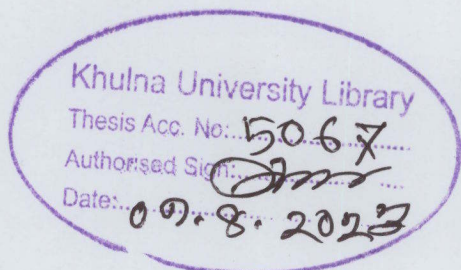


**EFFECT OF RHIZOBIUM INOCULUM AND NITROGEN
ON THE YIELD AND YIELD ATTRIBUTES OF
MUNGBEAN CV. Binamoog-5 (*Vigna radiata* L. Wilczek)**



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ABSTRACT

An experiment was conducted at the Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna during the period from April to June 2011 to study the effect of *Rhizobium* inoculum and nitrogen dose on the yield and yield attributes of mungbean cv. Binamoog-5. The experimental treatments included three levels of *Rhizobium* inoculum viz. i) without *Rhizobium* inoculum (B_0), ii) 50% recommended dose of *Rhizobium* inoculum @ 0.75 kg ha^{-1} (B_1) iii) 100% recommended dose of *Rhizobium* inoculum @ 1.5 kg ha^{-1} (B_2) and four levels of nitrogen viz. i) without nitrogen (Control) (N_0), ii) 50% recommended dose of nitrogen @ 8 kg ha^{-1} (N_1), iii) 100% recommended dose of nitrogen @ 16 kg ha^{-1} (N_2) and iv) 150% recommended dose of nitrogen @ 24 kg ha^{-1} (N_3). The experiment was laid out in a randomized complete block design with three replications. Experimental data on plant height, number of branches plant⁻¹, number of fertile pods plant⁻¹, number of sterile pods plant⁻¹, number of total pods plant⁻¹, pod length, number of seeds pod⁻¹, weight of 1000-seed, seed yield, stover yield, biological yield and harvest index were collected and analyzed statistically. All the yield and yield attributes expect 1000 seed weight varied significantly due to the effect of *Rhizobium* inoculum, nitrogen dose and their interaction. In case of *Rhizobium* inoculum, 100% dose (1.5 kg ha^{-1}) performed the best while among nitrogen doses 100% N (16 kg N ha^{-1}) showed the best results. Combined application of *Rhizobium* and nitrogen showed that treatment with 100% *Rhizobium* (1.5 kg ha^{-1}) and 50% N (8 kg N ha^{-1}) (B_2N_1) produced the highest seed yield (1.59 t ha^{-1}), followed by 50% *Rhizobium* (0.75 kg ha^{-1}) with 150%N (24 kg ha^{-1}) treatment. The lowest seed yield was obtained from control treatment (no *Rhizobium*+no nitrogen). So, at least 50% nitrogen could be saved by using *Rhizobium* biofertilizer without significant yield loss in mungbean.

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CONTENT

CHAPTER	TITLE	PAGE NO.
	ABSTRACT	
	Acknowledgement	i
	CONTENT	iii
	LIST OF TABLES	vi
	LIST OF FIGURES	vii
	LIST OF APPENDICES	viii
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	3
	2.1 Effects of <i>Rhizobium</i> inoculum on Variety	3
	2. 2 Effects of Integration of <i>Rhizobium</i> inoculum with Nitrogen	6
III	MATERIALS AND METHODS	14
	3.1 Experimental Site and Soil	14
	3.2 Climate and Weather	14
	3.3 Experimental Treatments	15
	3.4 Experimental Design and Layout	15
	3.5 Collection of <i>Rhizobium</i> inoculum as Biofertilizer	15
	3.6 Land Preparation	16
	3.7 Planting Materials	16
	3.8 Fertilizer Application	16
	3.9 Seed Inoculation and Sowing	16
	3.10 Intercultural Operations	17
	3.11 General Observations	17

CONTENT (Contd.)

CHAPTER	TITLE	PAGE NO.
	3.12 Determination of Maturity	17
	3.13 Sampling and Harvesting	17
	3.14 Threshing	17
	3.15 Drying, Cleaning and Weighing	17
	3.16 Recording of Data	18
	3.17 Data Recording Procedure	18
	3.18 Analysis of Data	20
IV	RESULTS AND DISCUSSION	21
	4.1 Effect of <i>Rhizobium</i> inoculum on yield and yield attributes of mungbean cv. Binamoog-5	21
	4.1.1 Plant height	21
	4.1.2 Number of branches plant ⁻¹	21
	4.1.3 Number of fertile pods plant ⁻¹	22
	4.1.4 Number of sterile pods plant ⁻¹	22
	4.1.5 Number of total pods plant ⁻¹	22
	4.1.6 Pod length	22
	4.1.7 Number of seeds pod ⁻¹	22
	4.1.8 1000-seed weight	25
	4.1.9 Seed yield	25
	4.1.10 Stover yield	25
	4.1.11 Harvest index (%)	25
	4.2 Effect of nitrogen level on yield and yield attributes of mungbean cv. Binamoog-5	27
	4.2.1 Plant height	27
	4.2.2 Number of branches plant ⁻¹	27
	4.2.3 Number of fertile pods plant ⁻¹	27
	4.2.4 Number of sterile pods plant ⁻¹	27

CONTENT (Contd.)

CHAPTER	TITLE	PAGE NO.
	4.2.5 Number of total pods plant ⁻¹	27
	4.2.6 Pod length	29
	4.2.7 Number of seeds pod ⁻¹	29
	4.2.8 1000-seed weight	29
	4.2.9 Seed yield	29
	4.2.10 Stover yield	31
	4.2.11 Harvest index (%)	31
	4.3 Interaction effect of <i>Rhizobium</i> inoculum and nitrogen dose on yield and yield attributes of mungbean cv. Binamoog-5	31
	4.3.1 Plant height	31
	4.3.2 Number of branches plant ⁻¹	31
	4.3.3 Number of fertile pods plant ⁻¹	33
	4.3.4 Number of sterile pods plant ⁻¹	33
	4.3.5 Number of total pods plant ⁻¹	33
	4.3.6 Pod length	35
	4.3.7 Number of seeds pod ⁻¹	35
	4.3.8 1000-seed weight	35
	4.3.9 Seed yield	35
	4.3.10 Stover yield	37
	4.3.11 Harvest index (%)	37
V	SUMMARY AND CONCLUSION	39
	REFERENCES	43

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
1	Effect of <i>Rhizobium</i> inoculum on the yield attributes of mungbean cv. Binamoog-5	23
2	Effect of integration dose on the yield attributes of mungbean cv. Binamoog-5	28
3	Effect of interaction of <i>Rhizobium</i> inoculum and nitrogen dose on the yield attributes of mungbean cv. Binamoog-5	34

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1	Effect of <i>Rhizobium</i> inoculum on fertile pods plant ⁻¹ , sterile pods plant ⁻¹ and total pods plant ⁻¹ of mungbean cv. Binamoog-5	24
2	Effect of <i>Rhizobium</i> inoculum on seed yield (tha ⁻¹) and stover yield (t ha ⁻¹) of mungbean cv. Binamoog-5	26
3	Effect of nitrogen dose on fertile pods plant ⁻¹ , sterile pods plant ⁻¹ and total pods plant ⁻¹ of mungbean cv. Binamoog-5	30
4	Effect of nitrogen dose on seed yield (tha ⁻¹) and stover yield (t ha ⁻¹) of Mungbean cv. Binamoog-5	32
5	Interaction effect of <i>Rhizobium</i> inoculum and nitrogen dose on seed yield (t ha ⁻¹) of mungbean cv. Binamoog-5	36
6	Interaction effect of <i>Rhizobium</i> inoculum and nitrogen dose on stover yield (t ha ⁻¹) of mungbean cv. Binamoog-5	38



CHAPTER I

INTRODUCTION

In Bangladesh, the main source of protein readily available to the bulk of the population is plant protein. The total production of pulses in Bangladesh is only 0.5 million tons against a high demand of 2.7 million tons annually. Even under such a situation there has been a consistent decrease in area and production of the pulse crops particularly during the last two decades. Mungbean is a superior pulse among the other pulses taken by the people of Bangladesh and the Sub-continent. However, recently it holds the third position in area (27.32 thousand hectares) and production (25 thousand tons) among the pulse crops in Bangladesh (BBS, 2010). The production of mungbean has been steadily decreasing due to reduction in area under mungbean cultivation because of mounting competition from other profitable crops, poor management and use of low yielding local varieties.

Cultivation of mungbean can improve the physical, chemical and biological properties of soil as well as increase soil fertility status through biological nitrogen fixation with symbiont *Rhizobium* inoculum from the atmosphere. On the other hand, fitting summer mungbean into usual rice-based cropping pattern may also make the farmers interested in cultivation of mungbean. Therefore, to meet the situation, it is necessary to boost up the production of a summer mungbean through adoption of appropriate technology.

Nitrogen constitutes one of the major essential plant nutrients, and the successful crop production depends mainly upon the availability of nitrogen in adequate amounts. Yet nitrogen is perhaps the single most important factor limiting the crop yields. It is an important major nutrient element for plant. For legumes, it is more useful because it is the main component of amino acids as well as proteins. Adequate supply of nitrogen is essential for normal growth and yield (Mozumder *et al.*, 2003). Without N it is not possible to synthesize the necessary proteins,

enzymes, DNA and RNA required in virtually all plant cells for their initial development, sustained growth and functioning to support other tissues of the plant. So, deficiencies in reduced N necessarily results in less biochemical machinery to catalyze plant metabolism and to generate new cells. Consequently, nitrogen deficiencies result in decreased crop leaf area, photosynthetic assimilation and seed growth (Sinclair and Vadez, 2002).

Seed inoculation with fertile *Rhizobium* inoculum can play a vital role in the formation of nodules to fix atmospheric nitrogen by symbiotic process in the root system of legume crops making the nutrient available to the plants. Bangladesh Institute of Nuclear Agriculture (BINA) has already selected some fertile *Rhizobium* inoculum 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 *Rhizobium* inoculum strains, which is known to influence nodulation, nitrogen fixation, growth and yield of mungbean. In Bangladesh, inoculation with *Rhizobium* increased 57% fertile nodule, 77% dry matter production, 64% seed yield and 40% hay yield over uninoculated control in mungbean cultivation has been reported (Chanda *et al.*, 1991).

Thus the present research was conducted to evaluate the effect of integration of *Rhizobium* biofertilizer with nitrogen fertilizer on mungbean production. Keeping all these in view, the present study was undertaken with the following objectives:

- To observe the combined effect of *Rhizobium* inoculum and nitrogen fertilizer on the yield and yield contributing characters of mungbean cv. Binamoog-5.

CHAPTER II

REVIEW OF LITERATURE

Research on mungbean is being carried out extensively in many countries of the world including Bangladesh and the South East Asian countries for its improvement of yield and quality. In Bangladesh the Pulses Research Centre at Ishwardi, under Bangladesh Agricultural Research Institute (BARI), and Bangladesh Institute of Nuclear Agriculture (BINA) have started research for improvement of this crop.

The effects of integration of biofertilizer inoculation with nitrogen on the performance of yield and yield attributes of mungbean (*Vigna radiata* L. Wilczek) varieties have been reviewed in this chapter.

2.1 Effects of *Rhizobium* inoculum on variety

It has been observed from a large number of field experiments at home and abroad that the growth and yield of mungbean were significantly affected by the seed inoculation with *Rhizobium* biofertilizer. It was reported by Almas *et al.* (2004) that yield of green gram with *Rhizobium* inoculum was higher than normal. Nadeem *et al.* (2004) found that the number of bearing branches plant⁻¹, number of seeds pod⁻¹, 1000-seed weight and yield were significantly affected by seed inoculation.

Mohammad and Hossain (2003) reported that biofertilizer significantly increased seed germination and decreased incidence of foot and root rot of mungbean. Treatment of seeds of Binamoog-3 with biofertilizer showed 5.67% increase in germination over control, but in case of Binarnoog-4 it was 10.81%. Biofertilizer resulted 77.79% reduction of foot and root rot disease incidence over control in Binamoog-3 and 76.78% reduction of foot and root rot disease in Binamoog-4. Seed treatment with biofertilizer also produced up to 20.83% highest seed yield (t ha⁻¹) over untreated control in Binamoog-3.

