EFFECT OF *RHIZOBIUM*, CROP RESIDUES AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF BLACKGRAM

BY

REG. No. : 00838

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

MASTER OF SCIENCE (MS)
IN
SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2008

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This is to certify that the thesis entitled "**Effect of *Rhizobium*, Crop Residues and Inorganic Fertilizers on Growth and Yield of Blackgram**" 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 Soil Science, embodies the result of a piece of bonafide research work carried out by **Mohammad Muksudul Alam**, Registration number: **00838** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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 gratitude to his respected supervisor Dr. Gopinath Chandra Sutradhar, Professor, Department of Soil Science, 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.

The author also expresses his gratefulness to respected Co-Supervisor, A. T. M. Shamsuddoha, Associate Professor & Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his scholastic 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 Soil Science, 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 Soil Science, SAU, for their valuable suggestions, instuctions, cordial help and encouragement during the period of the study.

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

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EFFECT OF *RHIZOBIUM*, CROP RESIDUES AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF BLACKGRAM

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ABSTRACT

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of *Rhizobium*, crop residues and inorganic fertilizers on yield contributing characters of blackgram. The treatments of the experiment were T_1: No *Rhizobium*, No organic, No chemical fertilizer (control), T_2: No *Rhizobium* + No organic + No Nitrogen + PK, T_3: N_{40} + PK, T_4: *Rhizobium* + PK, T_5: *Rhizobium* + N_{20} + PK, T_6: Crop residues + N_{20} + PK, T_7: *Rhizobium* + Crop residues + N_{20} + PK and T_8: Crop Residues + N_{40} + PK. The tallest plant (55.25 cm) was recorded from T_7 and the shortest plant (45.67 cm) was recorded from T_1. The highest seed yield (1.41 t ha^{-1}) was recorded from T_7 and the lowest (0.72 t ha^{-1}) was recorded from T_1. The highest stover yield (1.88 t ha^{-1}) was found from T_7 and the lowest (0.94 t ha^{-1}) was recorded from T_1. The maximum concentration of N (3.12%) was recorded from T_7 and the minimum (2.09%) was recorded from T_4. The maximum concentration of P (0.615%) was found from T_7, while the minimum (0.326%) was recorded from T_1. The maximum concentration of K in plant (0.706%) was recorded from T_7 and the minimum (0.370%) was recorded from T_1. The maximum concentration of S (0.79%) was recorded from T_8 and the minimum (0.39%) was recorded in T_1. The maximum concentration of N in seed (5.36%) was recorded from T_7 and the minimum (4.34%) was recorded from T_1. Treatment T_8 gave the maximum concentration of P in seed (0.544%), while T_1 (control) gave the minimum (0.290%). The maximum concentration of K (0.549%) was recorded from T_7 and the minimum (0.324%) was recorded from T_1. The maximum concentration of S in seed (0.29%) was recorded from T_7 and the minimum (0.39%) was recorded from T_1. The maximum N uptake by plant (40.50 kg ha^{-1}) was found in T_7 and the minimum (20.35 kg ha^{-1}) was recorded from T_1. The maximum P uptake by plant (4.43 kg ha^{-1}) was recorded from T_8, while the minimum (2.90 kg ha^{-1}) was recorded from T_2. The maximum K uptake by plant (19.88 kg ha^{-1}) was obtained from T_7 and the minimum (8.06 kg ha^{-1}) was recorded from T_2. The maximum S uptake by plant (9.32 kg ha^{-1}) was recorded from T_7 and the minimum (4.68 kg ha^{-1}) was recorded from T_1. The maximum N uptake by seed (89.71 kg ha^{-1}) was recorded from T_7 and the minimum (45.49 kg ha^{-1}) was recorded from T_1. The maximum P uptake by seed (12.97 kg ha^{-1}) was found from T_8, while the minimum (10.09 kg ha^{-1}) was recorded from T_3. The maximum K uptake by seed (30.24 kg ha^{-1}) was recorded from T_8 and the minimum (8.06 kg ha^{-1}) was recorded from T_2. The maximum S uptake by seed (3.73 kg ha^{-1}) was recorded from T_8 and the minimum (2.53 kg ha^{-1}) was recorded from T_1.

Chapter 1
Introduction

Chapter I

INTRODUCTION

In Bangladesh various types of pulse crops are grown. Among them lentil, blackgram, mungbean, chickpea, grasspea and cowpea are very important. Pulse crop is an important food crops because it provides a cheap source of easily digestible dietary protein. 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, 2005).

Among the pulse crops, blackgram (*Vigana mungo* L.) is one of the most important pulse in Bangladesh with good digestibility, flavour, and high protein content. Blackgram grain contains 51% carbohydrates, 26% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981; Kaul, 1982). The green plants can also be used as animal feed and its residues can be used as green manure. Being a short duration crop it fits well into the intensive cropping system (Ahmed *et al.*, 1978).

The crop is potentially useful in improving cropping pattern. Blackgram can fix atmospheric nitrogen through the symbiotic relationship between the host blackgram roots and a soil bacterium called *Rhizobium* and thus improves soil fertility. Blackgram is the most important pulse crop although not in terms of area (23,482 ha) and production (17,000 t) but its consumption is quite high as a common pulse in Bangladesh (BBS, 2006). Blackgram is cultivated with minimum land preparation and without fertilizer application and insect, diseases or weed control. All these factors are responsible for low yield of blackgram.

At present the area under pulse crops is 0.337 million hectares with a production of 0.279 million tones where blackgram is cultivated in the area of 23,482 hectares in

Bangladesh (BBS, 2006). The average yield of blackgram is 0.72 t ha^{-1} (BBS, 2006) which is very poor in comparison to blackgram growing countries in the world. There are many reasons of low yield of blackgram. The management of fertilizer is the important one that greatly affects the growth, development and yield of this crop.

Pulses although fix nitrogen from the atmosphere, it is evident that application of nitrogenous fertilizers becomes helpful in increasing the yield (Ardeshana *et al.*, 1993). Nitrogen is most useful for pulse crops because it is the component of protein (BARC, 1997). Nitrogen plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most different 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 Roam, 1981). On the other hand, excessive application of nitrogen is not only uneconomical, but it can prolong the growing period and delay crop maturity. Excessive nitrogen application causes physiological disorder (Obreza and Vavrina, 1993).

Phosphorus is another important essential macro elements for the normal growth and development of plant. Phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Phosphorus restricts the plant growth and remains immature (Hossain, 1990). Blackgram is a short duration crop, for that easily soluble fertilizer like as phosphorus should be applied in the field. On the other hand nutrient availability in a soil depends on some factors. Among them 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. Again secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al.*, 2004).

Now a days a number of organisms like *Rhizobium/Bradyrhzobium* have been identified for use as biological agent for fixing atmosphere nitrogen by symbiosis process with legume crops and making it available to the plants. To reduce the production cost and to fulfil the demand, more pulse production could be achieved through seed inoculation with *Rhizobium/Bradyrhzobium*. So, there is a large scope for utilizing the biological nitrogen fixing technology for obtaining more protein rich food from blackgram and also to improve nitrogen status of the soils in the country by selecting efficient use of blackgram inocula.

Incorporation of crop residues add organic matter and improves physical, chemical and biological condition of soil. So, incorporation of crop residues of rice in the field before growing blackgram in Kharif 1 season may have a positive effect on the productivity of land.

The farmers of Bangladesh generally grow blackgram by one ploughing but use almost no fertilizer. There is an ample scope of increasing the yield of blackgram per unit area with improved management practices and by using proper fertilizer. The farmers of our country hardly use fertilizer due to their poor socio-economic condition; as a result the yield becomes low although it has great potential to increase yield. Adequate supply of chemical fertilizer or bio-fertilizer is essential for normal growth and yield of a crop.

Hence, the present study was done to maximize seed yield of blackgram with using *Rhizobium*, crop residues and nitrogen and their different combination. Considering the above circumstances, the present investigation has been undertaken with the following objectives:

i. To study the effect of biofertilizer, chemical fertilizer and crop residues incorporation on the growth and yield of blackgram.

ii. To determine the optimum dose of nitrogen, phosphorus, potassium and *Rhizobium* for attaining the highest growth and yield of blackgram.

Chapter 2
Review of Literature

Chapter II

REVIEW OF LITERATURE

Blackgram is an important pulse crop in Bangladesh and in many countries of the world. The crop has conventional less concentration by the researchers on various aspects because normally it grows without less care or management practices. For that a very few studies related to growth, yield and development of blackgram have been carried out in our country. So the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the fertilizers, *Rhizobium* and crop residues so far been done at home and abroad on this crop and other pulse crop have been reviewed in this chapter.

