaves (13.74) was recorded from T_1 which was closely followed by T_8 (14.75) and T_3 (15.30), T_6 (16.39), T_9 (16.54), T_4 (17.50), T_{12} (18.28), T_2 (18.41), T_{10} (19.65) and T_5 (20.19). At 55 DAS, the maximum number of leaves plant^{-1} (25.76) was recorded from T_{14} which was statistically similar to T_{13} (25.34), T_{11} (24.91), T_7 (23.46), T_{10} (23.32), T_5 (21.24), T_{12} (21.08), T_2 (20.91), T_6 (20.09), T_4 (18.97), and T_9 (18.90); while the minimum numbers of leaves (16.14) was found from T_1 which was closely followed by T_8 (16.91), T_3 (18.23), T_9 (18.90), T_4 (18.97), T_6 (20.09), T_2 (20.91), T_{12} (21.08) and T_5 (21.24).

Table 2. Effect of inoculation and fertilization on number of leaves plant^{-1} of blackgram

Treatments	Number of leaves plant^{-1}			
	25 DAS	35 DAS	45 DAS	55 DAS
T_1	3.46 d	9.37 c	13.74 e	16.14 d
T_2	4.59 cd	11.13 a-c	18.41 a-e	20.91 a-d
T_3	4.24 cd	9.69 bc	15.30 c-e	18.23 b-d
T_4	4.71 cd	10.74 a-c	17.50 a-e	18.97 a-d
T_5	4.62 cd	11.59 a-c	20.19 a-e	21.24 a-d
T_6	4.28 cd	10.59 a-c	16.39 b-e	20.09 a-d
T_7	5.45 a-c	12.42 a	20.53 a-d	23.46 a-c
T_8	4.12 cd	9.63 bc	14.75 de	16.91 cd
T_9	5.07 bc	10.72 a-c	16.54 a-e	18.90 a-d
T_{10}	5.38 a-c	11.94 ab	19.65 a-e	23.32 a-c
T_{11}	5.43 a-c	12.23 a	21.43 a-c	24.91 ab
T_{12}	5.06 bc	10.44 a-c	18.28 a-e	21.08 a-d
T_{13}	6.26 ab	12.63 a	22.41 ab	25.34 a
T_{14}	6.52 a	12.83 a	23.06 a	25.76 a
$S\bar{x}$	0.430	0.753	1.930	2.029
CV(%)	5.05	11.71	8.12	6.67

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)
T_2: 20 kg N ha^{-1}
T_3: 40 kg P_2O_5 ha^{-1}
T_4: 30 kg K_2O ha^{-1}
T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_8: *Rhizobium* inoculation
T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}
T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}
T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}
T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

Nigamananda and Elamathi (2007), Malik *et al.* (2006), Dost *et al.* (2004), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993), Patel *et al.* (1992) and Sardana and Verma (1987) reported similar observations in mungbean.

4.1.3 Above ground dry matter plant^{-1}

Significant variation among the treatments was recorded for above ground dry matter plant^{-1}of blackgram due to the different treatments at 25, 35, 45 and 55 DAS (Appendix V). Above ground dry matter plant^{-1}of blackgram varied from 45.08-86.44 g, 62.67-116.46 g, 136.32-204.54 g and 245.79-405.47 g at 25, 35, 45 and 55 DAS. At 25 DAS, the highest above ground dry matter plant^{-1} (86.44 g) was observed from treatment T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar to T_{11} (85.18), T_{13} (84.75), T_7 (81.47), T_{10} (80.07), T_9 (74.92), T_5 (67.84), T_2 (67.69) and T_4 (67.22); the lowest above ground dry matter plant^{-1} (45.08 g) was recorded from T_1 (control) which was closely followed by T_8 (54.93), T_6 (57.52), and T_3 (62.83) (Table 3). At 35 DAS, the highest above ground dry matter plant^{-1} (116.46 g) was found from T_{14} which was statistically similar with T_{13} (114.61), T_{11} (113.70), T_7 (109.02), T_{10} (107.12), T_9 (101.74), and T_5 (92.44) and the lowest above ground dry matter plant^{-1} (62.67 g) was recorded from T_1 which was statistically similar to T_8 (74.42), T_6 (80.01), andT_3 (83.98). At 45 DAS, the highest above ground dry matter plant^{-1} (204.54 g) was found from T_{14} which was statistically similar to T_{13} (203.41), T_{11} (201.73), T_7 (182.20), T_{10} (181.83), T_5 (172.75), T_{12} (167.24), T_2 (162.81), and T_4

(157.34); the lowest above ground dry matter plant^{-1} (134.05 g) was obtained from T_3 which was statistically similar to T_1 (136.32), T_8 (136.73), T_9 (142.42), T_6 (151.40), T_4 (157.34), T_2 (162.81), T_{12} (167.24), T_5 (172.75), T_{10} (181.83), and T_7 (182.20). At 55 DAS, the highest above ground dry matter plant^{-1} (405.47 g) was recorded from T_{14} which was statistically similar to T_{13} (403.70), T_{11} (367.83), T_{12} (339.10), T_{10} (334.91), T_7 (330.10), and T_4 (309.22); the lowest total dry matter plant^{-1} (242.95 g) was recorded from T_8 which was statistically similar to T_1 (245.79), T_3 (259.47), T_9 (276.19), T_2 (277.83), T_6 (278.87), T_5 (301.37), T_4 (309.22), T_7 (330.10), T_{10} (334.91), and T_{11} (339.10).

