EFFECTS OF NITROGEN, *BRADYRHIZOBIUM* AND MICRONUTRIENTS (MOLYBDENUM AND BORON) ON MUNGBEAN (*Vigna radiata* L.)

MD. MONZUR ALAM

DEPARTMENT OF AGRICULTURAL CHEMISTRY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA 1207

December 2009

EFFECTS OF NITROGEN, *BRADYRHIZOBIUM* AND MICRONUTRIENTS (MOLYBDENUM AND BORON) ON MUNGBEAN (*Vigna radiata* L.)

A Thesis

By

MD. MONZUR ALAM

Registration No. 08-O3182

Semester: July-December 2009

MASTER OF SCIENCE (M.S)

IN

AGRICULTURAL CHEMISTRY

DEPARTMENT OF AGRICULTURAL CHEMISTRY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

December 2009

EFFECTS OF NITROGEN, *BRADYRHIZOBIUM* AND MICRONUTRIENTS (MOLYBDENUM AND BORON) ON MUNGBEAN (*Vigna radiata* L.)

A Thesis

By

MD. MONZUR ALAM

Registration No. 08-03182

Semester: July-December 2009

Submitted to the Department of Agricultural Chemistry,

Sher-e-Bangla Agricultural University, Dhaka

in partial fulfillment of requirement for the degree of

MASTER OF SCIENCE (M.S)

IN

AGRICULTURAL CHEMISTRY

DEPARTMENT OF AGRICULTURAL CHEMISTRY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

December 2009

EFFECTS OF NITROGEN, *BRADYRHIZOBIUM* AND MICRONUTRIENTS (MOLYBDENUM AND BORON) ON MUNGBEAN (*Vigna radiata* L.)

By

MD. MONZUR ALAM

Registration No. 08-03182

A Thesis

Submitted to the Department of Agricultural Chemistry,

Sher-e-Bangla Agricultural University, Dhaka

in partial fulfillment of requirement for the degree of

MASTER OF SCIENCE (M.S)

IN

AGRICULTURAL CHEMISTRY

Semester: July-December 2009

Approved as to style and contents by

Supervisor	Co-Supervisor
Dr. Md. Asadul Haque Bhuiyan	**Dr. Rokeya Begum**
Senior Scientific Officer	**Professor**
Soil Science Division	**Department of Agricultural Chemistry**
Bangladesh Agril. Research Institute	**Sher-e-Bangla Agril. University**
Joydebpur, Gazipur-1701	**Dhaka-1207**

Chairman
Md. Azizur Rahman Mazumder
Professor
Department of Agricultural Chemistry
Sher-e-Bangla Agril. University
Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled "**EFFECTS OF NITROGEN, *BRADYRHIZOBIUM* AND MICRONUTRIENTS (MOLYBDENUM AND BORON) ON MUNGBEAN (*Vigna radiata* L.)**" submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 in partial fulfillment of the requirements for the degree of Master of Science (M.S) in Agricultural Chemistry embodies the result of a piece of *bonafide* research work carried out by M**d. Monzur Alam**, Registration No. 08-03182 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2009
Place: Dhaka, Bangladesh

....

Supervisor
Dr. Md. Asadul Haque Bhuiyan
Senior Scientific Officer
Soil Science Division
Bangladesh Agril. Research Institute
Joydebpur, Gazipur-1701

Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

All praises are to Allah for enabling me to complete the thesis for the degree of Master of Science (M.S) in Agricultural Chemistry.

It is a great pleasure to express my profound sense of gratitude and indebtedness to my research supervisor Dr. Md. Asadul Haque Bhuiyan, Senior Scientific Officer, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur for his constant guidance, active supervision, generous help and encouragement throughout the period of research work and in preparing this thesis.

I am highly grateful to my co-supervisor Dr. Rokeya Begum, Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for her valuable advice, continuous guidance, technical suggestions and constructive criticisms on this thesis.

Profound appreciation and deep sense of gratitude are due to the Chairman of the Supervisory Committee, Md. Azizur Rahman Mazumder, Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for his kind cooperation and inspiration.

I am grateful to my teachers Dr. Md. Abdur Razzak, Associate Professor; Dr. Noorjahan Begum, Associate Professor; Md. Sirajul Islam Khan, Assistant Professor; Md. Tazul Islam Chowdhury, Assistant Professor; Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their valuable teaching, advice, encouragement and cooperation during the whole study period.

I am highly grateful to Dr. Shamsun Noor, Chief Scientific Officer and Head, Soil Science Division and Dr. Delowara Khanam, Principal Scientific Officer, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur for providing laboratory, library and computer facilities as well as moral support.

I am also thankful to Md. Eyakub Ali, Mst. Rokeya Khatun, Faridul Alam, Scientific Officer, Soil Science Division, BARI, Md. Monirul Islam, Mst. Farhana Yeasmin, Scientific Assistant, Md. Abdul Wahab Mollah, Afsari Khanam, Laboratory Attendant and Mst. Anowara, Research Assistant for their co-operation in conducting the experiment in the net house and data collection in the laboratory of BARI.

I am thankful to Abdus Salam Sarkar, Section Officer, Dept. of Agricultural Chemistry, Md. Basharul Islam, Computer Operator, Soil Science Division, BARI and Md. Alamgir, Junior Assistant (Computer) for their co-operation and careful typing of the manuscript.

I remember my parents and sisters for their sacrifice, blessings and inspiration throughout the academic life.

I am also grateful to all of my relatives, friends and well wishers who helped me directly or indirectly.

The Author

C O N T E N T S

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Abstract

A field experiment was conducted during March to June 2009 at the research field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur to study the effect of nitrogen, *Bradyrhizobium* inoculant, molybdenum and boron on growth, nodulation, and yield, yield contributing characters, nitrogen content and uptake of mungbean. The variety BARI Mung-5 and *Bradyrhizobium* inoculant (BARI RVr-401) was used for the above experiment. There were twelve treatment combinations viz. T_1: Control (non-inoculated and non-fertilized control), T_2: PKMo, T_3: PKB, T_4: *Bradyrhizobium* inoculant, T_5: N, T_6: PKMo + *Bradyrhizobium* Inoculant, T_7: PKB + *Bradyrhizobium* Inoculant, T_8: NPKMo, T_9: NPKB, T_{10}: PKMoB, T_{11}: PKMoB + *Bradyrhizobium* Inoculant and T_{12}: NPKMoB. After 35 and 50 days of sowing, 5 plants were uprooted from each plot in each days of nodule collection to study nodulation, dry matter production and plant growth. At maturity, yield and yield contributing characters were recorded. *Bradyrhizobium* inoculation significantly increased number of nodules, nodule weight, root and shoot length, seed and stover yield, yield attributes, nitrogen and protein yield of mungbean compared to non-inoculated control. *Bradyrhizobium* inoculation in presence of Mo and B recorded the highest nodule number and nodule weight, and also seed and stover yields. *Bradyrhizobium* inoculation alone or in presence of Mo or B also recorded higher nodulation over other treatment combinations. *Bradyrhizobium* inoculation was better than nitrogen in almost all the parameters studied. Molybdenum and boron also performed better results. This result indicated that the use of *Bradyrhizobium* inoculants with molybdenum and boron appeared to be an effective method for successful mungbean production.

CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilzek) is one of the major pulse crop grown in Bangladesh. It is considered as the quality pulse in the country but the production per unit area is very low (763 kg ha^{-1}) as compared to other countries of the world (BBS, 2006). Among the pulses, mungbean possess nutrient value having crude protein about 26.0%, crude fibre 5.2%, nitrogen free extract 62.9%, ether extract 1.1%, total ash 4.4%, Ca 0.2% and P 0.5% (Gowda and Kaul, 1982).

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.

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 Sarma (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).

Micronutrients play an important role in increasing yield of pulses and oilseed legume through their effects on the plant itself and on the nitrogen fixing symbiotic process (Bhuiyan *et al.*, 1996a; 1996b). But deficiencies of these nutrients have been very much pronounced under multiple cropping systems due to excess removal thereby necessity of their exogenous supply.

Molybdenum is essential for N_2-fixation and the amounts required are so small that the seed of grain legumes can contain sufficient molybdenum for the growth of one generation of plant (Harris *et al.*, 1965). The nitrogen fixing enzyme nitrogenase is composed of molybdenum and iron. Without adequate quantities of these elements, nitrogen fixation cannot occur. Molybdenum is a constituent of one of the two proteins, which together form Mo-nitrogenase, and therefore a sufficient supply of Mo is essential for nitrogen fixation in legumes. Effects of molybdenum application on different grain legumes nodulation have been documented (Bhuiyan *et al.*, 1999a, 2005).

Boron is essential micronutrient for cell division in the process of nodule formation (Mulder, 1948). Boron is essential for plants, has been considered a nonessential nutrient for rhizobia. The deficiency of B affects some grain legumes (Rerkasem *et al.*, 1987). The deficiency of boron and response of different grain legumes have been reported by some researchers (Rerkasem *et al.*, 1987; Bhuiyan *et al.*, 1999b, 2005 etc.).

The soils of different parts of Bangladesh are more or less deficient in boron and molybdenum as well as nitrogen fixing bacteria (*Rhizobium* spp.) which causes poor yield of pulses (Bhuiyan *et al.*, 1999a; Khanam *et al.*, 1994). Research results on pulses are available in relation to single application of molybdenum, boron or rhizobial inoculum and their interactions (Bhuiyan *et al.*, 1999a, 1999b, 2005).

Keeping the above viewpoint, this experiment was undertaken with the following objectives:

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

ii) To find out the suitable combination of *Bradyrhizobium*, nitrogen, molybdenum and boron for mungbean production.

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

2.1 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 15N labeled maize or mungbean residues. EM increased the 15N concentrations of maize at the V8 growth stage indicating better use of applied nutrients from organic matter. The uptake of 15N 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.

Asraf *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}).

2.2 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.

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

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

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

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

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

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

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

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

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

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

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

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

2.3 Effect of boron

Boron is an essential micronutrient for cell division in the process of nodule formation (Mulder, 1948). It is one of the most important micronutrients which is required for growth and development of plant. It helps in fruit setting and grain formation. The development of anthers and pollen is affected by boron deficiency. In boron deficient crop, the pollen does not accumulate starch and the nuclei when present are abnormal. It has been suggested that boron deficiency affects pollen development during the pollen mother cell stage (Canhong and Rerkasem, 1992). Thus boron deficiency can cause yield reduction by reducing grain set through impaired development of anther and pollen grain (Sansance and Benchawan, 1989). Rerkasem *et al*. (1991) observed that the poor grain set in wheat reduced grain yield by 40-50% on soils with low boron content (0.08-0.12 mg B kg^{-1}). Grain yield of wheat is depressed by poor number of grains ear^{-1} which may result from boron deficiency (Abedin *et al*., 1994). The problem can be corrected by boron application to the soil. It has been reported that the crop responds better to soil application than to foliar application (Chatterjee *et al*., 1980). The added boron causes higher formation of grains resulting in higher grain yield of wheat (Jahiruddin, 1991; Hossain *et al*., 1994; Khan *et al*., 1996). Improvement in grain set and 1000-grain weight in wheat by boron application was also observed by Singh and Singh (1976).

Reinbott and Blevins (1995) carried out experiments to determine the foliar applications of boron (B), magnesium (Mg), or B + Mg on soybean yield. Foliar 3 or Mg applied separately four times during reproductive growth did not affect soybean yield. However, four foliar application of B + Mg increased soybean yield by 12% at Mount Vernon and 4% at Columbia over a three-year period They also reported that 2.8 kg ha^{-1} B application to soil eight weeks prior to planting increased soybean yield by 11% during the first year and 13% in the second year but had no affect on soybean yield by the third year after application. When results from the first two years were combined, 2.8 kg ha^{-1} B applied to soil increased the number of pods $branch^{-1}$ by 17% and the number of branch pods $plant^{-1}$ by 39%.

Islam *et al*. (1995) in a field experiment on Grey Floodplain Soils at Bogra, Bangladesh, *Cicer arietinum* cv. Nabin was given 20 kg N + 60 kg P + 40 kg K+ 5 kg Zn + 1 kg B + 1 kg Mo ha^{-1} (complete fertilizer package, CFP). Omission of N, P, K, S, Zn, Mo and B gave seed yields of 73, 67, 50, 85, 96, 80 and 7% of the yield with CFP, respectively. Applying NPKS only or NPKS + cattle manure gave 5 and 8% of the yield with CFP. CFP + 1 kg B ha^{-1} gave 37% higher yields than with CFP alone. In the following year (1993/94), application of 2 kg B + 1 kg Mo ha^{-1} gave the optimum yield which was 14% higher than that obtained from 2 kg B alone.

Zhu *et al*. (1996) conducted an experiment with rapeseed and reported that the foliar application of B at seedling and internodes elongation stages gave better results than seed treatment or basal application. Concentrations of B in the spray solution in the range of 0.1 to 0.25% increased the seed yield significantly where 0.2% being the optimum concentration with a 17.8% yield increase over the control. Foliar application of B and Zn in combination produced higher than the application of either element alone.

Bowszys (1996) conducted a field trial with rapeseed and reported that the application of 0.4 kg B ha^{-1} increased seed yield significantly along with higher rates of seed formation.

Subbaiah and Mittra (1996) found in a field experiment on *Brassica juncea* cv. Varuna due to a foliar application of 500 ppm each of Zn and B and 50 ppm Mo singly or in all combinations. The application of Zn or B with recommended 80:40:20 kg N:P:K ha^{-1}, respectively increased the seed yield by 26 and 18% in the first year and by 49 and 47% in the second year over NPK alone, respectively. The increase in seed yield was associated with the increase in 1000-seed weight.

Saha *et al*. (1996) carried out a field trials in pre-kharif [pre-monsoon] seasons of 1993-94 at Pundibari, India where yellow sarson [*Brassica campestris* var. sarson] was given 0, 2.5 or 5.0 kg borax and 0, 1 or 2 kg sodium molybdate ha^{-1} applied as soil, 66% soil + 33% foliar or foliar applications and the residual effects were studied on summer greengram [*Vigna radiata*]. Greengram seed yield was the highest with a combination of 5 kg borax + 2 kg sodium molybdate. Soil application gave higher yields than foliar or soil + foliar application.

Islam *et al*. (1997) carried out experiments on a silt loam soil (Aeric Haplaquept) in Bangladesh to study the effect of S, Zn and B applications on autumn rice and their residual effects on the following mustard crop. Autumn rice responded significantly to S, Zn and B applications. Application of any two nutrients together increased grain yield but such an increase was significant only when S and Zn were applied combined. The highest grain yield (4.5 t ha^{-1}) was obtained in S + Zn + B treatment with a record of 41.8% yield increase over control while the application of S, Zn or B alone gave yield increases of 23.3, 21.7 and 14.6%, respectively. A large portion of the applied nutrients remained in the soil, which significantly increased the seed yield and nutrient uptake by the mustard crop.

Bora and Hazarika (1997) reported that B application increased the seed yield of mustard. The application of 30 kg borax produced the highest seeds yield of 1.30 t ha^{-1}. Boron application also increased seed oil content.

Lourduraj *et al*. (1997) conducted a field experiment and revealed that groundnut yield and monetary returns were increased by application of iron, zinc, boron and gypsum. When basal application of NPK was combined with application of 5 kg borax ha^{-1} + 25 kg $ZnSO_4$ kg ha^{-1} along with application of 500 kg gypsum ha^{-1} and 1% $FeSO_4$ spray on the 45th day, groundnut yield and returns were maximized.

Field experiment were conducted by Bhuiyan *et al*. (1998b) at Agricultural Research Station, Thakurgaon, Bangladesh to find out the effect of Mo, B and rhizobial inoculant on nodule number, nodule and shoot weights, and stover and grain yields of lentil. Significant differences were observed in all the characters studied. Rhizobial inoculant, Mo and B together produced significantly higher nodule number, nodule and shoot weights, and stover and grain yields over control. Crops response to B was better than the Mo. Grains yield of lentil were 115 and 94% higher over uninoculated and unfertilzed control during to *rabi* seasons.

Singh *et al*. (1998) conducted a field experiment at Kanpur, Uttar Pradesh in zaid (spring-summer) was given B, Fe, Zn, Mn, Cu, Mo or Na by soil or foliar application. Plant height, branch number, and stem, leaf and total dry weight were not significantly affected by treatment. Seed yield was 988 kg ha^{-1} in controls and 1,213-1,500 kg ha^{-1} with trace element fertilizers. The highest yield was given by soil-applied Na_2MoO_4.

YongHua and HongYan (1998) carried out a field experiment of boron (B) amelioration of aluminum (Al) toxicity was studied with mungbean cv. Minglu seedlings and cuttings (without roots) in a growth chamber. Mungbean seedlings and cuttings were grown in a solution culture with 0, 5 or 50 micro M B and 0, 2 or 5 mM Al for 16 days. The addition of B promoted elongation of epicotyls and hypocotyls, and increased seedling height and dry weight in the Al treated plants. High concentrations of B decreased soluble protein and increased chlorophyll content in seedlings treated with 2 mM Al. B had no ameliorative effect on cuttings grown with Al, although Al increased soluble protein content. It is concluded that B alleviation of Al toxicity was related to root function and Al toxicity may possibly be due, in part, to B deficiency.

An experiment was conducted by Bhuiyan *et al*. (1999a) on Himalayan Piedmont Soils of Dinajpur and Thakurgaon, Bangladesh to observe the effect of Mo, B and rhizobial inoculum on nodulation, yield and economic performance of chickpea. Inculation with *Rhizobium* strain (RCa-220) in presence of P, K, Mo and B fertilizers significantly increased nodulation, top dry matter and seed yield of the crop. The magnitude of increases in seed yield over control was 143% and 86% at Dinajpur and 132% and 174% at Thakurgaon.

Wang *et al*. (1999) reported that there is limited risk of B toxicity due to the use of borax fertilizer at up to 4 to 8 times recommended rates in rape-rice cropping rotations in Southeast China. The low risk of B toxicity can be attributed to relatively high B removal in harvested seed, grain and stubble, the redistribution of fertilizer B by leaching in the 0 to 60 cm layer and to boron sorption.

Verma and Mishra (1999) carried out a pot experiment with mungbean cv. PDM 54, boron was applied by seed treatment, soil application (basally or at flowering) or foliar spraying. Boron increased yield and growth parameters, with the best results in terms of seed yield plant^{-1} when the equivalent of 5 kg borax ha^{-1} was applied at flowering.

Mishra *et al*. (2001) conducted an experiment on the effect of nutrient management and plant growth regulators on the yield and economics of chickpea in Madhya Pradesh, India during the rabi season of 1998-99. Seed and stover yields were higher in B and cephalexin treatments compared to the other growth regulator treatments. Boron and P with S treatments gave the highest net returns.

Rizk and Abdo (2001) carried out two field experiments to investigate the response of rnungbean with some micronutrients. Two cultivars of mungbean (V-2010 and VC-l000) were used in this investigation. Zinc (0.2 or 0.4 g L^{-1}), Mn (1.5 or 2.0 g L^{-1}), B (3.0 or 5.0 g L^{-1}) and a mixture of Zn, Mn and B (0.2, 1.5 and 3.0 g L^{-1}), in addition to distilled water as control were sprayed once at 35 days after sowing (DAS). Generally, cultivar VC-1000 surpassed cultivar V-2010 in yield and its components as well as in the chemical composition of seeds with exception in 100-seed weight and phosphorus percentage in seeds. All treatments increased yield significantly and its components especially Zn (0.2 g L^{-1}), which showed highly significant increase in all characters under investigation compared to the control. All adopted treatments increased significantly protein percentage in seeds of the two mungbean cultivars.