2.1 Effect of NPK fertilizer

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India during 2005-06 to evaluate the effect of N application time as basal and as DAP (diammonium phosphate) or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N:P:K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments 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 $plant^{-1}$ (38.3), seeds pod^{-1}, flower number, fertility coefficient, grain yield (9.66 q ha^{-1}).

Malik *et al.* (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interactive effects of irrigation and phosphorus on greengram

(*Vigna radiata* cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) were arranged 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}.

Tickoo *et al.* (2006) carried out an experiment with mungbean cultivars Pusa 105 and Pusa Vishal sown at 22.5 and 30.0 cm spacing and supplied with 36-46 and 58-46 kg of N-P ha^{-1} in a field experiment conducted in New 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. Nitrogen and phosphorus 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 cultivars than 30.0 cm.

A field experiment was conducted by Raman and Venkataramana (2006) 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, no. of pods $plant^{-1}$ and number of seeds pod^{-1}) of greengram 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^{-1} was recorded with this treatment.

Bhat *et al.* (2005) conducted a study during the summer of 2004 in Uttar Pradesh, India to examine the effects of phosphorus levels on greengram. Four phosphorus rates (0, 30, 60 and 90 kg ha^{-1}) were used. All the phosphorus rates increased the seed yield significantly over control. The highest seed yield was observed with 90 kg P ha^{-1}, which was at par with 60 kg P ha^{-1}, and both were significantly superior to 30 kg P ha^{-1}. Likewise, 60 kg P ha^{-1} significantly improved the yield attributes except seed weight compared to 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^{-1}) 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^{-1} 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 kg ha^{-1}.

To investigate the effect of P and pressmud on nutrient uptake of blackgram and on the postharvest soil nutrient status, a field experiment was conducted by Poonkodi (2004) during 2000-01 in Tamil Nadu, India. 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^{-1}; 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. The treatment, 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. 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) conducted an experiment 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^{-1}. The increase in phosphorus levels decreased the days to flowering and increased the branches $plant^{-1}$, number of pods $plant^{-1}$, 1000-grain weight and grain yield. The highest yield of 1022 kg ha^{-1} was obtained at the phosphorus level of 100 kg ha^{-1} compared to a 774 kg ha^{-1} yield in the control. However, the most economical phosphorus level was 40 kg ha^{-1}, because it produced a grain yield statistically comparable to 100 kg P ha^{-1}.

Sulphur phosphorus interaction has been studied by Singh and Singh (2004) in field experiments on a soil deficient in S and medium in P with blackgram (*Phaseolus mungo*) as the test crop. 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 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. The antagonistic effect of S and P fertilizers on uptake and utilization of each other was more conspicuous when both were applied together.

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}.

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 $plant^{-1}$ was found to be significantly higher by 25 kg N ha^{-1}. Number of seeds pod^{-1} 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 P ha^{-1} resulted with maximum seed yield (1113 kg ha^{-1}).

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and 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.

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 P ha^{-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 the years. An increasing trend in harvest index was observed with increasing levels of P and application of PSB and FYM.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of greengram (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.

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 N-P-K kg ha^{-1} application. Again they revealed that seed inoculation + 50-50-0 N-P-K 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 $plant^{-1}$ 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.

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.

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 to 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}).

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 with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Trivedi *et al.* (1997) conducted a field experiment to study the effect of nitrogen, phosphorus and sulphur on yield and nutrient uptake of blackgram (*Vigna mungo*) at Gwalior, Madhya Pradesh, India during 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.

Trivedi (1996) carried out 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.

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.

Sharma *et al.* (1995) carried out a field trial in the monsoon season of 1991 at Gwalior, Madhya Pradesh, India 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.

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 t ha^{-1}) when compared with that of control (1.08 ton 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.

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. Seed protein content was the highest with NPK.

2.2 Effect of *Rhizobium*

A pot culture 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.

A study was carried out by Kumari and Nair (2003) 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.

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.

Manivannan *et al.* (2003) conducted a field experiment 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 (cv. ADT3). 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.

The effects of P (0, 20, 40 or 60 kg P_2O_5 ha^{-1}) 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 31.3% 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 $plant^{-1}$ and seed yield.

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.

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 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 $plant^{-1}$), and grain yield (758.3 and 732 kg ha^{-1}).

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 $plant^{-1}$, 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^{-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 *Vigna mungo*, *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%.

The interaction effects of *P. fluorescens* with *Rhizobium* in the management of blackgram (*Vigna mungo*) root rot caused by *M. phaseolina* was studied under in vitro and in vivo conditions (Shanmugam *et al.*, 2001). In a related experiment, a fluorescent pseudomonad strain (Pf 1) which effectively inhibited the mycelial growth of *M. phaseolina* was studied for its compatibility with *Rhizobium*. Dual cultures and calorimetric studies established the compatibility of *P. fluorescens* and *Rhizobium* in controlling the root rot pathogen. However, glass house and field studies showed that seed treatment and soil application of Pf 1 was the most effective treatment to reduce root rot incidence to increase yield.

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.

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.

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}).

Provorov *et al.* (1998) stated that seed inoculation of mungbean increased the seed yield by 38.2% over uninoculated control.

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 was 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.

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiate* cv. Pusa Baishakhi was seed 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.

2.3 Effect of crop residues

Two field experiments were conducted by Phongpan and Mosier (2002) in a rice-fallow-rice cropping sequence during consecutive dry and wet seasons of 1997 on a clay soil to determine the fate and efficiency of broadcast urea in combination with three residue management practices (no residue, burned residue and untreated rice crop residue). During a 70 d fallow period prior to flooding the soil for wet season rice, emissions of N_2O measured at weekly intervals from no residue, burned residue and residue treatments ranged from 25 to 128, 19 to 59 and 24 to 75 mg N m^{-2} ha^{-1}, respectively. Grain yield and N uptake were significantly increased by N application in the dry season but not significantly affected by residue treatments in either season.

Nelson (2002) also reasoned that subtracting the predicted amount of residue required to stay at or below T (calculated from the first set of analyses) from the amount of residue calculated from actual yield data would result in the amount of residue available for harvest. Some future hurdles to predict residue harvest potential from cropping systems include extending these results to all regions and soils, other crops, and extending the prediction to include more than just soil loss as a resource concern.

To fully consider the soil quality impacts of residue removal, this method should also consider effects on soil organic matter, nutrients, biota, and future crop yield.

There is also sufficient quantity to support commercial scale production (DiPardo, 2000). However, removing crop residues for bio-energy use can have a negative effect on natural resource quality. Crop residues performed many positive functions for agricultural ecosystems including:

- Protecting soil from erosion, thereby maintaining water and air quality by reducing runoff and sediment (via reduced water-induced soil erosion) and air-borne particulates (through decreased wind erosion).
- Increasing or maintaining soil organic matter and nutrients, leading to improved soil and water quality.
- Maintaining beneficial soil organisms and providing wildlife habitat.
- Improving plant-available water and drought resistance, potentially increasing yields.

Gale and Cambardella (2000) reported that as a physical buffer, crop residues protect soil from the direct impacts of rain, wind and sunlight leading to improved soil structure, reduced soil temperature and evaporation, increased infiltration, and reduced runoff and erosion. While some studies suggested that plant roots contributed more carbon to soil than surface residues, crop residue contributes to soil organic matter and nutrient increases, water retention, and microbial and macroinvertebrate activity. These effects typically lead to improved plant growth and increased soil productivity and crop yield.

Glassner *et al.* (1999) reported that crop residues perform many positive functions for agricultural soils that reduce erosion and promote sustainable production. In many regions, cover crops were a viable alternative that offer soil protection and added organic matter.

Green biomass, as with a cover crop, was considered to be 2.5 times more effective than crop residue in reducing wind erosion (in predictive models), especially if the residue was laying flat (McMaster and Wilhelm, 1997).

Paine *et al.* (1996) recommended growing these crops on marginal lands, such as highly erodible land, poorly drained soils or areas used for wastewater reclamation, which would avoid competition with food crops and increased the amount of arable land.

Chapter 3

Methods and Materials

Chapter III

MATERIALS AND METHODS

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of *Rhizobium*, crop residues and inorganic fertilizers on yield contributing characters of blackgram. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings-

3.1 Experimental site

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

3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, post monsoon or the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the 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 I.

3.3 Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment.

The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. The initial physical and chemical characteristics of soil are presented in Table 1.

Table 1. Initial characteristics of the soil in experimental field

1. pH		6.0
2. Particle-size analysis of soil	Sand	29.04
	Silt	41.80
	Clay	29.16
3. Textural Class		Silty Clay Loam
4. Organic matter (%)		0.840
5. Total N (%)		0.0670
6. Phosphorous (ppm)		8.333
7. Potassium (ppm)		25.00

3.4 Planting material

The variety Barimash-1 was used as the test crop. The seeds were collected from the Pulse Research Centre of the Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. Barimash-1 is a recommended variety of blackgram, which was developed by the National Seed Board. It grows both in kharif and rabi season. Life cycle of this variety ranges from 60 to 65 days. Maximum seed yield is 1.1-1.4 t ha^{-1}.

