# PERFORMANCE OF BLACKGRAM (*VIGNA MUNGO* L.) IN PRESENCE AND ABSENCE OF *BRADYRHIZOBIUM*

BY

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## A Thesis

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## *CERTIFICATE*

This is to certify that the thesis entitled, **"PERFORMANCE OF BLACKGRAM (*VIGNA MUNGO* L.) IN PRESENCE AND ABSENCE OF *BRADYRHIZOBIUM*"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY,** embodies the result of a piece of *bona fide* research work carried out by **MD. RASHEDUL ISLAM** Registration No. **05-01793** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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



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DEDICATED TO MY BELOVED PARENTS AND WIFE

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***The Author***

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# ABBREVIATIONS, ACRONYMS AND SYMBOLS

| | |
|---|---|
| AEZ | Agro-Ecological Zone |
| ANOVA | Analysis of Variance |
| App. | Appendix |
| BARI | Bangladesh Agricultural Research Institute |
| BAU | Bangladesh Agricultural University |
| BBS | Bangladesh Bureau of Statistics |
| BCR | Benefit and Cost Ratio |
| BNF | Biological Nitrogen Fixation |
| C | Carbon |
| CD | Cowdung |
| cm | Centimeter |
| cmol $kg^{-1}$ | Centimole per kilogram |
| Cu | Copper |
| DAS | Days After Sowing |
| DM | Dry Matter |
| DMRT | Duncan's Multiple Range Test |
| EC | Electrical Conductivity |
| FAO | Food and Agricultural Organization |
| g | Gram |
| K | Potassium |
| kg | Kilogram |
| kg $ha^{-1}$ | Kilogram per hectare |
| mg | Milligram |
| mm | Millimeter |
| MoP | Muriate of Potash |
| N | Nitrogen |
| nm | Nanometer |
| P | Phosphorus |
| ppm | Parts Per Million |
| PSO | Principal Scientific Officer |
| RCBD | Randomized Complete Block Design |
| S | Sulphur |
| t | ton |
| t $ha^{-1}$ | Ton per hectare |
| TSP | Triple Superphosphate |
| µg $g^{-1}$ | Microgram per gram |

## ABSTRACT

The experiment was conducted at the net house of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701 during the period from September to December 2011 to study the performance of three blackgram varieties with and without *Bradyrhizobium* inociulant. There were 15 treatment combinations and 3 replications were laid out in 45 pots in the experiment arranged in factorial randomized complete block design. The *Bradyrhizobium* strains of blackgram BARI RVm-301, BARI RVm-302, BARI RVm-303 and mixed culture along with a uninoculated control were used for the above experiment. The selected varieties were BARI Mash-1, BARI Mash-2 and BARI Mash-3. All the varieties showed better performance in presence of *Bradyrhizobium* inoculation. Among the three varieties, BARI Mash-2 gave the highest seed yield. *Bradyrhizobium* strains performed better than uninoculated treatment in respect of different parameters like nodule number and weight, root weight and shoot weight, root length and shoot length, pod length and pods plant$^{-1}$. *Bradyrhizobium* inoculation significantly increased nodule number and weight, seed yield, stover yield, plant height, 1000-seed weight, pods plant$^{-1}$, seeds pod$^{-1}$, N content in seed and stover, N uptake by stover and seed. Among the three strains and mixed culture, strain BARI RVm-302 gave the highest nodule biomass and seed yield. Interaction effects revealed with BARI Mash-2 inoculated with mixed culture gave the highest seed yield and N uptake while non-inoculated BARI Mash-1 gave the lowest seed yield.

# Chapter 1
# Introduction

# CHAPTER I

# INTRODUCTION

Pulse, a protein rich agricultural crop, plays an important role in human nutrition. It is the cheapest source of protein for the poor people. Pulses, being leguminous crops, are capable of fixing atmospheric nitrogen in the soil and enrich soil fertility. Thus they are considered as soil fertility building crops (Kumar *et al.*, 1963). Some of the pulse seeds are consumed when they are at green stage. But it is taken mostly in the form of soup and "dal". Sometimes it is grown as green manuring crops and cover crops (Shaikh, 1977). The green plants, the dried stems and leaves after separation of grain and the husks of seeds are the valuable food to the livestock. It is an excellent source of easily digestible protein.

Blackgram (*Vigna mungo* L.) is one of the major pulse crops grown in Bangladesh. It belongs to the family Leguminoceae and sub-family Papilionaceae. It is widely grown in the Indian subcontinent as a source of protein. These legumes can obtain nitrogen (N) from the atmosphere by fixation in their root nodules in symbiosis with soil rhizobia, and thus have the potential to yield well in N-deficient soils (Hafeez *et al.*, 1988). This characteristic is particularly important in developing countries due to the relatively high cost and/or restricted availability of chemical N fertilizers. Furthermore, incorporation of residues into the soil from a N-fixing legume crop may provide organic N for the subsequent benefit of a cereal crop (Rosales *et al.*, 1998).

Blackgram is one of the widely grown pulse crops in Bangladesh for human consumption, animal fodder as well as soil fertility building purpose. But high cost and environmentally risky chemical fertilizers cause serious and continuous problem for increasing blackgram production in developing countries including Bangladesh. This problems are likely to become serious in future. Biological nitrogen fixation (BNF) resulting from symbiosis between legume crops and root nodule bacterium *Rhizobium/Bradyrhizobium* can ameliorate the situation by reducing the N-fertilizer inputs required to ensure productivity.

Now a day, a number of organisms like *Rhizobium* has been identified to use as biological agent for fixing atmospheric nitrogen by process with legume crops and make available to the plants. Bangladesh Agricultural Research Institute (BARI) has isolated some *Rhizobium* strains for some pulse corps. It has already selected some *Bradyrhizobium* strains especially for blackgram varieties. To reduce the production cost and to fulfill the demand, more pulse production could be achieved through seed inoculation with *Bradyrhizobium* strains which is known to influence biological fixation, growth and yield of pulses. In Bangladesh, inoculation with *Bradyrhizobium* increased 63% nodule number, 22% nodule weight, 77% nodule weight, 12% stover yield and 23% seed yield over non-inoculated control (Bhuiyan *et al.*, 2010). Maximum yields were obtained when fertilizers are applied along with *Rhizobium* inoculation (Bali *et al.*, 1991).

By growing blackgram in Bangladesh, there is a large scope of utilizing the biological nitrogen fixing technology for obtaining protein rich food legume and also to improve nitrogen fertility of the soil of this country.

Unfortunately, there is a lack of sufficient research work on the nutrient requirement particularly phosphorus and the effect of seed inoculation of blackgram with effective rhizobial strain for successful cultivation of this crop in Bangladesh. The present investigation was, therefore, undertaken to evaluate the response of blackgram varieties to inoculation with *Bradyrhizobium* styrains with the following objectives:

i) To investigate the effect of *Bradyrhizobium* inoculation on the growth, nodulation, yield, nitrogen uptake and other yield contributing characters of blackgram.

ii) To assess the response of blackgram varieties to *Bradyrhizobium* inoculation.

# Chapter 2
# Review of Literature

# CHAPTER II

# REVIEW OF LITERATURE

Biofertilizers are cultivars of microorganisms which benefit the plants by providing nitrogen or phosphorus or rapid mineralization of organic materials. Of the biofertilizes, the use of *Bradyrhizobium* was studied in Bangladesh at large extent. Work on *Bradyrhizobium* inoculation on blackgram varieties is very little. Only limited number of research works has so far been carried out on the combined use of *Bradyrhizobium* inoculation on blackgram (*Vigna mung* L.) varieties and other pulse crops. However, available information on the contribution of *Bradyrhizobium* inoculation on blackgram and other crops has been reviewed in this chapter.

## 2.1 Effect of variety

Effect of variety on blackgram and other legume have been presented below:

Nag *et al*. (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties (BARI Mash-1, BARI Mash-2 and BARI Mash-3) to evaluate their yield and yield attributes. Among the three cultivars, BARI Mash-1 and BARI Mash-3 recorded the highest (1.60 t $ha^{-1}$ and the lowest seed yield (1.46 t $ha^{-1}$), respectively. BARI Mash-1 had the highest plant height, pods $plant^{-1}$, and seeds $pod^{-1}$, total dry matter yield.

Navgire *et al.* (2001) carried out an experiment on mungbean cultivars to different *Rhizobium* strains under rainfed condition. Seeds of mungbean cultivars BM-4, S-8 and BM-86 were inoculated with *Rhizobium* strains M-11-85, M-6-84, GR-4 and M-6-65. Cultivars S-8, BM-4 and BM-86 recorded the highest mean nodulation (16.7), plant biomass (8.29 q $ha^{-1}$) and grain yield (4.79 q $ha^{-1}$) during the experimental years. S-8, BM-4 and BM-86 recorded the highest nodulation, plant biomass and grain yield.

Maqsood *et al.* (2001) carried out a study in a sandy clay loam field to investigate the effect of phosphorus rates on the agronomic traits of two mashbean (*V. mungo*) genotypes (Mash-97 and Mash-88) at the University of Agriculture, Faisalabad, Pakistan, during 1998. The phosphorus rates were 0, 50, 75 and 100 kg $P_2O_5$ $ha^{-1}$. Mashbean genotypes did not differ significantly regarding number of plants $m^{-2}$, plant height, number of seeds $pod^{-1}$, total number of seeds $plant^{-1}$, 1000-seed weight, seed yield and harvest index. However, Mash-97 gave significantly more seeds $plant^{-1}$ than that of the Mash-88.

Sarkar *et al.* (2002) inoculated the seed of blackgram with strains of *Bradyrhizobium* viz. M-10, 129-USA, 480-M, and MK-5 before sowing in a field experiment conducted to determine the cultivars and *Bradyrhizobium* strain for suitable use in the locality. Cultivars M-16 recorded longer roots and higher root volume $plant^{-1}$, number of nodules $plant^{-1}$ and test weight compared to A-43. The interaction effects between cultivar A-43 and *Bradyrhizobium* strain MK-5 resulted in the highest root volume $plant^{-1}$ (1.30), number of nodules $plant^{-1}$ (7.03) and test weight (4.23 g), whereas the interaction effects between cultivar A-43 and *Bradyrhizobium* strain 480-M resulted in the longest roots (14.7 cm). Correlation coefficient studies showed high correlation between seed yield and dry weight, and root weight. Root length and root volume were inversely correlated with test weight.

Solaiman *et al.* (2003) carried out a study on mungbean to find out the response of mungbean cultivars BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1 to *Rhizobium* sp. strains TAL169 and TAL441 was investigated in Bangladesh. Bacterial inoculation of the seeds increased nodulation, nitrogenase activity, dry matter production, N content and N uptake. The best characteristics were obtained with BARI Mung-4 inoculated with strain TAL169.

Hayat *et al.* (2004) conducted a field experiment on mungbean during kharif 2000 in Rawalpindi, Pakistan to find out the effect of N and *Rhizobium* sp. inoculation on the yield, N uptake and economics of mungbean (cultivars NM 92 and NCM 209) was investigated The treatments were: control; 500 g *Rhizobium* inoculum, 30, 60 and 90 kg N $ha^{-1}$; and inoculum combined with N at 30, 60 and 90 kg $ha^{-1}$. N content was higher in nodules of NM 92 than NCM 209. The highest N content in nodules (2.80%) was obtained with inoculation + 30 kg N $ha^{-1}$. NCM 209 had higher N shoot content (2.13%) than NM 92 (1.87%). The highest shoot N content was obtained with inoculation + 30 kg N $ha^{-1}$. The highest soil N content was obtained with inoculation + 90 kg N $ha^{-1}$. NCM 209 produced higher yield than NM 92. The maximum economic yield for NM 92 and NCM 209 (768 and 910 kg $ha^{-1}$, respectively) was obtained with inoculation + 90 kg N $ha^{-1}$. The maximum biological yield (4,889 kg $ha^{-1}$) was obtained in NCM 209 with inoculation + 30 kg N $ha^{-1}$. NCM 209 showed higher biological yield than NM 92. The highest harvest index of 18.45% was obtained with inoculation + 30 kg N $ha^{-1}$. The maximum net income (Rs. 18,329 and Rs. 13,003 $ha^{-1}$) in NCM 209 and NM 92 was obtained with inoculation alone and inoculation + 30 kg N $ha^{-1}$, respectively. The highest benefit: cost ratio was obtained in NCM 209 with the inoculation treatment alone.

Hossain and Solaiman (2004) carried out a field experiment to study The effects of *Rhizobium* inoculation on the nodulation, plant growth, yield attributes, seed and stover yields, and seed protein content of six mungbean (*Vigna radiata*) cultivars were investigated. The mungbean cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Mung-2 and BU Mung-1. *Rhizobium* strains TAL169 and TAL441 were used for inoculation of the seeds. Two-thirds of seeds of each cultivar were inoculated with *Rhizobium* inoculant and the remaining one-third of seeds was kept uninoculated. The number and dry weight of nodules $plant^{-1}$, plant height, root length, number of main branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, 1000-seed weight, seed and stover yields, and seed protein content of the crop increased significantly due to inoculation of the seeds with *Rhizobium* strains. Among the cultivars, BARI Mung-4 performed the best in all aspects showing the highest seed yield of 1,135 kg $ha^{-1}$. *Rhizobium* strain TAL169 did better than TAL441 in most of the studied parameters. The number of pods $plant^{-1}$ and 1000-seed weight had positive correlations with seed yield. It was concluded that BARI Mung-4 in combination with TAL169 performed the best in terms of nodulation, plant growth, seed and stover yields, and seed protein content.

An experiment was conducted by Mozumder *et al.* (2005) from March to June 2003 in Mymensingh, Bangladesh to evaluate the response of summer mungbean cultivars Binamoog-2 and Kanti to *Bradyrhizobium* inoculation (inoculated and non-inoculated) and N application (0, 20, 40, 60 and 80 kg $ha^{-1}$). Nitrogen was applied as urea, whereas liquid mixture of *Bradyrhizobium* inocula (BINA MB 441, BINA MB 169 and BINA MB 301) was mixed with the seeds before sowing. Data were recorded for days to flowering, dry matter weight, number of nodules $plant^{-1}$, dry weight of nodule, plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, percentage of mature pods, number of seeds $pod^{-1}$, percentage of filled seeds, 1000-seed weight, seed weight $plant^{-1}$, seed yield, straw yield and harvest index. Benefit: cost (BC) ratio was also calculated. The highest seed yield (1,461 kg $ha^{-1}$) and BC ratio (2.18) were obtained in the treatment with 40 kg N $ha^{-1}$ along with *Bradyrhizobium* inoculation. The highest straw yield (4,702 kg $ha^{-1}$) was obtained in the treatment with 60 kg N $ha^{-1}$ with *Bradyrhizobium* inoculation.

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

Bhuiyan *et al.* (2007a) carried out an experiment with five mungbean varieties with or without *Bradyrhizobium* at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to find out the time of nodule initiation, nodulation pattern and their size distribution. The number of nodules increased progressively with the increasing growth period and reached the peak at 42 DAS (i.e. at 50% flowering stage). The number of nodules of 2–4 mm size started to decline after 42 DAS sharply and in case of <2 mm size nodules, the declining was noticeable after 56 DAS, while the bigger nodules were increased up to 63 DAS. The results suggested that nodule initiation in the roots of mungbean varieties started at 9 days of sowing seeds (DAS) reached the peak at 42 DAS and thereafter started reducing in numbers until 70 DAS due to spontaneous degeneration. Higher number of nodule in different sizes (<2.0 mm, 2.1-4.0 mm and >4 mm) was observed in BARI mung-2 at different DAS. *Bradyrhizobium* inoculation produced 8.8 (<2.0 mm), 8.5-8.6 (2.1-4.0 mm) and 0.2-0.4 (>4 mm) nodules plant$^{-1}$, while uninoculated plant produced 5.7 (<2.0 mm), 5.6 (2.1-4.0 mm) and 0.1-0.2 (>4 mm) nodules plant$^{-1}$.

Bhuiyan and Mian (2007) conducted experiments with or without *Bradyrhizobium* in five mungbean varieties at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to observe nodulation, biomass production and yield of mungbean. Five mungbean varieties viz. BARI Mung-2, BARI Mung-4, BARI Mung-5, BINA Mung-2 and Barisal local, and rhizobial inoculum (*Bradyrhizobium* strain BAUR-604) was used for the study. Application of *Bradyrhizobium* inoculant produced significant effect on nodulation, shoot dry weight, seed and stover yields. Seed inoculation significantly increased seed (0.98 t ha$^{-1}$ in 2001, 27% increase over control and 0.75 t ha$^{-1}$ in 2002, 29% increase over control) and stover (2.31 t ha$^{-1}$ in 2001 and 2.04 t ha$^{-1}$ in 2002) yields of mungbean.

Inoculated BARI Mung-2 produced the highest nodulation, dry matter production, seed and stover yields.

Bhuiyan *et al.* (2007b) carried out field studies with five mungbean varieties with/ without *Bradyrhizobium* inoculation at the Bangladesh Agricultural University Farm during *Kharif-I* 2001 and *Kharif-I* 2002 seasons to observe shoot dry matter production and nitrogen uptake by mungbean at different growth stages. Significant influences of the mungbean varieties were observed on dry matter production and nitrogen uptake. *Bradyrhizobium* inoculant significantly increased dry matter production. The highest dry matter production plant$^{-1}$ at 77 DAS was recorded in *Bradyrhizobium* inoculated plots. Inoculated BARI Mung-2 produced the highest shoot weights.

Sharma *et al.* (2007) conducted a field experiments during 2001-2006 to study the effect of agronomic management practices on biological nitrogen fixation in the extra-short-duration mungbean variety SML 668 in summer and kharif seasons in Punjab, India. Seed inoculation with *Rhizobium* recorded increase in yield by 12-16%. Conjunctive use of *Rhizobium* with phosphate solubilizing bacteria (PSB) and plant growth promoting rhizobacteria (PGPR) revealed synergistic effect on symbiotic parameters and grain yield of mungbean. Genotypes, VC 3890A, VC 6368, VC 6369-30-65, VC 6173-10 and VC 6090A showed higher nodulation and leghaemoglobin content than check SML 668. Their nodulation pattern was in clusters and mainly on the tap toot. The time of sowing showed remarkable variation in size and shape of nodules and leghaemoglobin content. Data recorded from tillage versus no-tillage experiment revealed more nodulation and leghaemoglobin content in no-tillage treatment.

Bhuiyan *et al.* (2008a) carried out field studies with and without *Bradyrhizobium* with five mungbean varieties to observe the yield and yield attributes of mungbean. They observed that application of *Bradyrhizobium* inoculant produced significant effect on seed and stover yields. Seed inoculation significantly increased seed (0.98 t $ha^{-1}$ in 2001, 27% increase over control and 0.75 t $ha^{-1}$ in 2002, 29% increase over control) and stover (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) yields of mungbean. *Bradyrhizobium* inoculation also significantly increased pods $plant^{-1}$, seeds $pod^{-1}$ and 1000-seed weight. Inoculated BARI Mung-2 produced the highest seed and stover yields as well as yield attributes such as pods $plant^{-1}$ and seed $pod^{-1}$.

A field experiment was conducted by Bhuiyan *et al.* (2010) at Bangladesh Agricultural Research Institute Central Farm, Gazipur during kharif-1 2010; Regional Agricultural Research Station (RARS), Jamalpur during kharif-2 season of 2009 and Regional Agricultural Research Station (RARS), Rahmatpur, Barisal during late rabi season of 2010 with the objectives to study the response of inoculation with different plant genotypes and different sites (Agro-ecological zones) with inoculation. Three varieties of blackgram viz. BARI Mash-1, BARI Mash-2 and BARI Mash-3 and rhizobial inoculum (*Bradyrhizobium* strain RVm-301) were used in this experiment. Each variety was tested with and without inoculation. At Joydebpur, among 3 varieties, BARI Mash-3 produced higher nodule weight, nodule weight, stover yield and seed yield but BARI Mash-1 gave higher nodule number, nodule weight and seed yield at Rahmatpur and Jamalpur.

Field studies was carried by out by Sangakkara *et al.* (2011) for testing the impact of fertilizer K on root development, seed yields, harvest indices, and N-use efficiencies of maize and mungbean, two popular smallholder crops over major and minor seasons. Application of 120 kg K $ha^{-1}$ optimized all parameters of maize in the major wet season, whereas the requirement was 80 kg K $ha^{-1}$ in the minor season. Optimal growth yields and N-use efficiencies of mungbean was with 80 kg K $ha^{-1}$ in both seasons. Information regarding rates of fertilizer K that optimized N use and yield of maize and mungbean during each of the two tropical monsoonal seasons of South Asia is presented.

## 2.2 Effect of *Bradyhizobium*

Effect of *Bradyrhizobium* inoculant on blackgram and other legume have been presented below:

Navgire *et al.* (2001) carried out an experiment on mungbean cultivars to different *Rhizobium* strains under rainfed conditions. Seeds of mungbean cultivars BM-4, S-8 and BM-86 were inoculated with *Rhizobium* strains M-11-85, M-6-84, GR-4 and M-6-65. Cultivars S-8, BM-4 and BM-86 recorded the highest mean nodulation (16.7), plant biomass (8.29 q $ha^{-1}$) and grain yield (4.79 q $ha^{-1}$) during the experimental years. S-8, BM-4 and BM-86 recorded the highest nodulation, plant biomass and grain 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 and was at par 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. The treatments consisted of *Rhizobium* (strains CRU 7 for blackgram and CRM 11 for greengram) seed inoculation, 15 t farmyard manure (FYM $ha^{-1}$, FYM + *Rhizobium*, 5 t compost $ha^{-1}$ (prepared from leaves and twigs of *Sesbania sesban*, *S. grandiflora*, *Cassia fistula*, *Cassia auriculiformis* and *Claricidia* (*Gliricidia*) along with cowdung and rock phosphate), compost + *Rhizobium*, 5 t biodigested slurry $ha^{-1}$, and biodigested slurry + *Rhizobium*. In general, seed inoculation of *Rhizobium* and application of organic amendments enhanced biomass, root nodulation, and grain yield. Biodigested slurry at 5 t $ha^{-1}$ + *Rhizobium* gave the greatest plant height (42.7 and 53.7 cm for blackgram and greengram, respectively), nodule number (23.3 and 24.0), nodule weight (45.3 and 42.3 mg) and grain yield (758 and 732 kg $ha^{-1}$).

Chatterjee and Bhattacharjee (2002) studied the effects of inoculation with *Bradyrhizobium* and phosphate soluble bacteria (PSB) on nodulation and grain yield of mungbean cv. B-1 in field trial conducted in West Bengal. Seeds of mungbean were inoculated with strains of *Rhizobium*, i.e JCa-1 and M-10 strains, at a population of 28.20 x $10^6$ and 32.66 x $10^6$ cells $ml^{-1}$, respectively, phosphate solubilizing bacteria containing *Bacillus polymyxa* and *Pseudomonus striata* at a population of 7 x $10^8$ cells $ml^{-1}$ at the time of the sowing. The plants inoculated with *Bradyrhizobium* strains and PSB showed increased rate of nodulation and N content. The percentage increased in seed yield over control was observed to be highly significant in plants inoculated with *Bradyrhizobium* strains and PSB.