Abdo (2001) conducted two field experiments at Giza Experimental Station, ARC, Egypt during the 1998 and 1999 seasons to study the effect of foliar spray with micronutrients (Zn, Mn, or B) on morphological, physiological and anatomical parameters of two mungbean (*Vigna radiata*) cultivars V-20 10 (Giza-1) and VC-1000. Zn (0.2 or 0.4 g L^{-1}), Mn (1.5 or 2.0 g L^{-1}), B (3.0 or 5.0 g L^{-1}) and a mixture of Zn, Mn and B (0.2, 1.5 and 3.0 g L^{-1}) in addition to distilled water as control were sprayed once at 35 days after sowing (DAS) The results showed that foliar spray with the adopted concentrations of Zn, Mn or B alone or in a mixture, increased significantly most of the growth parameters over control. Application of Zn (0.2 g L^{-1}) alone followed by a mixture of micronutrients resulted in better morphological and physiological parameters, stem length, number of branches, number of leaves, leaf area (LA), leaf area index (LAI) and shoot dry weight $plant^{-1}$. It was observed that mungbean cv. VC-1000 surpassed cv. V -2010 in all parameters under investigation.

Ali *et al.* (2002) reported that yield losses of varying magnitude in chickpea, e.g. 22-50% due to iron (Fe) up to 100% due to boron (B), and 16-30% due to sulphur (S).

Genotypic differences in response to application of Fe, B and zinc (Zn) have also been found among chickpea genotypes.

Bharti *et al.* (2002) carried out a field experiment in Bihar, India during the winter of 1997-98 to observe the effects of B (0, 1.5 and 2.5 kg ha^{-1}) application on the yield and nutrition of chickpea (cv. BG256). They reported that the mean seed yield, and seed and stover N and B content increased, whereas stover yield decreased with increasing B rates.

Islam *et al*. (2002) conducted a field experiment to study the effects of B, Zn and S, and weeding on the incidence and severity of yellow mosaic disease of mungbean and found that the mungbean was exposed to natural infection of yellow mosaic virus. The disease incidence, severity and mosaic in leaves were minimum with B + Zn + S treated plots when weeding was done. Consequently, there was a significant increase in yield compared to the plots when weeding was not done. Disease incidence and severity was also low in the B, Zn or S treated plots when weeding was done compared to B, Zn or S treated plots when weeding was not performed. The percentage of reduction in plant height, pod length, 1000-seed weight and seed yield due to yellow mosaic disease was minimum in B + Zn + S plot with weeding compared to B, Zn or S or B + Zn + S plot without weeding, respectively.

A field experiments were conducted by Singh *et al*. (2002) in sandy loam calcareous soil in Uttar Pradesh, India during 1995-96 to study the effect of boron application on yield of pea (cv. Rachna) and blackgram (cv. PV-19). Boron was applied as borax at the rates of 1, 2, 3 and 4 kg borax ha^{-1}, with a control. Application of borax up to 4 kg borax ha^{-1} significantly increased the grain yield of blackgram. The maximum yield was 15.42 q ha^{-1} and minimum grain yield of 1.65 q ha^{-1} was found in control. The additional grain yield over the control was 280, 431, 899 and 1,377 kg ha^{-1} at 1.0, 2.0, 3.0 and 4.0 kg borax ha^{-1}, respectively. Application of B progressively increased the grain yield of pea from 510 to 1,843 kg ha^{-1} up to 4 kg borax ha^{-1}.

Bharti *et al*. (2003) conducted a field trial in Muzaffarpur, Bihar, India during the 1997-1998 rabi season on chickpea cultivar (BG256) to study the effect of boron. The treatment comprised 0, 1.5 and 2.5 kg B ha^{-1}. The number, dry weight, nitrogenase activity, leghaemoglobin content and active ion content of the nodules increased with B application. Boron at 1.5 kg ha^{-1} was optimum for most of the characteristics.

Chitdeshwari and Poongothai (2004) revealed the response of groundnut to the soil application of Zn, B, S and Mo and also the seed treatment with Zn, B and S. A substantial yield increase was obtained with the soil application of Zn at 5 kg ha^{-1} in combination with B at 1.0 kg ha^{-1} and S at 40 kg ha^{-1}. The yield increase over the control was 24.2% for TMV 7 and 14.8% for JI 24. Zn had most pronounced effect on yield, followed by S and B.

Johnson *et al*. (2005) found that the primary nutrient problem in grain legumes is B deficiency, while in rice (*Oryza sativa*), Zn deficiency is more important and wheat (*Triticum aestivum*) suffer from both deficiencies. A series of field experiments were carried out over two seasons to compare soil fertilization and micronutrient seed priming as methods of improving Zn and B nutrient of each crop. Micronutrient treatments were evaluated for their effects on grain yield and grain micronutrient content. Soil B fertilization increased B content of the grain of lentil (*Lens culinaris*) and chickpea (*Cicer arietinum*).

Srivastava *et al*. (2005) observed that in absence of applied B, there was no yield as no yield as no pods were founds, in comparison to a yield of 300 kg ha^{-1} in the full nutrient treatment. There was yellowing of younger leaves and typical little leaf symptom when B was omitted. A typical concentration range of 15-20 ppm B was found on the shoot tips of chickpeas.

Johansen *et al.* (2005) found that chickpea grown on residual soil moisture after rice harvest is a promising crop for the High Barind Tract (HBT), an uplifted, slightly undulating area in northwestern Bangladesh where the soils have an acid surface horizon (pH 4.5-5.5 at 0-10 cm). to determine which elements could be limiting to chickpea. A subtractive design was used in which the absence of sulphur (S), boron (B), zinc (Zn) or molybdenum (Mo) was compared to a complete nutrient control. Only Mo was found to be limiting, giving a grain yield response of 73%.

Nassar (2005) conducted an experiment to evaluate the effect of foliar application of boron, zinc, manganese or iron on the seed and pod yields of groundnut as well as on the nutrient, oil and protein content of seeds. Boron was applied at rates of 75, 150 and 300 mg $litre^{-1}$ as boric acid, whereas zinc, manganese and iron were applied at rates of 150, 300 and 600 mg $litre^{-1}$ in EDTA form. Foliar spraying with 600 mg Fe, 600 mg Zn, 300 mg Mn and 150 mg B $litre^{-1}$ gave the highest seed and pod yields and recorded the highest seed nutrient, oil and protein contents.

Janakiraman (2005) observed that the effects of Fe, Zn and B fertilizers on the performance of groundnut (cv. K-134) and the treatments consisted of $FeSO_4$ at 10 kg ha^{-1}, $ZnSO_4$ at 5 kg ha^{-1}, borax at 1.0 kg ha^{-1}. The highest mean pod yield (1,688 kg ha^{-1} 58% increase over the control), oil content (48.5%), seed germination (90%), seedling length (25.6 cm), vigour index (2,304) and field emergence (89%) were obtained with combined effect of $FeSO_4$ + $ZnSO_4$ + borax.

Niranjana (2005) conducted a field experiment to investigate the effect of B (1 g kg^{-1} seed), Zn (2 and 4 g kg^{-1} seed) and Mo (2 and 4 g kg^{-1} seed) as seed treatments on the growth and yield of groundnut cv. KRG-1 on Alfisol, which was deficient in Zn (0.46 mg kg^{-1}) and Mo (0.032 mg kg^{-1}). He observed that the micronutrients showed significant effect on yield, oil content and growth parameters. The Zn at 4 g + Mo at 2 g kg^{-1} seed treatment recorded the highest pod yield of 24.99 q ha^{-1} and growth parameters, total number of nodules (57.4) and their dry weight (100.2 mg $plant^{-1}$), number of effective nodules (27.8) and their dry weight (70 mg $plant^{-1}$) as well as root length (13.7 cm) and its dry weight (887 mg), over the control. The extent of increase was 24.1.

Singaravel *et al.* (2006) performed a pot trial experiment to determine the effects of the treatment on the growth and yield of groundnuts cv. VRI 2. He found that the recommended NPK in combination with 25 kg zinc sulphate ha^{-1}, 10 kg borax ha^{-1} and 10 t composted coir pith ha^{-1} gave the highest values for plant height, dry matter production during the flowering, post flowering and harvesting stage of the crop. Number of pods $plant^{-1}$, crop yield, and N, P, K, Zn and B uptake of the groundnuts also increased.

Rao *et al.* (2006) carried out a field study to evaluate the response of mustard to zinc (0.5% zinc sulphate), boron (1.0 ppm borax) and molybdenum (0.1% ammonium molybdate) application in addition to the recommended NPK and FYM alone. Combined application of Zn, B and Mo gave the highest values for most yield attributes, closely followed by B and Mo. However, integrated use of B and Mo recorded the highest 1000-seed weight and seed yield, accounting for 24% increase over the recommended NPK and 56% increase over FYM alone.

Shil *et al.* (2007) found that boron played major role in augmenting yield. The highest mean yield (1.23 t ha^{-1}) was obtained with 2 kg ha^{-1} B and 1 kg ha^{-1} Mo, which was 52% higher over control. The optimum economic dose of boron was found to be 1.76 kg ha^{-1}.

Halder *et al.* (2007) revealed that Zn either single or in combination with B made significant effect on ginger production in micronutrient deficient soils. However boron produced 46.7% higher yield in first year and 89.9% higher yield in second year over boron control (Bo) while zinc 52.3% over zinc control. Integration of Zn and B at the maximum level (boron 3 kg ha^{-1} and Mo 4.5 ha^{-1}) significantly produced the highest ginger yield (25.5 and 26.8 t ha^{-1}) and 125 and 143% yield increase over Boron-Zinc control in two successive years of study.

2.4. Effect of molybdenum

Molybdenum plays a vital role in legume production. It is an essential micronutrient for all plants, being necessary for the formation of nitrate reductase. However, in legumes, it plays an additional role in symbiotic nitrogen fixation. Effect of

Mo and B on different grain legumes have been reported by various researchers (Verma *et al*., 1988; Tiwari *et al*., 1989; Bhuiyan *et al*., 1996a, 1996b, etc.). But in the legumes, it plays an additional role in the symbiotic nitrogen fixation. But research studies on the influence of molybdenum on blackgram are limited. Response of molybdenum and boron on different grain legumes have been reported by some researchers (Brodrick and Giller, 1991; Giller and Wilson, 1991; Robson, 1993; Bhuiyan *et al*., 1998a; Bhuiyan *et al*., 1999b; Bhuiyan *et al*., 2005). However, some of the information on the effect of Mo regarding mungbean and other legumes on yield is cited here:

Zaman *et al*. (1996) conducted an experiment on mungbean and observed that application of Mo (1 kg ha^{-1}) produced 97% and 150% higher nodule number and nodule weight, respectively over control and application of 2 kg B ha^{-1} in combination with 2 kg Mo ha^{-1} produced 176% to 229% higher nodules $plant^{-1}$ over control and 1000-seed weight increased by 34.2% over control due to application of Mo (2 kg ha^{-1}).

Chaudhary and Das (1996) conducted an experiment in Uttar Pradesh, India and found that P, S and Mo application significantly increased the canopy, nodule count, yield of rainfed blackgram (*Vigna mungo*), yield of succeeding safflower and reduced splash loss and conserved more soil water. Water stable aggregates, infiltration rate, organic carbon, total N, available P, K, S and Mo in soil increased considerably after the harvest of blackgram but decreased after the harvest of succeeding safflower.

Geetha *et al*. (1996) reported that pod yields of mungbean were significantly increased by seed treatment with 8 gm Mo kg^{-1} seed.

Sfredo *et al*. (1997) found that Mo significantly increased seed yield up to 0.48 t ha^{-1}.

Experiment were conducted at Central Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur by Bhuiyan *et al*. (1997b) to determine the effect of rhizobial inoculum, B and Mo on the growth, yield and economic performance of chickpea. They noted that *Rhizobium* inoculum along with P, K, B and Mo gave significantly higher nodule number, nodule weight, shoot weight, stover yield and seed yield. *Rhizobium* inoculum in presence or absence of P, K, Mo or B also gave better performance in producing nodule number and nodule weight.

Dwivedi *et al.* (1997) observed that soybean was given 0-12 kg P_2O_5 and 0-1.5 kg Mo ha^{-1}. Seed yield increased with increasing P and Mo rates.

Hazra and Tripathi (1998) observed that Mo application at the rate of 1.5 kg ha^{-1} to berseem increased forage and seed yield in calcareous soil.

Rosolem and Caires (1998) reported that a high N-uptake had been observed in limed plots probably due to an increase in molybdenum availability.

Mandal *et al*. (1998) observed that dry matter yield of lentil was increased by the app1ication of lime, P and Mo. Plant dry matter pot^{-1} was the highest with 100% lime + 50 mg P + 1 mg Mo. Yield response to Mo application was highest, followed by lime and P.

Mishra and Masood (1998) carried out a field study at Kanpur, Uttar Pradesh, mungbeans (*Vigna radiata*) cv. K-851 were given 0, 25 or 50 kg P_2O_5 ha^{-1} and 0, 2, 4 or

6 g Mo kg^{-1} seed by seed pelleting. Seed yield was 422, 624 and 714 kg ha^{-1} with the P rates as listed, and 486, 583, 649 and 628 kg from seed pelleting with increasing Mo rates. Nodule numbers were not significantly affected by treatment. Yield component data are tabulated.

Solaiman (1999) found increased nitrogenase activity due to seed inoculation along with Mo application in soybean. The highest nitrogenase activity (82.44 p.mol C_2H_4 $plant^{-1}hr^{-1}$) was obtained by inoculant + 1.5 kg Mo ha^{-1}.

An experiment was conducted by Bhuiyan *et al*. (1999b) in the light soil of Tobacco Research Station, Rangpur, Bangladesh to study the effect of rhizobial inoculum and micronutrients (Mo and B) on the growth, yield and economic performance of chickpea. A significant increased over control in nodule number, nodule mass, shoot mass, stover yield and seed yield due to rhizobial inoculation in the presence of P, K, Mo and B. Molybdenum or B application with P, K and *Rhizobium* also resulted in higher nodule number, nodule mass, stover yield, and seed yield then the other treatments except PKMoB + Inoculum. *Rhizobium* without any chemical fertilizer also gave significantly higher nodule number and mass then the uninoculated control**.**

Bhattacharyya and Pal (2001) conducted a field experiment in West Bengal, India, during the pre-kharif season to study the effect *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 $plant^{-1}$ and plant height.

Kliemann *et al*. (2002) conducted an experiment on productivity of soybean as a function of the application of cobalt and molybdenum and they found that cobalt and molybdenum did not increase the yield of soybean.

Bhuiyan *et al*. (2005) conducted field experiments on Calcareous Brown Floodplain Soils of Jessore to study the effect of *Rhizobium* inoculation and micronutrients (Mo and B) on the growth, yield and economic performance of soybean. Inoculation with P, K and B fertilization produced the highest nodule number, nodule and shoot dry weight, stover and seed yield of the crop. Inoculation either with B or Mo increased nodule number, nodule weight and seed yield than combined application of B and Mo.

Johansen *et al*. (2005) found that chickpea grown on residual soil moisture after rice harvest is a promising crop for the High Barind Tract (HBT), an uplifted, slightly undulating area in northwestern Bangladesh where the soils have an acid surface horizon (pH 4.5-5.5 at 0-10 cm). To determine which elements could be limiting to chickpea. A subtractive design was used in which the absence of sulphur (S), boron (B), zinc (Zn) or molybdenum (Mo) was compared to a complete nutrient control. Only Mo was found to be limiting, giving a grain yield response of 73%.

Rao *et al*. (2006) carried out a field study to evaluate the response of mustard to zinc (0.5% zinc sulphate), boron (1.0 ppm borax) and molybdenum (0.1% ammonium molybdate) application in addition to the recommended NPK and FYM alone. Combined application of Zn, B and Mo gave the highest values for most yield attributes, closely followed by B and Mo. However, integrated use of B and Mo recorded the highest 1000-

seed weight and seed yield, accounting for 24% increase over the recommended NPK and 56% increase over FYM alone.

Shil *et al*. (2007) found that boron played major role in augmenting yield. The highest mean yield (1.23 t ha^{-1}) was obtained with 2 kg ha^{-1} B and 1 kg ha^{-1} Mo, which was 52% higher over control. The optimum economic dose of boron was found to be 1.76 kg ha^{-1}.

Srinivasan *et al.* (2007) conducted field experiments during two consecutive seasons (rabi and kharif-2005) of India on acid soil to study the response of mungbean variety VBN (Gg) 2 to different methods and levels of molybdenum (Mo) application on number of nodules, grain yield and protein content. Doses applied were: 0.5, 1.0 and 1.5 kg Mo ha^{-1} as sodium molybdate (Na< sub>2</ sub>MoO< sub>4</ sub>) for soil application, 1.75, 3.5 and 5.25 g sodium molybdate kg^{-1} seed for seed treatment and 5 mg Na< sub>2</ sub>MoO< sub>4</ sub>/L for foliar application. Pooled data revealed that foliar application of Mo significantly increased the grain yield by 12.2%. Soil application of 1.0 kg Mo ha^{-1} and seed treatment with 3.5 g Na< sub>2</ sub>MoO< sub>4</ sub>/kg seed also increased the grain yield by 8.2% and 9.3% over the yields at lower doses while it was at par with yields at higher doses of Mo. Protein content of grain, number of nodules plant^{-1} of mungbean also increased with increasing doses of Mo under all methods of application. Based on the present findings it can be concluded that Na< sub>2</ sub>MoO< sub>4</ sub> should be sprayed for obtaining higher seed yield of good quality mungbean under acid soil conditions.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the experimental aspect of the work. The materials used and methods followed in performing this experiment has been presented in this chapter. This offers brief description of soil, experimental design, chemical fertilizer, intercultural operations and statistical analysis.

3.1 Objective

The experiment was conducted to study the response of *Bradyrhizobium*, nitrogen, molybdenum and boron on the growth, nodulation, yield, nitrogen uptake and other yield contributing characters of mungbean.

3.2 Site and soil

This experiment was conducted in the Soil Science Field of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period from March to June 2009. The physical and chemical characteristics of the soil are presented in Table 3.1.

3.3 Collection of soil sample

Three composite soil samples were collected from a depth of 0-15 cm taking one from each block immediately before fertilizer application. Each composite sample was air dried and ground to pass through a 10 mesh sieve and stored in polythene bags for mechanical and chemical analysis.

3.4 Climate

The climatic condition of the experimental area was characterized by high temperature and heavy rainfall during *kharif* season (March-September) and low rainfall and moderately low temperature during *rabi* season (October-February).

Table 3.1. Physical and chemical characteristics of the soils

Characteristics	BARI farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	27.4
% Silt (0.02-0.002 mm)	33.3
%Clay (< 0.002 mm)	39.3
Textural class	Clay loam
Colour	Grey
Consistency	Sticky and mud when wet
pH (1:2.5 Soil-Water)	6.2
CEC (cmol kg^{-1})	18.4
Exchangeable K (cmol kg^{-1})	0.21
Exchangeable Ca (cmol kg^{-1})	10.42
Exchangeable Mg (cmol kg^{-1})	7.34
Exchangeable Na (cmol kg^{-1})	0.16
Organic C (%)	0.93
Total N (%)	0.07
Available P (mg kg^{-1})	12.1
Available S (mg kg^{-1})	14.1
Available Zn (mg kg^{-1})	1.79
Available Cu (mg kg^{-1})	0.66
Available Fe (mg kg^{-1})	16.8
Available Mn (mg kg^{-1})	3.1

3.5 Crop

Summer mungbean (*Vigna radiata* L.) variety BARI Mung-5 was used as the test crop. The seeds of mungbean were collected from Soil Science Division, BARI, Joydebpur, Gazipur. The seeds were healthy, pulpy, well matured and free from mixture of the other seeds, weed seeds and extraneous materials.