Singh *et al.* (2004) conducted a field experiment in Ludhiana, Punjab, India during summer season and observed that among the mungbean genotypes (SML 134, SML 357 AND SML 668) significantly higher number of branches plant⁻¹ and pods plant⁻¹ were in SML 357 and SML 134, whereas pod length, 1000-seed weight and seed yield were higher in SML 668. Straw yield was highest in SML 134 but in case of harvest index it was lowest.

It was reported in Bangladesh condition that Barimoog-5 contributed higher seed yield than Barimoog-2. Binamoog-5 had the highest number of branches plant. The highest number of pods plant⁻¹ was recorded for Barimoog-3. Pod length was greatest in Barimoog-5. The lowest seed yield and harvest index were recorded for Barimoog-3 (Sarkar *et al.* 2004).

Taj *et al.* (2003) conducted an experiment with 5 mungbean cultivars (NM-92, NM 19-19, NM 121-125, N/41 and a local cultivar) during summer season in Pakistan. They found that among the cultivars, NM 121-125 recorded the highest average number of pods plant⁻¹ (18.18), number of seeds pod⁻¹ (9.79), 1000-seed weight (28.09 g) and seed yield (446.07 kg ha⁻¹).

Parameswarappa and Lamani (2003) conducted field experiment in India to evaluate the performance of 6 green gram cultivars (SEI-4, GMBL-1, GMBL-2, TM-97-55, SEL-3 and M-1) and found the SEL-4 was the most suitable genotype for seed yield, plant height, pods plant⁻¹, seed weight, days to flowering and days to maturity.

Ahmed *et al.* (2003) conducted a pot experiment in Bangladesh on the growth and yield of mungbean cultivars Kanti, Barimoog-4, Barimoog-5, BAUmung-1 and Binamoog-5. The seed yield of Kanti, Barimoog-3 and Barimoog-4 were higher than those of the rest of the cultivars.

Santella *et al.* (2001) evaluated the performance of 7 mungbean cultivars (Testigo, VC 1973C, VC 4443 A, VC 2768A, VC 1973A, ML 267 and NM 94) in a field experiment conducted in Venezuela. They reported that the

number of pods per plant, pod length, number of seeds pod⁻¹, 1000-seed weight and yield ranged from 31.75 to 53.00, 7.48 to 9.58 cm, 8.59 to 9.85, 34.18 to 63.23 g and 1175.05 to 1815.05 kg ha⁻¹, respectively.

In a field experiment, carried out by Nayak and Patra (2000) evaluated eight improved and 4 local mungbean cultivars. Results of their study revealed that yield was 0.45-0.63 tha⁻¹ in the improved cultivars and 0.61-1.01 tha⁻¹ in the local cultivars.

Selim (1999) conducted a field experiment during summer season in Egypt to evaluate productivity of six *Vigna radiata* genotypes (Kawamy-1, Giza-1, VC-1000, VC-2719, T-44 and M-53). He noticed that highest seed yield feddan⁻¹ (1088 kg feddan⁻¹) was obtained from Kawamy-1 followed by T-44 (1056 kg feddan⁻¹) and VC-1000 (981 kg feddan⁻¹).

Mitra *et al.* (1999) conducted a field experiment in India during the *Kharif* (rainy) seasons of 1996 and 1997 to study the effects of cultivars on the growth and seed yield of mungbean. They observed that Mungbean cv. GM-9002 had greater dry matter (at harvest), number of pods plant⁻¹, number of seeds pod⁻¹, 1000-seed weight, seed yield and total biomass yields than cv. UPM-12 or MH-309.

Mohanty *et al.* (1998) observed that among nine mungbean (*Vigna radiata*) cultivars, Kalamung was the best performing cultivar, with a potential seed yield of 793.65 kg ha⁻¹, the highest number of pods plant⁻¹ (18.67) and highest number of seeds pod⁻¹ (10.43). Days to 50% flowering were 56 days, compared to Anandpur and TARM-2 (51 and 52 days, respectively).

In a field experiment, carried out by Velu (1998) in India during *Kharif* season of 1991 and mungbean cv. Co 4, NARP I and Co GG 89047 were grown in the experimental field and reported that NARP I and Co GG 89047 resulted in higher seed yield.

Gebologlu *et al.* (1997) carried out a field experiment to study the performance of *Vigna radiata* cultivar and found that different varieties had different potentials in respect of seed yield. They recorded that the cultivar VC 3301A produced the best yield in comparison to VC 3945A, VC 4176A, VC 3746A and VC 2468A.

Srivastava and Srivastava (1996) in their experiment with mungbean (*Phaseolus radiata* and *Vigna radiata*) varieties found that variety PS 16, K851, Sunaina and PDM 11 produced higher yields than others. Kanakamany *et al.* (1996) conducted an experiment with twelve genotypes of *Vigna radiata* during summer 1995 in India, and found that cv. WGG 62 gave the highest yields among the genotypes tested. They also found that this high yield was contributed due to the higher number of pods plant⁻¹

Sinha *et al.* (1996) conducted a field experiment in Bihar with 40 mungbean cultivars. They found that significant variation existed among the cultivars for plant height, pods plant⁻¹ and single plant yield. BINA (1998) reported that MC-18 (Binamoog-5) produced higher seed yield over Binamoog-2. Field duration of Binamoog-5 was 78 days to mature while 82 days for Binamoog-2.

Thakuria and Shaharia (1990) reported that different varieties of mungbean differed significantly in plant height, 1000-seed weight and seed yield. Choi *et al.* (1991) conducted an experiment including nine mungbean varieties and concluded that the cultivar Seonhwanogdu performed better than others.

2. 2 Effects of Integration of *Rhizobium* inoculum with Nitrogen

Chatterjee and Bhattacharjee (2002) carried out an experiment to study the effect of inoculation with *Rhizobium* sp. and phosphate solubilizing bacteria (PSB) on the nodulation and seed yield of mungbean cv. B-1 at West Bengal, India and reported that plants inoculated with *Rhizobium* strains and PSB showed increased rate of nodulation, N content and seed yield over control.

Singh and Tarafdar (2001) conducted a field study in India to determine the effects of *Rhizobium* (strain M-10) on the yield and quality of summer-grown *V. radiata* and found that inoculation significantly increased the number of nodules, crop biomass, dry matter production (by 14%), seed (by 16%) and straw yields.

Bhattacharyya and Pal (2001) carried out field experiment in West Bengal, India during the *pre-Kharif* season of 1998 to study the effect of *Rhizobium* inoculation on mungbean and reported that inoculation significantly influenced the number of nodules plant⁻¹, dry matter accumulation in shoot, crop growth rate and plant height.

Kavathiya and Pandey (2001) carried out a pot experiment during the summer season of 1992-93 at College of Agriculture, S.K. Nagar, Gujrat, India to study the interaction of *Macrophomina phaseolina*, *Meloidogyne javanica* and *Rhizobium* on mungbean (*Vigna radiata* cv.K 851). Observations on seed germination, plant height, fresh shoot weight, root weight, number of nodules plant⁻¹, number of nematode galls plant⁻¹ from 45 days after sowing were recorded and the % of reduction/increase in each character was calculated. 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) were recorded in the *Rhizobium* treatment.

Chowdhury *et al.* (2000) carried out a pot experiment during *kharif* season in 1995 with mungbean in Salna, Bangladesh where mungbean line NM92 was inoculated with *Rhizobium* strain TAL 303. They reported that dry matter production increased with *Rhizobium* inoculation compared to uninoculation.

Upadhyay *et al.* (1999) carried out a field experiment where green gram seed was inoculated with *Rhizobium* or not inoculated and 0-60 kg P₂O₅ ha⁻¹ was given. They observed that seed yield was higher with inoculation (2.02 vs. 1.87 t ha⁻¹) and increased with upto 40 kg P₂O₅ (2.01 t ha⁻¹).

Provorov *et al.* (1998) observed that seed inoculation of mungbean (*Vigna radiata*) with strain CIAM 1901 of *Rhizobium* increased the herbage mass by 46.6%, seed mass by 39.2%, 1000 seed weight by 16.0%, seed N 30.0% and number of root nodules by 254.0%. These results were equivalent to applying 120 kg N ha⁻¹

Bhuiyan *et al.* (1998) stated that *Rhizobium* seed inoculation with 1 kg Mo ha⁻¹ and 1 kg B ha⁻¹ increased nodule number, nodule and shoot weight and seed yield compared with the control. Seed yield was 107% and 148% higher over control in two consecutive growing seasons.

Sharma and Khurana (1997) studied the fertility of single and multistrain inoculants in field experiment with summer mungbean variety SML32 and found that seed yield was superior in multistrain inoculants. On an average, single strain and multistrain *Rhizobium* inoculants increased the seed yield by 10.4% and 19.3% over uninoculated control respectively.

Patra and Bhattacharyya (1997) reported that in a field trial, *Vigna radiata* cv. B-1 was inoculated with *Rhizobium* and/or given 25 kg urea ha⁻¹. All treatments increased nodulation compared with control, with the highest nodule numbers and seed yield was higher with *Rhizobium* + 25 kg urea per hectare.

Thakur and Panwar (1995) carried out an experiment where mungbean cv. Pusa-105 and PS-16 were given the following treatments; seed inoculation with *Rhizobium* inoculum, soil inoculation with VAM fungus (*Glomus fascicula* Hum) or combination of both. Inoculation, either singly or combined increased plant height, leaf area, photosynthetic rate and total dry matter (DM) production compared with no inoculation.

Sattar and Ahmed (1995) conducted a field experiment at the farm of Rajbari Testing Station, BARI, Dinajpur on mungbean inoculated with *Rhizobium* inoculum and reported significant increase in hay and total protein yield.

Badole and Umale (1995) carried out a field experiment during the rainy season of 1990 with green gram (*Phaseolus radiatus*) cv. TAP 7, application of no fertilizers (not specified) gave seed yields of 0.92, 1.04, 1.17, 1.13 and 0.99 t ha⁻¹, respectively. Seed treatment in a magnetic field (200 gauzes) or with ammonium molybdate + Iron oxide + Potassium dihydrogen phosphate or seed inoculation with *Rhizobium* gave seed yields of 1.26, 1.01 and 1.02 t ha⁻¹, respectively.

Sarker *et al.* (1993) reported that *Rhizobium* inoculation along with P application and *Rhizobium* inoculation along with *Azotobacter chroococcum* were equally fertile in enhancing seed yield of green gram. Sharma *et al.* (1993) observed that in pot experiments seed and straw yield of *Vigna radiata* cv. Pusa Baishakhi increased with increase P up to or equivalent to 60 kg P ha⁻¹ and with *Rhizobium* inoculation and with a starter dose of nitrogen.

Rao and Rao (1993) carried out a pot experiment to study the effect of dual inoculation of blackgram (*Vigna mungo*) and greengram (*Phaseolus radiatus*) with VAM fungi, *Glomes mosseae* or *Glomus epigaeum* (both soil inoculated and seed inoculated). *Rhizobium* was studied and compared with plants which received dual inoculation showed significant increase in growth, P and N uptake, nodulation, leaf chlorophyll and total soluble sugars, total phenols and free amino acids contents in roots compared with those inoculated with *Rhizobium*.

Khurana and Poonam (1993) studied the *Rhizobium* inoculum strains (LMR 107, KM 1, M 10, GMBS I and MO 5) and *Vigna radiata* cv. ML 267 and PS 16, under field condition. Seed inoculation with *Rhizobium* inoculum strains increased the seed yield by 21.5% and 35.1 % over uninoculated control.

Chovatia *et al.* (1993) carried out a field experiment on clay soil during the summer season of 1989 at Narasari, Gujrat. Greengram (*Phaseolus radiatus*) cv. K 851 was seed inoculated with *Rhizobiurn* or not inoculated and found that seed yields were highest with seed inoculation (0.92 vs. 0.87 t ha⁻¹).

Chowdhury and Rosario (1992) carried out an experiment to determine the effects of Rhizobial inoculation on the growth and yield performance of mungbean at los Banos, Philippines in 1988. They observed that seed inoculation with *Rhizobium* increased seed yield and dry matter of mungbean.

