INFLUENCE OF BIO-FERTILIZER AND PLANT POPULATION ON GROWTH AND YIELD OF SUMMER MUNGBEAN (*Vigna radiata* L.)

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A Thesis

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CERTIFICATE

This is certify that the thesis entitled, "Influence of Bio-fertilizer and Plant Population on growth and Yield of Summer Mungbean (*Vigna radiata* L.) submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY, embodies the result of a piece of bona fide research work carried out by Md. Kamal Hossain, Registration No. 00597 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.

Dated : 27-12-2007
Dhaka, Bangladesh.

Professor Dr. Md. Hazrat Ali
Department of Agronomy
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Dedicated to

My

Beloved Parents

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ABSTRACT

An experiment was carried out at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka during the period from March to June, 2006 to study the influence of bio-fertilizer and plant population on growth and yield of mungbean (*Vigna radiata*). The experiment consisted of two levels of treatments viz. a). inoculation (No inoculation, BINA-MB 441 and BINA-MB-THA 301) and b). plant population (10, 20, 30, 40 and 50 plants m^{-2}). The experiment was laid out in a randomized complete block design (Factorial) with three replications. The results revealed that BINA-MB 441 performed the best. The highest seed yield (1.20 t ha^{-1}), number of nodules $plant^{-1}$, dry weight of nodules $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, weight of 1000 seeds, seed yield $plant^{-1}$, straw yield and harvest index were attained from BINA-MB 441. Plant population also significantly influenced all crop characters studied. The results revealed that 30 plants m^{-2} showed the best performance in respect of seed yield (1.25 t ha^{-1}) than other plant population treatment. The highest number of nodules $plant^{-1}$ (10.44), number of pods $plant^{-1}$ (14.26), number of seeds pod^{-1} (30.23), weight of 1000 seeds (47.54 g) and seed yield $plant^{-1}$ (5.61 g) were obtained from 10 plants m^{-2} whereas the highest plant height, LAI (2.31) and straw yield (3.65 t ha^{-1}) were found in 50 plants m^{-2}. Combination of BINA-MB 441 with 30 plants m^{-2} was found to be the best in respect of seed yield and straw yield. Combination of BINA-MB 441 with 10 plants m^{-2} was found the best in respect of number of nodules $plant^{-1}$ (13.32), number of pods $plant^{-1}$ (16.69), number of seeds pod^{-1} (32.24), weight of 1000 seeds (50.71 g) and seed yield $plant^{-1}$ (6.98 g) whereas significantly the highest plant height, leaf area index (2.99) and straw yield (3.97 t ha^{-1}) were found in BINA-MB 441 with 50 plants m^{-2}

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BARI	=	Bangladesh Agricultural Research Institute
^{0}C	=	Degree Centigrade
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar (s)
DAS	=	Days after sowing
et al.	=	and others (et elli)
etc.	=	Etcetera
g	=	gram (s)
kg	=	Kilogram (s)
kg ha^{-1}	=	Kilogram per hectare
LSD	=	Least Significant Difference
FAO	=	Food and Agricultural Organization
MP	=	Muriate of Potash
No.	=	Number
pH	=	Hydrogen ion concentration.
RCBD	=	Randomized Complete Block Design
RH	=	Relative Humidity
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource and Development Institute
TSP	=	Triple Super Phosphate
t ha^{-1}	=	Ton per hectare
viz.	=	Namely
@	=	At the rate of
%	=	Percent

CHAPTER 1

Introduction

INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the most important pulse crops of Bangladesh. It ranks fifth in acreage and production. The area under pulse crops in Bangladesh is 0.406 million hectares with a production of 0.322 million tones where mungbean is cultivated in the area of 0.108 million hectares with production of 0.03 million tones (BBS, 2005). It is considered as a poor man's meat. It contains almost double amount of protein as compared to cereals. It has good digestibility and flavour.

Mungbean contains 51% carbohydrate, 26% protein, 10% moisture, 4% minerals, 3% vitamins etc. Hence, on the point of nutritional value, mungbean is perhaps the best of all other pulses (Khan, 1981; Kaul, 1982). But unfortunately, there is an acute shortage of grain legumes production in the country. According to FAO (1999) a minimum intake of pulse by a human should be 80 g/day/capita for a balance diet, whereas in Bangladesh per capita daily consumption of pulses is only 14.19 g (BBS, 2005). Annually import of pulses in Bangladesh is approximately 55000 tons (BBS, 1994). This crop, like other pulses, also has the potentiality to improve the physical, chemical and biological properties of soil as well as can increase soil fertility status through Biological Nitrogen Fixation (BNF) from the atmosphere. It can also minimize the scarcity of fodder because the whole plant or it's by products can be used as good animal feed. So increase of pulse production is urgently needed to meet up the domestic demand and to increase pulse consumption as well as to minimize the scarcity of fodder.

Mungbean has wide adaptability and fits well in rice based cropping system whish are common in many Asian countries. Besides being used as food and feed, mungbean is also used as green manuring crop to improve soil fertility. Cultivation of mungbean increased symbiotic fixation of atmospheric N_2 by the nodules and the decomposition of crop, result in restoration of soil fertility (Miah, 1981). Mungbean being a deep rooted crop absorbs nutrients from the sub-soil, subsequently enriching the plough layers (Prasad and Kerketta, 1991).