3.5 Land preparation

The land was irrigated before ploughing. After having zoe condition 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 19 March 2007 and 30 March 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 are as follows:

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

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 8 plots where 8 treatments were allotted at random. There were 24 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m respectively.

3.8 Sowing of seeds in the field

The seeds of blackgram were sown on 04 April, 2007. Seeds were treated with Bavistin (2.5 g kg^{-1} seed) before sowing the seeds to control the seed borne disease. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm. Row to row distance was 30 cm.

3.9 Intercultural operations

3.9.1 Thinning

Seeds were germinated four days after sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second at 15 DAS to maintain proper plant population in each plot.

3.9.2 Irrigation and weeding

Irrigation was done as per treatments. The crop field was weeded twice; first weeding was done at 15 DAS and the second at 30 DAS.

3.9.3 Protection against insect and pest

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

3.10 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to black in colour. The matured pods were collected by hand picking from a pre demarcated area of three linear (6.0 m^2) at the center of each plot.

3.11 Data collection

The following data were recorded

i. Plant height (cm)
ii. Number of leaves $plant^{-1}$
iii. Number of branches $plant^{-1}$
iv. Number of pods $plant^{-1}$
v. Pod length (cm)
vi. Number of seeds pod^{-1}
vii. 1000- seed weight (g)
viii. Seed yield (t ha^{-1})

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

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

3.12 Procedure of data collection

3.12.1 Plant height (cm)

The heights were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot at 50 DAS.

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

The leaves (trifoliate) were counted from selected plants. The average number of leaves per plant was determined. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot at 50 DAS.

3.12.3 Number of brances $plant^{-1}$

Number of branches of selected plants from each plot was counted and the mean number was expressed on per plant basis. Data were recorded as the time of final harvest.

3.12.4 Number of pods per plant

Number of total pods of selected plants from each plot was counted and the mean number was expressed on per plant basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.12.5 Pod length

Pod length of selected plants from each plot was counted and the mean length was expressed on per pod basis. Data were recorded as the average of 10 pods selected at random from the inner rows plant of each plot.

3.12.6 Number of seeds pods^{-1}

The number of seeds in each pod was also recorded from randomly selected pods at the harvest. Data were recorded as the average of 10 pods selected at random from the inner rows of each plot.

3.12.7 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). Data were recorded as the average of 10 plants selected at random from the inner rows.

3.12.8 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}.

3.12.9 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}.

3.12.10 Number of nodule plant^{-1}

The number of nodule in each plant was recorded from randomly selected plant at the time of 50% flowering. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.13 Chemical analysis of plant and grain

3.13.1 Preparation of plant and grain samples

Ten selected plant per plot and grain were collected immediately after harvest. The selected plant was threshed. Both plant and grain were cleaned and dried in an oven at

65^0C for 48 hours. The dried samples were put into small paper bags and kept into a desiccators till being used.

3.13.2 Digestion of samples with sulphuric acid

For N determination, an amount of 0.1 g plant sample was taken into a 100 ml Kjeldahl flask. An amount of 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$; Se = 100:10:1), 2 ml 30% H_2O_2 and 3 ml conc. H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes; followed by heating at 200^0C. Heating was continued until the digest was clear, and colorless. After cooling, the contents were taken into a 100 ml volumetric flask and the volume was made with distilled water. A blank digestion was prepared in a similar way. This digest was used for determining the nitrogen contents on samples.

3.13.3 Digestion of with nitric-perchloric acid mixture

An amount of 0.5 g of plant sample was taken into a dry clean 100 ml Kjeldahl flask, 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature raising slowly to 200^0C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6 ml of 6N HCl were added to it. The content of the flask was boiled until they become clear and colourless. This digest was used for determining P, K and S.

3.13.4 Determination of element in the digest

Nitrogen, phosphorus, potassium and sulphur content in the digest were determined by similar method as described in soil analysis (3.14).

3.14. Soil Sample analysis

3.14.1 Total nitrogen

Total nitrogen of soil was determined by Micro Kjeldahl method where soil was digested with 30% H_2O_2, conc.H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder in the ratio of 100:10:1). Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Bremner and Mulvaney, 1982).

3.14.2 Available phosphorus

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.*, 1982). The phosphorus in the extract was then determined by developing blue colour using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue colour was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of standard curve.

3.14.3 Exchangeable potassium

Exchangeable potassium was determined by 1N NH_4OAC (pH 7.0) extract of the soil by using flame photometer (Black, 1965).

3.14.4 Available sulphur

Available sulphur in soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution (Page *et al.*, 1982) The S content in the extract was determined turbidimetrically and the intensity of turbid was measured by spectrophotometer at 420 nm wave length.

3.15 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of blackgram. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. 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

Chapter IV

RESULTS AND DISCUSSION

To determine the effect of *Rhizobium*, crop residues and inorganic fertilizers on yield and yield contributing characters of blackgram, the present study was conducted. Data on different yield contributing characters, yield and nutrients status of post harvest soil were recorded to find out the effect of treatments. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix II-VIII. The findings have been presented and discussed, and possible interpretations have given under the following headings:

4.1 Yield contributing characters and yield

4.1.1 Plant height

Plant height of blackgram varied significantly due to the different fertilizers (Appendix II). The tallest plant (55.25 cm) was recorded in T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically similar (53.63 cm and 52.42 cm) to T_8 (Crop residues + N_{40} + PK) and T_5 (*Rhizobium* + Crop residues+ N_{20} + PK), respectively (Table 2). On the other hand the shortest plant (45.67 cm) was recorded in T_1 (control), which was statistically similar (47.63 cm and 47.95 cm) to T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) and T_3 (N_{40} + PK), respectively.

Among different combinations, *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram as found in the highest plant height. This trend was similar or followed by the combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer. *Rhizibium* with other NPK fertilizer was also effective for the plant growth under the trial.

Table 2. Effect of *Rhizobium*, crop residues and inorganic fertilizers on yield contributing characters of blackgram

Treatment	Plant height (cm)	Number of leaves per plant	Number of branches per plant	Number of pods per plant
T_1	45.97 e	6.94 d	0.98 c	13.15 d
T_2	47.63 de	7.93 c	1.15 bc	13.27 d
T_3	47.95 cde	8.52 bc	1.21 bc	15.67 bc
T_4	50.25 bcd	8.60 bc	1.13 bc	14.57 cd
T_5	52.42 ab	9.48 ab	1.42 ab	17.17 ab
T_6	51.28 bc	8.90 ab	1.37 ab	15.78 bc
T_7	55.25 a	9.73 a	1.55 a	18.85 a
T_8	53.63 ab	9.43 ab	1.37 ab	17.25 ab
$LSD_{(0.05)}$	3.342	0.891	0.287	2.255
CV(%)	4.50	6.98	15.36	9.76

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

These findings were supported by Salimullah *et al.* (1987), Khurana and Poonam, (1993), Sattar and Ahmed (1995), Shukla and Dixit (1996), Bhattacharyya and Pal (2001), Dost *et al.* (2004), Duary *et al.* (2004) and Oad and Buriro (2005).

4.1.2 Number of leaves plant^{-1}

Due to the different fertilizers number of leaves plant^{-1} of blackgram showed statistically significant differences (Appendix II). The highest number of leaves plant^{-1} (9.73) was observed in T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically identical (9.43, 9.48 and 8.90) to T_8, T_5 and T_6 while the lowest number of leaves plant^{-1} (6.94) was obtained from T_1 (control), which was closely followed (7.93 and 8.52) by T_2 and T_3, respectively (Table 2).

The treatment *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram with maximum number of leaves plant^{-1}. Combinations of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizobium* with other NPK fertilizer were also effective. Again control gave the minimum number of leaves plant^{-1}. These findings were supported by Malik *et al.* (2003), Bhattacharyya and Pal (2001), Rajender *et al.* (2003), Nadeem *et al.* (2004), Dost *et al.* (2004), Vikrant (2005), Oad and Buriro (2005), Raman and Venkataramana (2006) and Nigamananda and Elamathi (2007).

4.1.3 Number of branches plant^{-1}

Number of branches plant^{-1} of blackgram differed significantly due to the different treatments under the trial (Appendix II). Treatment T_7 (*Rhizobium* + Crop residues + N_{20} + PK) gave the highest number of branches plant^{-1} (1.55) which was statistically similar to T_8, T_5 and T_6, respectively (Table 2). On the other hand, T_1 (control) gave the lowest number of branches plant^{-1} (0.98) which was closely followed (1.13, 1.15 and 1.21) by T_4, T_2 and T_3, respectively.