The plant treated with *Rhizobium* inoculants and NPK at recommended dose had maximum growth, which reflected in greater dry matter production. This finding was supported by Rajender *et al.* (2003), Bhattacharyya and Pal (2001) and Khurana and Poonam (1993).

Table 3. Effect of *Rhizobium* inoculation and fertilization on the above ground dry matter plant^{-1} of blackgram

Treatments	Above ground dry matter plant^{-1} (g) at			
	25 DAS	35 DAS	45 DAS	55 DAS
T_1	45.08 f	62.67 g	136.32 c	245.79 c
T_2	67.69 a-e	89.12 c-f	162.81 a-c	277.83 bc
T_3	62.83 c-f	83.98 d-g	134.05 c	259.47 c
T_4	67.22 a-e	88.11 c-f	157.34 a-c	309.22 a-c
T_5	67.84 a-e	92.44 a-f	172.75 a-c	301.37 bc
T_6	57.52 d-f	80.01 e-g	151.40 bc	278.87 bc
T_7	81.47 a-c	109.02 a-c	182.20 a-c	330.10 a-c
T_8	54.93 ef	74.42 fg	136.73 c	242.95 c
T_9	74.92 a-d	101.74 a-e	142.42 c	276.19 bc
T_{10}	80.07 a-c	107.12 a-d	181.83 a-c	334.91 a-c
T_{11}	85.18 a	113.70 ab	201.73 ab	367.83 ab
T_{12}	65.43 b-e	91.46 b-f	167.24 a-c	339.10 a-c
T_{13}	84.75 ab	114.61 ab	203.41 a	403.70 a
T_{14}	86.44 a	116.46 a	204.54 a	405.47 a
$S\bar{x}$	5.863	7.409	15.14	30.83
CV(%)	14.49	13.56	5.72	7.10

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)

T_2: 20 kg N ha^{-1}

T_3: 40 kg P_2O_5 ha^{-1}

T_4: 30 kg K_2O ha^{-1}

T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_8: *Rhizobium* inoculation

T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}

T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}

T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}

T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

4.1.4 Crop growth rate

Significant variation among the treatments was recorded for Crop Growth Rate (CGR) of blackgram at 25-35, 35-45 and 45-55 DAS (Appendix VI). At 25-35 DAS, the highest CGR (6.54 g m^{-2} day^{-1}) was obtained from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar to T_{13} (6.53 g m^{-2} day^{-1}), T_{11} (5.82 g m^{-2} day^{-1}), T_{12} (5.62 g m^{-2} day^{-1}), T_{10} (5.60 g m^{-2} day^{-1}), T_7 (5.57 g m^{-2} day^{-1}), T_5 (5.25 g m^{-2} day^{-1}), T_9 (5.25 g m^{-2} day^{-1}) and T_4 (4.91 g m^{-2} day^{-1}); the lowest CGR (3.65 g m^{-2} day^{-1}) was recorded from T_1 (control) which was closely followed by T_3 (3.97 g m^{-2} day^{-1}), T_6 (4.36 g m^{-2} day^{-1}), T_8 (4.36 g m^{-2} day^{-1}), T_2 (4.59 g m^{-2} day^{-1}), T_4 (4.91 g m^{-2} day^{-1}), T_5 (5.25 g m^{-2} day^{-1}) and T_9 (5.25 g m^{-2} day^{-1}) (Table 4). At 35-45 DAS, the highest CGR (9.79 g m^{-2} day^{-1}) was observed from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar to T_{13} (9.87 g m^{-2} day^{-1}), T_{11} (9.78 g m^{-2} day^{-1}), T_5 (8.92 g m^{-2} day^{-1}), T_{12} (8.42 g m^{-2} day^{-1}), T_{10} (8.30 g m^{-2} day^{-1}), T_2 (8.19 g m^{-2} day^{-1}), T_1 (8.18 g m^{-2} day^{-1}), T_7 (8.13 g m^{-2} day^{-1}), T_6 (7.93 g m^{-2} day^{-1}) and T_8 (6.92 g m^{-2} day^{-1}), the lowest CGR (4.52 g m^{-2} day^{-1}) was found from T_9 (*Rhizobium* inoculation + 20 kg N ha^{-1}) which was closely followed by T_3 (5.56 g m^{-2} day^{-1}), T_8 (6.92 g m^{-2} day^{-1}), T_4 (7.69 g m^{-2} day^{-1}), T_6 (7.93 g m^{-2} day^{-1}), T_1 (8.18 g m^{-2} day^{-1}), T_2 (8.19 g m^{-2} day^{-1}) and T_{10} (8.30 g m^{-2} day^{-1}). At 45-55 DAS, the highest CGR (20.09 g m^{-2} day^{-1}) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar to T_{13} (20.03 g m^{-2} day^{-1}), T_{12} (17.19 g m^{-2} day^{-1}), T_{11} (16.61 g m^{-2} day^{-1}), T_{10} (15.31 g m^{-2} day^{-1}), T_4 (15.19 g m^{-2} day^{-1}) and T_7 (14.79 g m^{-2} day^{-1}); the lowest CGR (10.62 g m^2 day^{-1}) was recorded from T_8 (*Rhizobium* inoculation) which was closely followed by T_1 (10.95 g m^{-2} day^{-1}), T_2 (11.50 g m^{-2} day^{-1}), T_3 (12.54 g m^{-2} day^{-1}), T_5 (12.86 g m^{-2} day^{-1}), T_6 (12.75 g m^{-2} day^{-1}), T_9 (13.38 g m^{-2} day^{-1}), T_7 (14.79 g m^{-2} day^{-1}), T_4 (15.19 g m^{-2} day^{-1}), T_{10} (15.31 g m^{-2} day^{-1}), T_{11} (16.61 g m^{-2} day^{-1}) and T_{12} (17.19 g m^{-2} day^{-1}).