Agro-ecological condition of Bangladesh is favourable for growing mungbean. The crop is usually cultivated during *rabi* season, but because of poor yield and marginal profit as compared to cereal crops, farmers prefer growing wheat to mungbean during *rabi* season. Besides, during the last decades, the release of high yielding cultivars of cereals have made it's cultivation less remunerative. Recently some photo-insensitive *kharif* cultivars have been introduced which have already received attention to the farmers (Sarker *et al.* 1980). During *kharif* season the crop fits well into the existing cropping system of many areas of Bangladesh.

The average yield of mungbean in this country is 550 kg ha^{-1} (BBS, 1980) which is much lower than that in India (1320 kg ha^{-1}) and some other countries (Daisy, 1979). It is partly due to low yielding potentiality and partly due to lack of appropriate agronomic practices. Inspite of multipurpose uses of this crop, attention was not paid in Bangladesh in past. But recently Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed a number of high yielding cultivars of summer mungbean.

In the development of appropriate management practices for mungbean, plant population plays an important role. Plant population is one of the most important yield contributing factors which can be manipulated to maximize yield (Babu and Mitra, 1989). In lower plant population, individual plant performance is better than that of higher plant population but within tolerable limit higher plant population produces higher yield ha^{-1} (Shukla and Dixit, 1996). Therefore, optimum plant population ensures normal plant growth because of efficient utilization of moisture, light space and nutrients, thus increases the yield of crop.

Nitrogen is the most important nutrient element among the major essential element of plant. For legume, nitrogen is more useful because it is the main component of amino acid as well as protein. Adequate supply of nitrogenous fertilizer is essential for normal growth and yield of a crop. In Bangladesh, most of the lands are deficient in organic matter and nitrogen. To fulfil the demand of nitrogen, usually urea or ammonium sulphate is being used. The price of these fertilizers is very high and often is not readily available in market. For this reason, the marginal farmers can not afford to apply balance fertilizer, as a result these crops do not provide with expected yield. The minimum use of nitrogen fertilizers would reduce energy demand costs, pollution and renew soil organic matter (Poincelot, 1986). The imbalanced application of chemical fertilizers is also detrimental to the environment. There is an organism, *Rhizobium* which can fix atmospheric nitrogen by symbiosis process with legume crops and make available to the plants. Bangladesh Institute of Nuclear Agriculture (BINA) isolated some *Rhizobium* strains for some pulse crops. They have already selected some *Bradyrhizobium* strains especially for mungbean cultivars. To reduce the production cost and fulfil the demand, more pulse production could be achieved through seed inoculation with *Bradyrhizobium* strain, which is known to influence nodulation, biological nitrogen fixation, growth and yield of pulses.

In Bangladesh, some studies have been done on plant population and Rhizobial bio-fertilizer performance separately but no report has been found on the combined response of these factors on summer mungbean. Considering the above facts, the study has been undertaken to find out the influence of plant population and bio-fertilizer on growth and yield performance of two summer mungbean cultivars.

Hence, the objectives of the study were:

i. To observe the effectiveness of *Bradyrhizobium* inocula on nodulation, growth and yield of summer mungbean.

ii. To study the effect of plant population on growth and yield of summer mungbean.

iii. To study the combine effect of plant population and bio-fertilizer on growth and yield of summer mungbean.

CHAPTER 2

Review of literature

REVIEW OF LITERATURE

Research works on the use of *Bradyrhizobium* inoculation on mungbean (*Vigna radiata L.*) are very limited. However, available information on the effect of *Rhizobium* inoculation on nodulation, dry matter production and grain yield of mungbean and few other legume crops have been reviewed in this chapter.

2.1 Effect of *Rhizobium/ Bradyrhizobium* inoculation:

2.1.1 Effect on plant height

Solaiman (2002) conducted a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculation increased plant height compared with uninoculated.

Hasanuzzaman (2001) conducted a field experiment on mungbean seed inoculation with *Bradyrhizobium* and reported that plant height significantly increased over uninoculated.

Roy (2001) reported that *Bradyrhizobium* inoculum significantly increased the plant height compared with uninoculated.

Kavathiya and Pandey (2000) conducted a pot experiment with *Rhizobium* on seed inoculation of mungbean and found that seed inoculated resulted in significantly increased plant height compared with uninoculated.

Mozumder (1998) conducted a field experiment on mungbean seed inoculation with different strains of *Bradyrhizobium* and reported that plant height significantly increased over uninoculated.

Fakir *et al.* (1998) conducted a field experiment on mungbean seed inoculation with different strains of *Bradyrhizobium* and application of chemical fertilizer. They observed that inoculation with N caused the longest plant.

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi seed was inoculated with *Rhizobium* or not inoculated, sown in rows 20, 30 or 40 cm apart and given 0-60 kg P_2O_5 ha^{-1}. They found that *Rhizobium* inoculation increased plant height.

Sattar and Ahmed (1995) carried out a field experiment on mungbean inoculation with *Rhizobium* inoculum and observed that *Rhizobium* inoculation increased plant height compared with controled.

Thakur and Panwar (1995) conducted a field trial where mungbean (*Vigna radiata* L.) seed (cv. Pusa-105 and PS-16) were inoculated with *Bradyrhizobium*, soil inoculated with VAM fungus or a combination of both. They found that inoculation either singly or combined increased plant height compared with no inoculation.

Rahman (1993) reported that seed inoculation of *Rhizobium* to mungbean (*Vigna radiata* L.) cv. Kanti increased plant height.

Samantary *et al.* (1993) observed that shoot length were the highest when inoculation was done with *Rhizobium*.