For number of branches plant^{-1} of blackgram, among the different fertilizers *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective. Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizobium* with other doses of NPK fertilizer had this trend. On the other hand, control condition i.e. no *Rhizobium*, no crop residues and no fertilizer gave the minimum number of branches per plant. This findings was supported by Khurana and Poonam (1993), Rajender *et al.* (2003), Nadeem *et al.* (2004), Oad and Buriro (2005), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2006) and Nigamananda and Elamathi (2007).

4.1.4 Number of pods plant^{-1}

Number of pods plant^{-1} of blackgram differed significantly due to different fertilizers (Appendix II). The highest number of pods plant^{-1} (18.85) was recorded in T_7 (*Rhizobium* + Crop residues+ N_{20} + PK), which was statistically identical (17.25, and 17.17) to T_8 and T_5, respectively, while the lowest number of pods plant^{-1} (13.15) was recorded in T_1 (control), which was statistically similar (13.27) with T_2 and T_4.

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram that leads to optimum reproductive growth which ensured maximum number of pods per plant. Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizibium* with other NPK fertilizer showed this trend. Again control treatment gave the minimum number of pods per plant. The findings of this study were supported by Sardana and Verma (1987), Salimullah *et al.* (1987), Patel *et al.* (1992), Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2003), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993), Oad and Buriro (2005).

4.1.5 Pod length

For the different treatments used in this experiment pod length of blackgram showed statistically significant differences (Appendix II). The maximum pod length (7.82 cm) was recorded in T_7 (*Rhizobium* + Crop residues+ N_{20} + PK), which was statistically similar (7.57 cm and 7.55 cm) to T_8 (Crop residues + N_{40} + PK) and T_5 (*Rhizobium* + Crop residues+ N_{20} + PK), respectively. On the other hand the minimum pod length (5.51 cm) was recorded in T_1 (control), which was statistically identical (6.00 cm) with T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) (Figure 1).

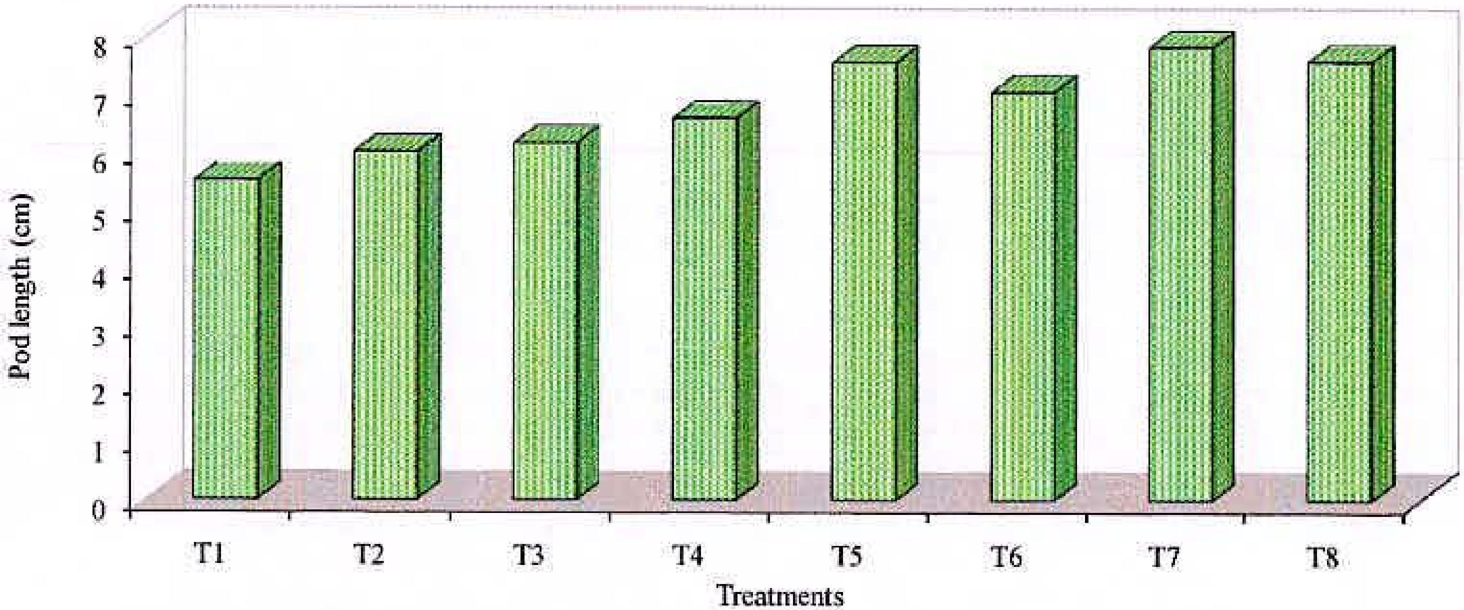

Figure 1. Effect of rhizobium, crop residues and inorganic fertilizers on pod length of blackgram

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control);
T_2: No *Rhizobium* + No organic + No Nitrogen + PK
T_3: N40 + PK
T_4: *Rhizobium* + PK
T_5: *Rhizobium* + N20 + PK
T_6: Crop Residues + N20 + PK
T_7: *Rhizobium* + Crop Residues + N20 + PK
T_8: Crop Residues + N40 + PK

Application of *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram that leads to optimum reproductive growth which ensured longest pod. Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizibium* with other NPK fertilizer also revealed this trend. Again control gave the shortest length of pod under the trial. The findings of this study were also supported by Patel *et al.* (1992), Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2003), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Sattar and Ahmed (1995) and Khurana and Poonam (1993).

4.1.6 Number of seeds pod^{-1}

Statistically significant variation was recorded for number of seeds per pod of blackgram due to the application of different treatments (Appendix III). The highest number of seeds per pod (11.45) was found from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was closely followed (10.82, 10.57 and 10.55) by T_8 (Crop residues + N_{20} + PK), T_6 (Crop residues+ N_{20} + PK) and T_5 (*Rhizobium* + Crop residues+ N_{20} + PK), respectively. On the other hand the lowest number of seeds per pod (8.35) was recorded from T_1 (control), which was closely followed (9.17, 9.20 and 9.38) by T_3 (N_{40} + PK), T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) andT_4 (*Rhizobium* + PK), respectively (Table 3).

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the reproductive growth of blackgram that leads to optimum development of seeds with the highest number seeds per pod.

Table 3. Effect of rhizobium, crop residues and inorganic fertilizers on yield contributing characters and yield of blackgram

Treatment	Number of seeds per pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)
T_1	8.35 d	42.50 c	0.72 c	0.94 e
T_2	9.20 c	44.25 bc	0.84 c	1.01 de
T_3	9.17 c	44.25 bc	0.86 c	1.09 d
T_4	9.38 c	44.25 bc	0.84 c	1.21 c
T_5	10.55 b	45.75 ab	1.22 ab	1.76 ab
T_6	10.57 b	44.50 bc	1.01 bc	1.25 c
T_7	11.45 a	46.75 a	1.41 a	1.88 a
T_8	10.82 b	45.75 ab	1.20 ab	1.66 b
$LSD_{(0.05)}$	0.573	1.945	0.287	0.114
CV(%)	3.93	2.96	19.27	5.58

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

Again control gave the minimum number of seeds per pod. Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2003), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001) and Oad and Buriro (2005) also found the similar results.

4.1.7 Weight of 1000-seeds

Weight of 1000 seeds of blackgram differed significantly due to the application of different treatments (Appendix III). The highest weight of 1000 seeds (46.75 g) was found from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically similar (45.75 g) with T_8 (Crop residues + N_{20} + PK) and the lowest weight of 1000 seeds (42.50 g) was recorded from T_1 (control), which was statistically identical (44.25 g) with T_2 (No *Rhizobium* + No organic + No Nitrogen + PK), T_3 (N_{40} + PK) and T_4 (No *Rhizobium* + PK), respectively (Table 3).

Similar results also reported by Sardana and Verma (1987), Salimullah *et al.* (1987), Patel *et al.* (1992), Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2003), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993), Oad and Buriro (2005).

4.1.8 Seed yield

Statistically significant variation was recorded for seed yield of blackgram due to the different treatments (Appendix III). The highest seed yield (1.41 t ha^{-1}) was recorded in T_7 (*Rhizobium* + Crop residues+ N_{20} + PK), which was statistically identical (1.22 t ha^{-1} and 1.20) to T_5 (*Rhizobium* + Crop residues+ N_{20} + PK) and T_8 (Crop residues + N_{20} + PK) and the lowest seed yield (0.72 t/ha) was recorded in T_1 (control), which was statistically identical (0.84 t/ha and 0.86 t/ha) to T_2 (No *Rhizobium* + No organic + No Nitrogen + PK), T_3 (N_{40} + PK) and T_4 (*Rhizobium* + PK), respectively (Table 3).