3.6 Variety

The salient characteristics of BARI Mung-5 are presented below:

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.

3.7 Land preparation

The land was opened on 01 March 2009. Ploughing and cross-ploughing were done with disc ploughs and harrows, and then well prepared by ploughing and cross-ploughing with the country plough followed by laddering uniformly. Weeds and stubbles were collected and removed. Plots were made by raising bunds. Land preparation was completed on 07 March 2009 to make it ready for sowing.

3.8 Fertilizer application

Gypsum and zinc sulphate were applied according to the Fertilizer Recommendation Guide (BARC, 2005). Gypsum @ 20 kg S ha^{-1} and zinc sulphate @ 5 kg ha^{-1} were applied as basal in all plots. Half amount of urea N and full doses of other fertilizers were applied one day before of seeds sowing. The rest half amount of urea was applied at 20 days after sowing (DAS). Nitrogen @ 50 kg N ha^{-1} as urea, phosphorus @ 22 kg P ha^{-1} as triple super phosphate, potash @ 42 kg K ha^{-1} as muriate of potash, boron @ 1 kg B ha^{-1} as boric acid and molybdenum @ 1 kg Mo ha^{-1} as sodium molybdate were applied as per treatments of the experiment as recommended levels.

3.9 Treatment under investigation

T_1: Control (Uninoculated)

T_2: PKMo ($P_{22}K_{42}Mo_1$ kg ha^{-1})

T_3: PKB ($P_{22}K_{42}B_1$ kg ha^{-1})

T_4: Inoculum (1.5 kg Inoculum ha^{-1})

T_5: N (N_{50} kg ha^{-1})

T_6: PKMo + Inoculum ($P_{22}K_{42}Mo_1$ kg ha^{-1} + 1.5 kg Inoculum ha^{-1})

T_7: PKB + Inoculum ($P_{22}K_{42}B_1$ kg ha^{-1} + 1.5 Inoculum kg ha^{-1})

T_8: NPKMo ($N_{50}P_{22}K_{42}Mo_1$ kg ha^{-1})

T_9: NPKB ($N_{50}P_{22}K_{42}B_1$ kg ha^{-1})

T_{10}: PKMoB ($P_{22}K_{42}Mo_1B_1$ kg ha^{-1})

T_{11}: PKMoB + Inoculum ($P_{22}K_{42}Mo_1B_1$ kg ha^{-1} + 1.5 kg Inoculum ha^{-1})

T_{12}: NPKMoB ($N_{50}P_{22}K_{42}Mo_1B_1$ kg ha^{-1})

3.10 Experimental design

The experiment was laid out in randomized complete block design with 4 replications. Each replication was represented by a block, which was distributed into 12 sub-plots. The treatments were randomly placed on the 12 sub-plots in each block. Thus, the total numbers of unit plots were 48 (12 treatments x 4 replications). The size of each unit plot was 4 m x 3 m and plot to plot distance was 1 m. Line to line distance was 30 cm and plant to plant distance was 10 cm.

3.11 Preparation of inoculants

3.11.1 Collection of strain

Strain (BARI RVr-401) was collected from Soil Microbiology Laboratory, BARI, Joydebpur, Gazipur.

3.11.2 Inoculation with peat media

From the ready broth, 20 mL were taken out with the sterile syringe and injected into polyethylene packet having sterile 50 g of peat in each packet. The inoculated packets were then incubated at 28^0C for two weeks and were ready for seed inoculation.

3.11.3 Viability count of *Bradyrhizobium*

Viability count of bradyrhizobia in the inoculant was made one day before injecting the peat following plate count method. The average number of bradyrhizobia was approximately above 10^8 cells g^{-1} in the inoculant. The initial bradyrhizobial population of the soil was below 10^3 cell g^{-1} of soil.

3.11.4 Seed coating with inoculant

Seeds of mungbean were taken in small polyethelene containing 42 g per packet. Out of 48 polyethylene packets 16 (T_4, T_6, T_7 and T_{11}) packets were made ready for mixing with 40% gum acacia @ 1 kg $seed^{-1}$. After gum coating the selected inoculum was mixed with the seeds (@ 50 g inoculum kg^{-1} seed) for each treatment by shaking the bag thoroughly. For each inoculant, separate polyethylene bag was used and mixed well with the seeds and care was taken to avoid contamination of the inoculants.

3.12 Sowing of seeds

Seeds were sown on the furrows on 08 March 2009 in the morning and the furrows were covered with soils soon after seeding. The line to line (furrow to furrow) distance was maintained at 30 cm with continuous distribution of seeds in the line.

3.13 Germination of seeds

Germination of seeds started from 3rd day of sowing. On the 4th day the percentage of germination was more than 80% and on the 5th day nearly all plants came out of the soil.

3.14 Intercultural operation

a) Weeding and thinning

Weeding and thinning were done on 20th day after sowing when the plants attained a height of about 8 to 10 cm. Plant to plant distance was maintained at 10 cm.

b) Drainage

During experimental period, once there was a heavy rainfall. At that time it was essential to drain the water from the field and the water was removed through the side drain.

c) General observation

The field was frequently observed to notice any change in plant characters as well as to check the attack of any pest and disease.

3.15 Plant sampling

Plant samples were collected from the field at 35 and 50 days after sowing and at harvest. From each plot, 10 plants randomly selected carefully uprooted with the help of a spade so that no nodules were left in the soil. The roots were then washed out carefully in water. The nodules from main root and branch root of each were collected and counted. The shoot portion of each plant was then separated from the root. The length of roots and shoots of each plant were recorded. The oven dried weights of roots, shoots and nodules were recorded.

3.16 Harvest

The crop was harvested at physiological maturity on first week of June 2009 after 80 days after sowing. Data from 10 plants on number of pods and seeds plant^{-1} and 1000-seed weight were recorded.

3.17 Threshing and processing

From each plot 10 plants were randomly selected and collected and then plants of each of 3 square meters were harvested and tied with rope separately. The harvested plant materials of 3 square meters were allowed to dry in the sun for 3 days. After drying, threshing and processing were done plot wise carefully. The processed seed and straw were again dried in the sun for 3 days. Seed and straw yields were recorded plot wise, which were then converted into yield in kg ha^{-1}.

3.18 Collection of plant (stover and seed)

About 50 g from each of dried seed and stover samples were collected from each plot. The sample were stored in polyethylene bags separately and tagged for chemical analysis.

3.19 Analysis of soil and plant

3.19.1 Soil analysis

The initial soil sample was analyzed (texture, pH, CEC, organic matter, total nitrogen, available phosphorous, sulphur and potassium) using the following methodology.

i) Mechanical analysis

Mechanical analysis of the soil samples was carried out by hydrometer method (Black, 1965) and the textural class was determined by using Marshall's Triangular Diagram (1947).

ii) Soil pH

Soil pH was determined using a glass electrode pH meter, soil water ratio being 1:2.5 as described by Jackson (1973).

iii) Organic carbon

Soil organic carbon was determined by wet oxidation method as outlined by Jackson (1973). Organic matter content was calculated by multiplying the percent organic carbon with the "Van Bemmelen Factor of 1.723.

iv) Total nitrogen

Total nitrogen in soil was determined by the Micro-Kjeldahl method. Digestion was made with H_2O_2, concentrated H_2SO_4 and catalyst mixture (K_2SO_4:$CuSO_4$, $5H_2O$:Se

= 10:1:0.1). Nitrogen in the digest was estimated by distilling with 40% NaOH followed by titration of the distillate trapped in H_2BO_3 with 0.01 N H_2SO_4 (Page *et al.*, 1989).

v) Available phosphorus

Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ at pH 8.5. The phosphorus in the extract was then determined by developing the blue colour by $SnCl_2$ reduction of phosphomolybdate complex and measuring the colour colorimetrically at 660 nm (Olsen *et al*., 1982).

vi) Exchangeable potassium

Exchangeable potassium of the soil was determined from the 1N NH_4OAc extract of the soil using flame photometer as described by Page *et al*. (1989).

vii) Cation exchange capacity (CEC)

Cation exchange capacity of soil was determined by sodium saturation method as outlined by Page *et al*. (1989). The soil samples were saturated with 1N NaOAc solution followed by replacing the Na^+ from the saturated samples by 1N NH_4OAc at pH 7.0. The amount of Na^+ in the extract was then determined by flame photometer and putting the readings to the standard curve for Na^+. The results were expressed as me 100 g^{-1} soil.

3.19.2 Plant analysis (seed and stover)

The whole plant (seed and stover) samples of mungbean of all treatments were powdered to 60 mesh separately using a Wiley mill and stored in a desiccators for chemical analysis. For determination of nitrogen 0.1 g of oven dried ground sample was taken into a 100 ml digestion flask and then 1.1 g of catalyst mixture (K_2SO_4 : $CuSO_4$,

$5H_2O$: Se = 100:10.01) 2 ml 30% H_2O_2 and 5 ml concentrated H_2SO_4 were added. The flask was swirled and allowed to stand for about 10 minutes then the flask was heated until the conbtents became colorless. Digestion was carried out in digestion flasks at 380^0C for 1.5 hour. After cooling the digest was transferred into a 100 mL volumetric flask and the volume was made up to the mark with distilled water. The distillate was titrated against 0.01 N H_2SO_4. A blank reagent was prepared by the same process. These digests were used to determine total N.

3.20 Data were recorded

a) Before harvest (35 and 50 days after sowing)

i) Total nodule plant^{-1}
ii) Dry weight of nodules (mg plant^{-1})
iii) Root weight (g plant^{-1})
iv) Shoot weight (g plant^{-1})
v) Root length (cm)
vi) Shoot length (cm)

b) After harvest

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

ix) N uptake by seed (kg ha^{-1})

x) N content in stover

xi) N uptake by stover (kg ha^{-1})

xii) P content in seed

xiv) Protein yield (kg ha^{-1})

3.21 Statistical analysis

Data of all the above characters have been analyzed statistically. Statistical analysis was done following RCBD design of the IRRISTAT package Programme. Duncan’s Multiple Range Test was done as and when necessary.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out during March 2009 in the field of Soil Science Division of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur with a view to observe the response of *Bradyrhizobium*, nitrogen, molybdenum and boron on the growth, nodulation, yield, nitrogen uptake and other yield contributing characters of mungbean. The results are presented and discussed in this chapter.

4.1 Effect of nodulation

4.1.1 Nodule on main root plant^{-1}

Nodulation is an important factor for biological nitrogen fixation by *Bradyrhizobium* inoculants in mungbean. Nodule is formed on roots of mungbean plants through infection by *Bradyrhizobium* bacterium and it grows inside the nodules, and can fix atmospheric nitrogen. The results on the production of nodule on main root plant^{-1} under different treatments were presented in (Figure 4.1 and Appendix 1). The highest nodules on main root plant^{-1} (4.80 and 14.19) were recorded in PKMoB + Inoculum at 35 and 50 DAS, respectively. All the treatments showed significant result in forming nodules on main root than control treatment at 35 days after sowing. The highest nodules on main root (14.19 plant^{-1}) were produced at 50 days after sowing (DAS) in PKMoB + Inoculums treatment which was significantly higher over all other treatment combination. It also indicates that nodule formation on main root increased with the passage of time. At 35 and 50 DAS, the highest numbers of main root nodules were observed in PKMoB + Inoculum treatment which was identical with PKMo + Inoculums treatment at 35

DAS and the lowest nodules at 35 and 50 days were found in control and T_5 treatment respectively. All the fertilizer treatments receiving inoculum, inoculum plus molybdenum, inoculum plus boron and inoculum plus molybdenum plus boron showed tatistically significant response in nodule formation on main root over control. 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).

4.1.2 Nodule on branch root plant^{-1}

Higher number of nodules (3.29 plant^{-1} at 35 DAS and 7.85 plant^{-1} at 50 DAS) on branch root was recorded in PKMoB + Inoculum which were significantly higher over all other treatment combinations except T_7 at 50 days (Fig. 4.2 and App. 1). Lower number of nodule on branch root plant^{-1} was recorded in each case than the main root in both the DAS. Among the treatments, PKMo + *Bradyrhizobium* and PKB + *Bradyrhizobium* showed similar performances in nodule formation on the branch root at 35 DAS (Appendix 1). From the treatment PKMo and PKB showed similar performances in nodule formation on the branch root at 50 DAS. Nitrogen has no significant impact on nodule formation on branch root at 50 DAS. Potdukhe and Guldekar (2003) reported that the highest nodule numbers 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).

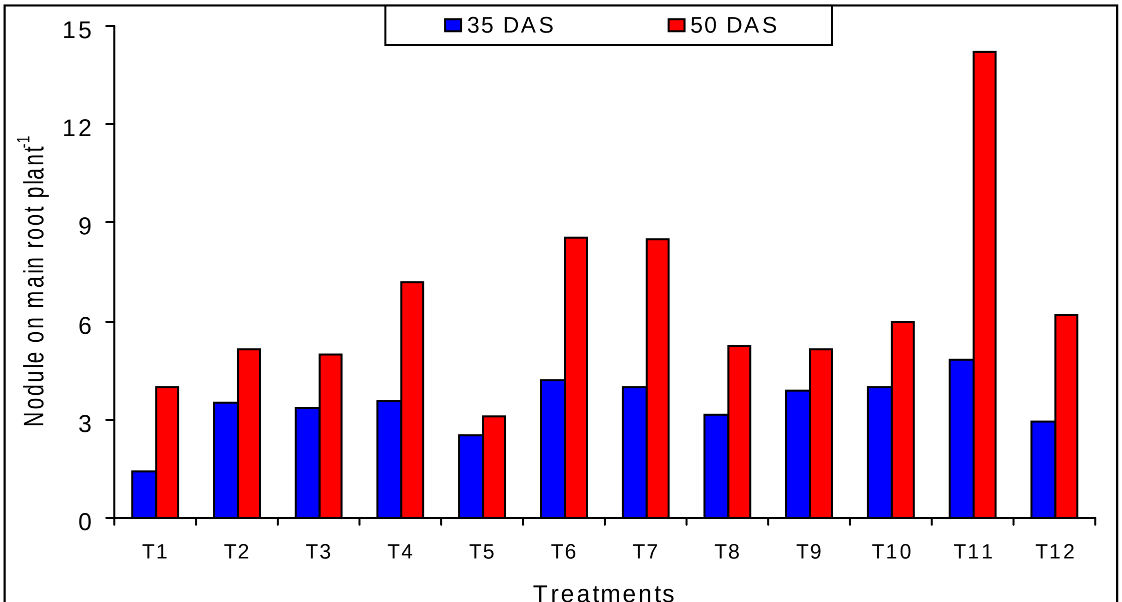
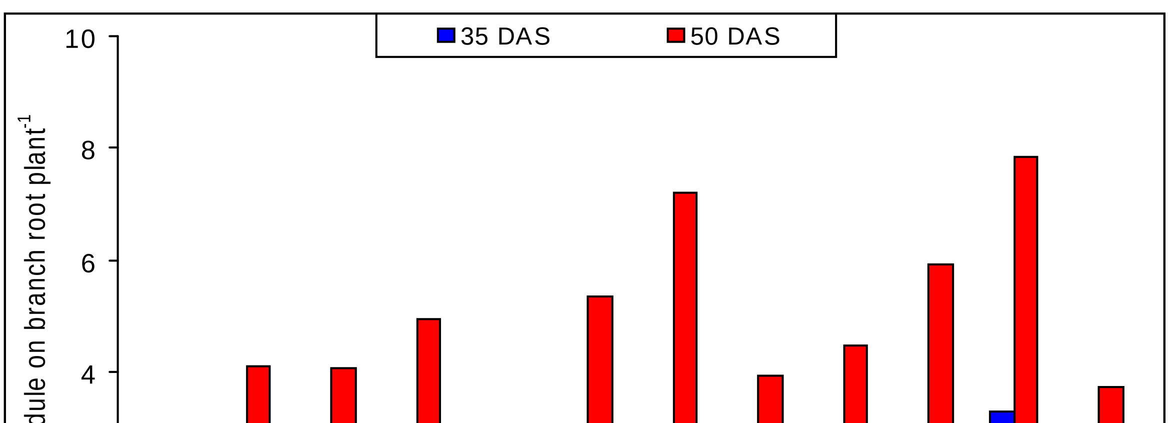


Fig. 4.1. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on main root nodule in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB



4.1.3 Total nodule number plant^{-1}

The highest total number of nodules (8.09 at 35 DAS and 22.04 at 50 DAS) was recorded in the treatment, PKMoB + Inoculum (Fig. 4.3 and App. 1). Among the treatments, *Bradyrhizobium* inoculated plants produced significantly higher number of nodules plant^{-1} than the non-inoculated control plants or N treated plants which indicate production of nodules plant^{-1} increased with the application of *Bradyrhizobium* inoculation. The highest number of total nodules (8.09 at 35 DAS and 22.04 at 50 DAS) was noted in PKMoB + Inoculum treatment which was significantly higher over all other treatments combination. The second highest number of total nodules was observed in PKMo + Inoculum treatment at 35 DAS and PKB + Inoculum at 50 DAS, the lowest number of total nodules was noted in control at 35 days and at 50 DAS in T_5 treatment. This might be due to synergistic effect of micronutrients with *Bradyrhizobium* inoculant for nodule formation. Among the treatments, *Bradyrhizobium* inoculant produced higher number of nodules plant^{-1} than did the micronutrients (Mo and B). *Bradyrhizobium* in combination with micronutrient molybdenum or boron showed better performance in nodule formation than NPKMo or NPKB at both the DAS. Nitrogen showed very low effect on nodule formation. 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).

4.1.4 Nodule weight

The highest total nodule dry weight (8.00 mg plant^{-1} at 35 DAS and 65.12 mg plant^{-1} at 50 DAS) was recorded in T_{11} (PKMoB + *Bradyrhizobium*) treatment which was significantly different from all other treatments (Fig. 4.4 and App. 1). Nodule weight increases with the passage of time. Among the treatments, only *Bradyrhizobium* produced higher nodule weight than nitrogen at both the dates of nodule collection. Among the treatment, PKMo + Inoculum and PKB + Inoculum showed statistically similar performance in nodule weight both at 35 and 50 DAS. The treatment PKMo and PKB showed similar performance in nodule weight at both DAS. The plant which did not take any chemical fertilizers or inoculants recorded the lowest nodule weight at 50 DAS. Nitrogen showed very low effect on nodule weight. When molybdenum and boron was applied with *Bradyrhizobium* it showed better result on nodule dry weight than Mo + Inoculum and B + Inoculum. 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) 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.