Table 4. Effect of *Rhizobium* inoculation and fertilization on the crop growth rate of blackgram

Treatments	Crop Growth Rate (g $m^{-2}day^{-1}$)		
	25-35 DAS	35-45 DAS	45-55 DAS
T_1	3.65 d	8.18 a-c	10.95 b
T_2	4.59 b-d	8.19 a-c	11.50 b
T_3	3.97 cd	5.56 bc	12.54 b
T_4	4.91 a-d	7.69 a-c	15.19 ab
T_5	5.25 a-d	8.92 ab	12.86 b
T_6	4.36 b-d	7.93 a-c	12.75 b
T_7	5.57 a-c	8.13 a-c	14.79 ab
T_8	4.36 b-d	6.92 a-c	10.62 b
T_9	5.25 a-d	4.52 c	13.38 b
T_{10}	5.60 a-c	8.30 a-c	15.31 ab
T_{11}	5.82 ab	9.78 a	16.61 ab
T_{12}	5.62 a-c	8.42 a-c	17.19 ab
T_{13}	6.53 a	9.87 a	20.03 a
T_{14}	6.54 a	9.79 a	20.09 a
$S\bar{x}$	0.507	1.156	1.954
CV(%)	7.08	9.98	7.24

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)
T_2: 20 kg N ha^{-1}
T_3: 40 kg P_2O_5 ha^{-1}
T_4: 30 kg K_2O ha^{-1}
T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_8: *Rhizobium* inoculation
T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}
T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}
T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}
T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

4.1.5 Relative growth rate

Due to the different treatments Relative Growth Rate (RGR) of blackgram varied significantly at 25-35, 35-45 and 45-55 DAS (Appendix VII). At 25-35 DAS, the highest RGR (0.148 g g^{-1} day^{-1}) was obtained from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{13} (0.147 g g^{-1} day^{-1}), T_{11} (0.145 g g^{-1} day^{-1}), T_7 (0.144 g g^{-1} day^{-1}), T_9 (0.143 g g^{-1} day^{-1}), T_{10} (0.143 g g^{-1} day^{-1}), T_{12} (0.140 g g^{-1} day^{-1}), T_5 (0.139 g g^{-1} day^{-1}), T_6 (0.135 g g^{-1} day^{-1}), T_2 (0.133 g g^{-1} day^{-1}), T_3 (0.132 g g^{-1} day^{-1}), T_4 (0.131 g g^{-1} day^{-1}) and T_8 (0.129 g g^{-1} day^{-1}); the lowest RGR (0.124 g g^{-1} day^{-1}) was recorded from T_1 (control) which was followed by T_8 (0.129 g g^{-1} day^{-1}), T_4 (0.131 g g^{-1} day^{-1}), T_3 (0.132 g g^{-1} day^{-1}), T_2 (0.133 g g^{-1} day^{-1}), T_6 (0.135 g g^{-1} day^{-1}), T_5 (0.139 g g^{-1} day^{-1}), T_{12} (0.140 g g^{-1} day^{-1}), T_9 (0.143 g g^{-1} day^{-1}), T_{10} (0.143 g g^{-1} day^{-1}) and T_7 (0.144 g g^{-1} day^{-1}) (Table 5). At 35-45 DAS, the highest RGR (0.195 g g^{-1} day^{-1}) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{11} (0.194 g g^{-1} day^{-1}), T_{13} (0.194 g g^{-1} day^{-1}), T_5 (0.190 g g^{-1} day^{-1}), T_1 (0.186 g g^{-1} day^{-1}), T_2 (0.186 g g^{-1} day^{-1}), T_7 (0.186 g g^{-1} day^{-1}), T_{10} (0.186 g g^{-1} day^{-1}), T_{12} (0.186 g g^{-1} day^{-1}), T_4 (0.182 g g^{-1} day^{-1}), T_6 (0.182 g g^{-1} day^{-1}) and T_8 (0.179 g g^{-1} day^{-1}); the lowest RGR (0.159 g g^{-1} day^{-1}) was found from T_9 which was followed by T_3 (0.169 g g^{-1} day^{-1}). At 45-55 DAS, the highest RGR (0.231 g g^{-1} day^{-1}) was recorded from T_{14} which was statistically similar with T_{13} (0.230 g g^{-1} day^{-1}), T_{11} (0.222 g g^{-1} day^{-1}), T_{12} (0.220 g g^{-1} day^{-1}), T_{10} (0.218 g g^{-1} day^{-1}), T_4 (0.217 g g^{-1} day^{-1}), T_7 (0.216 g g^{-1} day^{-1}), T_9 (0.212 g g^{-1} day^{-1}), T_5 (0.211 g g^{-1} day^{-1}) and T_6 (0.210 g g^{-1} day^{-1}); the lowest RGR (0.203 g g^{-1} day^{-1}) was recorded from T_8 (*Rhizobium* inoculation) which was followed by T_1 (0.204 g g^{-1} day^{-1}), T_2 (0.205 g g^{-1} day^{-1}), T_4 (0.209 g g^{-1} day^{-1}), T_6 (0.210 g g^{-1} day^{-1}), T_5 (0.211 g g^{-1} day^{-1}), T_9 (0.212 g g^{-1} day^{-1}), T_7 (0.216 g g^{-1} day^{-1}), T_4 (0.217 g g^{-1} day^{-1}), T_{10} (0.218 g g^{-1} day^{-1}), T_{12} (0.220 g g^{-1} day^{-1}) and T_{11} (0.222 g g^{-1} day^{-1}).