Malik *et al*. (2002) studied the effects of seed inoculation with *Rhizobium* and P application (at 0, 30, 50, 90 and 110 kg $ha^{-1}$) on the growth, seed yield and quality of mungbean cv. NM-98. Seed inoculation with *Rhizobium* and application of 70 kg $ha^{-1}$ resulted in the highest number of pods $plant^{-1}$ (22.5), number of seed $pod^{-1}$ (12.1), 1000-seed weight (42.3 g) and seed yield (1,158 kg $ha^{-1}$). Plant height at harvest was the highest when inoculated with *Bradyrhizobium* (68.2 cm).

Potdukhe and Guldekar (2003) carried out a field experiment to find out the synergistic effects of combined inoculations of *Rhizobium*, phosphate-solubilizing bacteria (PSB, *Azospirillum brasilense*) and antagonistic bacteria (AB) on nodulation and grain yield of mungbean cv. TARM-18 which were investigated during the kharif season of 1997-98, 1998-99 and 1999-2000 in Akola, Maharashtra, India. The highest nodule number (20.3 $plant^{-1}$) and nodule dry weight (107.2 mg $plant^{-1}$) were obtained under the treatments with

*Rhizobium* alone and *Rhizobium* + AB. Plant dry weight was maximum under the treatment *Rhizobium* + AB. High grain yield (507 kg $ha^{-1}$) was obtained under the seed treatment with *Rhizobium* + *A. brasilense* + AB.

A study was conducted by Kumari and Nair (2003) to isolate efficient native strains of *Rhizobium* or *Bradyrhizobium* spp. 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. 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. At Vellayani, the nodule number, plant dry weight and yield in blackgram were significantly high in the treatment combination of POP KA-F-B-6. At Kayamkulam, significant increases were obtained only in nodule number, nodule dry weight and yield. The results indicated that for acidic soils, the mere development of efficient native strains of *Rhizobium* or *Bradyrhizobium* alone was not sufficient but it should be along with a package of practices recommendation consisting of application of organic manure and liming to neutralize the soil pH.

A field experiment was conducted by Kumar *et al.* (2003) during 2001-02 on the sandy loam soil of Haryana, India to investigate the effect of *Rhizobium* sp. seed inoculation, FYM (farmyard manure) at 5 t $ha^{-1}$, vermicompost at 2.5 and 5 t $ha^{-1}$, and 4 levels of fertilizers (control, no chemical fertilizer; 75% recommended dose of fertilizer, RDF; 100% RDF. N:P at 20:40 kg $ha^{-1}$; and 125% RDF) on the performance of mungbean cv. Asha. *Rhizobium* sp. inoculation significantly increased the grain yield. Increasing RDF levels up to 100% also increased grain yield. Vermicompost at 5 t $ha^{-1}$ produced 16.5 and 9.5% higher grain yield compared to FYM at 5 t $ha^{-1}$ and vermicompost at 2.5 t $ha^{-1}$, respectively, in 2002.

However, the organic amendment did not affect the grain $pod^{-1}$ in 2001 and the 1000-grain weight in both years. The interaction of the different treatments was significant in 2002. Vermicompost application at both levels resulted in higher yield compared to FYM. Yield increased with increasing fertilizer rate up to 125% RDF, when applied with FYM, but yield was higher under the treatment 100% RDF + vermicompost (both rates).

Solaiman *et al*. (2003) carried out a study on mungbean to find out the response of mungbean cultivars BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1 to *Rhizobium* sp. strains TAL169 and TAL441 was investigated in Bangladesh. Bacterial inoculation of the seeds increased nodulation, nitrogenase activity, dry matter production, N content and N uptake. The best characteristics were obtained with BARI Mung-4 inoculated with strain TAL169.

A field experiment was conducted by Singh and Pareek (2003) during the rainy season of 1998 in India to investigate the effect of P fertilizers (at 0, 15, 30, 45 and 60 kg $P_2O_5$ $ha^{-1}$) and biofertilizers (*Rhizobium* sp.; phosphate solubilizing bacteria, PSB; and combination of *Rhizobium* + PSB) on the growth and yield of mungbean cv. RMG 62. All biofertilizer treatments increased growth and yield characters, except pod length and test weight. The highest values for all the parameters studied were obtained with *Rhizobium* + PSB: dry matter accumulation $m^{-1}$ row at 50 days after sowing and at harvest; branches $plant^{-1}$ at harvest; number of nodules $plant^{-1}$; pods $plant^{-1}$; and seed yield $ha^{-1}$. The dry matter accumulation, pods $plant^{-1}$, number of seeds $plant^{-1}$, test weight and seed yield were highest with P at 45 kg $P_2O_5$ $ha^{-1}$ than the other P rates.

A field trial was conducted by Sharma and Upadhyay (2003) during in kharif seasons of 1998 and 1999 in Palampur, Himachal Pradesh, India to investigate the effect of seed inoculation with *Bradyrhizobium* sp. strains (Ludhiana, Local and IARI isolates, in a sticker solution of 10% sugar and 40% gum arabic) on the growth and yield of mungbean. Seed inoculation with the local strain resulted in the maximum values for plant height and dry matter accumulation, followed by Ludhiana and IARI strains. The local strain also resulted in the highest yield, number of pods per plant and number of branches plant$^{-1}$.

Kumar and Chandra (2003) conducted a field experiment during 1995/96 at Pantnagar, Uttar Pradesh, India to investigate the effects of combined inoculation of *Rhizobium* strain M-27 (a nitrogen-fixing bacterium) and *Glomus caledonium* (a vesicular arbuscular mycorrhiza or VAM) with different levels of P (0, 25, 50 and 75 kg ha$^{-1}$) on nodulation, biomass production and grain yield of mungbean cv. Pusa Baishakhi. Combined inoculation of *Rhizobium* + VAM gave significantly more nodules at 30 and 50 days after sowing (DAS) and higher grain yield and biomass than single inoculation with either *Rhizobium* or VAM. Application of P significantly reduced VAM colonization at 30 and 50 DAS, but increasing P level significantly increased biomass production and grain yield over the untreated control.

Hayat *et al*. (2004) conducted a field experiment during kharif 2000 in Rawalpindi, Pakistan to find out the effect of N and *Rhizobium* sp. inoculation on the yield, N uptake and economics of mungbean (cultivars NM 92 and NCM 209). The treatments were: control; 500 g *Rhizobium* inoculum, 30, 60 and 90 kg N ha$^{-1}$ and inoculum combined with N at 30, 60 and 90 kg ha$^{-1}$. N content was higher in nodules of NM 92 than NCM 209. The highest N content in nodules (2.80%) was obtained with inoculation + 30 kg N ha$^{-1}$. NCM 209 had higher N shoot content (2.13%) than NM 92 (1.87%). The highest shoot N content was obtained with inoculation + 30 kg N ha$^{-1}$. The highest soil N content was obtained with inoculation + 90 kg N ha$^{-1}$. NCM 209 produced higher yield than NM 92. The maximum economic yield for NM 92 and NCM 209 (768 and 910 kg ha$^{-1}$, respectively) was obtained with inoculation + 90 kg N ha$^{-1}$. The maximum biological yield (4,889 kg ha$^{-1}$) was obtained in NCM 209 with inoculation + 30 kg N ha$^{-1}$. NCM 209 showed higher biological yield than NM 92. The highest harvest index of 18.45% was obtained with inoculation + 30 kg N $ha^{-1}$. The maximum net income (Rs. 18,329 and Rs. 13,003 $ha^{-1}$) in NCM 209 and NM 92 was obtained with inoculation alone and inoculation + 30 kg N $ha^{-1}$, respectively. The highest benefit: cost ratio was obtained in NCM 209 with the inoculation treatment alone.

Muhammad *et al.* (2004) conducted a field experiment in Pakistan during 2003 to study the effect of phosphorus and *Rhizobium* inoculum on yield and yield components of mungbean cv. NM-92 under the rainfed conditions. Phosphorus at 0, 20, 35, 50, 65 and 80 kg $ha^{-1}$ combined with a basal dose of 20 kg N $ha^{-1}$ was applied with and without inoculum. Plant height and number of branches $plant^{-1}$ were significantly affected with both inoculum and P application. The highest plant height (72.6 cm) was recorded in the plot receiving 35 kg $P_2O_5$ $ha^{-1}$ + *Rhizobium* inoculum while the highest number of branches $plant^{-1}$ (4.2) was recorded at 65 kg $P_2O_5$ + Inoculum. The impact of inoculum and P was also significant on the number of pods $plant^{-1}$. The maximum numbers of pods (17.0) were recorded at 80 kg $P_2O_5$ $ha^{-1}$ + Inoculum. However, the number of grains $pod^{-1}$ increased only with an increase of P levels. The maximum grains $pod^{-1}$ (10.9) was recorded at 80 kg $P_2O_5$ $ha^{-1}$ followed by 10.83 at 65 kg $P_2O_5$ $ha^{-1}$. Both inoculum and P equally contributed in the increase of 1000-grain weight. The highest 1000-grain weight (52.3 g) was recorded in treatments receiving 65 and 80 kg $P_2O_5$ $ha^{-1}$ + Inoculum. Similarly, both P and inoculum significantly affected grain yield. The highest grain yield (1,018 kg $ha^{-1}$) was with 65 kg $P_2O_5$ $ha^{-1}$ + Inoculum but was at par with the grain yield recorded at 35 kg $P_2O_5$ $ha^{-1}$ + Inoculum. *Rhizobium* inoculation increased grain yield by 7.4%. The application of 35 kg $P_2O_5$ $ha^{-1}$ + *Rhizobium* inoculum was the most economical rate giving additional net return of Rs. 5,975 $ha^{-1}$ with VCR of 7.6 compared to the control.

A pot experiment was conducted by Raza *et al.* (2004) in a greenhouse to study the effect of co-inoculation with *Rhizobium japonicum* [*Bradyrhizobium japonicum*] and 2 plant growth promoting rhizobacterial (PGPR) strains (Q7 and Q14) on mungbean. *R. japonicum*, Q7 and Q14 showed better results than the uninoculated control whether inoculated alone or in combination with each other. The co-inoculation of Q7 and Q14 with *R. japonicum* showed better results than *R. japonicum* alone. Q7 + *R. japonicum* increased plant height, root length, number of nodules and number of grains pod$^{-1}$ by 10.8, 5.5, 56.5 and 37.7%, respectively compared with *R. japonicum* alone, while Q14 + *R. japonicum* decreased these parameters but increased the number of pods plant$^{-1}$, 100-grain weight and number of grains plant$^{-1}$ by 66.1, 43.1 and 68.6%, respectively, compared with *R. japonicum* alone. Q7 promoted vegetative growth but grain size was less compared with the other treatments while Q14 showed bold grain size and more yield.

Hossain and Solaiman (2004) carried out a field experiment to study The effects of *Rhizobium* inoculation on the nodulation, plant growth, yield attributes, seed and stover yields, and seed protein content of six mungbean (*Vigna radiata*) cultivars were investigated. The mungbean cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1. *Rhizobium* strains TAL169 and TAL441 were used for inoculation of the seeds. Two-thirds of seeds of each cultivar were inoculated with *Rhizobium* inoculant and the remaining one-third of seeds was kept uninoculated. The number and dry weight of nodules plant$^{-1}$, plant height, root length, number of main branches plant$^{-1}$, number of pods plant$^{-1}$, pod length, 1000-seed weight, seed and stover yields, and seed protein content of the crop increased significantly due to inoculation of the seeds with *Rhizobium* strains. Among the cultivars, BARI Mung-4 performed the best in all aspects showing the highest seed yield of 1,135 kg ha$^{-1}$. *Rhizobium* strain TAL169 did better than TAL441 in most of the studied parameters. The number of pods plant$^{-1}$ and 1000-seed weight had positive correlations with seed yield. It was concluded that BARI Mung-4 in combination with TAL169 performed the best in terms of nodulation, plant growth, seed and stover yields, and seed protein content.

An experiment was conducted by Mozumder *et al.* (2005) from March to June 2003 in Mymensingh, Bangladesh to evaluate the response of summer mungbean cultivars Binamoog-2 and Kanti to *Bradyrhizobium* inoculation (inoculated and non-inoculated) and N application (0, 20, 40, 60 and 80 kg $ha^{-1}$). Nitrogen was applied as urea, whereas liquid mixture of *Bradyrhizobium* inocula (BINA MB 441, BINA MB 169 and BINA MB 301) was mixed with the seeds before sowing. Data were recorded for days to flowering, dry matter weight, number of nodules $plant^{-1}$, dry weight of nodule, plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, percentage of mature pods, number of seeds $pod^{-1}$, percentage of filled seeds, 1000-seed weight, seed weight $plant^{-1}$, seed yield, straw yield and harvest index. Benefit: cost (BC) ratio was also calculated. The highest seed yield (1,461 kg $ha^{-1}$) and BC ratio (2.18) were obtained in the treatment with 40 kg N $ha^{-1}$ along with *Bradyrhizobium* inoculation. The highest straw yield (4,702 kg $ha^{-1}$) was obtained in the treatment with 60 kg N $ha^{-1}$ with *Bradyrhizobium* inoculation.

Dudeja and Duhan (2005) carried out a field experiment to focuses on nitrogen fixation, particularly in mungbeans (*Vigna radiata*) and urdbeans (*Vigna mungo*). Field responses of mungbean and urdbean to rhizobial inoculation, strategies to improve and optimize nitrogen fixation (via appropriate management practices, selection of efficient host genotype and selection of efficient and competitive rhizobia), effects of macronutrients and micronutrients, of interaction with different microbes, of different stresses (e.g. salinity) and of inoculation strategies on growth, nitrogen fixation, nodulation and yield were observed.

Mandal *et al.* (2006) conducted a study to identify strains of *Rhizobium* that can grow in acid soils and fix nitrogen in mungbean. Forty six *Bradyrhizobium* strains were isolated from nodules of mungbean crop collected from Ranchi, Dumka and Singhbhum districts of Jharkhand, India, and were screened for their ability to grow in low pH, low P and high Al concentration in liquid basal medium imposing stress in different combinations. Acid tolerant mungbean isolates (BRM 1 and BDKM 4) were used for incorporation of antibiotic. Two bulk soil samples having different pH (4.6 and 5.5) were collected from upland and medium land field at BAU Research Farm, Kanke, Ranchi, for pot experiment. Results indicated that in general, soils of moderate acidity (pH 5.5) supported more population at both early and prolonged periods than soil with high acidity. Higher adhesion of cells of all isolates along with respective uninoculated control on homologous host was observed in moderately acidic soil than in soil of high acidic value. The highest number of adhered cells on respective host was found in case of isolate BDKM 4 of mungbean (mean 18.7 cells), which were significantly superior to BRM 1 isolate and over control. Interactions of isolate x soil pH were also significant. Isolate BDKM 4 was identified as the most effective (number of nodules plant$^{-1}$ 3.95 and adhered cells of 21.1%). It is concluded that acid tolerant isolates (BRM 1 and BDKM 4) exhibited better survival in soil of less acidity. The isolate BRM 1 was found to be highly ineffective and was able to infect and form nodules on the host. Isolate BDKM 4 showed superiority over native rhizobia in terms of dry mass of nodules and shoot.

Anjum *et al.* (2006) conducted a field experiment on mungbean (*Vigna radiata*) is capable of fixing atmospheric nitrogen through *Rhizobium* species living in its root nodules to evaluate the effect of inoculations and nitrogen levels on performance of mungbean, a pot experiment was conducted during spring 2004. Mungbean cv. NM-98 was sown at 20 kg ha$^{-1}$ in pots. Seed and soil inoculation, and nitrogen levels at 15, 30 and 45 kg ha$^{-1}$ were applied. Data on number of pods plant$^{-1}$, number of seeds plant$^{-1}$, 100-seed weight and seed yield were recorded. Yield and yield components of mungbean crop were significantly affected by both inoculation and fertilizer application. Seed inoculation was more effective and gave better results than soil inoculation.

Sharma *et al.* (2006) conducted a field experiment to evaluate efficacy of liquid and carrier based *Rhizobium* inoculants with respect to nodulation, leghaemoglobin contents and grain yield in mungbean, urdbean and pigeonpea during kharif 2003 in Punjab, India. Liquid as well as carrier based inoculants of *Rhizobium* strains were tested along with uninoculated control. All the inoculants significantly increased nodule number as compared to uninoculated control in all the three pulse crops (13-66%). No significant difference in leghaemoglobin contents was observed with carrier and liquid based *Rhizobium* inoculants in all the three pulse crops. Significant increase in grain yield was recorded with liquid inoculant in urdbean (20%). However in mungbean and pigeon pea, performance of liquid based *Rhizobium* inoculants was at par to carrier based inoculants. Thus, the liquid inoculants were found to be equally effective to the carrier based inoculants.

Bhuiyan *et al.* (2007a) carried out an experiment with five mungbean varieties with or without *Bradyrhizobium* at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to find out the time of nodule initiation, nodulation pattern and their size distribution. The number of nodules increased progressively with the increasing growth period and reached the peak at 42 DAS (i.e. at 50% flowering stage). The number of nodules of 2–4 mm size started to decline after 42 DAS sharply and in case of $<2$ mm size nodules, the declining was noticeable after 56 DAS, while the bigger nodules were increased up to 63 DAS. The results suggested that nodule initiation in the roots of mungbean varieties started at 9 days of sowing seeds (DAS) reached the peak at 42 DAS and thereafter started reducing in numbers until 70 DAS due to spontaneous degeneration. Higher number of nodule in different sizes ($<2.0$ mm, 2.1-4.0 mm and $>4$ mm) was observed in BARI mung-2 at different DAS. *Bradyrhizobium* inoculation produced 8.8 ($<2.0$ mm), 8.5-8.6 (2.1-4.0 mm) and 0.2-0.4 ($>4$ mm) nodules plant$^{-1}$, while uninoculated plant produced 5.7 ($<2.0$ mm), 5.6 (2.1-4.0 mm) and 0.1-0.2 ($>4$ mm) nodules plant$^{-1}$.

Bhuiyan and Mian (2007) conducted experiments with or without *Bradyrhizobium* in five mungbean varieties at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to observe nodulation, biomass production and yield of mungbean. Five mungbean varieties viz. BARI Mung-2, BARI Mung-4, BARI Mung-5, BINA Mung-2 and Barisal local, and rhizobial inoculum (*Bradyrhizobium* strain BAUR-604) was used for the study. Application of *Bradyrhizobium* inoculant produced significant effect on nodulation, shoot dry weight, seed and stover yields. Seed inoculation significantly increased seed (0.98 t $ha^{-1}$ in 2001, 27% increase over control and 0.75 t $ha^{-1}$ in 2002, 29% increase over control) and stover (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) yields of mungbean. Inoculated BARI Mung-2 produced the highest nodulation, dry matter production, seed and stover yields.

Bhuiyan *et al.* (2007b) carried out field studies with five mungbean varieties with/ without *Bradyrhizobium* inoculation at the Bangladesh Agricultural University Farm during *Kharif-I* 2001 and *Kharif-I* 2002 seasons to observe shoot dry matter production and nitrogen uptake by mungbean at different growth stages. Significant influences of the mungbean varieties were observed on dry matter production and nitrogen uptake. *Bradyrhizobium* inoculant significantly increased dry matter production. The highest dry matter production $plant^{-1}$ at 77 DAS was recorded in *Bradyrhizobium* inoculated plots. Inoculated BARI Mung-2 produced the highest shoot weights.

Sharma *et al.* (2007) conducted a field experiments during 2001-2006 to study the effect of agronomic management practices on biological nitrogen fixation in the extra-short-duration mungbean variety SML 668 in summer and kharif seasons in Punjab, India. Seed inoculation with *Rhizobium* recorded increase in yield by 12-16%. Conjunctive use of *Rhizobium* with phosphate solubilizing bacteria (PSB) and plant growth promoting rhizobacteria (PGPR) revealed synergistic effect on symbiotic parameters and grain yield of mungbean. Genotypes, VC 3890A, VC 6368, VC 6369-30-65, VC 6173-10 and VC 6090A showed higher nodulation and leghaemoglobin content than check SML 668. Their nodulation pattern was in clusters and mainly on the tap toot. The time of sowing showed remarkable variation in size and shape of nodules and leghaemoglobin content. Data recorded from tillage versus no-tillage experiment revealed more nodulation and leghaemoglobin content in no-tillage treatment.

Bhuiyan *et al.* (2008a) carried out field studies with and without *Bradyrhizobium* with five mungbean varieties to observe the yield and yield attributes of mungbean. They observed that application of *Bradyrhizobium* inoculant produced significant effect on seed and stover yields. Seed inoculation significantly increased seed (0.98 t $ha^{-1}$ in 2001, 27% increase over control and 0.75 t $ha^{-1}$ in 2002, 29% increase over control) and stover (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) yields of mungbean. *Bradyrhizobium* inoculation also significantly increased pods $plant^{-1}$, seeds $pod^{-1}$ and 1000-seed weight. Inoculated BARI Mung-2 produced the highest seed and stover yields as well as yield attributes such as pods $plant^{-1}$ and seed $pod^{-1}$.

Bhuiyan *et al.* (2008b) conducted a field experiment at Regional Agricultural Research Station, Jamalpur on blackgram and reported that inoculated plants gave significantltly higher nodule number, nodule weight, shoot weight and seed yield compared to non-inoculated plants.

Delic *et al.* (2009) carried out a field experiment on *Vigna mungo* (L.) with rhizobial inoculation in Serbian soils and estimated that inoculation plants produced significantly higher shoot dry weight (SDW), yield , total N content as well as protein yield in respect to untreated control. According to plant shoot yield and yield attributes strain 542 was highly effective without significant differences in comparison to its treatment in combination with mineral nitrogen as well as uninoculated control with full rate of mineral N, 80 kg N $ha^{-1}$.

Taking into account these results and aims of sustainable agriculture 542 strains might be recommended as active agent of N microbiological fertilizer.

Bhuiyan *et al.* (2010) conducted a field experiment at Bangladesh Agricultural Research Institute Central Farm, Gazipur during kharif-1 2010; Regional Agricultural Research Station (RARS), Jamalpur during kharif-2 season of 2009 and Regional Agricultural Research Station (RARS), Rahmatpur, Barisal during late rabi season of 2010 with the objectives to study the response of inoculation with different plant genotypes and different sites (Agro-ecological zones) with inoculation. Three varieties of blackgram viz. BARI Mash-1, BARI Mash-2 and BARI Mash-3 and rhizobial inoculum (*Bradyrhizobium* strain RVm-301) were used in this experiment. Each variety was tested with and without inoculation. Inoculated plants gave significantly higher nodule number, nodule weight, stover yield and seed yield compared to non-inoculated plants at all the locations. Root weight and shoot weight were found significantly higher at Joydebpur only.