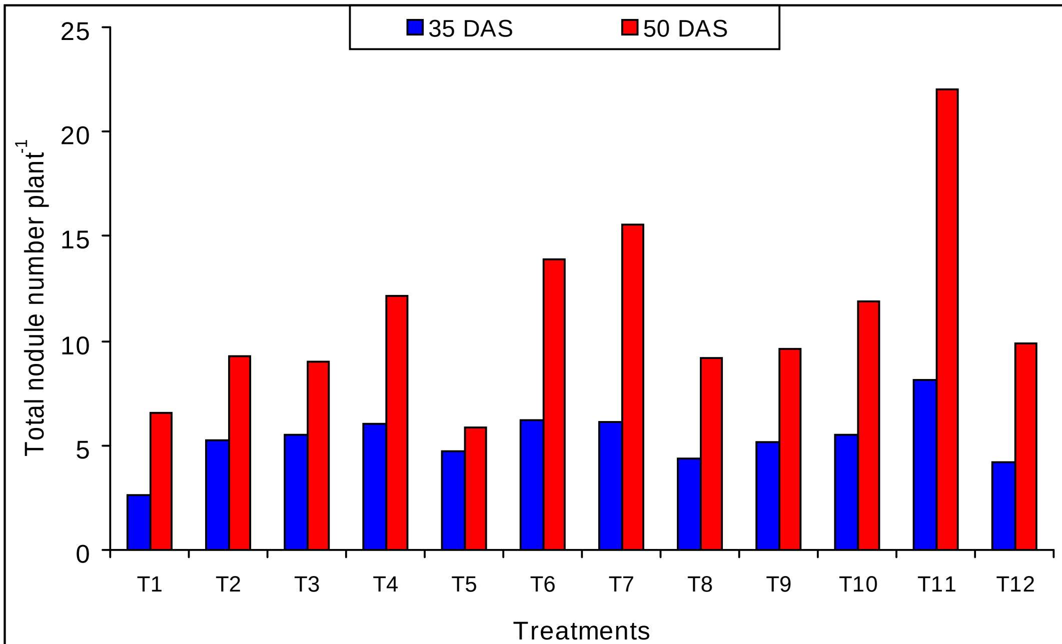
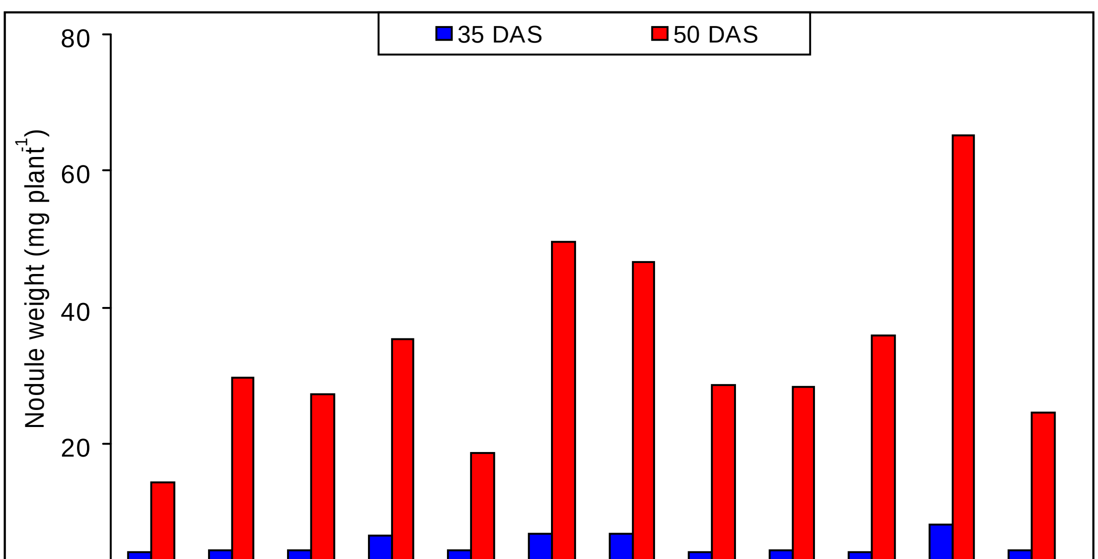


Fig. 4.3. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on total nodule number in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB



4.2 Root and shoot dry weight

4.2.1 Root weight

Chemical or biofertilizer have significant effect on root weight at 35 DAS at 50 DAS, they gave identical result (Fig. 4.5 and App. 2). The highest root weight (0.11 g $plant^{-1}$) at 35 DAS was obtained in T_{12}, while the non-inoculated and non-fertilized control (T_1) gave the lowest root weight (0.06 g $plant^{-1}$). Among the treatments, PKMo and PKB showed identical root weight at 50 DAS, PKMo + Inoculums and PKB + inoculums also showed similar performance in nodule weight and NPKMo and NPKB showed similar performance in nodule weight. Root weight increases with increasing of time. All the treatment gave identical root weight except Control, PKMo and PKB at 50 DAS. The results are in agreement with the findings of Singh and Singh (2004). 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.

4.2.2 Shoot weight

The highest shoot weight 1.21 g $plant^{-1}$ at 35 DAS was observed in PKMoB + *Bradyrhizobium* and 2.12 g $plant^{-1}$ at 50 DAS in NPKMoB, and the lowest (0.85 g $plant^{-1}$ at 35 DAS and 1.50 g $plant^{-1}$ at 50 DAS) was obtained in T_1 (Control) (Fig. 4.6 and App. 2). There was no significant difference among the different treatments in shoot weight at 35 and 50 DAS. 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 reported that inoculation significantly influenced dry matter accumulation in the shoot. Singh and Singh (2004) found that dry matter yield increased with the application of phosphorus. 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) reported that *Rhizobium* seed treatment produced markedly higher dry matter. 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}. Sharma and Upadhyay (2003) reported that seed inoculation with *Bradyrhizobium* sp strains showed maximum values of dry matter production. Delic *et al*. (2009) reported that inoculation plants produced significantly higher shoot dry weight (SDW).

4.3 Root and shoot length

4.3.1 Root length

The highest root length (5.54 cm at 35 DAS and 7.30 cm at 50 DAS) was obtained from PKMoB + Inoculum and NPKMoB, respectively while the lowest root lengths were noted in control (Fig. 4.7 and App. 3). The second highest root length at 35 and 50 DAS were found in T_{12} (NPKMoB) and T_{11} (PKMoB + Inoculum), respectively. The lowest root lengths were obtained in T_1 at both the DAS. It indicates that combination application of B and Mo and *Bradyrhizobium* or N, B and Mo has a good influence on root growth of mungbean plant. At 50 DAS, root length was significant. The above results confirmed the results of 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 lenth of the crop increased significantly due to inoculation of the seed with *Rhizobium* strains.

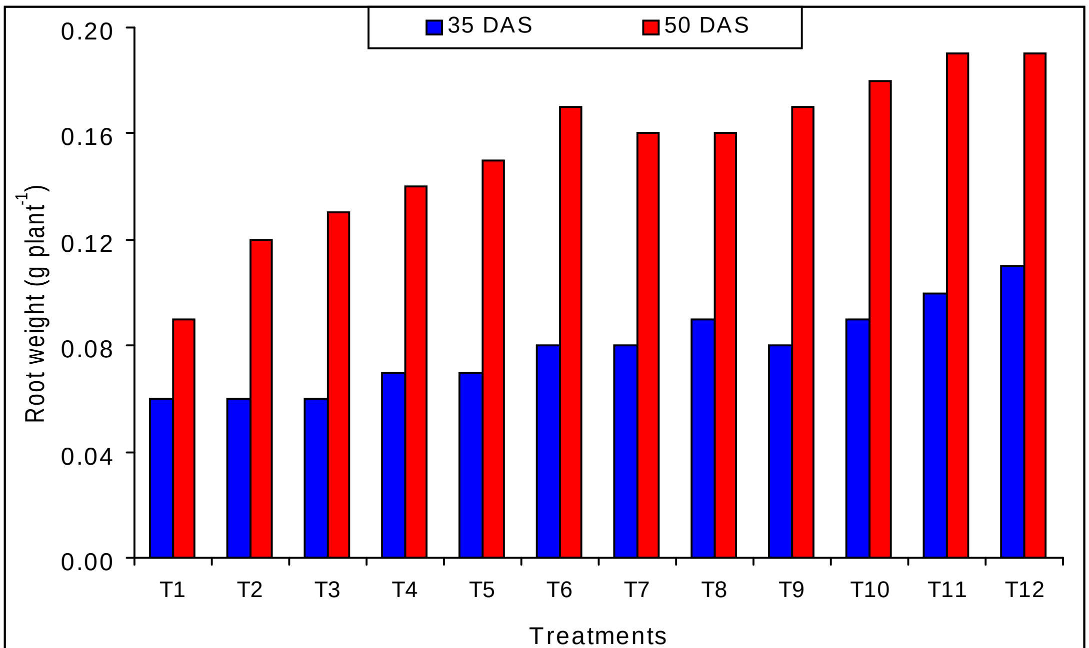
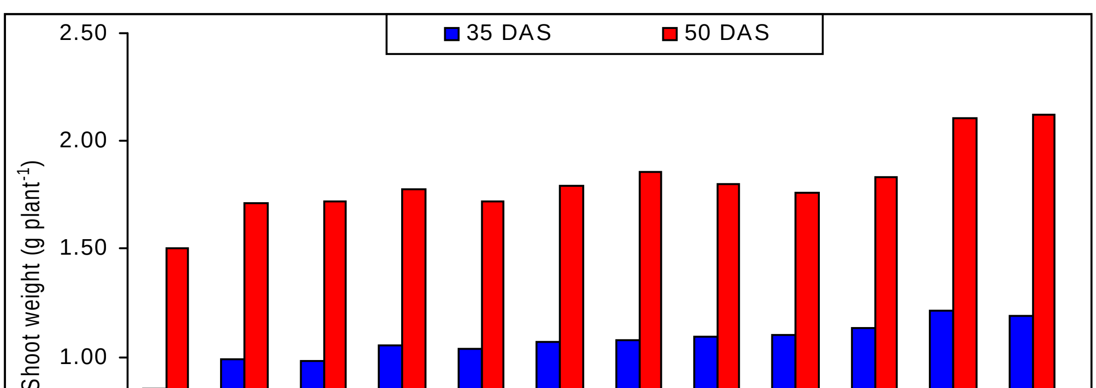


Fig. 4.5. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on root weight in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB



4.3.2 Shoot length

Bradyrhizobium inoculant alone or in combination with PKMoB had no effect on shoot length both at 35 and 50 DAS though the highest shoot length (30.20 cm at 35 DAS and 40.70 at 50 DAS) was obtained from T_{12} (NPKMoB) which was statistically similar with all the treatments (Fig. 4.8 and App. 3). The lowest shoot length was obtained from T_1 (control). At 50 DAS, the highest shoot length (40.70 cm) was found in T_{12} (NPKMoB) which was indicated to all other treatments. Mahmud *et al*. (1997) reported that plant height was significantly increased with increasing phosphorus application. Similar results were observed by Maqsood *et al*. (2001). 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.

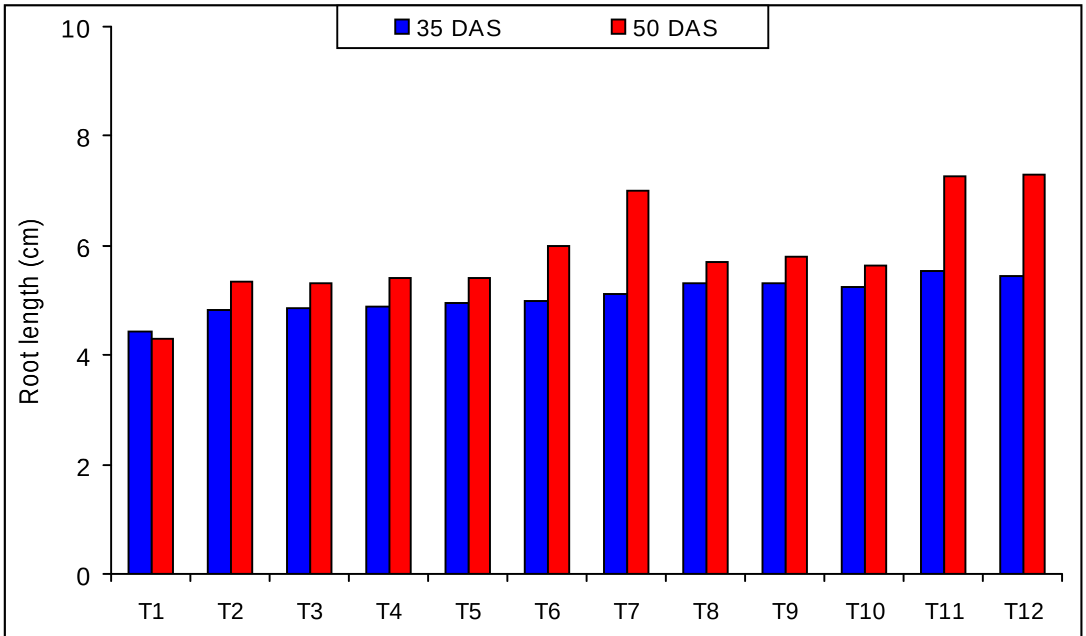


Fig. 4.7. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on root length in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB

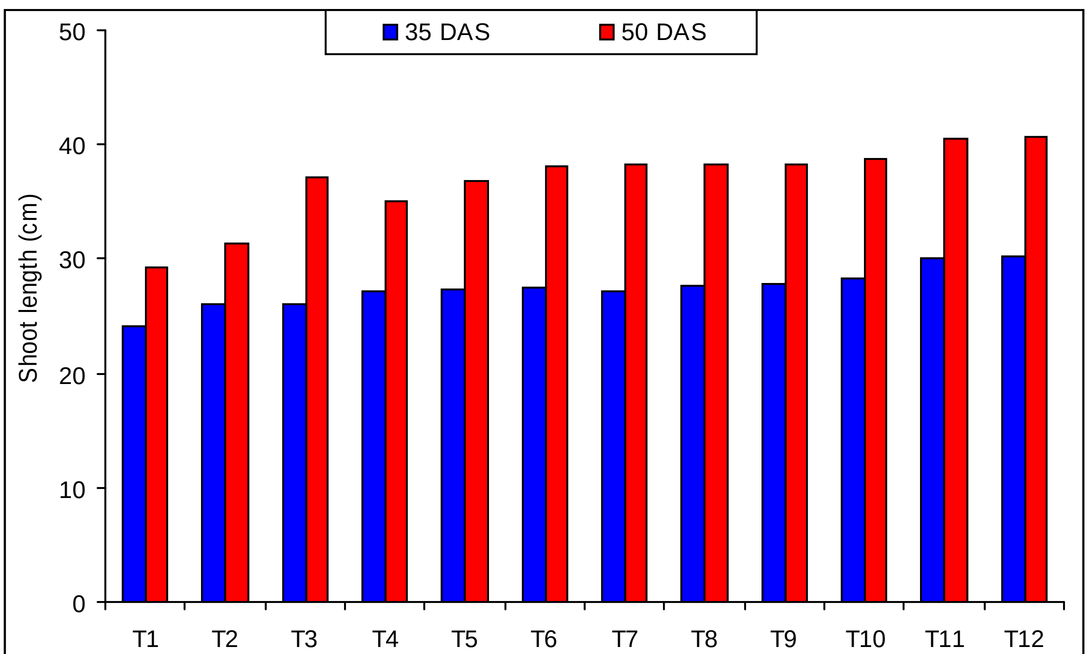


Fig. 4.8. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on shoot length in mungbean

4.4 Growth and yield attributes

4.4.1 Plant height

The highest plant height (43.2 cm) was obtained from T_{11} (PKMoB + Inoculum) which were statistically identical to all other treatments but significantly higher than T_1 (control) (Table 4.1). Among the nutrient elements, NPKMoB gave the second highest plant height. 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*. Asraf *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}.

4.4.2 Pod length

All the fertilizer treatments showed no significant response in terms of pod length. The highest pod length (8.01 cm) was recorded in treatment T_{12} (NPKMoB) that was identical to all other treatment combinations and the lowest pod length of 7.00 cm was recorded in control plot (Table 4.1). Shil *et al.* (2007) reported that the highest pod length was the highest in full doses of fertilizers while control plants recorded the lowest pod length. Srinivas and Shaik (2002) studied that the interactions effects between N and P were not significant for pod length. Hossain and Solaiman (2004) also reported that pod length increased significantly due to inoculation of the seeds with *Rhizobium* strains.

Table 4.1. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on yield attributes of mungbean

Treatment	Plant height (cm)	Pod length (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	1000-seed weight (g)
T_1: Control	30.1b	7.00	15.1	9.06	36.5
T_2: PKMo	39.2ab	7.32	16.9	9.92	37.0
T_3: PKB	39.7a	7.35	15.1	9.90	36.8
T_4: Inoculum	36.3ab	7.50	18.1	9.99	37.0
T_5: N	37.0ab	7.51	17.5	10.10	37.1
T_6: PKMo+Inoculum	41.9a	7.61	18.9	10.39	36.7
T_7: PKB+Inoculum	41.7a	7.60	18.8	10.40	37.3
T_8: NPKMo	40.7a	7.61	18.9	10.41	37.3
T_9: NPKB	40.3a	7.63	18.7	12.38	37.3
T_{10}: PKMoB	40.0a	7.72	19.3	10.35	37.0
T_{11}: PKMoB+Inoculum	43.2a	8.00	22.6	15.21	37.7
T_{12}: NPKMoB	42.4a	8.01	20.9	14.40	37.7
Level of significance	*	NS	NS	NS	NS
LSD (0.05)	8.58	-	-	-	-
CV (%)	15.2	19.5	16.6	15.9	6.8

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT
NS = Not significant

4.4.3 Pods $plant^{-1}$

Number of pods $plant^{-1}$ in different treatments showed no significant variation. The highest pod number (22.6) was obtained from T_{11} (PKMoB + Inoculum) and the lowest in control T_1 (15.1) (Table 4.1). Between two micronutrient, Mo showed better performance (16.9 pods $plant^{-1}$) than did B but combined application of each of the micronutrients Mo and B with inoculums (*Bradyrhizobium*) gave better pods number (18.9 and 18.8, respectively) rather than individual application of each of micronutrients. 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 $plant^{-1}$ (29.0, 56.0, 63.9 and 32.6, respectively). Bhuiyan *et al.* (2008a) reported that *Bradyrhizobium* inoculation in mungbean plots also significantly increased pods $plant^{-1}$.

4.4.4 Seeds pod^{-1}

No significant response was observed due to application of different fertilizers in seeds pod^{-1}. The highest seeds pod^{-1} (15.21) was obtained from T_{11} (PKMoB + Inoculum) and the lowest seeds pod^{-1} (9.06) was obtained from T_1 (control) (Table 4.1). 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}.

4.4.5 1000-seed weight

There was no significant difference among the different treatments in 1000-seed weight. The highest 1000-seed weight of 37.7 was obtained from T_{11} (PKMoB + Inoculum) + T_{12} (NPKMoB) and the lowest 1000-seed weight of 36.5 g was obtained from control treatment (T_1). Srinivas and Shaik (2002) reported that 1000-seed weight generally increased due to rhizobial inoculation. Shil *et al.* (2007) reported that 1000-seed weight was the highest in full doses of fertilizers while control plants recorded the lowest in 1000-seed weight. Bhuiyan *et al.* (2008a) opined that *Bradyrhizobium* inoculation also significantly increased 1000-seed weight. Hossain and Solaiman (2004) reported that 1000-seed weight increased significantly due to inoculation of the seeds with *Rhizobium* strains. Among the mungbean cultivars, Malik *et al*. (2002) studied that seed inoculation with *Rhizobium* application resulted in the highest 1000-seed weight (42.3 g).