Table 5. Effect of *Rhizobium* inoculation and fertilization on the relative growth rate of blackgram

Treatments	Relative growth rate (g g^{-1} day^{-1})		
	25-35 DAS	35-45 DAS	45-55 DAS
T_1	0.124 b	0.186 ab	0.204 b
T_2	0.133 ab	0.186 ab	0.205 b
T_3	0.132 ab	0.169 bc	0.209 b
T_4	0.131 ab	0.182 ab	0.217 ab
T_5	0.139 ab	0.190 a	0.211 ab
T_6	0.135 ab	0.182 ab	0.210 ab
T_7	0.144 ab	0.186 ab	0.216 ab
T_8	0.129 ab	0.179 ab	0.203 b
T_9	0.143 ab	0.159 c	0.212 ab
T_{10}	0.143 ab	0.186 ab	0.218 ab
T_{11}	0.145 a	0.194 a	0.222 ab
T_{12}	0.140 ab	0.186 ab	0.220 ab
T_{13}	0.147 a	0.194 a	0.230 a
T_{14}	0.148 a	0.195 a	0.231 a
$S\bar{x}$	0.006	0.006	0.006
CV(%)	4.74	6.71	4.29

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)
T_2: 20 kg N ha^{-1}
T_3: 40 kg P_2O_5 ha^{-1}
T_4: 30 kg K_2O ha^{-1}
T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_8: *Rhizobium* inoculation
T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}
T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}
T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}
T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

4.1.6 Nodules $plant^{-1}$

Nodules $plant^{-1}$ of blackgram varied significantly with treatment difference at 45 DAS (Appendix V). The number of nodules $plant^{-1}$ varied from 13.20-23.48(Figure 1). The maximum number of nodules $plant^{-1}$ (23.48) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was statistically similar (22.93, 21.58, 20.92 and 20.60) with T_{13} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}), T_{11} (*Rhizobium* inoculation + 30 kg K_2O ha^{-1}), T_{10} (*Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}) and T_7 (20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}), respectively. The minimum number of nodules $plant^{-1}$ (13.20) was recorded from T_1 (control) which was followed (17.07) by T_3 (40 kg P_2O_5 ha^{-1}). Any treatment with *Rhizobium* showed increased number of nodules. This findings was supported by Malik *et al.* (2006), Raman and Venkataramana (2006), Dost *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Patel *et al.* (1992) and Salimullah *et al.* (1987) in mungbean crop.

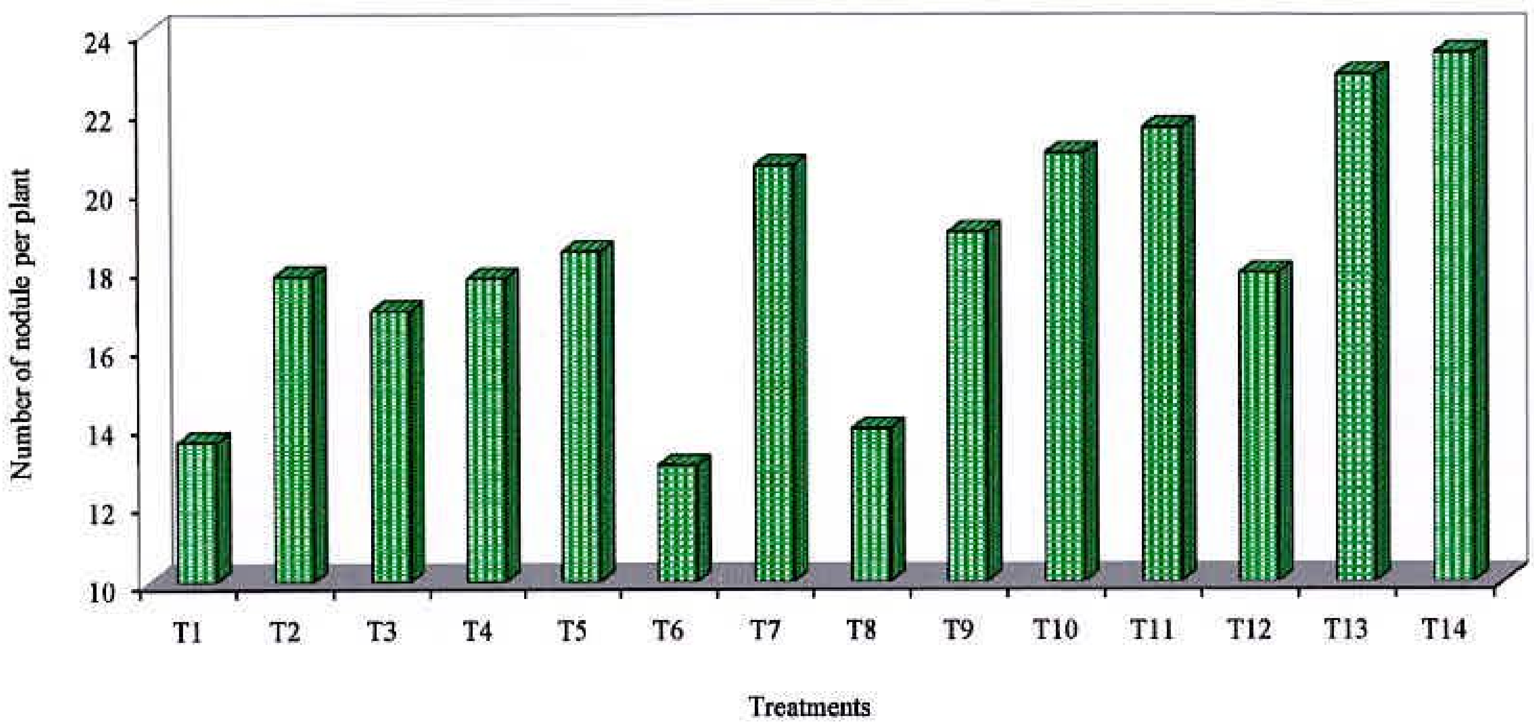

Figure 1. Effect of *Rhizobium* inoculation and fertilization on the number of nodules plant^{-1} of blackgram ($S_{\bar{x}}$ = 1.087) at 45 DAS