### 2.3 Interaction of effect of variety and *Bradyrhizobium*

Interaction effect of variety and *Bradyrhizobium* inoculant on blackgram and other legumes have been presented below:

Navgire *et al.* (2001) carried out an experiment on mungbean cultivars to different *Rhizobium* strains under rainfed conditions. Seeds of mungbean cultivars BM-4, S-8 and BM-86 were inoculated with *Rhizobium* strains M-11-85, M-6-84, GR-4 and M-6-65. Cultivars S-8, BM-4 and BM-86 recorded the highest mean nodulation (16.7), plant biomass (8.29 q $ha^{-1}$) and grain yield (4.79 q $ha^{-1}$) during the experimental years. S-8, BM-4 and BM-86 recorded the highest nodulation, plant biomass and grain yield.

Kumar *et al.* (2002) conducted a field experiment to determine the effect of different levels N (0, 10, 20, 30 kg $ha^{-1}$) and P (0,20,40, 60 kg $ha^{-1}$) on nutrient content and nutrient uptake mungbean genotypes (MH 85-111, Basant and T44) during summer 1999 and 2000 in

Harayana, India. MH 85-111 had significantly higher uptake of N (21.0) and P (18.8%) than that of T44. The N content in grain due to N and P levels did not differ significantly, however, it was higher in straw with 20 kg N and 40 kg $P_2O_5$. The N and P uptake increased significantly with 20 kg N and 40 kg $P_2O_5$ $ha^{-1}$ over the control. The crop yield increased when supplied with 30 kg N $ha^{-1}$ or 40 kg $P_2O_5$ $ha^{-1}$.

Sarkar *et al.* (2002) inoculated the seed of blackgram with strains of *Bradyrhizobium* viz. M-10, 129-USA, 480-M, and MK-5 before sowing in a field experiment conducted to determine the cultivars and *Bradyrhizobium* strain for suitable use in the locality. Cultivars M-16 recorded longer roots and higher root volume $plant^{-1}$, number of nodules $plant^{-1}$ and test weight compared to A-43. The interaction effects between cultivar A-43 and *Bradyrhizobium* strain MK-5 resulted in the highest root volume $plant^{-1}$ (1.30), number of nodules $plant^{-1}$ (7.03) and test weight (4.23 g), whereas the interaction effects between cultivar A-43 and *Bradyrhizobium* strain 480-M resulted in the longest roots (14.7 cm). Correlation coefficient studies showed high correlation between seed yield and dry weight, and root weight. Root length and root volume were inversely correlated with test weight.

Solaiman *et al.* (2003) carried out a study on mungbean to find out the response of mungbean cultivars BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1 to *Rhizobium* sp. strains TAL169 and TAL441 was investigated in Bangladesh. Bacterial inoculation of the seeds increased nodulation, nitrogenase activity, dry matter production, N content and N uptake. The best characteristics were obtained with BARI Mung-4 inoculated with strain TAL169.

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An experiment was conducted by Mozumder *et al.* (2005) from March to June 2003 in Mymensingh, Bangladesh to evaluate the response of summer mungbean cultivars Binamoog-2 and Kanti to *Bradyrhizobium* inoculation (inoculated and non-inoculated) and N application (0, 20, 40, 60 and 80 kg $ha^{-1}$). Nitrogen was applied as urea, whereas liquid mixture of *Bradyrhizobium* inocula (BINA MB 441, BINA MB 169 and BINA MB 301) was mixed with the seeds before sowing. Data were recorded for days to flowering, dry matter weight, number of nodules $plant^{-1}$, dry weight of nodule, plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, percentage of mature pods, number of seeds $pod^{-1}$, percentage of filled seeds, 1000-seed weight, seed weight $plant^{-1}$, seed yield, straw yield and harvest index. Benefit: cost (BC) ratio was also calculated. The highest seed yield (1,461 kg $ha^{-1}$) and BC ratio (2.18) were obtained in the treatment with 40 kg N $ha^{-1}$ along with *Bradyrhizobium* inoculation. The highest straw yield (4,702 kg $ha^{-1}$) was obtained in the treatment with 60 kg N $ha^{-1}$ with *Bradyrhizobium* inoculation.

Bhuiyan *et al.* (2007a) carried out an experiment with five mungbean varieties with or without *Bradyrhizobium* at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to find out the time of nodule initiation, nodulation pattern and their size distribution. The number of nodules increased progressively with the increasing growth period and reached the peak at 42 DAS (i.e. at 50% flowering stage). The number of nodules of 2–4 mm size started to decline after 42 DAS sharply and in case of <2 mm size nodules, the declining was noticeable after 56 DAS, while the bigger nodules were increased up to 63 DAS. The results suggested that nodule initiation in the roots of mungbean varieties started at 9 days of sowing seeds (DAS) reached the peak at 42 DAS and thereafter started reducing in numbers until 70 DAS due to spontaneous degeneration. Higher number of nodule in different sizes (<2.0 mm, 2.1-4.0 mm and >4 mm) was observed in BARI mung-2 at different DAS. *Bradyrhizobium* inoculation produced 8.8 (<2.0 mm), 8.5-8.6 (2.1-4.0 mm) and 0.2-0.4 (>4 mm) nodules plant$^{-1}$, while uninoculated plant produced 5.7 (<2.0 mm), 5.6 (2.1-4.0 mm) and 0.1-0.2 (>4 mm) nodules plant$^{-1}$.

Bhuiyan and Mian (2007) conducted experiments with or without *Bradyrhizobium* in five mungbean varieties at the Bangladesh Agricultural University Farm during kharif-I 2001 and kharif-I 2002 seasons to observe nodulation, biomass production and yield of mungbean. Five mungbean varieties viz. BARI Mung-2, BARI Mung-4, BARI Mung-5, BINA Mung-2 and Barisal local, and rhizobial inoculum (*Bradyrhizobium* strain BAUR-604) was used for the study. Application of *Bradyrhizobium* inoculant produced significant effect on nodulation, shoot dry weight, seed and stover yields. Seed inoculation significantly increased seed (0.98 t ha$^{-1}$ in 2001, 27% increase over control and 0.75 t ha$^{-1}$ in 2002, 29% increase over control) and stover (2.31 t ha$^{-1}$ in 2001 and 2.04 t ha$^{-1}$ in 2002) yields of mungbean. Inoculated BARI Mung-2 produced the highest nodulation, dry matter production, seed and stover yields.

Bhuiyan *et al.* (2007b) carried out field studies with five mungbean varieties with/ without *Bradyrhizobium* inoculation at the Bangladesh Agricultural University Farm during *Kharif-I* 2001 and *Kharif-I* 2002 seasons to observe shoot dry matter production and nitrogen uptake by mungbean at different growth stages. Significant influences of the mungbean varieties were observed on dry matter production and nitrogen uptake. *Bradyrhizobium* inoculant significantly increased dry matter production. The highest dry matter production plant$^{-1}$ at 77 DAS was recorded in *Bradyrhizobium* inoculated plots. Inoculated BARI Mung-2 produced the highest shoot weights.

Bhuiyan *et al.* (2008a) carried out field studies with and without *Bradyrhizobium* with five mungbean varieties to observe the yield and yield attributes of mungbean. They observed that application of *Bradyrhizobium* inoculant produced significant effect on seed and stover yields. Seed inoculation significantly increased seed (0.98 t $ha^{-1}$ in 2001, 27% increase over control and 0.75 t $ha^{-1}$ in 2002, 29% increase over control) and stover (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) yields of mungbean. *Bradyrhizobium* inoculation also significantly increased pods $plant^{-1}$, seeds $pod^{-1}$ and 1000-seed weight. Inoculated BARI Mung-2 produced the highest seed and stover yields as well as yield attributes such as pods $plant^{-1}$ and seed $pod^{-1}$.

A field experiment was conducted by Bhuiyan *et al.* (2010) at Bangladesh Agricultural Research Institute Central Farm, Gazipur during kharif-1 2010; Regional Agricultural Research Station (RARS), Jamalpur during kharif-2 season of 2009 and Regional Agricultural Research Station (RARS), Rahmatpur, Barisal during late rabi season of 2010 with the objectives to study the response of inoculation with different plant genotypes and different sites (Agro-ecological zones) with inoculation. Three varieties of blackgram viz. BARI Mash-1, BARI Mash-2 and BARI Mash-3 and rhizobial inoculum (*Bradyrhizobium* strain RVm-301) were used in this experiment. Interaction effects revealed that BARI Mash-3 gave the highest seed yield (1.09 t $ha^{-1}$) with inoculation at Joydebpur but inoculated BARI Mash-1 gave the highest seed yield at Jamalpur and Rahmatpur.

# Chapter 3
# Materials and Methods

# CHAPTER III

# MATERIALS AND METHODS

This chapter deals with the experimental aspect of the work. Details of the experimental materials and methods followed in the study are presented in this chapter. The experiment was carried out during the period from September to December, 2011. This chapter offers a brief description of soil, treatments, design, fertilizer, biofertilizer, intercultural operations, chemical and statistical analysis.

## 3.1 Experimental site

The experiment was carried out in pots at the Net House of Soil Science Division in Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The experimental site is situated at $24.09^0$ North Latitude and $90.50^0$ East Longitude. The elevation of the experimental site is 8.2 m above the sea level.

## 3.2 Collection and preparation of soil sample

The soil used in this experiment was collected from a selected area of Central Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The initial surface soils of 0-15 cm depth were collected. The soils were put into polyethylene bag and were taken to the laboratory. Then, it was spread on the floor and sun dried for one month. When it dried, the clods were broken with hammer to make it friable. The soil was sieved to remove weeds, stubbles and hard clods. A composite soil sample was kept in polyethylene bag for chemical analysis.

## 3.3 Soil

The experiment was conducted on clay loam soil of the Order Inceptisols. The soil of BARI farm is high land having irrigation facilities. The morphological, physical and chemical characteristics of the experimental soil are presented in Tables 3.1 and 3.2.

**Table 3.1. Morphological characteristics of the soils of experiment field**

| Characters | |
|---|---|
| General soil type | Shallow Grey Terrace Soil |
| Taxonomic soil classification: | |
| Order | Inceptisols |
| Sub-order | Aquept |
| Sub-group | Aeric Albaquept |
| Soil series | Chhiata |

**Table 3.2. Physical and chemical characteristics of the soils**

| Characteristics | BARI farm |
|---|---|
| Mechanical fractions: | |
| % Sand (0.2-0.02 mm) | 27.5 |
| % Silt (0.02-0.002 mm) | 33.5 |
| %Clay (< 0.002 mm) | 39.0 |
| Textural class | Clay loam |
| Colour | Grey |
| Consistency | Sticky and mud when wet |
| pH (1:2.5 Soil-Water) | 6.3 |
| CEC (cmol $kg^{-1}$) | 17.5 |
| Exchangeable K (cmol $kg^{-1}$) | 0.22 |
| Exchangeable Ca (cmol $kg^{-1}$) | 9.41 |
| Exchangeable Mg (cmol $kg^{-1}$) | 7.15 |
| Exchangeable Na (cmol $kg^{-1}$) | 0.15 |
| Organic C (%) | 0.95 |
| Total N (%) | 0.072 |
| Available P (mg $kg^{-1}$) | 13.0 |
| Available S (mg $kg^{-1}$) | 15.0 |
| Available Zn (mg $kg^{-1}$) | 1.59 |
| Available Cu (mg $kg^{-1}$) | 0.59 |
| Available Fe (mg $kg^{-1}$) | 17.9 |
| Available Mn (mg $kg^{-1}$) | 3.5 |

### 3.4 Climate

The climate of the experimental site is sub-tropical, wet and humid. Heavy rainfall occurs in the monsoon (Mid April to Mid August) and scanty during rest of the year.

### 3.5 Crop: Blackgram (*Vigna mungo* L.)

#### 3.5.1 Blackgram variety

**BARI Mash-1**

BARI Mash-1 was developed by Bangladesh Agricultural Research Institute (BARI) and it was released in 1990 by the National Seed Board. Plant height of this variety ranges from 33-35 cm; maximum field duration from 70-75 days and average yield from 1,400-1,500 kg $ha^{-1}$. In seedling stage the seedling is erect in nature; stem and leaf are dark green. Stems are comparatively bulky and leaves are broad and long. The colours of the flowers are blue and seeds are spotted light blackish brown. It is resistant to powdery mildew and downy mildew (Afzal *et al*., 1999).

**BARI Mash-2**

National Seed Board (NSB) released this line as a variety in 1996. This variety was developed by BARI from the cross between two advance lines BMA-2191 and BMA-2140 acquired from India. Plant height of this variety ranges from 33-35 cm, maximum field duration 70-75 days after emergence. Average yield is 1,500-1,700 kg $ha^{-1}$. The seedling is green in colour and the corolla is yellowish-green. Mature pods are black and have hair. Seeds are blackish. It is highly tolerant to yellow mosaic virus (YMV) and *Cercospora* leaf spot (CLS) disease (Bakr *et al*., 2004).

**BARI Mash-3**

BARI Mash-3 was developed from the cross between two advance lines BMA 2140 and BMA-2038 acquired from India. It was released in 1996. It has erect growth habit and attains a height of 35-37 cm. It flowers 35-40 days after emergence and reaches physiological maturity when 70-75 days after emergence. Leaves are trifoliate, alternate and green. The corolla is yellowish green. BARI Mash-3 produced a mean seed yield of 1,800 kg $ha^{-1}$. It is highly tolerant to *Cercospora* leaf spot (CLS) and yellow mosaic virus (Bakr *et al*., 2004).

**3.6 Sowing period: 2011 (Kharif II)**

**3.7 Treatments of the experiment**

The experiment consisted of two factors:

**Factor A:** **Variety : 3**

$V_1$ : BARI Mash-1

$V_2$ : BARI Mash-2

$V_3$ : BARI Mash-3

**Factor B:** ***Bradyrhizobium* Inoculant : 5**

i) $F_1$: Without *Bradyrhizobium* inoculation

ii) $F_2$ : Strain BARI RVm-301

iii) $F_3$ : Strain BARI RVm-302

iv) $F_4$ : Strain BARI RVm-303

v) : $F_5$ : Mixed culture (BARI RVm-301, BARI RVm-302 & BARI RVm-303)

**3.8 Treatment combinations and experimental design**

Thus, there were 15 treatment combinations (3 varieties of blackgram x 5 *Bradyrhizobium*) for the experiment. The experiment was laid out in a factorial randomized complete block design (RCBD) with three replications and the total numbers of treatment combinations were thus 45. The combinations were as follows:

Treatment combinations: Variety 3 x *Bradyrhizobium* 5 = 15

$T_1V_1F_1$: BARI Mash-1 x Uninoculated
$T_2V_1F_2$: BARI Mash-1 x Strain BARI RVm-301
$T_3V_1F_3$: BARI Mash-1 x Strain BARI RVm-302
$T_4V_1F_4$: BARI Mash-1 x Strain BARI RVm-303
$T_5V_1F_5$: BARI Mash-1 x Mixed culture
$T_6V_2F_1$: BARI Mash-2 x Uninoculated
$T_7V_2F_2$: BARI Mash-2 x Strain BARI RVm-301
$T_8V_2F_3$: BARI Mash-2 x Strain BARI RVm-302

$T_9V_2F_4$: BARI Mash-2 x Strain BARI RVm-303

$T_{10}V_2F_5$: BARI Mash-2 x Mixed culture

$T_{11}V_3F_1$: BARI Mash-3 x Uninoculated

$T_{12}V_3F_2$: BARI Mash-3 x Strain BARI RVm-301

$T_{13}V_3F_3$: BARI Mash-3 x Strain BARI RVm-302

$T_{14}V_3F_4$: BARI Mash-3 x Strain BARI RVm-303

$T_{15}V_3F_5$: BARI Mash-3 x Mixed culture



### 3.9 Pot preparation

To conduct the experiment earthen pots (35 x 25 x 25 $cm^3$) were collected and each pot was poured with 10 kg finely ground sieved soil.

### 3.10 Fertilizer application

Triple super phosphate (TSP), muriate of potash (MoP) and gypsum were applied in all pots as basal according to the fertilizer recommendation guide (BARC, 2005) and the doses were 22 kg P $ha^{-1}$, 42 K $ha^{-1}$ and 20 kg S $ha^{-1}$ before sowing of seeds. Urea was applied neither in the inoculated nor in the uninoculated pots.

### 3.11 Preparation and amendment of peat material

The peat soil was collected from Gopalgonj and the pH was measured by glass electrode method. The pH of the peat soil was 4.5 and it was adjusted to 6.8 by adding $CaCO_3$ solution. Fifty grams of amended peat having 8 percent moisture was taken in each polyethylene bag and the bags were sealed up. Then they were sterilized by autoclaving in $120^0$C at 15 PSI for three consecutive days for one hour each day. The sealed peat was ready for inoculation.

### 3.12 Inoculum preparation

The bradyrhizobial inoculant was prepared in the Soil Microbiology Laboratory of Bangladesh Agricultural Research Institute (BARI) using the broth culture. The *Bradyrhizobium* strains (BARI RVm-301, BARI RVm-302 and BARI RVm-303) were collected from the stock culture of the laboratory. Yeast mannitol broth was prepared in a 500 mL Erlenmeyer flask. The liquid medium was sterilized for 30 minutes at $121^0$ C at 15 PSI. The medium was kept for cooling. After cooling, a small portion of *Bradyrhizobium* culture was aseptically transferred from agar slant to the liquid medium in the flask with the help of a sterile inoculation needle. The flask was then placed in the shaker at $28^0$C under 120 rpm to enhance bradyrhizobial growth. After 4-5 days, the medium in the flask showed dense growth and then the broth culture was taken out from the shaker. From this ready broth, 30 mL were taken out by sterile syringe and injected into the polyethylene packet having the sterile peat. Finally, the moisture percent of the packet was adjusted to 50 percent. The inoculated packets were then incubated at $28^0$C for two weeks to make them ready for seed inoculation.

### 3.13 Viability count of *Bradyrhizobium*

Viability count of bradyrhizobia in the inoculant was made one day before injecting into the peat following plate count method (Vincent, 1970). The average number of bradyrhizobia was approximately above $10^8$ cells $g^{-1}$ in the inoculant.

### 3.14 Procedure for inoculation

Inoculation was done just before sowing. Healthy 20 blackgram seeds of each variety were taken into polyethylene bags separately and sufficient sticker solution (4% gum acacia solution) was added to each bag with sterilized pipettes. It was followed by addition of desired peat based *Bradyrhizobium* inoculant to each polyethylene bag and mixed thoroughly for uniform distribution and good adherence of inoculant on the surface of each seed.

### 3.15 Sowing

Twenty healthy blackgram seeds (BARI Mash-1, BARI Mash-2 and BARI Mash-3), inoculated with BARI RVm-301, BARI RVm-302 and BARI RVm-303, mixed culture (BARI RVm-301, BARI RVm-302 and BARI RVm-303) or non-inoculated, were sown on $5^{th}$ September 2011 in each pot by dibbling method. After sowing the seed, the soil was saturated with water.

### 3.16 Intercultural operation

The seedlings of the crop emerged out within 3-4 DAS. Thinning and first weeding were done 5 days after sowing of seeds. In thinning one of the seedlings was removed from each hole in which both the planted seeds germinated. The geminated seedlings were removed for thinning by Khurpi. Uprooting was not done since this injures the adjacent seedlings that were left behind. Finally three plants were kept in each pot for final harvesting of the crop. Second weeding was done 20 days after the first weeding. After second weeding, 12 plants in each pot were allowed to grow. Necessary water was added to the pots at a regular interval of 7 days until crop maturity to maintain proper moisture content. Pest did not infest the blackgram crop. No disease was observed in the pot experiment.

### 3.17 Collection of samples

The following observations were made regarding the growth, yield and nutrient content from the sample plants during the course of experiment.

#### 3.17.1 Plant

Plant samples were collected at 35 and 50 DAS days after sowing to record data on nodule and shoot parameters. Three plants from each pot were selected randomly and uprooted carefully by digging soil with the help of "khurpi". All possible precautions were taken to minimize the loss of nodules.

#### 3.17.2 Study on nodulation

The plants uprooted for sampling were washed in running water cautiously to make them free from adhering soil particles and dipped in fresh water contained in a tray to avoid shrinkage of nodules. The nodules were counted, kept separately pot-wise and their dry weights were recorded. The data on nodule number and nodule mass were recorded by taking

3 randomly selected plants from each pot at two times. The data on nodule mass were expressed in mg plant$^{-1}$ on oven dry basis.

### 3.17.3 Shoot weight and root weight

After separation of the roots, dry shoot and root weights of three selected plants were recorded.

### 3.17.4 Shoot length and root length

Shoot and root lengths of the plant samples of three selected plants were recorded

## 3.18 Harvesting and data recording on yield and yield contributing characters

Yield data were collected from each pot. The seeds and stover were dried and weighed adjusting at 14% moisture content and yields were converted to g plant$^{-1}$. The following parameters were recorded:

i) Seed yield (g plant$^{-1}$)
ii) Stover yield (g plant$^{-1}$)
iii) Plant height (cm)
iv) Pod length (cm)
v) No. of Pods plant$^{-1}$
vi) No. Seeds pod$^{-1}$
vii) 100-seed weight (g)

## 3.19 Estimation of N

The N concentration in seed and stover was determined by micro-Kjeldahl method.

## 3.20 Plant analysis

### 3.20.1 Collection and preparation of plant samples for chemical analysis

Plant sample (seed and stover) was collected from bulk harvest. The seed and sotver sample was then oven dried at 65°C for 24 hours. To obtain homogenous powder, the samples were finely ground and passed through a 60-mesh sieve. The samples were stored in polyethylene bags for N determination.

### 3.20.2 Chemical analysis of plant samples

Seed and sotver of blackgram were analyzed for determination of N concentrations following the methods described below:

**Nitrogen**

The plant sample (0.1 g grain seed and sotver) was digested with conc. $H_2SO_4$, hydrogen peroxide and $K_2SO_4$-catalyst mixture ($K_2SO_4$: $CuSO_4$. $5H_2O$: Se = 10: 1: 0.1) at 200°C for one and a half-hour. Nitrogen in the digest was estimated by distilling the digest with 10N NaOH followed by titration of the distillate trapped in $H_3BO_3$ indicator solution with 0.01N $H_2SO_4$.

### 3.21 Nitrogen uptake

Nitrogen uptake by seed and stover blackgram was computed from the respective chemical concentration and dry matter yields of seeds and sotver.