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative and reproductive growth of blackgram and the ultimate results was the highest seed yield. Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizibium* with other NPK fertilizer showed this trend. The lowest seed yield was observed in the control due to minimum vegetative and reproductive growth. The findings of this study were also supported by Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2006), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Oad and Buriro (2005).

4.1.9 Stover yield

Stover yield of blackgram differed significantly due to the application of different treatments (Appendix III). The highest stover yield (1.88 t/ha) was found from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically similar (1.76 t/ha) with T_5 (*Rhizobium* + Crop residues+ N_{20} + PK) and the lowest stover yield (0.94 t/ha) was recorded from T_1 (control), which was statistically identical (1.01 t/ha) with T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) (Table 3).

The treatment *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram and the ultimate results was the highest stover yield. Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizibium* with other NPK fertilizer gave the comparable results. Again control gave the lowest stover yield due to minimum vegetative growth. The findings of this study were also supported by Vikrant (2005), Raman and Venkataramana (2006), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Oad and Buriro (2005).

4.1.10 Number of nodules plant^{-1}

Statistically significant variation was recorded for number of nodules per plant for different treatments (Appendix III). The highest number of nodules per plant (24.24) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically similar (21.98) with T_5 (*Rhizobium* + Crop residues+ N_{20} + PK) and the lowest number of nodule per plant (11.40) was recorded from T_1 (control), which was statistically similar (13.38) with T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) (Figure 2). The results indicate that rhizobium inoculation significantly increased nodulation of blackgram.

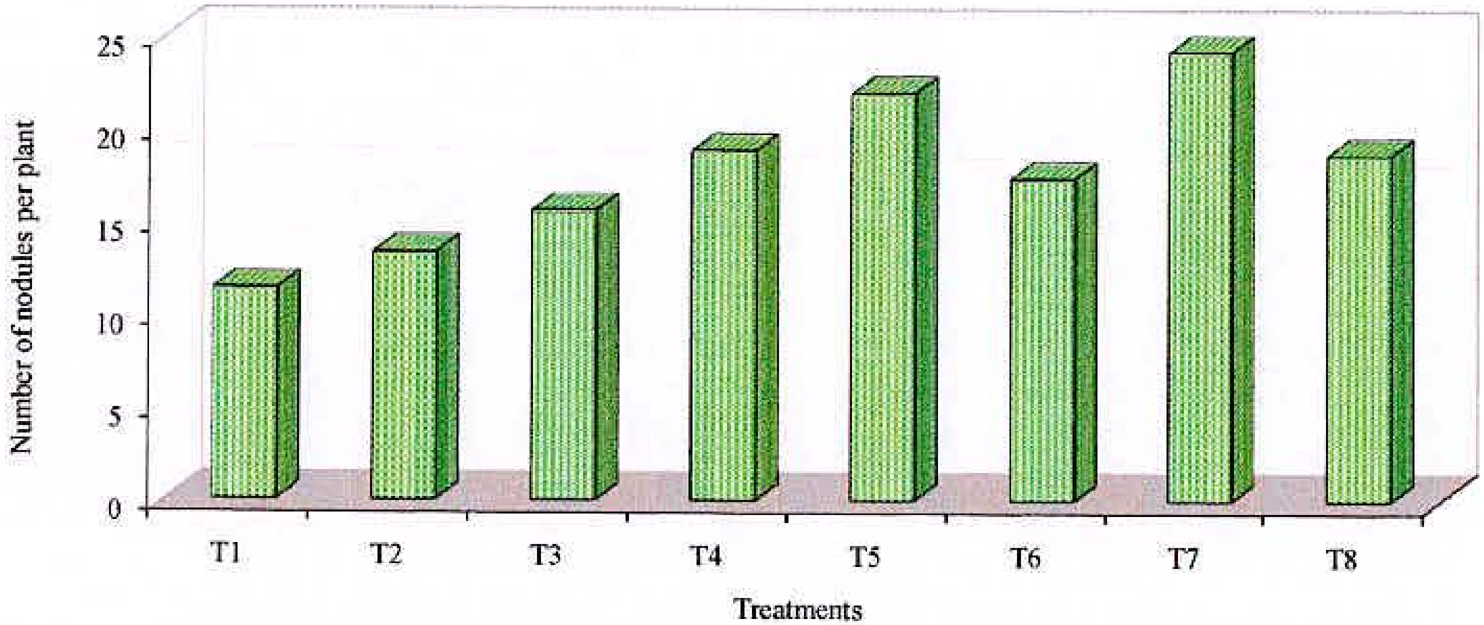

Figure 2. Effect of rhizobium, crop residues and inorganic fertilizers on number of nodules per plant of blackgram

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control); T_2: No *Rhizobium* + No organic + No Nitrogen + PK
T_3: N40 + PK
T_4: *Rhizobium* + PK
T_5: *Rhizobium* + N20 + PK
T_6: Crop Residues + N20 + PK
T_7: *Rhizobium* + Crop Residues + N20 + PK
T_8: Crop Residues + N40 + PK

4.2 NPKS concentration in plant

4.2.1 N concentration in plant

Concentration of N in plant of blackgram differed significantly due to the application of different treatments (Appendix IV). The maximum concentration of N (3.12%) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was closely followed by T_5 (*Rhizobium* + Crop residues+ N_{20} + PK) (2.55%) and the minimum concentration of N in plant (2.09%) was recorded from T_4 (*Rhizobium* + PK), which was statistically identical with T_1 (2.16%) (Table 4).

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram and the ultimate results was the highest concentration of N in plant. Nitrogen is the pre-condition of formation of amino acids. The finding of this study also supported by Raman and Venkataramana (2006) and Oad and Buriro (2005).

4.2.2 P concentration in plant

Statistically significant variation was recorded for the concentration of P in plant of blackgram due to the application of different treatments (Appendix IV). The maximum concentration of P (0.615%) was found from T_7 (*Rhizobium* + Crop residues + N_{20} + PK) which was statistically identical with T_3, T_4, T_5 and T_6 (Table 4) the minimum concentration of P in plant was recorded from T_1 (control).

Table 4. Effect of *Rhizobium*, crop residues and inorganic fertilizers on N, P, K, S in plant of blackgram

Treatment	Concentration in plant (%)			
	N	P	K	S
T_1	2.16 cd	0.326 c	0.370 d	0.39 d
T_2	2.55 bc	0.457 b	0.535 c	0.46 d
T_3	2.71 b	0.530 ab	0.582 bc	0.67 bc
T_4	2.09 d	0.568 ab	0.525 c	0.63 bc
T_5	2.43 bcd	0.517 ab	0.546 c	0.60 c
T_6	2.33 bcd	0.521 ab	0.543 c	0.63 bc
T_7	3.12 a	0.615 a	0.706 a	0.72 ab
T_8	2.55 bc	0.488 b	0.641 ab	0.79 a
$LSD_{(0.05)}$	0.354	0.104	0.081	0.104
CV(%)	9.62	14.33	10.31	11.52

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

The treatment *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram and the ultimate results was the highest concentration of P in plant. Oad and Buriro (2005) and Raman and Venkataramana (2006) also reported the similar results.

4.2.3 K concentration in plant

Concentration of K in plant of blackgram differed significantly due to the application of different treatments under the trial (Appendix IV). The maximum concentration of K in plant (0.706%) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically identical (0.641%) with T_8 (Crop residues+ N_{40} + PK) and the minimum concentration of K in plant (0.370%) was recorded from T_1 (control) which was closely followed by treatment T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) (0.535%) (Table 4). The finding of this study was also supported by Salimullah *et al.* (1987), Patel *et al.* (1992), and Oad and Buriro (2005).

4.2.4 S concentration in plant

Statistically significant variation was recorded for the concentration of S in plant of blackgram due to the application of different treatments (Appendix IV). The maximum concentration of S (0.79%) was recorded from T_8 (Crop residues+ N_{40} + PK) which was statistically identical (0.72%) with T_7 (*Rhizobium* + N_{20} + PK) and the minimum concentration of S in plant (0.39%) was recorded from T_1 (control) which was similar (0.46%) with T_2 (No *Rhizobium* + No organic + No Nitrogen + PK) (Table 4).

The findings of this study were also supported Oad and Buriro (2005) and Raman and Venkataramana (2006).

4.3 NPKS concentration in seed

4.3.1 N concentration in seed

Concentration of N in seed of blackgram differed significantly due to the application of different fertilizers (Appendix V). The maximum concentration of N in seed (5.36%) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was identical with T_4, T_6 and T_8 (Table 5). On the other hand minimum concentration of N in seed (4.34%) was recorded from T_1 (control).

Treatment *Rhizobium* +crop residues + minimum doses of nitrogen + phosphorous and potassium fertilizer was more effective for the vegetative growth of blackgram and the ultimate results was the highest concentration of N in seed. The findings of this study were also supported by Patel *et al.* (1992) and Raman and Venkataramana (2006).