Pandher *et al.* (1991) reported that inoculation of *Vigna radiata* cv. ML 131 with single and multiple strains of *Rhizobium* increased root nodule number and seed yield. Multiple strain inoculation did not increase dry weight (DW) of plants and nodule compared to uninoculated controls.

Singh and Kumari (1990) reported that *Vigna radiata* seed when inoculated with *Rhizobium* increased Mn and P content in seeds and straw and N content in straw only. Chanda *et al.* (1991) reported that *Rhizobium* inoculums responded positively with the varieties of mungbean viz., MB87 and MB246. Dry matter production increased 77% due to inoculation over the non-inoculated (control).

Basu and Bandyopadhyay (1990) carried out a field trial during the *Kharif* season in West Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or JCa-1, and grown in presence of 30-40 kg N ha⁻¹. Inoculation increased number of pods plant⁻¹ and seeds pod⁻¹ and N uptake. JCa- 1 was superior to M-10, and number of pods plant⁻¹, number of seeds pod⁻¹, 1000-seed weight and N uptake increased with increasing N rates up to 30 kg N ha⁻¹.

Ghosh (2004) from a pot experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh with different levels of nitrogen indicated that number of branches plant⁻¹ was gradually increased with increasing N level @ 25 kg N ha⁻¹

Masud (2003) conducted a plot experiment at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh and observed the highest plant height with the application of 30 kg N ha⁻¹ while Ghosh (2004) found highest plant height at 25 kg N ha⁻¹.

Srinivas *et al.* (2002) conducted an experiment and stated that the effects of N (0, 20, 40 and 60 kg ha⁻¹) along with seed inoculation with *Rhizobium* culture on the growth, yield and yield components of green gram. They observed that number of pods plant⁻¹, pod length and number of seeds pod⁻¹ were increased with increasing rates of N up to 40 kg ha⁻¹.

Pathak *et al.* (2001) conducted an experiment in India to study the effect of N levels (0, 10, 20 or 30 kg ha⁻¹) on growth and yield of green gram under rainfed conditions during the summer of 1999. Application of 20 kg N ha⁻¹ yielded at par with that of 30 kg N ha⁻¹ whereas it had higher yield than 10 kg ha⁻¹ and no nitrogen treatments.

Provorov *et al.* (1998) carried out an experiment on the effect of inoculation on the seed production of mungbean grown in Uzbekistan. They observed that seed inoculation of mungbean with strain CIAMI 901 of *Rhizobium* inoculum increased the seed mass by 39.2% and 1000-seed weight by 16%. These results were equivalent to applying 120 kg N ha⁻¹. Best results were obtained with inoculations +60 kg N ha⁻¹.

Mozumder (1998) carried out a field trial at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March to June 1994 to study the effects of five nitrogen levels on two varieties of summer mungbean and reported that nitrogen produced negative effect on nodule production and starter dose of (nitrogen 40 kg ha⁻¹) gave the maximum seed yield (1607 kg ha⁻¹).

Quah and Jaffar (1994) noted that seed yield of mungbean increased significantly by the application of nitrogen fertilizer at 50 kg ha⁻¹. Kaneria and Patel (1995) conducted a field experiment on a vertisol in 1989-91 in Gujrat, India where mungbean cv. K 581 was sown and given 0 or 20 kg N ha⁻¹. The application of 20 kg N ha⁻¹ to mungbean significantly increased the seed yield from 1.08 (no nitrogen) to 1.14 t ha⁻¹.

Santos *et al.* (1993) conducted an experiment on mungbean cv. Berken, grown in pots in podzolic soil using 7 levels of N (0, 25, 50, 100, 200, 400 and 500 kg per ha) and NH_4NO_3 . They noted that nodule number increased strongly, between flowering and maturity; in plants grown at 100 kg N ha⁻¹, suggesting a delay in nodulation occurred. Poor nodulation and depletion of soil N as indicated by the low N concentration in the young mature level at the maturity. Plants grown at 400 and 500 kg N ha⁻¹ failed to nodulate.

Gopala *et al.* (1993) carried out a field trial to find out the response of mungbean cultivars (Pusa Baishakhi, LGG 407, LGG 410 and MS 267) to a uniform dose of 20 kg N ha⁻¹. It was concluded that plant height, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) increased at 20 kg N ha⁻¹. Tank *et al.* (1992) followed that mungbean fertilized with 20 kg N ha⁻¹ could be assigned significantly higher number of pods plant⁻¹ over the unfertilized control.

Chowdhury and Rosario (1992) had undertaken a study to point out the effects of 0, 30, 60 or 90 kg N ha⁻¹ on the growth and yield performance of mungbean at Los Banos, Philippines. They noted that application of N at the levels above 30 kg ha⁻¹ reduced the seed yield.

Tank *et al.* (1992) observed that mungbean fertilized with 40 kg N ha⁻¹ produced the highest seed yield plant⁻¹ while the lowest was observed in control treatment condition (0 kg N ha⁻¹). Leelavathi *et al.* (1991) reported that different levels of nitrogen showed significant difference in seed yield of mungbean upto certain level (60 kg N ha⁻¹).

Suhartatik (1991) reported that N fertilizers significantly increased the plant height of mungbean. He also observed that N fertilizers significantly increased the number of pods plant⁻¹ of mungbean.

Agbenin *et al.* (1991) revealed that application of N significantly increased plant height, seed yield, dry weight, crop growth rate and nutrient uptake of mungbean over control.

A field experiment was carried out by Sarkar and Banik (1991), results showed that application of N improved plant productivity and significantly enhanced the seed yield of mungbean. The maximum seed yield was obtained from 20 kg N ha⁻¹. Both 10 and 20 kg N ha⁻¹ gave significantly higher seed yield over the control. Results also revealed that application of 10 kg N ha⁻¹ to mungbean resulted in appreciable improvement in yield attributes like 1000-seed weight over the control and straw yield increased by 24 percent.

Hamid (1991) evaluated the effects of foliar application of nitrogen on mungbean cv. Mubarik. In both pot and field trials 10 kg N ha⁻¹ increased number of pods plant⁻¹.

Murakami *et al.* (1990) reported that without N fertilizer, N fixation started at 12 days after sowing (DAS), increased rapidly at 34 DAS (flowering) to reach a peak at 45 DAS had a secondary peak at 60 DAS and then decreased until the plant died (83 DAS). With N fertilizer, N fixation started at 14 DAS, increased slowly to reach a much lower peak at 50 DAS and then decreased. Nodulation was greatly decreased by application of N, but fixation/unit nodule weight was similar in both N treatments. The percentage N derived from the air of 78 mungbean cultivars was 0-100% at 33 DAS and >60% in all cultivars at 60 DAS. They suggested that these cultivars may respond to applied N than high fixing cultivars.

From the detail discussion presented above, it appears that the *Rhizobium* inoculum and nitrogen had a significant effect on the growth and the yield performance of summer mungbean. So it is important to study the effect of integration of biofertiizer inoculation with nitrogen on the performance of summer mungbean varietie

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Field Laboratory, Agrotechnology Discipline Khulna University, Khulna from April to June 2011 (*Kharif* season) to study the effect of *Rhizobium* inoculum and nitrogen management on the yield and yield attributes of mungbean cv. Binamoog-5. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental Site and Soil

The experimental field was located at 23.75° North latitude and 89.25° East longitudes at an altitude of 18 m. The topography of the experimental field was medium low belonging the Agro-ecological Zone-13 (AEZ-13) named Ganges Tidal Flood Plain. The soil was clay loam in nature with a pH value of 7.4 (UNDP and FAO, 1988). The physical and chemical properties of the soil are presented in Appendix I.

3.2 Climate and Weather

The climate of the locality was sub-tropical. It was characterized by high temperature and heavy rainfall during April to September and low rainfall associated with moderately low temperature during October to March. During the experimental period, the maximum (35.05° C) and minimum (25.0°C) temperature were recorded in the month of April 2011 to June 2011 whereas maximum relative humidity (98.0%) and total rainfall (383 mm) were measured in June 2011. The prevailing weather condition i.e. temperature, rainfall and relative humidity during the period of study is presented in Appendix II.

3.3 Experimental Treatments

The study consisted of two factors viz. (A) *Rhizobium* inoculum and (B) Nitrogen doses

Factor A: *Rhizobium* inoculum

Legend

- | | |
|---|----------------|
| i) Without <i>Rhizobium</i> inoculum | B ₀ |
| ii) 50% recommended dose of <i>Rhizobium</i> inoculum @ 0.75 kg ha ⁻¹ | B ₁ |
| iii) 100% recommended dose of <i>Rhizobium</i> inoculum @ 1.5 kg ha ⁻¹ | B ₂ |

Factor B: Nitrogen doses

Legend

- | | |
|---|----------------|
| i) Without Nitrogen (Control) | N ₀ |
| ii) 50% recommended dose of Nitrogen @ 8 kg ha ⁻¹ | N ₁ |
| iii) 100% recommended dose of Nitrogen @ 16 kg ha ⁻¹ | N ₂ |
| iv) 150% recommended dose of Nitrogen @ 24 kg ha ⁻¹ | N ₃ |

Rhizobium inoculum was used as biofertilizer and urea was used as the source of nitrogen.

3.4 Experimental Design and Layout

The experiment was laid out in a two factors randomized complete block design with three replications. The size of the unit plot was 6 m² (3 m x 2.0 m) and was separated by 0.5 m wide bund. The blocks were separated by 0.5 m. In this experiment, total numbers of plots were 36. Each replication was divided into 12 unit plots where the treatment combinations were allocated at random.

3.5 Collection of *Rhizobium* inoculum as Biofertilizer

Liquid broth of BINA-MB mix culture, a mixture of three *Rhizobium* inoculum strains viz. BINA-MB-441, BINA-MB-169 and BINA-MB-301, was used in this experiment. The *Rhizobium* inoculum strains used in the present study were collected from the Soil Microbiology Laboratory of BINA, Mymensingh.

3.6 Land Preparation

The experimental plot was opened with a power tiller on 20 March 2011 and subsequently ploughed twice with country plough followed by laddering to achieve a medium tilth required for the crop. The land was finally prepared on 30 March 2011 by country plough followed by laddering.

3.7 Planting Materials

Binamoog-5

Planting materials used in this experiment was Binamoog-5 as HYV of mungbean. It was developed by BINA in 1998. Plant height of this variety ranges from 60 to 75 cm and seeds are light green in colour. It gives 30 to 40% more yield than Kanti. This variety requires 70 to 80 days to harvest after sowing. It is resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus. The yield potential of this variety varies from 1.2-1.45 t ha⁻¹.

3.8 Fertilizer Application

Nitrogen application was done as per experimental treatments. Other fertilizer doses were TSP (Tripple super phosphate) @ of 75 kg ha⁻¹ and MoP (Muriate of Potash) @ 35 kg ha⁻¹. All the fertilizers except nitrogen were used during final land preparation and the nitrogen fertilizer was applied as its split doses as per recommendation.

3.9 Seed Inoculation and Sowing

The quantity of seed for each plot (12 g) was weighed on the area basis @ 20 kg ha⁻¹ and kept in polythene bags. The seeds were mixed with molasses for adhering to the *Rhizobium* inoculum. Then the *Rhizobium* inoculum was mixed thoroughly with the seed and the seeds were placed in a cool dry place to avoid sticking together. The seeds were line sown on 3 April, 2011. After sowing, the seeds were covered with 100g soil to preserve moisture.

3.10 Intercultural Operations

First weeding was done at 20 days after sowing (DAS) and second weeding was done on 40 DAS. Irrigation was given at the early stages of crop growth. However, there was heavy rainfall on 22 April and 11 May 2011. Drainage was done to remove the excess water from the field at that time. The insecticide Malathion 57EC was sprayed @ 1.5 l ha⁻¹ at the time of 50% pod formation stage to control pod borer. The insecticide Nitro 55EC was sprayed @ 1.5 l ha⁻¹ at the flowering stage to control white fly and leaf insects.

3.11 General Observations

The crops were frequently monitored to note any change in plant characters. The crops looked good since the initial stage and they maintained a satisfactory growth till harvest.

3.12 Determination of Maturity

At the time when 80% of the pods turned brown in colour, the crop was assessed to attain its maturity.