### 3.22 Soil analysis

Methods of soil analysis are presented in Table 3.3

**Table 3.3. Methods used for soil analysis**

| Soil Properties | Methods |
|---|---|
| Soil texture | Hydrometer method (Black, 1965). The texture class was determined using Marshall's Triangular Coordinates of USDA system |
| pH | Glass-electrode pH meter with 1:2.5 soil-water ratio (Jackson, 1973). |
| Organic carbon | Wet digestion method (Nelson and Sommers, 1982). The organic matter was oxidized by 1N potassium dichromate and the amount of organic carbon in the aliquot was determined by titration against 0.5N ferrous sulphate heptahydrate solution in presence of 0.025 M O-phenanthroline ferrous complex. |
| Total N | Microkjeldahl method (Bremner and Mulvaney, 1982). Soil sample was digested with conc. $H_2SO_4$ in presence of $K_2SO_4$ catalyst mixture ($K_2SO_4$: $CuSO_4$: Se = 10:1:1). Nitrogen in the digest was estimated by distilling the digest with 10N NaOH followed by titration of the distillate trapped in $H_3BO_3$ indicator solution with 0.01N $H_2SO_4$. |
| $NH_4^+$-N | Extracted by 2M KCl solution (1:10 soil-extractant ratio). The aliquot was steam distilled with MgO and Devardas alloy (Keeney and Nelson, 1982). |

| Soil Properties | Methods |
|---|---|
| CEC | Sodium acetate saturation method (Rhoades, 1982). The soil was leached with an excess of 1 M sodium acetate solution to remove the exchangeable cations and saturate the exchange material with sodium. The replaced sodium was determined by flame photometer. |
| Available P | Extracted by 0.5M $NaHCO_3$ (pH 8.5) and determined colorimetrically using molybdate blue ascorbic acid method (Olsen and Sommers, 1982). |
| Available K | Extracted by repeated shaking and centrifugation of the soil with neutral 1M $NH_4OAc$ followed by decantation. The K concentration in the extract was determined by flame photometer as outlined by Knudsen *et al.* (1982). |
| Available S | Extracted by 500 ppm P solution from Ca $(H_2PO_4).H_2O$ and estimated by turbidimetric method using $BaCl_2$ (Fox *et al.*, 1964). |
| Available Zn | Extracted by 0.05N HCl solution and determined directly by AAS (Page *et al.*, 1982). |
| Available Cu, Mn and Fe | Extracted by 0.005M DTPA solution and directly measured by AAS (Lindsay and Norvell, 1978). |
| Bulk density | Core sampling procedure (Black, 1965). |
| Water holding capacity | Determined gravimetrically using brass box following the method of Klute as described by Black (1965). |

### 3.23 Statistical analysis

The collected data were analyzed statistically and Duncan's Multiple Range Test (DMRT) using a computer IRRISTAT and M-stat package programmes (Freed, 1992) adjudged the means. The correlation co-efficient were done for different variables wherever needed using Microsoft EXCEL programme 1997.

# Chapter 4
# Results and Discussion

# CHAPTER IV

# RESULTS AND DISCUSSION

The experimental data regarding nodulation, dry matter production, plant growth, yield and yield attributing characters of three blackgram varieties were analyzed on the basis of the design and interpreted. The results of the experiments are presented and discussed in this chapter. Data on seed and stover yields, the yield contributing characters, and nitrogen concentration in seed and stover have also been recorded.

## 4.1 Total number of nodule

### 4.1.1 Effect of variety

Observation on total nodule number $plant^{-1}$ revealed that three varieties of blackgram were identical both at 35 DAS and 50 DAS (Fig. 4.1 and App. 4.1). At 35 DAS, the highest number of nodules (5.53 $plant^{-1}$) was produced by BARI Mash-1 and BARI Mash-3. BARI Mash-2 produced (5.33) lesser number of nodules $plant^{-1}$. At 50 DAS, BARI Mash-1 gave the highest nodule number (7.77 $plant^{-1}$) that was identical with BARI Mash-2 and BARI Mash-3. It indicated that all the three blackgram varieties produced identical number of nodules at both the sampling dates. Roy (2001) conducted a field experiment on three mungbean varieties of mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and reported that varieties differed significantly on nodule number of mungbean. Bhuiyan *et al.* (2010) carried out field experiments at Joydebpur, Jamalpur and Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed that BARI Mash-3 gave significantly higher nodule number at Joydebpur and Jamalpur while not-significant effects on nodule number was observed at Rahmatpur.

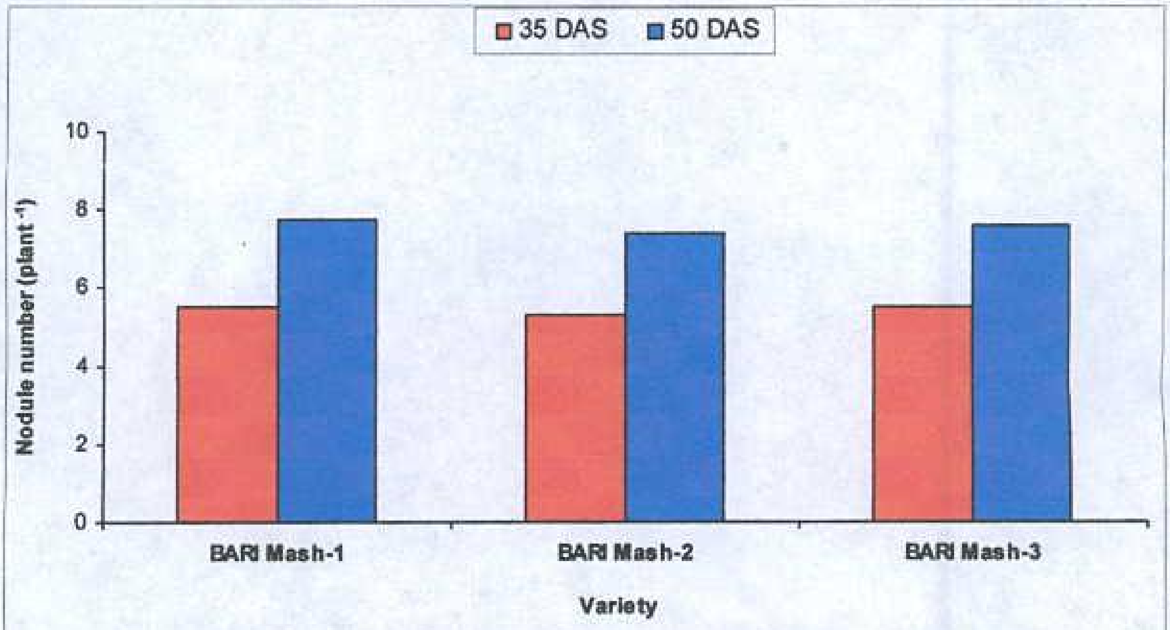


**Fig. 4.1. Effect of variety on nodule number of blackgram**

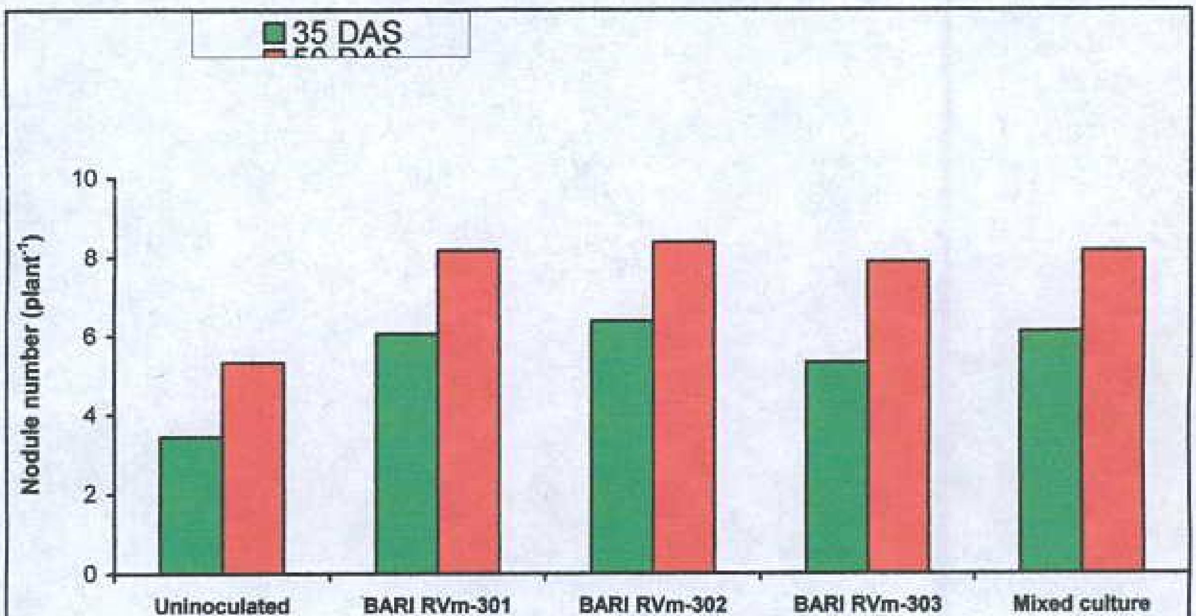


**Fig. 4.2. Effect of *Bradyrhizobium* inoculant on nodule number of mungbean**

### 4.1.2 Effect of *Bradyrhizobium*

There was highly significant response of *Bradyrhizobium* inoculant on total number of nodule plant$^{-1}$ (Fig. 4.2 and App. 4.2). Inoculated plants produced significantly higher number of nodules over uninoculated plant at both the DAS. At 35 DAS, the highest number of nodules (6.39 nodule plant$^{-1}$) was produced by the application of *Bradyrhizobium* inoculant strain BARI RVm-302 which was identical with BARI RVm-301 and mixed culture, and the lowest number of nodules was produced in uninoculated plant (3.44 nodule plant$^{-1}$). Strain BARI RVm-303 gave minimum nodules. At 50 DAS, BARI RVm-302 also showed the highest number of nodules (8.39 nodule plant$^{-1}$) which was identical with that of all other strains and mixed culture. The lowest number of nodule (5.33 plant$^{-1}$) was noted in uninoculated plant. Jayakumar *et al.* (1997) reported that *Rhizobium* inoculation increased number of nodules plant$^{-1}$ compared to controls. Nagarajan and Balachandar (2001) reported that seed inoculation of *Rhizobium* enhanced root nodulation. Kumari and Nair (2003) found that the extent of root nodulation were more in blackgram and greengram where *Bradyrhizobium* inoculation were done.

### 4.1.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect between varieties and *Bradyrhizobium* inoculation was not significant on total number of nodule at both 35 DAS and 50 DAS (Table 4.1). At 35 DAS, the highest number of nodule (7.00 nodule plant$^{-1}$) was obtained by the treatment combinations of BARI Mash-1 x mixed culture and the minimum nodules (3.33 plant$^{-1}$) was observed in BARI Mash-1 x uninoculated treatment. In case of 50 DAS, the highest nodule number (8.50 nodule plant$^{-1}$) was produced by the interaction of BARI Mash-1 x BARI RVm-302, BARI Mash-1 x mixed culture and BARI Mash-3 x mixed culture. BARI Mash-3 x Uninoculated treatment gave the lowest nodule number (5.00 nodule plant$^{-1}$). Sarkar *et al.* (2002) reported that the interaction effect between cultivar A-43 and *Bradyrhizobium* strain MK-5 resulted in the highest number of nodules plant$^{-1}$ (7.03). Hossain and Solaiman (2004) reported that BARI Mung-4 in combination with TAL169 performed the best in terms of nodulation. Bhuiyan and Mian (2007) reported that among five mungbean varieties inoculated BARI Mung-2 produced the highest nodule number (19.3 plant$^{-1}$ in 2001 and 19.0 plant$^{-1}$ in 2002) in mungbean. Bhuiyan *et al*. (2006) also observed that the number of total nodules plant$^{-1}$ was the highest (19) at 42 DAS in inoculated BARI Mung-2. Solaiman *et al*. (2003) observed that BARI Mung-4 inoculated with strain TAL 169 produced higher nodulation. Naher (2000) also reported similar results. Bhuiyan and Mian (2009) reported that inoculated BARI Mung-2 produced greater number of nodules at different sampling dates over uninoculated plant.

**Table 4.1. Interaction effect of varieties and *Bradyrhizobium* inoculation on nodule number and nodule weight of blackgram**

| Treatment | Nodule no. plant$^{-1}$ | | Nodule weight (mg plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 x Uninoculated | 3.33 | 5.50 | 3.83 | 7.23 |
| BARI Mash-1 x BARI RVm-301 | 5.50 | 8.00 | 5.80 | 10.60 |
| BARI Mash-1 x BARI RVm-302 | 6.50 | 8.50 | 6.70 | 11.73 |
| BARI Mash-1 x BARI RVm-303 | 5.33 | 8.33 | 5.53 | 10.80 |
| BARI Mash-1 x Mixed culture | 7.00 | 8.50 | 7.30 | 10.83 |
| BARI Mash-2 x Uninoculated | 3.50 | 5.50 | 3.70 | 7.17 |
| BARI Mash-2 x BARI RVm-301 | 6.17 | 8.37 | 6.87 | 11.50 |
| BARI Mash-2 x BARI RVm-302 | 6.17 | 8.37 | 6.87 | 11.57 |
| BARI Mash-2 x BARI RVm-303 | 5.33 | 7.33 | 6.83 | 11.00 |
| BARI Mash-2 x Mixed culture | 5.50 | 7.50 | 5.90 | 11.25 |
| BARI Mash-3 x Uninoculated | 3.50 | 5.00 | 3.57 | 7.00 |
| BARI Mash-3 x BARI RVm-301 | 6.50 | 8.17 | 7.00 | 11.00 |
| BARI Mash-3 x BARI RVm-302 | 6.50 | 8.30 | 7.00 | 11.50 |
| BARI Mash-3 x BARI RVm-303 | 5.33 | 8.00 | 6.13 | 11.25 |
| BARI Mash-3 x Mixed culture | 5.83 | 8.50 | 6.63 | 11.73 |
| SE (±) | 0.32 | 0.47 | 0.42 | 0.44 |
| Level of sig. | NS | NS | NS | NS |
| CV (%) | 10.2 | 10.8 | 12.2 | 7.4 |

NS = Not significant

### 4.2 Nodule weight

#### 4.2.1 Effect of variety

The variation in nodule weight was not significantly influenced due to different varieties at both 35 and 50 DAS (Fig. 4.3 and App. 4.1). At 35 DAS, maximum nodule weight (6.07 mg $plant^{-1}$) was obtained with BARI Mash-3 and the minimum nodule weight (5.83 mg $plant^{-1}$) was produced by BARI Mash-1 and BARI Mash-2 (Fig. 4.3 and Appendix. 4.1). At 50 DAS, the maximum nodule weight (10.50 mg $plant^{-1}$) was observed in BARI Mash-2 and BARI Mash-3, and minimum nodule weight (10.24 mg $plant^{-1}$) was observed in BARI Mash-1. The above results differed with the findings of Roy (2001). He carried out a field experiment on three mungbean varieties using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and found that nodule weight varied significantly due to different varieties. Bhuiyan *et al*. (2010) carried out field experiments at Joydebpur, Jamalpur and Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed that BARI Mash-3 gave significantly higher nodule weight at Joydebpur and BARI Mash-1 gave significantly higher nodule weight at Jamalpur while it was not-significant effect on nodule weight was observed at Rahmatpur.

#### 4.2.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* inoculation was significant on nodule weight at both 35 DAS and 50 DAS (Fig. 4.4 and App. 4.2). Weight of nodule was maximum (6.86 mg $plant^{-1}$) at 35 DAS in BARI RVm-302 which was identical with BARI RVm-301 and mixed culture but differed from that of BARI RVm-303. The minimum nodule weight (3.70 mg $plant^{-1}$) was produced by uninoculated treatment at 35 DAS. At 50 DAS, the minimum nodule weight (7.13 mg $plant^{-1}$) was produced by uninoculated plant and the maximum nodule weight (11.60 mg $plant^{-1}$) was produced by BARI RVm-302 which was identical with other strains and mixed culture. Nagarajan and Balachandar (2001) reported that *Rhizobium* gave higher nodule weight (45.3 and 42.3 mg) in blackgram and greengram. Tomar *et al*. (2003) found that *Rhizobium* gave the highest and 34.7% more nodule dry mass. Kumari and Nair (2003) observed significant increases in nodule dry weight due to *Rhizobium* inoculation.

### 4.2.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of varieties and *Bradyrhizobium* inoculation on weight of nodules was not significant on nodule weight at 35 DAS and 50 DAS (Table 4.1). At 35 DAS, the maximum nodule weight (7.30 mg plant$^{-1}$) was produced by BARI Mash-1 x mixed culture and the minimum nodule weight (3.57 mg plant$^{-1}$) was produced by BARI Mash-3 x uninoculated treatment. At 50 DAS, the maximum nodule weight (11.73 mg plant$^{-1}$) was produced by Mash-1 x BARI RVm-302 and BARI Mash-3 x mixed culture. While the minimum nodule weight (7.00 mg plant$^{-1}$) at 50 DAS was produced by BARI Mash-3 x uninoculated treatment. Bhuiyan and Mian (2007) observed that BARI Mung-2 gave the highest nodule weight with *Bradyrhizobium* inoculation. Bhuiyan *et al.* (2006) also found that the highest dry weight of nodules was recorded in BARI Mung-2 with inoculation. Mozumder *et al*. (2005) found that inoculated BINA Moog-2 gave higher nodule weight.



## 4.3 Root weight

### 4.3.1 Effect of variety

The varietal effect on root weight at 35 DAS was not significant though the maximum root weight (0.04 g plant$^{-1}$) was produced by BARI Mash-2 (Table 4.2). At 50 DAS the weight of roots was significantly influenced by different varieties. The maximum root weight (0.14 g plant$^{-1}$) at 50 DAS was produced by BARI Mash-2 which was identical with that of BARI Mash-3 and the minimum root weight (0.12 g plant$^{-1}$) was produced by BARI Mash-1. Bhuiyan *et al*. (2010) carried out field experiments at Joydebpur, Jamalpur and Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed that BARI Mash-3 gave significantly higher root weight at Joydebpur but it was not significant effect on root weight was found at Jamalpur and Rahmatpur.

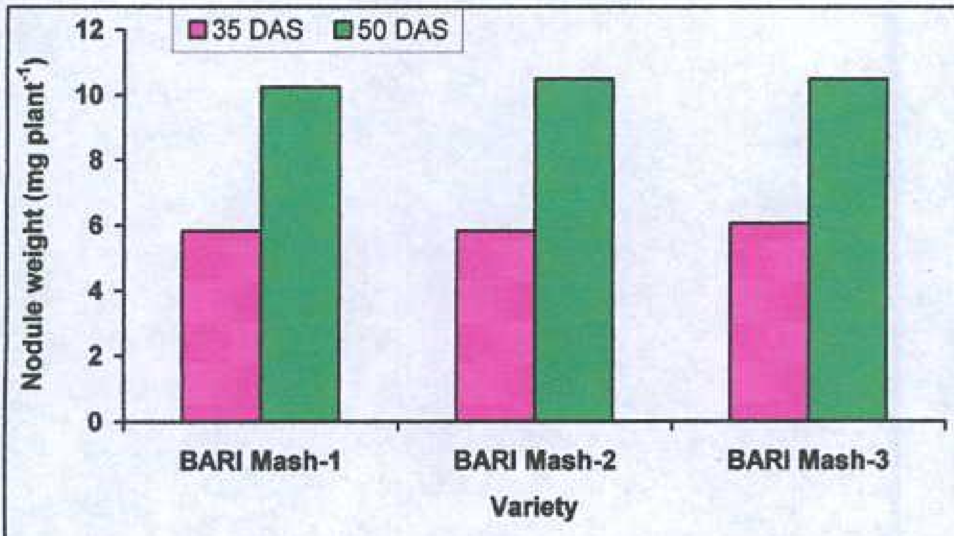


**Fig. 4.3. Effect of variety on nodule weight in blackgram**

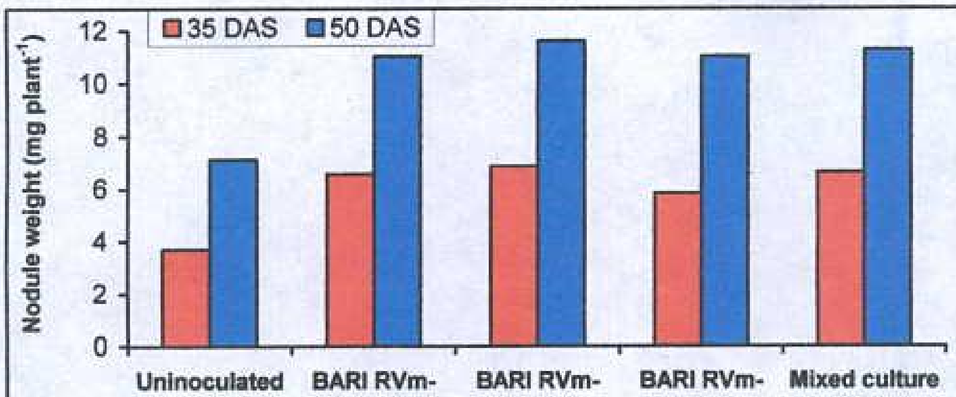


**Fig. 4.4. Effect of *Bradyrhizobium* inoculant on nodule weight in blackgram**

**Table 4.2. Effects of varieties on root weight and shoot weight of blackgram**

| Variety | Root weight (g plant$^{-1}$) | | Shoot weight (g plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 | 0.038 | 0.12b | 0.097 | 2.10a |
| BARI Mash-2 | 0.040 | 0.14a | 0.097 | 2.01b |
| BARI Mash-3 | 0.039 | 0.13ab | 0.097 | 1.99b |
| SE (±) | 0.0016 | 0.004 | 0.0027 | 0.03 |
| Level of sig. | NS | ** | NS | * |

In a column, the figures(s) having different letter(s) differed significantly
* Significant at 5% level, ** Significant at 1% level
NS = Non significant

### 4.3.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* was highly significant on root weight of Mash (Table 4.3). At 35 DAS, the maximum root weight (0.043 g plant$^{-1}$) was produced by mixed culture and the minimum root weight was produced by uninoculated plant. At 50 DAS, the minimum root weight (0.10 g plant$^{-1}$) was produced in uninoculated plants. All the strains produced identical root weight at 50 DAS. Srivastav and Poi (2000) found that inoculation with M-10 strain in greengram resulted in the highest dry matter production. Sharma *et al.* (2000) reported that seed inoculated with 1 of 9 *Rhizobium* strains increased dry matter accumulation. Parveen *et al.* (2002) reported that the maximum root dry weight (0.37 g plant$^{-1}$) was observed with single *Bradyrhizobium* sp.