4.3.2 P concentration in seed

Concentration of P in seed of blackgram differed significantly due to the application of different treatments (Appendix V). Treatment T_8 (Crop residues + N_{40} + PK) gave the maximum concentration of P in seed (0.544%) (Table 5).

Table 5. Effect of *Rhizobium*, crop residues and inorganic fertilizers on N, P, K and S in seed of blackgram

Treatment	Concentration in seed (%)			
	N	P	K	S
T_1	4.34 b	0.290 c	0.324 c	0.21 b
T_2	4.42 b	0.295 c	0.466 ab	0.29 a
T_3	4.35 b	0.464 ab	0.440 abc	0.28 a
T_4	4.76 ab	0.443 b	0.486 ab	0.26 a
T_5	4.47 b	0.411 b	0.495 ab	0.30 a
T_6	4.87 ab	0.419 b	0.373 bc	0.28 a
T_7	5.36 a	0.465 ab	0.549 a	0.29 a
T_8	5.02 ab	0.544 a	0.543 a	0.27 a
$LSD_{(0.05)}$	0.699	0.081	0.114	0.047
CV(%)	8.13	13.09	16.45	12.27

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

The treatment 7 was more effective for the vegetative growth of blackgram and the ultimate results was the highest concentration of P in seed. Raman and Venkataramana (2006) also found the similar results in their studies.

4.3.3 K concentration in seed

Statistically significant variation was recorded in terms of concentration of K in seed of blackgram due to the application of different treatments (Appendix V). The maximum concentration of K (0.0.549%) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) which was statistically identical with T_8 (Crop residues+ N_{40} + PK) (0.543%) and the minimum concentration of K in seed (0.324%) was recorded from T_1 (control) (Table 5).

Combination of *Rhizobium*, with recommended doses of nitrogen, phosphorous and potassium fertilizer and *Rhizibium* with other NPK fertilizer showed this trend in concentration of K in seed. The findings of this study were also supported by Salimullah *et al.* (1987), Patel *et al.* (1992), and Oad and Buriro (2005).

4.3.4 S concentration in seed

Due to the application of different treatments concentration of S in seed of blackgram showed statistically significant differences (Appendix V). The maximum concentration of S in seed (0.29%) was recorded from T_7 (*Rhizobium* + crop residues + N_{20} + PK) which was statistically identical with all others treatments except control (Table 5).

Rhizobium, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer treatment was more effective for the vegetative growth of blackgram and the ultimate results was the highest concentration of S in seed due to highest uptake. Raman and Venkataramana (2006) also reported the similar results.

4.4 NPKS uptake by plant

4.4.1 N uptake by plant

N uptake by plant of blackgram differed significantly due to the application of different treatments (Appendix VI). The maximum N uptake by plant (40.50 kg ha^{-1}) was found from T_7 (*Rhizobium* + Crop residues+ N_{20} + PK) and the minimum N uptake by plant (20.35 kg ha^{-1}) was recorded from T_1 (Table 6).

Rhizobium, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer treatment had the most favourable effect for the availability of nutrients and the ultimate results was the highest N uptake by plant. The finding of this study was also supported by Raman and Venkataramana (2006).

Table 6. Effect of *Rhizobium*, crop residues and inorganic fertilizers on N, P, K, S uptake by plant of blackgram

Treatment	Uptake by plant (kg/ha)			
	N	P	K	S
T_1	20.35 e	3.14 cd	8.82 d	4.68 e
T_2	21.72 de	2.90 de	8.06 d	4.88 e
T_3	23.49 d	3.43 bc	8.06 d	5.80 d
T_4	26.19 c	3.47 bc	11.82 c	5.76 d
T_5	38.07 b	3.73 b	12.64 c	6.34 c
T_6	26.98 c	3.61 b	13.85 c	7.32 b
T_7	40.50 a	4.15 a	16.95 b	7.50 b
T_8	35.79 b	4.43 a	19.88 a	9.32 a
$LSD_{(0.05)}$	2.391	0.330	2.562	0.359
CV(%)	5.58	5.97	3.82	3.72

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

4.4.2 P uptake by plant

Significant variation was recorded in terms of N uptake by plant of blackgram due to the application of different treatments (Appendix VI). The maximum P uptake by plant (4.43 kg ha^{-1}) was recorded from T_8 (Crop residues+ N_{40} + PK) which was statistically identical (4.15 kg ha^{-1}) with T_7 (*Rhizobium* + Crop residues + N_{40} + PK), while the minimum P uptake by plant (2.90 kg ha^{-1}) from T_2 (Table 6).

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the availability of nutrients and the ultimate results was the highest P uptake by plant. The finding of this study also supported by Raman and Venkataramana (2006)..

4.4.3 K uptake by plant

K uptake by plant of blackgram varied significantly due to the application of different treatments (Appendix VI). The maximum K uptake by plant (19.88 kg ha^{-1}) was obtained from T_8 (Crop residues+ N_{20} + PK) which was followed by T_7 (*Rhizobium* +Crop residues + N_{40} + PK). The minimum K uptake by plant (8.06 kg ha^{-1}) was recorded from T_2 and T_3which was identical with T_1 (control) (Table 6).

4.4.4 S uptake by plant

Due to the application of different treatments S uptake by plant of blackgram varied significantly (Appendix VI). The maximum S uptake by plant (9.32 kg ha^{-1}) was recorded from T_8 (Crop residues + N_{20} + PK) and the minimum S uptake by plant (4.68 kg ha^{-1}) was recorded from T_1 (control) (Table 6). The finding of this study was also supported by Raman and Venkataramana (2006).

4.5 NPKS uptake by seed

4.5.1 N uptake by seed

Statistically significant variation was recorded in terms of N uptake by seed of blackgram as influenced by different treatments (Appendix VII). The maximum N uptake by seed (89.71 kg ha^{-1}) was recorded from T_7 (*Rhizobium* + Crop residues+ N_{40} + PK) which was identical withT_5 (77.35 kg ha^{-1} and T_8. The minimum N uptake by seed (45.49 kg ha^{-1}) was recorded from T_1 (Table 7).

Treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the availability of nutrients and the ultimate results was the highest N uptake by seed. Combination of *Rhizobium* with minimum doses of nitrogen and phosphorous and potassium fertilizer and crop residues plus full dose of N plus PK gave identical result . The findings of this study was also supported Raman and Venkataramana (2006).

Table 7. Effect of *Rhizobium*, crop residues and inorganic fertilizers on N, P, K, S uptake by grain of blackgram

Treatment	Uptake by grain (kg/ha)			
	N	P	K	S
T_1	45.49 c	10.10 d	23.91 de	2.53 ef
T_2	53.42 c	10.12 d	23.69 de	2.65 de
T_3	54.52 c	10.09 d	24.35 de	2.71 de
T_4	53.57 c	10.31 cd	25.70 cd	2.82 d
T_5	77.35 ab	10.83 c	27.75 bc	3.11 c
T_6	63.88 bc	10.33 cd	25.56 cd	3.05 c
T_7	89.71 a	11.42 b	29.64 ab	3.39 b
T_8	76.24 ab	12.97 a	30.24 a	3.73 a
$LSD_{(0.05)}$	18.22	0.559	2.201	0.178
CV(%)	19.27	3.28	5.28	4.03

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

4.5.2 P uptake by seed

Because of the application of different treatments P uptake by seed of blackgram showed statistically significant differences (Appendix VII). The maximum P uptake by seed (12.97 kg ha^{-1}) was found from T_8, which was significant over all other treatments, while the minimum P uptake by seed (10.09 kg ha^{-1}) was recorded from T_3 (Table 7).

Among the different treatments *Rhizobium*, crop residues, minimum doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the availability of nutrients and the ultimate results was the highest P uptake by seed with due to maximum growth. The finding of this study was also supported by Raman and Venkataramana (2006).

4.5.3 K uptake by seed

K uptake by seed of blackgram differed significantly due to the application of different treatments (Appendix VII). The maximum K uptake by seed (30.24 kg ha^{-1}) was recorded from T_8 (Crop residues + N_{40} + PK) which was followed (29.64 kg ha^{-1}) by T_7 (*Rhizobium* + Crop residues + N_{20} + PK) and the minimum K uptake by seed (8.06 kg ha^{-1}) was recorded from T_2 (Table 7).

Crop residues, full doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the availability of nutrients. Raman and Venkataramana (2006) also reported the similar results.

4.5.4 S uptake by seed

Statistically significant variation was in terms of S uptake by seed of blackgram was observed due to the application of different treatments (Appendix VII). The maximum S uptake by seed (3.73 kg ha^{-1}) was recorded from T_8 (Crop residues + N_{40} + PK) and the minimum S uptake by seed (2.53 kg ha^{-1}) was recorded from T_1 (control) (Table 7).