4.5 Yield characteristics

4.5.1 Seed yield

The highest seed yield (1.39 t ha^{-1}) was obtained from T_{11} (PKMoB + Inoculum) and the lowest seed weight (0.71 t ha^{-1}) was obtained from T_1 (control) (Table 4.2). The second highest seed weight (1.38 t ha^{-1}) was found in T_{12} (NPKMoB). Application of PKMo + Inoculum showed better performance than NPKMo for seed weight. On the other hand, PKB + Inoculum also showed higher seed yield than NPKB. Only Inoculum gave better seed yield than application of only N. Same trend was observed in T_{11} and T_{12} where *Bradyrhizobium* inoculant in combination with PKMoB performed better than NPKMoB. It indicates that instead of applying urea N, *Bradyrhizobium* inoculant gave better result. Kumari and Nair (2003) found that yields were more in blackgram and greengram inoculated with *Bradyrhizobium*. Srinivas and Shaik (2002) studied that the interaction effects between N and P were not significant for seed yield. Tomar *et al*. (2003) observed that P application and inoculation treatments increased grain yields in blackgram. 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}). Malik *et al.* (2003) observed that fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted in the maximum seed yield (1,113 kg ha^{-1}). Asraf *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.

4.5.2 Stover yield

Different fertilizers had significant effect on stover yield. The highest stover weight of 2.25 t ha^{-1} was obtained from T_{11} (PKMoB + Inoculum) which is identical to all other treatments except Control, PKB and Inoculum, and the lowest (1.10 t ha^{-1}) was obtained from T_1 (control) (Table 4.2). Among the treatments, T_2, T_5, T_7, T_8 and T_{10} showed statistically similar performance. Bhuiyan and Mian (2007) reported that application of *Bradyrhizobium* inoculant produced significant effect on stover weight. 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.

Table 4.2 Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on yield of mungbean

Treatment	Stover	Seed	Seed yield increase

	yield (t ha^{-1})	yield (t ha^{-1})	over control (%)
T_1: Control	1.10d	0.71c	-
T_2: PKMo	1.69abc	1.17ab	64.8
T_3: PKB	1.67bc	1.15ab	62.0
T_4: Inoculum	1.47cd	1.10ab	54.9
T_5: N	1.78abc	0.97bc	36.6
T_6: PKMo+Inoculum	1.96abc	1.35ab	90.1
T_7: PKB+Inoculum	1.88abc	1.29ab	81.7
T_8: NPKMo	1.95abc	1.25ab	76.1
T_9: NPKB	2.22ab	1.27ab	78.9
T_{10}: PKMoB	1.81abc	1.23ab	73.2
T_{11}: PKMoB+Inoculum	2.25a	1.39a	95.8
T_{12}: NPKMoB	2.23ab	1.38a	94.4
Level of significance	**	**	-
LSD (0.05)	0.49	0.33	-
CV (%)	18.6	19.3	-

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT

4.6. Nitrogen and protein content

4.6.1 Nitrogen content in seed

There was no significant variation in all the treatments on nitrogen content in seed. The highest nitrogen content in seed 3.43% was obtained from T_{12} (NPKMoB) which was significantly different from control (Table 4.3). Combined application of micronutrient (Mo and B) with *Bradyrhizobium* produce higher N content in seed than individual application of both the micronutrient. Chatterjee and Bhattacharjee (2002) reported that 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. 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%).

4.6.2 Nitrogen content in stover

All the treatments showed positive response in N content in stover as compared to control. The highest N content (1.57%) was obtained from T_{11} (PKMoB + Inoculum) and the lowest N content (1.47%) in stover was obtained from T_1 (control) (Table 4.3). 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.

Table 4.3 Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on nitrogen and protein content in seed and stover of mungbean

Treatment	N content in seed (%)	N content in stover (%)	Protein content in seed (%)	Protein content in stover (%)
T_1: Control	3.19	1.47	19.93	9.22
T_2: PKMo	3.24	1.51	20.25	9.44
T_3: PKB	3.25	1.50	20.31	9.30
T_4: Inoculum	3.21	1.54	20.07	9.63
T_5: N	3.33	1.53	20.81	9.57
T_6: PKMo+Inoculum	3.34	1.56	20.88	9.75
T_7: PKB+Inoculum	3.35	1.55	20.94	9.70
T_8: NPKMo	3.35	1.51	20.94	9.44
T_9: NPKB	3.24	1.52	20.25	9.50
T_{10}: PKMoB	3.28	1.44	20.50	8.97
T_{11}: PKMoB+Inoculum	3.42	1.57	21.35	8.92
T_{12}: NPKMoB	3.43	1.56	21.46	9.75
Level of significance	NS	NS	NS	NS
LSD (0.05)	-	-	-	-
CV (%)	8.00	8.7	8.00	8.8

NS = Not significant

4.6.3 Protein content in seed

Protein content in seed showed positive result by the different treatments with compare to control. The highest protein content (21.46%) in seed were obtained from T_{12} and the lowest from control plot (19.9%) (Table 4.3). Delic *et al*. (2009) noted that inoculated plants produced significantly higher protein yield in seeds in respect to untreated control. Malik *et al.* (2003) observed that 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}. Srinivasan *et al.* (2007) noted that protein content in grain of mungbean also increased with increasing doses of Mo under all methods of application

4.6.4 Protein content in stover

Protein content in stover was increased due to the combined application of PKMoB + Inoculum (Table 4.3). The highest protein content in stover (9.75%) was recorded at T_{12} (NPKMoB). The lowest protein content in stover (9.22%) was recorded at non-inoculated and non-fertilized control. Delic *et al*. (2009) estimated that inoculation plants produced significantly higher total N content as well as protein yield in respect to untreated control.

4.7 Nitrogen uptake and protein yield

4.7.1 Nitrogen uptake by seed

Nitrogen uptake by seed of mungbean was significantly increased due to combined application of fertilizers (Fig. 4.9 and App. 4). The highest N uptake (47.66 kg ha^{-1}) was recorded at T_{11} (PKMoB + Inoculum) which was identical to T_{12} treatment. The lowest N uptake in seed (22.77 kg ha^{-1}) was recorded in control. Rosolem and Caires (1998) reported that a high N-uptake had been observed in limed plots probably due to an increase in molybdenum availability. 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. Srinivasan *et al.* (2007) observed that protein content of grain also increased with increasing doses of Mo under all methods of application. 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) found that inoculation with NK-4 into blackgram resulted in the highest nitrogen uptake.

4.7.2 Nitrogen uptake by stover

Application of fertilizers and *Bradyrhizobium* inoculants showed significant variation in N uptake by stover of mungbean (Fig. 4.10 and App. 4). The highest amount of N uptake in stover (35.29 kg ha^{-1}) was recorded in T_{11} (PKMoB + Inoculum) which was which was identical with T_{12} (NPKMoB). The lowest N uptake in stover (16.35 kg ha^{-1}) was recorded in control. 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.

4.7.3 Protein yield by seed

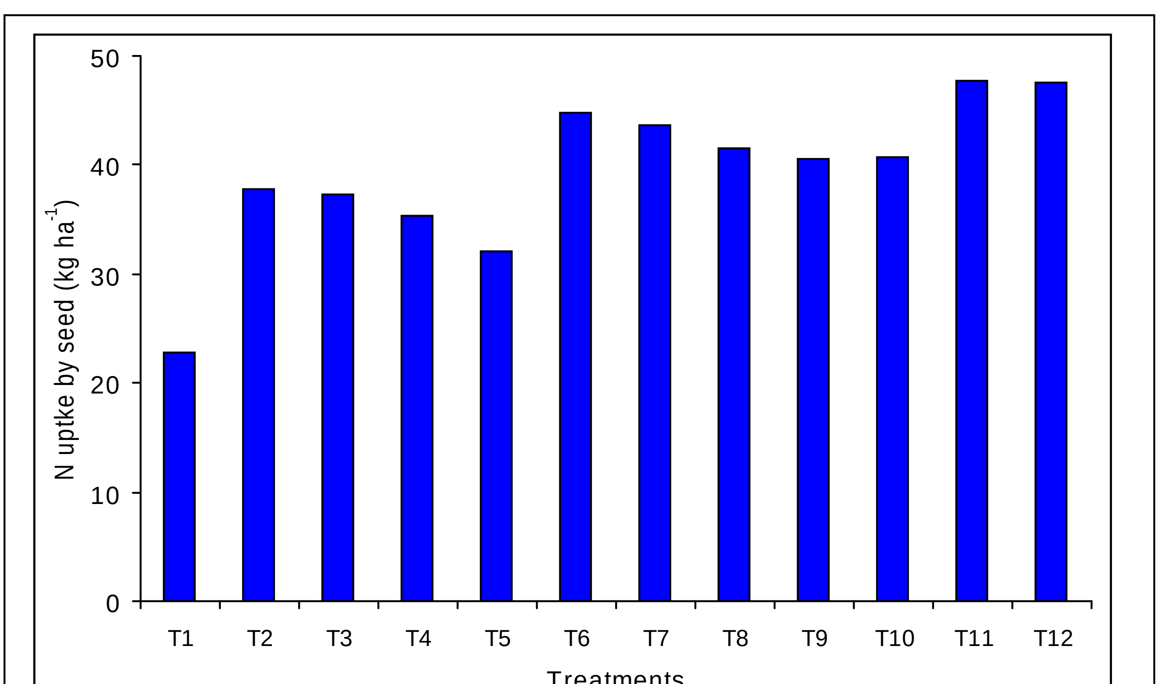
Chemical fertilizers and *Bradyrhizobium* had significant effect on protein yield by seed (Fig. 4.11 and App. 4). The highest protein yield by seed was recorded at T_{11} was (297 kg ha^{-1}) which was identical to the treatment at T_{12} and the lowest protein yield by seed (142 kg ha^{-1}) was noted in control. Bhuiyan *et al*. (2007b) found that inoculation significantly increased protein yield by seed.

4.7.4 Protein yield by stover

The highest amount of protein yield by stover (220 kg ha^{-1}) was noted in T_{11} (PKMoB + Inoculum) which was identical to T_{12} (Fig. 4.12 and App. 4). The lowest protein yield by stover (102 kg ha^{-1}) was recorded in control. Bhuiyan *et al.* (2007b) found that inoculation significantly increased the protein yield in blackgram and mungbean

4.7.5. Total nitrogen uptake by seed and stover

Application of fertilizers and *Bradyrhizobium* inoculants showed significant variation in total N uptake by seed and stover of mungbean (Fig. 4.13 and App. 4). The highest amount of N uptake in seed and stover (82.68 kg ha^{-1}) was recorded in T_{12} (NPKMoB) which was identical with T_{11} (PKMoB + Inoculum). The lowest total N uptake in seed and stover (39.12 kg ha^{-1}) was recorded in control.



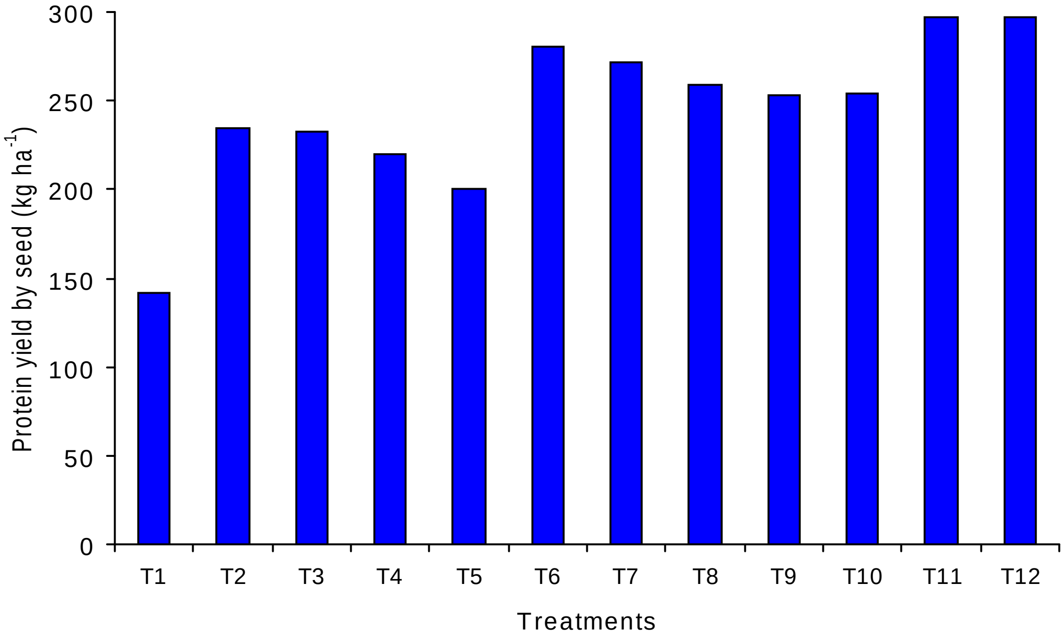


Fig. 4.11. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on protein yield by seed in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB

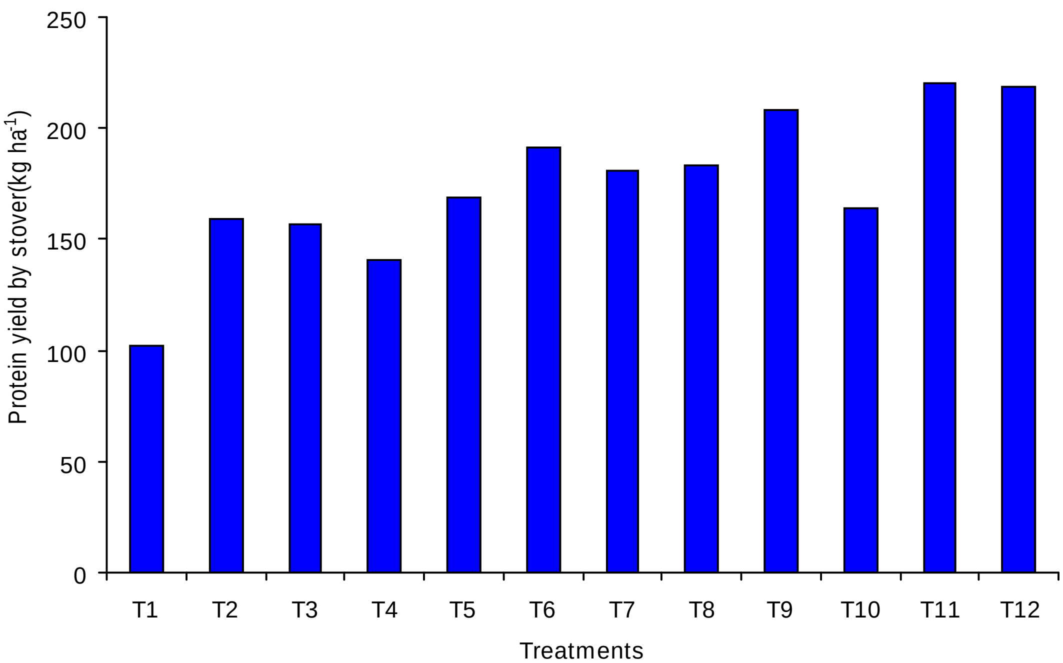


Fig. 4.12. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on protein yield by stover in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB

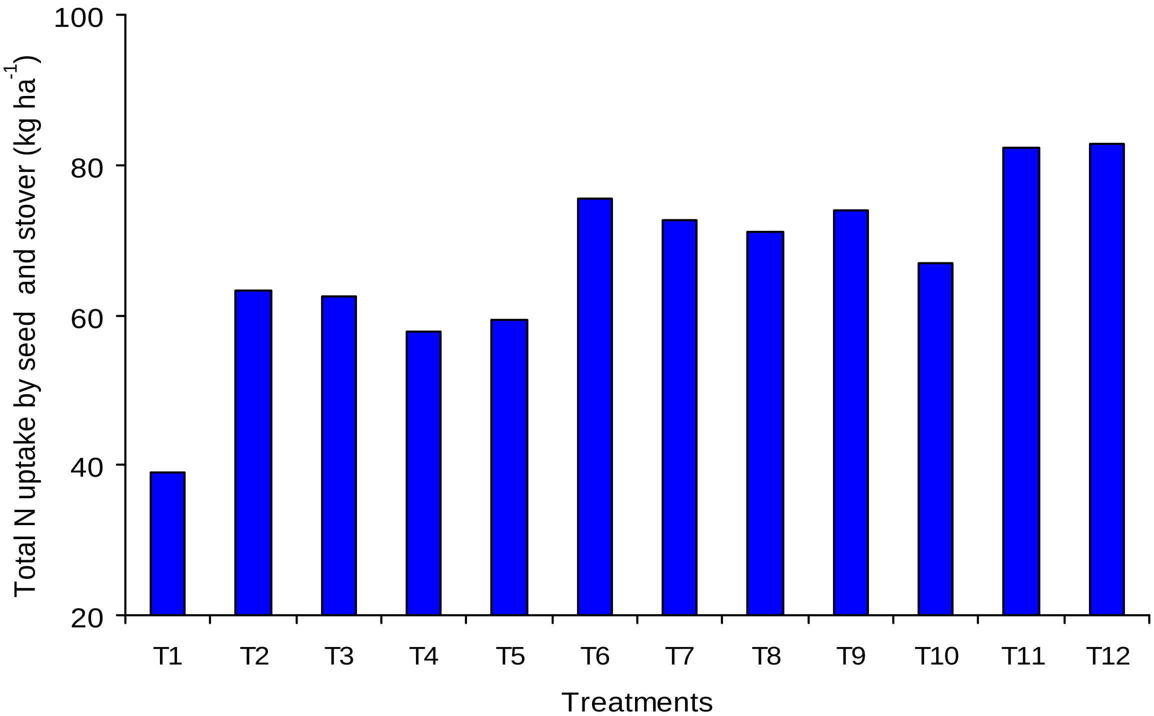


Fig. 4.13. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on total N uptake by seed and sotver in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB

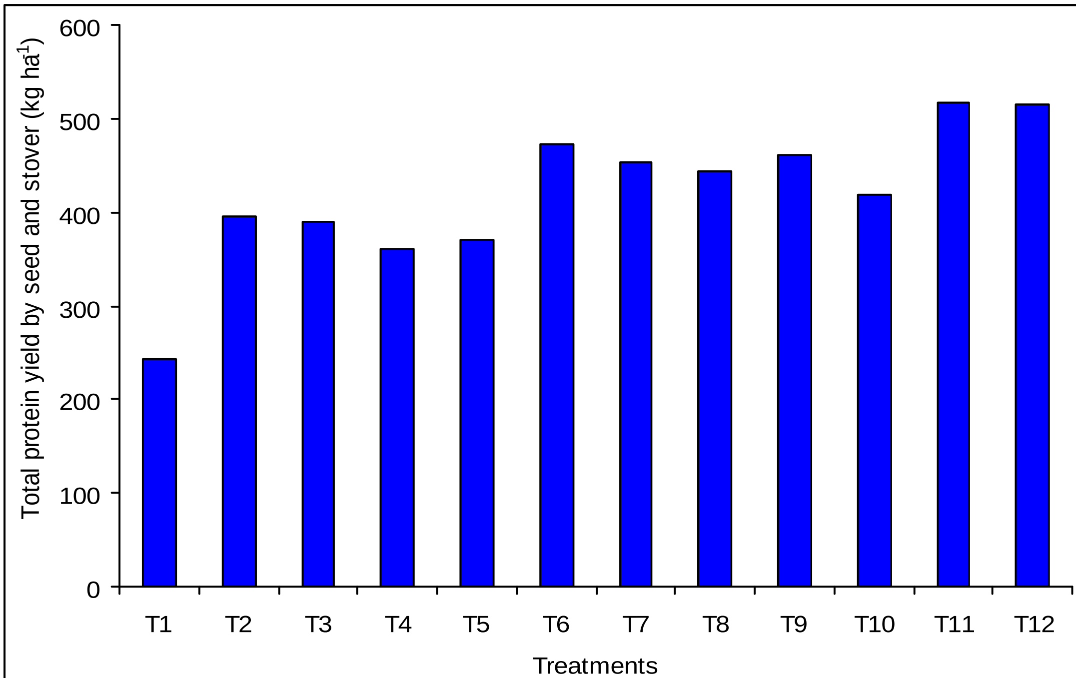


Fig. 4.14. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (Mo & B) on total protein yield by seed and stover in mungbean

T_1: Control, T_2: PKMo, T_3: PKB, T_4: Inoculum, T_5 : N, T_6 : PKMo + Inoculum., T_7 : PKB + Inoculum, T_8 : NPKMo, T_9 : NPKB, T_{10} : PKMoB, T_{11}: PKMoB + Inoculum, T_{12} : NPKMoB

4.7.6. Total protein yield by seed and stover

Application of fertilizers and *Bradyrhizobium* inoculants showed significant variation in total protein yield by seed and stover of mungbean (Fig. 4.14 and App. 4). The highest total amount of protein yield in seed and stover (518 kg ha^{-1}) was recorded in T_{11} (PKMoB + Inoculum) which was which was identical with T_{12} (NPKMoB).The lowest total N uptake in seed and stover (244 kg ha^{-1}) was recorded in control.