**Table 4.3. Effect of *Bradyrhizobial* inoculants on root weight and shoot weight of blackgram**

| *Bradyrhizobium* inoculant | Root weight (g plant$^{-1}$) | | Shoot weight (g plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| Uninoculated | 0.032b | 0.10b | 0.081b | 1.72b |
| BARI RVm-301 | 0.040a | 0.14a | 0.098a | 2.09a |
| BARI RVm-302 | 0.042a | 0.14a | 0.101a | 2.10a |
| BARI RVm-303 | 0.040a | 0.14a | 0.100a | 2.13a |
| Mixed culture | 0.043a | 0.14a | 0.104a | 2.12a |
| SE (±) | 0.0021 | 0.005 | 0.0034 | 0.04 |
| Level of sig. | ** | ** | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

### 4.3.3 Interaction effect of variety and *Bradyhizobium*

The root weight of different varieties of BARI Mash did not vary significantly due to interaction with different strains of *Bradyrhizobium* (Table 4.4). At 35 DAS, the highest value (0.047 g $plant^{-1}$) was recorded by the interaction of BARI Mash-3 x mixed culture and the minimum root weight (0.028 g $plant^{-1}$) was recorded by the interaction of BARI Mash-1 x uninoculated treatment. At 50 DAS, the maximum root weight (0.16 g $plant^{-1}$) was recorded by the interaction of BARI Mash-2 x BARI RVm-302 and BARI Mash-3 x BARI RVm-301 and the minimum root weight (0.097 g $plant^{-1}$) was recorded by the interaction of BARI Mash-1 x uninoculated plant. Kavathiya and Pandey (2000) conducted a pot experiment during the summer season of 1992-1993 in Gujrat, India and reported that fresh root weight (4.42 g) were recorded in the *Rhizobium* inoculation treatment. Parveen *et al.* (2002) conducted a field experiment to observe the effect of rhizospheric microorganisms on growth and yield of greengram (*Phaseolus radiata*) and reported that the maximum root dry weight (0.37 g $plant^{-1}$) was observed in inoculation with single *Bradyrhizobium* sp. only.



## 4.4 Shoot weight

### 4.4.1 Effect of variety

The effect of variety on variation in shoot weight was not significant at 35 DAS but it was significant at 50 DAS (Table 4.2). At 50 DAS, the highest shoot weight (2.10 g $plant^{-1}$) was produced by BARI Mash-1 which differed from BARI Mash-2 and BARI Mash-3, and the lowest shoot weight (1.99 g $plant^{-1}$) was produced by BARI Mash-3. Roy (2001) observed that varieties differed significantly on shoot weight of mungbean. Bhuiyan *et al.* (2010) conducted field experiments at Joydebpur, Jamalpur and Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed that the shoot weight did not vary sinificantly at all the locations. Nag *et al.* (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties (BARI Mash-1, BARI

Mash-2 and BARI Mash-3) to evaluate their yield and yield attributes. Among the three cultivars, BARI Mash-1 recorded the highest dry matter yield.

**Table 4.4. Interaction effect of varieties and *Bradyrhizobium* inoculants on root weight and shoot weight of blackgram**

| Treatment | Root weight (g plant$^{-1}$) | | Shoot weight (g plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 x Uninoculated | 0.028 | 0.10 | 0.087 | 1.90c |
| BARI Mash-1 x BARI RVm-301 | 0.043 | 0.12 | 0.093 | 2.13abc |
| BARI Mash-1 x BARI RVm-302 | 0.038 | 0.13 | 0.100 | 2.23a |
| BARI Mash-1 x BARI RVm-303 | 0.040 | 0.14 | 0.097 | 2.20ab |
| BARI Mash-1 x Mixed culture | 0.040 | 0.13 | 0.107 | 2.03abc |
| BARI Mash-2 x Uninoculated | 0.033 | 0.10 | 0.080 | 1.70d |
| BARI Mash-2 x BARI RVm-301 | 0.037 | 0.15 | 0.097 | 1.93c |
| BARI Mash-2 x BARI RVm-302 | 0.040 | 0.16 | 0.103 | 2.00b |
| BARI Mash-2 x BARI RVm-303 | 0.043 | 0.15 | 0.100 | 2.20ab |
| BARI Mash-2 x Mixed culture | 0.043 | 0.15 | 0.103 | 2.23a |
| BARI Mash-3 x Uninoculated | 0.033 | 0.10 | 0.077 | 1.57d |
| BARI Mash-3 x BARI RVm-301 | 0.037 | 0.16 | 0.103 | 2.20ab |
| BARI Mash-3 x BARI RVm-302 | 0.043 | 0.13 | 0.100 | 2.07abc |
| BARI Mash-3 x BARI RVm-303 | 0.037 | 0.13 | 0.103 | 2.00bc |
| BARI Mash-3 x Mixed culture | 0.047 | 0.14 | 0.103 | 2.10abc |
| SE (±) | 0.0036 | 0.008 | 0.006 | 0.07 |
| Level of sig. | NS | NS | NS | ** |
| CV (%) | 16.0 | 11.0 | 10.7 | 6.1 |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Not significant

#### 4.4.2 Effect of *Bradyrhizobium*

*Bradyrhizobium* inoculants showed significant effect on shoot weight at both 35 DAS and 50 DAS (Table 4.3). At 35 DAS, the maximum value (0.104 g plant$^{-1}$) was recorded by mixed culture that was identical with all other strains and the lowest shoot weight (0.081 g plant$^{-1}$) was observed in uninoculated plant. At 50 DAS, the strain BARI RVm-303 showed the highest performance on shoot weight (2.13 g plant$^{-1}$) which was also identical with other strains but superior to uninoculated plant. Jayakumar *et al.* (1997) reported that *Rhizobium* inoculation increased the dry weight of plants compared to that of controls. Srivastav and Poi (2000) found that inoculation with M-10 strain in greengram resulted in the highest dry matter production. Sharma *et al.* (2000) reported that seed inoculated with 1 of 9 *Rhizobium* strains increased dry matter accumulation. Manivannan *et al.* (2003) reported that *Rhizobium* seed treatment produced markedly higher dry matter. Kavathiya and Pandey (2000) reported that maximum fresh shoot weight (5.33 g) was recorded in the *Rhizobium* treated plot. Bhattacharyya and Pal (2001) conducted a field experiment in West Bengal, India, during the pre-*kharif* season of 1998 to study the effect of *Rhizobium* inoculation and reported that inoculation significantly influenced dry matter accumulation in the shoot.

### 4.4.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect between variety and *Bradyrhizobium* on shoot weight was not significant at 35 DAS but it was significant at 50 DAS (Table 4.4). The interaction effect between BARI Mash-1 x mixed culture showed the highest performance on shoot weight (0.107 g plant$^{-1}$) and the lowest shoot weight (0.077 g plant$^{-1}$) was produced by the interaction of BARI Mash-3 x uninoculated treatment. At 50 DAS, the highest value of shoot weight (2.23 g plant$^{-1}$) was recorded by the interaction of BARI Mash-1 x BARI RVm-302 and BARI Mash-2 x mixed culture, and the lowest shoot weight (1.57) was recorded by the interaction of BARI Mash-3 x uninoculated treatment. Chowdhury *et al.* (2000) carried out a pot experiment during *kharif* season in 1995 with mungbean at IPSA, Salna, Gazipur, Bangladesh where mungbean line NM-92 was inoculated with *Rhizobium* strain TAL 303 and found that dry matter production was increased by about 50% due to *Bradyrhizobium* inoculation. Bhuiyan and Mian (2007) conducted experiments with or without *Bradyrhizobium* in five mungbean varieties at Bangladesh Agricultural University Farm during *kharif*-I 2001 and *kharif*-I 2002 seasons and observed that BARI Mung-5 with *Bradyrhizobium* inoculant gave the highest shoot weight in 2001 and BARI Mung-4 with

*Bradyrhizobium* inoculant gave the highest shoot weight in 2002. Bhuiyan *et al.* (2007b) also found that inoculated BARI Mung-2 produced the highest shoot weights. Mozumder *et al.* (2005) found that inoculated Kanti gave higher shoot weight in mungbean.

### 4.5 Root length

#### 4.5.1 Effect of variety

The effect of variety on root length was significant at 35 DAS but it was not significant at 50 DAS (Table 4.5). At 35 DAS, BARI Mash-1 produced the highest root length (3.63 cm) which differed from BARI Mash-2 and BARI Mash-3, and the lowest root length (2.73 cm) was produced by BARI Mash-3. But at 50 DAS, higher root length (3.67 cm) was produced by BARI Mash-3 and lower root length (3.60 cm) was produced by BARI Mash-2. Roy (2001) conducted a field experiment on three mungbean varieties of mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and found that varieties differed significantly on root length of mungbean.

**Table 4.5. Effects of varieties on root length and shoot length of blackgram**

| Variety | Root length (cm) | | Shoot length (cm) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 | 3.63 a | 3.63 | 24.16ab | 32.02b |
| BARI Mash-2 | 3.09 b | 3.60 | 26.20a | 33.55a |
| BARI Mash-3 | 2.73 b | 3.67 | 23.83b | 32.18b |
| SE (±) | 0.17 | 0.107 | 0.57 | 0.341 |
| Level of sig. | ** | NS | * | ** |

In a column, the figures(s) having different letter(s) differed significantly
* Significant at 1% level, ** Significant at 1% level
NS = Not significant

#### 4.5.2 Effect of *Bradyrhizobium*

The result presented in Table 4.6 showed that the effect of *Bradyrhizobium* on root length was significant both at 35 DAS and 50 DAS. The highest root length at 35 DAS produced by BARI RVm-301 was identical with BARI RVM-302 and mixed culture but different from BARI RVm-303 and uninoculated control. At 50 DAS, BARI RVm-301 also showed higher root length (4.11 cm) which was statistically identical with BARI RVm-302 and BARI RVm-303 but it was significantly different in mixed culture. The above results confirmed the results of Sudhakar *et al.* (1989) who conducted an experiment on blackgram and found that *Rhizobium* inoculation increased crop growth rate compared to non-inoculated control. Sharma *et al.* (2000) reported that plant growth was increased with *Rhizobium* inoculation, with the local strain giving the best results. Sarkar *et al.* (2002) reported that bradyrhizobial strain 480-M gave the longest roots (14.72 cm) in blackgram.

**Table 4.6. Effect of *bradyrhizobial* inoculants on root length and shoot length of blackgram**

| *Bradyrhizobium* inoculant | Root length (cm) | | Shoot length (cm) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| Uninoculated | 2.66c | 2.83c | 22.78b | 29.00c |
| BARI RVm-301 | 3.67a | 4.11a | 25.11a | 36.39a |
| BARI RVm-302 | 3.40ab | 4.00a | 25.89a | 33.83b |
| BARI RVm-303 | 2.93bc | 3.83a | 24.11ab | 31.08c |
| Mixed culture | 3.11abc | 3.38b | 25.77a | 32.61b |
| SE (±) | 0.22 | 0.138 | 0.74 | 0.44 |
| Level of sig. | * | ** | * | ** |

In a column, the figures(s) having different letter(s) differed significantly
* Significant at 5% level, ** Significant at 1% level
NS = Not significant

### 4.5.3 Interaction effect of variety and *Bradyrhizobium*

The interaction of variety and *Bradyrhizobium* on root length was not significant at 35 DAS and significant at 50 DAS (Table 4.7). The highest root length (4.50 cm) at 35 DAS was found by the interaction of BARI Mash-1 x BARI RVm-302 and the lowest root length (2.47 cm) was found by the interaction of BARI Mash-2 x uninoculated treatment. At 50 DAS, the highest root length (4.83 cm) was found by the interaction of BARI Mash-3 x BARI RVm-301 and the lowest root length (2.50 cm) was found by the interaction of BARI Mash-3 x uninoculated treatment.

**Table 4.7. Interaction effect of varieties and *Bradyrhizobium* inoculants on root length and shoot length of blackgram**

| Treatment | Root length (cm) | | Shoot length (cm) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 x Uninoculated | 3.00 | 3.33cde | 22.67 | 28.83f |
| BARI Mash-1 x BARI RVm-301 | 3.83 | 4.33ab | 23.33 | 38.00a |
| BARI Mash-1 x BARI RVm-302 | 4.50 | 3.66bcd | 25.83 | 30.00def |
| BARI Mash-1 x BARI RVm-303 | 3.33 | 3.66bcd | 23.67 | 31.25cde |
| BARI Mash-1 x Mixed culture | 3.50 | 3.16def | 25.32 | 32.00cd |
| BARI Mash-2 x Uninoculated | 2.47 | 2.66ef | 24.00 | 29.50ef |
| BARI Mash-2 x BARI RVm-301 | 4.33 | 3.16def | 27.33 | 33.00c |
| BARI Mash-2 x BARI RVm-302 | 3.00 | 4.33ab | 27.33 | 39.75a |
| BARI Mash-2 x BARI RVm-303 | 3.83 | 4.16b | 25.00 | 30.00def |
| BARI Mash-2 x Mixed culture | 2.83 | 3.66bcd | 27.33 | 35.50b |
| BARI Mash-3 x Uninoculated | 2.50 | 2.50f | 21.67 | 28.66f |
| BARI Mash-3 x BARI RVm-301 | 2.83 | 4.83a | 24.67 | 38.16a |
| BARI Mash-3 x BARI RVm-302 | 2.70 | 4.00bc | 24.50 | 31.75cd |
| BARI Mash-3 x BARI RVm-303 | 2.63 | 3.66bcd | 23.67 | 32.00cd |
| BARI Mash-3 x Mixed culture | 3.00 | 3.33cde | 24.67 | 30.33def |
| SE (±) | 0.37 | 0.23 | 1.28 | 0.76 |
| Level of sig. | NS | ** | NS | ** |
| CV (%) | 20.5 | 11.4 | 9.0 | 4.1 |

In a column, the figures(s) having different letter(s) differed significantly

** Significant at 1% level, NS = Not significant

### 4.6 Shoot length

#### 4.6.1 Effect of variety

The effect of variety on shoot length was significant at both 35 DAS and 50 DAS (Table 4.5). At 35 DAS, BARI Mash-2 showed the longest shoot length (26.20 cm) which was identical to BARI Mash-1. The shortest shoot length was observed in BARI Mash-3. At 50 DAS, the longest shoot length (33.55 cm) was produced by BARI Mash-2 that differed from other two varieties. Roy (2001) carried out a field experiment on three mungbean varieties of mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and noted that varieties differed significantly on shoot length of mungbean. Nag *et* *al*. (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties and observed that BARI Mash-1 had the highest plant height. Kumari and Nair (2003) found that the extent of plant growth were more in blackgram and greengram where *Bradyrhizobium* inoculation were done.

### 4.6.2 Effect of *Bradyrhizobium*

Effect of *Bradyrhizobium* on shoot length was significant at 35 DAS and highly significant at 50 DAS (Table 4.6). The longest shoot (25.89 cm) was observed in the inoculants BARI RVm-302 and it was identical with all other strains. The shortest value of shoot (22.78 cm) was noted by uninoculated plant. At 50 DAS, BARI RVm-301 produced the longest shoot (36.39 cm) and the shortest value was observed in uninoculated plants. The longest shoot length recorded by BARI RVm-301 was superior to all other strains at 50 DAS. Nagarajan and Balachandar (2001) reported that *Rhizobium* gave the maximum plant height (42.7 and 53.7 cm for blackgram and greengram, respectively). Bhattacharya and Pal (2001) reported that *Rhizobium* inoculation significantly increased plant height. Malik *et al*. (2002) studied that plant height at harvest was the highest when inoculated with *Bradyrhizobium* (68.13 cm). Ashraf *et al*. (2003) found that the tallest plants (69.93 cm) were obtained with seed inoculation. Kumari and Nair (2003) observed that the extent of plant growth were more in blackgram and greengram where *Bradyrhizobium* inoculation was done. Sriramachandrasekharan and Vaiyapuri (2003) reported that *Rhizobium*-inoculated blackgram showed better growth than the non-inoculated crop.

### 4.6.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of variety x *Bradyrhizobium* on shoot length was not significant at 35 DAS but it was significant at 50 DAS (Table 4.7). At 35 DAS, the longest shoot length (27.33 cm) was noted by the interaction of BARI Mash-2 x BARI RVm-301, BARI Mash-2 x BARI RVm-302 and BARI Mash-2 x mixed culture, and the shortest value was observed by the interaction of BARI Mash-3 x uninoculated plant. At 50 DAS, BARI Mash-2 x BARI RVm-302 showed the longest shoot (39.75 cm) which was identical with BARI Mash-1 x BARI RVm-301, BARI Mash-3 x BARI RVm-301 treatments and BARI Mash-3 x uninoculated showed the lowest result (28.66 cm). Thakur and Panwar (1995) conducted a field trial where seeds of *Vigna radiata* cv. Pusa-105 and PS-16 were inoculated with inoculant. They found that inoculation either singly or combined increased plant height compared with non-inoculated control treatment. These findings are in conformity with the findings of Mozumder (1998); Naher (2000) and Kamrujjaman (2003).

**4.7 Stover yield**

**4.7.1 Effect of variety**

The variation in stover yield was highly significant due to varietal different (Fig. 4.5 and App. 4.3). The highest stover yield (2.72 g $plant^{-1}$) was recorded by BARI Mash-2 which was superior to BARI Mash-1 and BARI Mash-3. The lowest strover yield (2.17 g $plant^{-1}$) was produced by BARI Mash-3. Roy (2001) carried out a field experiment on three mungbean varieties of mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and noted that varieties differed significantly on stover yield of mungbean. Bhuiyan *et al*. (2010) carried out field experiments at Joydebpur, Jamalpur and Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed that BARI Mash-3 gave significantly higher stover yield at Joydebpur and BARI Mash-1 at Jamalpur but had not significant effect among three varieties on stover yield of all the varieties at Rahmatpur. Nag *et al*. (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties (BARI Mash-1, BARI Mash-2 and BARI Mash-3) to evaluate their yield and yield attributes. Among the three cultivars, BARI Mash-1 recorded the highest total dry matter yield.

### 4.7.2 Effect of *Bradyrhizobium*

The application of *Bradyrhizobium* had significant influenced on strain yield of Mash (Fig. 4.6 and App. 4.4). Mixed culture showed the highest stover yield (2.60 g $plant^{-1}$) which was identical with all other strains and the lowest stover yield (2.05 g $plant^{-1}$) was produced by uninoculated plant. Bhuiyan and Mian (2007) reported that application of *Bradyrhizobium* inoculant produced significant effect on stover yields (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) of mungbean. Nagarajan and Balachandar (2001) reported that seed inoculation of *Rhizobium* enhanced biomass. Srinivas and Shaik (2002) opined that seed inoculation with *Bradyrhizobium* culture enhanced haulm yield in mungbean. Singha and Sarma (2001) reported that *Rhizobium* inoculation produced the highest straw yield. Bhuiyan *et al.* (2008a) observed that application of *Bradyrhizobium* inoculant produced significant effect on stover yields (2.31 t $ha^{-1}$ in 2001 and 2.04 t $ha^{-1}$ in 2002) yields of mungbean. Hossain and Solaiman (2004) reported that stover yields increased significantly due to inoculation of the seeds with *Rhizobium* strains. Sriramachandrasekharan and Vaiyapuri (2003) reported that *Rhizobium*-inoculated blackgram showed higher stover yield $pot^{-1}$ (81.1 g) than the non-inoculated crop.

### 4.7.3 Interaction effect of variety and *Bradyrhizobium*

Stover yield was significantly influenced by the interaction effect of variety and *Bradyrhizobium* (Table 4.8). The highest stover yield (3.34 g $plant^{-1}$) was produced by BARI Mash-2 x mixed culture which was statistically different from all other treatment combinations and the interaction of BARI Mash-1 x uninoculated showed the lowest value (1.86 g $plant^{-1}$). Hossain and Solaiman (2004) reported that BARI Mung-4 in combination with TAL169 performed the best in terms of stover yields. Bhuiyan and Mian (2007) reported that inoculated BARI Mung-2 produced the highest stover yields. Bhuiyan *et al.* (2008a) observed that inoculated BARI Mung-2 produced the highest stover yields. Mozumder *et al.* (2005) observed that inoculated Kanti gave higher stover yield in mungbean.