4.2 Yield components

4.2.1 Pods plant^{-1}

Number of pods plant^{-1} of blackgram showed statistically significant variation for the application of different treatments (Appendix VIII). Number of pods plant^{-1} varied from 14.00-19.67 for different treatments (Table 6). The maximum number of pods plant^{-1} (19.67) was found from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{13} (19.13), T_{11} (18.53), T_7 (18.47), T_{10} (17.60), T_5 (17.20), T_2 (17.00), T_9 (16.27), T_4 (16.20) and T_{12} (15.67) respectively. The minimum number of pods (13.73) was obtained from T_6 (40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was closely followed by T_8 (13.73), T_1 (14.00), T_3 (14.80), T_{12} (15.73), T_4 (16.20), T_9 (16.27), T_2 (17.00), T_5 (17.20), and T_{10} (17.60). This finding was supported by Rajendran *et al.* (1974) and Subramanian and Radhakrishnan (1983). Similar results were also reported by Sattar and Ahmed (1995), Salimullah *et al.* (1987) and Patel *et al.* (1992) in mungbean crop.

4.2.2 Pod length

Significant variation was recorded for pod length of blackgram due to the application of different treatments (Appendix VIII). Pod length varied from 5.29-8.32 for different treatments (Table 6). The longest pod (8.32 cm) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{13} (8.11 cm), T_{11} (7.87 cm), T_7 (7.76 cm), T_{10} (7.70 cm), T_5 (7.09 cm), T_2 (6.91 cm), T_4 (6.68 cm), T_{12} (6.80 cm) and T_9 (6.19 cm). The shortest pod (5.25 cm) was found from T_8 (*Rhizobium* inoculation) which was statistically similar to T_1 (5.29 cm), T_6 (5.33 cm), T_3 (5.74 cm), T_9 (6.19 cm), T_{12} (6.80 cm), T_4 (6.68 cm), T_2 (6.91 cm) and T_5 (7.09 cm). This findings was supported by Subrahamanyan (1987). Similar results were also reported by Dost *et* *al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Khurana and Poonam (1993) in mungbean crop.

4.2.3 Seeds pod^{-1}

Number of seeds pod^{-1} of blackgram showed significant variation due to the different treatments (Appendix VIII). Number of seeds pod^{-1} varied from 4.53-8.70 for different treatments (Table 6). The maximum number of seeds pod^{-1} (8.70) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{13} (8.47), T_{11} (8.27), T_7 (7.87), T_{10} (7.73), T_{12} (6.73) and T_2 (6.60). The minimum number of seeds pod^{-1} (4.53) was recorded from T_1 (control) which was statistically similar to T_6 (5.20), T_3 (5.73), T_4 (6.07), T_9 (6.33), T_5 (6.40), T_2 (6.60) and T_{12} (6.73).

This findings was supported by Kulsum *et al.* (2007) and Imrie, B. (2005). Similar results were also reported by Nigamananda (2007), Raman and Venkataramana (2006), Malik *et al.* (2006), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Khurana and Poonam (1993) and Mahboob and Asghar (2002) in mungbean crop.

4.2.4 Weight of thousand seeds

Weight of 1000 seeds of blackgram differed significantly due to the different treatments under the trial (Appendix VIII). Thousand seed weight varied from 19.09 to 29.25 g for different treatments (Table 6). The highest weight of 1000 seeds (29.25 g) was found from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar to T_{13} (28.55 g), T_7 (26.67 g), T_{11} (26.49 g), T_{10} (25.48 g) and T_9 (24.66 g). The lowest weight of 1000 seeds (18.29 g) was obtained from T_6 (40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was closely followed by T_8 (19.08 g), T_1 (19.09 g), T_3 (21.42 g), T_2 (21.87 g), T_4 (22.02 g), T_{12} (23.10 g) and T_5 (23.16 g).

Table 6. Effect of *Rhizobium* inoculation and fertilization on the yield contributing characters of blackgram

Treatments	Pods $plant^{-1}$ (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000 seed weight (g)
T_1	14.00 c	5.29 c	4.53 f	19.09 de
T_2	17.00 a-c	6.91 a-c	6.60 a-f	21.87 c-e
T_3	14.80 bc	5.74 bc	5.73 d-f	21.42 c-e
T_4	16.20 a-c	6.68 a-c	6.07 c-f	22.02 c-e
T_5	17.20 a-c	7.09 a-c	6.40 b-f	23.16 b-e
T_6	13.67 c	5.33 c	5.20 f	18.29 e
T_7	18.47 ab	7.76 ab	7.87 a-d	26.67 a-c
T_8	13.73 c	5.25 c	5.53 ef	19.08 de
T_9	16.27 a-c	6.19 a-c	6.33 b-f	24.66 a-d
T_{10}	17.60 a-c	7.70 ab	7.73 a-e	25.48 a-c
T_{11}	18.53 ab	7.87 ab	8.27 a-c	26.49 a-c
T_{12}	15.73 a-c	6.80 a-c	6.73 a-f	23.10 b-e
T_{13}	19.13 ab	8.11 a	8.47 ab	28.55 ab
T_{14}	19.67 a	8.32 a	8.70 a	29.25 a
$S\bar{x}$	1.308	0.674	0.674	1.734
CV(%)	13.67	7.19	7.35	12.77