Among the different treatments crop residues, full doses of nitrogen with recommended doses of phosphorous and potassium fertilizer was more effective for the availability of S. The finding of this study were also supported by Raman and Venkataramana (2006).

4.6 pH, organic matter and NPKS Status of post harvest soil

4.6.1 PH

Statistically significant variation was recorded in terms of pH in post harvest soil of blackgram due to the application of different treatments (Appendix VIII). The highest pH (5.18) was recorded from T_8 (Crop residues+ N_{40} + PK) which was statistically similar (5.07) with T_7 (*Rhizobium* + Crop residues + N_{40} + PK). On the other hand the lowest pH (4.26) was recorded from T_1 (control) (Figure 3).

4.6.2 Organic matter

Organic matter in post harvest soil of blackgram varied significantly due to the application of different treatments (Appendix VIII). The highest organic matter (1.17%) was obtained from T_7 (*Rhizobium* + Crop residues + N_{20} + PK) which was closely followed (1.08) by T_5 (*Rhizobium* N_{20} + PK). On the other hand the lowest organic matter (0.89%) was recorded from T_1 (control) (Figure 4).

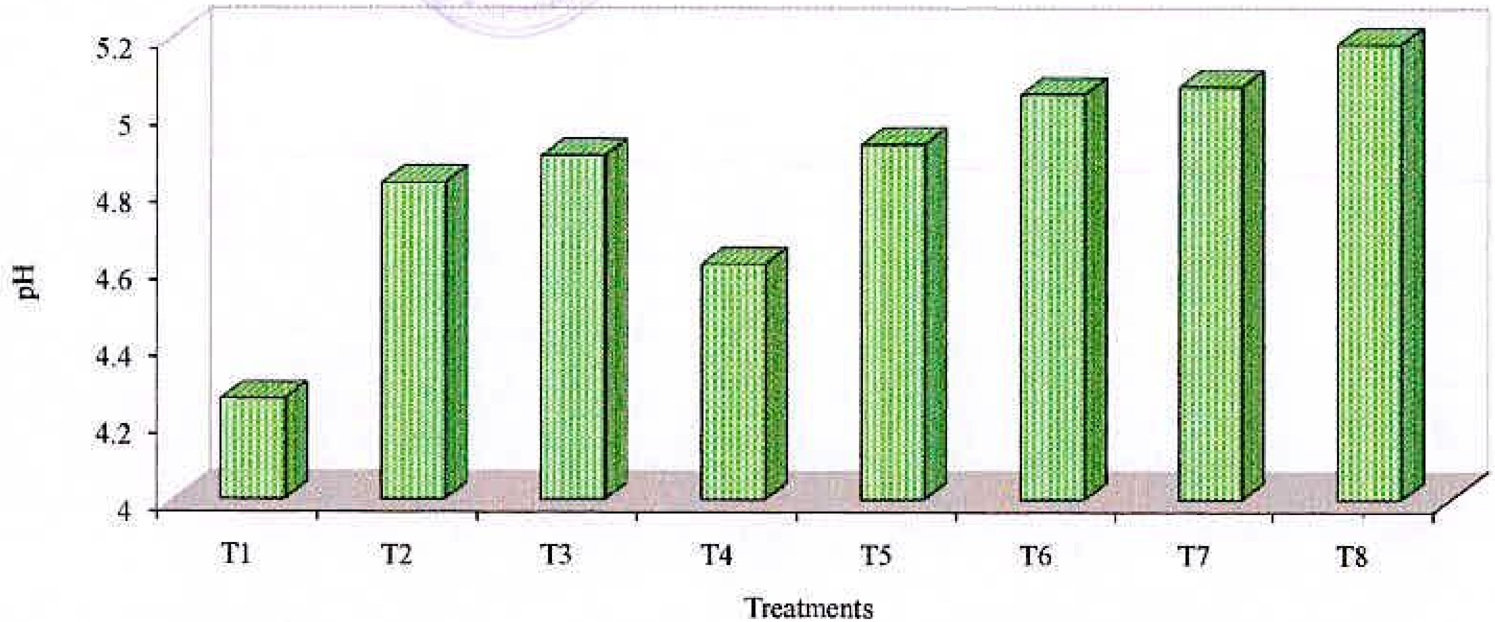

Figure 3. Effect of rhizobium, crop residues and inorganic fertilizers on pH in post harvest soil of blackgram

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control); T_2: No *Rhizobium* + No organic + No Nitrogen + PK
T_3: N40 + PK
T_4: *Rhizobium* + PK
T_5: *Rhizobium* + N20 + PK
T_6: Crop Residues + N20 + PK
T_7: *Rhizobium* + Crop Residues + N20 + PK
T_8: Crop Residues + N40 + PK

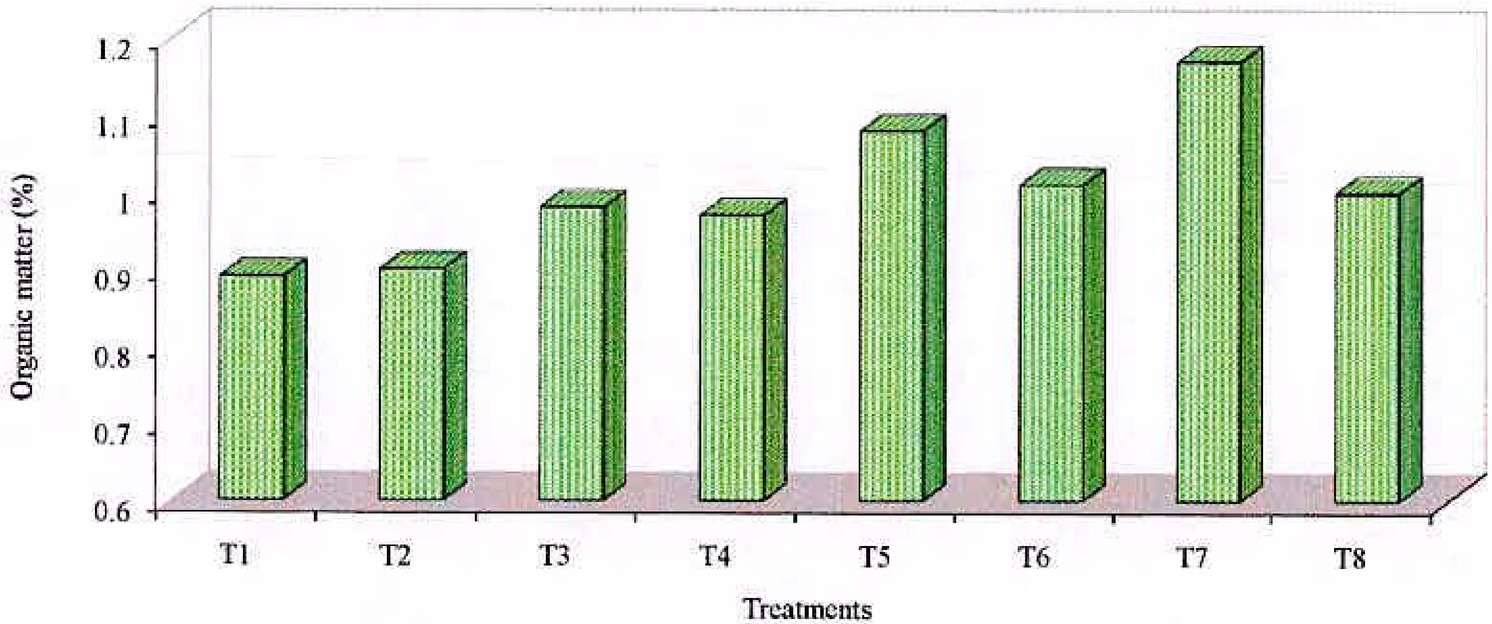

Figure 4. Effect of rhizobium, crop residues and inorganic fertilizers on organic matter in post harvest soil of blackgram

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control); T_2: No *Rhizobium* + No organic + No Nitrogen + PK
T_3: N40 + PK
T_4: *Rhizobium* + PK
T_5: *Rhizobium* + N20 + PK
T_6: Crop Residues + N20 + PK
T_7: *Rhizobium* + Crop Residues + N20 + PK
T_8: Crop Residues + N40 + PK

Probably incorporation of crop residues added organic matter due to their decomposition. The finding of this study also supported by the earlier findings of Sardana and Verma (1987) and Oad and Buriro (2005).

4.6.3 N in post harvest soil

Statistically significant variation was recorded in terms of N in post harvest soil of blackgram for the application of different treatments (Appendix VIII). The highest N in post harvest soil (0.09 ppm) was recorded from T_7 (*Rhizobium* + N_{20} + PK) and the lowest N in post harvest soil (0.05 ppm) was recorded from T_1, T_2 and T_3 (Table 8).