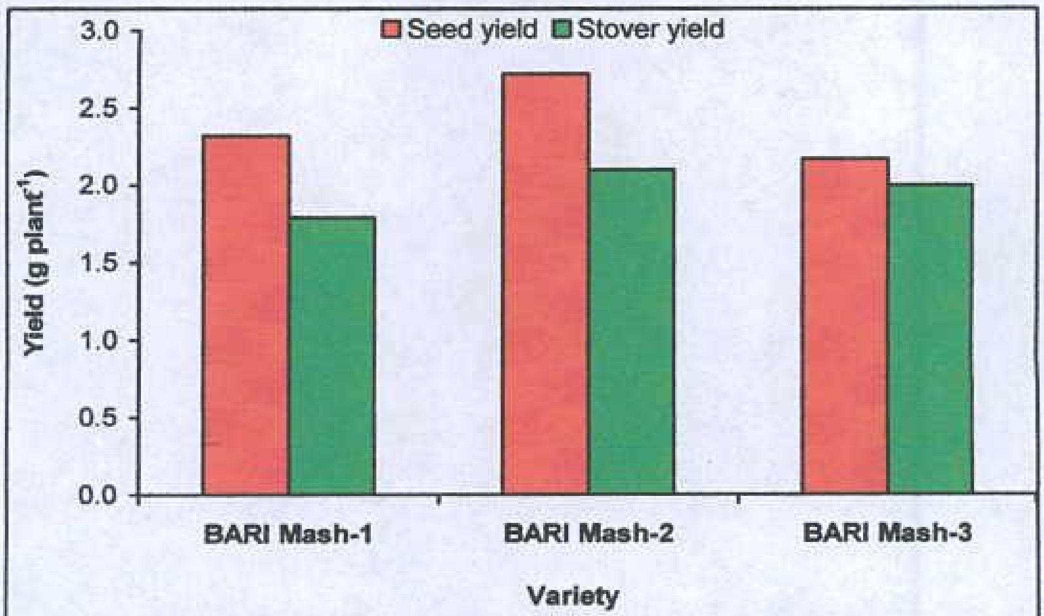


Fig. 4.5. Effect of varieties on stover and seed yield of blackgram

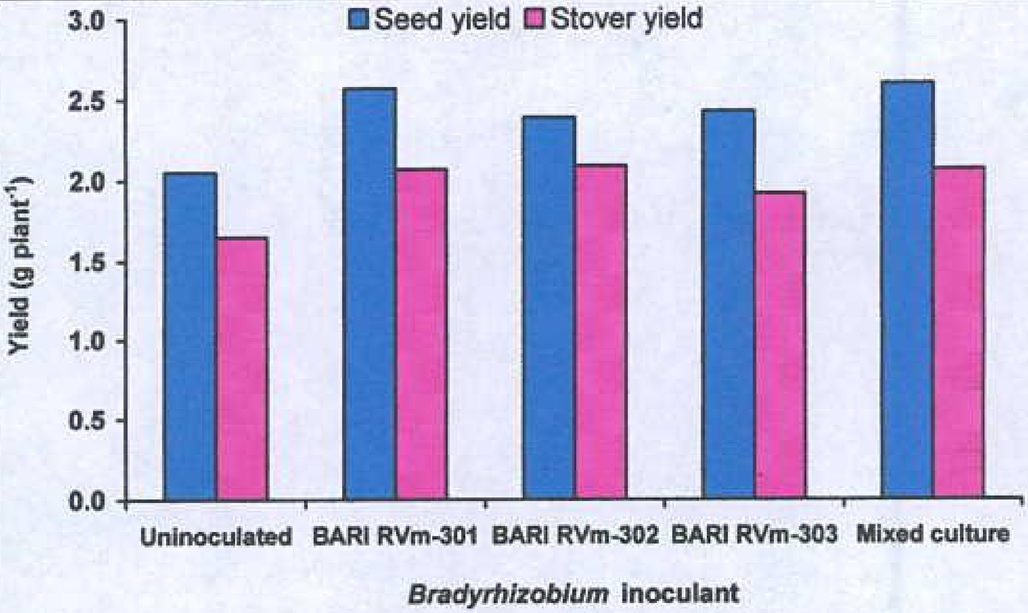


Fig. 4.6. Effects of *Bradyrhizobium* inoculant on seed yield and stover yield of blackgram

**Table 4.8. Interaction effects of varieties and *Bradyrhizobium* inoculant on stover yield and seed yield of blackbram**

| Treatment | Stover yield (g plant$^{-1}$) | Seed yield (g plant$^{-1}$) |
|---|---|---|
| BARI Mash-1 x Uninoculated | 1.86f | 1.23f |
| BARI Mash-1 x BARI RVm-301 | 2.57bcd | 2.14a-d |
| BARI Mash-1 x BARI RVm-302 | 2.51cd | 1.91cde |
| BARI Mash-1 x BARI RVm-303 | 2.46cd | 1.85e |
| BARI Mash-1 x Mixed culture | 2.21def | 1.81e |
| BARI Mash-2 x Uninoculated | 2.30cde | 1.86de |
| BARI Mash-2 x BARI RVm-301 | 2.91b | 2.07b-e |
| BARI Mash-2 x BARI RVm-302 | 2.44cd | 2.22ab |
| BARI Mash-2 x BARI RVm-303 | 2.60bc | 1.92cde |
| BARI Mash-2 x Mixed culture | 3.34a | 2.42a |
| BARI Mash-3 x Uninoculated | 1.98ef | 1.84e |
| BARI Mash-3 x BARI RVm-301 | 2.21def | 2.00b-e |
| BARI Mash-3 x BARI RVm-302 | 2.21def | 2.15abc |
| BARI Mash-3 x BARI RVm-303 | 2.23cde | 1.97b-e |
| BARI Mash-3 x Mixed culture | 2.23cde | 1.98b-e |
| SE (±) | 0.13 | 0.10 |
| Level of sig. | ** | ** |
| CV (%) | 9.3 | 8.5 |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level



**4.8 Seed yield**

**4.8.1 Effect of variety**

The seed yield of blackbram varied significantly due to varietal difference (Fig. 4.5 and App. 4.3). BARI Mash-2 showed the highest result (2.10 g plant$^{-1}$) which was identical with that of BARI Mash-3 but differed from BARI Mash-1. The lowest seed yield (1.79 g plant$^{-1}$) was produced by BARI Mash-1. Roy (2001) carried out a field experiment on three mungbean varieties of mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and found that varieties had significant influence on seed yield of mungbean. Bhuiyan *et al.* (2010) conducted field experiments at Joydebpur, Jamalpur and

Rahmatpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and observed not significant effect of varieties on seed yield at all the locations. Nag *et al.* (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties (BARI Mash-1, BARI Mash-2 and BARI Mash-3) to evaluate their yield and yield attributes. Among the three cultivars, BARI Mash-1 recorded the highest seed yield (1.60 t $ha^{-1}$). Kumari and Nair (2003) found that the extent of yield were more in blackgram and greengram where *Bradyrhizobium* inoculation were done.

### 4.8.2 Effect of *Bradyrhizobium*

*Bradyrhizobium* inoculant showed highly significant effect on seed yield of blackgram (Fig. 4.6 and App. 4.4). The highest seed yield (2.09 g $plant^{-1}$) was produced by the inoculant BARI RVm-302 which was identical with BARI RVm-301 and mixed culture but differed from that of BARI RVm-303. The lowest seed yield (1.65 g $plant^{-1}$) was produced by uninoculated plant. The result was similar with the findings of Bhuiyan *et al.* (2006). Malik *et al.* (2002) studied that seed inoculation with *Rhizobium* resulted in the highest seed yield (1,158 kg $ha^{-1}$). Chatterjee and Bhattacharjee (2002) noted that plants inoculated with *Bradyrhizobium* strains showed increased seed yield over control. Parveen *et al.* (2002) obtained the maximum seed yield (6.6 g $plant^{-1}$) with single *Bradyrhizobium* sp. Osunde *et al.* (2003) reported that *Bradyrhizobium* inoculation increased 40% seed yield. Ashraf *et al.* (2003) found that seed inoculation was optimum for the production of high seed yield by mungbean cv. NM-98. Manivannan *et al.* (2003) reported that *Rhizobium* seed treatment had markedly higher crop yield. Kumari and Nair (2003) observed significant increase in yield due to *Rhizobium* inoculation. Sriramachandrasekharan and Vaiyapuri (2003) reported that *Rhizobium*-inoculated blackgram showed higher pod yield (50.3 g) than the non-inoculated crop.

### 4.8.3 Interaction effect of variety and *Bradyrhizobium*

The seed yield of blackgram was significantly influenced by the interaction effect of variety x *Bradyrhizobium* on (Table 4.8). The highest seed yield (2.42 g plant$^{-1}$) was produced by the interaction of BARI Mash-2 x mixed culture which was identical with BARI Mash-1 x BARI RVm-301, BARI Mash-2 x BARI RVm-302 and BARI Mash-3 x BARI RVm-302, and the lowest seed yield was produced by the treatment of BARI Mash-1 x uninoculated interaction. Hossain and Solaiman (2004) reported that BARI Mung-4 in combination with TAL169 performed the best in terms of seed production. Bhuiyan and Mian (2007) also reported that inoculated BARI Mung-2 produced the highest seed yields. Bhuiyan *et al.* (2008a) also observed that inoculated BARI Mung-2 produced the highest seed yields. Similar results were observed by Ara (2004) and Mozumder (1998).



## 4.9 Plant height

### 4.9.1 Effect of variety

The plant height of blackgram was not significantly influenced due to different varieties (Table 4.9) though the tallest plant height (31.83 cm) was found in BARI Mash-3 and the shortest plant height (29.40 cm) was produced by BARI Mash-1. Nag *et al.* (2000) found that BARI Mash-1 recorded the highest plant height.

**Table 4.9. Effects of varieties on plant height, pod length, no. of pods plant$^{-1}$, seed pod$^{-1}$ and 100-seed weight of blackgram**

| Variety | Plant height (cm) | Pod length (cm) | Pods plant$^{-1}$ | Seeds pod$^{-1}$ | 100-seed weight (g) |
|---|---|---|---|---|---|
| BARI Mash-1 | 29.40 | 3.45 | 4.36 | 3.80 | 4.33 |
| BARI Mash-2 | 31.43 | 3.51 | 4.63 | 3.86 | 4.34 |
| BARI Mash-3 | 31.83 | 3.51 | 4.48 | 3.65 | 4.33 |
| SE (±) | 1.03 | 0.07 | 0.10 | 0.10 | 0.028 |
| Level of sig. | NS | NS | NS | NS | NS |

NS = Not significant

### 4.9.2 Effect of *Bradyrhizobium*

Interaction with *Bradyrhizobium* did not have significant effect on plant height of blackgram (Table 4.10). Though the highest plant height (33.06 cm) was produced by the inoculant BARI RVm-301 and the lowest plant height (29.00 cm) was recorded by uninoculated plant. Sharma *et al.* (2000) reported that the growth was increased with *Rhizobium* inoculation and the local strain gave the best results. Nagarajan and Balachandar (2001) reported that *Rhizobium* gave the greatest plant height (42.7 and 53.7 cm for blackgram and greengram, respectively). Bhattacharyya and Pal (2001) reported that *Rhizobium* inoculation significantly influenced plant height. Malik *et al.* (2002) studied that plant height at harvest was the highest when inoculated with *Bradyrhizobium* (68.13 cm). Kumari and Nair (2003) observed that the extent of plant growth were more in blackgram and greengram where *Bradyrhizobium* inoculation was done.

**Table 4.10. Effects of *Bradyrhizobium* inoculant on plant height, pod length, no. of pods plant$^{-1}$, no. of seed pod$^{-1}$ and 100-seed weight of blackgram**

| *Bradyrhizobium* inoculant | Plant height (cm) | Pod length (cm) | No. of pods plant$^{-1}$ | No. of seeds pod$^{-1}$ | 100-seed weight (g) |
|---|---|---|---|---|---|
| Uninoculated | 29.00 | 3.24c | 3.87c | 3.28b | 4.31 |
| BARI RVm-301 | 33.06 | 3.76a | 4.87a | 4.01a | 4.34 |
| BARI RVm-302 | 30.67 | 3.65ab | 4.83a | 3.83a | 4.34 |
| BARI RVm-303 | 30.39 | 3.38c | 4.37b | 3.94a | 4.35 |
| Mixed culture | 31.33 | 3.42bc | 4.50ab | 3.80a | 4.35 |
| SE (±) | 1.33 | 0.09 | 0.13 | 0.13 | 0.037 |
| Level of sig. | NS | ** | ** | ** | NS |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Not significant

### 4.9.3 Interaction effect of variety and *Bradyrhizobium*

The interaction of variety x *Bradyrhizobium* did not have significant effect (Table 4.11). Though the highest plant height (34.33 cm) was produced by the interaction of BARI Mash-3 x BARI RVm-301 and the lowest plant height (27.33 cm) was produced by the interaction of BARI Mash-1 x uninoculated treatment. Thakur and Panwar (1995) found that inoculation either singly or combinedly increased plant height compared with no inoculation. Bhattacharya and Pal (2001) reported that application of rhizobial inoculum influenced plant height comparing with control. Nagarajan and Balachandar (2002) found that *Rhizobium* inoculation increased the higher plant height (53.7 cm). These findings are in conformity with the findings of Mozumder (1998); Naher (2000) and Kamrujjaman (2003). Mozumder *et al.* (2005) found that non-inoculated BINA Moog-2 gave lower plant height.

**Table 4.11. Interaction effects of varieties and *Bradyrhizobium* inoculant on plant height, pod length, pods plant$^{-1}$, seeds pod$^{-1}$ and 100-seed weight of blackgram**

| Treatment | Plant height (cm) | Pod length (cm) | Pods plant$^{-1}$ | Seeds pod$^{-1}$ | 100-seed weight (g) |
|---|---|---|---|---|---|
| BARI Mash-1 x Uninoculated | 27.33 | 3.22 | 3.66g | 3.10 | 4.31 |
| BARI Mash-1 x BARI RVm-301 | 32.33 | 3.80 | 5.22a | 3.92 | 4.33 |
| BARI Mash-1 x BARI RVm-302 | 30.33 | 3.75 | 4.39cf | 4.05 | 4.34 |
| BARI Mash-1 x BARI RVm-303 | 28.67 | 3.23 | 4.50b-e | 4.38 | 4.34 |
| BARI Mash-1 x Mixed culture | 28.33 | 3.23 | 4.02efg | 3.57 | 4.35 |
| BARI Mash-2 x Uninoculated | 29.67 | 3.26 | 4.11def | 3.44 | 4.32 |
| BARI Mash-2 x BARI RVm-301 | 32.50 | 3.75 | 4.66a-e | 3.97 | 4.35 |
| BARI Mash-2 x BARI RVm-302 | 30.00 | 3.65 | 4.83abc | 3.78 | 4.34 |
| BARI Mash-2 x BARI RVm-303 | 31.00 | 3.37 | 4.44b-e | 3.97 | 4.35 |
| BARI Mash-2 x Mixed culture | 34.00 | 3.54 | 5.08ab | 4.16 | 4.35 |
| BARI Mash-3 x Uninoculated | 30.00 | 3.25 | 3.83fg | 3.30 | 4.30 |
| BARI Mash-3 x BARI RVm-301 | 34.33 | 3.73 | 4.72a-d | 4.13 | 4.34 |
| BARI Mash-3 x BARI RVm-302 | 31.67 | 3.55 | 5.28a | 3.66 | 4.33 |
| BARI Mash-3 x BARI RVm-303 | 31.50 | 3.55 | 4.16def | 3.48 | 4.35 |
| BARI Mash-3 x Mixed culture | 31.67 | 3.48 | 4.39c-f | 3.68 | 4.34 |
| SE (±) | 2.31 | 0.16 | 0.23 | 0.22 | 0.063 |
| Level of sig. | NS | NS | * | NS | NS |
| CV (%) | 13.0 | 7.8 | 8.8 | 10.3 | 2.5 |

In a column, the figures(s) having different letter(s) differed significantly
* Significant at 5% level, NS = Not significant

### 4.10 Pod length

#### 4.10.1 Effect of variety

The effect of variety on pod length of blackgram was not significantly (Table 4.9) though the longest pod length (3.51 cm) was produced by BARI Mash-2 and BARI Mash-3, and the shortest pod length (3.45 cm) was produced BARI Mash-1. Naher (2000) observed significant variation on pod length in mungbean. The present result is in agreement with Ara (2004).

#### 4.10.2 Effect of *Bradyrhizobium*

The pod length of blackgram was significantly influenced due to the application of *Bradyrhizobium* inoculant (Table 4.10). The longest pod (3.76 cm) was found by inoculant BARI RVm-301 and BARI RVm-302 was identical with BARI RVm-301. The shortest pod length (3.24 cm) was produced by uninoculated plant. Hossain and Solaiman (2004) reported that pod increased significantly due to inoculation of the seeds with *Rhizobium* strains. Malik *et al.* (2003) observed that various growth and yield components were significantly affected by varying levels of nitrogen. Similar results due to *Bradyrhizobium* inoculation on mungbean were observed by Naher (2000) and Ara (2004).

#### 4.10.3 Interaction effect of variety and *Bradyrhizobium*

The interaction of variety x *Bradyrhizobium* did not have significant effect on pod length of blackgram (Table 4.11). BARI Mash-1 x BARI RVm-301 showed the highest pod length (3.80 cm) and the lowest pod length (3.22 cm) was produced by the interaction of BARI Mash-1 x uninoculated plant. Similar non-significant interaction result on pod length of mungbean was observed by Naher (2000). But, significant result on pod length was found by Ara (2004) in mungbean.

### 4.11 Pods plant$^{-1}$

#### 4.11.1 Effect of variety

Varieties did not show significant effect on pods plant$^{-1}$ (Table 4.9). Though maximum pods plant$^{-1}$ (4.63) was found in BARI Mash-2 and the minimum pods plant$^{-1}$ (4.48) was produced by BARI Mash-1. Roy (2001) conducted a field experiment on three mungbean using five stains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and opined that varieties differed significantly on pods plant$^{-1}$ of mungbean. Nag *et al*. (2000) conducted field experiment at Barisal, Bangladesh during 1997-1998 on three blackgram varieties and found that BARI Mash-1 had the highest pods plant$^{-1}$.

#### 4.11.2 Effect of *Bradyrhizobium*

The inoculant *Bradyrhizobium* had significant effect on pods plant$^{-1}$ of blackgram (Table 4.10). The highest pods plant$^{-1}$ (4.87) was produced by BARI RVm-301 and the lowest pods plant$^{-1}$ (3.87) was produced by uninoculated plant. BARI RVm-301, BARI RVm-302 and mixed culture produced identical no. of pods plant$^{-1}$. Malik *et al*. (2002) studied that seed inoculation with *Rhizobium* application resulted in the highest number of pods plant$^{-1}$ (22.47). Ashraf *et al*. (2003) found that seed inoculation resulted in the highest number of pods plant$^{-1}$.



#### 4.11.3 Interaction effect of variety and *Bradyrhizobium*

The number of pods plant$^{-1}$ was significantly influenced by the interaction of effect of variety x *Bradyrhizobium* (Table 4.11). The highest pods plant$^{-1}$ (5.28) was produced by the interaction of BARI Mash-3 x BARI RVm-302 which was identical with that of BARI Mash-2 x BARI RVm-301, BARI Mash-2 x BARI RVm-302 and BARI Mash-3 x BARI RVm-303, and the lowest pods plant$^{-1}$ (3.66) was produced by BARI Mash-1 x uninoculated plant.

## 4.12 Number of seeds pod$^{-1}$

### 4.12.1 Effect of variety

The effect of variety on seeds pod$^{-1}$ was also non-significant (Table 4.9). Though the maximum seeds pod$^{-1}$ (3.86) was produced by BARI Mash-2 and the minimum was found in BARI Mash-3. Nag *et al*. (2000) found that BARI Mash-1 recorded the highest no. of seeds pod$^{-1}$. Roy (2001) carried out a field experiment on three mungbean varieties of mungbean using five strains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and observed that varieties differed significantly on no. of seeds pod$^{-1}$ of mungbean. But, Bhuiyan *et al*. (2008a), Naher (2000) and Ara (2004) observed significant variation in no. of seeds pod$^{-1}$ among different varieties of mungbean.



### 4.12.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* on the production of no. of seeds pod$^{-1}$ varied significantly (Table 4.10). The highest number of no. of seeds pod$^{-1}$ (4.01) was produced by BARI RVm-301. All the strains produced identical results on no. of seeds pod$^{-1}$. The lowest number of seeds pod$^{-1}$ (3.28) was produced by uninoculated condition. Srinivas and Shaik (2002) reported studied that seed inoculation with *Rhizobium* culture increased number of seeds per pod relative to the control.

### 4.12.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of variety x *Bradyrhizobium* on no. of seeds pod$^{-1}$ was not significant (Table 4.11). Though the highest no. of seeds pod$^{-1}$ (4.38) was produced by the interaction of BARI Mash-1 x BARI RVm-303 and the lowest no. of seeds pod$^{-1}$ (3.10) was produced by BARI Mash-1 x uninoculated plant. Bhuiyan *et al.* (2008a) observed that inoculated BARI Mung-2 produced the highest no. of seeds pod$^{-1}$. Naher (2000) also observed similar non-significant result on seeds pod$^{-1}$ in mungbean. The result also is in agreement with the findings of Ara (2004).

### 4.13 Hundred seed weight

#### 4.13.1 Effect of variety

The effect of variety on 100-seed weight was not significant (Table 4.9) though higher 100-seed weight (4.34 g) was produced by BARI Mash-2. Roy (2001) conducted a field experiment on three mungbean varieties using five strains of *Bradyrhizobium* or without *Bradyrhizobium* inoculant and reported that varieties differed significantly on 1000-seed weight of mungbean. Bhuiyan *et al*. (2010) conducted field experiments at Joydebpur on three blackgram varieties with or without *Bradyrhizobium* inoculation and did not observed significant effect on 1000-seed weight at Joydebpur and Rahmatpur.

#### 4.13.2 Effect of *Bradyrhizobium*

The effect of *Bradyhizobium* on 100-seed weight was non-significant (Table 4.10). Though the maximum value (4.35 g) was recorded by the treatment BARI RVm-303 and mixed culture, and the lowest 100-seed weight (4.31 g) was observed in uninoculated plant. Malik *et al*. (2002) studied that seed inoculation with *Rhizobium* application resulted in the uninoculated plant. Srinivas and Shaik (2002) reported studied that seed inoculation with *Rhizobium* culture increased number of 1000-seed weight relative to the control.

#### 4.13.3 Interaction effect of variety and *Bradyrhizobium*

Not significant interaction effect between variety and *Bradyhizobium* inoculants on 100-seed weight was found (Table 4.11). Though the highest value was recorded by several interactions and the lowest value was recorded by the interaction of BARI Mash-1 x uninoculated. Pusa Baisakhi which was fertilized with various levels of nitrogen (0, 10 and 20 kg N $ha^{-1}$) and reported that the highest levels of N applications resulted in the average maximum test weight. Sarkar *et al*. (2002) reported that interaction effects between cultivar A-43 and *Bradyrhizobium* strain MK-5 resulted in higher test weight (4.23 g). Bhuiyan *et al*. (2008a) found that BARI Mung-5 with *Bradyrhizobium* inoculation gave the highest 1000-

seed weight (40.4 g in 2001 and 40.7 g in 2002). Mozumder (1998) reported that BINA Mung-2 x I gave the highest 1000-seed weight. Naher (2000) found the highest 1000-seed weight in BINA Mung-5 with *Bradyrhizobium* inoculation. But, Ara (2004) reported that the highest 1000-seed weight in mungbean was found in BARI Mung-3 x *Bradyrhizobium* plus *Azotobacter* treatment. Mozumder *et al.* (2005) found that Bina Moog-2 and Kanti gave higher 1000-seed weight.



### 4.14 N content in seed

#### 4.14.1 Effect of variety

Variety did not show any significant effect on N content in seed (Table 4.12). The highest value of N content in seed (3.18%) was observed in BARI Mash-2 followed by BARI Mash-3 and BARI Mash-1.

**Table 4.12. Effects of variety on N content in seed and stover of blackgram**

| Variety | N content (%) | |
|---|---|---|
| | Seed | Stover |
| BARI Mash-1 | 3.13 | 1.45 |
| BARI Mash-2 | 3.18 | 1.45 |
| BARI Mash-3 | 3.15 | 1.45 |
| SE (±) | 0.02 | 0.02 |
| Level of sig. | NS | NS |

NS = Not significant

#### 4.14.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* on N content in seed was highly significant (Table 4.13). The highest amount of N content in seed (3.21%) was observed in BARI RVm-303 and the lowest amount of N (3.02%) in seed was observed in uninoculated plant, and BARI RVm-301, BARI RVm-302 and mixed culture were identical to each other. Reddy and Mallaiah (2001) found that *Rhizobium* inoculation increased nitrogen content of fresh seeds in the inoculated plants, while that in non-inoculated controls was only 2.72%. They also reported that the plants inoculated with the AH isolate showed better nodulation and nitrogen content compared to the plants inoculated with the VM isolate. Chatterjee and Bhattacharjee (2002) noted that plants inoculated with *Bradyrhizobium* strains showed increased N content.

**Table 4.13. Effect of *Bradyrhizobial* inoculants on N content in seed and stover of blackgram**

| *Bradyrhizobium* inoculant | N content (%) | |
|---|---|---|
| | Seed | Stover |
| Uninoculated | 3.02c | 1.40 |
| BARI RVm-301 | 3.16b | 1.46 |
| BARI RVm-302 | 3.18b | 1.48 |
| BARI RVm-303 | 3.21a | 1.44 |
| Mixed culture | 3.19b | 1.47 |
| SE (±) | 0.03 | 0.03 |
| Level of sig. | ** | NS |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level, NS = Not significant

#### 4.14.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of variety and *Bradyrhizobium* on N content in seed was non-significant (Table 4.14). The highest value (3.27%) was observed by the interactions of BARI Mash-2 x BARI RVm-303. The lowest value (3.00%) was produced by BARI Mash-2 x uninoculated condition. The results corroborated with the findings of Bhuiyan *et al.* (2007b).

### 4.15 N content in stover

#### 4.15.1 Effect of variety

The effect of variety on N content in stover was non-significant. All the varieties showed same value (1.45%) (Table 4.12).

### 4.15.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* on N content in stover was non-significant (Table 4.13) though the highest value (1.48%) recorded by BARI RVm-302 while the lowest value (1.40%) was recorded by uninoculated plant. Chatterjee and Bhattacharjee (2002) studied the effects of inoculation with *Bradyrhizobium* and reported that the plants inoculated with *Bradyrhizobium* strains and PSB showed increased rate of N content. Delic *et al.* (2009) estimated that inoculation plants produced significantly higher total N content as well as protein yield in respect to untreated control.

**Table 4.14. Interaction effect of varieties and *Bradyrhizobium* inoculants on N content in seed and stover of blackgram**

| Treatment | N content (%) | |
|---|---|---|
| | Seed | Stover |
| BARI Mash-1 x Uninoculated | 3.03 | 1.40 |
| BARI Mash-1 x BARI RVm-301 | 3.13 | 1.47 |
| BARI Mash-1 x BARI RVm-302 | 3.15 | 1.50 |
| BARI Mash-1 x BARI RVm-303 | 3.17 | 1.43 |
| BARI Mash-1 x Mixed culture | 3.17 | 1.47 |
| BARI Mash-2 x Uninoculated | 3.00 | 1.40 |
| BARI Mash-2 x BARI RVm-301 | 3.17 | 1.47 |
| BARI Mash-2 x BARI RVm-302 | 3.23 | 1.47 |
| BARI Mash-2 x BARI RVm-303 | 3.27 | 1.43 |
| BARI Mash-2 x Mixed culture | 3.23 | 1.47 |
| BARI Mash-3 x Uninoculated | 3.03 | 1.40 |
| BARI Mash-3 x BARI RVm-301 | 3.17 | 1.43 |
| BARI Mash-3 x BARI RVm-302 | 3.17 | 1.47 |
| BARI Mash-3 x BARI RVm-303 | 3.20 | 1.47 |
| BARI Mash-3 x Mixed culture | 3.17 | 1.47 |
| SE (±) | 0.05 | 0.05 |
| Level of sig. | NS | NS |
| CV (%) | 2.6 | 5.6 |

NS = Not significant

#### 4.15.3 Interaction effect of variety and *Bradyrhizobium*

The N content in stover of blackgram did not vary significantly due to interaction effect of variety x *Bradyrhizobium* on (Table 4.14). The highest value (1.50%) was recorded by the interaction of BARI Mash-1 x BARI RVm-302 and the lowest value was recorded (1.40) by BARI Mash-1 x uninoculated treatment BARI Mash-2 x uninoculated and BARI Mash-3 x uninoculated treatment. Solaiman *et al.* (2003) observed that BARI Mung-4 inoculated with strain TAL 169 had higher N content in stover.

### 4.16 N uptake by seed

#### 4.16.1 Effect of variety

The effect of variety on N uptake by seed was highly significant (Fig. 4.7 and App. 4.5). BARI Mash-2 gave the highest value (66.86 mg plant$^{-1}$) which was differed from BARI Mash-3 and BARI Mash-1, and the lowest value (56.14 mg plant$^{-1}$) was recorded by BARI Mash-1. Solaiman *et al.* (2003) carried out a study on mungbean cultivars BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-1 and BU Mung-1. The highest N uptake was obtained with BARI Mung-4. Bhuiyan *et al.* (2007b) reported that BARI Mung-2 produced the highest N uptake.

#### 4.16.2 Effect of *Bradyrhizobium*

The effect of *Bradyrhizobium* on uptake by seed was highly significant (Fig. 4.8 and App. 4.6). The highest value (66.63 mg plant$^{-1}$) was recorded by BARI RVm-302 which was identical to all other strains. The lowest value (49.74 mg plant$^{-1}$) was observed in uninoculated plant. Bhuiyan *et al.* (2007b) carried out field studies with five mungbean varieties with/without *Bradyrhizobium* inoculation and observed that inoculation significantly increased nitrogen uptake of mungbean. Srivastav and Poi (2000) also stated that inoculation with M-10 strain in greengram gave the highest nitrogen fixation. Solaiman *et al.* (2003) observed that *Rhizobium* inoculation increased N uptake.

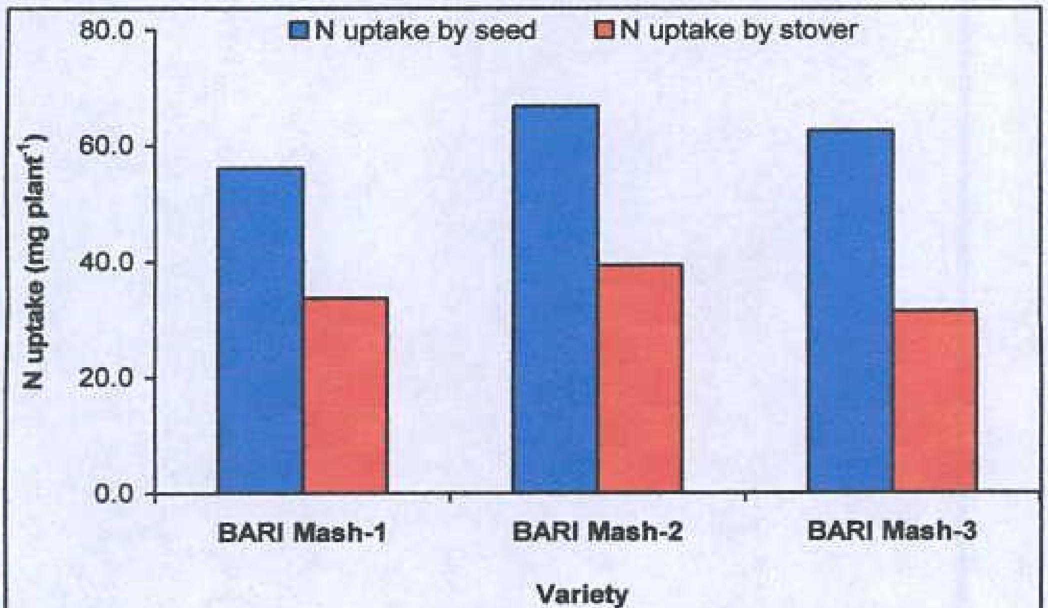


**Fig. 4.7. Effect of varieties on N uptake by seed and stover of blackgram**

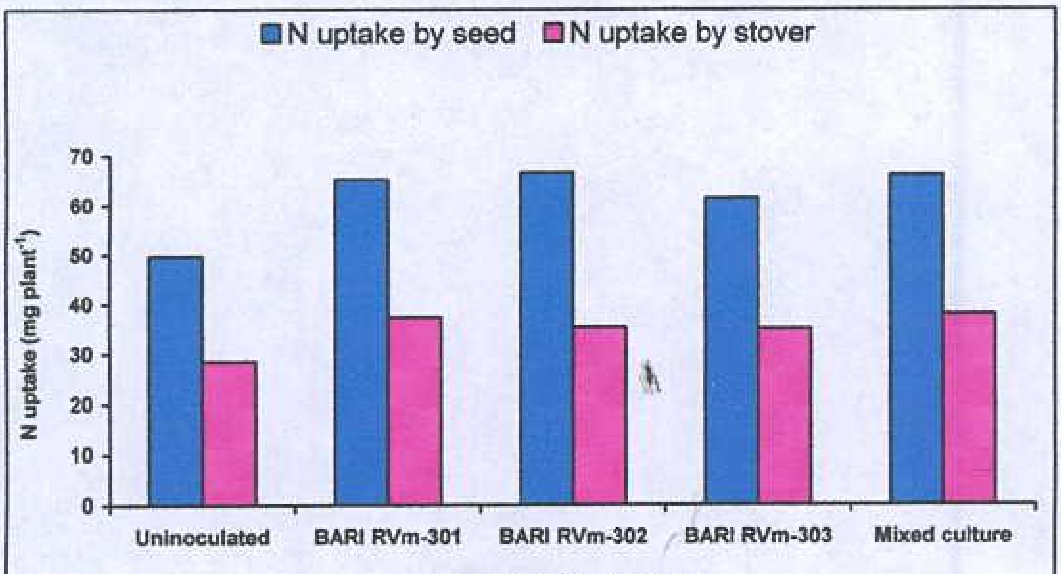


**Fig. 4.8. Effect of *Bradyrhizobium* inoculant on N uptake by seed and stover of blackgram**

### 4.16.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of variety x *Bradyrhizobium* on N uptake by seed was significant (Table 4.15). The highest N uptake by seed (78.29 mg $plant^{-1}$) was recorded by the interaction of BARI Mash-2 x mixed culture and the lowest value (37.33 mg $plant^{-1}$) was recorded by the interaction of BARI Mash-1 x uninoculated treatment. Bhuiyan *et al.* (2007b) found the highest N uptake by inoculated BARI Mung-2. Solaiman *et al.* (2003) found that BARI Mung-4 inoculated with strain TAL 169 gave higher N uptake by seed.

**Table 4.15. Interaction effect of varieties and *Bradyrhizobium* inoculants on N uptake by seed and stover in blackgram**

| Treatment | N uptake (mg $plant^{-1}$) | |
|---|---|---|
| | Seed | Stover |
| BARI Mash-1 x Uninoculated | 37.33g | 25.84f |
| BARI Mash-1 x BARI RVm-301 | 66.90bcd | 37.67bc |
| BARI Mash-1 x BARI RVm-302 | 60.25c-f | 37.66bc |
| BARI Mash-1 x BARI RVm-303 | 58.73def | 35.20cd |
| BARI Mash-1 x Mixed culture | 57.51ef | 34.38cde |
| BARI Mash-2 x Uninoculated | 55.93f | 32.12cde |
| BARI Mash-2 x BARI RVm-301 | 65.68b-e | 42.73b |
| BARI Mash-2 x BARI RVm-302 | 71.63ab | 35.85cd |
| BARI Mash-2 x BARI RVm-303 | 62.75b-f | 37.17bcd |
| BARI Mash-2 x Mixed culture | 78.29a | 49.01a |
| BARI Mash-3 x Uninoculated | 55.97f | 27.61ef |
| BARI Mash-3 x BARI RVm-301 | 63.42b-f | 31.78de |
| BARI Mash-3 x BARI RVm-302 | 68.00bc | 32.47cde |
| BARI Mash-3 x BARI RVm-303 | 63.10b-f | 32.72cde |
| BARI Mash-3 x Mixed culture | 62.62b-f | 32.63cde |
| SE (±) | 3.21 | 1.98 |
| Level of sig. | * | ** |
| CV (%) | 9.0 | 9.1 |

In a column, the figures(s) having different letter(s) differed significantly
*Significant at 5% level, ** Significant at 1% level

### 4.17 N uptake by stover

#### 4.17.1 Effect of variety

The effect of variety on N uptake by stover was also highly significant (Fig. 4.7 and App. 4.5). The highest N uptake by stover (39.38 mg plant$^{-1}$) was observed in BARI Mash-2. BARI Mash-1 and BARI Mash-3 were identical but it was inferior to BARI Mash-2.

#### 4.17.2 Effect of *Bradyrhizobium*

The N uptake by sotver of blackgram was highly significant due to different *Bradyrhizobium* strain (Fig. 4.8 and App. 4.6). The highest value (38.01 mg plant$^{-1}$) was recorded by mixed culture and the lowest value (28.52 mg plant$^{-1}$) was noted in uninoculated plant. Srivastav and Poi (2000) conducted a field experiment to determine the symbiotic efficiencies of greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) and found symbiotic variations due to the effect of both the host and inoculant strains. Inoculation with M-10 strain in greengram resulted in the highest dry matter production and nitrogen fixation.

#### 4.17.3 Interaction effect of variety and *Bradyrhizobium*

The interaction effect of variety and *Bradyrhizobium* on N uptake by stover was highly significant (Table 4.15). The highest value (49.01 mg plant$^{-1}$) was recorded by the interaction of BARI Mash-2 x mixed culture and the lowest value (25.84 mg plant$^{-1}$) was observed in the interaction of BARI Mash-1 x uninoculated plant. Srivastav and Poi (2000) conducted a field experiment to determine the symbiotic efficiencies of greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) and found symbiotic variations due to the effect of both the host and inoculant strains. Inoculation with M-10 strain in greengram resulted in the highest dry matter production and nitrogen fixation. Similar significant result due interaction effect of variety and fertilizer was observed by Ara (2004). She found that BARI Mung-4 x *Bradyrhizobium* plus *Azotobacter* gave the highest N uptake (54.78 kg ha$^{-1}$) and the lowest N uptake (26.48 kg ha$^{-1}$) was noted in BARI Mung-4 x Uninoculated control treatment.

Solaiman *et al*. (2003) reported that BARI Mung-4 inoculated with strain TAL 169 higher N uptake by stover.

### 4.18 Correlation

Correlation matrix among the plant characters of blackgram have been shown in Tables 4.16-4.18. Most of the plant characters were correlated among themselves. In the present study, nodule number had positive and significant correlation with nodule weight, root weight, shoot weight, root length and shoot length; nodule weight with root weight, shoot weight, root length and shoot length; root weight with shoot weight, root length and shoot length; shoot weight with root length and shoot length; root length with shoot length (Table 4.16). These results confirmed the findings of Bhuiyan (2004). He observed positive and significant correlation of nodule number with nodule weight, root weight, and shoot weight of inoculated mungbean.

A highly significant and positive correlation was observed between plant height and stover yield, seeds pod$^{-1}$; stover yield and seed yield, pods plant$^{-1}$, seeds pod$^{-1}$; seed yield and pod length, pods plant$^{-1}$, seeds pod$^{-1}$; pod length and pods plant$^{-1}$, seeds pod$^{-1}$; pods plant$^{-1}$ and seeds pod$^{-1}$ (Table 4.17). Stover yield was also correlated with N content in seed, N uptake by seed, N uptake by stover (Table 4.18). Seed yield was also strongly correlated with N content in seed, N uptake by seed and N uptake by stover. Nitrogen content in seed was also correlated with N content in stover, N uptake by seed, N uptake by stover; N content in stover with N uptake by stover; N uptake by seed with N uptake by stover. Solaiman (1999) found positive correlation among mungbean growth, N uptake and yield parameters. Hossain and Solaiman (2004) observed that the number of pods plant$^{-1}$ and 1000-seed weight had positive correlations with seed yield.

**Table 4.16. Correlation matrix among different plant characters of blackgram at 50 DAS (n = 45)**

| Characters | Correlation coefficient (r value) | | | | |
|---|---|---|---|---|---|
| | Nodule weight | Root weight | Shoot weight | Root length | Shoot length |
| Nodule number | 0.697** | 0.550** | 0.516** | 0.423** | 0.374* |
| Nodule weight | - | 0.680** | 0.516** | 0.536** | 0.392** |
| Root weight | - | - | 0.457** | 0.542** | 0.540** |
| Shoot weight | - | - | - | 0.516** | 0.349* |
| Root length | - | - | - | - | 0.610** |

**Table 4.17. Correlation matrix among yield and yield contributing characters of blackgram (n = 45)**

| Characters | Correlation coefficient (r value) | | | | | |
|---|---|---|---|---|---|---|
| | Stover yield | Seed yield | Pod length | Pods plant$^{-1}$ | Seeds pod$^{-1}$ | 100-seed weight |
| Plant height | 0.382** | 0.249$^{NS}$ | 0.230$^{NS}$ | 0.225$^{NS}$ | 0.431** | 0.075$^{NS}$ |
| Stover yield | - | 0.539** | 0.259$^{NS}$ | 0.415** | 0.436** | -0.047$^{NS}$ |
| Seed yield | - | - | 0.425** | 0.673** | 0.327* | 0.212$^{NS}$ |
| Pod length | - | - | - | 0.512** | 0.332* | 0.014$^{NS}$ |
| Pods plant$^{-1}$ | - | - | - | - | 0.322* | 0.109$^{NS}$ |
| Seeds pod$^{-1}$ | - | - | - | - | - | 0.209$^{NS}$ |

**Table 4.18. Correlation matrix among yield and nutrient content of blackgram (n = 45)**

| Characters | Correlation coefficient (r value) | | | | |
|---|---|---|---|---|---|
| | Seed yield | N content in seed | N content in stover | N uptake by seed | N uptake by stover |
| Stover yield | 0.539$^{**}$ | 0.401* | 0078$^{NS}$ | 0.570** | 0.961** |
| Seed yield | - | 0.409** | 0.092$^{NS}$ | 0.984** | 0.530** |
| N content in seed | - | - | 0.362$^{*}$ | 0.564** | 0.469** |
| N content in stover | - | - | - | 0.149$^{NS}$ | 0.349* |
| N uptake by seed | - | - | - | - | 0.574** |

# Chapter 5

# Summary and Conclusion

# CHAPTER V

# SUMMARY, CONCLUSION AND RECOMMENDATION

A pot culture experiment was conducted at the net house of Soil Science Division in Bangladesh Agricultural Research Institute (BARI), Joyebpur, Gazipur during September to December 2011 to evaluate the performance of blackgram varieties and *Bradyrhizobium* on growth, nodulation, yield, nitrogen content and uptake, and other yield contributing characters.

There were 15 treatment combinations with five *Bradyrhizobium* inoculation treatments namely non-inoculated and inoculated with strain BARI RVm-301, BARI RVm-302, BARI RVm-303 and mixed culture on three blackgram varieties. There were 45 pots in the experiment arranged in factorial randomized complete block design. Each of the earthen pot was filled with 10 kg of sieved soil. All chemical fertilizers except nitrogen were applied as basal and at recommended levels at the time of pot filling. Blackgram seeds (BARI Mash-1, BARI Mash-2 and BARI Mash-3) inoculated and non-inoculated were sown on 5$^{th}$ September, 2011, taking 20 seeds in each pot following dibbling method. Necessary water was added to the pots at a regular interval of 7 days until crop maturity to maintain proper moisture content.

Data on nodulation and dry matter production were recorded at two stages of growth viz. 35 and 50 days after sowing and for seed yield, stover yield, at the time of plant harvest. The crop was harvested at maturity and seed stover yield were recorded at 14% moisture content.

The seed and stover was chemically analyzed for N content and uptake. All the data were statistically analyzed by F-test and the differences between treatments means were adjudged by Duncan's Multiple Range Test (DMRT).

An bridged account of the result obtained is summarized below:

Significant influences of *Bradyrhizobium* inoculant were observed on nodulation, root length, yields (seed and stover), nitrogen content and uptake by the seed and stover. The highest total nodule number (16.00 and 20.00 plant$^{-1}$), nodule weight (19.25 and 72.50 mg plant$^{-1}$), shoot weight (1.55 and 4.58 g plant$^{-1}$), root length (7.63 and 8.50 cm) were obtained from strain BARI RVm-302 at both 35 and 50 DAS, respectively. The highest root weight (0.04 g plant$^{-1}$ at 30 DAS) was observed in BARI Mash-2, in case of 50 DAS, the highest (0.14 g plant$^{-1}$) was observed in BARI Mash-2. The highest shoot length (25.89 cm) was obtained form BARI RVm-302 at 30 DAS, but incase of 50 DAS, it was obtained from BARI RVm-301 (36.39 cm). The treatment in uninoculated was produced the lowest root weight, root length, shoot weight, shoot length at both 35 and 50 DAS.

The treatment BARI RVm-301 produced the highest plant height (33.06 cm), the highest no. of pod plant$^{-1}$ (4.87) and no. of seed pod$^{-1}$ (4.01). The highest stover yield was produced by mixed culture (2.60 g plant$^{-1}$) and BARI Mash-2 produced the highest stover yield. BARI RVm-302 produced the highest seed yield (2.09 g plant$^{-1}$), BARI RVm-301 produced the highest pod length (3.76 cm) and the highest value of 100-seed weight (43.5 g) was produced by BARI RVm-303 and mixed culture. The lowest pod, seed yield, stover yield, plant height no. of pods plant$^{-1}$, no. of seed pod$^{-1}$ and 100-seed weight were recorded in uninoculated.

The interaction effect of variety and *Bradyrhizobium* was not-significant on total nodule number (at 35 DAS) and nodule weight (at 50 DAS).

The highest total number of nodules (7.00 and 8.50 plant$^{-1}$ at 35 and 50 DAS, respectively) was observed in the interaction BARI Mash-1 x mixed culture. The highest root weight (0.047 g plant$^{-1}$) was observed in BARI Mash-3 x mixed culture at 35 DAS. The highest shoot weight (0.11g plant$^{-1}$) was obtained in BARI Mash-1 x mixed culture at 35 DAS and at 50 DAS the highest shoot weight was produced by the interaction BARI Mash-3 x mixed culture and BARI Mash-2 x BARI RVm-301. The highest root length (4.50 cm) was observed in BARI Mash-1 x BARI RVm-302 at 35 DAS and at 50 DAS, the highest root length (4.83 cm) was observed in BARI Mash-3 x BARI RVm-301. The highest shoot length was recorded by the interaction BARI Mash-2 x BARI RVm-302 and the lowest shoot length (22.67 cm, 28.83 cm) was produced by the interaction BARI Mash-1 x uninoculated treatment at 35 DAS and 50 DAS respectively. The highest seed yield and stover yield (2.42 g plant$^{-1}$ and 3.34 g plant$^{-1}$, respectively) were obtained from BARI Mash-2 x mixed culture and the lowest seed yield and stover yield (1.23 g plant$^{-1}$ and 1.86 g plant$^{-1}$) was produced by the interaction BARI Mash-1 x uninoculated treatment. The highest plant height (34.33 cm) was produced by BARI Mash-2 x mixed culture and the highest pod length (3.80 cm) was recorded by the interaction BARI Mash-1 x BARI RVm-301. The highest no. of pod plant$^{-1}$ was produced by the interaction BARI Mash-2 x BARI RVm-303 and the highest no. of seed pod$^{-1}$ (4.38) was observed in BARI Mash-1 x BARI RVm-303. The lowest plant height, pod length, pods plant$^{-1}$, seed plant$^{-1}$ and 100 seed weight was observed in the interaction BARI Mash-1 x uninoculated treatment.

From the above investigation, it may be concluded that blackgram (BARI Mash-1) production may be increased with use of *bradyrhizobium* inoculant. Further studies at different Agro-ecological Zone of Bangladesh by using bradyrhzobium inoculant are required for final recommendation.

## 5.1 RECOMMENDATION AND SUGGESTION FOR FUTURE RESEARCH

1. Considering the trend of soil fertility decline, the use of bradyrhizobial inoculant should be used for cultivation of blackgram.

2. Instead of applying nitrogenous fertilizers for blackgram production, bio-fertilizer (bradyrhizobial inoculant) should be used. Because nitrogenous fertilizer is now a days a costly chemical fertilizer in Bangladesh. So, bradyrhizobial inoculant should be used in different pulses like blackgram for higher production of pulses to meet up the protein requirement of people our sweet motherland, Bangladesh.

# References

## REFERENCES


Afzal, M.A., M.A. Bakr and M.L. Rahman. 1999. Blackgram cultivation in Bangladesh. Lentil, Blackgram and Mungbean Development Pilot Project, Pulses Res. Station, BARI, Gazipur. 19: 64.

Anjum, M.S., Z.I. Ahmed and C.A. Rauf. 2006. Effect of *Rhizobium* inoculation and nitrogen fertilizer on yield and yield components of mungbean. Intl. J. Agric. Biol. 8(2): 238-240.

Ara, N. 2004. Effect of *Bradyrhizobium* and azotobacter on growth, yield and nutrient uptake of mungbean varieties. M.S. Thesis, Department of Soil Science, Bangladesh Agric. Univ., Mymensingh. pp. 1-70.

Ashraf, M., M. Mueen-Ud-Din and N.H. Warrick. 2003. Production efficiency of mungbean (*Vigna radiata* L.) as affected by seed inoculation and NPK application. Intl. J. Agric. Biol. 5(2): 179-180.

Bakr, M.A., M.A. Afzal, A. Hamid, M.M. Haque and M.S. Aktar. 2004. Blackgram in Bangladesh. Lentil, Blackgram and Mungbean Development Pilot Project, Pulses Research Centre, BARI, Gazipur-1701. 60 pp. Publication No. 25.

Bali, A.S., K.N. Sing, M.H. Shah and B.A. Khandey. 1991. Effect of nitrogen and phosphorus fertilizer on yield and plant characters of mungbean (*Vigna radiata* L. Wilczek) under late sown condition of Kashmir valley. Fertilizer News, India. 36(7): 59-61.

BARC. 2005. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council. Farmgate, New Airport Road, Dhaka-1215.

BBS (Bangladesh Bureau of Statistics). 2011. Year Book of Agricultural Statistics of Bangladesh. Statistics Division, Ministry of Planning. Govt. of Bangladesh. p. 123.

Bhattacharyya, J. and A.Q. Pal. 2001. Effect of *Rhizobium* inoculation, phosphorus and molybdenum on the growth of summer greengram (*Vigna radiata* L. Wilczek). Indian Agric. 39(2): 173-179.

Bhuiyan, M.A.H. 2004. Evaluation of introducing mungbean into cereal based cropping pattern for sustainable soil fertility and productivity. Ph.D Thesis, Dept. of Soil Sci., Bangladesh Agril. Univ., Mymensingh. pp.1-217.

Bhuiyan, M.A.H. and M.H. Mian. 2007. Effects of *Bradyrhizobium* inoculation on nodulation, biomass production and yield of mungbean. Bangladesh J. Microbiol. 24(2): 95-99.

Bhuiyan, M.A.H., D. Khanam, M.E. Ali, M.R. Khatun, F. Alam and M.A. Rahman. 2008b. Influence of variety on the response of blackgram to inoculation with elite strains of *Bradyrhizobium*. Annual Research Report 2007-2008, Soil Science Division, Bangladesh Agril. Res. Inst. pp. 333-307.

Bhuiyan, M.A.H., D. Khanam, M.E. Ali, M.R. Khatun, F. Alam, M.A. Rahman and M.R. Islam. 2010. Response of blackgram varieties to inoculation with elite strain of *Bradyrhizobium*. Annual Research Report, Soil Sci. Div., Bangladesh Agril. Res. Inst. Joydebpur, Gazipur. pp. 240-246.

Bhuiyan, M.A.H., M.H. Mian and M.S. Islam. 2006. Nodulation in five mungbean varieties with or without *Bradyrhizobium* inoculation. Bangladesh J. Microbiol. 23(1): 43-48.

Bhuiyan, M.A.H., M.H. Mian and M.S. Islam. 2007b. Effect of *Bradyrhizobium* inoculation on dry matter production and nitrogen uptake in mungbean. Bangladesh J. Agric. and Environ. 3(2): 7-16.

Bhuiyan, M.A.H., M.H. Mian and M.S. Islam. 2008a. Studies on the effect of *Bradyrhizobium* inoculation on yield and yield attributes of mungbean. Bangladesh J. Agril. Res. 33(3): 449-457.

Bhuiyan, M.A.H., M.H. Mian, M.S. Islam and M.R. Islam. 2007a. Effects of inoculation with *Bradyrhizobium* on nodulation pattern, nodule senescence and size distribution in mungbean. Bangladesh J. Agril. Res. 32(2): 269-282.

Bhuiyan, M.A.H., Mian, M.H. and Islam, M.S. 2006. Nodulation in five mungbean varieties with or without *Bradyrhizobium* inoculation. Bangladesh J. Microbiol. 23(1): 43-48.

Black, C.A. 1965. Methods of Soil Analysis, Part I. Agron. Monograph. 9. ASA Madison. Wisconsin. USA.

Bremner, J.M. and Mulvaney, C.S. 1982. Total Nitrogen *In*. Methods of Soil Analysis, Ed. Page, AL., Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Agron. Inc. Madison, Wisconsin. USA. pp. 595-622.

Chatterjee, A. and P. Bhattacharjee. 2002. Influence of combined inoculation and *Bradyrhizobium* and phosphobacteria on mungbeans in field. J. Mycol. Res. 40(2): 201-203.

Chowdhury, M.M.U., M.H. Ullah and Z.U. Mahmmud. 2000. Dry matter production in mungbean (*Vigna radiata* (L) Wilczek) as influenced by *Bradyrhizobium* inoculation and phosphorus application. Legume Res. 23(1): 15-20.

Delic, D., O. Stajkovic, D. Kuzmanovic, N. Rasulic, J. Knezevic, B. Vukcevic and Milicic. 2009. The effect of *Rhizobial* inoculation on growth and yield of *Vigna radiata* L. in Serbian Soils. Technology in Animal Husbandry. 25(5-6): 1197-1202.

Dudeja, S.S. and J.S. Duhan. 2005. Biological nitrogen fixation research in pulses with special reference to mungbean and urdbean. Indian J. Pulses Res. 18(2): 107-118.

Fox, R.L., Olsen, R.A. and Rhoades, H.F. 1964. Evaluating the sulphur status of soil by plant and soil test. Soil Sci. Soc. Am. Proc. 28: 243-246.

Freed, R.D. 1992. MSTAT-C. Crop and Soil Science Department, Michigon State University, USA.

Hafeez, F.Y., Z. Aslam and K.A. Malik. 1988. Effect of salinity and inoculation on growth, nitrogen fixation and nutrient uptake of *Vigna radiata* (L.) Wilczek. Plant Soil 106: 3-8.

Hayat, R., S. Ali and F.S. Khan. 2004. Effect of nitrogen and *Rhizobium* inoculation on yield, N-uptake and economics of mungbean. Intl. J. Agric. Biol. 6(3): 547-551.

Hossain, D. and A.R.M. Solaiman. 2004. Performances of mungbean varieties as affected by *Rhizobium* inoculants. Bull. Inst. Trop. Agric., Kyushu Univ. 27: 35-43.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi, India.

Jayakumar, M., M. Eyini and R. Velmurugan. 1997. Effect of seed *Rhizobium*-pelleting treatment and addition of coir-pith compost to soil on growth and nodulation of fluoride-water-irrigated blackgram (*Phaseolus mungo*). Indian J. Agric. Sci. 67(12): 601-603.

Kamrujjaman, M. 2003. Effect of rhizobium inoculants on nodulation, growth and yield of blackbram varieties. M.S. Thesis, Department of Soil Science, Bangladesh Agric. Univ., Mymensingh. pp. 1-77.

Kavathiya, Y.A. and R.N. Pandey. 2000. Interaction studies on *Meloidogyne javanica*, *Rhizobium* species and *Macrophomina phaseolina* in mungbean. J. Mycol. Plant Path. 30(1): 91-93.

Keeney, D.R. and Nelson, D.W. 1982. Nitrogen inorganic Forms. *In*: Methods of Soil Analysis. Part 2. 2$^{nd}$ Ed. Page, A.L. Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Inc. Madison, Wisconsin., USA. pp. 643-693.

Knudsen, D., Petterson, G.A. and Pratt, P.F. 1982. Lithium, Sodium and Potassium, *In*. Methods of Soil Analysis, Part 2, 2$^{nd}$ Ed., Page. A.L., Miller. R.H. and Keeney, D.R. 1982. Amer Soc. Agron. Inc. Madi. Wis., USA. pp. 225-245.

Kumar, L.S.S., A.C. Agarwala, H.R. Arakeri and M.O. Kamath. 1963. Pulses Agriculture in India. Asian Publishing House, New Delhi. Vol. 2, Crop. 38.

Kumar, N. and R. Chandra. 2003. *Rhizobium* and VA mycorrhizal inoculation effect on mungbean (*Vigna radiata*) with varying phosphorus levels. Legume Res. 26(4): 284-287.

Kumar, S., R.C. Singh and V.S. Kadian. 2003. Performance of mungbean as influenced by seed inoculation with *Rhizobium* and levels of organic and inorganic sources of nutrients. Indian J. Pulses Res. 16(1): 67-68.

Kumari, K.S.M. and S.K. Nair. 2003. Use of acid tolerant strains of *Bradyrhizobium* sp. for blackgram and greengram. Legume Res. 26(1): 60-62.

Malik, M.A., S. Hussain, E.A. Warraich, A. Habib and S. Ullah. 2002. Effect of seed inoculation and phosphorus application on growth, seed yield and quality of mungbean (*Vigna radiata* L.) cv. NM-98). Intl. J. Agric. Biol. 4(4): 515-516.

Mandal, K., S. Kumar and K. Yadav. 2006. Nodulation and survival of acid tolerant mungbean rhizobia in acid soils. Indian J. Pulses Res. 19(1): 121-123.

Manivannan, V., K. Thanunathan, V. Imayavaramban and N. Ramanathan. 2003. Growth and growth analysis of rice-fallow blackgram as influenced by foliar application of nutrients with and without *Rhizobium* seed inoculation. Legume Res. 26(4): 296-299.

Maqsood, M., M.U. Hassan, M.I. Hussain and M.T. Mahmood. 2001. Effect of different levels of phosphorus on agronomic traits of two mashbean genotypes (*Vigna mungo* L.). Pakistan J. Agric. Sci. 38(1/2): 81-83.

Mozumder, S.N. 1998. Effect of nitrogen and rhizobial fertilizer on two varieties of summer mungbean (*Vigna radiata* L. Wilczek). M.S. Thesis, Dept. of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-76.

Mozumder, S.N., M. Salim, A.K. Podder, M.M. Zaman and M.I. Haque. 2005. Effect of nitrogen and *Bradyrhizobium* on the yield of mungbean. J. Agric. Rural Dev. 3(1/2): 73-78.

Muhammad, D., A.H. Gurmani and M. Khan. 2004. Effect of phosphorus and *Rhizobium* inoculation on the yield and yield components of mungbean under the rainfed conditions of D.I. Khan. Sarhad J. Agric. 20(4): 575-582.

Nag, B.L., A. Rahman and M.A. Rahman. 2000. Growth analysis and yield performance of blackgram varieties. Legume Res. 23(3): 146-150.

Nagarajan, P. and D. Balachandar. 2001. Influence of *Rhizobium* and organic amendments on nodulation and grain yield of blackgram and greengram in acid soil. Madras Agric. J. 88(10/12): 703-705.

Naher, S. 2000. Comparative performance of bio-fertilizer and chemical fertilizer on the yield and yield contributing characters of mungbean. M.S. Thesis, Dept. of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-62.

Navgire, K.D., V.V. Datar, B.V. Asewar and A.L. Dahiwal. 2001. Response of mungbean cultivars to different *Rhizobium* strains under rainfed conditions. Annals Plant Physiol. 15(2): 134-137.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, Organic carbon and Organic matter. *In*: Methods of Soil Analysis. Part. 2. 2$^{nd}$ Ed. Page, A.L., Miller, R.H. and Keeny, D.R. (Eds.). Amer. Soc. Agron. Madison, Wisconsin, USA. pp. 539-579.

Olsen, S.R. and Sommers, L.E. 1982. Phosphorus, *In*: Methods of Soil Analysis. Part II. 2$^{nd}$ Ed. Page, A.L. Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Inc. Madison, Wisconsin, USA. pp. 403-430.

Osunde, A.D., S. Gwam, A. Bala, N. Sanginga, and J.A. Okogun. 2003. Response of *Bradyrhizobium* inoculation by two promiscuous soybean cultivars in soils of the southern Guineu Savanna Zone of Nigeria. Biol. Fert. Soils. 37(5): 274-279.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of Soil Analysis. Part 2. 2$^{nd}$ Ed. Amer. Soc. Agron., Inc., Medison, Wisconsin, USA.

Parveen, S., M.S. Khan and A. Zaidi. 2002. Effect of rhizospheric microorganisms on growth and yield of greengram (*Phaseolus radiatus*). Indian J. Agril. Sci. 72(7): 421-423.

Potdukhe, S.R. and D.D. Guldekar. 2003. Studies on synergistic effect of dual inoculation of *Rhizobium*, BSP and antagonistic bacteria on nodulation and grain yield of mungbean. Annals Plant Physiol. 17(1): 78-80.

Raza, W., M.J. Akhtar, M. Arshad and S. Yousaf. 2004. Growth, nodulation and yield of mungbean (*Vigna radiata* L.) as influenced by coinoculation with *Rhizobium* and plant growth promoting rhizobacteria. Pakistan J. Agril. Sci. 41(3/4): 125-129.

Reddy, A.S. and K.V. Mallaiah. 2001. Studies on the effect of *Rhizobium* inoculation on blackgram. *In*: Bioinoculants for Sustainable Agriculture and Forestry. *Proc. Nat. Symp.* held on February 16-18, 2001. pp. 93-98.

Rhoades, J.D. 1982. Cation Exchange Capacity. *In*: Methods of Soil Analysis. Part-2, 2nd Ed. (Page, A.L., Miller, R.H. and Keeney, D.R. eds.). 1982. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA. pp. 149-157.

Roasales, C.M., F.G. Rivera, R.A. Hautea and E. Del Rosario. 1998. Field evaluation of $N_2$ fixation by mungbean in the Philippines and residual effects on maize. *In*: Improving yield and nitrogen fixation of grain legumes in the tropics and sub-tropic of Asia. pp. 65-75. (IAEA TECDOC-1027; Vienna).

Roy, A.K. 2001. Response of biofertilizer to nodulation, growth and yield of different varieties of summer mungbean (*Vigna radiata* L.). M.S. Thesis, Dept of Soil Sci., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-123.

Sangakkara, R., P. Amarasekera and P. Stamp. 2011. Growth, yields, and nitrogen-use efficiency of maize (*Zea mays* L.) and mungbean (*Vigna radiata* L. Wilczek) as affected by potassium fertilizer in Tropical South Asia. Communications in Soil Sci. and Plant Analysis. 42(7): 832-843.

Sarkar, H.K., A.K. Pal and R. Baisya. 2002. Effect of *Bradyrhizobium* inoculation on blackgram [*Vigna mungo* (L.) Hepper] with special reference to root and nodule parameters. J. Interacademicia. 6(3): 260-265.

Shaikh, M.A.Q. 1977. Grain legumes in Bangladesh. Induced Nutritions for the Improvement of grain legume production in South Eash Asia. IAEA-TDCDOC-203. Inter. Atomic Energy Agency, Vienna. pp. 61-77.

Sharma, P., H.S. Sekhon, V. Khanna and G. Singh. 2007. Biological nitrogen fixation in mungbean: facts and findings. Acta Horticulture. 752: 597-601.

Sharma, P., R.P Gupta and V. Khanna. 2006. Evaluation of liquid *Rhizobium* inoculants in mungbean, urdbean, and pigeonpea under field conditions. Indian J. Pulses Res. 19(2): 208-209.

Sharma, S. and R.G. Upadhyay. 2003. Effect of seed inoculation with various *Bradyrhizobium* strains on growth and yield attributes of mungbean [*Vigna radiata* (L.) Wilczek]. Legume Res. 26(3): 211-214.

Sharma, S., R.G. Upadhyay and C.R. Sharma. 2000. Effect of *Rhizobium* inoculation and nitrogen on growth, dry matter accumulation and yield of blackgram (*Vigna mungo* (L.) Hepper). Legume Res. 23(1): 64-66.

Singh, B. and R.G. Pareek. 2003. Effect of phosphorus and biofertilizers on growth and yield of mungbean. Indian J. Pulses Res. 16(1): 31-33.

Singha, D.D. and A. Sarma. 2001. Response of blackgram (*Phaseolus mungo*) to phosphorus fertilization and *Rhizobium* inoculation in the hill soils of Assam. Annals Agril. Res. 22(1): 151-153.

Solaiman, A.R.M. 1999. Effects of *Bradyrhizobium japonicum* inoculation and molybdenum on soybean. Bangladesh J. Botany. 28(2): 181-182.

Solaiman, A.R.M., D. Hossain and M.M Haque. 2003. Responses of mungbean varieties to *Rhizobium* inoculation in respect of nodulation, nitrogenase activity, dry matter yield, and nitrogen uptake. Korean J. Crop Sci. 48(5): 355-360.

Srinivas, M. and M. Shaik. 2002. Effect of *Rhizobium* inoculation and different levels of nitrogen and phosphorus on yield and economics of greengram (*Vigna radiata* L. Wil.). Crop Res. 24(3): 463-466.

Sriramachandrasekharan, M.V. and V. Vaiyapuri. 2003. Influence of granular insecticide-carbofuran in association with *Rhizobium* on nodulation, growth and yield of blackgram. J. Ecobiol. 15(2): 107-111.

Srivastav, A.K. and S.C. Poi. 2000. Response of greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) to *Bradyrhizobium* as well as the residual effects of *Bradyrhizobium* strains on the same crops. Advances in Plant Sci. 13(2): 431-435.

Thakur, A.K. and J.D.S. Panwar. 1995. Effect of *Rhizobium*-VAM interactions on growth and yield in mungbean (*Vigna radiata* L. Wilczek) under field condition. Indian J. Plant Physiol. 38: 62-65.

Tickoo, J.L., N. Chandra, B. Gangaiah and H.K. Dikshit. 2006. Performance of mungbean (*Vigna radiata*) varieties at different row spacing and nitrogen-phosphorus fertilizer levels. Indian J. Agril. Sci. 76(9): 564-565.

Tomar, A., N. Kumar, R.P. Pareek and R. Chandra. 2003. Residual effect of blackgram inoculated *Rhizobium*, VAM and PSB on succeeding wheat crop. Indian J. Pulses Res. 16(2): 141-143.

Vincent, J.M. 1970. Selective Indicator Media. A. Manual for the practical study of the root nodule bacteria. IBP Hand Book No. 15: 4.

# Appendices

**Appendix 4.1. Effects of varieties on nodule number and nodule weight of blackgram**

| Variety | Nodule no. plant$^{-1}$ | | Nodule weight (mg plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| BARI Mash-1 | 5.53 | 7.77 | 5.83 | 10.24 |
| BARI Mash-2 | 5.33 | 7.41 | 5.83 | 10.50 |
| BARI Mash-3 | 5.53 | 7.59 | 6.07 | 10.50 |
| SE (±) | 0.144 | 0.21 | 0.19 | 0.20 |
| Level of sig. | NS | NS | NS | NS |

NS = Non significant

**Appendix 4.2. Effect of *Bradyrhizobium* inoculants on nodule number and nodule weight of blackgram**

| *Bradyrhizobium* inoculant | Nodule no. plant$^{-1}$ | | Nodule weight (mg plant$^{-1}$) | |
|---|---|---|---|---|
| | 35 DAS | 50 DAS | 35 DAS | 50 DAS |
| Uninoculated | 3.44c | 5.33b | 3.70c | 7.13b |
| BARI RVm-301 | 6.06a | 8.18a | 6.56a | 11.03a |
| BARI RVm-302 | 6.39a | 8.39a | 6.86a | 11.60a |
| BARI RVm-303 | 5.33b | 7.89a | 5.83b | 11.02a |
| Mixed culture | 6.11a | 8.17a | 6.61a | 11.27a |
| SE (±) | 0.19 | 0.27 | 0.24 | 0.26 |
| Level of sig. | ** | ** | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

**Appendix 4.3. Effects of varieties on stover yield and seed yield of blackgram**

| Variety | Stover yield (g plant$^{-1}$) | Seed yield (g plant$^{-1}$) |
|---|---|---|
| BARI Mash-1 | 2.32a | 1.79b |
| BARI Mash-2 | 2.72a | 2.10a |
| BARI Mash-3 | 2.17b | 2.00a |
| SE (±) | 0.06 | 0.04 |
| Level of sig. | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

**Appendix 4.4. Effects of *Bradyrhizobium* inoculant on stover yield and seed yield of blackgram**

| *Bradyrhizobium* inoculant | Stover yield (g plant$^{-1}$) | Seed yield (g plant$^{-1}$) |
|---|---|---|
| Uninoculated | 2.05b | 1.65c |
| BARI RVm-301 | 2.57a | 2.07ab |
| BARI RVm-302 | 2.39a | 2.09a |
| BARI RVm-303 | 2.43a | 1.92b |
| Mixed culture | 2.60a | 2.07ab |
| SE (±) | 0.08 | 0.06 |
| Level of sig. | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

**Appendix 4.5. Effects of variety on N content in seed and stover and N uptake by seed and stover in blackgram**

| Variety | N uptake (mg plant$^{-1}$) | |
|---|---|---|
| | Seed | Stover |
| BARI Mash-1 | 56.14c | 33.75b |
| BARI Mash-2 | 66.86a | 39.38a |
| BARI Mash-3 | 62.62b | 31.44b |
| SE (±) | 1.43 | 0.89 |
| Level of sig. | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

**Appendix 4.6. Effect of *Bradyrhizobium* inoculants on N content in seed and stover, N uptake by seed and stover in blackgram**

| *Bradyrhizobium* inoculant | N uptake (mg plant$^{-1}$) | |
|---|---|---|
| | Seed | Stover |
| Uninoculated | 49.74b | 28.52a |
| BARI RVm-301 | 65.33a | 37.39a |
| BARI RVm-302 | 66.63a | 35.33a |
| BARI RVm-303 | 61.53a | 35.03a |
| Mixed culture | 66.14a | 38.01a |
| SE (±) | 1.85 | 1.14 |
| Level of sig. | ** | ** |

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level