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)
T_2: 20 kg N ha^{-1}
T_3: 40 kg P_2O_5 ha^{-1}
T_4: 30 kg K_2O ha^{-1}
T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_8: *Rhizobium* inoculation
T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}
T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}
T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}
T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}
T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}
T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

The yield components were the resultant partition of dry matter. The plant treated with Rhizobium and NPK at recommended dose had a better growth, drymatter production, which eventually increased the yield components. This findings was supported by the earlier findings of Poonkodi (2004). Similar results were also reported by Dost *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Khurana and Poonam (1993), Sattar and Ahmed (1995) and Salimullah *et al.* (1987) in mungbean crop.

4.3 Yield and harvest index

4.3.1 Seed yield

A statistically significant difference was observed in terms of seed yield of blackgram due to the different treatments (Appendix IX). Seed yield varied from 0.92 to 1.48 t ha^{-1} for different treatments (Table 7). The highest seed yield (1.48 t ha^{-1}) was recorded from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar with T_{13} (1.36 t ha^{-1}), T_{11} (1.32 t ha^{-1}), T_9 (1.28 t ha^{-1}), T_{10} (1.28 t ha^{-1}) and T_7 (1.27 t ha^{-1}); while the lowest seed yield (0.88 t ha^{-1}) was obtained from T_6 (40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was closely followed by T_1 (0.92 t ha^{-1}), T_8 (0.97 t ha^{-1}), T_3 (1.05 t ha^{-1}), T_2 (1.07 t ha^{-1}), T_4 (1.10 t ha^{-1}) and T_5 (1.11 t ha^{-1}).

Treatment T_{14} had maximum yield components which elevated the seed yield. This findings was the agreement of those reported by Patel *et al.* (1984) and Rajendran *et al.* (1974). Similar results were also reported by Dost *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Sattar and Ahmed (1995) and Khurana and Poonam (1993) and Salimullah *et al.* (1987) in mungbean crop.

4.3.2 Stover yield

Stover yield of blackgram showed statistically significant differences due to the different treatments (Appendix IX). The stover yield varied from 2.84 to 4.23 t ha^{-1} (Table 7). The highest stover yield (4.23 t ha^{-1}) was found from T_{14} (*Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}) which was statistically similar with T_{13} (3.98 t ha^{-1}), T_7 (3.76 t ha^{-1}), T_{11} (3.68 t ha^{-1}) and T_{10} (3.61 t ha^{-1}); while the lowest stover yield (2.84 t ha^{-1}) was recorded from T_1 (control) which was closely followed by T_6 (2.90 t ha^{-1}), T_8 (3.01 t ha^{-1}), T_3 (3.27 t ha^{-1}), T_5 (3.34 t ha^{-1}), T_2 (3.39 t ha^{-1}), T_4 (3.45 t ha^{-1}) and T_{12} (3.48 t ha^{-1}). This finding was supported by Gunjkar et al (1999). Similar results were also reported by Bhattacharyya and Pal (2001) in green gram and by Nadeem *et al.* (2004), Rajender *et al.* (2003) and Khurana and Poonam (1993) in mungbean crop.

4.3.3 Biological yield

Significant difference was recorded in terms of biological yield of blackgram due to the different treatments (Appendix IX).The biological yield varied from 3.76 t ha^{-1} to 5.71 t ha^{-1} (Table 7). The highest biological yield (5.71 t ha^{-1}) was from T_{14} (Rhizobium inoculation + 20 kg N ha^{-1} + 40 kg P2O5 ha^{-1} + 30 K2O ha^{-1}) which was statistically similar to T13 (5.35 t ha^{-1}), T7 (5.03 t ha^{-1}), T11 (5.00 t ha^{-1}), T10 (4.90 t ha^{-1}) and T9 (4.84 t ha^{-1}); the lowest biological yield (3.76 t ha^{-1}) was found from T_1 (control) which was closely followed by T_6 (3.78 t ha^{-1}), T8 (3.98 t ha^{-1}), T_3 (4.32 t ha^{-1}), T_2 (4.46 t ha^{-1}), T_4 (4.55 t ha^{-1}) and T_{12}(4.63 t ha^{-1}).

This trend was similar or followed by the combination of *Rhizobium* and any type of NPK fertilizer or their combination. Again control gave the lowest plant growth with minimum biological yield. Sole application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Kulsum *et al.* (2007). Similar results were also reported by Nigamananda and Elamathi (2007) and Bhattacharyya and Pal (2001) in green gram.

4.3.4 Harvest index

Due to the different treatments harvest index of blackgram showed statistically significant variation (Appendix IX). The harvest index varied from 23.18 to 26.42% (Table 7). The highest harvest index (26.42%) was obtained from T_9 (*Rhizobium* inoculation + 20 kg N ha^{-1}) which was statistically similar to T_{11} (26.28%), T_{10} (26.21%), T_{14} (25.90%), T_{13} (25.51%), T_7 (25.23%), T_5 (25.00%), T_{12} (24.71%), T_8 (24.42%) and T_1 (24.40%); the lowest harvest index (23.18%) was attained from T_6 (40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}) which was followed by T_2 (24.08%), T_4 (24.12%), T_3 (24.21%), T_1 (24.40%), T_8 (24.42%), T_{12} (24.71%), T_5 (25.00%) and T_7 (25.23%).