4.8 Correlation

Correlation matrix among the plant characters of mungbean has been shown in Tables 4.4-4.6. Most of the plant characters were strongly correlated among themselves. In the present study, nodule number had positive and significant correlation with nodule weight and other plant characters also correlated among them (Table 4.4). 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 yield and yield contributing parameters (Table 4.5) except seed yield and 1000-seed weight, seeds $pods^{-1}$, stover yield and 1000-seed weight and seeds pod^{-1}. Seed and stover yield were also strongly correlated with N uptake by seed and stover, protein content and protein yield of mungbean (Table 4.6). Solaiman (1999) found positive correlation among mungbean growth, N uptake and yield parameters.

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. 4.15), nodule number and root weight (Fig. 4.16), nodule number and shoot weight (Fig. 4.17), nodule number and root length (Fig. 4.18), nodule number and shoot length (Fig. 4.19), nodule number and seed yield (Fig. 4.20), nodule number and stover yield (Fig. 4.21), nodule number and N uptake (Fig. 4.22), nodule weight and seed yield (Fig. 4.23), nodule weight and stover yield (Fig. 4.24), nodule weight and N uptake (Fig. 4.25), nodule weight and protein yield (Fig. 4.26), shoot weight and seed yield (Fig. 4.27), shoot weight and stover yield (Fig. 4.27), stover yield and seed yield (Fig. 4.29), seed yield and protein yield (Fig. 4.30).

Table 4.4. Correlation matrix among different plant characters of mungbean at 50 DAS (n = 48)

Characters	Correlation coefficient (r value)				
	Nodule weight	Root weight	Shoot weight	Root length	Shoot length
Nodule number	0.909**	0.381**	0.305*	0.498**	0.293*
Nodule weight	-	0.410**	0.271NS	0.468**	0.237NS
Root weight	-	-	0.410**	0.508**	0.206NS
Shoot weight	-	-	-	0.271NS	0.146NS
Root length	-	-	-	-	0.421*

Table 4.5. Correlation matrix among yield and yield contributing characters of mungbean (n = 48)

Characters	Correlation coefficient (r value)				
	Stover yield	1000-seed weight	Plant height	Pods plant^{-1}	Seeds pod^{-1}
Seed yield	0.509**	-0.030NS	0.275*	0.462**	0.188NS

Stover yield	-	0.197^{NS}	0.299^{*}	0.372*	0.175^{NS}
1000-seed weight	-	-	0.121^{NS}	0.105^{NS}	0.005^{NS}
Plant height	-	-	-	0.149^{NS}	0.135^{NS}
Pods $plant^{-1}$	-	-	-	-	0.152^{NS}

Table 4.6. Correlation matrix among yield and nutrient content of mungbean (n = 48)

Characters	Correlation coefficient (r value)						
	Stover yield	N content in stover	N uptake by stover	N content in seed	N uptake by seed	Protein content	Protein yield
Seed yield	0.509^{**}	0.250^{NS}	0.552^{**}	0.107^{NS}	0.948^{**}	0.107^{NS}	0.949^{**}
Stover yield	-	0.155^{NS}	0.958^{**}	0.294^{*}	0.560^{**}	0.294^{*}	0.560^{**}
N content in stover	-	-	0.420^{**}	0.044^{NS}	0.238^{NS}	0.044^{NS}	0.238^{NS}
N uptake by stover	-	-	-	0.282^{NS}	0.596^{**}	0.282^{NS}	0.596^{**}
N content in seed	-	-	-	-	0.408^{**}	0.999^{**}	0.408^{**}
N uptake by seed	-	-	-	-	-	0.408^{**}	0.999^{**}
Protein content	-	-	-	-	-	-	0.408^{**}

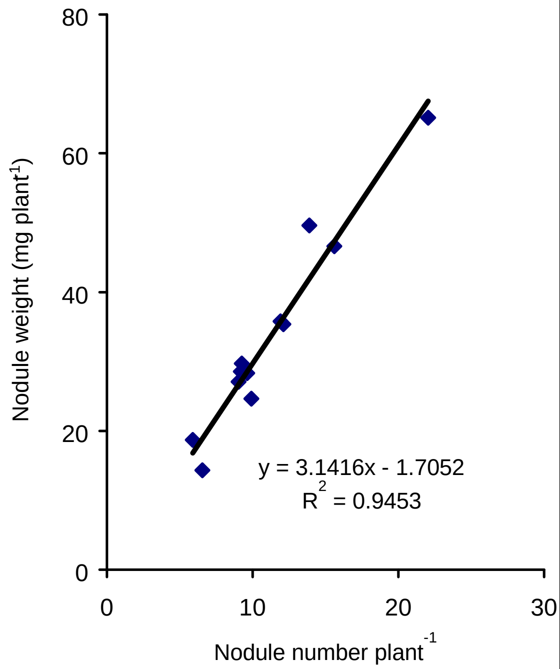


Fig. 4.15. Relationship between nodule number and nodule weight of mungbean at 50 DAS

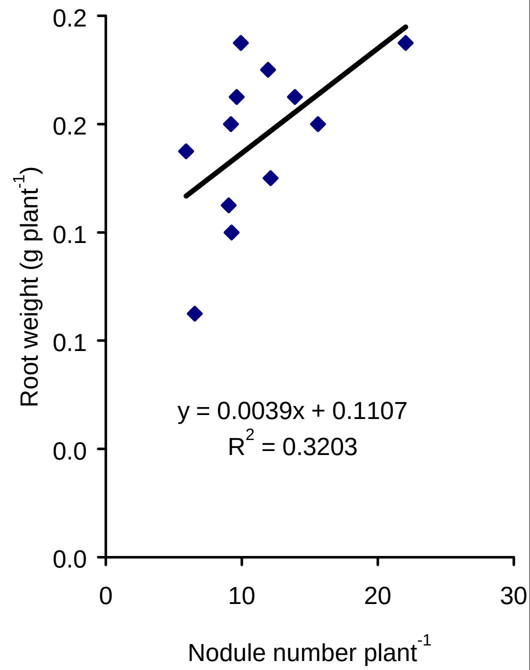
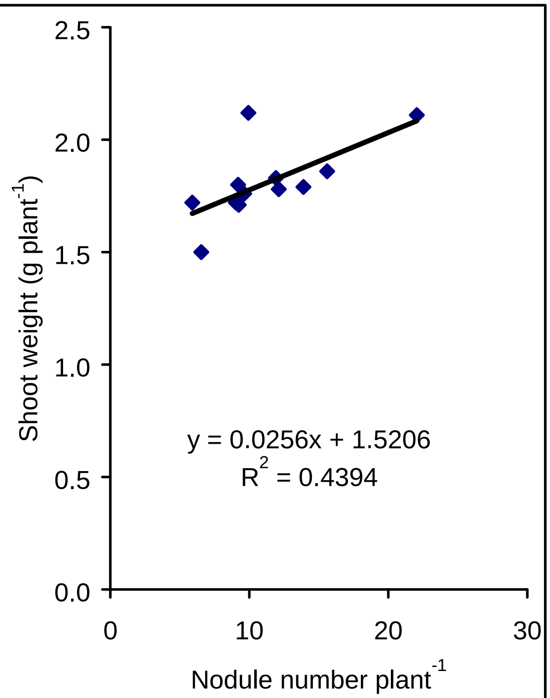
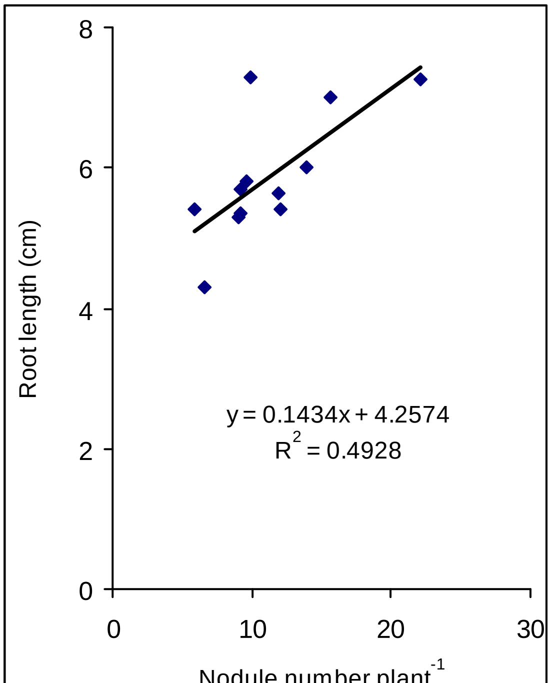


Fig. 4.16. Relationship between nodule number and root weight of mungbean at 50 DAS





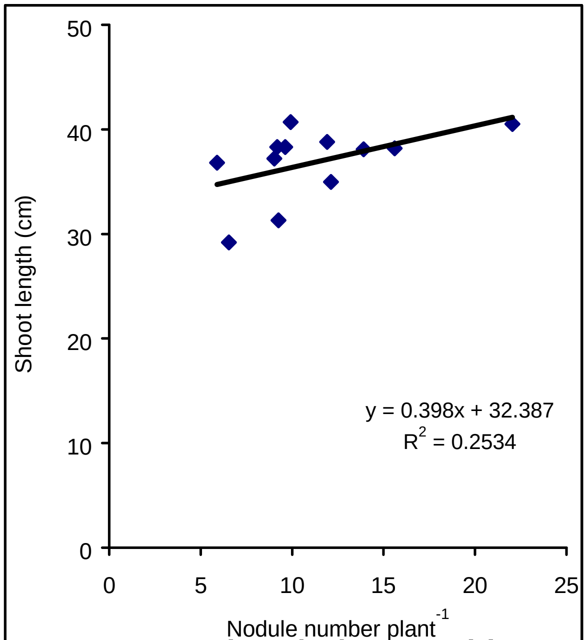


Fig. 4.19. Relationship between nodule number and shoot length of mungbean at 50 DAS