3.13 Sampling and Harvesting

The crops were harvested from central 2.0 m² area of each plot for yield data on different dates as they attained maturity. For collecting yield and yield contributing characters, five randomly selected plants from each plot were uprooted carefully tagged properly and used for recording necessary data.

3.14 Threshing

The crop bundles were sun dried for two days by placing them on threshing floor. Seeds were separated from the plants by manually.

3.15 Drying, Cleaning and Weighing

The seeds thus collected were dried in the sun for reducing the moisture to about nearly 13% level. The dried seeds and straws were cleaned and weighed plot wise and the weight was converted into (t ha⁻¹).

3.16 Recording of Data on Yield and Yield Contributing Characters

Data were recorded on the following characters-

- i) Plant height (cm)
- ii) Number of branches plant⁻¹ (no)
- iii) Number of fertile pods plant⁻¹ (no)
- iv) Number of sterile pods plant⁻¹ (no)
- v) Number of total pods plant⁻¹ (no)
- vi) Pod length (cm)
- vii) Number of seeds pod⁻¹ (no)
- viii) 1000-seed weight (g)
- ix) Seed yield (t ha⁻¹)
- x) Stover yield (t ha⁻¹)
- xi) Harvest index (%)

3.17 Data Recording Procedure

A brief outline of data recording procedure is given below:

i) Plant height

The plant height was measured from ground level to the tip of the main stem after harvesting and was expressed in cm.

ii) Number of branches plant⁻¹

From each plot the number of branches plant⁻¹ was counted at harvest from 5 randomly selected plants.

iii) Number of fertile pods plant⁻¹

Pod bearing seed called fertile pod. The number of pods from 5 randomly selected plants of each plot was determined at the time of harvest to find out the number of fertile pods plant⁻¹.

iv) Number of sterile pods plant⁻¹

Pod that does not bears seed called sterile pod. The number of pods from 5 randomly selected plants of each plot was determined at the time of harvest to find out the number of sterile pods plant⁻¹.

v) Number of total pods plant⁻¹

The number of pods from 5 randomly selected plants of each plot was determined at the time of harvest to find out the total number of pods plant⁻¹.

vi) Pod length

Length of 15 pods from 5 randomly selected plants of each plot was measured with the help of a centimeter scale and their average value was recorded.

vii) Number of seeds pod⁻¹

Pods were separated and 5 pods from each of 5 randomly selected plants of each plot were taken randomly and the seeds were separated and counted. Then the average seed number pod⁻¹ was calculated.

viii) 1000-seed weight

The weight of 1000-seed was taken from seed lot of each plot.

ix) Seed yield

Plants of central 2 m² area of each plot were harvested at complete maturity. The seeds of each pod were separated from the plants manually and were dried in the sun to a constant weight. Seed yields were recorded plot wise and yields were then converted to ton per hectare basis.

x) Stover yield

After pod separation, the plants were sundried for several days to a constant weight. The stover was then weighed and expressed on ton per hectare basis.

xi) Harvest index (%)

Harvest index was calculated with the following formula:

$$\text{Harvest index} = \frac{\text{Seed yield}}{\text{Seed yield} + \text{Stover yield}} \times 100$$

3.18 Analysis of Data

The collected data were compiled and analyzed statistically using the analysis of variance technique and the differences among treatment means were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984) with the help of a computer based package programme MSTAT-C.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present experiment regarding the effect of *Rhizobium* inoculum and nitrogen dose on the yield and yield components of mungbean have been presented and discussed in this chapter. Summary of analysis of variance have been presented in Appendix III. Results along with different interaction combinations are presented in Tables 1-3 and Figures 1-6.

4.1 Effect of *Rhizobium* inoculum on yield and yield attributes of mungbean cv. Binamoog-5

Effect of *Rhizobium* inoculum on all studied characters of summer mungbean cv Binamoog-5 such as plant height, number of branches plant⁻¹, number of total pods plant⁻¹, number of fertile pods plant⁻¹, number of sterile pods plant⁻¹, average length of pod, number of seeds pod⁻¹, seed yield, stover yield, harvest index were statistically significant except 1000-seed weight (Appendix III).

4.1.1 Plant height

The tallest plant at harvest (62.35 cm) was obtained from 50% *Rhizobium* inoculum application and the lowest was in the control (without *Rhizobium* inoculum) (Table 1). Similar results were reported by Shukla and Dixit (1996) who stated that *Rhizobium* inoculum increased plant height of summer green gram.

4.1.2 Number of branches plant⁻¹

The highest number of branches plant⁻¹ (3.07) was recorded from 100% *Rhizobium* inoculum application. The lowest number of branches plant⁻¹ (0.46) was recorded from control treatment (without *Rhizobium* inoculum) *Rhizobium* inoculum (Table 1). Shukla and Dixit (1996) also observed that *Rhizobium* inoculation increased the number of branches plant⁻¹ in summer green gram (*Phaseolus radiatus*).

4.1.3 Number of fertile pods plant⁻¹

Number of fertile pods plant⁻¹ was significantly affected by *Rhizobium* inoculum. The highest number of fertile pods plant⁻¹ (25.99) was recorded from 50% *Rhizobium* inoculum treatment. The lowest number of fertile pods plant⁻¹ (10.55) was recorded from control treatment (Figure 1).

4.1.4 Number of sterile pods plant⁻¹

The highest number of sterile pods plant⁻¹ (2.49) was recorded from control treatment (B₀) which was statistically identical to B₁. The lower number of sterile pods plant⁻¹ (2.05) was recorded in 50% *Rhizobium* inoculum treatment (Figure 1).

4.1.5 Number of total pods plant⁻¹

Rhizobium inoculum plays a significant role in number of pods plant⁻¹. The highest number of pods (28.35) was observed from 100% *Rhizobium* inoculum treatment and the lowest number of pods plant⁻¹ (12.51) was observed in control treatment (Figure 1). Similar results were reported by Mohanty *et al.* (1998). They observed that among nine mungbean (*Vigna radiata*) cultivars, Kalamung was the best performing cultivar, with the highest number of pods plant⁻¹ (18.67) and higher number of seeds pod⁻¹ (10.43) compared to other cultivars.

4.1.6 Pod length

The longest pod (8.99 cm) was found in 50% *Rhizobium* inoculum treatment and the shortest pod length (6.74 cm) was obtained in control treatment (Table 1).

4.1.7 Number of seeds pod⁻¹

The highest number of seeds pod⁻¹ (11.58) was obtained from 100% *Rhizobium* inoculum treatment. The lowest number of seeds pod⁻¹ (9.72) was found from control treatment (Table 1). Farrag (1995) reported from a field trial, with 23 mungbean accessions that number of pods plant⁻¹, and number of seeds pod⁻¹ varied among the tested accessions.

Table 1. Effect of *Rhizobium* inoculum on the yield attributes of mungbean cv. Binamoog-5

Treatment	Plant height (cm)	Number of branches plant ⁻¹ (no.)	Pod length (cm)	Number of seeds pod ⁻¹ (no.)	1000-seed weight(g)	Harvest index (%)
B ₀	40.17c	0.46 c	6.74 c	9.717 c	35.22	43.45c
B ₁	62.35 a	2.17 b	8.99 a	10.55b	34.40	46.15a
B ₂	55.81 b	3.07 a	8.45 ab	11.58a	35.75	43.77b
Level of significance	0.05	0.01	0.05	0.01	NS	0.01
CV (%)	5.58	5.60	4.41	2.21	1.09	3.48

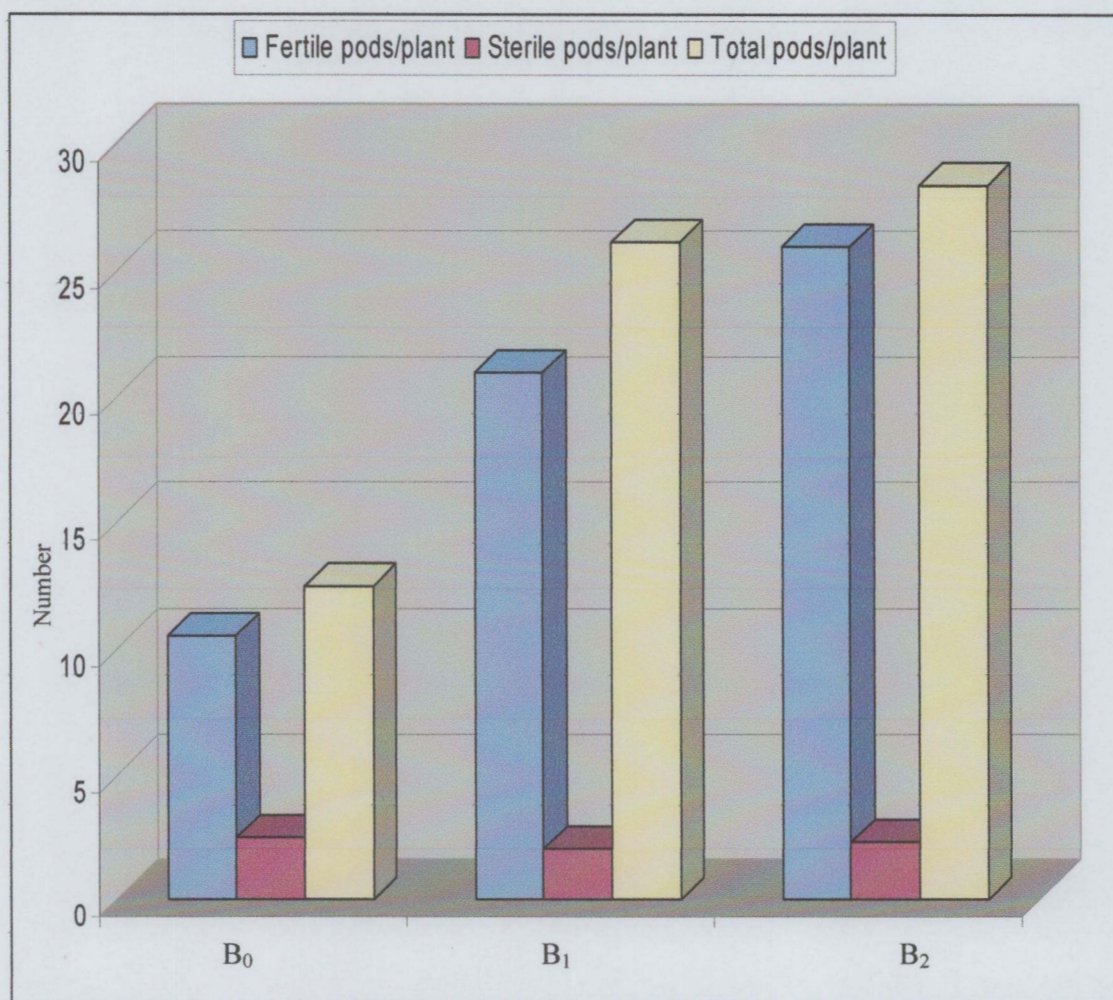
In a column having similar letter(s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

B₀ = Without *Rhizobium* inoculum (Control)

B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)

B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)

NS = Not Significant



Rhizobium inoculum

B₀ = Without *Rhizobium* inoculum (Control)

B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)

B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)

Figure 1. Effect of *Rhizobium* inoculum on fertile pods plant⁻¹, sterile pods plant⁻¹ and total pods plant⁻¹ of mungbean cv. Binamoog-5

4.1.8 1000-seed weight

Thousand seed weight was not significantly affected by *Rhizobium* inoculum. However, numerically the highest 1000-seed weight (35.75 g) was found in 100% *Rhizobium* inoculum treatment and the lowest 1000-seed weight (34.40 g) was obtained in 50% *Rhizobium* inoculum treatment (Table 1). However Kalita and Shah (1988) studied 19 cultivars of *Vigna radiata* and found that 1000-seed weight was the highest in Gajaral-2 and the lowest in ML 131.

4.1.9 Seed yield

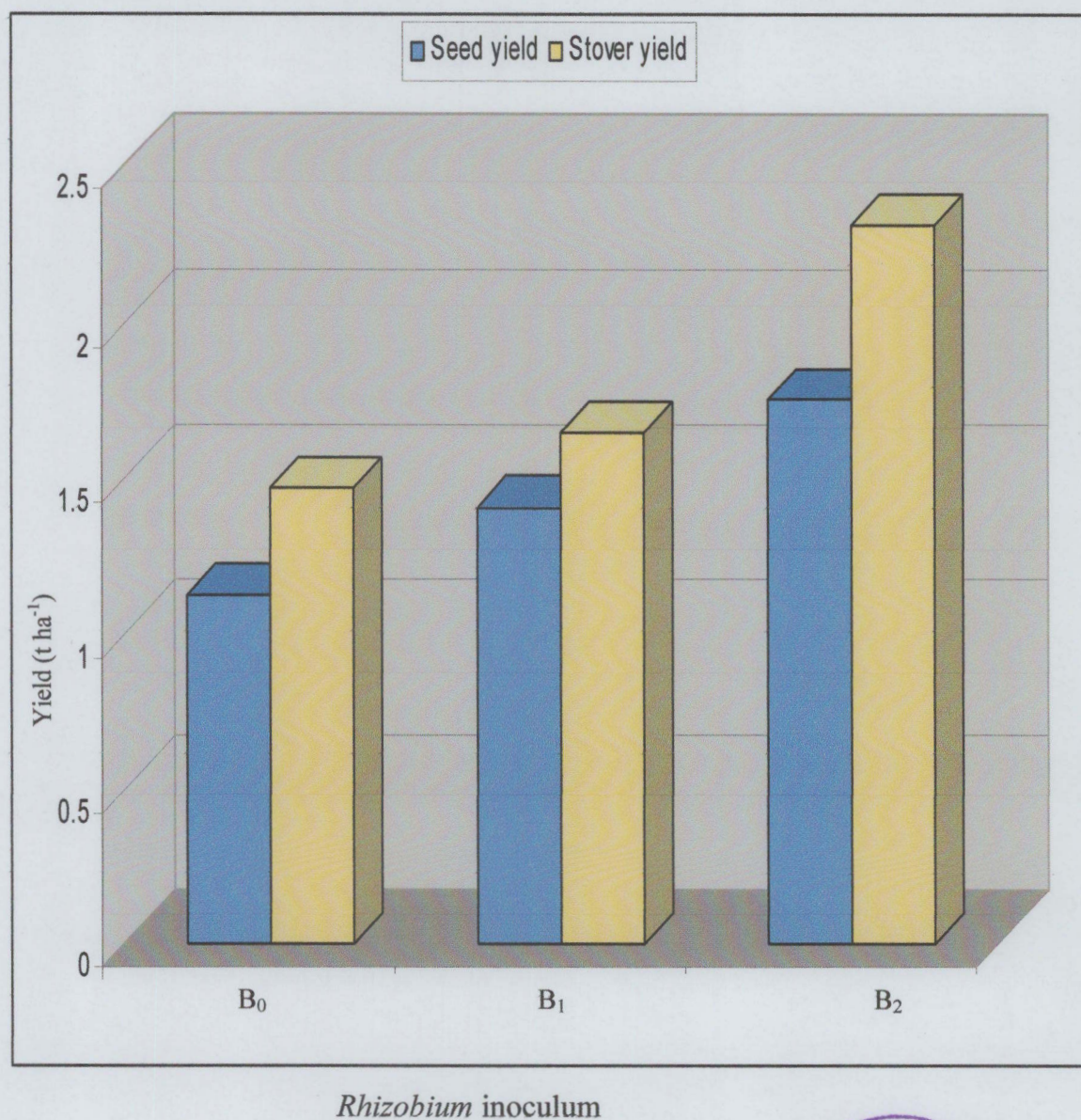
The highest seed yield (1.76 t ha⁻¹) was recorded from 100% *Rhizobium* inoculum treatment. The lowest seed yield (1.13 t ha⁻¹) was obtained from control treatment (Figure 2). This result indicates that higher seed yield may be obtained through 100% dose of *Rhizobium* that is 1.5 kg ha⁻¹. Normal dose of *Rhizobium* inoculum is effective on the vegetative and reproductive growth (seed yield) of summer mungbean. Ahmed *et al.* (1987) reported that the mungbean variety MB-55 (inoculated by *Rhizobium spp.*) produced the higher seed yield than MB-63 at all the three locations (Ishurdi, Kishoreganj and BINA).

4.1.10 Stover yield

The highest stover yield (2.31tha⁻¹) was found in 100% *Rhizobium* inoculum treatment. The lowest stover yield (1.47 t ha⁻¹) was obtained from control treatment (Fig. 2).

4.1.11 Harvest index (%)

The highest harvest index (46.15%) was found in 100% *Rhizobium* inoculum treatment. The lowest harvest index (43.45%) was found in control treatment (Table 1). Aguiar and Villareal (1989) observed that harvest index was significantly influenced by *Rhizobium* inoculum.



B₀ = Without *Rhizobium* inoculum (Control)
 B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)
 B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)



Figure 2. Effect of *Rhizobium* inoculum on seed yield (t ha⁻¹) and stover yield (t ha⁻¹) of mungbean cv. Binamoog-5

4.2 Effect of Nitrogen on Yield and Yield Attributes of Mungbean CV. Binamoog-5

4.2.1 Plant height

The tallest plant at harvest (48.25 cm) was obtained from 100% (16 kg ha⁻¹) nitrogen followed by 50% N (8 kg ha⁻¹) and the shortest plant height (43.57 cm) was found in control treatment (Table 2). Mitra (1989) reported that application of nitrogen increased plant height in grasspea and mungbean.

4.2.2 Number of branches plant⁻¹

The highest number of branches plant⁻¹ (2.08) was obtained from application of 100% N (16 kg ha⁻¹) (N₂). The lowest number of branches plant⁻¹ (1.53) was found from control treatment (Table 2). Nooden and Leopold (1998) reported that branch number increased in foliar application in legume which supported the result.

4.2.3 Number of fertile pods plant⁻¹

The highest number of fertile pods plant⁻¹ (19.73) was obtained from 100% N (16 kg ha⁻¹) treatment. The lowest number of fertile pods plant⁻¹ (15.45) was found from 150% N (24 kg ha⁻¹) treatment (Figure 3).

4.2.4 Number of sterile pods plant⁻¹

The highest number of sterile pods plant⁻¹ (2.74) was obtained from 50% N (8 kg ha⁻¹) treatment. The lowest number of sterile pods plant⁻¹ (2.00) was found from control treatment (Figure 3).

4.2.5 Number of total pods plant⁻¹

The highest number of pod production (22.06) was obtained from 100% N treatment. The lowest number of pod production (17.95) was found from control treatment (Fig. 3). Khan *et al.* (2002) observed that number of pods plant⁻¹ were in higher values in the uninoculated mungbean plants than inoculated plants.

Table 2. Effect of nitrogen dose on the yield attributes of mungbean cv. Binamoog-5

Nitrogen dose	Plant height (cm)	Number of branches plant ⁻¹ (no.)	Pod length (cm)	Number of seeds pod ⁻¹ (no.)	1000-seed weight (g)	Harvest index (%)
N ₀	43.57 d	1.53d	7.73 d	10.05d	32.89	43.16bcd
N ₁	46.17 b	1.86 b	7.90 a	11.32 ab	32.08	45.47a
N ₂	48.25 a	2.08 a	7.88 b	11.89 a	32.42	43.20bc
N ₃	44.57 c	1.68 c	7.78c	10.87 c	32.29	43.45b
Level of significance	0.05	0.01	0.01	0.01	NS	0.01
CV (%)	5.58	5.60	4.41	6.21	1.09	3.48

In a column having similar letter(s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

N₀= Without Nitrogen (Control)

N₁= 50 % Nitrogen (8 kg ha⁻¹)

N₂= 100 % Nitrogen (16 kg ha⁻¹)

N₃= 150 % Nitrogen (24 kg ha⁻¹)

NS = Not Significant

4.2.6 Pod length

The longest pod (7.90 cm) was obtained from 50% N (8 kg ha⁻¹) treatment. The shortest pod (7.73 cm) was found from control treatment (Table 2).

4.2.7 Number of seeds pod⁻¹

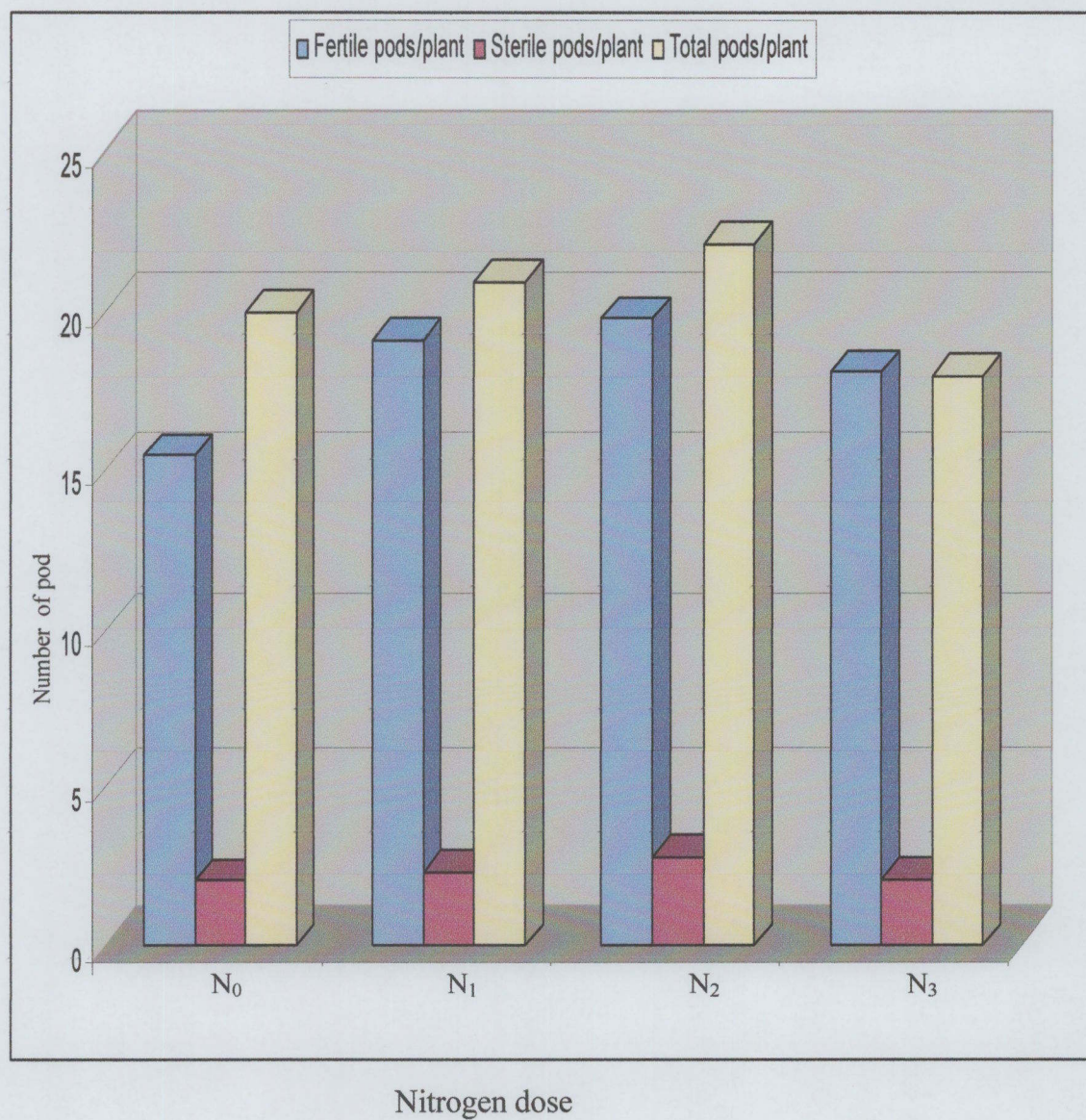
The highest number of seeds pod⁻¹ (11.89) was obtained from 100% N (16 kg ha⁻¹) treatment. The lowest number of seeds pod⁻¹ (10.05) was found from N₀ (control) treatment (Table 2).

4.2.8 1000-seed weight

There was no significant role of fertilizer dose on 1000-seed weight (Appendix III). However, numerically the highest 1000-seed weight (32.89 g) was found from control treatment and the lowest 1000-seed weight (32.08 g) was obtained from 50% N (8 kg ha⁻¹) treatment (Table 2).

4.2.9 Seed yield

The highest seed yield (1.45 t ha⁻¹) was recorded from 50% N (8 kg ha⁻¹) treatment which is followed by 50% N (8 kg ha⁻¹) treatment. The lowest seed yield (1.38 t ha⁻¹) was obtained from without N treatment (Fig. 4). This result indicates that maximum seed yield may be obtained through using lower dose of nitrogen (8 kg ha⁻¹). Grain yield reduced in 100% (16 kg ha⁻¹) and 150% (24 kg ha⁻¹) nitrogen treatment which may be the cause of higher vegetative growth resulted in higher stover yields in these treatments. It would be that a little or not nitrogen dose is effective where *Rhizobium* inoculum is used as nitrogenous fertilizer. Khan *et al.* (2002) reported that seed yield was highest in the uninoculated mungbean plants than inoculated plants.



N₀= Without Nitrogen (Control)

N₁= 50 % Nitrogen (8 kg ha⁻¹)

N₂= 100 % Nitrogen (16 kg ha⁻¹)

N₃= 150 % Nitrogen (24 kg ha⁻¹)

Figure 3. Effect of nitrogen dose on fertile pods plant⁻¹, sterile pods plant⁻¹ and total pods plant⁻¹ of mungbean cv. Binamoog-5

4.2.10 Stover yield

The highest stover yield (1.93 t ha⁻¹) was recorded from 100% N (16 kg ha⁻¹) treatment. The lowest stover yield (1.68 t ha⁻¹) was obtained from control treatment (Fig. 4). Gill *et al.* (1985) reported that normal dose of nitrogen significantly increased the straw yield of mungbean.

4.2.11 Harvest index (%)

The highest harvest index (45.47%) was found from 50% N (8 kg ha⁻¹) treatment. The lowest harvest index (43.10%) was obtained control treatment (Table 2). Gill *et al.* (1985) reported that normal dose of nitrogen significantly increased the harvest index of mungbean cultivars.

4.3 Interaction effect of *Rhizobium* inoculum and nitrogen dose on yield and yield attributes of mungbean cv. Binamoog-5

Rhizobium inoculum and nitrogen dose had combined significant influence on all observed plant characters, except 1000-seed weight of Binamoog-5 (Appendix III).

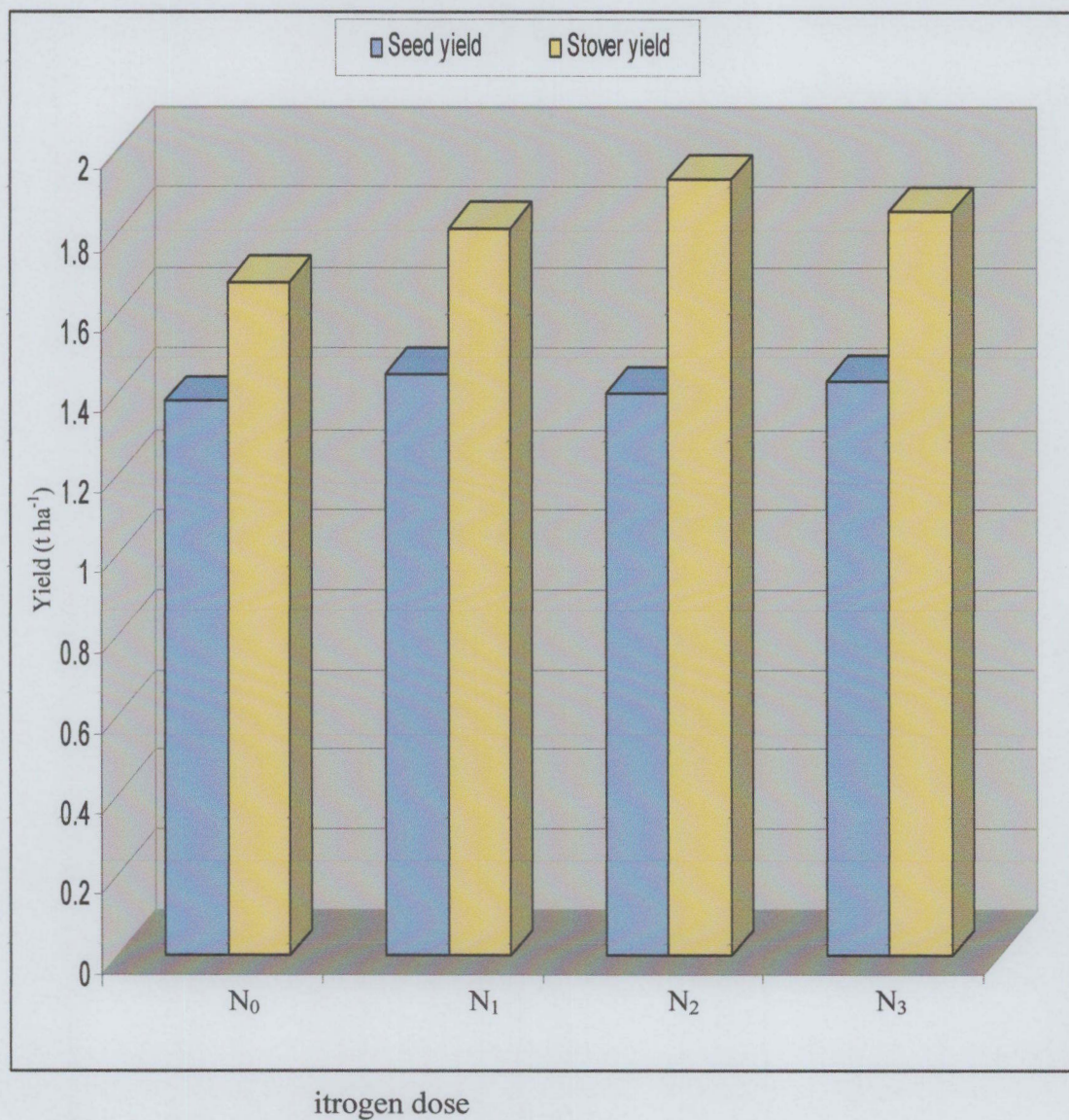
4.3.1 Plant height

It is evident that Binamoog-5 produced the tallest plant height (65.65 cm) with control treatment of *Rhizobium* inoculum and 100% N (16 kg ha⁻¹) followed by B₀N₁, B₀N₀. The shortest plant height (33.20 cm) was with 150% *Rhizobium* inoculum treatment and 50% N (B₂N₂) followed by B₂N₃ (Table 3)

4.3.2 Number of branches plant⁻¹

The highest number of branches plant⁻¹ (3.35) was obtained from 100% *Rhizobium* inoculum and 100% N (16 kg ha⁻¹) (B₁N₂) which was followed by B₂N₂. The lowest one (0.35) was obtained from treatment combination without *Rhizobium* inoculum and 150% N (B₀N₃) which was followed by B₀N₁ and B₀N₀

(Table 3). Basu and Bandyopadhyay (1990) carried out a field trial during the *kharif*



N₀= Without Nitrogen (Control)

N₁= 50 % Nitrogen (8 kg ha⁻¹)

N₂= 100 % Nitrogen (16 kg ha⁻¹)

N₃= 150 % Nitrogen (24 kg ha⁻¹)

Figure 4. Effect of nitrogen dose on seed yield (t ha⁻¹) and stover yield (t ha⁻¹) of mungbean cv. Binamoog-5

(monsoon) season in West Bengal where *Vigna radiata* was inoculated with *Rhizobium* inoculum strain M-10 grown in presence of 30-40 kg N ha⁻¹. N uptake increased with increasing N rates upto 30 kg N ha⁻¹. Nitrogen uptake decreased at the highest N application rate.

4.3.3 Number of fertile pods plant⁻¹

The highest number of fertile pods plant⁻¹ (27.45) was obtained from 100% *Rhizobium* inoculum treatment and 50% N (B₂N₁) followed by B₂N₂, B₂N₃. The lowest number of fertile pods plant⁻¹ (9.25) was obtained from 50% *Rhizobium* inoculum treatment and control treatment of N (B₁N₀) followed by B₀N₂, B₀N₀, B₀N₃ (Table 3).

4.3.4 Number of sterile pods plant⁻¹

The highest number of sterile pods plant⁻¹ (4.30) was obtained from 100% *Rhizobium* inoculum treatment and 50% N (B₂N₁) followed by B₂N₃, B₁N₂, B₁N₃. The lowest number of sterile pods plant⁻¹ (1.10) was obtained from control treatment (B₀N₀) which was statistically similar to B₁N₁, B₀N₁, and B₁N₀ (Table 3).

4.3.5 Number of total pods plant⁻¹

The highest number of pods plant⁻¹ (29.70) was found from 100% *Rhizobium* inoculum (recommended dose) treatment and 50% N (B₂N₁) followed by B₂N₃, B₂N₂. The lowest number of pods plant⁻¹ (11.85) was obtained from 0% *Rhizobium* inoculum treatment and 150% N (B₀N₃) followed by B₀N₀, B₀N₁ (Table 3).

Table 3. Effect of interaction of *Rhizobium* inoculum and nitrogen dose on the yield attributes of mungbean cv. Binamooog-5

<i>Rhizobium</i> x Nitrogen	Plant height(cm)	Number of branches plant ⁻¹	Fertile pods plant ⁻¹ (no.)	Sterile pods plant ⁻¹ (no.)	Total pods plant ⁻¹ (no.)	Pod length (cm)	Number of seeds pod ⁻¹ (no.)	1000-seed weight (g)	Harvest index (%)
B ₀ N ₀	61.78 c	0.50j	10.45ij	1.10l	12.35k	6.82h	9.30j	34.05	40.36l
B ₀ N ₁	63.80 b	0.45k	12.15h	2.20ij	13.05j	6.65l	10.23h	34.96	42.85j
B ₀ N ₂	65.65 a	1.64f	10.45ij	2.25gh	13.65i	6.68k	10.55e	34.17	41.18k
B ₀ N ₃	61.17 b	0.35l	10.46i	2.80c	11.85l	6.71j	9.26k	34.58	43.49h
B ₁ N ₀	59.33 e	1.85d	9.25k	2.20ij	14.65h	6.75i	9.25l	34.75	43.38i
B ₁ N ₁	40.40h	1.05h	17.85f	2.10k	15.85g	8.83e	11.30c	34.28	46.06d
B ₁ N ₂	42.25g	3.35a	15.25g	2.65d	17.05f	8.89d	10.30g	34.33	46.11c
B ₁ N ₃	43.35 f	1.65e	22.10d	2.40e	20.45e	8.96b	11.31b	34.79	44.60e
B ₂ N ₀	38.20 i	1.09g	18.45e	2.25gh	25.25d	8.92c	10.51f	34.53	46.48b
B ₂ N ₁	36.65 j	0.85i	27.45a	4.30a	29.74a	9.40a	9.31i	35.56	47.52a
B ₂ N ₂	33.20 l	3.25b	26.45b	2.30f	26.65c	8.61f	11.26d	34.48	43.78f
B ₂ N ₃	34.35 k	2.45c	24.85c	3.35b	28.25b	8.36g	12.41a	35.63	43.70g
Level of significance	0.05	0.01	0.01	0.01	0.01	0.05	0.01	NS	0.01
CV (%)	5.58	5.60	5.47	7.52	4.42	4.41	2.21	1.09	3.48

In a column having similar letter(s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

B₀ = Without *Rhizobium* inoculum (Control)
 B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)
 B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)
 NS = Not Significant

N₀= Without nitrogen (Control)
 N₁= 50 % nitrogen (8 kg ha⁻¹)
 N₂= 100 % nitrogen (16 kg ha⁻¹)
 N₃= 150 % nitrogen (24 kg ha⁻¹)

4.3.6 Pod length

It is evident that Binamoog-5 produced the longest pod length (9.40 cm) in 100% *Rhizobium* inoculum and 50% N (B_2N_1) which was statically similar to B_1N_3 , B_2N_0 , B_1N_2 and the shortest pod length (6.65 cm) was with 0% *Rhizobium* inoculum treatment and 50% N (B_0N_1) which was statistically identical with B_0N_2 , B_0N_3 , B_1N_0 and B_0N_0 (Table 3).

4.3.7 Number of seeds pod⁻¹

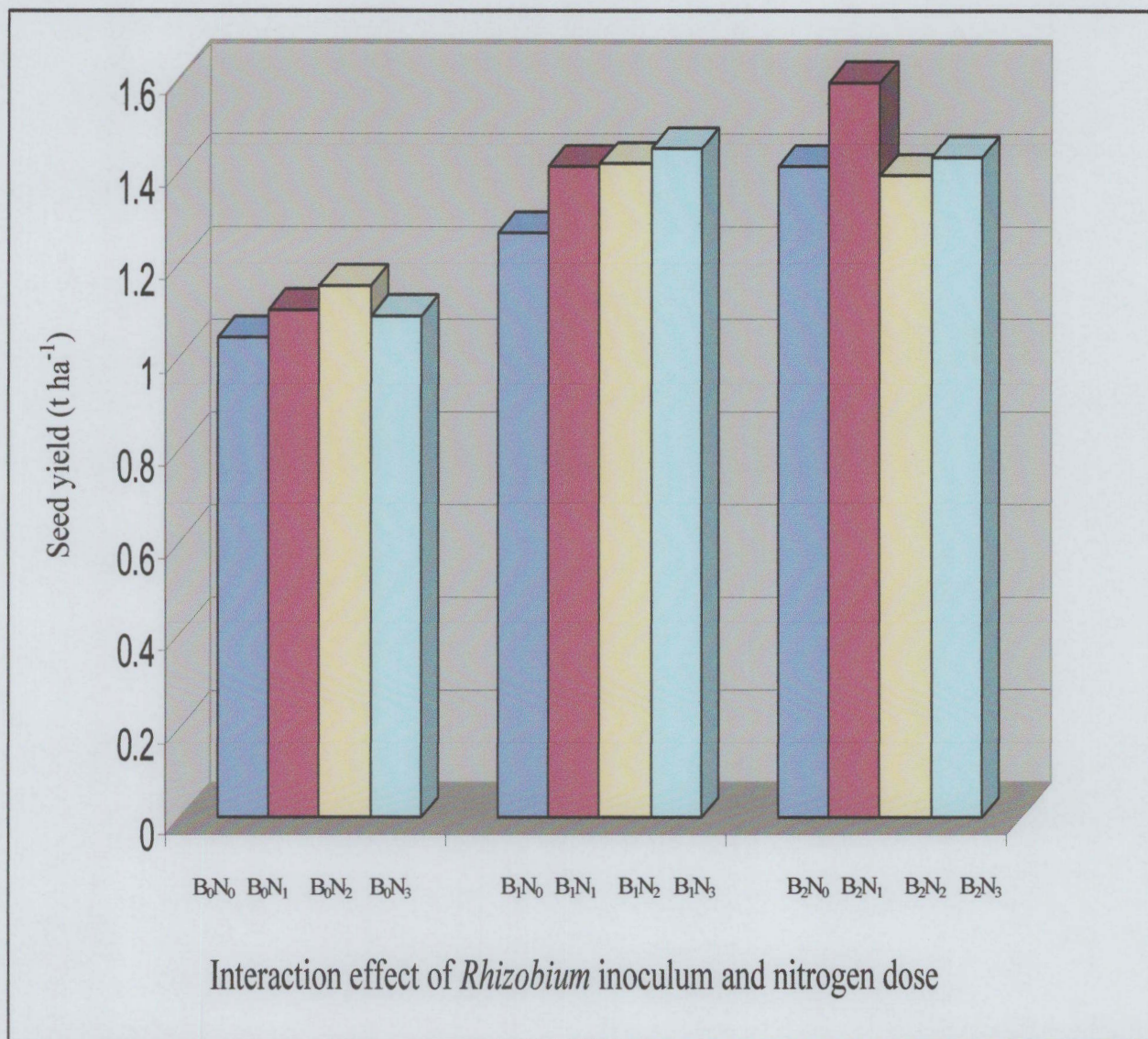
The highest number of seeds pod⁻¹ (12.41) was obtained from interaction of 100% *Rhizobium* inoculum treatment and 150% N (B_2N_3) followed by B_1N_3 and B_1N_1 . The lowest number of seeds pod⁻¹ (9.25) was obtained from 50% *Rhizobium* inoculum and control treatment of N (B_1N_0) which was statistically similar with B_0N_3 and B_0N_0 (Table 3). Keren and Bidhan (1985) reported that use of higher dose of *Rhizobium* and nitrogen increases the number of seeds of mungbean.

4.3.8 1000-seed weight

Thousand seed weight was not significantly affected by the interaction between *Rhizobium* inoculum and nitrogen dose (Appendix III). However, numerically the highest 1000-seed weight (35.56 g) was obtained from 100% *Rhizobium* inoculum and 150% N (B_2N_3) and the lowest 1000-seed weight (34.05 g) was in control treatment (B_0N_0) (Table 3).

4.3.9 Seed yield

The highest seed yield (1.59 t ha⁻¹) was obtained from interaction of 100% *Rhizobium* inoculum treatment and 50% N (B_2N_1) followed by B_1N_3 , B_2N_3 and the lowest seed yield (1.04 t ha⁻¹) was obtained from control treatment (B_0N_0) which was statically identical with B_0N_3 (Figure 5 and Appendix VI). This results indicate that higher grain yield in mungbean can be achieved through the seed inoculation of 1.5 kg ha⁻¹ *Rhizobium* biofertilizer and application of 8 kg ha⁻¹ nitrogen (50% of recommended dose). Seed yield was reduced due to higher dose



B₀ = Without *Rhizobium* inoculum (Control)

B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)

B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)

N₀ = Without Nitrogen (Control)

N₁ = 50 % Nitrogen (8 kg ha⁻¹)

N₂ = 100 % Nitrogen (16 kg ha⁻¹)

N₃ = 150 % Nitrogen (24 kg ha⁻¹)

Figure 5. Interaction effect of *Rhizobium* inoculum and nitrogen dose on seed yield (t ha⁻¹) of mungbean cv. Binamoog-5

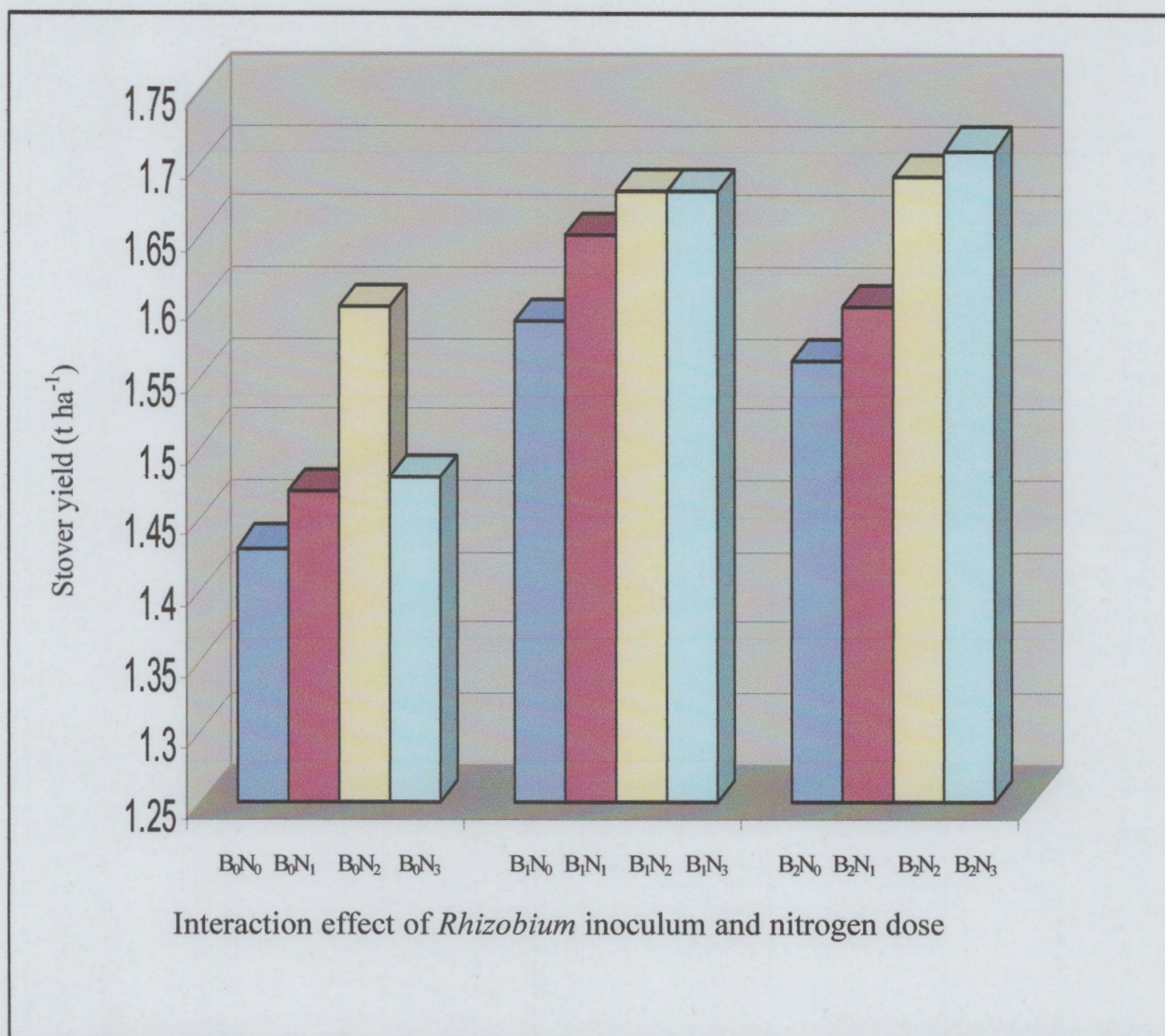
of nitrogen may be due to the higher stover yield in these treatment combination. Ardeshtna *et al.* (1993) reported that mungbean seed yield increased with the application up to 20 kg N ha⁻¹ as urea and seed inoculation with *Rhizobium* inoculum. Pathak *et al.* (2001) also in a trial with green gram grown in the summer season and found seed yields of 1.01 t ha⁻¹, 1.20 t ha⁻¹ and 1.24 t ha⁻¹ respectively.

4.3.10 Stover yield

The highest stover yield (1.71 t ha⁻¹) was obtained from 100% *Rhizobium* inoculum treatment with 150% N (B₂N₃) followed by B₂N₂, B₁N₃, B₁N₂ and the lowest stover yield (1.43 t ha⁻¹) was obtained from control treatment which was statistically identical with B₀N₁, B₀N₃ (Figure 6 and Appendix VI).

4.3.11 Harvest index (%)

The highest harvest index (47.52%) was obtained from treatment combination 100% *Rhizobium* inoculum treatment and 50% N (B₂N₁) which was followed by B₂N₀ and the lowest harvest index (40.36%) was obtained from control treatment (B₀N₀) which was followed by B₀N₂ treatment combination (Table 3).



B₀ = Without *Rhizobium* inoculum (Control)

B₁ = 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)

B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)

N₀ = Without Nitrogen (Control)

N₁ = 50 % Nitrogen (8 kg ha⁻¹)

N₂ = 100 % Nitrogen (16 kg ha⁻¹)

N₃ = 150 % Nitrogen (24 kg ha⁻¹)

Figure 6. Interaction effect of *Rhizobium* inoculum and nitrogen dose on stover yield (t ha⁻¹) of mungbean cv. Binamoog-5

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna during the period from April to June 2011 to study the effect of *Rhizobium* inoculum and nitrogen doses on the yield and yield attributes of mungbean cv. Binamoog-5. The experimental treatments included three levels of *Rhizobium* inoculum viz. without *Rhizobium* inoculum (B_0), 50% *Rhizobium* inoculum (B_1), and 100% *Rhizobium* inoculum (B_2), and four levels of nitrogen doses, viz. without nitrogen (N_0), 50% nitrogen (N_1), 100% nitrogen (N_2), 150% nitrogen (N_3). The experiment was laid out in a randomized complete block design with three replications. Each block was divided into 12 unit plots where the treatment combinations were allocated at random. The size of the unit plot was 6 m² (3.0 m x 2.0 m) and was separated by 0.5 m wide bund. The blocks were separated by 0.5 m wide band *Rhizobium* inoculum biofertilizer was applied to seeds just before sowing and N was applied as urea just before sowing of seeds according to the treatment. The seeds were sown in line manually on 3 April 2011 @ 20 kg ha⁻¹. After sowing, the seeds were covered with soil to preserve moisture. Nitrogen application was done as per experimental treatments. Other fertilizer doses were TSP (Tripple super Phosphate) @ of 75 kg ha⁻¹ and MoP (Muriate of Potash) @ 35 kg ha⁻¹. First weeding was done at 20 DAS and second weeding was done on 40 DAS. Irrigation was given at the early stages of crop growth. However, there was heavy rainfall on 22 April and 11 May 2011. Drainage was done to remove the excess water from the field at that time.

The crop was harvested from central 2.0 m² area of each plot for yield data on different dates (10.06.11, 14.06.11 and 20.06.11) as they attained maturity. For collecting yield and yield contributing characters, five randomly selected plants from each plot were uprooted carefully tagged properly and used for recording necessary data. The data were analyzed statistically following ANOVA technique and

the mean differences were adjudged by DMRT. The results revealed that plant height was significantly affected by the *Rhizobium* inoculum. The highest plant height (62.35 cm) was obtained from 50% *Rhizobium* inoculum treatment. The highest number of branches plant⁻¹ (3.07) was recorded from 100% *Rhizobium* inoculum treatment and the lowest one (0.46) was recorded from control treatment. *Rhizobium* inoculum significantly influenced the number of pods plant⁻¹. The highest number of pods plant⁻¹ (28.35) was observed from 100% *Rhizobium* inoculum treatment and the lowest one (12.51) was observed in control treatment. Number of fertile pods plant⁻¹ was significantly affected by *Rhizobium* inoculum. The highest number of fertile pods plant⁻¹ (25.99) was recorded from 100% *Rhizobium* inoculum treatment, while the lowest one (10.55) was recorded from control treatment. Number of sterile pods plant⁻¹ was significantly affected by *Rhizobium* inoculum. The highest number of sterile pods plant⁻¹ (2.49) was recorded from control treatment. The lowest number of sterile pods plant⁻¹ (2.05) was recorded from 50% *Rhizobium* inoculum treatment (Appendix IV). Pod length was significantly affected by *Rhizobium* inoculum. Number of seeds pod⁻¹ was significantly affected by the *Rhizobium* inoculum. The highest number of seeds pod⁻¹ (11.58) was obtained from 100% *Rhizobium* inoculum treatment and the lowest one (9.72) was found with control treatment. The highest seed yield (1.56 t ha⁻¹) was recorded from 100% *Rhizobium* inoculum treatment. The lowest seed yield (1.13 t ha⁻¹) was obtained from control treatment. The highest stover yield (2.31 t ha⁻¹) was found in 100% *Rhizobium* inoculum treatment. The lowest stover yield (1.47 t ha⁻¹) was obtained from control treatment of *Rhizobium* inoculum. The highest harvest index (46.15%) was found in 50% *Rhizobium* inoculum treatment and the lowest harvest index (43.45%) was found in control treatment.

There was significant effect of nitrogen dose on plant height. The tallest plant (48.25 cm) was observed in 100% N. The highest number of branches plant⁻¹ (2.08) was obtained from 100% N. The highest pod production (22.06) was obtained from 100% N. The highest number of fertile pods plant⁻¹ (19.73) was

obtained from 100% N. The lowest number of fertile pods plant⁻¹ (15.45) was found from control treatment. Nitrogen dose exerted a significant influence on the number of sterile pods plant⁻¹. There was significant effect of nitrogen dose on pod length. Number of seeds pod⁻¹ was significantly affected by the nitrogen dose. The highest number of seeds pod⁻¹ (11.89) was obtained from 100% N. Thousand seed weight was found non significant. The lowest number of seeds pod⁻¹ (10.05) was found from control treatment. Thousand seed weight was found non significant. The highest 1000-seed weight (32.89 g) was found from control treatment and the lowest 1000-seed weight (31.08 g) was obtained from 50% N. Nitrogen dose significantly influenced seed yield. The highest seed yield (1.59 t ha⁻¹) was found in 100% N treatment and the lowest seed yield (1.38 t ha⁻¹) was obtained from control treatment. . The highest stover yield (1.93 t ha⁻¹) was found in 100% N treatment and the lowest stover yield (1.68 t ha⁻¹) was obtained from control treatment. Harvest index varied significantly due to nitrogen management.

Number of branches plant⁻¹ was significantly affected by the interaction between *Rhizobium* inoculum and nitrogen dose. The highest number of branches plant⁻¹ (3.35) was obtained from the interaction of 100% *Rhizobium* inoculum treatment with 100% N. Number of pods plant⁻¹ was significantly affected by the interaction between *Rhizobium* inoculum and nitrogen management. The highest number of pods plant⁻¹ (29.70) was found from 100% *Rhizobium* inoculum treatment fertilized with 150% N. The lowest number of pods plant⁻¹ (11.85) was obtained from 0% *Rhizobium* inoculum fertilized with 150% N. Number of fertile pods plant⁻¹ was significantly affected by the interaction between *Rhizobium* inoculum and nitrogen dose. The highest number of fertile pods plant⁻¹ (27.45) was obtained from the treatment combination of 100% *Rhizobium* inoculum treatment with 50% N (Table-3). The lowest number of fertile pods plant⁻¹ (9.25) was obtained from the interaction of 50% *Rhizobium* inoculum with no nitrogen. Number of sterile pods plant⁻¹ was significantly affected by the interaction between *Rhizobium* inoculum and nitrogen



dose. The highest number of sterile pods plant⁻¹ (4.30) was obtained from 100% *Rhizobium* inoculum treatment fertilized with 50% N. The lowest number of sterile pods plant⁻¹ (1.10) was obtained from control treatment. The highest number of seeds pod⁻¹ (13.27) was obtained from the treatment combination of 100% *Rhizobium* inoculum treatment and 100% N. The lowest number of seeds pod⁻¹ (9.25) was obtained from the interaction of 50% *Rhizobium* inoculum treatment and without N. Seed yield was significantly affected by the interaction between *Rhizobium* inoculum and nitrogen dose. The highest seed yield (1.59 t ha⁻¹) was obtained from 100% *Rhizobium* inoculum treatment fertilized with 50% N and the lowest seed yield (1.04 t ha⁻¹) was obtained from control treatment. The highest stover yield (2.71 t ha⁻¹) was obtained from the combination 100% *Rhizobium* inoculum with 150% N and the lowest one (1.43 t ha⁻¹) was obtained from the interaction between no inoculum and no nitrogen. The highest harvest index (47.52%) was obtained from 100% *Rhizobium* inoculum with no N and the lowest one (40.36%) was obtained from control treatment.

In view of the above findings it may be concluded that the highest seed yield of mungbean cv. Binamoog-5 could be obtained with application of *Rhizobium* inoculum @ 1.5 kg ha⁻¹ with 50% N (8 kg ha⁻¹). So at least 50% nitrogen could be saved by using *Rhizobium* biofertilizer without significant yield loss. This conclusion has been made based on the results of the study that was conducted in *kharif-I* season only. Further research is, therefore, necessary to arrive at a definite conclusion.

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APPENDICES

Appendix I. Morphological, physical and chemical characteristics of the soil (0-15 cm) of the experimental plot

A) Morphological characteristics:

- | | |
|---------------------|-------------------------------|
| i) Soil tract | Ganges Tidal Flood Plain |
| ii) Parent material | High Ganges Tidal Flood Plain |

B) Physical characteristics

- | | |
|------------------------------|-------------|
| (i) Sand (2.00-0.5 mm) | :25.2% |
| (ii) Silt (0.5-0.002 mm) | :72.0% |
| (iii) Clay (<below 0.002 mm) | :2.8% |
| (iv) Textural class | : Clay loam |

C. Chemical characteristics

Sl. No.	Soil characteristics	Analytical data
1.	pH	7.4
2.	Sand	7.74
3.	Silt	76.88
4.	Clay	15.38
5.	Organic carbon (%)	0.93
6.	Total nitrogen (%)	0.13
7.	Available phosphorus (ppm)	21.58
8.	Available potassium (ppm)	0.32
9.	Exchangeable potassium (ppm)	0.28



Source: Soil Resource Development Institute (SRDI), Daulatpur, Khulna .

**Appendix II. Mean monthly air temperature (maximum and minimum)
relative humidity and total rainfall during the experimental
period (April 2011-June 2011) at Khulna University, Khulna, Bangladesh.**

Months	Air temperature ($^{\circ}\text{C}$)		Relative Humidity (%)		Total Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
April	33.09	25.00	80.4	25.0	105
May	35.05	26.20	78.0	43.4	170
June	32.20	26.45	98.0	48.5	383

Source: Regional Meteorological Office, Gollamari, Khulna.

Appendix III. Analysis of variance for yield and yield contributing characters of mungbean cv. Binamoog-5

Source	Degrees of freedom	Mean square										
		Plant height	No. of branches plant ⁻¹	No. of pods plant ⁻¹	No. of fertile pods plant ⁻¹	No. of sterile pods plant ⁻¹	Pod length	No seeds pod ⁻¹	1000-seed weight	Seed yield	Stover yield	Harvest index (%)
Replication	2	0.144	0.53	0.79	0.85	0.53	0.26	1.10	0.32	0.01	0.02	2.43
Rhizobium	2	3151.64**	27.19**	1003.95*	967.61**	0.84**	21.20**	18.09*	1163.39 ^{NS}	1.36*	2.59*	33.05*
Nitrogen dose (N)	2	103.88**	0.72**	39.02*	44.87*	1.42*	1.21**	8.62*	1.47 ^{NS}	0.02*	0.16*	15.35*
B x N	4	0.58**	0.04**	2.14*	3.66*	1.99*	0.51**	1.07*	0.43 ^{NS}	0.005	0.09*	11.10*
Error	25	0.07	0.01	0.007	0.007	0.23	0.12	0.06	0.13	0.001	0.02	2.37

* indicates significant at 5% level of probability.

** indicates significant at 1% level of probability.

NS = Not significant at $P \geq 0.05$.

Appendix IV. Effect of *Rhizobium* inoculum on the yield and yield attributes of mungbean cv. Binamoog-5

<i>Rhizobium</i>	Fertile pods plant ⁻¹ (no.)	Sterile pods plant ⁻¹ (no.)	Total pods plant ⁻¹ (no.)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)
B₀	10.55 d	2.49 a	12.51 d	1.13 c	1.47 c
B₁	20.98 c	2.05 c	26.13 c	1.41 b	1.65 b
B₂	25.99 a	2.31 b	28.35 a	1.76 a	2.31 a
Level of significance	0.01	0.05	0.01	0.01	0.01
CV (%)	5.47	7.52	4.42	1.89	7.41

In a column having similar letter(s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

B₀ = Without *Rhizobium* inoculum(Control)

B₁= 50% *Rhizobium* inoculum (0.75 kg ha⁻¹)

B₂ = 100% *Rhizobium* inoculum (1.5 kg ha⁻¹)

**Appendix V. Effect of nitrogen dose on the yield and yield attributes
of mungbean cv.Binamoog-5**

Nitrogen dose	Fertile pods plant⁻¹ (no.)	Sterile pods plant⁻¹ (no.)	Total pods plant⁻¹ (no.)	Seed yield (t ha⁻¹)	Stover Yield (t ha⁻¹)
N₀	15.45d	2.00 b	19.94 c	1.38d	1.68d
N₁	19.08 b	2.26 b	20.90 b	1.45a	1.81 c
N₂	19.73 a	2.74 a	22.06 a	1.40c	1.93 a
N₃	18.08c	2.05 b	17.95 d	1.43b	1.85b
Level of significance	0.01	0.01	0.01	0.01	0.01
CV (%)	5.47	7.52	4.42	1.89	7.41

In a column having similar letter(s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

N₀= Without Nitrogen (Control)

N₁= 50 % Nitrogen (8 kg ha⁻¹)

N₂= 100 % Nitrogen (16 kg ha⁻¹)

N₃= 150 % Nitrogen (24 kg ha⁻¹)