This finding was supported by Subramanian and Radhakrishnan (1983). Similar result were also reported by Raman and Venkataramana (2006), Dost *et al.* (2004), Nadeem *et al.* (2004) and Rajender *et al.* (2003) in mungbean crop.

Table7. Effect of *Rhizobium* inoculation and fertilization on the seed yield, stover yield, biological yield and harvest index of blackgram

Treatments	Seed yield ($t ha^{-1}$)	Stover yield ($t ha^{-1}$)	Biological yield	Harvest Index (%)
T_1	0.92 de	2.84 f	3.76 e	24.40 a-d
T_2	1.07 c-e	3.39 b-f	4.46 b-e	24.08 cd
T_3	1.05 c-e	3.27 c-f	4.32 c-e	24.21 b-d
T_4	1.10 b-e	3.45 b-f	4.55 b-e	24.12 cd
T_5	1.11 b-e	3.34 b-f	4.46 b-e	25.00 a-d
T_6	0.88 e	2.90 ef	3.78 e	23.18 d
T_7	1.27 a-c	3.76 a-c	5.03 a-c	25.23 a-d
T_8	0.97 de	3.01 d-f	3.98 de	24.42 a-d
T_9	1.28 a-c	3.56 b-e	4.84 a-d	26.42 a
T_{10}	1.28 a-c	3.61 a-d	4.90 a-d	26.21 a-c
T_{11}	1.32 a-c	3.68 a-d	5.00 a-c	26.28 ab
T_{12}	1.15 b-d	3.48 b-f	4.63 b-e	24.71 a-d
T_{13}	1.36 ab	3.98 ab	5.35 ab	25.51 a-c
T_{14}	1.48 a	4.23 a	5.71 a	25.90 a-c
$S\bar{x}$	0.082	0.593	0.619	0.626
CV(%)	12.28	10.21	10.50	13.04

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No inoculation and fertilization)

T_2: 20 kg N ha^{-1}

T_3: 40 kg P_2O_5 ha^{-1}

T_4: 30 kg K_2O ha^{-1}

T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_8: *Rhizobium* inoculation

T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}

T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}

T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}

T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}

T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}

T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 K_2O ha^{-1}

Chapter 5

SUMMARY AND CONCLUSION

The response of blackgram to the application of *Rhizobium* inoculant and fertilizer on crop growth and yield were investigated at SAU farm during the period from March to May 2007. The variety BARI mash-3 was used as the test crop. The treatments of the experiment were as T_1: Control (No inoculation and fertilization), T_2: 20 kg N ha^{-1}, T_3: 40 kg P_2O_5 ha^{-1}, T_4: 30 kg K_2O ha^{-1}, T_5: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, T_6: 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_7: 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_8: *Rhizobium* inoculation, T_9: *Rhizobium* inoculation + 20 kg N ha^{-1}, T_{10}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1}, T_{11}: *Rhizobium* inoculation + 30 kg K_2O ha^{-1}, T_{12}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, T_{13}: *Rhizobium* inoculation + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}, T_{14}: *Rhizobium* inoculation + 20 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

The tallest plants (33.81 cm, 47.79 cm, 70.29 cm and 81.03cm) were obtained from T_{14} at 25, 35, 45 and 55 DAS, respectively and the shortest plants (16.90 cm, 28.20 cm, 39.71 cm and 46.97 cm) were recorded from T_1 and T_8 at different days. The maximum number of leaves $plant^{-1}$ (6.52, 12.83, 23.06 and 25.76) were obtained from T_{14} at 25, 35, 45 and 55 DAS, respectively and the minimum number of leaves $plant^{-1}$ (3.46, 9.37,13.74 and16.14) were recorded from T_1 at different days. The maximum number of nodules $plant^{-1}$ (23.48) was recorded from T_{14} and the minimum (13.20) from T_1 at 45 days. The highest above ground dry matter plant^{-1} (86.44 g, 116.46 g, 204.54 g and 405.47 g) were obtained from T_{14} at 25, 35, 45 and 55 DAS, respectively and the lowest above ground dry matter plant^{-1} (45.08 g, 62.67 g, 136.32 g and 245.79 g) were recorded from T_1 at 25, 35, 45 and 55 DAS respectively.

At 25-35 DAS, the highest CGR (6.54 g m^{-2} day^{-1}) was recorded from T_{14}, while the lowest (3.65 g m^2 day^{-1}) was recorded from T_1. At 35-45 DAS, the highest CGR (9.87 g m^{-2} day^{-1}) was found from T_{13}, while the lowest (4.52 g m^{-2} day^{-1}) was recorded from T_9. At 45-55 DAS, the highest CGR (20.09 g m^{-2} day^{-1}) was recorded from T_{14}, while the lowest (10.62 g m^{-2} day^{-1}) was recorded from T_8.

At 25-35 DAS, the highest RGR (0.148 g g^{-1} day^{-1}) was found from T_{14}, while the lowest (0.124 g g^{-1} day^{-1}) was recorded from T_1. At 35-45 DAS, the highest RGR (0.195 g g^{-1} day^{-1}) was recorded from T_{14}, while the lowest (0.159 g g^{-1} day^{-1}) was recorded from T_9. At 45-55 DAS, the highest RGR (0.231 g g^{-1} day^{-1}) was recorded from T_{14}, while the lowest (0.203 g g^{-1} day^{-1}) was obtained from T_8.