Thakuria and Saharia (1990) reported that different varieties of mungbean differed significantly in respect of plant height.

2.1.2 Effect on nodulation

Kavathiya and Pandey (2000) conducted a pot experiment with *Rhizobium* on seed inoculation of mungbean and found 69 nodules plant^{-1}.

Mandal and ray (1999) conducted a field experiment where mungbean cv. 105, B-1 and Hooghly local were not inoculated; seed inoculated with *Rhizobium* and 20, 30 or 40 kg ha^{-1} urea were given. They revealed that nodulation was the greatest in inoculation with N treatment in B-1.

Islam *et al.* (1999) conducted an experiment to study the performance of some *Bradyrhizobial* inoculants on soybean at BINA experimental farm, Mymensingh. They were found that total number nodules were significantly the lowest in uninoculated and the highest in inoculants' treatments. All the *Bradyrhizobium* inoculation treatments performed better in nodulation of soybean.

Provorov *et al.* (1998) observed that seed of mungbean (*Vigna radiate* L.) inoculation with stain CIMA1901 of *Bradyrhizobium* increased the number of root nodules by 24%. These results were equivalent to applying 120 kg N ha^{-1}.

Bhuyan *et al.* (1998) conducted a field experiment at regional Agricultural Research Station, Ishwardi, Pabna to evaluate the effect of seed inoculation with four *Bradyrhizobium* inoculum. They observed that inoculations significantly increased the nodule number over uninoculated or control.

Das *et al.* (1997) conducted a field trial where mungbean (*Vigna radiata*) cv. Nayagarh local seeds were inoculated with *Rhizobium* and/or VAM culture which was applied @ 15 kg ha^{-1}. They observed that number of nodules was increased with dual inoculation compared with uninoculated.

Patra and Bhattacharyya (1997) carried out a field trial with mungbean (*Vigna radiata*) cv. B-1, *Rhizobium* and urea (25 kg ha^{-1}). They found that all treatments increased nodulation compared with controls. They also reported that the highest nodule numbers were given by *Rhizobium* + urea.

Poonam and Khurana (1997) conducted field experiment to study the effect of single and multistrain inoculants of *Rhizobium* in summer mungbean variety SML32. Number of nodules was superior in multistrain inoculants.

Sattar and Ahmed (1995) conducted a field experiment on mungbean (*Vigna radiata* L.) to study the response of inoculation with *Bradyrhizobium* inoculants incorporating BINA 403, BINA 407, RC 3824 and RC 3825 strains as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the number of nodules significantly.

Hoque and Barrow (1993) carried out field trials at various locations in Bangladesh and found that the inoculants markedly increased nodule number of soybean, lentil and mungbean compared with uninoculated and urea-N treatments.

Sangakara and Marambe (1989) observed that inoculation significantly increased nodulation of mungbean (*Vigna radiata* L.) 21 days after sowing. Seed and soil inoculation before sowing increased nodulation number per plant at flowering.

Patel *et al.* (1986) found that response of *Rhizobium* inoculation in respect of nodulation was found to be significantly high.

Khan *et al.* (1985) observed that inoculation of black gram seed with different *Rhizobium* strains showed highly significant effect on nodulation.

Vaishya *et al.* (1983) reported the seed inoculation with Rhizobium strain M1 significantly increased the number of nodules of 12 mungbean (*Vigna radiata*) cultivars.

Hoque *et al.* (1982) reported that application of inoculum G-13 produced 22.1 nodules per plant compared to only 6.6 per plant in uninoculated or controlled.

2.1.3 Effect on nodule dry weight

Bhuiyan *et al.* (1998) stated that *Rhizobium* seed inoculation with 1 kg Mo ha^{-1} and 1 kg B ha^{-1} increased nodule dry weight compared with the control.

Gupta and Namdeo (1996) observed a field experiment in chickpea that seed inoculation increased nodules dry weight per plant ranged from 32 to 62 mg with inoculation compared with 23 mg with N application and 27 mg with no inoculation.

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi seed was inoculated with *Rhizobium* or not inoculated. They found that *Rhizobium* inoculation increased nodule weight plant^{-1}.

Sattar and Ahmed (1995) conducted a field experiment on mungbean (*Vigna radiata* L.) to study the response of inoculation with *Bradyrhizobium* inoculants incorporating BINA 403, BINA 407, RC 3824 and RC 3825 strains as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the nodule dry weight significantly.

Rasal (1995) carried out an experiment where green gram was given seed inoculation with *Aspergillus awamori* or *Microbes* alone or in combination with *Rhizobium* and/or the recommended rate of P fertilizer (RRP). He found that dry weight of nodules were the highest with inoculation with *Aspergillus awamori + Rhizobium + RRP*.

Hoque and Barrow (1993) carried out field trials at various locations in Bangladesh and found that the inoculants markedly increased nodule dry weight of soybean, lentil and mungbean compared with uninoculated and urea-N treatments.

Hoque and Hashem (1993) observed that the use of *Rhizobium* inoculants as bio-fertilizer was remarkably beneficial on nodule dry weight of soybean and groundnut.

Bhuiyan and Obidullah (1992) reported from a field experiment with mungbean that *Rhizobium* inoculation increased nodule dry weight significantly.

Bhuiya *et al.* (1984) carried out a field experiment at BAU farm and observed that the inoculation of mungbean gave the higher dry weight of nodules compared with control. They also reported that larger sized nodules were produced due to inoculation.

2.1.4 Effect on leaf area index

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi seed was inoculated with *Rhizobium* or not inoculated, sown in rows 20, 30 or 40 cm apart and given 0-60 kg P_2O_5 ha^{-1}. They found that *Rhizobium* inoculation increased leaf area index.

2.1.5 Effect on the number of pods $plant^{-1}$

Podder *et al.* (1999) conducted a field experiment with mungbean at Brahmaputra Floodplain soil to evaluate the effect of seed inoculation with 8 bradyrhizobial treatments showed better performance in recording number of pods $plant^{-1}$ over controlled.

Basu and Bandyopadhyay (1990) carried out a field trail during the *kharif* (monsoon) season in West Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or JCA1 and grown in presence of 30-40 kg N ha^{-1}. Inoculation increased numbers of pods $plant^{-1}$. JCA-1 was superior to M-10.

Rahman (1989) observed significantly higher number of pods per plant due to inoculation over control in soybean.

Gill *et al.* (1985) reported that inoculation significantly increased number of pods plant^{-1}.

2.1.6 Effect on the number of seeds pod^{-1}

Podder *et al.* (1999) conducted a field experiment with mungbean at Brahmaputra Floodplain soil to evaluate the effect of seed inoculation with eight Bradyrhizobial treatments showed better performance in recording number of pod plant^{-1}, number of seed plant^{-1}, 1000 seed weight and seed yield over uninoculated.

Basu and Bandyopadhyay (1990) carried out a field trail during the kharif (monsoon) season in West Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or JCA1 and grown in presence of 30-40 kg N ha^{-1}. Inoculation increased numbers of seeds pod^{-1} JCa-1 was superior to M-10.

2.1.7 Effect on the weight of 1000 seeds

Podder *et al.* (1999) conducted a field experiment with mungbean at Brahmaputra Floodplain soil to evaluate the effect of seed inoculation with eight Bradyrhizobial treatments showed better performance regarding 1000 seeds weight over controlled.

Thakuria and Saharia (1990) reported that different varieties of mungbean differed significantly in respect of 1000 seed weight.

Rahman (1989) observed significantly higher 1000 seeds weight yield due to inoculation over control in soybean.

2.1.8 Effect on the number of seed yield plant^{-1}

Podder *et al.* (1999) conducted a field experiment with mungbean at Brahmaputra Floodplain soil to evaluate the effect of seed inoculation with 8 bradyrhizobial treatments showed better performance in recording number of seeds plant^{-1} over uninoculated.

Gill *et al.* (1985) reported that inoculation increased number of seeds plant^{-1}.

2.1.9 Effect on seed and straw yield

Solaiman (2002) conducted a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that inoculated seed significantly increased grain yield compared with uninoculated.

Hasanuzzaman (2001) conducted a field experiment where mungbean seeds were inoculated with *Bradyrhizobium* strain and found that *Bradyrhizobium* inoculum significantly increased the grain yield compared with uninoculated.

Roy (2001) reported that *Bradyrhizobium* inoculum significantly increased the seed yield compared with uninoculated in mungbean cultivars.

Shivesh and Sharma (2001) reported that grain yield were at maximum when mungbean seeds were treated with the local isolate.

Chowdhury *et al.* (2000) conducted a pod experiment during *Kharif* in 1995 with mungbean seed inoculated with *Bradyrhizobium*. He found that seed yield increased significantly when the seed were inoculated with *Bradyrhizobium*.

Deb (2000) reported from a pot trial that *Rhizobium* inoculation with Mo in mungbean (*Vigna radiate* L.) increased grain yield compared with uninoculated plant.

Podder *et al.* (1999) conducted a field experiment with mungbean at Brahmaputra Floodplain soil to evaluate the effect of seed inoculation with eight Bradyrhizobial treatments showed better performance in recording seed yield over uninoculated.

Upadhyay *et al.* (1999) conducted a pot experiment where green gram seed was inoculated with *Rhizobium* or not inoculated and 0-60 kg P_2O_5 ha^{-1} was given. They observed that seed yield was higher with inoculation (2.02 VS. 1.87 t ha^{-1}) and increased with up to 40 kg P_2O_5 (2.01 t ha^{-1}).

Bhuiyan *et al.* (1998) stated that *Rhizobium* seed inoculation with 1 kg Mo ha^{-1} and 1 kg B ha^{-1} increased seed yield compared with the control. Seed yield was 107% and 148% higher over control in two consecutive growth seasons.

Provorov *et al.* (1998) stated that seed inoculation of mungbean increased the seed yield by 39.2% over uninoculated.

Mozumder (1998) conducted a field experiment on mungbean seed inoculated with different strains of *Bradyrhizobium* and reported that grain yield significantly increased over uninoculated.

Poonom and Khurana (1997) conducted field experiment to study the effect of single and multi strain inoculants of *Rhizobium* in summer mungbean variety SML32. Grain yield was superior in multi strain inoculants. On an average, single and multi strain *Rhizobium* inoculants increased the yield by 10.4% and 19.3% over controlled, respectively.

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi seed was inoculated with *Rhizobium* or not inoculated. They found that *Rhizobium* inoculation increased seed yield.

Sattar and Ahmed (1995) conducted a field experiment at the farm of Agricultural Research Center, Rajbari; Dinajpur on mungbean inoculated with *Bradyrhizobium* and recorded significant increase in hay and seed yield.

Badole and umale (1995) reported that in a field experiment during the rainy season of 1990 with green gram (*Vigna radiata*) cv. TAP 7, application of no fertilizers or 25, 50, 75 or 100% of the recommended fertilizers (not specified) gave seed yields of 0.92, 1.04, 1.17, 1.13 and 0.99 t ha^{-1}, respectively.

Chowdhury and Rosario (1994) stated that seed inoculated with *Rhizobium* increased the seed yield of mungbean.

Jet and Rathore (1994) reported that inoculation of green gram seed with *Rhizobium* gave increased seed yield.

Ardeshna *et al.* (1993) reported that mungbean seed yield increased with the application up to 20 kg N ha^{-1} as urea, 40 kg P_2O_5 as single super phosphate and seed inoculation with *Rhizobium* [0.76 t ha^{-1} vs. 0.70 t ha^{-1} (without inoculation)].

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

Sarker *et al.* (1993) reported that *Rhizobium* inoculation along with P application and *Rhizobium* inoculation along with *Azotobacter chroococcum* were equally effective in enhancing grain 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_2O_5 up to or equivalent of 60 kg P_2O_5 ha^{-1} and with *Rhizobium* inoculation and with a starter dose of nitrogen.

Prasad and Ram (1992) observed that green gram cv. Pusa Baishakhi on alluvial soil, *Bradyrhizobium* strains M-5 inoculum and 2.5 ppm of both Zn and Cu gave the highest seed yield (1.27 t ha^{-1}) compared to control (0.86 t ha^{-1}).

Hoque (1991) reported that the *Rhizobium* strain was the best strain among the strain used in an experiment in Bangladesh Agricultural University, Mymensingh in respect of seed yield of mungbean. The result and other studies showed 20-60% increased in seed yield of mungbean when inoculated seeds were sown.

Pandher *et al.* (1991) observed that inoculation of mungbean (*Vigna radiata* L.) cv. ML 131 with single and multiple strains of *Rhizobium* increased seed yield.

Thakuria and Saharia (1990) reported that different varieties of mungbean differed significantly in respect of grain yield.

Sangakara and Marambe (1989) observed that mungbean (*Vigna radiata* L.) seed inoculation plus applied N (25 kg ha^{-1}) gave seed yields 8.1-10.1 g per plant, compared with 8.3 g with N (25 kg ha^{-1}) alone and 5.2-6.5 g with inoculation alone. Seed inoculation was the most effective method.

Maiti *et al.* (1988) in trials with green gram (*Vigna radiata*) and lentil grown in soils given 60 or 100 kg ha^{-1} each of P_2O_5 and nitrogen and seed inoculation increased the *Vigna radiata* seed yields by 15-20 and 5-10%, respectively but had no significant effect on seed yields.

Gupta *et al.* (1988) in pot trials with *Vigna radiata* grown in a P-deficient soil found that seed inoculation with *Rhizobium* and/or application of 40 kg P_2O_5 ha^{-1} increased the seed yield $plant^{-1}$.

Prasad and Ram (1988) in pot trials with *Vigna radiata* cv. Pusa Baisakhi, effects of mixing into soil of 0, 2.5 and 5.0 ppm Zn and/or *Rhizobium* on nodulation and seed yields were studied. Inoculation + 2.5 ppm Zn + 2.5 ppm Cu gave the highest values for seed yields ha^{-1}.

Patel *et al.* (1986) found that response of *Rhizobium* inoculation in respect of grain yield was found to be significantly high.

Gill *et al.* (1985) reported that inoculation increased the straw and grain yield.

Ali and Chandra (1985) observed that Rhizobium inoculation increased the grain yield of most of the pulse crops from 10 to 20 percent but the legume required a specific group of *Rhizobia.*

Iswarna and Marwaha (1982) observed marked increase in seed yield of mungbean (*Vigna radiata*) due to *Rhizobium* inoculation in pot culture experiment.

Srevastava and Tewari (1981) reported that inoculation and phosphorous increased the grain and straw yields in green gram with a slight advantage from split application but their grains were not significant.

2.1.10 Effect on harvest index

Gill *et al.* (1985) reported that inoculation increased the harvest index.

Srevastava and Tewari (1981) reported that inoculation and phosphorous increased the harvest index in green gram with a slight advantage from split application but their grains were not significant.

2.2 Effect of plant population

2.2.1 Effect on plant height

El-Habbasha *et al.* (1996) reported that increasing plant density increased plant height of mungbean.

Shukla and Dixit (1996) carried out a field experiment during 1989-1990 to study the response of summer green gram (*Phaseolus raditus* L.) to *Rhizobium* inoculation, plant population and different levels of phosphorus. Plant population at 30 cm row spacing increased plant height and found superior at 40 and 20 cm spacing. Interaction between inoculation and row spacing was also found significant for yield attributes and grain yield.

Brathwaite (1982) noticed that increasing crop density remained unaffected plant height. He recommended crop density of 1,48,000 plants ha^{-1}.

Muesca and Oria (1981) observed that with a dense stand (25 plants m^{-2}) plant height was the highest (68 cm).

Hoq and Hossain (1981) conducted an experiment and observed that significant effect of plant density on the plant height of mungbean because of using different spacing.

2.2.2 Effect on nodulation and dry weight of nodule

Shukla and Dixit (1996) carried out a field experiment during 1989-1990 to study the response of summer green gram (*Phaseolus raditus* L.) to *Rhizobium* inoculation, plant population and different levels of phosphorus. Plant population at 30 cm row spacing increased the number of nodules $plant^{-1}$, nodule weight $plant^{-1}$ and found superior to 40 and 20 cm spacing.

2.2.3 Effect on leaf area index

Shukla and Dixit (1996) carried out a field experiment during 1989-1990 to study the response of summer green gram (*Phaseolus raditus* L.) to *Rhizobium* inoculation, plant population and different levels of phosphorus. Plant population at 30 cm row spacing increased the leaf area index and found superior to 40 and 20 cm spacing.

By working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density increased leaf area index.

Leaf area development rates differ even at the vertical level in mungbean and cowpeas. The growth rate of mungbean is slow during the early vegetative phase but it increases with the advancement of the age of the plant. Increasing LAI by higher population density or by other cultural practices is likely to lead to higher yield potential (AVRDC, 1981).

Williams (1967) noticed that in the early stage of growth closer spacing showed higher crop growth rate and yield but in later stages all except the widest spacing gave constant yield in mungbean. The higher LAI and crop growth rates were obtained at higher density than at lower plant density (Sprent *et al.* 1977).

2.2.4 Effect on number of pods plant^{-1}

El-Habbasha *et al.* (1996) reported that increasing plant density decreased the number of pods plant^{-1} of mungbean.

In Thailand, Pookpakdi and Pataradilok (1993) investigated the response of genotypes of mungbean and black gram to planting dates and plant population densities sown at 2,00,000, 4,00,00 and 80,000 plants ha^{-1}. They observed that pod number plant^{-1} decreased with increasing density.

Panwar and Sirohi (1987) studied on the effect of plant population on grain yield and its components in mungbean. They used 4 cultivars and 2 plant population of mungbean and showed that the number of pods plant^{-1} decreased with increasing density in all cultivars.

While working with 2 mungbean cultivars Neciosup (1986) observed that the number of pods plant^{-1} was higher in the higher population.

By working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density increased pod number plant^{-1}.

Brathwaite (1982) noticed that increasing crop density decreased number of pods plant^{-1}. He recommended crop density of 1,48,000 plants ha^{-1}.

Muesca and Oria (1981) observed that with a dense stand (25 plants m^{-2}) number of pods plot^{-1} was the greatest (484 plot^{-1}).

2.2.5 Effect on number of seeds/ pods

Miranda *et al.* (1997) reported that in a field experiment in Gurupi, Tocanties, Brazil with *V. radiata* cv. Ouro Verde in 1994/1995 and a local indeterminate cultivar of *V. umbellata* in 1995, plants were grown at densities of 1,00,000, 2,00,000, 3,00,000, 4,00,000 and 5,00,000 plants ha^{-1}. Average number of seeds pod^{-1} decreased with increased density in *V. radiata* occurred at 3,00,000 plants ha^{-1}.

Panwar and Sirohi (1987) studied on the effect of plant population on grain yield and its components in mungbean. They used 4 cultivars and 2 plant population of mungbean. They showed that the number of seeds pod^{-1} on branches increased with increasing plant density in all cultivars.

By working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density had little effect on the average number of seeds pod^{-1} (8.2-8.6).

2.2.6 Effect on the weight of 1000 seeds

While working with 2 mungbean cultivars Neciosup (1986) observed that 1000 seed weight was higher in the higher population.

By working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density had little effect on 1000 seeds weight (42.60-47.10 g).

2.2.7 Effect on number of seed yield plant^{-1}

El-Habbasha *et al.* (1996) reported that increasing plant density decreased seed yield plant^{-1} of mungbean.

Panwar and Sirohi (1987) studied on the effect of plant population on grain yield and its components in mungbean. They used 4 cultivars and 2 plant population of mungbean. They showed that the seed yield plant^{-1} decreased with increasing plant density in all cultivars.

Muesca and Oria (1981) observed that seed yield plant^{-1} was the highest (369 g plot^{-1}) at the lowest density of 10 plants m^{-2}.

2.2.8 Effect on seed yield, straw yield and harvest index

Singh *et al.* (1998) conducted a field experiment with six mungbean (*Vigna radiata*) genotypes at Patnagar, India, during 1995 under seed rates 25, 30 and 35 kg ha^{-1}. Significant differences in yield components were observed among sowing rates and grain yield ha^{-1} was the greatest under the 30 kg ha^{-1} sowing rate.

Miranda *et al.* (1997) reported that in a field experiment in Gurupi, Tocanties, Brazil with *V. radiata* cv. Ouro Verde in 1994/1995 and a local indeterminate cultivar of *V. umbellata* in 1995, plants were grown at densities of 1,00,000, 2,00,000, 3,00,000, 4,00,000 and 5,00,000 plants ha^{-1}. A stand density of 3,00,000 plants ha^{-1} gave the highest average seed yields of 0.94 and 1.06 t ha^{-1} in *V. radiata* and *V. umbellata*, respectively.

Shukla and Dixit (1996) carried out a field experiment during 1989-1990 to study the response of summer green gram (*Phaseolus raditus* L.) to *Rhizobium* inoculation, plant population and different levels of phosphorus. Plant population at 30 cm row spacing increased the grain yields (18.5%) and found superior to 40 and 20 cm spacing. Interaction between inoculation and row spacing was also found significant for yield attributes and grain yield.

Tomar and Tiwari (1996) also conducted a field trail in the late spring season of 1983 and 1984 to study response of green gram and black gram genotypes to plant density. They found that mean yield increased with increasing plant density up to 8,00,000 plants ha^{-1} in green gram and 10,00,000 plants ha^{-1} in black gram.

At Joydebpur, Haque (1995) carried out a field trail on *Vigna radiata* cultivar BM7703 using populations of 2,50,000, 3,33,333, 4,00,000 or 5,00,000 plants ha^{-1} and found that 3,33,333 plants ha^{-1} gave the highest seed yield.

Rezai and Hasanzadeh (1995) conducted a field experiment at the Research Station, College of Agriculture at Davark, Najof-Abad, Iran, *V. radiata* cv. Parto, Gohar and VC 1973 were sown on 6 dates at 15 days intervals between 21 April and 9 July at spacing of 7 or 14 cm. Seed yield was not significantly affected by plant spacing.

Singh and Singh (1995) conducted a field experiment with 4 cultivar each of mungbean (*Vigna radiata*) and urdbeans (*V. mungo*), were shown at 20, 25 or 30 kg seeds ha^{-1} (mungbean) and 30, 35 or 40 kg seeds ha^{-1} (urdbean). Seed yield of mungbean was the highest (1.32 t ha^{-1}) in cv. Pant M2 and it increased with seed rate.

Borah (1994) conducted a field experiment to study the performance of green gram genotypes under different seed rates (20, 30 and 35 kg ha^{-1}) during summer season. He found that seed yield increased constantly with increase in seed rate.

In Thailand, Pookpakdi and Pataradilok (1993) investigated the response of genotypes of mungbean and black gram to planting dates and plant population densities sown at 2,00,000, 4,00,00 and 80,000 plants ha^{-1}. They observed that yield of both crops generally increased with increasing plant density.

Mimber (1993) carried out a field trail on *Vigna radiata* cultivar Walet using 4,00,000, 6,00,000 or 8,00,000 plant populations ha^{-1}, with 20 cm row spacing, variable intra row spacing or 2 plants $hill^{-1}$ and found that yield increased with increasing plant population.

In a field experiment in 1983-84, Tomar *et al.* (1993) using 4 cultivars each of mungbean and urdbean at populations of 4,00,000, 6,00,000, 8,00,000 or 10,00,000 plants ha^{-1} found that a population of 10,00,000 plants ha^{-1} gave higher yield and higher returns than any other plant populations.

Singh *et al.* (1991) carried out a field experiment to study the effect of spacing and seed rate on the yield of black gram. They reported that plant population increased with the increasing seed rate and seed yields were 0.32, 0.48 and 0.55 t ha^{-1} with 16, 24 and 32 kg ha^{-1} seed rates respectively.

Thakuria and Saharia (1990) conducted a field trail with two green gram cultivars grown at 2,22,000 and 3,30,000 plants ha^{-1} and obtained average seed yields of 619 and 680 kg ha^{-1} respectively.

Jain *et al.* (1988) conducted at field experiment with 4 mungbean cultivars and found that crops grown in rows 30 cm apart (3,33,000 plants ha^{-1}) gave yields of 1.86 t ha^{-1} compared with 1.50 and 1.70 t ha^{-1} in crops grown in rows 15, 22.5 or 37.5 cm apart.

Panwar and Sirohi (1987) studied on the effect of plant population on grain yield and its components in mungbean. They used 4 cultivars and 2 plant population of mungbean. They showed that the yield ha^{-1} increased with increasing plant density in all cultivars.

While working with 2 mungbean cultivars Neciosup (1986) observed that yield increased proportionally with increasing population.

By working with 3 plant population densities of mungbean, Trung and Yoshida (1985) found that increasing plant density increased seed.

A high plant population (4,00,000 plants ha^{-1}) as compared to low plant population (2,00,000 plants ha^{-1}) produced maximum grain yield in trails of Singh and Malhotra (1983) and Maheshwari *et al.* (1974) in North India. They reported that maximum grain yield was obtained from a population of 3,00,000 to 4,00,000 plants ha^{-1}.

In a population study, involving two varieties, Jeswani and Saini (1981) found that the highest grain yield of mungbean was obtained in the dry season with 4,00,000 plants ha^{-1}, followed by 5,00,000 and 6,00,000 plants ha^{-1}.

It has been observed from a large number of trails conducted on grain legumes in India that they respond favourably to increased plant population from 1,00,000 to 5,00,000 plants ha^{-1} depending upon the growth conditions (Saini and Das, 1979).

Tsiung (1978) reported that in mungbean the harvest index decline before the maximum grain yield was attained, usually from the low density. He also reported that there was an increase in harvest index up to density giving the higher grain yield. All studies were consistent in showing a progressive decline in harvest index at densities above the maximum grain yield.

Beech and Wood (1978) conducted several studies and reported that in most studies, a higher plant population up to 4,50,000 plants ha^{-1} gave higher yields in mungbean under good management conditions.

Cagampang *et al.* (1977) determined optimum plant population of mungbean in the range of 3,00,000 to 4,00,000 plants ha^{-1} in the wet season and 4,00,000 to 5,00,000 plants ha^{-1} in the dry season to attain maximum yield.

CHAPTER 3

Materials and methods

MATERIALS AND METHODS

Details of different materials used and methodologies followed in the experiment are presented in this chapter.

3.1 Experimental site

The experiment was carried out at the Agronomy Field, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from March 21 to June 13, 2006 on "Influence of Bio-fertilizer and Plant Population on Growth and Yield of Mungbean". Field view of the experimental field is shown in Appendix I.

3.2 Soil

Initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. The physio-chemical properties of the soil are presented in Appendix II. The soil of the experimental plots belonged to the agro ecological zone of Madhupur Tract (AEZ-28) & shown in Appendix III.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of mean temperature (^0C), relative humidity (%), monthly mean rainfall (mm) and sunshine hours recorded by the Dhaka meteorology centre, Dhaka for the period of experimentation was presented in Appendix IV.