4.6.4 P in post harvest soil

P in post harvest soil of blackgram varied significantly due to the application of different treatments (Appendix VIII). The highest P in post harvest soil (20.60 ppm) was recorded from T_7 (*Rhizobium* + N_{20} + PK) and the lowest P in post harvest soil (15.88 ppm) was recorded from T_1 (control) (Table 8).

4.6.5 K in post harvest soil

Due to the application of different treatments K in post harvest soil of blackgram showed statistically significant difference (Appendix VIII). The highest K in post harvest soil (0.15 meq/100 g soil) was found from T_7 (*Rhizobium* + N_{20} + PK) and the lowest K in post harvest soil (0.11 meq/100 g soil) was obtained from T_1 (control) (Table 8).

4.6.6 S in post harvest soil

Statistically significant variation was recorded in terms of S in post harvest soil of blackgram for the application of different treatments (Appendix VIII). The highest S in post harvest soil (0.39 ppm) was found from T_8 (*Rhizobium* + Crop residues + N_{20} + PK) and the lowest S in post harvest soil (0.15 ppm) was found from T_1 (control) (Table 8).

Table 8. Effect of rhizobium, crop residues and inorganic fertilizers on pH, organic matter and N, P, K, S in post harvest soil of blackgram

Treatment	Post harvest soil			
	N (ppm)	P (ppm)	K (meq/100 g soil)	S (ppm)
T_1	0.05 c	15.88 c	0.11 c	0.15 c
T_2	0.05 c	17.40 bc	0.14 a	0.17 c
T_3	0.05 c	18.51 abc	0.14 a	0.30 ab
T_4	0.06 b	17.12 bc	0.12 bc	0.31 ab
T_5	0.08 a	18.51 abc	0.14 a	0.29 b
T_6	0.08 ab	17.14 bc	0.14 a	0.31 ab
T_7	0.09 a	20.60 a	0.15 a	0.33 ab
T_8	0.08 ab	19.11 ab	0.13 ab	0.39 a
$LSD_{(0.05)}$	0.015	2.577	0.015	0.081
CV(%)	12.32	9.72	11.95	19.47

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

T_1: No *Rhizobium*, No organic, No chemical fertilizer (control)

T_2: No *Rhizobium* + No organic + No Nitrogen + PK

T_3: N_{40} + PK

T_4: *Rhizobium* + PK

T_5: *Rhizobium* + N_{20} + PK

T_6: Crop Residues + N_{20} + PK

T_7: *Rhizobium* + Crop Residues + N_{20} + PK

T_8: Crop Residues + N_{40} + PK

Chapter 5
Summary and Conclusion

Chapter V

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of *Rhizobium*, crop residues and inorganic fertilizers on yield and yield contributing characters of blackgram. The treatments of the experiment were T_1: No *Rhizobium*, No organic, No chemical fertilizer (control), T_2: No *Rhizobium* + No organic + No Nitrogen + PK, T_3: N_{40} + PK, T_4: *Rhizobium* + PK, T_5: *Rhizobium* + N_{20} + PK, T_6: Crop Residues + N_{20} + PK, T_7: *Rhizobium* + Crop Residues + N_{20} + PK and T_8: Crop Residues + N_{40} + PK. The single factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters, yield and nutrients status of post harvest soil were recorded to find out the effect of treatments.

The tallest plant (55.25 cm), the highest number of leaves per plant (9.73), number of branches per plant (1.55), number of pods per plant (18.85), maximum pod length (7.82 cm), number of seeds per pod (11.45), weight of 1000 seeds (46.75 g), seed yield (1.41 t/ha) and stover yield (1.88 t/ha) was found from T_7 and the lowest of parameters was recorded from T_1. The highest number of nodules per plant (24.24) was recorded from T_7 and the lowest (11.40) was recorded from T_1.

The maximum concentration of N in plant (3.12%), and the minimum (2.09%) was recorded from T_4. The maximum concentration of P (0.615%), K in plant (0.706%), S in plant (0.79%) was recorded from T_8 and the minimum (0.39%) was recorded from T_1. The maximum concentration of N in seed (5.36%), P in seed (0.544%), K in seed

(0.549%) S in seed (0.29%) was recorded from T_7 and the minimum (0.39%) was recorded from T_1.

The maximum N uptake by plant (40.50 kg ha^{-1}) was found from T_7 and the minimum (20.35 kg ha^{-1}) was recorded from T_1. The maximum N uptake by plant (4.43 kg ha^{-1}) was recorded from T_8, while the minimum (2.90 kg ha^{-1}) was recorded from T_2. The maximum K uptake by plant (19.88 kg ha^{-1}) was obtained from T_7 and the minimum (8.06 kg ha^{-1}) was recorded from T_2. The maximum S uptake by plant (9.32 kg ha^{-1}) was recorded from T_7 and the minimum (4.68 kg ha^{-1}) was recorded from T_1. The maximum N uptake by seed (89.71 kg ha^{-1}) was recorded from T_7 and the minimum (45.49 kg ha^{-1}) was recorded from T_6. The maximum P uptake by seed (12.97 kg ha^{-1}) was recorded from T_8, while the minimum (10.09 kg ha^{-1}) was recorded from T_3. The maximum K uptake by seed (30.24 kg ha^{-1}) was recorded from T_8 and the minimum (8.06 kg ha^{-1}) was recorded from T_2. The maximum S uptake by seed (3.73 kg ha^{-1}) was recorded from T_8 and the minimum (2.53 kg ha^{-1}) was recorded from T_1.

The highest pH (5.18) was recorded from T_8 and the lowest (4.26) was recorded from T_1. The highest organic matter (1.17%), N in post harvest soil (0.09 ppm), P in post harvest soil (20.60 ppm) K in post harvest soil (0.15 meq/100 g soil) was found from T_7 and the lowest of these parameters was obtained from T_1. The highest S in post harvest soil (0.39 ppm) was found from T_8 and the lowest (0.15 ppm) was found from T_1.

From the above discussion it can be concluded that application of rhizobium, crop residues, N at 20 kg ha^{-1} along with P and K was most favorable for improving yield and yield contributing characters of black gram.

Considering the situation of the present experiment, the following recommendations and suggestions may be made:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.

2. Residual effect of crop residues on succeeding crop should have been investigated.

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APPENDICES

Appendix I. 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 (%)	Rainfall (mm) (total)	*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 II. Analysis of variance of the data on yield contributing characters of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Number of leaves per plant	Number of branches per plant	Number of pods per plant	Pod length (cm)
Replication	3	3.398	0.423	0.017	1.679	0.185
Treatment	7	41.099**	3.408**	0.140**	16.088**	2.854**
Error	21	5.165	0.367	0.038	2.351	0.128

**: Significant at 0.01 level of probability

Appendix III. Analysis of variance of the data on yield contributing characters and yield of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square				
		Number of seeds per pod	Weight of 1000 seeds (g)	Seed yield (t/ha)	Stover yield (t/ha)	Number of nodules per plant
Replication	3	0.292	2.917	0.008	0.012	2.735
Treatment	7	4.468**	6.786**	0.233**	0.527**	72.124**
Error	21	0.152	1.750	0038	0.006	2.440

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on N, P, K, S in plant of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square			
		Concentration in plant (%)			
		N	P	K	S
Replication	3	0.128	0.000	0.002	0.001
Treatment	7	0.428**	0.030**	0.038**	0.045**
Error	21	0.058	0.005	0.003	0.002

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on N, P, K, S in seed of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square			
		Concentration in seed (%)			
		N	P	K	S
Replication	3	0.038	0.004	0.003	0.002
Treatment	7	0.547*	0.030**	0.025**	0.033**
Error	21	0.226	0.003	0.006	0.005

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

Appendix VI. Analysis of variance of the data on N, P, K, S uptake by plant of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square			
		Uptake by plant (%)			
		N	P	K	S
Replication	3	5.381	1.025	0.005	0.125
Treatment	7	246.080**	12.451**	3.256**	4.256**
Error	21	2.643	2.356	0.568	0.621

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on N, P, K, S uptake by grain of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square			
		Uptake by seed (%)			
		N	P	K	S
Replication	3	30.716	0.586	1.256	2.015
Treatment	7	938.079**	8.452**	11.058**	6.498**
Error	21	153.466	1.212	2.156	1.582

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on pH, organic matter and N, P, K, S in post harvest soil of blackgram as influenced by rhizobium, crop residues and inorganic fertilizers

Source of variation	Degrees of freedom	Mean square					
		Post harvest soil					
		pH	Organic matter (%)	K (meq/100 g soil)	N (ppm)	P (ppm)	S (ppm)
Replication	3	0.005	0.006	0.0001	0.902	0.0001	0.001
Treatment	7	0.348**	0.033**	0.001**	8.488*	0.001**	0.027**
Error	21	0.027	0.003	0.0001	3.070	0.0001	0.003

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