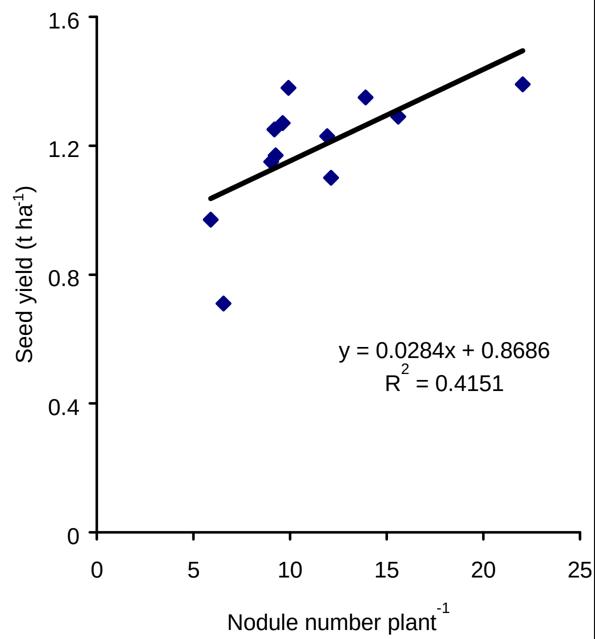


Fig. 4.20. Relationship between nodule number and seed yield of mungbean

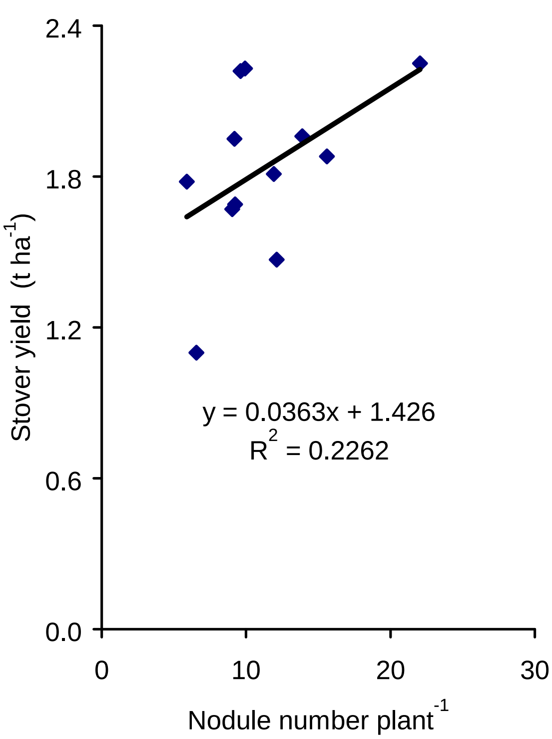


Fig. 4.21. Relationship between nodule number and stover yield of mungbean

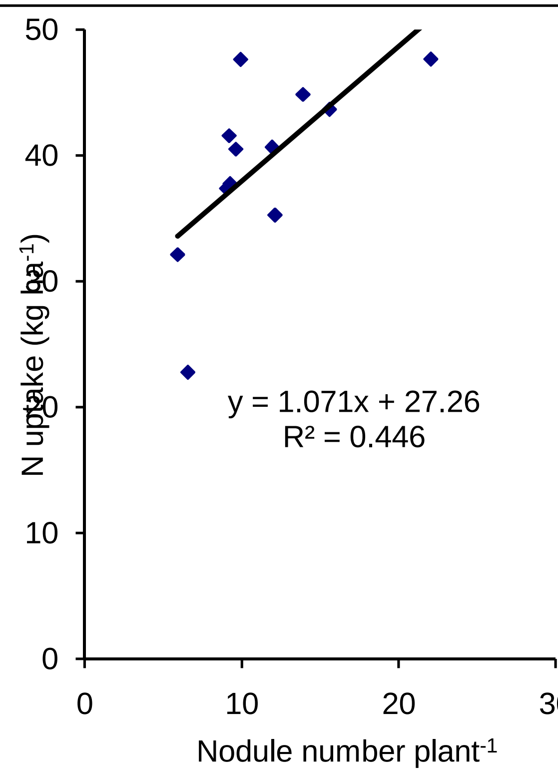


Fig. 4.22. Relationship between nodule number and N uptake of mungbean

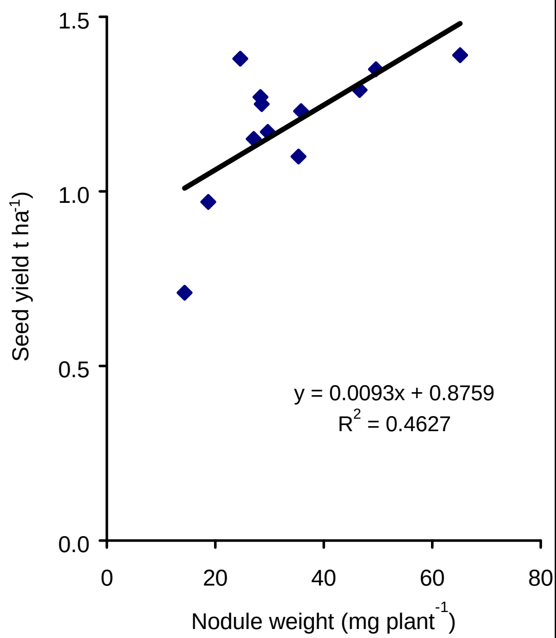


Fig. 4.23. Relationship between nodule weight and seed yield of mungbean

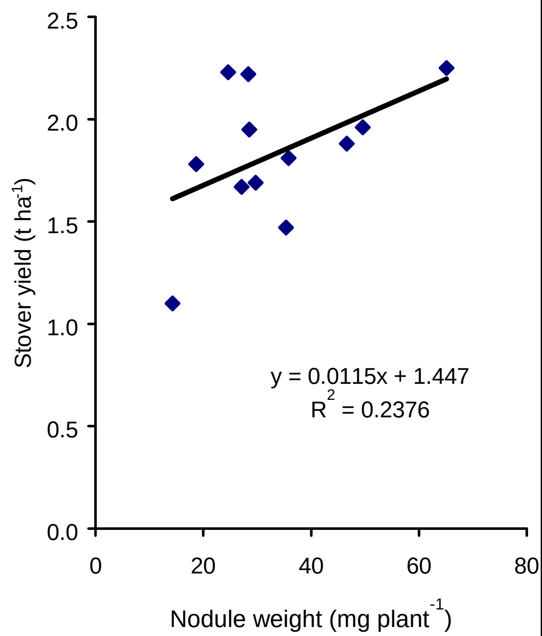


Fig. 4.24. Relationship between nodule weight and stover yield of mungbean

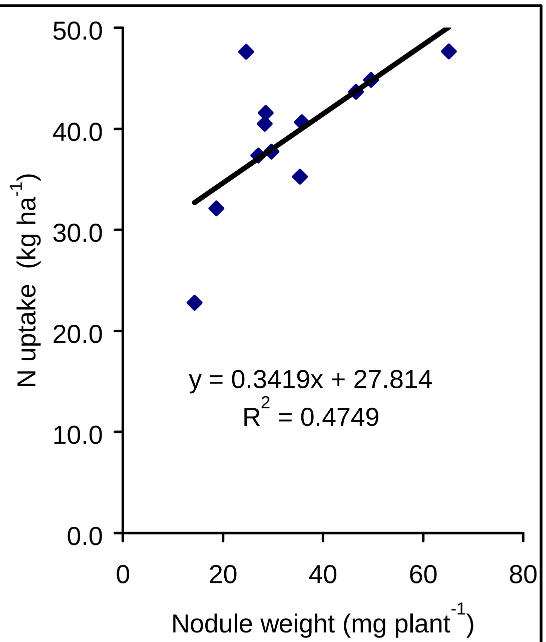


Fig. 4.25. Relationship between nodule weight and N uptake of mungbean

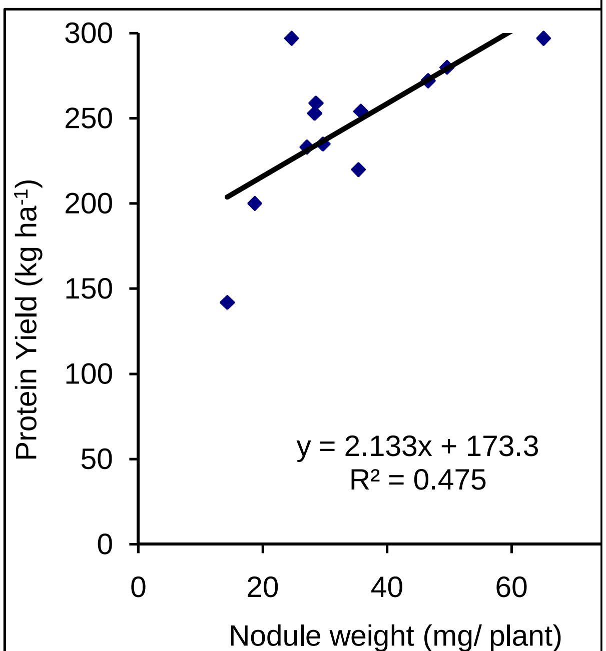


Fig. 4.26. Relationship between nodule weight and protein yield of mungbean

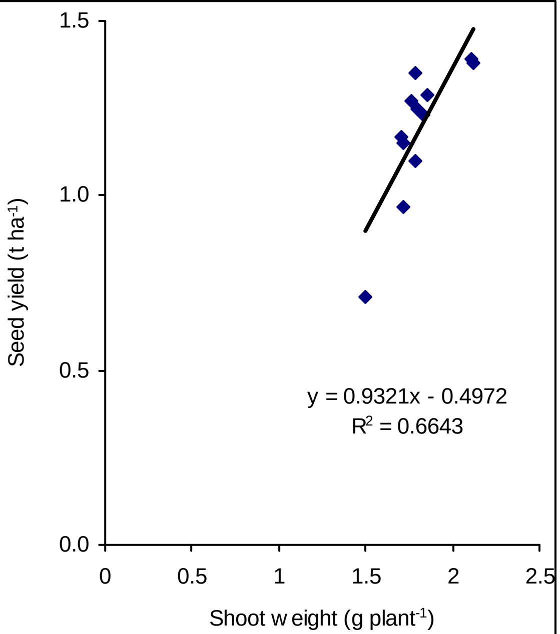


Fig. 4.27. Relationship between shoot weight and seed yield of mungbean

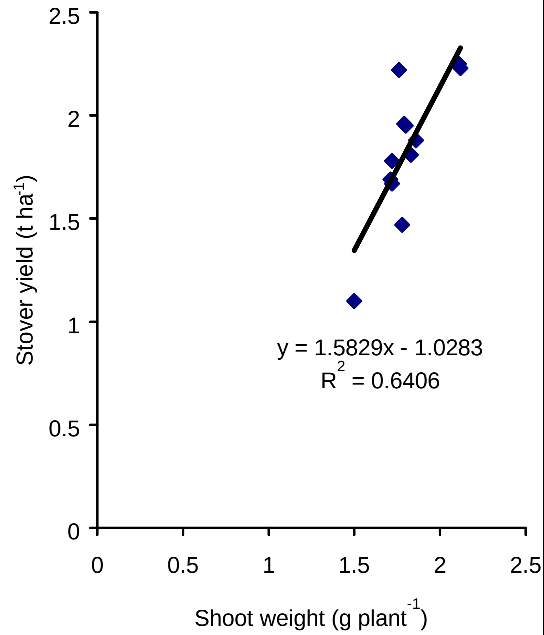


Fig. 4.28. Relationship between shoot weight and stover yield of mungbean

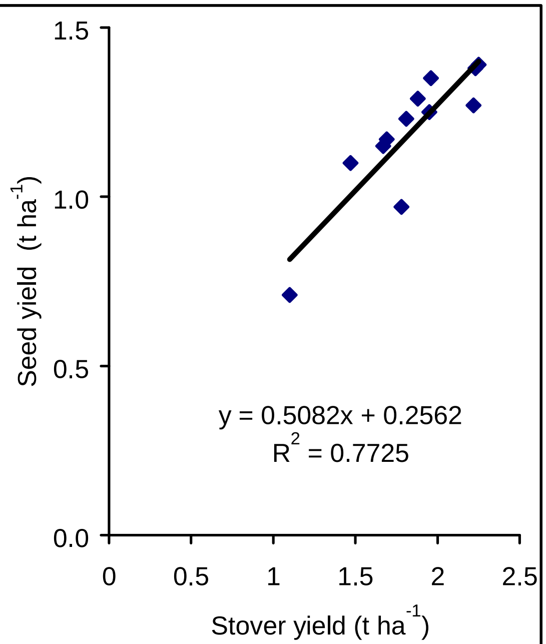


Fig. 4.29. Relationship between stover yield and seed yield of mungbean

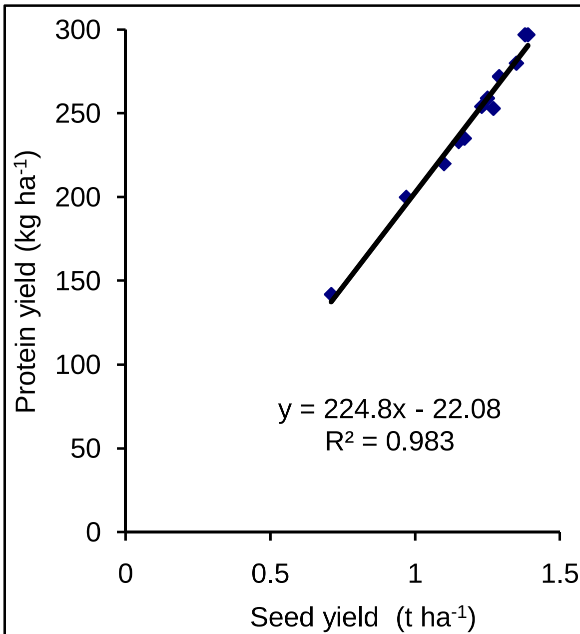


Fig. 4.30. Relationship between seed yield and protein yield of mungbean

4.9. Benefit cost ratio analysis

The benefit cost analysis (BCR) of mungbean has been given in Table 4.7. The highest BCR (7.11) was noted for only 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 other chemical fertilizers based on BCR. For poor farmers, only inoculum was suitable for mungbean cultivation at the aforesaid area. The BCR followed the following trend T_4: Inoculum> T_6: PKMo + Inoculum> T_7: PKB + Inoculum> T_{11}: PKMoB + Inoculum> T_9: NPKB> T_{12}: NPKMoB> T_3: PKB> T_5: N> T_{10}: PKMoB> T_8: NPKMo> T_2: PKMo.

Table 4.7. Benefit cost ratio analysis for mungbean

Treatments	Seed yield (t ha^{-1})	Stover 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: Control	0.71	1.10	2,780	43,700	43,700	-	-
T_2: PKMo	1.17	1.69	7,412	71,890	64,478	20,778	2.80
T_3: PKB	1.15	1.67	6,750	70,670	63,920	20,220	2.99
T_4: Inoculum	1.10	1.47	2,930	67,470	64,540	20,840	7.11
T_5: N	0.97	1.78	4,084	59,980	55,896	12,196	2.98
T_6: PKMo+Inoc.	1.35	1.96	7,562	82,960	75,398	31,698	4.19
T_7: PKB+Inoc.	1.29	1.88	6,900	79,280	72,380	28,680	4.15
T_8: NPKMo	1.25	1.95	8,716	76,950	68,234	24,534	2.81
T_9: NPKB	1.27	2.22	8,054	78,420	70,366	26,666	3.31

T_{10}: PKMoB	1.23	1.81	8,300	75,610	67,310	23,610	2.84
T_{11}: PKMoB+Inoc.	1.39	2.25	8,450	85,650	77,200	33,500	3.96
T_{12}: NPKMoB	1.38	2.23	9,604	85,030	75,426	31,726	3.30

Urea = Tk. 12 kg^{-1}, TSP= Tk. 17 kg^{-1}, MP= Tk. 18 kg^{-1}, Gypsum= Tk. 10 kg^{-1}, $ZnSO_4$= Tk. 120 kg^{-1}, Sodium molybdate= Tk. 500 kg^{-1}, Boric acid= Tk. 100 kg^{-1}, Inoculum= Tk. 100 kg^{-1}, Mungbean seed= Tk. 60 kg^{-1}, Mungbean stover= Tk. 1 kg^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was carried out during March to June 2009 at research field of Soil Science Division of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur to evaluate the effect of *Bradyrhizobium* inoculation, nitrogen, molybdenum and boron on growth, nodulation, yield and nitrogen uptake, and other yield contributing characters of mungbean and find out the suitable combination of *Bradyrhizobium*, nitrogen, molybdenum and boron for mungbean production followed by RCBD technique. Triple super phosphate (22 kg P ha^{-1}), muriate of potash (42 kg K ha^{-1}), gypsum (20 kg S ha^{-1}), zinc sulphate (5 kg Zn ha^{-1}), sodium molybdate (1 kg Mo ha^{-1}) and boric acid (1 kg B ha^{-1}) were applied as basal dose at the time of final land preparation. Mungbean seeds were inoculated and were sown on 08 March 2009.

Data for total nodule number, nodule on main root, nodule on branch root, nodule weight, root weight, shoot weight, root length and shoot length were recorded at two stages of growth viz. 35 and 50 DAS, and for seed and stover and other yield attributing data were taken at the time of plant maturity. Nitrogen content, protein content, nitrogen uptake and protein yield data were taken after chemical analysis of plant and seed samples.

Abridged account of the different plant characters were analyzed statistically and the significant mean differences were adjusted by DMRT.

The highest number nodules of main root plant^{-1} (4.80 and 14.19) were from found in PKMoB + Inoculum at 35 and 50 DAS, respectively. All the inoculated treatments showed significant result in forming nodules on main root than on control plant. The highest number of nodules (3.29 plant^{-1} at 35 DAS and 7.85 plant^{-1} at 50 DAS) on branch root was recorded in PKMoB + Inoculum which were significantly higher over all other treatments combination. Nitrogen has no significant impact on nodule formation on branch root. *Bradyrhizobium* inoculated plants produced significantly higher number of nodules plant^{-1} than the non-inoculated control plants or N treated plants. It was observed that the highest number of total nodules of 22.04 plant^{-1} was recorded at 50 DAS, which indicates production of nodules plant^{-1} increased with the increase of time upto 50 DAS. It was observed that *Bradyrhizobium* inoculation and application of B significantly influenced the number of nodules plant^{-1}. Nodule weight increases with the passage of time. Among the treatments, only *Bradyrhizobium* produced higher nodule weight than did nitrogen at both the dates of nodule collection.

The highest root weight (0.11 and 0.19 g plant^{-1}) was obtained in T_{12} at 35 and 50 DAS while the non-inoculated control (T_1) gave the lowest root weight. Among the treatments there was significant difference but all the treatments produced higher root weight than did control at 50 DAS. No significant effect on shoot weight was observed at 35 and 50 DAS due to *Bradyrhizobium* inoculation though the highest shoot weight (2.12 g plant^{-1}) at 50 DAS was obtained in T_{12} (NPKMoB) and the lowest (1.50 g plant^{-1}) was obtained in T_1 (Control). The highest root length (7.30 cm) was observed in T_{12} (NPKMoB). The lowest root lengths (4.29 cm) were obtained in T_1 at 50 DAS. *Bradyrhizobium* inoculant alone or in combination with PKMoB had no effect on shoot length at 35 and 50 DAS. The highest plant height (43.2 cm) at harvesting stage was obtained from T_{11} (PKMoB + Inoculum) which was identical to all other treatments but different from T_1 (control) and Inoculum. All the fertilizer treatments showed insignificant response in terms of pod length. The highest pod length (8.01 cm) was recorded in treatment T_{12} (NPKMoB) that was identical to all other treatment combinations but different from T_1 and the lowest pod length of 7.00 cm was recorded in control plant. All the fertilizer treatments showed significant response in pods plant^{-1}. The highest pod number (22.6) was obtained from T_{11} (PKMoB + Inoculum) which was significantly different from control (T_1). No significant response due to application of different fertilizer was observed for seeds pod^{-1}. There was no significant relationship among the different treatments in 1000-seed weight. The highest 1000-seed weight of 37.7 was obtained from T_{11} (PKMoB + Inoculum) and the lowest 1000-seed weight of 36.5 g was obtained from control treatment (T_1). *Bradyrhizobium* inoculaiton had significant effect on mungbean stover weight. The highest stover yield of 2.25 t ha^{-1} was obtained from T_{11} (PKMoB + Inoculum) and the lowest of 1.10 t ha^{-1} was obtained from T_1 (control). The highest seed yield (1.39 t ha^{-1}) was obtained from T_{11} (PKMoB + Inoculum) and the lowest seed yields (0.71 t ha^{-1}) was obtained from T_1 (control). The highest nitrogen content in seed (3.43%) was obtained from T_{12} (NPKMoB). The highest N content in stover (1.57%) was obtained from T_{11} (PKMoB + Inoculum) and the lowest N content (1.47%) in stover was obtained from T_1 (control).

REFERENCES

Abdo, F.A. 2001. The response of two mungbean cultivars to zinc, manganese and boron I. Morphological, physiological and anatomical aspects. Bull. Fac. Agric. Cairo Univ. 52(3): 445-456.

Abedin, M.J., M. Jahiruddin, M.S. Hoque, M.R. Islam and M.U. Ahmed. 1994. Application of boron in improving grain yield of wheat. Progress. Agric. 5(1): 75-79.

Ali, M.Y., L. Krishnamurthy, N.P. Saxena, O.P. Rupela, J. Kumar and C. Johanson. 2002. Scope for genetic manipulation of mineral acquisition in chickpea. Plant Soil. 245(1): 123-134.

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

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

BARC. 2005. Fertilizer Recommendation Guide. Published by Bangladesh Agricultural Research Council, Farmgate, Dhaka.

BARI. 1998. Barimoog-5. A leaflet of Bangladesh Agril. Res. Inst. pp.1-6.

BBS. 2006. Statistical Yearbook of Bangladesh. 26th Edition. Bangladesh Bureau of Statistics. Planning Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, Dhaka, Bangladesh. p. 143.

Bharti, N., M. Murtuza and A.P. Singh. 2002. Effect of boron- *Rhizobium* relationship on yield, nitrogen and boron nutrition of chickpea (*Cicer arietinum*). J. Res. Birsa Agric. Univ. 14(2):175-179.

Bharti, N., M. Murtuza and A.P. Singh. 2003. Effect of boron on symbiotic nitrogen fixation in chickpea (*Cicer arietinum*). J. Res. Birsa Agril. Univ. 15(2): 19-23.

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

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

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

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

Bhuiyan, M.A.H**.**, D. Khanam and M.Y. Ali. 1999a. Chickpea root nodulation and yield as affected by micronutrient application and *Rhizobium* inoculation. Intl. Chickpea Pigeonpea Newsletter. 6: 28-29.

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

Bhuiyan, M.A.H., D. Khanam, M.H.H. Rahman and A.K.M. Hossain. 1997b. Influence of *Rhizobium* inoculum, molybdenum and boron on chickpea (*Cicer arietinum* L.) in Grey Terrace Soil of Bangladesh. Ann. Bangladesh Agric. 7 (2): 119-126.

Bhuiyan, M.A.H., D. Khanam, M.H.H. Rahman and M.A. Hossain. 2005. Effect of rhizobial inoculum and micronutrients (molybdenum and boron) on the growth and yield of soybean. Bangladesh J. Microbiol. 22(2): 123-125.

Bhuiyan, M.A.H., D. Khanam, M.H.H. Rahman and M.Z. Islam. 1996a. Effect of Mo, B and inoculant on nodulation and yield of soybean. Thai J. Agric. Sci. 29(1): 55-63.

Bhuiyan, M.A.H., D. Khanam, M.H.H. Rahman, A.K.M.H. Rahman and M.R. Khatun. 1996b. Effect of molybdenum, boron and rhizobial inoculum on nodulation and yield of groundnut. Bangladesh J. Agril. Res. 21(1): 64-74.

Bhuiyan, M.A.H., D. Khanam, M.M. Kadir and A.K.M. Hossain. 1999b. Response of chickpea (*Cicer arietinum* L.) to molybdenum, boron and *Rhizobium* inoculation in Himalayan Piedmont Soils. Progress. Agric. 10(1 & 2): 103-106.

Bhuiyan, M.A.H., D. Khanam, M.R. Khatun and M.S. Hassan. 1998a. Effect of molybdenum, boron and *Rhizobium* on nodulation, growth and yield of chickpea. Bull. Inst. Trop. Agric., Kyushu Univ. 21: 1-7.

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

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

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

Bhuiyan, M.A.H., M.H.H. Rahman, D. Khanam and M.R. Khatun. 1997a. Effect of micronutrients (Mo and B) and rhizobial inoculum on nodulation and yield of groundnut. Legume Res. 20(3/4): 155-159.

Bhuiyan, M.A.H., M.S. Kabir and D. Khanam. 1998b. Effects of boron, molybdenum and rhizobial inoculation on nodulation and yield of lentil. Bangladesh J. Seed Sci. Tech. 21(1&2): 39-44.

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

Bora, P.C. and U. Hazarica. 1997. Effect of lime and boron on rainfed tora (*Brassica campestris*) sub sp. oleifera var. toria. Indian J. Agron. 42(2): 361-364.

Bowszys, T. 1996. Response of winter rape to foliar application of boron fertilizer. Reakcja repaku ozimego dolcstue nawzenie borem. Zeszyty problemowe Postepow Nauk Rolniczych. 436(1): 71-76.

Brodrick. S.J. and K.E. Giller. 1991. Genotypic difference in molybdenum accumulation affects N_2-fixation in tropical *Phaseolus vulgaris* L. J. Expt. Bot. 42: 1339-1343.

Canhong, C. and B. Rerkasem. 1992. Effect of boron on male fertility in wheat. *In:* Boron Deficiency in Wheat. CIMMYT. Mexico. pp. 5-8.

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

Chaudhary, H.P. and S.K. Das. 1996. Effect of P, S and Mo application on yield of rainfed blackgram and their residual effect on safflower and soil and water conservation in an eroded soil. J. Indian Soc. Soil Sci. 44(4): 741-745.

Chitdeshwari, T and S. Poongothai. 2004. Effect of micronutrients and sulphur on groundnut yield and nutrient availability in a demonstration trial. Legume Res. 27(4): 299-301.

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

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

Dwivedi, B.S., M. Ram, B.P. Sing, M. Das and R.N. Prashad. 1997. Different response of crops to boron fertilization in acid alfisols. Indian J. Agric. Sci. 60(2): 122-127.

Geetha, K.N., A.G. Shankar and K.S. Shankar. 1996. Effect of molybdenum, zinc and calcium on productivity of groundnut (*Arachis hypogaea*). J. Oilseeds Res. 13(2): 167-172.

Giller, K.K. and K.J. Wilson. 1991. Nitrogen fixation in tropical cropping systems. C.A.B. Intger., Willingford. Oxon Ox 108 DE. U.K. pp. 211-212.

Gowda, C.L.L. and A.K. Kaul. 1982. Pulses in Bangladesh. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur and Food and Agricultural Organization of the United Nations. p. 13.

Halder, N.K., N.C. Shil, M.A. Siddiky, R. Gomes and J.U. Sarkar. 2007. Response of ginger to zinc and boron fertilization. Asian J. Plant Sci. 6(2): 394-398.

Harris, H.B., M.B. Parker and B.J. Johnson. 1965. Influence of molybdenum content of soybean seed and other factors associated with seed source on progeny response to applied molybdenum. Agron. J. 57: 397-399.

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

Hazra, C.R. and S.B. Tripathi. 1998. Effect of secondary micronutrient on yield and quality of forages. Fertilizer News. 43(1): 77-82.

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

Hossain, M.A., M. Jahiruddin, M.S. Hoque and M.I. Ali. 1994. Effect of genotype and sowing date on the response to boron in wheat. Pakistan J. Sci. Ind. Res. 37(10): 432-435.

Islam, M.A., U.K. Saha, M.S. Islam and R.R. Saha. 1995. Fertilizing chickpea for high yield with special emphasis on boron and molybdenum in Grey Floodplain Soils of Bangladesh. Annals Bangladesh Agric. 5(1): 43-49.

Islam, M.R., M.A. Ali, M.S. Islam, A.F.M.G.F. Hossain, 2002. Effects of nutrients and weeding on the incidence of mungbean mosaic. Pakistan J. Plant Path. 1(2): 48-50.

Islam, M.R., T.M. Riasat and M. Jahiruddin. 1997. Direct and residual effects of S, Zn and B on yield and nutrient uptake in a rice mustard cropping system. J. Indian Soc. Soil. Sci. 45(1): 126-129.

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

Jahiruddin, M. 1991. Influence of boron, copper and molybdenum on grain formation in wheat. *In*: Proc. Workshop Bangladesh Agril. Univ. Res. Progress. Mymensingh (Bangladesh). pp. 105-112.

Janakiraman, N., P. Venkataravana and C. Seenappa. 2005. Effects of iron, zine and boron on yield and seed quality of groundnut (*Arachis hypogaea* L.). Mysore J. Agril. Sci. 39(2): 286-288.

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

Johansen, C., A.M. Musa, J.V.D.K.K. Rao, D.F. Harris, M.Y. Ali and J.G. Lauren. 2005. Molybdenum response of chickpea in the High Barind Tract (HBT) of Bangladesh and in Eastern India. Micronutrients in South and South East Asia: Proc. Intl. Workshop held in Katmandu, Nepal, 8-11 Sep., 2004, 205-220.

Johnson, S.E., J.G. Lauren, R.M. Welch and J.M. Duxbury. 2005. A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Nepal. Expt. Agric. 41(4): 427-448.

Kabir, M.E., A. Hamid, M.M. Haque, E. Nawata and M.A. Karim. 2005. Effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Japanese J. Trop. Agric. 49(2): 119-125.

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

Khan, M.A., M. Jahiruddin and M. Bodruzzaman. 1996. Response of wheat to boron in relation to different varieties and sowing dates. Bangladesh J. Agril. Sci. 23(2): 27-32.

Khanam, D., M.H.H. Rahman, D. Begum, M.A. Haque and A.K.M. Hossain. 1994. Inoculation and varietal interactions of chickpea (*Cicer arietinum* L.) in Bangladesh. Thai J. Agric. Sci. 27: 123-130.

Kliemann, A.A., M.C. Castro and F.F. Dliveira. 2002. Productivity of soybean as a function of the application of cobalt and molybdenum. Madras Agril. J. 7(1): 59-65.

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

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

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

Lourduraj A.C., P.K Krishnan and V. Geethalakshmi. 1997. Micronutrioent fertilization in groundnut. Madraj Agril. J. 84(7): 362-363.

Mahmud, M., U.F. Chiezey, M.K. Ahmed and I. Rufai. 1997. Effects of different levels of phosphorus fertilizer and intra-row spacing on the grain yield, growth and yield components of blackgram (*Vigna mungo* (L) Hepper). Discovery Innovation. 9(1/2): 47-51.

Malik, M.A., M.F. Saleem, A. Ali and I. Mahmood. 2003. Effect of nitrogen and phosphorus application on growth, yield and quality of mungbean (*Vigna radiata* L.). Pakistan J. Agril. Sci. 40(3/4): 133-136.

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

Mandal, B., S. Pal and L.N. Mandal. 1998. Effect of molybdenum phosphorus and lime application to acid soil on dry matter yield and molybdenum nutrition of lentil. J. Plant Nutr. 21(1): 137-147.

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

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

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

Meenakumari, K.S and S.K. Nair. 2001. Influence of soil chemical properties on root nodulation by *Bradyrhizobium* sp in cowpea, blackgram and mungbean. J. Trop. Agric. 39 (1): 62-64.

Mishra, S.K., G.K. Shrivastava, D. Pandey and R.S. Tripathi. 2001. Optimization of chickpea production through nutrient management and growth regulations under rice based cropping system in vertisols. Annals Agric. Res. 22(2): 299-301.

Mishra, J.P. and A. Masood. 1998. Phosphorus and molybdenum management in summer mungbean. Indian J. Pulses Res. 11(1): 100-102.

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

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

Mulder, E.G. 1948. Investigations on the nitrogen nutrition of pea plants. Plant Soil. 1: 179-212.

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

Nassar, K.E.M. 2005. Response of peanut crops to foliar application of some micronutrients under sandy soil condition. Annals Agric. Sci. 43(4): 2003-2014.

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

Niranjana, H.G., S.S. Prakash, Basavegowda, N.A. Yelladhalli and H.T. Chandranath. 2005. Effect of micronutrient seed treatment on growth and yield of groundnut. Seed Res. 33(2): 138-141.

Oad, F.C. and U.A. Buriro. 2005. Influence of different NPK levels on the growth and yield of mungbean. Indus J. Plant Sci. 4(4): 474-478.

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

Page, A.L., R.H. Miller and D.R. Keeney. 1989. Methods of Soil Analysis. Part 2. 2nd Ed. Amer. Soc. Agron., Inc., Medison, Wisconsin, USA.

Panda, P.K., H. Sen, A. Mukherjee and M.R. Satapathy. 2003. Studies on the effect of NK fertilization on the performance of yambean-pigeonpea intercropping system and its residual effect on the succeeding mung. Legume Res. 26(4): 235-241.

Patel, J.J., K.D. Mevada and R.L. Chotaliya. 2003. Response of summer mungbean to date of sowing and level of fertilizers. Indian J. Pulses Res. 16(2): 122-124.

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

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

Rana, K.S. and R.S. Choudhary. 2006. Productivity, nitrogen uptake and water use in maize (*Zea mays* L.) + mungbean intercropping system as affected by nitrogen levels under rainfed conditions. Crop Res. Hisar. 32(3): 306-308.

Rao, K.T., G.J. Naidu and G. Subbaiah. 2006. Effect of foliar application of micronutrient on yield and yield attributes on Indian mustard {*Brassica juncea* (L)}. Agril. Sci. Digest. 26(2): 144-146.

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

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

Reinbott, T.M. and D.G. Blevins. 1995. Response of soyaben to foliar application boron and magnesium and soil applied boron. J. Plant Nutrition. (USA). 18(1): 179-200.

Rerkasem, B., R. Netsangtip, J.F. Loneragan and R.W. Bell. 1987. Boron deficiency in grain legumes. *In: Proc. Inter. Workshop* on *Food Legumes*. Improvement in Asian Farming System. Khon Kaen, Thailand. ACIAR. No. 18. p. 267.

Rerkasem, B., S. Loadkaew and S. Jamiod. 1991. Assessment of grain set failure and diagnosis for boron deficiency in wheat. *In*: Pproc. Wheat for Non Traditional Warm Areas, D.A. Sandeers ed., UNDP/CIMMYT. pp. 26-30.

Rizk, W.M. and F.A. Abdo. 2001. The response of two mungbean cultivars to zinc, manganese and boron II. Yield and chemical composition of seed. Bulletin Faculty Agric. Cairo Univ. 52(3): 467-477.

Robson, A.D. 1993. Nitrogen fixation Vol. III Legumes. Broughton. W.J. ed., Clarendon Press. Oxford. pp. 36-55.

Roselem, R.A. and E.F. Caries. 1998. Yield and nitrogen uptake of peanuts as affected by lime, cobalt and molybdenum. J. Plant Nutr. 21(5): 827-835.

Saha, A., B.K. Mandal and P. Mukhopadhyay. 1996. Residual effect of boron and molybdenum on the yield of succeeding mungbean in summer. Indian Agriculturist. 40(1): 11-16.

Sangakhara, U.R. 2003. Nitrogen dynamics, growth and yield of a cereal legume intercropping system as affected by effective microorganisms and Kyusei nature farming. Seventh Intl. Conf. Kyusei Nature Farming Proc. Conf. held at Christchurch, New Zealand, 15-18-January 2002. pp. 77-81.

Sansance, J. and R. Benchawan. 1989. Correcting boron deficiency induced ear sterility in wheat and barely. J. Soils Fert. (Thailand). 11(3): 200-209.

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

Sfredo, G.J., C.M. Borkerf, A.L. Nepomuceno and M.C.N. Deoliveira. 1997. Effectiveness of products containing trace elements applied to the seed on yield and protein content of soybean seed. Field Crop Abst. 24(4): 237.

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

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

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

Sharma, S., C.R. Sharma and R.G. Upadhayay. 1999. Response of various strains of *Rhizobium* and nitrogen on symbiotic and physiological parameters, biochemical constituents and yield of blackgram (*Vigna mungo* L. Hepper). Legume Res. 22(4): 233-236.

Sharma, S., N.S. Daramwal, C.R. Sharma and R.G. Upadhyay. 2001. Influence of various doses of nitrogen and phosphorus on protein content, yield and its attributes of mungbean [*Vigna radiata* (L.) Wilczek]. Res. Crops. 2(2): 108-111.

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

Sharma, U.C. 1992. Response of soybean (*Glycine max*.) to micronutrients in acidic soil of Nagaland. Indian J. Hill farming. 5(1): 75-76.

Shil, N.C., S. Noor, M.H. Ullah, M.A.H. Bhuiyan and A.T.M. Farid. 2007. Response of mungbean to boron and molybdenum fertilization. Bangladesh J. Agric. Environ. 3(1): 17-24.

Singaravel, R., V. Parasath and D. Elayaraja. 2006. Effect of organics and micronutrients on the growth, yield of groundnut in coastal soil. Intl. J. Agril. Sci. 2(2): 401-402.

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

Singh, S.K., H.K. Saxena and T.K. Das. 2002. The effect of kind of micronutrients and their method of application on mungbean (*Vigna radiata* (L.) Wilczek) under zaid condition. Annals Agril. Res. 19(4): 454-457.

Singh, Y.P. and R. Singh. 2004. Interaction effect of sulphur and phosphorus on growth and nutrient content of black gram (*Phaseolus mungo* L.). J. Indian Soc. Soil Sci. 52(3): 266-269.

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

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

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

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

Srinivasan, S., R.V. Selvi, S. Ramesh, M. Pandiyan, M. Sunder, R. Kannan and R. Marimuthu. 2007. Response of mungbean to different methods and levels of molybdenum application under acid soil conditions. Acta-Horticulturae. 752: 473-476.

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

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

Srivastava, S.P., C. Johansen, R.K. Neupane and M. Joshi. 2005. Severe boron deficiency limiting grain legumes in the inner Terai of Nepal. Micronutrients in South and South-East Asia: Proc. Intl. Workshop held in Katmandu, Nepal, 8-11 September, 2004. pp. 67-76.

Subbaiah, G. and B.N. Mittra. 1996. Effect of foliar spray of micronutrients on yield and oil content of Indian mustard (*Brassica juncea*). Indian J. Agron. 41(1): 95-97.

Sultana, S., J. Ullah, F. Karim and Asaduzzaman 2009. Response of mungbean to integrated nitrogen and weed management. American Eurasian J. Agron. 2(2): 104-108.

Tanwar, S.P.S., G.L. Sharma and M.S. Chahar. 2002. Effects of phosphorus and biofertilizers on the growth and productivity of blackgram. Annals Agric. Res. 23(3): 491-493.

Tanwar, S.P.S., G.L. Sharma and M.S. Chahar. 2003. Economics of blackgram (*Vigna mungo* (L.) Hepper) cultivation as influenced by phosphorus levels and biofertilizers. Legume Res. 26(2): 149-150.

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

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

Tiwari, V.N., L.K. Lehri and A.N. Pathak. 1989. *Rhizobium* inoculation of legumes as influenced by phosphorus and molybdenum fertilization. J. Indian Soc. Soil Sci. 37(4): 712-716.

Tomar, A., N. Kumar, R.P. Pareek and A.K. Chaube. 2001. Synergism among VA mycorrhiza, phosphate solubilizing bacteria and *Rhizobium* for symbiosis with blackgram (*Vigna mungo* L.) under field conditions. Pedosphere. 11(4): 327-332.

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

Vaishya, U.K., G.R. Gayendragadkar and R.L. Pandey. 1983. Effect of *Rhizobium* inoculation on nodulation and grain yield of mungbean (*Vigna radiata* L. Wilczek). Indian J. Microbiol. 23: 228-230.

Verma, L.P., P.C. Ran and B.R. Maurya. 1988. Response of chickpea to phosphorus and molybdenum in alluvium of Eastern Uttar Prodesh. Intl. Chickpea Newsletter. 18: 31-33.

Verma, R.J. and P.H. Mishra. 1999. Effects of doses and methods of boron application on growth and yield of mungbean. Indian J. Pulse Res. 12(1): 115-118.

Wang, Z., F. Zhang and K. Shen. 1999. Comparative analysis of free amino acid in *Brassica napus* L. under different boron levels. China Agric. Univ. 1(1): 73-78.

YongHua, Y. and Z. HongYan. 1998. Boron amelioration of aluminum toxicity in mungbean seedlings. J. Plant Nutrition. 21(5): 1045-1054.

Zaman, A.K.M.M., M.S. Alam, B. Roy and A.H. Beg. 1996. Effect of B and Mo application on mungbean. Bangladesh J. Agril. Res. 21(1): 118-124.

Zhu, H., X. Zhang and C. Sun. 1996. Characteristics of micronutrients uptake by rape plants and the methods of B and Zn application. Oil Crops (China). 18(2): 59-61.

Appendix 1. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on nodulation in mungbean

Treatment	35 DAS				50 DAS			
	Total nodule number $plant^{-1}$	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Nodule weight (mg $plant^{-1}$)	Total nodule number $plant^{-1}$	Nodule on main root $plant^{-1}$	Nodule on branch root $plant^{-1}$	Nodule weight (mg $plant^{-1}$)
T_1: Control	2.63h	1.45g	1.18e	3.98c	6.55 f	4.00fg	2.55f	14.31f
T_2: PKMo	5.25c-f	3.50b-e	1.75cde	4.22c	9.25e	5.15ef	4.10def	29.69cd
T_3: PKB	5.49b-e	3.35cde	2.14bc	4.27c	9.03 e	4.97ef	4.06def	27.10d
T_4: Inoculum	6.00bcd	3.55b-e	2.45b	6.56b	12.12 d	7.16cd	4.95cd	35.36c
T_5: N	4.70efg	2.54f	2.16bc	4.31c	5.90f	3.09g	2.81ef	18.70ef
T_6: PKMo+Inoculum	6.25b	4.20ab	2.05bcd	6.73b	13.90c	8.55b	5.35cd	49.60b
T_7: PKB+Inoculum	6.15bc	3.98bc	2.18bc	6.76b	15.60b	8.50bc	7.20ab	46.61b
T_8: NPKMo	4.40fg	3.17cdef	1.24e	4.05c	9.19e	5.25ef	3.94def	28.54d
T_9: NPKB	5.20def	3.86 bcd	1.34e	4.32c	9.62e	5.13ef	4.49cde	28.34d
T_{10}: PKMoB	5.48b-e	3.97bc	1.51de	4.12c	11.92d	6.00de	5.92bc	35.79c
T_{11}: PKMoB+Inoculum	8.09a	4.80a	3.29a	8.00a	22.04a	14.19a	7.85a	65.12a
T_{12}: NPKMoB	4.20g	2.95ef	1.25e	4.26c	9.92e	6.17de	3.75def	24.62de
Level of sig.	**	**	**	**	**	**	**	**
LSD (0.05)	0.84	0.67	0.54	1.07	1.58	1.25	1.52	6.39
CV (%)	11.0	13.5	19.9	14.5	9.7	13.4	22.2	13.2

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT

Appendix 2. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on root and shoot dry weight of mungbean

Treatment	35 DAS		50 DAS	
	Root weight (g plant^{-1})	Shoot weight (g plant^{-1})	Root weight (g plant^{-1})	Shoot weight (g plant^{-1})
T_1: Control	0.06d	0.85	0.09	1.50
T_2: PKMo	0.06d	0.99	0.12cd	1.71
T_3: PKB	0.06d	0.98	0.13bcd	1.72
T_4: Inoculum	0.07cd	1.05	0.14a-d	1.78
T_5: N	0.07cd	1.04	0.15abc	1.72
T_6: PKMo+Inoculum	0.08bc	1.07	0.17abc	1.79
T_7: PKB+Inoculum	0.08bc	1.08	0.16abc	1.86
T_8: NPKMo	0.09a	1.09	0.16abc	1.80
T_9: NPKB	0.08bc	1.10	0.17abc	1.76
T_{10}: PKMoB	0.09ab	1.13	0.18abc	1.83
T_{11}PKMoB+Inoc.	0.10ab	1.21	0.19a	2.11
T_{12}: NPKMoB	0.11a	1.19	0.19a	2.12
Level of significance	**	NS	**	NS
LSD (0.05)	0.024	-	0.05	-
CV (%)	21.9	13.4	21.7	16.9

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT

NS = Not significant

Appendix 3. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on root and shoot length of mungbean

Treatment	35 DAS		50 DAS	
	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)
T_1: Control	4.43	24.10	4.29c	29.20
T_2: PKMo	4.82	26.10	5.35bc	31.30
T_3: PKB	4.85	26.00	5.30bc	37.20
T_4: Inoculum	4.90	27.10	5.41bc	34.99
T_5: N	4.95	27.30	5.40bc	36.80
T_6: PKMo+Inoculum	5.00	27.50	6.00abc	38.10
T_7: PKB+Inoculum	5.12	27.15	7.00ab	38.20
T_8: NPKMo	5.31	27.70	5.70abc	38.30
T_9: NPKB	5.30	27.80	5.81abc	38.30
T_{10}: PKMoB	5.26	28.30	5.65ab	38.80
T_{11}PKMoB+Inoc.	5.54	30.10	7.25a	40.50
T_{12}: NPKMoB	5.43	30.20	7.30a	40.70
Level of significance	NS	NS	**	NS
LSD (0.05)	1.14	-	1.52	-
CV (%)	15.6	10.2	17.7	17.4

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT

NS = Not significant

Appendix 4. Effect of nitrogen, *Bradyrhizobium* inoculant and micronutrients (molybdenum and boron) on nitrogen uptake by seed and stover, and protein yield by seed and stover of mungbean

Treatment	N uptake by seed (kg ha^{-1})	N uptake by stover (kg ha^{-1})	Total N uptake by seed and stover (kg ha^{-1})	Protein yield by seed (kg ha^{-1})	Protein yield by stover (kg ha^{-1})	Total protein yield by seed and stover (kg ha^{-1})
T_1 : Control	22.77c	16.35d	39.12c	142c	102d	244c
T_2 : PKMo	37.75ab	25.49bc	63.24b	235ab	159bc	395b
T_3 : PKB	37.37ab	25.13bc	62.50b	233ab	157bc	390b
T_4 : Inoculum	35.27ab	22.58cd	57.85b	220ab	141cd	361b
T_5 : N	32.13bc	27.18abc	59.30b	200bc	169abc	370b
T_6 : PKMo+Inoculum	44.85ab	30.72abc	75.57ab	280ab	191abc	472ab
T_7 : PKB+Inoculum	43.65ab	29.08abc	72.72ab	272ab	181abc	454ab
T_8 : NPKMo	41.58ab	29.41abc	70.99ab	259ab	183abc	443ab
T_9 : NPKB	40.51ab	33.32ab	73.82ab	253ab	208ab	461ab
T_{10} : PKMoB	40.65ab	26.27abc	66.91ab	254ab	164abc	418ab
T_{11} PKMoB+Inoculum	47.66a	35.29a	82.21a	297a	220a	518a
T_{12} : NPKMoB	47.63a	35.05a	82.68a	297a	219a	516a
Level of significance	**	**	**	**	**	**
LSD (0.05)	11.01	8.17	15.27	68.78	51.04	95.43
CV (%)	19.5	20.3	15.8	19.5	20.3	15.8

In a column, means followed by a common letter are not significantly differed at 5% level by DMRT