The maximum number of flowers plant^{-1} (42.07), the maximum number of pods plant^{-1} (19.67), the maximum pod length (8.32 cm), the maximum number of seeds pod^{-1} (8.70) and the highest weight of 1000 seeds (29.25 g) were achieved with T_{14}. The minimum number of flowers plant^{-1} (19.80), the minimum number of pods plant^{-1} (13.73), the minimum pod length (5.25 cm), the minimum number of seeds pod^{-1} (4.53) and the lowest weight of 1000 seeds (18.29 g) were recorded from T_1, T_8, T_8, T_1 and T_6 respectively.

Treatment T_{14} gave the highest seed yield (1.48 t ha^{-1}), highest stover yield (4.23 t ha^{-1}) and highest biological yield (5.71 t ha^{-1}) while T_{6}, T_{1}, T_{1} and T_{6} respectively was found minimum to give this parameters. The highest harvest index (26.42%) was recorded from T_{9}, while the lowest (23.18%) was recorded from T_{6}.

From the above results and discussion it may be calculated that blackgram plant to be given with *Rhizobium* inoculants or NPK fertilizer at recommended dose. Being a pulse crop it is required a starter dose of NPK for initial support of plant growth before nodule formation on its root. To achieve higher yield of blackgram a package management with *Rhizobium* inoculant and only PK could be suggested for farmer.

This study should be repeated for different blackgram growing areas of Bangladesh to validate the findings.

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APPENDICES

Appendix I. Physical and chemical characteristics of initial soil (0-5 cm depth) before seed sowing

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis	
Sand	27%
Silt	43%
Clay	30%
Textural class	silty-clay
pH	5.6
Organic carbon	0.45%
Total N	0.03%
Available P	20.00 ppm
Exchangeable ions	0.10 me/100 g soil
Available S	45 ppm

Source: SRDI, Farmghate, Dhaka.

Appendix II. Monthly record of air temperature, relative humidity, rainfall and Sunshine of the experimental site during the period from March to May 2007

Month	Air temperature (°c)		Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
March, 2007	31.4	19.6	54	11	8.2
April, 2007	33.6	23.6	69	163	6.4
May, 2007	34.7	25.9	70	185	7.8

* Source: Bangladesh Meteorological Department (Climate and weather division) Agargaon, Dhaka - 1212

Appendix III. Analysis of variance of the data on plant height of blackgram as influenced by *Rhizobium* inoculation and fertilization

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm)			
		25 DAS	35 DAS	45 DAS	55 DAS
Replication	2	0.312	4.172	5.925	25.140
Treatment	13	76.068**	108.059**	262.785**	344.529**
Error	26	18.005	21.905	77.517	112.450

** Significant at 0.01 level of probability

Appendix IV Analysis of variance of the data on number of leaves plant^{-1} of blackgram as influenced by *Rhizobium* inoculation and fertilization

Source of variation	Degrees of freedom	Mean square			
		Number of leaves plant^{-1}			
		25 DAS	35 DAS	45 DAS	55 DAS
Replication	2	0.003	0.624	0.027	1.555
Treatment	13	2.085**	4.009*	25.189*	28.977*
Error	26	0.554	1.702	11.170	12.354

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on number of nodules plant^{-1} and total dry matter plant^{-1} of blackgram as influenced by *Rhizobium* inoculation and fertilization

Source of variation	Degrees of freedom	Mean square				
		Number of nodule plant^{-1}	Above ground dry matter plant^{-1} (g) at			
			25 DAS	35 DAS	45 DAS	55 DAS
Replication	2	2.781	33.365	43.441	131.406	868.285
Treatment	13	33.305**	477.520**	807.143**	1921.268**	8636.724**
Error	26	5.757	103.115	164.677	687.457	2851.914

** Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on crop growth rate of blackgram as influenced by *Rhizobium* inoculation and fertilization of blackgram

Source of variation	Degrees of freedom	Mean square		
		Crop Growth Rate (g $m^{-2}day^{-1}$)		
		CGR (25-35 DAS)	CGR(35-45 DAS)	CGR (45-55 DAS)
Replication	2	0.120	0.803	5.163
Treatment	13	2.347**	7.007*	28.196**
Error	26	0.772	4.008	11.450

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on relative growth rate of blackgram as influenced by *Rhizobium* inoculation and fertilization

Source of variation	Degrees of freedom	Mean square		
		Relative growth rate (g g^{-1} day^{-1})		
		RGR (25-35 DAS)	RGR(35-45 DAS)	RGR (45-55 DAS)
Replication	2	0.0001	0.0001	0.0001
Treatment	13	0.0002**	0.0001*	0.00015*
Error	26	0.0001	0.0001	0.0001

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters of blackgram as influenced by *Rhizobium* inoculation and fertilization

Source of variation	Degrees of freedom	Mean square				
		Flowers plant^{-1} (No.)	Number of pods plant^{-1}	Pod length (cm)	Seeds pod^{-1} (No.)	1000 seed weight (g)
Replication	2	3.920	1.783	1.242	1.045	3.313
Treatment	13	125.737**	12.092*	3.540*	5.047**	36.542**
Error	26	31.815	5.130	1.362	1.361	9.018

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on yield of blackgram as influenced by inoculation and fertilization as influenced by *Rhizobium* inoculation and fertilization on yield of blackgram

Source of variation	Degrees of freedom	Mean square			
		Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
Replication	2	0.001	0.068	0.083	0.770
Treatment	13	0.093**	0.462**	0.959**	2.903*
Error	26	0.020	0.125	0.236	1.177

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability