A COMPERATIVE STUDY ON NITROGENOUS AND BIOFERTILIZER ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled, **"A COMPERATIVE STUDY ON NITROGENOUS AND BIOFERTILIZER ON GROWTH AND YIELD OF MUNGBEAN"** 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 (M.S.) in Agricultural Chemistry, embodies the result of a piece of *bona fide* research work carried out by **MD. ELIASH HOSSAIN** Registration No. 05-01706 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

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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
$\mu g\ g^{-1}$	Microgram per gram

ABSTRACT

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from April 2011 to July 2011 to study the performance of two mungbean varieties without *Bradyrhizobium* and with nitrogen/*Bradyrhizobium*. There were six treatment combinations and four replications were laid out in Randomized Complete Block Design (RCBD) technique. The *Bradyrhizobium* strain BARI RVr-403 was used for the above experiment. The selected varieties were BARI Mung-5 and BARI Mung-6. The above varieties were tested with or without nitrogen/*Bradyrhizobium* inoculation. BARI Mung-5 performed better than BARI Mung-6 variety 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}. But BARI Mung-6 produced higher 1000-seed weight, stover yield, seed yield, plant height and seeds pod^{-1} than BARI Mung-5. *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. Interaction effects revealed that BARI Mung-5 with *Bradyrhizobium* inoculation recorded the highest nodulation but inoculated BARI Mung-6 recorded the highest seed yield compared to other treatment combinations. Non-inoculated BARI Mung-5 gave the lowest yield. The highest N uptake by seed and stover was found in BARI Mung-6 x Inoculum treated plot. Economic analysis revealed that the highest BCR (1.31) was noted in inoculated BARI Mung-5.

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilezek) is one of the most important pulse crops in the country for its high digestibility, good flavour and high content. It holds the 3rd position in price, 3rd in protein content, and 4th in both acreage and production in Bangladesh (BBS, 2011; Sarker *et al*., 1982). Hence, from the point of nutritional value, mungbean is perhaps the best of all others pulses (Khan *et al*., 1982). It contains 51% carbohydrate, 26% protein, 3% minerals and 3% vitamins (Kaul, 1982). It contributes about 9.14% of total pulse production (BBS, 2011). Mungbean is mainly grown localized area of Barisal, Patuakhali and Faridpur regions.

Mungbean is one of the widely grown pulse crops in Bangladesh for human consumption, animal fodder as well as soil fertility building purpose. But costly and environmentally risky chemical fertilizers cause serious and continuous problem for increasing mungbean production in developing countries including Bangladesh. These problems are likely to become serious in future. Biological Nitrogen Fixation (BNF) resulting from symbiosis between legume crops and root nodule bacterium *Bradyrhizobium* can ameliorate these problems by reducing the chemical N-fertilizer input required to ensure productivity.

As a legume, mungbean is capable of utilizing atmospheric nitrogen through symbiotic association with *Bradyrhizobium* sp. (*Vigna*) and thereby can meet the requirement of the element. Inoculation of mungbean with effective *Bradyrhizobium* inoculant is necessary for soils where the organisms are ineffective or where they are absent or scarce (Vincent, 1970).

Mungbean cultivation has been declining due to low yield and less economic return whereas it is an important pulse crop in Bangladesh. This trend should be measured by introducing high-yielding mungbean varieties and making the practice of rhizobial inoculation. Fitting summer mungbean into our usual rice-based cropping pattern may also make the farmers interested in utilizing mungbean.

The successful growing of mungbean is dependent on the availability of its microsymbiont bacteria in soil. *Bradyrhizobium* strains are present in all soils of Bangladesh but they may not be equally effective in nodulation and N-fixation. In this situation, inoculation can meet the challenge by providing superior strains in the soil, so that the most effective nodulation and nitrogen fixation are obtained. Thus it was thought that there is a scope for utilizing the effective bradyrhizobial strains for obtaining more yield of mungbean under field conditions which may play vital role in improving soil environment and agricultural sustainability.

Now a day a number of organisms like *Bradyrhizobium* has been identified to use as biological agent for fixing atmospheric nitrogen by processing with legume crops and make available to the plants. Bangladesh Agricultural Research Institute (BARI) isolated some *Rhizobium* strains for some pulse crops. It has already been selected some *Bradyrhizobium* strains especially for mungbean 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 increase biological nitrogen fixation. *Bradyrhizobium* inoculation increased mungbean seed yield from 4.3% to 16.2% (Vaishya *et al.*, 1983). In Bangladesh, inoculation with *Bradyrhizobium* increased 25% dry matter production, 28% grain yield and 21% hay yield over non-inoculated control (Bhuiyan and Mian, 2007). Maximum yields were obtained when fertilizers applied together with *Bradyrhizobium* inocula. Singha and Sharma (2001) reported that *Rhizobium* inoculation significantly increased the number (2.2%) and mass (9.5%) of root nodules plant^{-1} compared to control. Meenakumari and Nair (2001) reported that N content of fresh seed was 5.78% in the inoculated plants, while that in non-inoculated control was only 2.7%. Seed inoculation with *Bradyrhizobium* significantly increased seed yield (0.88 t ha^{-1}, 28.0% increase over control) and stover yield (2.18 t ha^{-1}) of mungbean (Bhuiyan and Mian, 2007). *Bradyrhizobium* inoculation also significantly increased pods plant^{-1}, seeds pod^{-1} and 1000-seed weight (Bhuiyan *et al.*, 2008a).

The present research work was undertaken to evaluate the effect of *Bradyrhizobium* inoculants and nitrogenous fertilizer on mungbean production with the following objectives:

1. To observe the effect of nitrogenous and *Bradyrhizobium* inoculant on nodulation, growth, yield and nitrogen uptake by mungbean.

2. To investigate the interaction effect of mungbean varieties and biofertilizer/ nitrogenous fertilizers.

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 combined use of *Bradyrhizobium* inoculation/nitrogen and mungbean varieties is very little. Only limited number of research works has so far been carried out on the combined use of *Bradyrhizobium* inoculation/nitrogen on mungbean (*Vigna radiata* L.) and other pulse crops. However, available information on the contribution of *Bradyrhizobium* inoculation and nitrogen on mungbean and other variety/varieties has been reviewed in this chapter.

2.1 Effect of variety

Effect of variety on mungbean 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.

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 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.

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.

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* in 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}.

An experiment was carried out by Bhuiyan and Mian (2009) at Bangladesh Agricultural University Farm to find out the time of nodule initiation, nodulation pattern and their size distribution. 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 in this experiment. The experiment was designed in randomized complete block design having four replications in each treatment. Each variety was tested with or without inoculation. 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 (1-2, 2-3 mm) started to decline after 42 DAS sharply and in case of <1 mm size nodules, the declining was noticeable after 21 DAS, while the bigger nodules (3-4 and >4 mm were increased up to 56 DAS. No effective nodule of any size was found at 77 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 was observed in Barimung-2 at different DAS. At 14 DAS, smaller size nodules were higher than the bigger nodules in all the varieties. At 42 DAS, the highest number of nodules 0.3 (<1 mm), 7.4 (1-2 mm), 4.4 (2-3 mm, 2.7 (3-4 mm) and 0.3 (>4 mm) $plant^{-1}$ was found in BARI Mung-2, while the other varieties produced the nodules in the range of 0.2-0.3 (<1 mm), 5.6-7.0 (1-2 mm), 3.3-4.2 (2-3 mm), 2.0-2.5 (3-4 mm) and 0.2-0.3 (>4 mm) $plant^{-1}$. It indicated that BARI Mung-2 always produced larger size nodules at different sampling dates. Smallest size (<1 mm) nodules increased up to 21 DAS, whereas medium (1-2 and 2-3 mm) size nodules also increased up to 42 DAS and the larger (3-4 mm) to the largest (>4 mm) at 56 DAS and then decreased. At the same DAS, *Bradyrhizobium* inoculation produced 0.3 (<1 mm), 7.8 (1-2 mm), 4.7 (2-3 mm), 2.8 (3-4 mm) and 0.3 (>4 mm) nodules plant^{-1}, while uninoculated plant produced 0.2 (<1 mm), 5.4 (1-2 mm), 3.2 (2-3 mm), 1.9 (3-4 mm) and 0.2 (>4 mm) nodules plant^{-1}. Inoculated BARI Mung-2 always produced greater number and size of nodules at different sampling dates over uninoculated plant.

2.2 Effect of nitrogen

Effect of nitrogen on mungbean and other legumes have been presented below.

Sharma *et al.* (2001) carried out a field experiment on mungbean cv. Pusa Baisakhi which was fertilized with various levels of nitrogen (0, 10 and 20 kg N ha^{-1}) and phosphorus (0, 30 and 60 kg P_2O_5 ha^{-1}) under mid-hill conditions in Himachal Pradesh, India during the kharif seasons of 1998 and 1999. The highest levels of N and P_2O_5 applications resulted in the average maximum test weight, biological and grain yields, harvest index and seed protein content.

Srinivas and Shaik (2002) conducted field experiment during the kharif seasons to study the effects of N (0, 20, 40 and 60 kg ha^{-1}) and P (0, 25, 50 and 75 kg ha^{-1}) along with seed inoculation with *Rhizobium* culture on the growth and yield components of greengram. Plant height generally increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} followed by decrease with further increase in N. Number of seeds pod^{-1}, 1000-seed weight, seed and haulm yields generally increased. Seed inoculation with *Rhizobium* resulted in higher values for the parameters measured relative to the control. The interaction effects between N and P were not significant for the number of pods plant^{-1}, pod length, seed and haulm yield.

Malik *et al.* (2003) carried out a field experiment on mungbean (*Vigna radiata* L.) in Pakistan to determine the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean (*Vigna radiata*) cv. NM-98. Although plant population was not affected significantly, various growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted in the maximum seed yield (1,113 kg ha^{-1}). Protein content (25.6%) was maximum in plots treated with 50 kg N + 75 kg P ha^{-1}, followed by 25.1% protein content in plots treated at 25 kg N + 75 kg P ha^{-1}. The highest net income (Rs. 21,375) was obtained by applying 25 kg N + 75 kg P ha^{-1}.

Patel *et al*. (2003) conducted a field experiment in Gujrat, India during the summer seasons of 1995 to 1998 on sandy loam soils to determine the suitable sowing date, and nitrogen and phosphorus requirements of summer mungbean (cv. GM3). Treatments comprised: all the 27 combinations of three sowing dates: 15 February, 1 March and 15 March; three nitrogen rates: 10, 20 and 30 kg N ha^{-1}; and three phosphorus rates: 20, 40 and 60 P ha^{-1}. Results indicated that sowing mungbean on 1 March recorded significantly higher grain yields, 37 and 16% higher than those of early (15 February) or late-sown crops (15 March), respectively. Application of 10 kg N ha^{-1} recorded significantly higher grain yield over the control. Treatment with 40 kg P ha^{-1} produced 15 and 18% higher grain yields than treatments with 20 and 60 kg P ha^{-1}, respectively. The highest net return of Rs. 18,240 ha^{-1} was recorded from mungbean sown on 1 March and treated with 20 kg N ha^{-1} and 40 kg P ha^{-1}.

Sangakhara (2003) carried out a field experiment in Sri Lanka in 1999 to determine the impact of effective microorganisms (EM) on N dynamics in a cereal (maize cv. Ruwan)-legume (mungbean) cropping system, using ^{15}N labeled maize or mungbean residues. EM increased the ^{15}N concentrations of maize at the V8 growth stage indicating better use of applied nutrients from organic matter. The uptake of ^{15}N was greater from mungbean residues rather than from maize. EM also increased biological N fixation. The synergistic effects of EM in organic systems were evident from this field study.

Ashraf *et al.* (2003) conducted a field experiment at Faisalabad in Pakistan to observe the effects of seed inoculation of a biofertilizer and NPK application on the performance mungbean cv. NM-98. The treatments consisted of the seed inoculation of *Rhizobium phaseoli* singly or in combination with 20:50:0, 40:50:0 or 50:50:50 NPK kg ha^{-1} (urea), P (single super phosphate) and K (potassium sulphate) were applied during sowing. The tallest plants (69.9 cm) were obtained with seed inoculation + 50:50:0 kg NPK ha^{-1}. Seed inoculation + 50:50:0 or 50:50:50 kg ha^{-1} resulted in the highest number of pods $plant^{-1}$ (29.0, 56.0, 63.9 and 32.6, respectively) and seed yield (1,053, 1,066, 1,075 and 1,072 kg ha^{-1}). Harvest index was the highest with seed inoculation in combination with NPK and 40:50:0 (25.23), 50:50:0 (24.70) or 50:50:50 (27.5). Seed inoculation along with NPK at 30:50:0 kg ha^{-1} was optimum for the production of high seed yield by mungbean cv. NM-98.

Panda *et al.* (2003) conducted field experiments in West Bengal, India to evaluate the effects of NK application on the productivity of yambean (*Pachyrhizus erosus*)-pigeonpea (*Cajanus cajan*) intercropping system and its residual effect on the succeeding mung (*Vigna radiata*). Marketable tuber yield of yambean increased linearly with increasing NK levels, with the highest being recorded with NK at 80 kg ha^{-1} applied in 2 splits (22.9 t ha^{-1}) closely followed by 100 kg NK ha^{-1} applied in 2 splits (22.4 t ha^{-1}). For pigeonpea, the maximum grain (14.38 q ha^{-1}), stick (8.08 q ha^{-1}) and bhusa yield (9.96 q ha^{-1}) were recorded with 80 kg NK ha^{-1} applied in 2 splits. The highest level of NK (100 kg ha^{-1}) applied in 3 splits to yambean-pigeonpea intercropping system registered the maximum grain yield of the succeeding mungbean (9.43 q ha^{-1}), which was 33% higher than 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.

A field experiment was laid out by Oad and Buriro (2005) to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan during the spring season of 2004. The different NPK levels significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.3 cm, germination of 90.5%, satisfactory plant population of 162, prolonged days taken to maturity of 55.5, long pods of 5.02 cm, seed weight per plant of 10.5 g, seed index of 3.52 g and the highest seed yield of 1,205 kg ha^{-1}. There was no significant change in the crop parameters beyond this level.

Kabir *et al.* (2005) carried out a field experiment on mungbean to find out the effects of salinity, the growth, plant water relations as well as uptake of nutrient elements in mungbean (*Vigna radiata* L. Wilczek). This study was initiated to examine whether the application of higher levels of nitrogen (N) would improve the salinity tolerance of this crop. Mungbean plants (var. BARI Mung 3) were grown in pots; each filled with 12 kg air-dried loamy soil, inside a plastic greenhouse under natural light conditions during the summer of 2001, with three levels of N, equivalent to 13.3 (low), 40 (medium) and 60 (high) kg ha^{-1} with 0 and 75 mM NaCl. Salinity disturbed the plant water status seriously. Relative water content, xylem exudation rate and leaf water potential decreased by salinity. Application of higher levels of N improved the water status of the plants. Yield and yield components were also adversely affected by salinity, except for the number of seeds per pod. Grain yield and yield components were noticeably improved by the application of high levels of N. The concentrations of N, P, K and Ca markedly decreased by salinity, while that of Na remarkably increased. The concentrations of the nutrients tended to increase, while that of Na to decrease with the application of increased levels of N. It was concluded that the application of higher levels of N improved the water relations and accumulation of nutrient elements as well as yield in mungbean under saline conditions.

Rana and Choudhary (2006) conducted a field experiment during 2000 and 2001 in New Delhi, India to evaluate the relative moisture utilization by maize grown as sole crop or in maize-mungbean intercropping system. Total grain production in terms of maize equivalent was higher in maize (75 cm) + two rows of mungbean. Total N uptake and water use efficiency were also highest in maize (75 cm) + two rows of mungbean. All parameters increased with increasing concentration of N up to 120 kg ha^{-1}.

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.

Sultana *et al*. (2009) conducted a field experiment during the period from March 2007 to June 2007 at Sher-e-Bangla Agricultural University, Dhaka with nitrogen and weed management in mungbean where nitrogen (0, 20 kg ha^{-1} at vegetative, 20 kg N ha^{-1} at vegetative and flowering) and weeding (no weeding, one weeding at vegetative, two weeding at vegetative and flowering) was done. Result showed that application of 20 kg N ha basal showed significantly higher values of all growth parameters like number of leaflet (24.3 at 20 DAS and 24.3 at 40 DAS), leaf area (23.3 cm^2 at 20 DAS and 102.2 cm^2 at 40 DAS), Leaf dry weight (0.30, 6.99 and 10.61 g at 10, 17 and 24 DAS, respectively) and shoot dry weight (2.76 and 4.69 g at 17 and 24 DAS, respectively). This treatment also produced significantly more number of branches (1.67), pods $plant^{-1}$ (17.8) and seed yield (1,982 kg ha^{-1}).

Yaqub *et al*. (2010) carried out pattern based experiment at Pakistan to evaluate the induction of short-duration (maturity period, 55-70 days) mungbean [*Vigna radiata* (L.) Wilczek] as a grain legume in the pre-rice niche of the rice-wheat annual double cropping system and found that induction of a short-duration grain legume in the rice-wheat system appears to be more attractive as it offers short-term additional benefits to farmers and is equally beneficial in sustaining the productivity of rice-wheat system over time. The mungbean crop (grown without mineral N fertilizer) produced 1,166 kg ha^{-1} of grain in addition to 4,461 kg ha^{-1} of the manure biomass (containing 52 kg N ha^{-1}) that was ploughed under before planting rice with urea-N applied in the range of 0-160 kg N ha^{-1}. Averaged across urea-N treatments, manuring significantly increased the number of tillers $plant^{-1}$ (11%

increases), rice grain yield (6% increase), grain N content (4% increase) and grain N uptake (9% increase). Significant residual effects of manuring were observed on the subsequent wheat crop showing higher grain yield (21% increases), grain N uptake (29% increase) and straw yield (15% increase). The results suggested the feasibility of including mungbean in the pre-rice niche to improve the productivity of the annual rice-wheat double cropping system.

Kayani *et al*. (2010) conducted experiment to investigate the impact of legume on the oncoming wheat crop. Mungbean (NM92) was planted during Kharif 2007. The wheat variety Inqalab-91 was sown before and after the mungbean plantation during Rabi 2006-07 and 2007-08. Twelve different treatments were applied having different doses of N and P but Farm Yard Manure (FYM) remained constant. Six parameters were selected to investigate the potential effects of the legume viz., soil physico-chemical properties, plant height, spike length, number of grains spike^{-1}, 1000 grains weight and yield plot^{-1}. The results showed significant increase in plant height, spike length, number of grains/spike, 1000-grains weight and yield/plot after cropping mungbean. The yield was obtained at an increase of 26.90% after mungbean application. Based on results, cereal legume crop rotation is highly recommended.

A field experiment was conducted by Mohammad *et al*. (2010) to study the effect of crop residues and tillage practices on BNF, WUE and yield of mungbean (*Vigna radiata* (L.) Wilczek) under semi arid rainfed conditions at the Livestock Research Station, Surezai, Peshawar in North West Frontier Province (NWFP) of Pakistan. The experiment comprised of two tillage i) conventional tillage (T1) and ii) no-tillage (T0) and two residues i) wheat crop residues retained (+) and ii) wheat crop residues removed (-) treatments. Basal doses of N @ 20: P @ 60 kg ha^{-1} was applied to mungbean at sowing time in the form of urea and single super phosphate respectively. Labeled urea having 5% N-15 atom excess was applied @ 20 kg N ha^{-1} as aqueous solution in micro plots (1m^2) in each treatment plot to assess BNF by mungbean. Similarly, maize and sorghum were grown as reference crops and were fertilized with N-15 labeled urea as aqueous solution having 1% N-15 atom excess @ 90 kg N ha^{-1}. The results obtained showed that mungbean yield (grain/straw) and WUE were improved in no-tillage treatment as compared to tillage treatment. Maximum mungbean grain yield (1224 kg ha^{-1}) and WUE (6.61 kg ha^{-1} mm^{-1}) were obtained in no-tillage (+ residues) treatment. The N concentration in mungbean straw and grain was not significantly influenced by tillage or crop residue treatments. The amount of fertilizer-N taken up by straw and grain of mungbean was higher under no-tillage with residues-retained treatment but the differences were not significant. The major proportion of N (60.03 to 76.51%) was derived by mungbean crop from atmospheric N-2 fixation, the remaining (19.6 to 35.91%) was taken up from the soil and a small proportion (3.89 to 5.89%) was derived from the applied fertilizer in different treatments. The maximum amount of N fixed by mungbean (82.59 kg ha^{-1}) was derived in no-tillage with wheat residue-retained treatment. By using sorghum as reference crop, the biological nitrogen fixed by mungbean ranged from 37.00 to 82.59 kg ha^{-1} whereas with maize as a reference crop, it ranged from 34.74 to 70.78 kg ha^{-1} under different treatments. In comparison, non-fixing (reference) crops of sorghum and maize derived upto 16.6 and 15.5% of their nitrogen from the labeled fertilizer, respectively. These results suggested that crop productivity, BNF and WUE in the rainfed environment can be improved with minimum tillage and crop residues retention.

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.

2.3 Effect of *Bradyrhizobium* inoculation

Effect of *Bradyrhizobium* inoculation on mungbean and other legumes have been presented below:

Kavathiya and Pandey (2000) conducted a pot experiment with *Rhizobium* on mungbean (*Vigna radiata* cv. K 851) and found that nodule plant^{-1} increased significantly over uninoculated control. They also reported that maximum seed germination (96.6%), plant height (24.6 cm), fresh shoot weight (5.33 g), fresh root weight (4.42 g) and nodulation (69 healthy nodules plant^{-1}) was recorded in the *Rhizobium* treatment.

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.

Bhattacharyya and Pal (2001) conducted a field experiment in West Bengal, India, during the pre-kharif season to study the effect of *Bradyrhizobium* inoculation, P (at 0, 20 kg ha^{-1}) and Mo (at 0, 0.5 and 1 kg ha^{-1}) on the number of nodules plant^{-1} of summer greengram cv. T-44. Inoculation and application of P and Mo significantly influenced the number of nodules plant^{-1}, dry matter accumulation in the shoot, crop growth rate and plant height comparing with control.

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}).

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.

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.

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.

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.

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

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.

Bhuiyan *et al.* (2008b) conducted a field experiment at Regional Agricultural Research Station, Jamalpur on blackgram and reported that inoculated plants gave significantly 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.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

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 kharif-I season of 2011 for finding out the nodulation, biomass production, yield and N uptake of two varieties of mungbean with three fertility levels.

3.1 Experimental site

The experiment was carried out at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. The experimental site is situated at 23°77' North Latitude and 90°30' East Longitude. The elevation of the experimental site is 1.0 m above the sea level. The area belongs to the Agro-ecological Zone (AEZ- 28): Madhupur Tract.

3.2 Soil

The experiment was conducted on Silty clay loam soil of the Order Inceptisols. The soil of SAU 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 experiment field

Characters	SAU farm
Locality	SAU, Dhaka
Geographic position	23°77' North Latitude 90°30' East Longitude 1.0 m height above the mean sea level
Agro-ecological zone	Madhupur Tract (AEZ-28)
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Land type	High land

Table 3.2. Physical and chemical characteristics of the soils

Characteristics	SAU farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	29.93
% Silt (0.02-0.002 mm)	40.27
%Clay (< 0.002 mm)	29.80
Textural class	Clay loam
Soil pH	6.9
Organic C (%)	0.61
Organic matter (%)	1.05
Total N (%)	0.08
Available P (ppm)	12.78
Available K (ppm)	43.29
Available S (ppm)	23.74
Available B (ppm)	0.36

3.3 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.

3.4 Crop: Mungbean

3.5 Mungbean varieties

Two mungbean varieties viz. BARI Mung-5 and BARI Mung-6 were used in the study. The salient characteristics of these varieties are presented below:

BARI Mung–5

BARI released BARI Mung-5 in 1997. Plant height of this variety ranges from 40 to 45 cm and seeds are deep green in colour. One thousand seed weight is about 40 to 42 g. The variety requires 55 to 60 days to mature, and average yield is 1,200 kg ha^{-1}. It is resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus (BARI, 1998). One of the main characteristics of the variety is synchronization in pod ripening in the summer season.

BARI Mung–6

BARI released BARI Mung-6 in 2003. Plant height of this variety ranges from 40 to 45 cm and seeds are deep green in colour. One thousand seed weight is about 45 to 50 g. The variety requires 55 to 60 days to mature, and average yield is 1,500 kg ha^{-1}. It is also resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus (BARI, 2009).

3.6 Year: Kharif-I 2011

3.7 Treatments and experimental design

The experiment was laid out in a randomized complete block design with four replications. Each plot was measured 2.4 m x 2 m.

A. Crop variety: 2

1. BARI Mung-5
2. BARI Mung-6

B. Fertility level: 3

1. Control (without N and Inoculum)
2. N (N_{50} kg ha^{-1})
3. Inoculated (*Bradyrhizobium* Inoculum 1.5 kg ha^{-1})

Hence, there were 6 treatment combinations as follows:

$T_1V_1F_1$:BARI Mung-5 x Uninoculated

$T_2V_1F_2$: BARI Mung-5 x N_{50}

$T_3V_1F_3$: BARI Mung-5 x Inoculated with *Bradyrhizobium*

$T_4V_2F_1$: BARI Mung-6 x Uninoculated

$T_5V_2F_2$: BARI Mung-6 x N_{50}

$T_6V_2F_3$: BARI Mung-6 x Inoculated with *Bradyrhizobium*

3.8 Land preparation

The experimental lands were opened with a power tiller on 15 April 2011 and subsequently ploughed twice followed by laddering. The lands were finally prepared on 22 April 2011.

3.9 Fertilizer application

After making the lay out of the experiment, the lands were fertilized on 25 April 2011 with 22, 42, 20 and 5 kg ha^{-1} of P, K, S and Zn in the form of triple superphosphate, muriate of potash, gypsum and zinc sulphate, respectively. Nitrogen was applied as urea in this experiment where necessary.

3.10 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 $CaCO_3$. 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 for three consecutive days for one hour each day. The sealed peat was ready for inoculation.

3.11 Inoculum preparation

The bradyrhizobial inoculant was prepared in the Soil Microbiology Laboratory of BARI using the broth culture. The *Bradyrhizobium* strain (BARI RVr-402) was collected from the stock culture of the laboratory. Yeast extract mannitol broth was prepared in a 250 ml Erlenmeyer flask. The liquid medium was sterilized for 30 minutes at 121°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°C under 120 rpm to enhance bradyrhizobial growth. After 6-7 days, the medium in the flask showed dense growth and then the broth culture was taken out from the shaker. From this ready broth, 20 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°C for two weeks to make them ready for seed inoculation.

3.12 Viability count of *Bradyrhizobium*

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

3.13 Procedure for inoculation

Inoculation was done just before sowing. Healthy mungbean seeds @ 25 g for each plot were taken into polyethylene bags separately and 1 ml of the sticker solution (4% gum acacia solution) was added to each bag with sterilized pipettes. It was followed by addition of 1.25 g of the 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.

3.14 Sowing

Mungbean was sown on 27 April 2011. Healthy seeds of mungbean @ 35 kg ha^{-1} were sown by hand as uniformly as possible in furrows. Different polyethylene bags were used for different treatments and the uninoculated seeds were sown first to avoid the risk of contamination. Seeds were sown in the afternoon and immediately covered with soil to avoid sunlight. Line to line distance was 30 cm.

3.15 Intercultural operation

Weeding was done at 12 and 35 days after sowing. Thinning was done on the same date of 1st weeding to maintain optimum plant density. Plant to plant distance was maintained at 10.0 cm. A light irrigation was given after sowing for germination of seed. Pest did not infest the mungbean crop at the early stage. The insecticide Diazinon 60 EC was sprayed @ 0.02% after 40 days of sowing to control caterpillar. No disease was observed in the experimental field.

3.16 Collection of samples

3.16.1 Soil

Soil samples from experimental plots were collected before sowing. The collected soil samples were dried, ground, sieved and stored for chemical analysis.

3.16.2 Plant

Plant samples were collected at 35 DAS and 50 DAS to record data on nodule and shoot parameters. Ten plants from each plot 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.

3.16.2.1 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 plot-wise and their dry weights were recorded.

3.16.2.2 Nodule number and mass

The data on nodule number (main root and branch root) and nodule mass were recorded by taking 10 randomly selected plants from each plot at two DAS (35 DAS and 50 DAS). The data on nodule mass were expressed in mg plant^{-1} on oven dry basis.

3.16.2.3 Shoot weight and root weight

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

3.16.2.4 Shoot length and root length

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

3.16.2.5 Estimation of N

The N concentrations in stover and seed were determined by micro-Kjeldahl method.

3.16.2.6 Harvesting and data recording on yield and yield contributing characters

Yield data were collected from an area of 2.4m x 2m of each plot. The seeds and stover were dried and weighed adjusting at 14% moisture content and yields were converted to kg ha^{-1}. The following parameters were recorded:

i) Plant height (cm)
ii) Pod length (cm)
iii) Pods $plant^{-1}$
iv) Seeds pod^{-1}
v) 1000-seed weight (g)
vi) Seed yield (t ha^{-1})
vii) Stover yield (t ha^{-1})

3.17 Seed and stover sampling for analysis

Mungbean seeds and stover were sampled plot-wise, dried, ground and stored for chemical analysis.

3.18 Plant analysis

3.18.1 Collection and preparation of plant samples for chemical analysis

Plant samples (seed and stover) were collected from bulk harvest. The stover was washed under running tap water followed by rinsing with distilled water to remove surface contamination. The stover was immediately air-dried and was chopped off into smaller pieces. The seed and stover samples were 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.

3.18.2 Chemical analysis of plant samples

Seed and stover samples of mungbean were analyzed for determination of N concentrations following the methods described below:

Nitrogen

The plant samples (0.1 g seed, 0.2 g straw) were 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^{0}C for one and a half-hour.

3.19 Nutrient uptake

Nitrogen uptake by mungbean was computed from the respective chemical concentration and dry matter yields.

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Observation on nodulation on roots of two mungbean varieties was done at 35 and 50 days after sowing (DAS). The number of total nodules, nodule on main root and branch root separately were higher at 35 DAS (Figs. 4.1-4.12 and App. 4.1.-4.3). The number of nodules declined at 50 DAS.

Rhizobia are usually present in the soil and multiply in the rhizospheric zone of the plant when the seed germinates. Very early, these rhizobia penetrate the root of the young seedlings through a mechanism that remains poorly understood (FAO, 1983). The higher nodulation was observed at 35 DAS (i.e. at 50% flowering stage) and decreased thereafter. This might be due to senescence of nodules at pod formation stage.

The results on the production of nodule $plant^{-1}$ under different treatments i.e. varietal response, nitrogen/*Rhizobium* inoculant response and their interaction response at two days after sowing have been presented in Figs. 4.1-4.12 and App. 4.1-4.3.

4.1. Nodule on main root

4.1.1. Effect of variety

BARI Mung-5 produced significantly higher number of main root nodules (3.42 $plant^{-1}$ at 35 DAS and 3.17 $plant^{-1}$ at 50 DAS) than BARI Mung-6 (3.08 $plant^{-1}$ at 35 DAS and 2.31 $plant^{-1}$ at 50 DAS) (Fig. 4.1 and App. 4.1).

4.1.2. Effect of fertilizer

Results presented in Fig. 4.2 and App. 4.2 showed that significantly higher number of main root nodule (4.21 $plant^{-1}$ at 35 DAS and 3.04 $plant^{-1}$ at 50 DAS) was found when inoculated with *Bradyrhizobium* compared to N_{50} (3.21 $plant^{-1}$ at 35 DAS) and control (2.33 $plant^{-1}$ at 35 DAS and 2.21 $plant^{-1}$ at 50 DAS). Nodule number on main root recorded by inoculated plant was identical with N_{50} at 50 DAS only. Meenakumari and Nair (2001) conducted a study in 7 different locations to evaluate root nodulation of cowpea, blackgram and mungbean, and observed that root nodulation of cowpea, blackgram and mungbean were uniformly better when *Bradyrhizobium* inoculant was applied. Kumari and Nair (2003) found that the extent of improvement in root nodulation was more in blackgram and greengram inoculated with *Bradyrhizobium*. Tanwar *et al.* (2002) reported that the interaction between P rate and biofertilizers was significant in regard to the number of nodules. The inoculation of both biofertilizers along with the application of 60 kg P_2O_5 gave the highest number of nodules plant^{-1} (40.5).

4.1.3. Interaction effect of variety and fertilizer

The interaction between varieties and fertilizer was non-significant on main root nodule production (Fig. 4.3 and App. 4.3). Number of main root nodule plant^{-1} was the highest in BARI Mung-5 x Inoculums (4.50 at 35 DAS and 3.75 at 50 DAS) and it was observed that in all control plots nodules were lower irrespective of varieties. BARI Mung-6 x U showed the lowest number of main root nodule (2.08 plant^{-1} at 35 DAS and 2.08 plant^{-1} at 50 DAS).

4.2. Nodule of branch root

4.2.1. Effect of variety

Nodule on branch root was significantly higher (9.14 plant^{-1}at 35 DAS and 4.05 plant^{-1} at 50 DAS) in BARI Mung-5 while nodule on branch root was lower (6.83 plant^{-1} at 35 DAS and 3.04 plant^{-1} at 50 DAS) in BARI Mung-6 (Fig. 4.4 and App. 4.1). The minimum number of branch root nodule was 50 DAS with BARI Mung-6. Nodule on branch root was higher at 35 DAS than at 50 DAS. It indicated that nodule number on branch root was higher at 50% flowering stage.

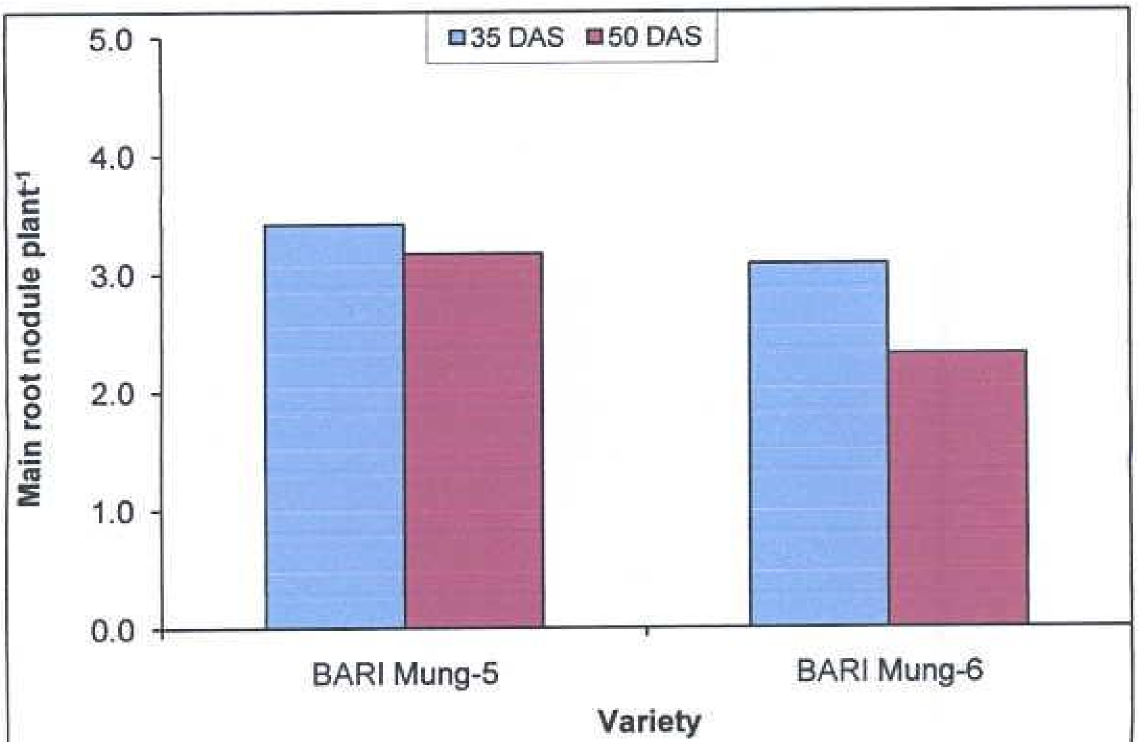

Fig. 4.1. Effect of variety on main root nodule in mungbean

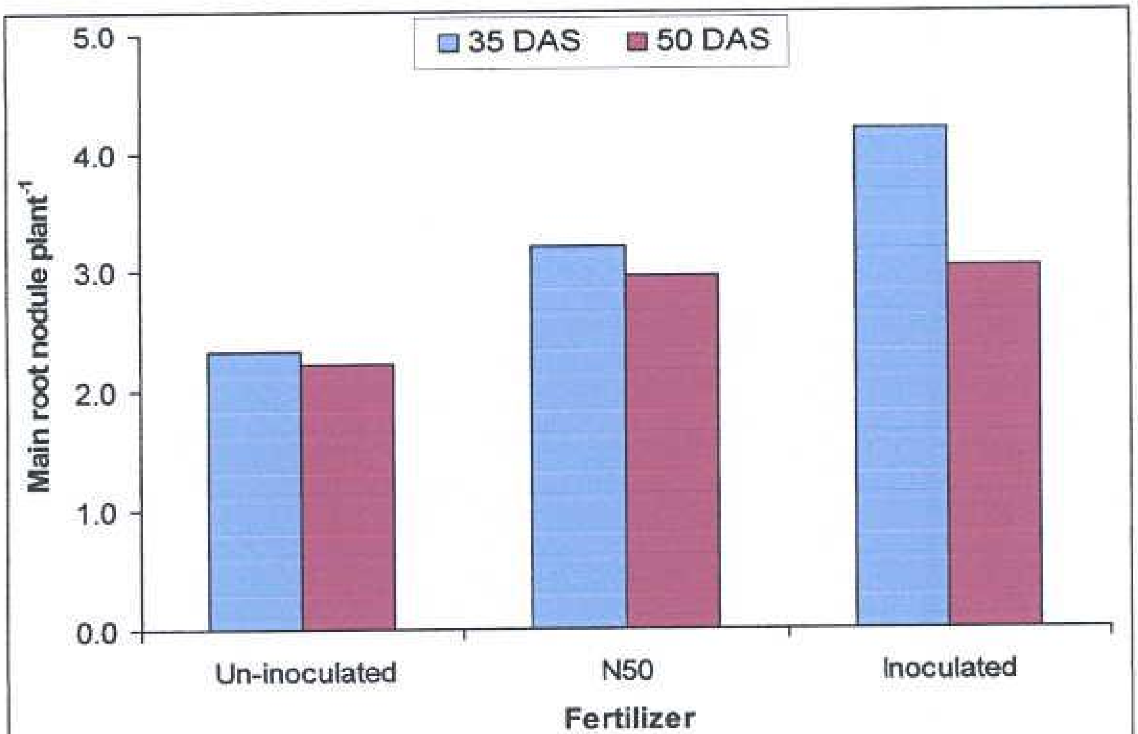

Fig. 4.2. Effect of fertilizer on main root nodule in mungbean

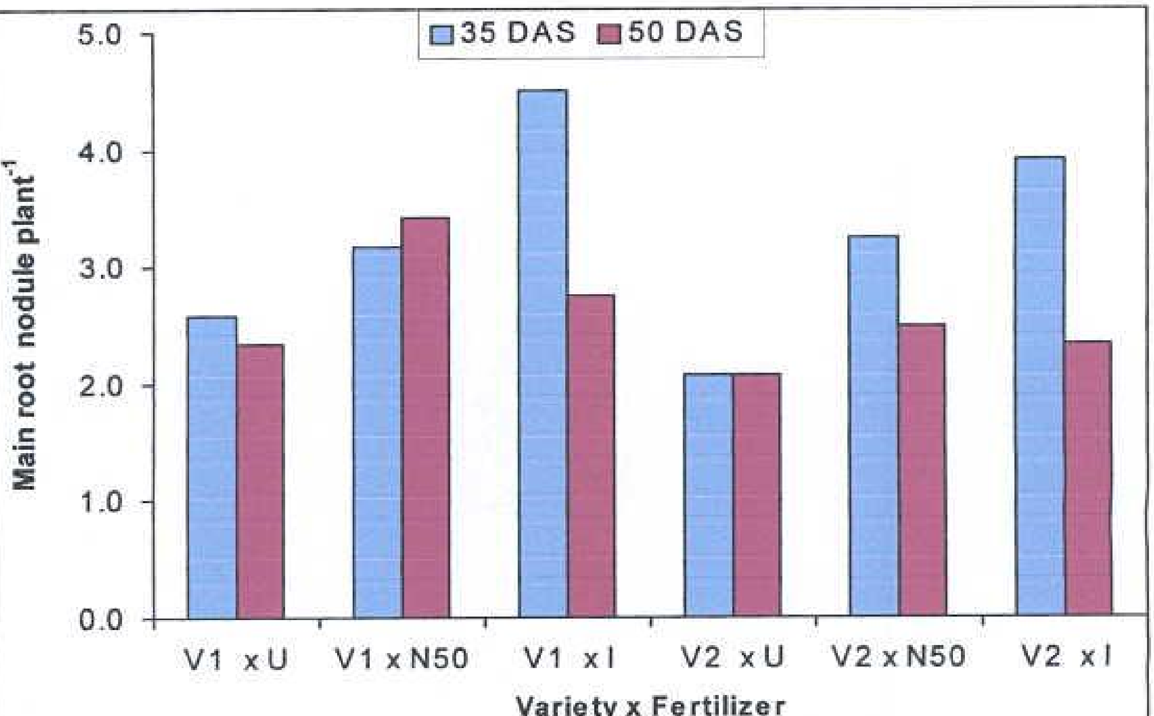

Fig. 4.3. Interaction effect of variety and fertilizer on main root nodule in mungbean

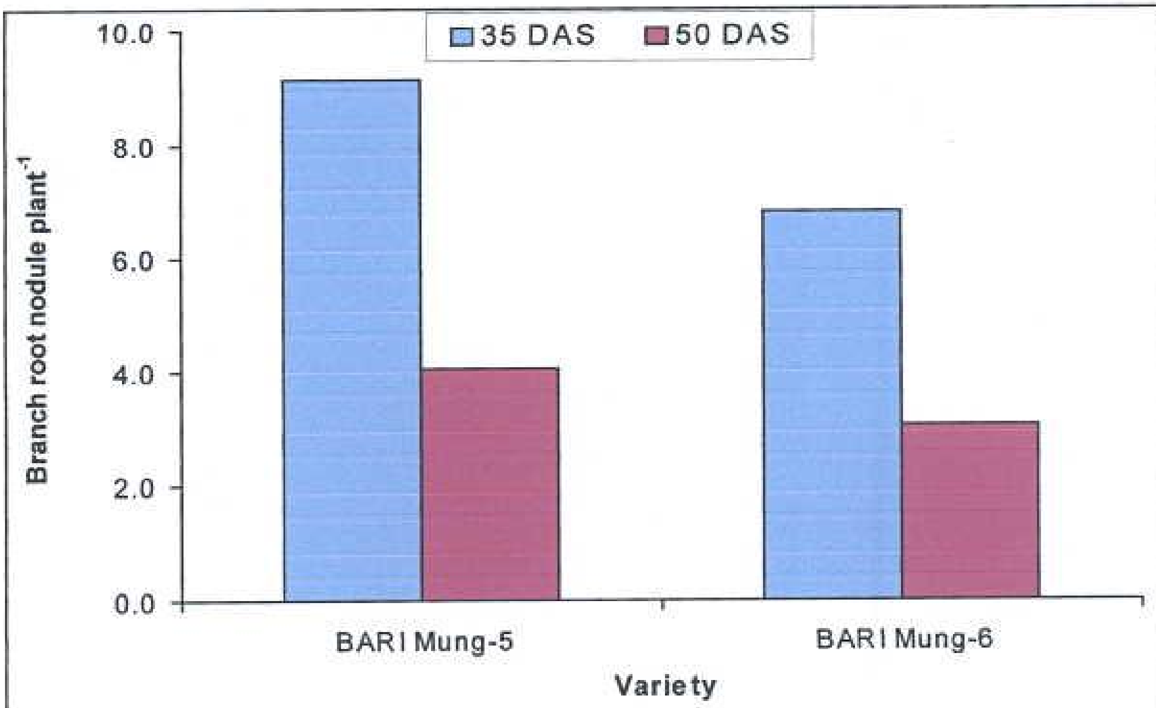

Fig. 4.4. Effect of variety on branch root nodule in mungbean

4.2.2. Effect of fertilizer

The maximum number of effective nodule of branch root (9.83 plant^{-1} at 35 DAS and 4.21 plant^{-1} at 50 DAS) was recorded due to application of *Bradyrhizobium* inoculum and the lowest number of branch root nodule (5.38 plant^{-1} at 35 DAS and 2.96 plant^{-1} at 50 DAS) was found in non-inoculated control (Fig. 4.5 and App. 4.2). Nitrogen has no significant impact on nodule formation on branch root at 50 DAS. Potdukhe and Guldekar (2003) reported that the highest nodule number was obtained under the treatment with *Rhizobium*. The above result was similar with the result of Bhuiyan *et al*. (2006). Tanwar *et al*. (2002) reported that the interaction between P rates and biofertilizers was significant with regard to the number of nodules. The inoculation of both biofertilizers along with the application of 60 kg P_2O_5 gave the highest number of nodules plant^{-1} (40.5). Kumar and Chandra (2003) reported that combined inoculation of *Rhizobium* gave significantly more nodule at 30 and 50 days after sowing (DAS). Alam (2009) also observed similar results.

4.2.3. Interaction effect of variety and fertilizer

The interaction between varieties and fertilizer on branch root nodule production was non-significant at 35 DAS but significant at 50 DAS (Fig. 4.6 and App. 4.3). Number of branch root nodule was higher in BARI Mung-5 x I (11.50 plant^{-1} at 35 DAS and 4.58 plant^{-1} at 50 DAS). BARI Mung-5 x U produced slight higher branch root nodule (6.33 plant^{-1} at 35 DAS) than BARI Mung-6 x U (4.42 plant^{-1} at 35 DAS) and BARI Mung-6 x N_{50} (2.83 plant^{-1} at 3.5 DAS) than Mung-6 x U (2.75 plant^{-1} at 50 DAS). The lowest number of branch root nodule (2.75 plant^{-1} at 50 DAS) was noted in BARI Mung-6 x U.

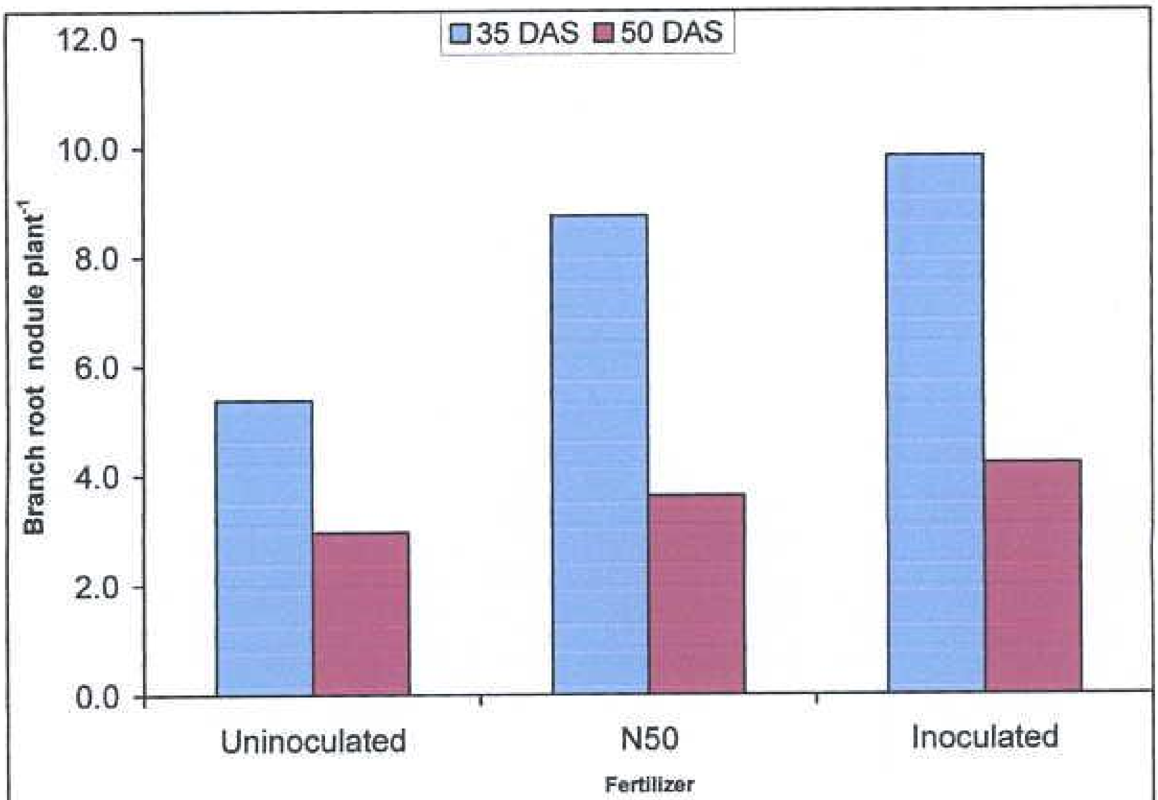

Fig. 4.5. Effect of fertilizer on branch root nodule in mungbean

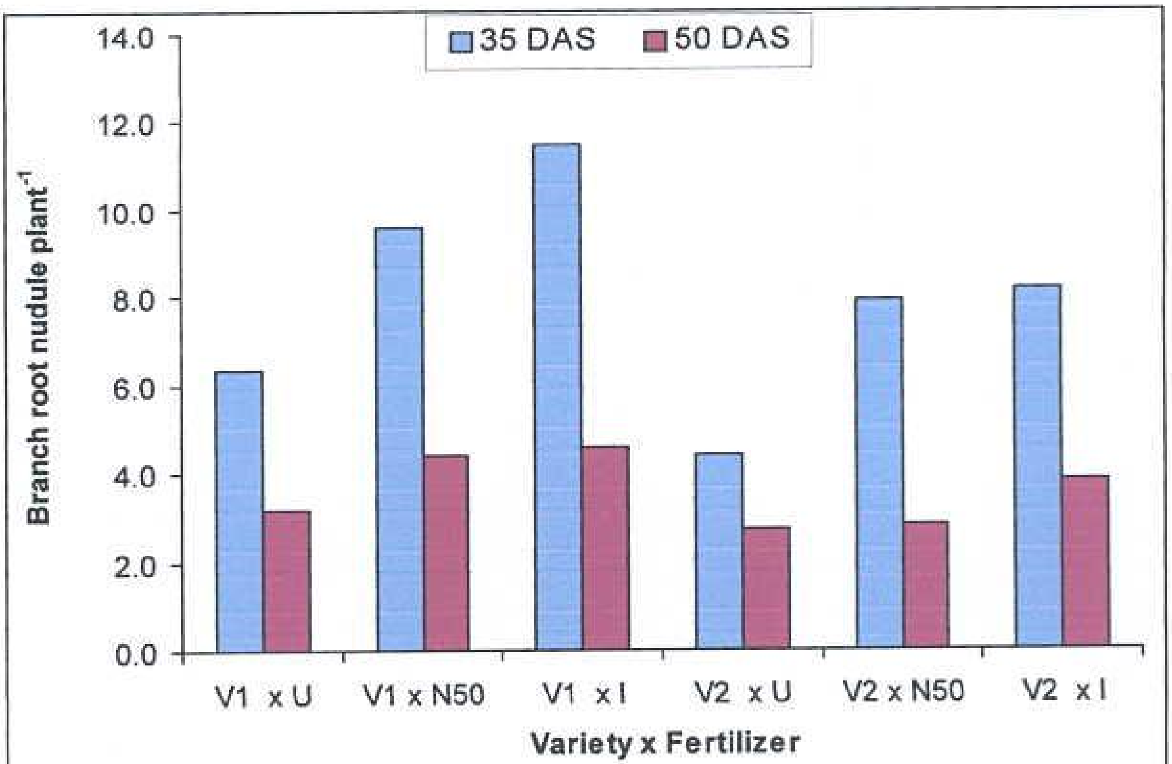

Fig. 4.6. Interaction effect of variety and fertilizer on branch root nodule in mungbean

4.3. Total nodule

4.3.1. Effect of variety

Observation on total nodule number plant^{-1} revealed that varieties differed significantly between two varieties (Fig. 4.7 and App. 4.1). This result conformed that nodule production varied from variety to variety (Murakami *et al.*, 1991; Patel and Patel, 1991; Pal and Lal, 1993; Bhuiyan *et al.*, 1999). Influence of two mungbean varieties on total nodule number was significant at two sampling dates i.e. at 35 and 50 DAS. It is an important parameter under study, since nodulation is the main criterion of biological nitrogen fixation by *Bradyrhizobium* inoculants on legumes. BARI Mung-5 produced significantly higher number of effective total nodule (12.56 plant^{-1} at 35 DAS and 7.22 plant^{-1} at 50 DAS) compared to that found in BARI Mung-6.

As stated earlier that the number of total nodule plant^{-1} increased with the advancement of growth at 35 DAS, thereafter, started declining. It appeared that the peak nodulation in mungbean occurred between pre-flowering and pod filling stage. This might be due to peak nodulation in mungbean at 50% flowering stage and degeneration of nodules after 50% flowering stage. Patel and Patel (1991) reported that significantly more number of nodules plant^{-1} in mungbean was observed at 30 DAS followed by 45 and 15 DAS. Pal and Lal (1993) also reported that nodules were higher at 45 DAS than 60 DAS in mungbean. Akhtaruzzaman (1998) also observed maximum nodulation at 40 DAS than at 30 and 20 DAS in mungbean. 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-1 and BU Mung-1. The best characteristics were obtained with BARI Mung-4 in nodulation. 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. They reported that cultivars S-8, BM-4 and BM-86 recorded the highest mean nodulation

(16.7). Hossain and Solaiman (2004) reported that the number of nodules plant^{-1} increased significantly due to inoculation of the seeds with *Rhizobium* strains. Bhuiyan *et al.* (2007a) reported that 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. Sarkar *et al.* (2002) reported that cultivar M-16 recorded higher number of nodules plant^{-1} compared to A-43. Bhuiyan and Mian (2007) reported that among five mungbean varieties in BARI Mung-2 produced the highest nodule number (19.3 plant^{-1} in 2001 and 19.0 plant^{-1} in 2002)) in mungbean.

4.3.2. Effect of fertilizer

The maximum number of effective total nodules (14.04 plant^{-1} at 35 DAS and 7.25 plant^{-1} at 50 DAS) was recorded due to application of *Bradyrhizobium* inoculated and the lowest number of total nodules (7.71 plant^{-1} at 35 DAS and 5.17 plant^{-1} at 50 DAS) was found in non-inoculated control (Fig. 4.8 and App. 4.2). Chatterjee and Bhattacharjee (2002) studied the effects of inoculation with *Bradyrhizobium* and found that inoculation with *Bradyrhizobium* strains increased rate of nodulation and N content. Kumari and Nair (2003) found that the extents of improvement in root nodulation were more in blackgram and greengram inoculated with *Bradyrhizobium*. Bhuiyan and Mian (2007) also found that application of *Bradyrhizobium* inoculant induced significant effect on nodulation. Bhattacharyya and Pal (2001) observed that *Bradyrhizobium* inoculation and application of P and Mo significantly influenced the number of nodules plant^{-1}. Bhuiyan *et al.* (2007a) reported that number of nodules increased progressively with increasing growth period and reached the peak at 42 DAS (i.e. at 50% flowering stage). Hossain and Solaiman (2004) reported that the number of nodules plant^{-1} increased significantly due to inoculation of the seeds with *Rhizobium* strains. Kavathiya and Pandey (2000) found that nodule plant^{-1} increased significantly over uninoculated control. Singha and Sarma (2001) reported that *Rhizobium* inoculation significantly increased the number (2.2%) compared to the control indicating increased efficiency of the crop to fix the atmospheric N.

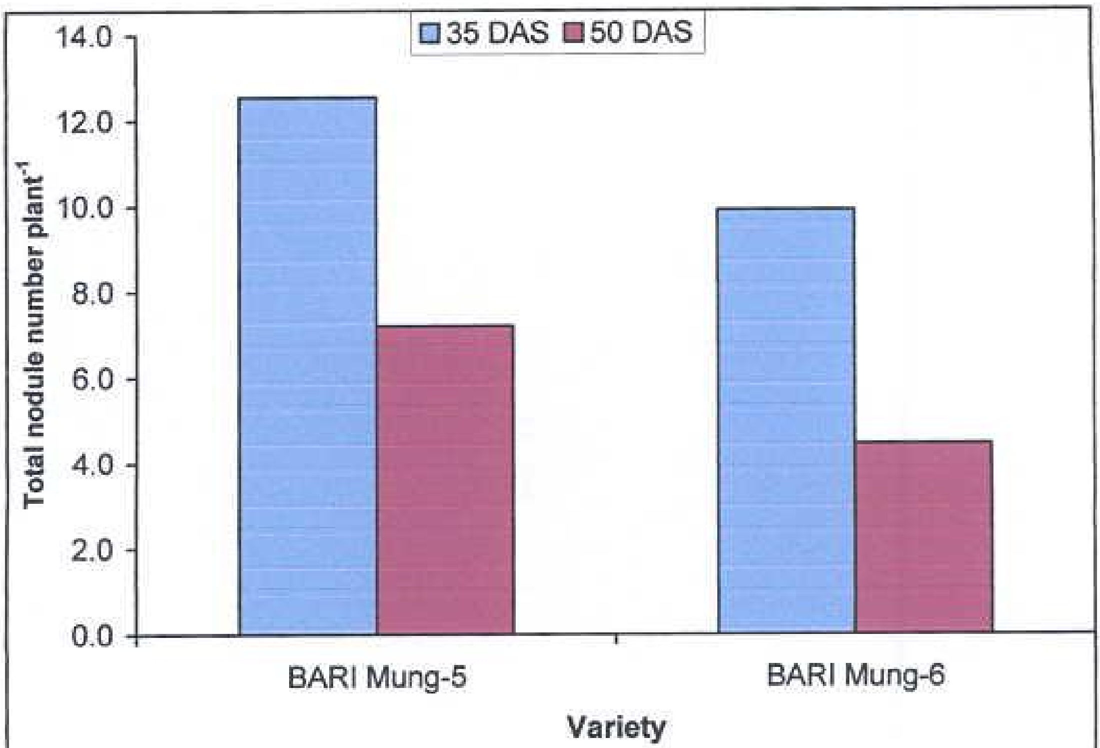

Fig. 4.7 Effect of variety on total nodule number in mungbean

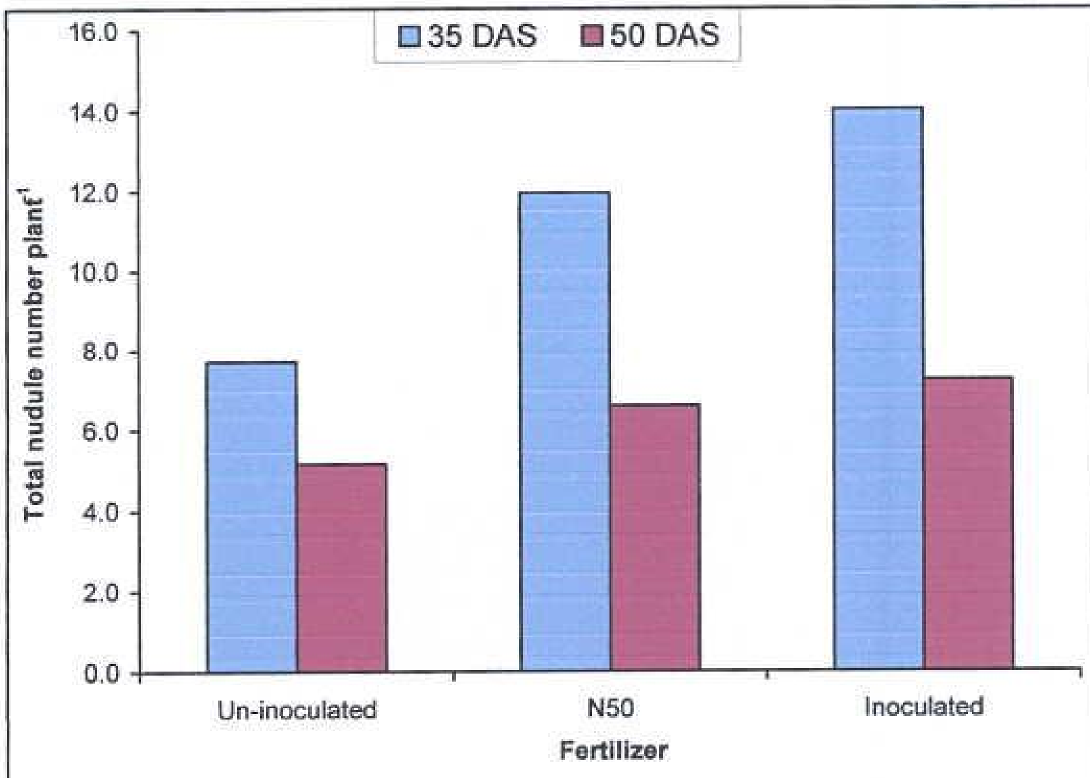

Fig. 4.8. Effect of fertilizer on total nodule number in mungbean

4.3.3. Interaction effect of variety and fertilizer

Results presented in Fig. 4.9 and App. 4.3 revealed that there was non-significant interaction at 35 DAS and significant interaction at 50 DAS between the mungbean varieties and fertilizers to produce effective total number of nodules plant^{-1}. The highest number of total nodules (16.00 plant^{-1} at 35 DAS and 8.33 plant^{-1} at 50 DAS) was observed by the BARI Mung-5 x I. The lowest number of total nodule (6.50 plant^{-1} at 35 DAS and 4.84 plant^{-1} at 50 DAS) was found in BARI Mung-6 x U. The results agreed well with the findings of Chowdhury *et al.* (1997) who observed that nodule was higher in inoculated mungbean at flowering stage followed by pod filling and pre-flowering. Rao *et al.* (1991) found nodules in mungbean two weeks after sowing. Murakami *et al.* (1991) reported that in mungbean, nodulation started at 12 DAS, increased rapidly at 34 DAS (flowering) reaching a peak at 45 DAS and then decreased until the plants died (83 DAS). Akhtaruzzaman (1998) also observed maximum nodulation at 40 DAS than that at 30 and 20 DAS in mungbean. With respect to time of sampling, greater nodule numbers were obtained at 35 DAS compared to 50 DAS, which was supported by Datt and Bhardwaj (1995). They reported that the nodule number and nodule dry weight of cowpea increased significantly by *Rhizobium* inoculation at 45 DAS followed by 55, 30 and 15 DAS. This might be due to the high requirement of N at the flowering and pod-filling stage (Rennie and Kemp, 1984). Chatterjee and Bhattacharjee (2002) studied the effects of inoculation with *Bradyrhizobium* and found that inoculation with *Bradyrhizobium* strains increased rate of nodulation and N content. Osunde *et al.* (2003) reported that inoculation increased nodule number in mungbean. Kumari and Nair (2003) found that the extent of improvement in root nodulation, plant growth and yield were more in blackgram and greengram inoculated with *Bradyrhizobium*. In another study, Bhuiyan *et al.* (2006) found that inoculated plants produced significantly higher nodule number (17.51 plant^{-1} in 2001 and 17.61 plant^{-1} in 2002) at 42 DAS compared to that in non-inoculated plant (11.35 plant^{-1} in 2001 and 11.52 plant^{-1} in 2002). The lowest number of nodules (3.50 plant^{-1}

in 2001 and 3.47 plant^{-1} in 2002) was obtained at 14 DAS in non-inoculated plants. Bhuiyan *et al.* (2007a) found that the number of nodules increased progressively with the advancement of growth and reached the peak at 42 DAS (i.e. at 50% flowering stage). 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. Sarkar *et al.* (2002) reported that interaction effects 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 gave higher nodulation.

4.4. Nodule weight

4.4.1. Effect of variety

The tested mungbean varieties differed in nodule weight at both sampling dates (Fig. 4.10 and App. 4.1). There was significant variation between the varieties of mungbean recorded at 35 DAS but non-significant at 50 DAS. The variety BARI Mung-5 produced significantly higher nodule dry weight (19.28 mg plant^{-1} at 35 DAS) compared to that found in BARI Mung-6 (13.94 mg plant^{-1} at 35 DAS). But BARI Mung-6 produced numerically higher nodule dry weight (13.92 mg plant^{-1} at 50 DAS) than BARI Mung-5 (12.14 mg plant^{-1} at 50 DAS). Mozumder *et al.* (2005) evaluated 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). The highest dry weight of nodule was found when *Bradyrhizobium* was applied. Bhuiyan *et al.* (2006) found that BARI Mung-2 gave the highest nodule dry weight among 5 varieties of mungbean. Bhuiyan (2004) also reported similar results.

4.4.2. Effect of fertilizer

Application of different fertilizer showed significant variation in the production of dry nodule weight at both the DAS (Fig. 4.11 and App. 4.2). The highest dry nodule weight (19.67 mg plant^{-1} at 35 DAS and 16.88 mg plant^{-1} at 50 DAS) noted in inoculated plant was statistically identical to that produced by nitrogen treatment at 35 DAS. The lowest number of dry nodule weight (12.67 mg plant^{-1} at 35 DAS and 11.00 mg plant^{-1} at 50 DAS) was found in non-inoculated plant. Sattar and Ahmed (1995) carried out a field experiment on mungbean (*Vigna raidata* L.) to study the response of inoculation with *Bradyrhizobium* inoculants incorporating BINA 403, BINA 407, RCR 3824 and RCR 3825 strains as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the number of nodules and nodule weight significantly compared to non-inoculated treatment. Singha and Sarma (2001) reported that *Rhizobium* inoculant had 9.5% higher nodule dry weight than non-inoculated control. Sharma *et al.* (1999) found that application of inoculants increased nodule dry weight plant^{-1}. Nagarajan and Balachandar (2001) reported that *Rhizobium* gave higher nodule weight (45.3 and 42.3 mg) in blackgram and greengram. Tomar *et al.* (2001) 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. Mozumder *et al.* (2005) observed that the highest dry weight of nodule was found when *Bradyrhizobium* was applied. Hossain and Solaiman (2004) reported that the dry weight of nodules plant^{-1} increased significantly due to inoculation of the seeds with *Rhizobium* strains. Singha and Sharma (2001) reported that *Rhizobium* inoculation significantly increased nodule mass (9.5%) compared to the control indicating increased efficiency of the crop to fix the atmospheric N.

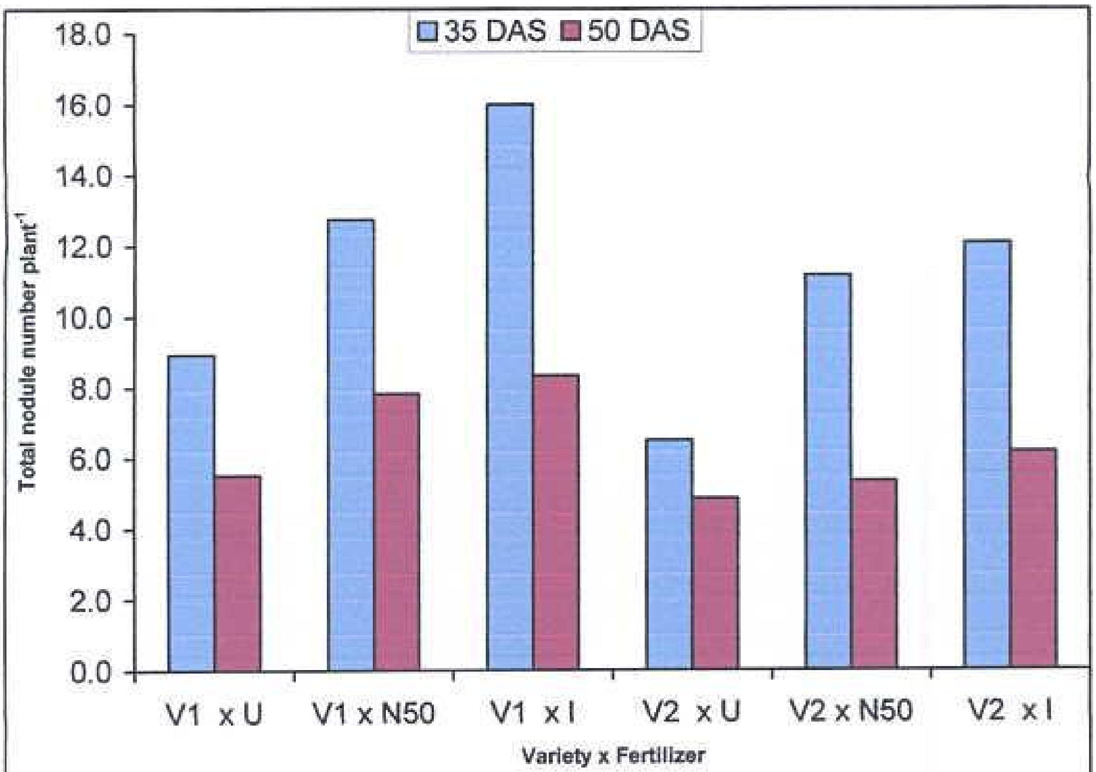

Fig. 4.9. Interaction effect of variety and fertilizer on total nodule number in mungbean

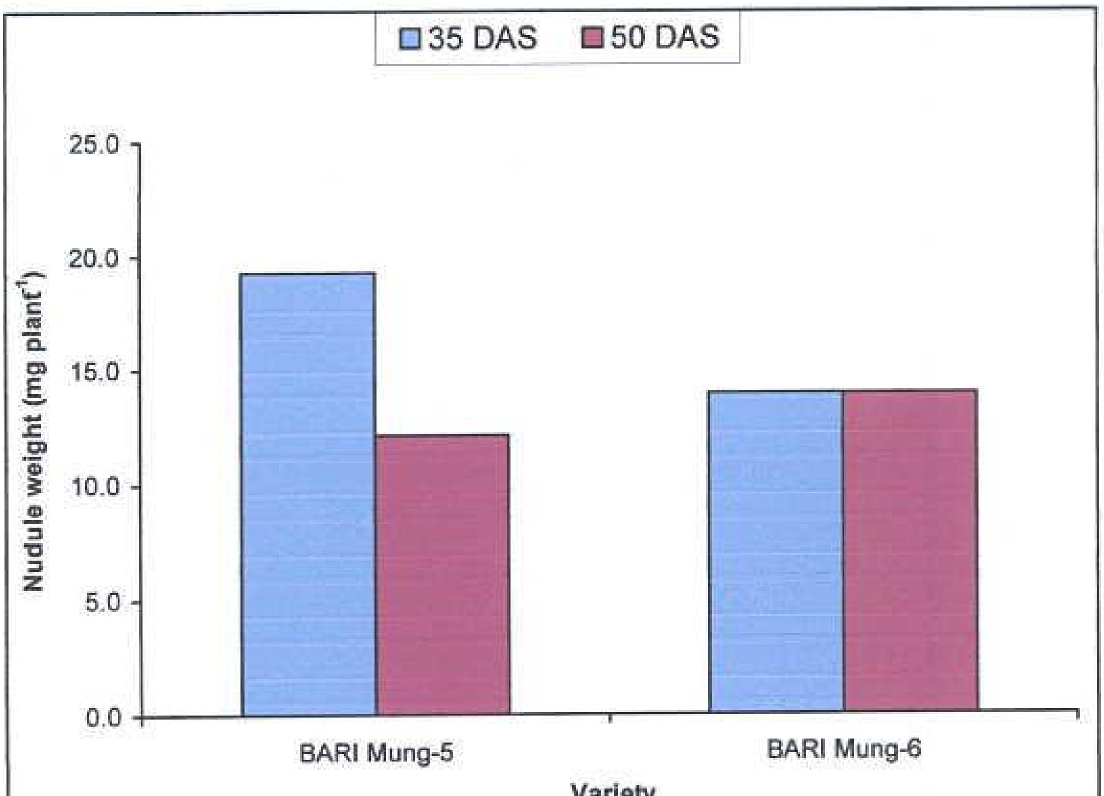

Fig. 4.10. Effect of variety on nodule weight in mungbean

4.4.3. Interaction effect of variety and fertilizer

Results presented in Fig. 4.12 and App. 4.3 showed that there was no significant interaction effect of mungbean varieties and *Rhizobium* inoculants regarding plant^{-1} dry weight of nodule at 50 DAS. The highest nodule weight (24.25 mg plant^{-1} at 35 DAS and 17.17 mg plant^{-1} at 50 DAS) was found in BARI Mung-5 x I and BARI Mung-6 x I, respectively. The lowest nodule dry weight (12.33 mg plant^{-1} at 35 DAS and 9.83 mg plant^{-1} at 50 DAS) was recorded the BARI Mung-6 x U and BARI Mung-5 x I, respectively. 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.* (1998) found that inoculated BINA Moog-2 gave higher nodule weight.

4.5. Root weight

4.5.1. Effect of variety

Plant root dry matter and its rate of accumulation increased with plant age (Table 4.1). There was no significant variation on root weight of the two mungbean varieties. The higher root weight (0.16 g plant^{-1} at 35 DAS and 0.35 g plant^{-1}) was recorded in BARI Mung-5 which was statistically identical to that of BARI Mung-6.

4.5.2. Effect of fertilizer

The effect of different fertilizer on root weight was statistically significant (Table 4.2). The highest root weight (0.17 g plant^{-1} at 35 DAS and 0.41 g plant^{-1} at 50 DAS) was obtained with the N_{50}. The lowest amount of root weight (0.13 g plant^{-1} at 35 DAS and 0.29 g plant^{-1} at 50 DAS) was found in non-inoculated control. Kavathiya and Pandey (2000) reported that fresh root weight (4.42 g) was recorded in the *Rhizobium* inoculation treatment. Perveen *et al.* (2002) opined that the maximum root dry weight (0.37 g plant^{-1}) was observed in inoculation with single *Bradyrhizobium* sp. only. Sharma *et al.* (2006) noted that seed inoculated with 1 of 9 *Rhizobium* strains increased dry matter accumulation.

Table 4.1. Effect of variety on weight and length of root and shoot in mungbean

Variety	35 DAS				50 DAS			
	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)
BARI Mung-5	0.16	1.26a	10.91a	25.36	0.35	2.18	11.22	32.97
BARI Mung-6	0.15	1.10b	9.62b	24.37	0.34	2.09	10.25	32.70
SE(±)	-	0.031	0.34	-	-	-	-	-
Level of sig.	NS	**	*	NS	NS	NS	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

Table 4.2. Effect of fertilizer on weight and length of root and shoot in mungbean

Fertilizer	35 DAS				50 DAS			
	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)
Uninoculated	0.13b	1.11	9.67	23.99	0.29c	1.90b	10.50	31.96
N_{50}	0.17a	1.24	10.70	24.93	0.41a	2.20ab	10.75	33.08
Inoculated	0.16ab	1.20	10.43	25.68	0.35b	2.31a	10.96	33.46
SE(±)	0.0093	-	-	-	0.014	0.103	-	-
Level of sig.	*	NS	NS	NS	**	*	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

4.5.3. Interaction effect of variety and fertilizer

The interaction effect of variety and fertilizers on root weight was statistically non-significant (Table 4.3). The highest root weight (0.18 g $plant^{-1}$ at 35 DAS and 0.43 g $plant^{-1}$ at 50 DAS) was obtained in BARI Mung-5 x N_{50} and BARI Mung-6 x N_{50}, respectively. It was revealed that inoculated treatment gave higher root weight then control.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. Perveen *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.

Table 4.3. Interaction effect of variety and fertilizer on weight and length of root and shoot in mungbean

Variety x Fertilizer	35 DAS				50 DAS			
	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)	Root weight (g $plant^{-1}$)	Shoot weight (g $plant^{-1}$)	Root length (cm)	Shoot length (cm)
BARI Mung-5xU	0.13	1.17	10.40	24.32	0.32	2.15	11.00	31.67
BARI Mung-5xN_{50}	0.18	1.34	11.46	24.98	0.40	2.17	11.25	33.50
BARI Mung-5xI	0.16	1.29	10.87	26.78	0.35	2.21	11.42	33.75
BARI Mung-6xU	0.14	1.05	8.94	23.67	0.26	1.65	10.00	32.25
BARI Mung-6xN_{50}	0.17	1.15	9.94	24.88	0.43	2.22	10.25	32.67
BARI Mung-6xI	0.16	1.12	9.99	24.57	0.34	2.41	10.50	33.17
SE(±)	-	-	-	-	-	-	-	-
Level of sig.	NS	NS	NS	NS	NS	NS	NS	NS
CV(%)	17.1	9.0	11.5	12.5	11.6	13.7	11.5	7.8

U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*
NS = Non significant

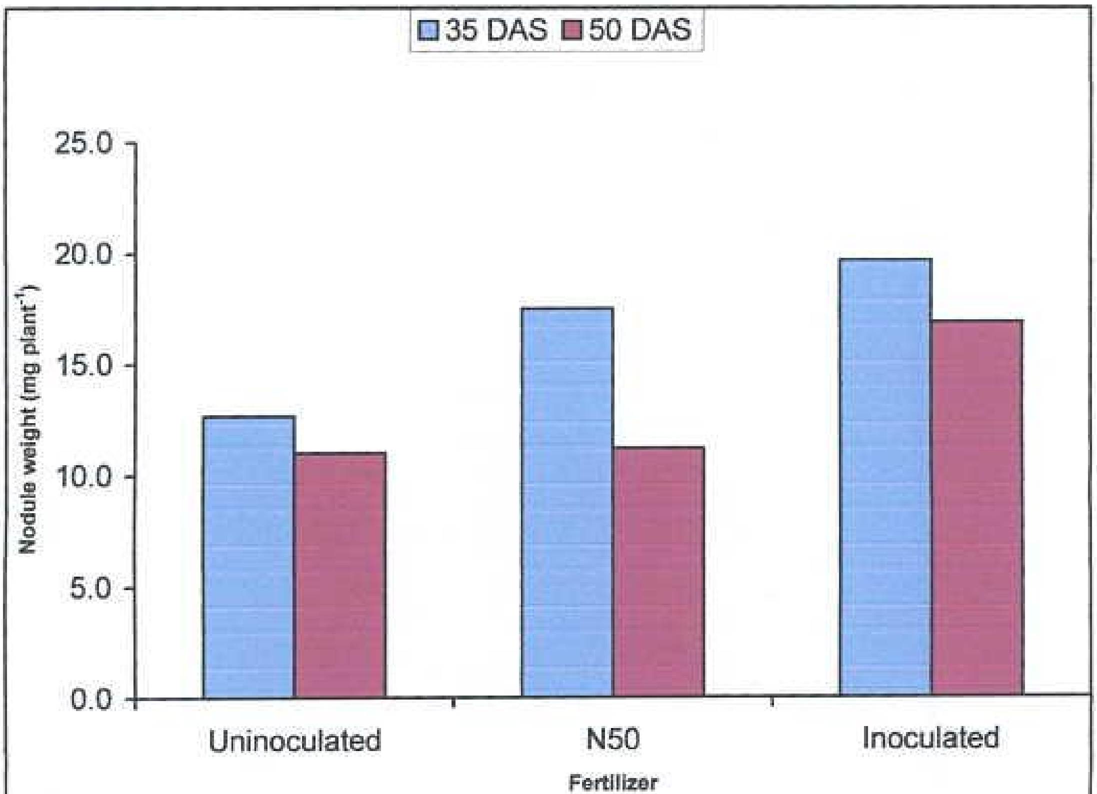

Fig. 4.11. Effect of fertilizer on nodule wight in mungbean

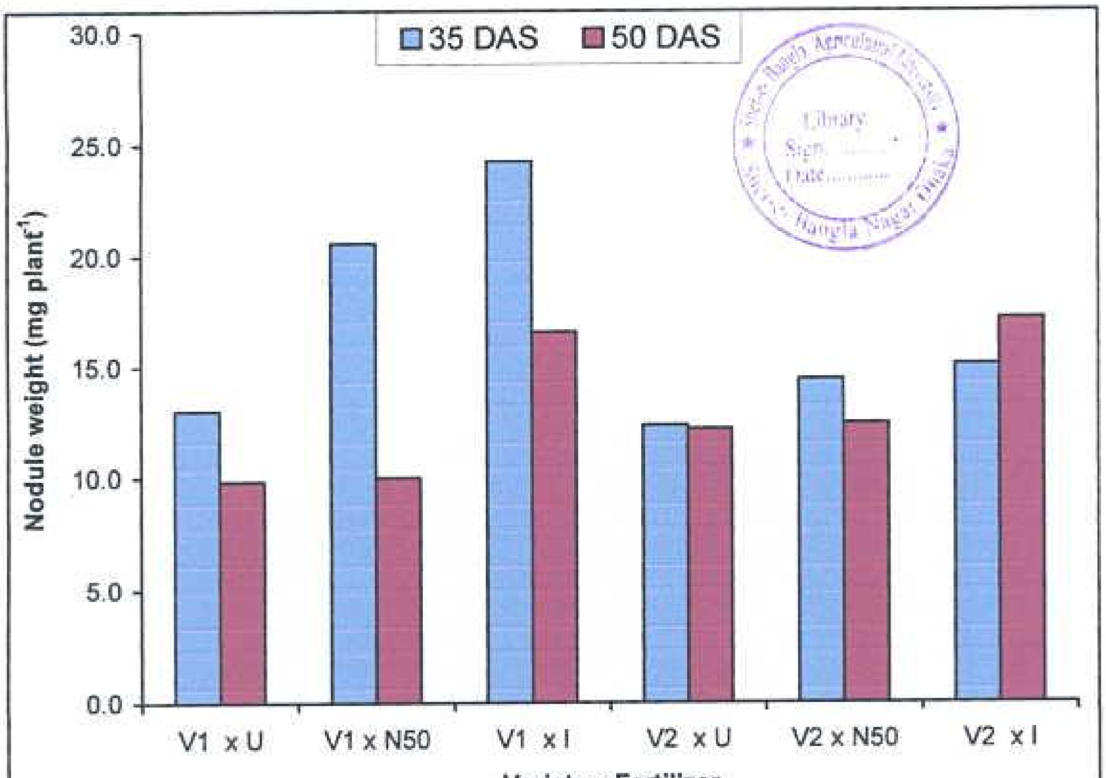

Fig. 4.12. Interaction effect of variety and fertilizer on nodule weight in mungbean

4.6. Shoot weight

4.6.1. Effect of variety

Shoot dry weight of the tested genotypes is presented in Table 4.1. At the early growth stages (35 DAS), shoot dry weight was very low. With the progress of growing period, shoot dry weight increased progressively. At 35 DAS shoot dry weight of BARI Mung-5 was statistically different from BARI Mung-6 but identical at 50 DAS. BARI Mung-5 produced significantly higher shoot weight (1.26 g plant^{-1} at 35 DAS) compared to that found in BARI Mung-6 (1.10 g plant^{-1} at 35 DAS). The results were in agreement with Bhuiyan (2004). Abdo (2001) conducted field experiments with two mungbean culitvars V-2010 (Giza-1) and VC-1000, and observed that mungbean cv. VC-1000 surpassed cv. V-2010 in shoot dry weight. Bhuiyan and Mian (2007) reported that among five mungbean varieties BARI Mung-2 produced the highest shoot weight in mungbean. Bhuiyan *et al.* (2007b) reported that significant influences of the mungbean varieties were observed on dry matter production. BARI Mung-2 produced the highest shoot weight.

4.6.2. Effect of fertilizer

The effects of different fertilizers were significant at 50 DAS but non-significant at 35 DAS on the shoot weight of mungbean (Table 4.2). The highest shoot weight (1.24 g plant^{-1} at 35 DAS) was noted in N_{50}. Inoculated treatment gave the highest shoot weight (2.31 g plant^{-1} at 50 DAS) which was statistically identical to N_{50} but superior to control. The shoot weight (1.11 g plant^{-1} at 35 DAS and 1.90 g plant^{-1} at 50 DAS) was recorded to uninoculated control. Kavathiya and Pandey (2000) reported that maximum fresh shoot weight (5.33 g) was recorded in the *Rhizobium* treated plot. Bhattacharyya and Pal (2001) observed that inoculation significantly influenced dry matter accumulation in the shoot. Jayakumar *et al.* (1997) reported that *Rhizobium* inoculation increased the dry weight of plants compared to controls. Srivastav and Poi (2000) found that inoculation with M-10 strain in greengram resulted in the highest dry matter production. Sharma *et al.* (2006) reported that seed inoculated with 1 of 9 *Rhizobium* strains increased dry matter accumulation. Manivannan *et al.* (2003) observed that *Rhizobium* seed treatment produced markedly higher dry matter. Sharma and Upadhyay (2003) reported that seed inoculation with *Bradyrhizobium* sp strains showed maximum values of dry matter production. Delic *et al.* (2009) found that inoculated plants produced significantly higher shoot dry weight (SDW). Sultana *et al.* (2009) opined that application of 20 kg N ha^{-1} showed significantly higher shoot dry weight (2.76 and 4.69 g at 17 and 24 DAS, respectively).

4.6.3. Interaction effect of varieties and fertilizer

The interaction effect of varieties and fertilizers on shoot dry weight was statistically non-significant (Table 4.3). Though, the highest shoot weight (1.34 g $plant^{-1}$ at 35 DAS and 2.41 g $plant^{-1}$ at 50 DAS) was found in BARI Mung-5 x N_{50} and BARI Mung-6 x I, respectively. The lowest shoot weight (1.05 g $plant^{-1}$ at 35 DAS and 1.65 g $plant^{-1}$ at 50 DAS) was noted in BARI Mung-6 x U. Kavathiya and Pandey (2000) reported that maximum fresh shoot weight (5.33 g) was recorded in the *Rhizobium* treated plot. 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. 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. 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 Bina Moog-2 and Kanti higher shoot weight.

4.7. Root length

4.7.1. Effect of variety

There was significant variation between the two varieties of mungbean at 35 DAS (Table 4.1). The higher root length (10.91 cm at 35 DAS and 11.22 cm at 50 DAS) was recorded in BARI Mung-5 which was statistically superior to that of BARI Mung-6 variety at 35 DAS. Sarkar *et al*. (2002) reported that cultivars M-16 recorded longer roots compared to A-43.

4.7.2. Effect of fertilizer

Root length was non-significant both at 35 and 50 DAS. The highest root length (10.70 cm at 35 DAS and 10.96 cm at 50 DAS) was produced by N_{50} and *Bradyrhizobium* inoculant, respectively which was identical to non-inoculated control (Table 4.2). The lowest root length (9.67 cm at 35 DAS and 10.50 cm at 50 DAS) was recorded in non-inoculated plant. But, Sharma *et al*. (2006) reported that plant growth was increased with *Rhizobium* inoculation, with the local strain giving the best results. Sarker *et al*. (2002) reported that bradyrhizobial strain 480-M gave the longest roots (14.7 cm). Hossain and Solaiman (2004) showed that root length of the crop increased significantly due to inoculation of the seed with *Rhizobium* strains.

4.7.3. Interaction effect of variety and fertilizer

The interaction effect of mungbean varieties and fertilizer/inoculants did not show any significant influence on root length of the crop (Table 4.3). The highest root length (11.46 cm at 35 DAS and 11.42 cm at 50 DAS) was recorded BARI Mung-5 x N_{50} and BARI Mung-5 x I, respectively. The root length of minimum size (8.94 cm at 35 DAS and 10.00 cm at 50 DAS) was noted in BARI Mung-6 x Uninoculum.

4.8. Shoot length

4.8.1. Effect of variety

There was non-significant variation in the shoot length of two varieties of mungbean recorded at 35 DAS and 50 DAS (Table 4.1). BARI Mung-5 produced higher (25.36 cm at 35 DAS and 32.97 cm at 50 DAS) shoot length compared to that found in BARI Mung-6 (24.37 cm at 35 DAS and 32.70 cm at 50 DAS). Shoot length increased over time irrespective of varietal differences. It appears that shoot length increased with age. Similar results regarding plant height of mungbean varieties were reported by Thakuria and Saharia (1990); Patra and Bhattacharyya (1998); Rahman (2000); Roy (2001). BARI Mung-6 produced shorter plants at both the stage. Similar findings were observed by Mahmud (1997) and Mozumder (1998). They reported that there was no significant difference among the different varieties. Abdo (2001) conducted field experiments with two mungbean culitvars V-2010 (Giza-1) and VC-1000 and observed that mungbean cv. VC-1000 surpassed cv. V-2010 in stem length.

4.8.2. Effect of fertilizer

The effect of different fertilizer was non-significant on shoot length of mungbean (Table 4.2). Though, the highest shoot length (25.68 cm at 35 DAS and 33.46 cm at 50 DAS) was noted in inoculum which was identical to others fertilizers. The shoot length (23.99 cm at 35 DAS and 31.96 cm at 50 DAS) was minimum size in uninoculated control. Shoot length was non-significant due to application of nitrogen or inoculum both at 35 and 50 DAS, though application of nitrogen and inoculum gave higher shoot length than non-inoculated plant. Nagarajan and Balachandar (2001) observed that seeds treated with bio-digested slurry at 5 t ha^{-1} + *Rhizobium* produced the highest plant height (53.7 cm). Meenakumari and Nair (2001) conducted a study in 7 different locations to evaluate plant growth characters of cowpea, blackgram and mungbean and observed that and plant growth characters of cowpea, blackgram and mungbean were uniformly better with inoculation. Kumari and Nair (2003) found that the extent of improvement in plant growth was more in blackgram and mungbean inoculated with *Bradyrhizobium*. Ashraf *et al.* (2003) found that the tallest plants (69.9 cm) were obtained with seed inoculation. Sriramachandrasekharan and Vaiyapuri (2003) reported that *Rhizobium* inoculated blackgram showed better growth than the non-inoculated crop.

4.8.3. Interaction effect of variety and fertilizer

The interaction effect of varieties and fertilizers was statistically non-significant (Table 4.3). The highest shoot length (26.78 cm at 35 DAS and 33.75 cm at 50 DAS) was noted in BARI Mung-5 x I. 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).

4.9. Plant height

4.9.1. Effect of variety

Plant height of two mungbean varieties did not vary significantly (Table 4.4). BARI Mung-6 had the higher plant height of 36.36 cm and lower plant 36.31 cm was observed in BARI Mung-5. Similar results regarding plant height of mungbean varieties were reported by Mozumder (1998). The taller plant was recorded from BARI Mung-6 which was identical with that of BARI Mung-5. The genotypic variation might be responsible for this result.

Table 4.4. Effect of variety on yield attributes in mungbean

Variety	Plant height (cm)	Pod length (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	1000-seed weight (g)
BARI Mung-5	36.31	6.17	12.67	10.60	41.30
BARI Mung-6	36.36	6.08	12.58	11.50	42.00
SE(±)	-	-	-	-	-
Level of sig.	NS	NS	NS	NS	NS

NS = Non significant

4.9.2. Effect of fertilizer

The different fertilizer showed beneficial effects on plant height of mungbean (Table 4.5). All the fertilizers recorded statistically superior plant heights compared to that found whit out any fertilizer. Inoculant produced the tallest plant (37.79 cm). The shortest plant (33.83 cm) was found in uninoculated control. Thakur and Panwar (1995) found that inoculation either singly or combined increased plant height compared with no inoculation. Bhattacharyya and Pal (2001) reported that application of rhizobial inoculum influenced plant height comparing with control. Meenakumari and Nair (2001) observed that plant growth characters of cowpea, blackgram and mungbean were uniformly better when *Rhizobium* inoculant was applied. Sharma *et al.* (2000) reported that the growth was increased with *Rhizobium* inoculation and the local strain gave the best results. Kumari and Nair (2003) observed that the extent of plant growth were more in blackgram and greengram where *Bradyrhizobium* inoculation was done. Srinivas and Shaik (2002) showed that plant height generally increased with increasing rates of P and with increasing rates of N up to 40 kg ha^{-1} followed by decrease with further increase in N. Malik *et al.* (2002) studied that plant height (68.2 cm) at harvest was the highest when inoculated with *Bradyrhizobium*. Ashraf *et al.* (2003) observed that the tallest plants (69.9 cm) in mungbean were obtained with seed inoculation + 50:50:0 kg NPK ha^{-1}. Hossain and Solaiman (2004) reported that plant height increased significantly due to inoculation of the seeds with *Rhizobium* strains. Kavathiya and Pandey (2000) reported that maximum plant height (24.6 cm) was recorded in the *Rhizobium* treatment. Similar results were observed by Naher (2000) and Kamrujjaman (2003).

Table 4.5. Effect of fertilizer on yield attributes in mungbean

Fertilizer	Plant height (cm)	Pod length (cm)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
Uninoculated	33.83b	5.81b	10.00b	9.15b	39.88b
N_{50}	37.38a	6.31a	13.63a	12.13a	43.25a
Inoculated	37.79a	6.25a	14.25a	11.88a	41.88a
SE(±)	1.13	0.13	0.59	0.57	0.65
Level of sig.	*	*	**	**	**

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

4.9.3. Interaction effect of variety and fertilizer

The interaction effect of mungbean varieties and fertilizer were not statistically significant in recorded plant height (Table 4.6). The tallest plant height (39.25 cm) was recorded in BARI Mung-6 x N_{50}. The shortest plant height (32.33 cm) was noted in BARI Mung-6 x Uninoculum. Thakur and Panwar (1995) found that inoculation either singly or combined 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 (2001) found that *Rhizobium* inoculation increased induced the higher plant height (53.7 cm). These findings are in conformity with the findings of Mozumder (1998); Naher (2000) and Kamrujjaman (2003).

Table 4.6. Interaction effect of variety and fertilizer on yield attributes in mungbean

Variety x Fertilizer	Plant height (cm)	Pod length (cm)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
BARI Mung-5xU	35.33	5.88	9.50	8.56	38.50
BARI Mung-5xN_{50}	35.50	6.38	13.50	11.75	43.75
BARI Mung-5xI	38.08	6.25	15.00	11.50	41.75
BARI Mung-6xU	32.33	5.75	10.50	9.75	41.25
BARI Mung-6xN_{50}	39.25	6.25	13.75	12.50	42.75
BARI Mung-6xI	37.50	6.25	13.50	12.25	42.00
SE(±)	-	-	-	-	-
Level of sig.	NS	NS	NS	NS	NS
CV(%)	8.8	6.2	13.1	14.6	4.4

U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*
NS = Non significant

4.10. Pod length

4.10.1. Effect of variety

The two varieties of mungbean did not vary significantly with respect to pod length (Table 4.4). The longer pod (6.17 cm) was found in BARI Mung-5 and the smaller pod (6.08 cm) was found in BARI Mung-6. Naher (2000) observed significant variation on pod length in mungbean. The present result is in agreement with Ara (2004).

4.10.2. Effect of fertilizer

The effects of different fertilizers were significant on pod length of mungbean (Table 4.5). The longest pod length (6.31 cm) was noted in N_{50} which was identical with *Bradyrhizobium* inoculant. The smallest pod length (5.81 cm) was found in uninoculated plant. Hossain and Solaiman (2004) reported that pod length 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 fertilizer

The interaction effect of variety and fertilizers was non-significant (Table 4.6). The highest pod length (6.38 cm) found in BARI Mung-5 x N_{50} which was superior to all other treatments. The lowest pod length (5.75 cm was found in BARI Mung-6 x U. 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 any significant variation on pods palnt^{-1} (Table 4.4). BARI Mung-5 produced higher number of pods plant^{-1} (12.67) compared to that found in BARI Mung-6 (12.58). Bhuiyan *et al.* (2008a) observed that BARI Mung-2 gave the highest pods plant^{-1} among 4 varieties of mungbean. Mozumder (1998) and Ara (2004) also found similar results. But, the results were contradictory with the findings of Naher (2000) and Bhuiyan *et al.* (2008a). They reported insignificant variation among mungbean and blackgram varieties on pods plant^{-1}.

4.11.2. Effect of fertilizer

The different fertilizer excreted significant effect on the formation of pods palnt^{-1} (Table 4.5). The highest number of pods palnt^{-1} (14.25) was found in inoculation which was superior to non-significant control but identical with N_{50}. The smallest number of pods palnt^{-1} (10.00) was noted in uninoculum. Malik *et al.* (2002) reported that seed inoculation with *Rhizobium* resulted in the highest number of pods plant^{-1} (22.47). Ashraf *et al.* (2003) observed that seed inoculation + 50:50:0 or 50:50:50 kg N: P: K ha^{-1} resulted in the highest number of pods plant^{-1} (28.97, 56.00, 63.90 and 32.56, respectively). Bhuiyan *et al.* (2008a) reported that *Bradyrhizobium* inoculation in mungbean plots also significantly increased pods plant^{-1}. Hossain and Solaiman (2004) reported that number of pods plant^{-1} increased significantly due to inoculation of the seeds with *Rhizobium* strains. Sultana *et al.* (2009) found that application of 20 kg N ha basal produced significantly higher pods plant^{-1} (17.8). Malik *et al.* (2002) reported that seed inoculation with *Rhizobium* resulted in the highest number of pods plant^{-1} (22.5). Similar results were observed by Ara (2004) and Naher (2000).

4.11.3. Interaction effect of variety and fertilizer

The interaction effect of mungbean varieties and fertilizers was not statistically significant (Table 4.6). In both the varieties, the higher number of pods palnt^{-1} (15.00) was found in BARI Mung-5 x I and the lowest number of pods palnt^{-1} (9.50) was found in BARI Mung-5 x U. Bhuiyan *et al.* (2008a) observed that inoculated BARI Mung-2 produced the highest pods plant^{-1}. Ara (2004) found that BARI Mung-4 with *Bradyrhizobium* plus *Azotobacter* gave the highest pods plant^{-1} in mungbean. Similar non-significant effects on pods plant^{-1} were observed by Mozumder (1998), Naher (2000) and Bhuiyan *et al.* (2008a) in mungbean.

4.12. Seeds pod^{-1}

4.12.1. Effect of variety

The number of seeds pod^{-1} did not significantly affected by two varieties (Table 4.4). BARI Mung-6 showed higher seeds pod^{-1} (11.50) than BARI Mung-5 (10.60). But, Bhuiyan *et al.* (2008a), Naher (2000) and Ara (2004) observed significant variation in seeds pod^{-1} among different varieties of mungbean.

4.12.2. Effect of fertilizer

The different fertilizers exerted significant effect on the number of seed pod^{-1} (Table 4.5). The highest number of seeds pod^{-1} (12.13) was showed in N_{50} which was identical with *Bradyrhizobium* inoculant and the lowest number of seeds pod^{-1} (9.15) was found in non-inoculated control. Bhuiyan *et al.* (2008a) observed that *Bradyrhizobium* inoculation significantly increased seeds pod^{-1}. Shil *et al.* (2007) reported that seeds pod^{-1} was the highest in full doses of fertilizers while control plants recorded the lowest seeds pod^{-1}. Srinivas and Shaik (2002) opined that *Rhizobium* inoculation in mungbean increased the number of seeds pod^{-1}. Malik *et al.* (2002) reported that seed inoculation with *Rhizobium* resulted in the highest number of seed pod^{-1} (12.1). But, Naher (2000) did not find any significant effect on seeds pod^{-1} due to application of *Bradyrhizobium* inoculant.

4.12.3. Interaction effect of variety and fertilizer

The interaction effect of mungbean varieties and fertilizers was statistically non-significant (Table 4.6). The highest number of seeds pod^{-1} (12.50) was found in BARI Mung-6 x N_{50}. The lowest number of seeds pod^{-1} (8.56) was found with out any fertilizer. Bhuiyan *et al.* (2008a) observed that inoculated BARI Mung-2 produced the highest seed 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. 1000-seed weight

4.13.1. Effect of variety

The two varieties of mungbean did not vary significantly in case of 1000-seed weight (Table 4.4). The maximum seed weight (42.00 g) was produced in BARI Mung-6 and the minimum seed weight (41.30 g) was found in BARI Mung-5. Rizk and Abdo (2001) carried out field experiments with two mungbean cultivars (V-2010 and VC-1000), and cultivar VC-1000 surpassed cultivar V-2010 in 1000-seed weight. Sarkar *et al.* (2002) reported that cultivars M-16 recorded higher test weight compared to A-43. Mazumder (1998) and Ara (2004) also reported similar results. But, Bhuiyan (2008a) and Naher (2000) found significant variation on 1000-seed weight in different mungbean varieties.

4.13.2. Effect of fertilizer

The different fertilizer exerted significant effect on 1000-seed weight of mungbean (Table 4.5). The maximum 1000-seed weight (43.25 g) was found by the application of N_{50}, which was statistically identical with inoculant but different from control and the lowest seed weight was observed in non-inoculated control (39.88 g). Srinivas and Shaik (2002) reported that 1000-seed weight generally increased due to rhizobial inoculation. Bhuiyan *et al.* (2008a) opined that *Bradyrhizobium* inoculation also significantly increased 1000-seed weight. Srinivas and Shaik (2002) reported that 1000-seed weight generally increased due to rhizobial inoculation. Malik *et al.* (2002) studied that seed inoculation with *Rhizobium* application resulted in the highest 1000-seed weight (42.3 g). Hossain and Solaiman (2004) reported that 1000-seed weight increased significantly due to inoculation of the seeds with *Rhizobium* strains. Srinivas and Shaik (2002) found that 1000-seed weight generally increased due to N application.

4.13.3. Interaction effect of variety and fertilizer

The interaction effect of varieties and fertilizers on 1000-seed weight statistically non-significant (Table 4.6). The 1000-seed weight was the highest (43.75 g) in BARI Mung-5 × $N_{50.}$ The minimum 1000-seed weight (38.50 g) was showed in BARI Mung-5×U. Sharma *et al.* (2001) carried out a field experiment on mungbean cv. 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.

4.14. Stover yield

4.14.1. Effect of variety

There was significant variation in stover yields of the two varieties of mungbean (Fig. 4.13 and App. 4.4). The higher stover yield (1985 kg ha^{-1}) was produced by the BARI Mung-6 which was superior to BARI Mung-5 (1858 kg ha^{-1}). Hossain and Solaiman (2004) carried out a field experiment on six mungbean cultivars. The mungbean cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1. The best characteristics were obtained with BARI Mung-4 than other in stover yield. Navgire *et al.* (2001) found that cultivars S-8, BM-4 and BM-86 recorded the highest plant biomass (8.29 q ha^{-1}). Bhuiyan and Mian (2007) reported that among five mungbean varieties BARI Mung-2 produced the highest stover yield in mungbean. Ara (2004) gave significantly higher stover yield in BARI Mung-3 than BARI Mung-4. Bhuiyan *et al.* (2008a) observed that BARI Mung-2 gave the highest stover yield (1.03 t ha^{-1}).

4.14.2. Effect of fertilizer

The different *Bradyrhizobium* inoculants showed significatn increase in stover yield of mungbean (Fig. 4.14 and App. 4.5). The highest stover yield of (2290 kg ha^{-1}) was obtained due to the application of inoculum which was superior to N_{50} and non-inoculated control (1500 kg ha^{-1}). 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 P at 45 kg ha^{-1} with *Rhizobium* inoculation produced the highest straw yield and was at par with the application of 25 and 35 kg P ha^{-1}. 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.

4.14.3. Interaction effect of variety and fertilizer

The interaction effect of mungbean varieties and *Rhizobium* inoculants were statistically significant in recording stover yields (Fig. 4.15 and App. 4.6). The stover yield highest from 2300 kg ha^{-1} recorded in BARI Mung-5 x I. The lowest stover yield (1400 kg ha^{-1} was noted in BARI Mung-6 x U. Hossain and Solaiman (2004) reported that BARI Mung-4 in combination with TAL169 performed the best in terms of stover yields. Similar non-significant results on stover yield in grasspea were observed by Bhuiyan *et al.* (1999, 2006). 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.

4.15. Seed yield

4.15.1. Effect of variety

There was significant difference between the seed yields of two mungbean varieties (Fig. 4.13 and App. 4.4). The variety BARI Mung-6 recorded a seed yield of 836 kg ha^{-1} while it was 770 kg ha^{-1} for the variety BARI Mung-5. The present result is in agreement with Samanta *et al.* (1999) who reported that varieties of mungbean differed significantly in seed yield. In modern varieties, the reasons for obtaining higher seed yield might be due to high dry matter accumulation, more number of pods $plant^{-1}$ and 1000-seed weight as compared to local variety. Rizk and Abdo (2001) carried out field experiments with two mungbean field experiments with two mungbean cultivar (V-2010 and VC-1000) and cultivar VC-1000 surpassed cultivar V-2010 in yield. Tickoo *et al.* (2006) carried out field experiments with two mungbean field experiments with two mungbean cultivars Pusa 105 and Pusa Vishal, and reported that cultivar Pusa Vishal recorded higher CV. Pusa 105 in grain yield. Navgire *et al.* (2001) carried out field experiments on mungbean cultivars BM-4, S-8 and BM-86. The cultivar S-8, BM-4 and BM-86 recorded the highest in grain yield. Hossain and Solaiman (2004) carried out a field experiment on six mungbean cultivars. The mungbean cultivars were BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BINA Moog-2 and BU Mung-1. The best characteristics were obtained with BARI mung-4 than other in seed yield. Bhuiyan and Mian (2007) reported that among five mungbean varieties BARI Mung-2 produced the highest seed yield in mungbean. Ara (2004), Mozumder (1998), Naher (2000) also reported similar results.

4.15.2. Effect of fertilizer

Seed yield of mungbean varied significantly due to *Rhizobium* inoculum (Fig. 4.14 and App. 4.5). The inoculated plants showed the highest seed yield (876 kg ha^{-1}) which was statistically superior to other treatments. The lowest seed yield (716 kg ha^{-1}) was showed in non-inoculated plant. Sharma and Khurana (1997) studied the effectiveness of single and multi-strain inoculants in field experiment with summer mungbean variety SML-32 and found that grain yield was higher in multi-strain inoculant treatments. On an average, single strain and multi-strain *Rhizobium* inoculants increased the grain yield by 10.4% and 19.3% over uninoculated control, respectively. Bhattacharya and Pal (2001) conducted a field experiment and reported that inoculation of *Rhizobium* influenced maximum seed yield comparing with control. Perveen *et al.* (2002) observed the maximum seed yield (6.6 g $plant^{-1}$) with single *Bradyrhizobium* sp. inoculation. Bhuiyan and Mian (2007) reported that application of *Bradyrhizobium* inoculant produced significant effect on seed yields in case of crop. Seed inoculation significantly increased seed yield (0.98 t ha^{-1} in 2001, 27% increase over control and 0.75 t ha^{-1} in 2002, 29% increase over control) of mungbean. Kumari and Nair (2003) found that yields were more in blackgram and greengram inoculated with *Bradyrhizobium*. Tanwar *et al.* (2003) observed that the application of 60 kg P ha^{-1} along with inoculation of *Rhizobium* gave the highest seed yield (10.93 q ha^{-1}). Ashraf *et al.* (2003) showed that seed inoculation along with NPK at 30:50:0 kg ha^{-1} was optimum for the production of high seed yield by mungbean cv. NM-98. Hossain and Solaiman (2004) reported that seed yields increased significantly due to inoculation of the seeds with *Rhizobium* strains. Sharma *et al.* (2001) reported that the highest levels of N applications resulted in the grain yields of mungbean. Sultana *et al.* (2009) observed that application of 20 kg N ha basal produced significantly higher seed yield (1,982 kg ha^{-1}). Malik *et al.* (2002) reported that seed inoculation with *Rhizobium* resulted in the highest seed yield (1,158 kg ha^{-1}).

4.15.3. Interaction effect of variety and fertilizer

The interaction effects of mungbean varieties and *Rhizobium* inoculums were non-significant in recording seed yield (Fig. 4.15 and App. 4.6). The seed yield ranged from 686 kg ha^{-1} recorded in BARI Mung-5 × U and the highest seed yield (890 kg ha^{-1}) was found in BARI Mung-6 × I. Hossain and Solaiman (2004) reported that BARI Mung-4 in combination with TAL169 performed the best in terms of seed. 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). Mozumder *et al.* (2005) found that inoculated BINA Moog-2 gave higher seed yield where interaction effects of variety and *Bradyrhiozobium* was significant.

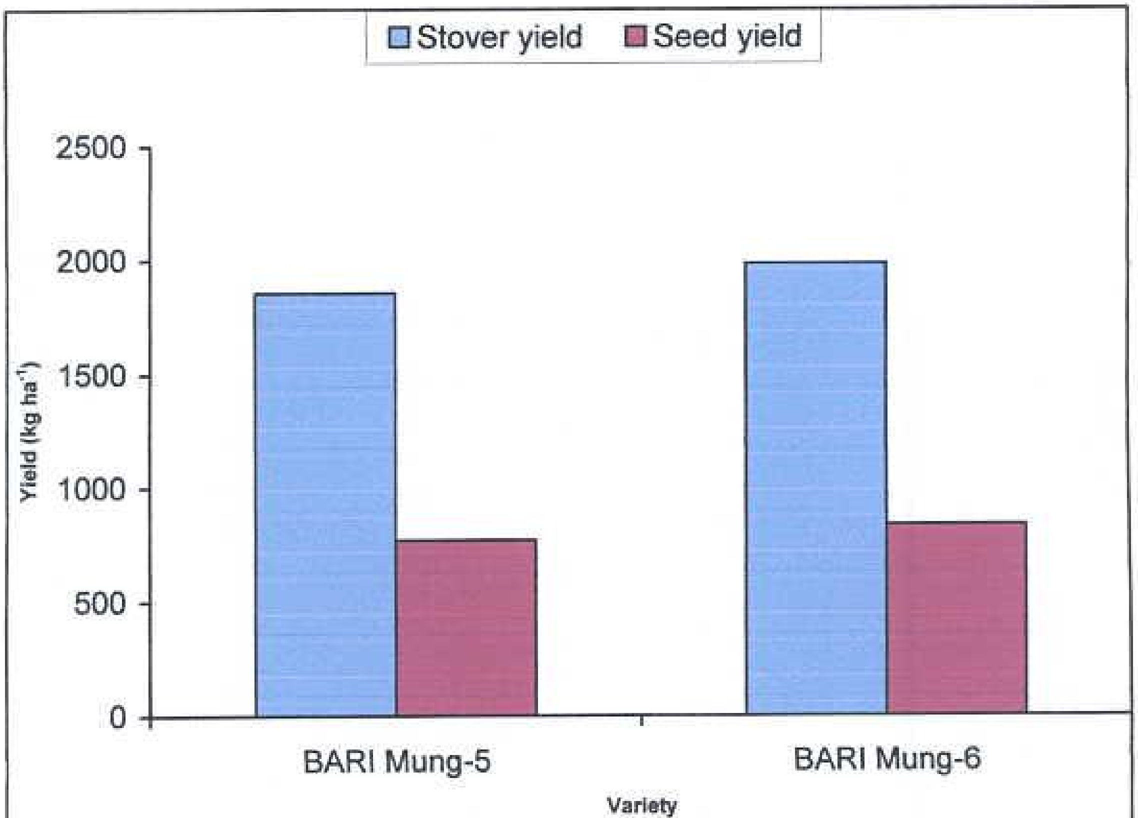

Fig. 4.13. Effect of variety on yield of mungbean

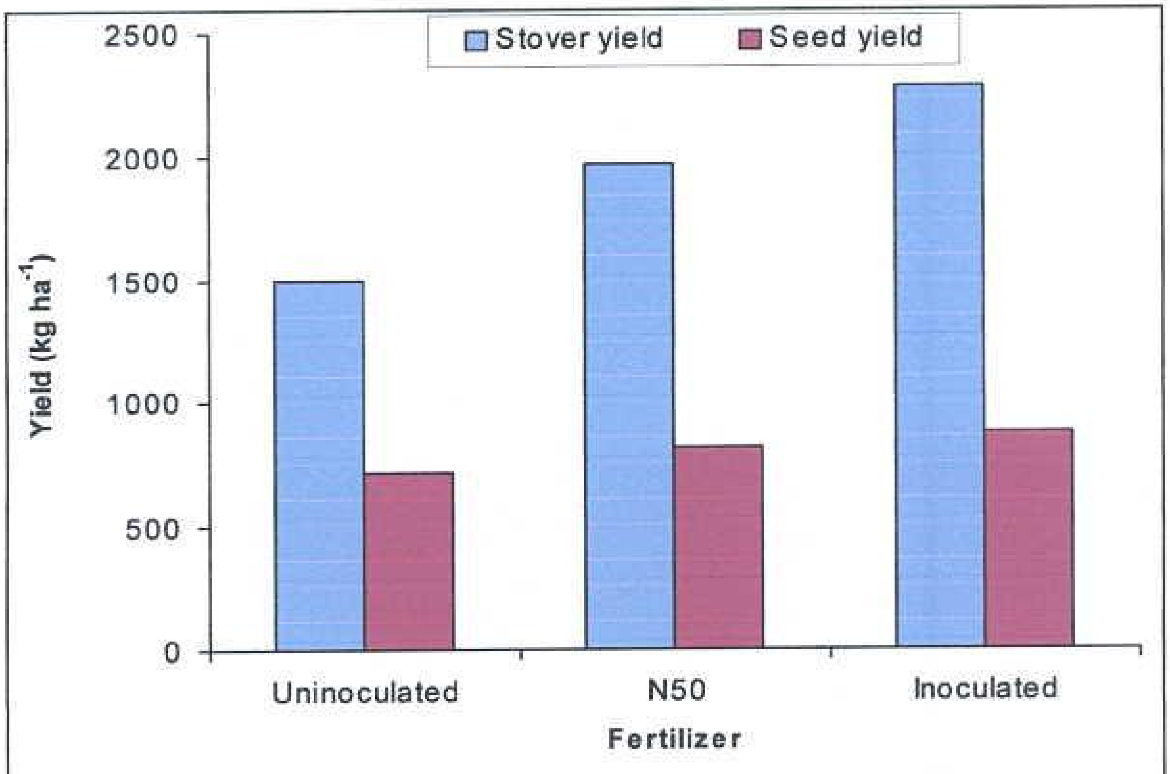

Fig. 4.14. Effect of fertilizer on yield of mungbean

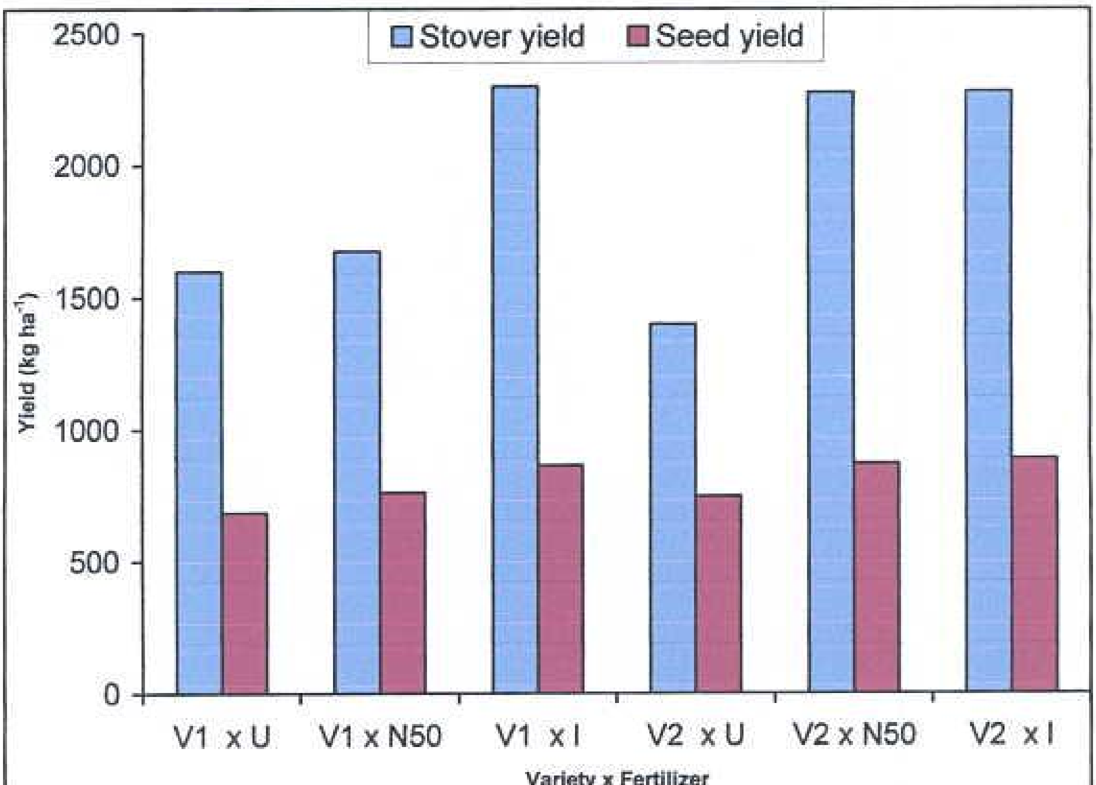

Fig. 4.15. Interaction effect of variety and fertilizer on yield of mungbean

4.16. Nitrogen content in seed

4.16.1. Effect of verity

The tested mungbean varieties did not differ significantly in nitrogen content (Table 4.7). Virtually two varieties recorded the same amount of nitrogen content in seed (3.34 %). Hayat *et al.* (2004) observed that 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%). Rizk and Abdo (2001) carried out field experiments with two mungbean field experiments with two mungbean cultivars (V-2010 and VC-1000), and cultivar VC-1000 surpassed cultivar V-2010 in the N-content. Solaiman *et al.* (2003) reported that the best characteristics were obtained with BARI Mung-4 in N content. Bhuiyan *et al.* (2007b) also reported similar results.

4.16.2. Effect of fertilizer

Effect of *Rhizobium* inoculum on N concentration in mungbean seed was significant (Table 4.8). The more N content in seed (3.36%) was found in inoculated mungbean. The less N control in seed (3.32%) was noted in uninoculated mungbean. 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. The lowest N content (3.19%) in seed was recorded in non-inoculated control. Reddy and Mallaiah (2001) opined that the nitrogen content of the fresh seeds was 5.78% in the inoculated plants, while that in non-inoculated controls was only 2.72%. Delic *et al.* (2009) noted that inoculation plants produced significantly higher total N content as well as protein yield in respect to untreated control. Solaiman *et al.* (2003) investigated that inoculation seeds increased N content in seed. Bhuiyan *et al.* (2007b) found similar results.

4.16.3. Interaction effect of variety and fertilizer

Nitrogen content in seed was higher under BARI Mung-6×I (3.36 %) plots than BARI Mung-5 × U (3.31 %) plots (Table 4.9). The results corroborates with the findings of Bhuiyan *et al.* (2007b). Solaiman *et al.* (2003) observed that BARI Mung-4 inoculated with strain TAL 169 gave higher N content in seed.

Table 4.7. Effect of variety on N content in seed and stover, and N uptake by seed and stover in mungbean

Variety	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
BARI Mung-5	3.34	1.52	25.72b	28.25
BARI Mung-6	3.34	1.52	27.94a	30.29
SE(±)	-	-	0.46	-
Level of sig.	NS	NS	**	NS

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

Table 4.8. Effect of fertilizer on N content in seed and stover, and N uptake by seed and stover in mungbean

Fertilizer	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
Uninoculated	3.32b	1.50	23.74c	22.43c
N_{50}	3.35a	1.53	27.35b	30.12b
Inoculated	3.36a	1.54	29.40a	35.26a
SE(±)	0.0051	-	0.56	0.85
Level of sig.	**	NS	**	**

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

Table 4.9. Interaction effect of variety and fertilizer on N content in seed and stover, and N uptake by seed and stover in mungbean

Variety x Fertilizer	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
BARI Mung-5 x U	3.31	1.50	22.71	24.00b
BARI Mung-5 x N_{50}	3.35	1.53	25.52	25.53b
BARI Mung-5 x I	3.35	1.53	28.92	35.23a
BARI Mung-6 x U	3.32	1.49	24.78	20.87b
BARI Mung-6 x N_{50}	3.35	1.53	29.17	34.71a
BARI Mung-6 x I	3.36	1.55	29.88	35.28a
SE(±)	-	-	-	1.20
Level of sig.	NS	NS	NS	**
CV(%)	0.4	2.8	5.9	8.2

In a column, the figures(s) having different letter(s) differed significantly
**Significant at 1% level
NS = Non significant
U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*

4.17. Nitrogen content in stover

4.17.1. Effect of variety

The test mungbean varieties did not differ significantly in nitrogen content in stover (Table 4.7). Similar N control in stover (1.52% and 1.52%) was observed by BARI Mung-5 and BARI Mung-6.

4.17.2. Effect of fertilizer

Effect of *Bradyrhizobium* inoculum on N concentration in mungbean stover was non-significant (Table 4.8). The inoculated plant accumulated about (1.54%) N in stover than uninoculated plant (1.50%). It might be higher N concentration of nitrogen in inoculated mungbean. 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.

4.17.3. Interaction effect of variety and fertilizer

Nitrogen content in stover was the highest under BARI Mung-5 × I (1.55%) and the lowest in BARI Mung-6 × U (1.49%) plots (Table 4.9). Srivastav and Poi (2000) reported that symbiotic variations of greengram and blackgram were observed due to the host and inoculant strains. They also observed that inoculation with M-10 strain in greengram gave the highest dry matter production and nitrogen fixation, while NK-4 inoculation into blackgram gave the highest nitrogen uptake and grain yield. Solaiman *et al.* (2003) found that BARI Mung-4 inoculated with strain TAL 169 gave higher N content in stover.

4.18. Nitrogen uptake by seed

4.18.1. Effect of variety

Nitrogen uptake was significantly influenced by two varieties of mungbean (Table 4.7). BARI Mung-6 recorded significantly higher nitrogen uptake (27.94 kg ha^{-1}) by seed compared to that of BARI Mung-5 (25.72 kg ka^{-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 best characteristics were obtained with BARI Mung-4 in N uptake. Bhuiyan *et al.* (2007b) reported that BARI Mung-2 produced the highest N uptake.

4.18.2. Effect of fertilizer

Nitrogen uptake was also highly significantly influenced by the different fertilizers over control (Table 4.8). The higher nitrogen uptake by seed (29.40 kg ha^{-1}) recorded in inoculated which were statistically different from other fertilizers. The lowest result was obtained in uninoculated control (23.74 kg ha^{-1}). 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.

4.18.3. Interaction effect of variety and fertilizer

The interaction effect of varieties and fertilizers on nitrogen uptake was non-significant (Table 4.9). The highest result of nitrogen uptake by seed was found in BARI Mung-6 x I (29.88 kg ha^{-1}) which was identical to all other treatments. The lowest amount of nitrogen uptake by seed obtained in BARI Mung-5 x U (22.71 kg ha^{-1}). Bhuiyan *et al.* (2007b) found that inoculated BARI Mung-2 produced the highest N uptake. Solaiman *et al.* (2003) reported that BARI Mung-4 inoculated with strain TAL 169 gave higher N uptake by seed.

4.19. Nitrogen uptake by stover

4.19.1. Effect of variety

There was no significant difference between the two varieties of mungbean on nitrogen uptake by the stover (Table 4.7). The higher nitrogen uptake by stover (30.29 kg ha^{-1}) was recorded in BARI Mung-6 than BARI Mung-5 (28.25 kg ha^{-1}).

4.19.2. Effect of fertilizer

The different fertilizers had the significant effect on nitrogen uptake by the stover (Table 4.8). The higher nitrogen uptake by stover was found in inoculated plant (35.26 kg ha^{-1}) which was superior to N_{50} and uninoculated control (22.43 kg ha^{-1}). 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.

4.19.3. Interaction effect of variety and fertilizer

The interaction effect of varieties and fertilizers on nitrogen uptake by stover was significant (Table 4.9). Both the varieties of mungbean recorded statistically identical nitrogen uptake with inoculation i.e. BARI Mung-6 x I (35.28 kg ha^{-1}) and BARI Mung-5 x I (35.23 kg ha^{-1}) recorded similar results which was superior to others except BARI Mung-6 x N_{50}. The lowest amount of nitrogen uptake by stover (20.87 kg ha^{-1}) was found in BARI Mung-5 x Uninoculum. 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) observed that BARI Mung-4 inoculated with strain TAL 169 gave higher N uptake by stover.

4.20 Correlation

Correlation matrix among the plant characters of mungbean has been shown in Tables 4.10-4.12. Most of the plant characters were correlated among themselves. In the present study, nodule number had positive and significant correlation with nodule weight with shoot weight with root length (Table 4.10). 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 pod plant-1 and seed yield, seed pod^{-1} and stover yield and seed pod^{-1} and seed yield (Table 4.11) Stover yield was also strongly correlated with N uptake by stover. Seed yield was also strongly correlated with N content in seed, N uptake by seed and N uptake by stover yield of mungbean (Table 4.12). 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.

Figures 4.15-4.30 represents the relationship among different plant characters of mungbean. A positive and linear correlation was observed between nodule number and nodule weight (Fig. 4.16), nodule number and root weight (Fig. 4.17), nodule number and shoot weight (Fig. 4.18), nodule number and seed yield (Fig. 4.19), nodule number and stover yield (Fig. 4.20), nodule number and N uptake by seed (Fig. 4.21), nodule number and N uptake by stover (Fig. 4.22), nodule weight and shoot weight (Fig. 4.23), nodule weight and stover yield (Fig. 4.24), nodule weight and seed yield (Fig. 4.25), nodule weight and N uptake by seed (Fig. 4.26), nodule weight and N uptake by stover (Fig. 4.27), shoot weight and seed yield (Fig. 4.28), shoot weight and stover yield (Fig. 4.29), stover yield and seed yield (Fig. 4.30), seed yield and protein yield (Fig. 4.31).

Table 4.10. Correlation matrix among different plant characters of mungbean at 35 DAS (n = 24)

Characters	Correlation coefficient (r value)				
	Nodule weight	Root weight	Shoot weight	Root length	Shoot length
Nodule number	0.756**	0.346^{NS}	0.567*	0.377^{NS}	0.235^{NS}
Nodule weight	-	0.187^{NS}	0.604*	0.439^{NS}	0.337^{NS}
Root weight	-	-	0.311^{NS}	0.463^{NS}	0.277^{NS}
Shoot weight	-	-	-	0.540*	0.270^{NS}
Root length	-	-	-	-	0.359^{NS}

**Significant at 1% level, *Significant at 5% level, NS = Non significant

Table 4.11. Correlation matrix among yield and yield contributing characters of mungbean (n = 24)

Characters	Correlation coefficient (r value)					
	Pod length	Pod plant^{-1}	Seeds pod^{-1}	Seed yield	1000 seed weight	Stover yield
Plant height	0.341^{NS}	0.361^{NS}	0.163^{NS}	0.471^{NS}	0.176^{NS}	0.450^{NS}
Pod length	-	0.425^{NS}	0.301^{NS}	0.180^{NS}	0.426^{NS}	0.321^{NS}
Pod plant^{-1}	-	-	0.698**	0.550*	0.487^{NS}	0.505*
Seed pod^{-1}	-	-	-	0.606**	0.469^{NS}	0.189^{NS}
Seed yield	-	-	-	-	0.326^{NS}	0.305^{NS}
1000 seed weight	-	-	-	-	-	0.162^{NS}

**Significant at 1% level, *Significant at 5% level, NS = Non significant

Table 4.12. Correlation matrix among yield and nutrient content of mungbean (n = 24)

Characters	Correlation coefficient (r value)				
	N content in stover	N uptake by seed	N uptake by stover	Stover yield	Seed yield
N content in seed	0.541*	0.740**	0.656**	0.336NS	0.714**
N content in stover	-	0.278NS	0.435NS	0.108NS	0.257NS
N uptake by seed	-	-	0.741**	0.310NS	0.999**
N uptake by stover	-	-	-	0.697**	0.734**
Stover yield	-	-	-	-	0.305NS

**Significant at 1% level, *Significant at 5% level, NS = Non significant

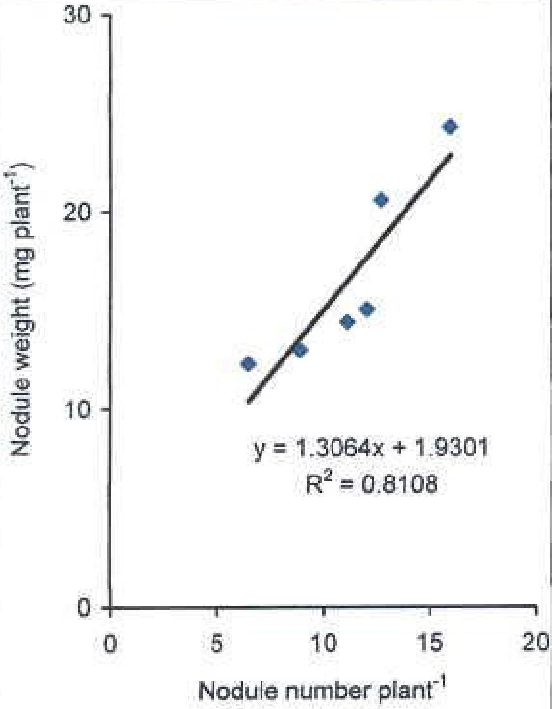

Fig. 4.16. Relationship between nodule number and nodule weight of mungbean at 35 DAS

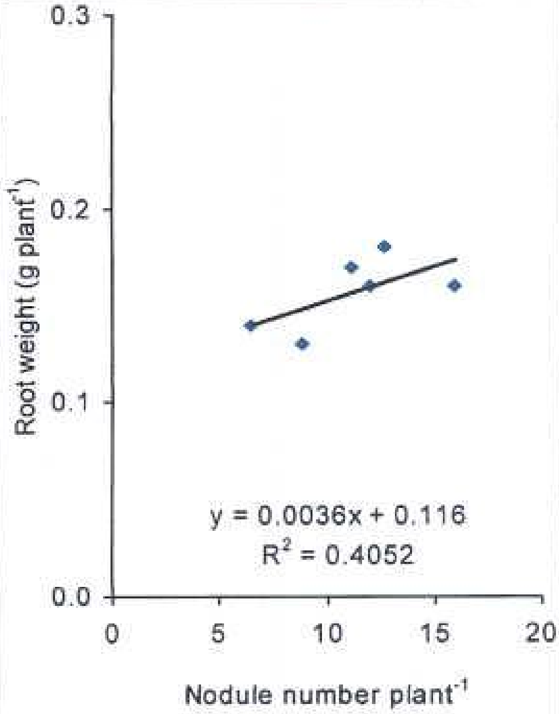

Fig. 4.17. Relationship between nodule number and root weight of mungbean at 35 DAS

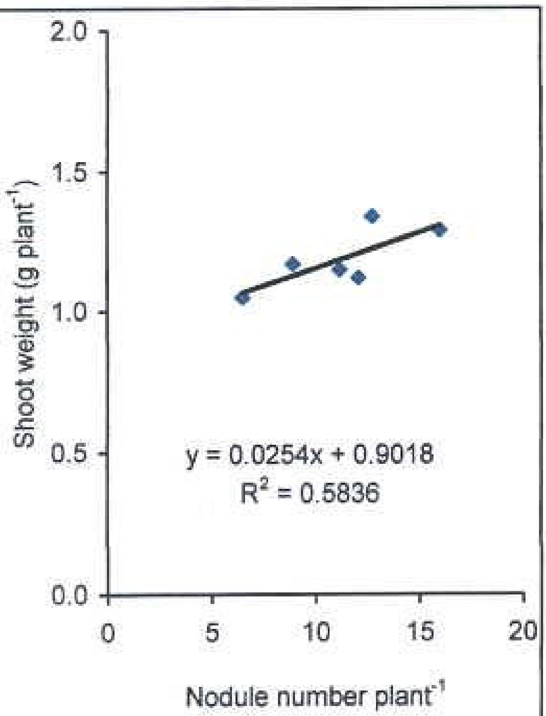

Fig. 4.18. Relationship between nodule number and shoot weight of mungbean at 35DAS

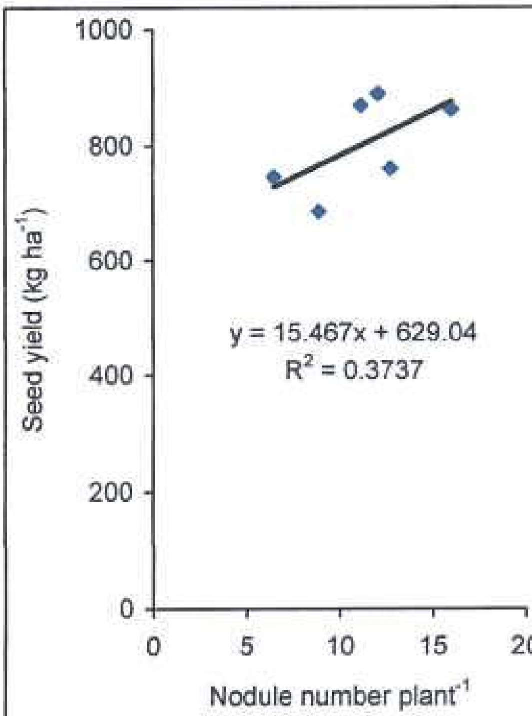

Fig. 4.19. Relationship between nodule number and seed yield of mungbean

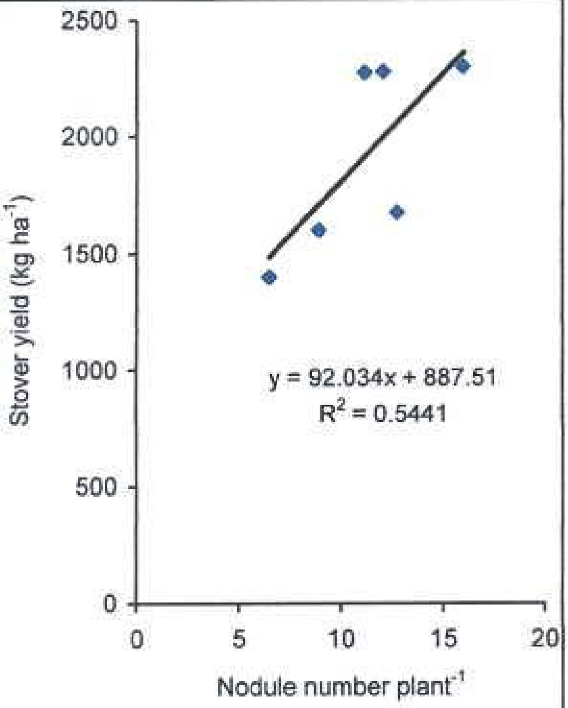

Fig. 4.20. Relationship between nodule number and stover yield of mungbean

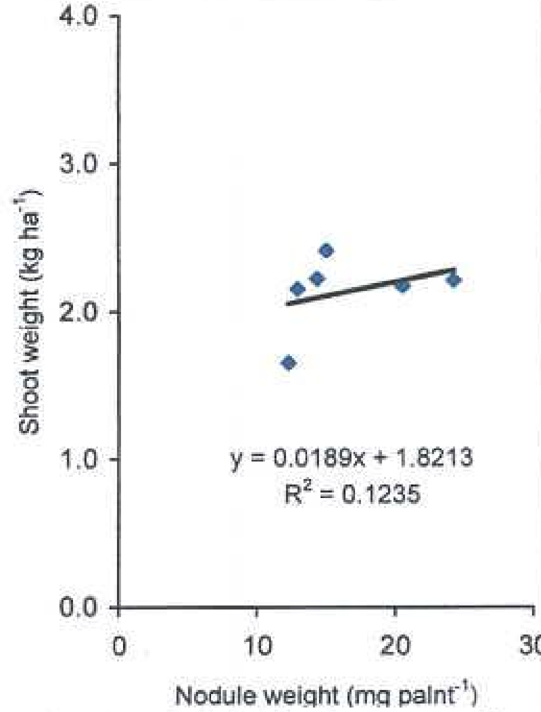

Fig. 4.21. Relationship between nodule number and nitrogen uptake by seed of mungbean

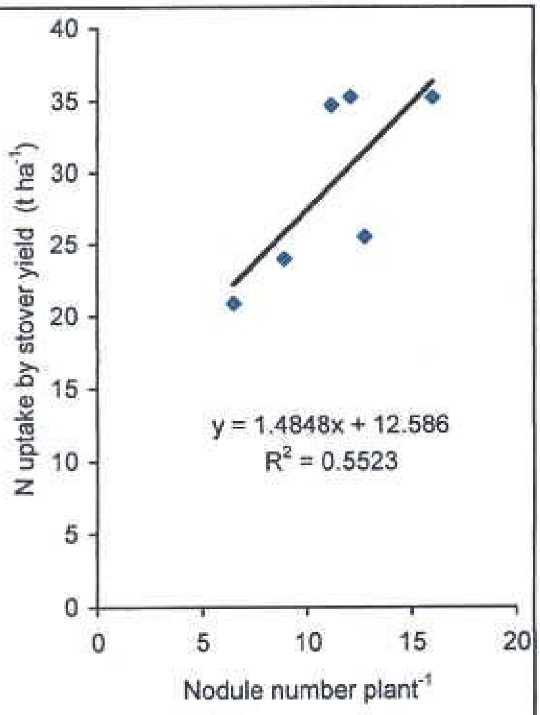

Fig. 4.22. Relationship between nodule number and N uptake stover yield of mungbean

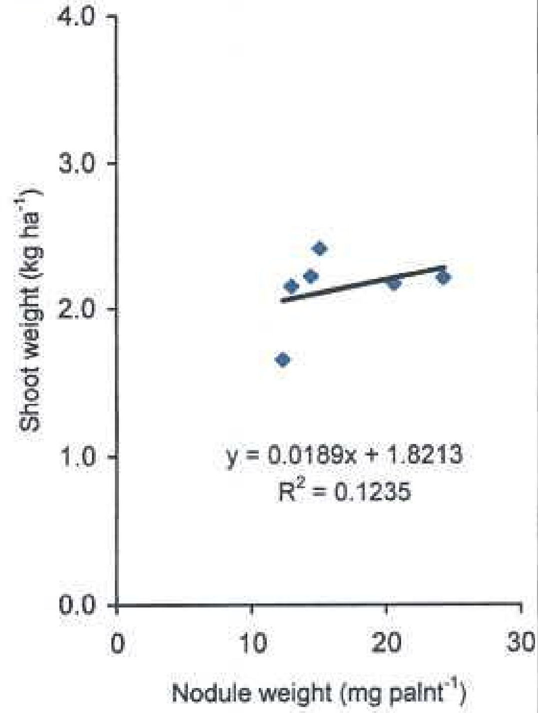

Fig. 4.23. Relationship between nodule weight and shoot weight of mungbean

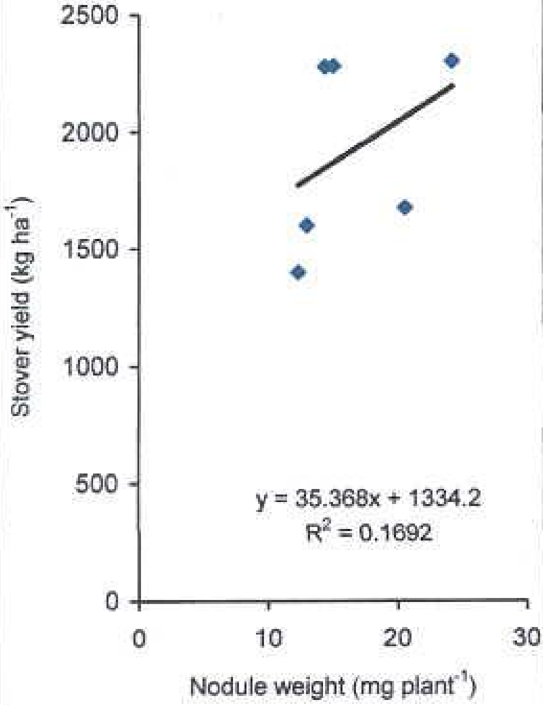

Fig. 2.24. Relationship between nodule weight and stover yield of mungbean

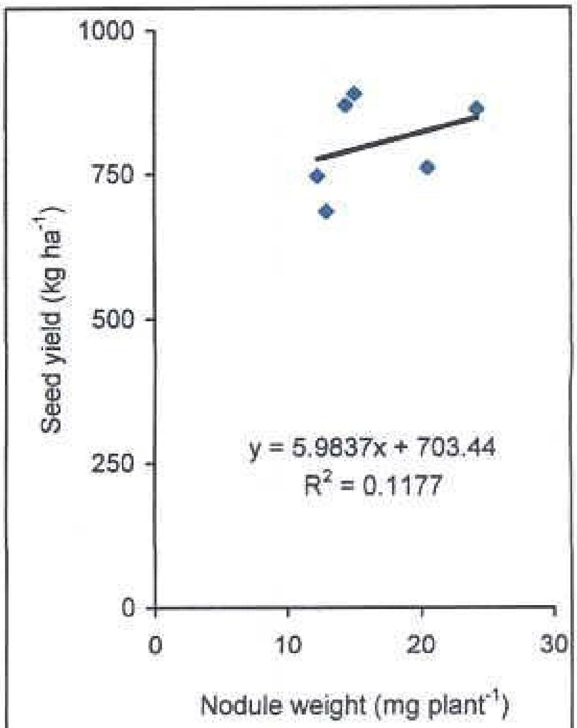

Fig. 2.25. Relationship between nodule weight and seed yield of mungbean

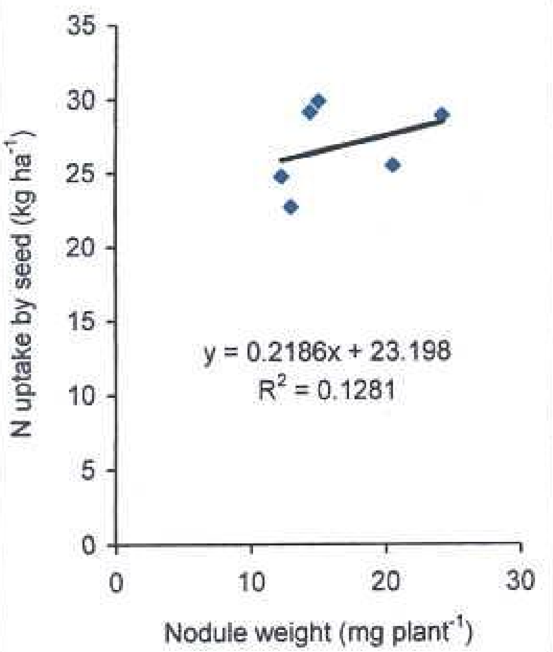

Fig. 4.26. Relationship between nodule weight and N uptake by stover of mungbean

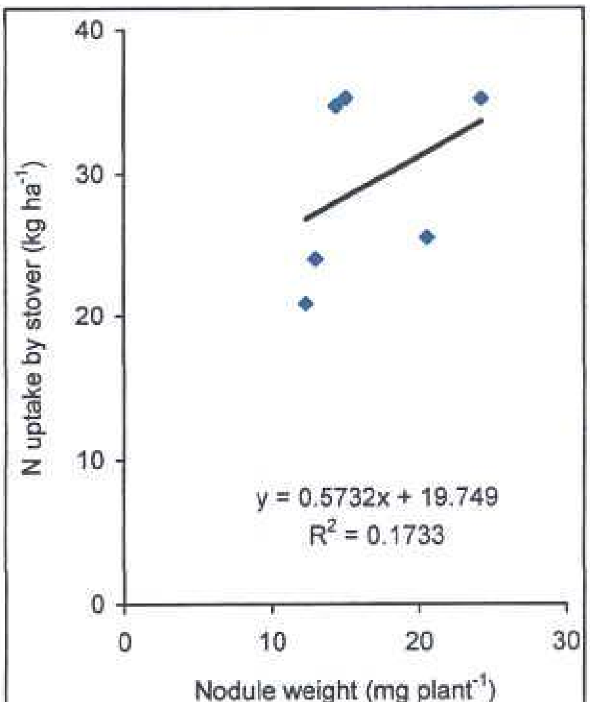

Fig. 4.27. Relationship between seed yield and stover yield of mungbean

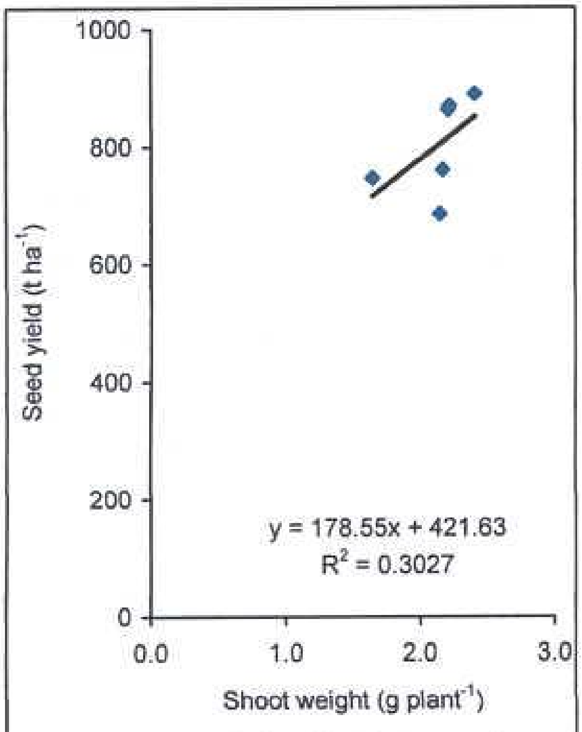

Fig. 4.28. Relationship between shoot weight and seed yield of mungbean

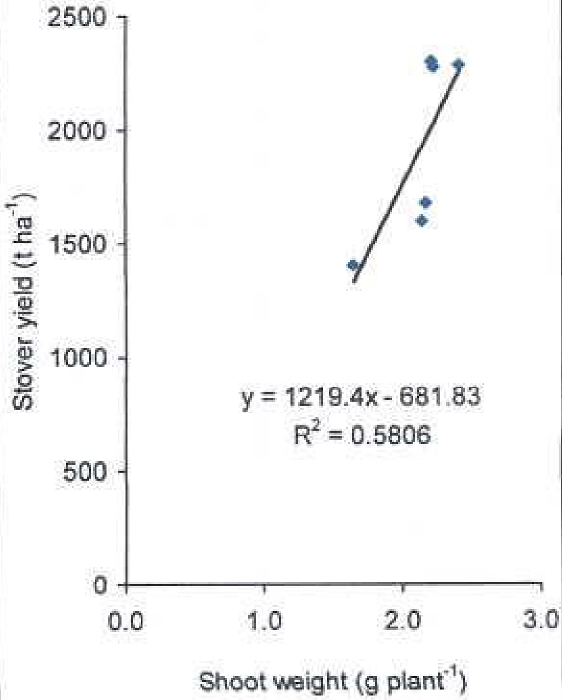

Fig. 4.29. Relationship between shoot weight and stover yield of mungbean

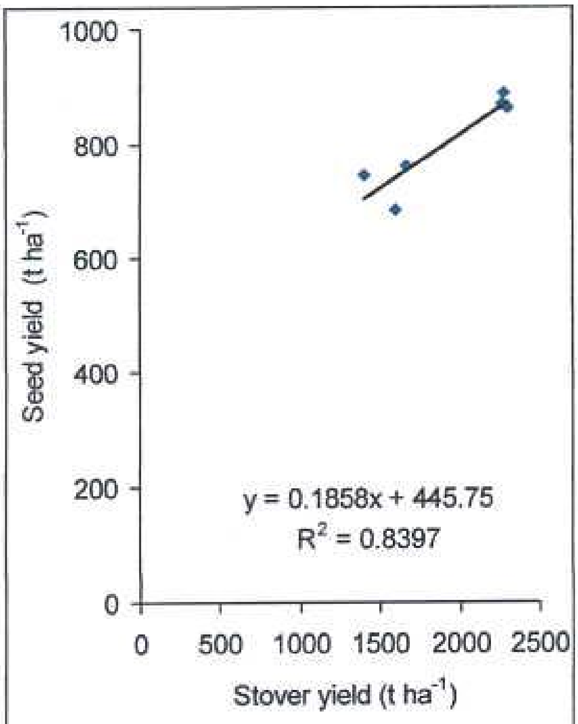

Fig. 4.30. Relationship between stover yield and seed yield of mungbean

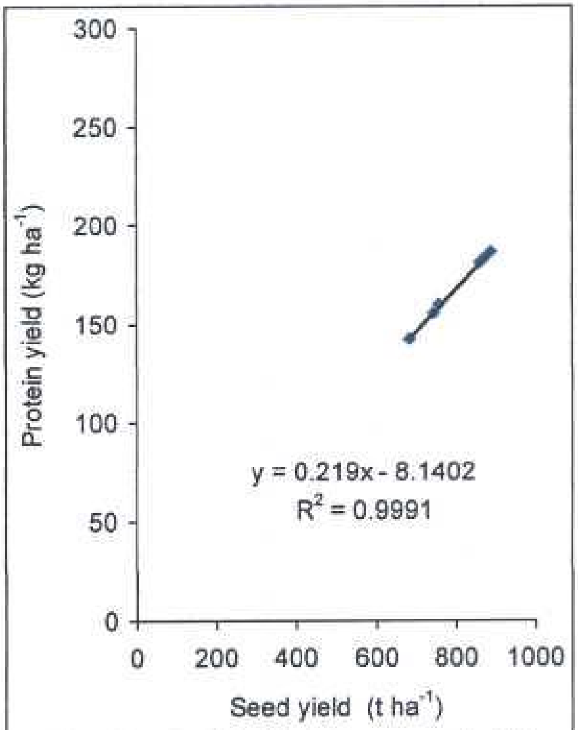

Fig. 4.31. Relationship between seed yield and protein yield of mungbean

4.21. Benefit cost ratio analysis

The benefit cost analysis (BCR) of mungbean has been given in Table 4.13. The highest BCR (1.31) was noted for BARI mung-5 x inoculum treatment. The second highest BCR was noted BARI mung-6 x inoculum treatment. For calculating BCR, only the cost of chemical fertilizers and inoculum were considered and other operational costs remained constant. The inoculum was more profitable than nitrogenous fertilizers based on BCR. The BCR followed the following trend $T_3V_1I > T_6V_2I > T_5V_2N > T_2V_1N$.

Table 4.13. Benefit cost ratio analysis for mungbean

Treatments	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})	Variable cost (Tk ha^{-1})	Gross return (Tk ha^{-1})	Net return (Tk ha^{-1})	Net return over control (Tk ha^{-1})	Benefit cost ratio
T_1: U	1600	686	6743	35100	28357	-	-
T_2: N_{50}	1675	761	8913	37887	28974	617	0.07
T_3: I	2300	863	6893	44300	37407	9050	1.31
T_4: U	1400	747	6743	38050	31307	-	-
T_5: N_{50}	2275	870	8913	44637	35724	4417	0.49
T_6: I	2280	890	6893	45640	38747	7440	1.08

Urea = Tk. 20 kg^{-1} , TSP= Tk. 22 kg^{-1}, MP= Tk. 15 kg^{-1}, Gypsum= Tk. 15 kg^{-1}, $ZnSO_4$= Tk. 100 kg^{-1}, Inoculum= Tk. 100 kg^{-1}, Mungbean seed= Tk. 50 kg^{-1}, Mungbean stover= Tk. 0.50 kg^{-1}.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was carried out during Kharif-I season of 2011 at Sher-e-Bangla Agricultural University (SAU) Farm in the Madhupur Tract (AEZ 28, Paleaustult) of Bangladesh with an objective of finding out the nodulation, biomass production and yield and N uptake by two mungbean varieties in presence and absence of nitrogen/*Rhizobium* inoculation. A summary of methodology and results of this study is given below.

The soil of the experimental field initially had a pH of 6.9, organic carbon 1.05%, total N 0.08%, available P 12.78 ppm, exchangeable K 43.29 ppm, available S 23.74 ppm, available B 0.36 ppm. The experiment was designed with six treatment combinations, laid out in a randomized complete block design (RCBD) with four replications. Each plot size was 2.4 m x 2 m. Two mungbean varieties viz. BARI Mung-5 and BARI Mung-6 were used in the study. Each variety was treated with N_{50}/*Rhizobium* inoculant and not treated with *Rhizobium* inoculant.

The seeds were sown in April 2011 and harvested in July 2011. All recommended cultural practices were followed to grow the crop. Frequent samplings were done at 35 and 50 days after sowing (DAS) for counting nodule number and nodule biomass, and dry matter production, root and shoot length. The crop was harvested at maturity seed and stover yields were recorded at 14% moisture content. The seed and stover samples were chemically analyzed for N content. All the data were statistically analyzed by F-test and the differences between treatments means were adjudged by Duncan's Multiple Range Test (DMRT).

Significant influences of the mungbean varieties were observed on nodulation, dry matter production and yields (seed and stover) and nutrient uptake by the crop. The higher number of nodules on main root, branch root, total nodule, nodule weight, root weight, shoot weight, root length and shoot length were obtained from BARI Mung-5 while seed and stover yields of mungbean were obtained from BARI Mung-6. BARI Mung-6 recorded lower nodulation and dry matter production. BARI Mung-6 produced higher seed yield (836 kg ha^{-1}) and stover yield (1985 kg ha^{-1}). Higher number of 1000-seed weight was also recorded in BARI Mung-6.

Application of *Bradyrhizobium* inoculant produced significant effect on various crop characters. The highest nodule number of 14.04 $plant^{-1}$ at 35 DAS and nodule weight of 19.67 mg $plant^{-1}$ were recorded in *Bradyrhizobium* inoculated plants. Seed inoculation significantly increased seed (876 kg ha^{-1}) and stover (2290 kg ha^{-1}) yields of mungbean. *Bradyrhizobium* inoculation also significantly increased pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight.

Inoculated BARI Mung-5 produced the highest nodule number, nodule weight and shoot weights. The highest seed was recorded in inoculated BARI Mung-6 and stover were recorded in N_{50} x BARI Mung-5 while higher yield attributes such as pods $plant^{-1}$ in inoculated BARI Mung-5 and seeds pod^{-1} were recorded in N_{50} x BARI Mung-6 treatment. The higher N concentration and N uptake were also observed in inoculated BARI Mung-6. Considering nodulation, biomass production, seed and stover yields, BARI Mung-6 was found to be the best variety between the two.

5.1 Conclusions

The present study revealed the following important findings:

1. Nodule number and nodule weight of mungbean increased progressively up to 35 (DAS) and thereafter started reducing in numbers until harvesting due to spontaneous degeneration.

2. Between two mungbean varieties, BARI Mung-5 was found better in respect of nodule formation while growth and yield (grain and stover) were found better in BARI Mung-6. Therefore, BARI Mung-6 may be considered as the suitable variety for cultivation at Agro-ecological zone-28 (Madhupur Tract) of Bangladesh. The highest seed & stover yield of mungbean was found with the innoculant of Bradyrhizobium due to the highest number of nodule which was statistically at with N_{50} $kgha^{-1}$

5.2 Recommendation and suggestions for future research

1. Considering the increasing trend of soil fertility reduction, the use of rhizobial inoculant should be used for cultivation of mungbean.

2. Instead of applying nitrogenous fertilizers for mungbean production bio fertilizer (rhizobial inoculant fertilizer) should be used. Because nitrogenous fertilizer is now a days a costly chemical fertilizer in Bangladesh. So rhizobial inoculant should be used in different pulses like mungbean for higher production of pulses to meet up the protein requirement of our suit motherland, Bangladesh. Mungbean may draw the attention of farmers for three reasons- (i) it is a short duration crop (not only a green manure) which will return cash money; (ii) a good source of plant protein; (iii) a good pulse crop for biomass production.

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Appendices

Appendix 4.1. Effect of variety on nodulation in mungbean

Variety	35 DAS				50 DAS			
	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)
BARI Mung-5	3.42a	9.14a	12.56a	19.28a	3.17a	4.05a	7.22a	12.14
BARI Mung-6	3.08b	6.83b	9.92b	13.94b	2.31b	3.04b	4.45b	13.92
SE(±)	0.076	0.25	0.29	0.51	0.14	0.13	0.15	-
Level of sig.	**	**	**	**	**	**	**	NS

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

Appendix 4.2. Effect of fertilizer on nodulation in mungbean

Fertilizer	35 DAS				50 DAS			
	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)
Uninoculated	2.33c	5.38c	7.71c	12.67b	2.21b	2.96b	5.17b	11.00b
N_{50}	3.21b	8.75b	11.96b	17.50a	2.96a	3.62ab	6.58a	11.21b
Inoculated	4.21a	9.83a	14.04a	19.67a	3.04a	4.21a	7.25a	16.88a
SE(±)	0.094	0.31	0.35	0.62	0.17	0.16	0.19	0.88
Level of sig.	**	**	**	**	**	**	**	**

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

Appendix 4.3. Interaction effect of variety and fertilizer on nodulation in mungbean

Variety x Fertilizer	35 DAS				50 DAS			
	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Total nodule $plant^{-1}$	Nodule weight (mg $plant^{-1}$)
BARI Mung-5xU	2.58	6.33	8.92	13.00c	2.34	3.17cd	5.50bc	9.83
BARI Mung-5xN_{50}	3.17	9.58	12.75	20.58b	3.42	4.42b	7.83a	10.00
BARI Mung-5xI	4.50	11.50	16.00	24.25a	3.75	4.58a	8.33a	16.58
BARI Mung-6xU	2.08	4.42	6.50	12.33c	2.08	2.75d	4.84c	12.17
BARI Mung-6xN_{50}	3.25	7.92	11.17	14.42c	2.50	2.83d	5.34c	12.42
BARI Mung-6xI	3.92	8.17	12.08	15.08c	2.33	3.83bc	6.17b	17.17
SE(±)	-	-	-	0.88	-	0.22	0.26	-
Level of sig.	NS	NS	NS	**	NS	*	**	NS
CV(%)	8.2	11.0	8.9	10.6	17.5	12.3	8.3	19.1

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

NS = Non significant
U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*

Appendix 4.4. Effect of variety on seed and stover yield of mungbean

Variety	Stover yield (kg ha^{-1})	Seed yield (kg ha^{-1})
BARI Mung-5	1858b	770b
BARI Mung-6	1985a	836a
SE(±)	41.77	13.23
Level of sig.	*	**

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

Appendix 4.5. Effect of fertilizer on seed and stover yield of mungbean

Fertilizer	Stover yield (kg ha^{-1})	Seed yield (kg ha^{-1})
Uninoculated	1500c	716c
N_{50}	1975b	816b
Inoculated	2290a	876a
SE(±)	51.15	16.21
Level of sig.	**	**

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

Appendix 4.6. Interaction effect of variety and fertilizer on seed and stover yield of mungbean

Variety x Fertilizer	Stover yield (kg ha^{-1})	Seed yield (kg ha^{-1})
BARI Mung-5xU	1600bc	686
BARI Mung-5xN_{50}	1675b	761
BARI Mung-5xI	2300a	863
BARI Mung-5xU	1400c	747
BARI Mung-5xN_{50}	2275a	870
BARI Mung-5xI	2280a	890
SE(±)	72.34	-
Level of sig.	**	NS
CV(%)	7.5	5.7

In a column, the figures(s) having different letter(s) differed significantly
**Significant at 1% level
NS = Non significant
U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*

Appendix 4.7. Effect of variety on N content in seed and stover, and N uptake by seed and stover in mungbean

Variety	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
BARI Mung-5	3.34	1.52	25.72b	28.25
BARI Mung-6	3.34	1.52	27.94a	30.29
SE(±)	-	-	0.46	-
Level of sig.	NS	NS	**	NS

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

Appendix 4.8. Effect of fertilizer on N content in seed and stover, and N uptake by seed and stover in mungbean

Fertilizer	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
Uninoculated	3.32b	1.50	23.74c	22.43c
N_{50}	3.35a	1.53	27.35b	30.12b
Inoculated	3.36a	1.54	29.40a	35.26a
SE(±)	0.0051	-	0.56	0.85
Level of sig.	**	NS	**	**

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

Appendix 4.9. Interaction effect of variety and fertilizer on N content in seed and stover, and N uptake by seed and stover in mungbean

Variety x Fertilizer	N content in seed (%)	N content in stover (%)	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})
BARI Mung-5 x U	3.31	1.50	22.71	24.00b
BARI Mung-5 x N_{50}	3.35	1.53	25.52	25.53b
BARI Mung-5 x I	3.35	1.53	28.92	35.23a
BARI Mung-5 x U	3.32	1.49	24.78	20.87b
BARI Mung-5 x N_{50}	3.35	1.53	29.17	34.71a
BARI Mung-5 x I	3.36	1.55	29.88	35.28a
SE(±)	-	-	-	1.20
Level of sig.	NS	NS	NS	**
CV(%)	0.4	2.8	5.9	8.2

**Significant at 1% level, NS = Non significant
U = Without *Bradyrhizobium*, I = Inoculated with *Bradyrhizobium*