3.4 Experimental details

3.4.1 Planting materials

The variety of mungbean used for the present study was BARI mung-5. The seeds of this variety were collected from the Pulses Research Station of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristic of this variety is mentioned below:

BARI mung-5 (Taiwani)

The variety was released by Bangladesh Agricultural Research Institute (BARI) in 1997. Average plant height is 40-45 cm. Leaves, pods and seeds are comparatively large. Leaves and seeds are darker green. Average weight of thousand seeds is 40-42 g. The variety is resistant to *Cercospora* leaf spot and yellow mosaic virus. Maximum seed yield is 1.2-1.5 t ha^{-1}. Seeds contain 20-22 % protein and 49.46% carbohydrate.

Bradyrhizobium **Inoculam**

The *Bradyrhizobium* strain used in the present study were collected from the Soil Microbiology Laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Liquid broth of BINA-MB-441 and BINA-MB-THA-301 were mix individually with seed and then used in this experiment.

3.4.2 Experimental treatment

Two factors were included in the experiment namely, Inoculation/ Bio-fertilizer and Plant population. The treatments were designated as follows:

Factor A. Inoculation/ Bio-fertilizer: 3 (Three)

i. Control (I_0)

ii. Inoculation with BINA-MB-441 (I_1)

iii. Inoculation with BINA-MB-THA-301 (I_2)

Factor B. Plant population: 5 (Five)

i. 10 plants m^{-2} (P_1)

ii. 20 plants m^{-2} (P_2)

iii. 30 plants m^{-2} (P_3)

iv. 40 plants m^{-2} (P_4)

v. 50 plants m^{-2} (P_5)

3.5 Experimental design and layout:

The experiment was laid out in a Randomized Complete Block Design (Factorial) with three replications. Each block was divided into fifteen unit plots. Total numbers of unit plots were 45. The net size of unit plot was 8 m^2 (4.0 m x 2 m). The distance mentioned between two unit plots was 0.5 m and blocks were 1 m. Layout of the experiment was done on 19 February, 2006 and the treatments were allocated randomly. A layout of the experiment has been shown in Appendix II.

3.6 Procedure of the experiment

3.6.1 Land preparation

The land was irrigated before ploughing. After having zoe condition the land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on February 20 and 21, 2006 respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly.

3.6.2 Fertilizer application

The field was uniformly fertilized with 80 and 30 kg ha^{-1} P and K respectively, applied at the final land preparation. N @ 40 kg ha^{-1} was applied on 21 February , 2006 just before the sowing of seed.

3.6.3 Germination test

Germination test was performed before seed sowing in the field. Three layers of filter papers were placed on Petridishes. Each Petridish contained 100 seeds. Germination percentage was calculated by using the following formula.

$$\% \text{ Germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds taken for germination}} \times 100$$

3.6.4 Seed inoculation and sowing

Considering 90% purity, 80% germination, 20% safety allowance and 1000-seeds weight (42 g), seeds were mixed with liquid *Bradyrhizobium* cultures both BINA-MB-441 and BINA-MB-THA-301 individually. Then the quantity of seed required for each plot was weighed on the basis of experimental specification and placed in a cool place after keeping in polythene bags. The seeds were sown continuously in 25 cm apart rows at about 3 cm depth in the early morning of 21 February , 2006 and covered with soil.

3.6.5 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.6.5.1 Thinning

After emergence of the seedlings the thinning was done where necessary on 13 March , 2006 (20 DAS) to maintain the recommended plant population plot^{-1} which was specified in the experiment (10, 20, 30, 40 and 50 plants m^{-2}).

3.6.5.2 Weeding

The experimental plots were weeded two times. First weeding was done at the time of thinning (20 DAS) and second weeding on 30 DAS on 28 March , 2006.

3.6.5.3 Irrigation and drainage

No irrigation was given as there was no symptom of moisture stress during the experimentation.

3.6.5.4 Plant protection measures

Plants were infested by pod borer (*Maruca testulalis*) to some extent which was successfully controlled by applying Ripcord 10EC @ 1 ml Liter^{-1} of water for 5 decimal lands. It was also attacked yellow mosaic disease caused by yellow mosaic virus that was controlled in proper way. Before sowing, seed was treated with Bavistin 50WP to protect seed borne disease.

3.7 General observation

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

3.8 Determination of maturity

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

3.9 Harvesting and sampling

The crops were harvested on different dates as they attained maturity. From prefixed 1.0 m^2 area of each plot, five plants were selected randomly before harvesting and uprooted for data recording. The rest of the plants of those areas were harvested plot wise and were bundled separately, tagged and brought to a clean threshing floor.

3.10 Threshing

The crop bundles were sundried for two days by placing them on threshing floor. Seed were separated from the plants by beating the bundles with bamboo sticks.

3.11 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to about 14% level. The dried seeds and straw were cleaned and weighed/ plot.

3.12 Recording of data

The following observations regarding nodulation, growth parameters, yield and yield contributing characters were made:

A. Nodulation and growth parameters

i. Plant height (cm)

ii. Number of nodules $plant^{-1}$

iii. Weight of oven dried nodules $plant^{-1}$ (g)

iv. Leaf area index

B. Yield and yield contributing characters

i. Number of pods plant^{-1}

ii. Number of seeds pod^{-1}

iii. Weight of 1000 seeds (g)

iv. Seed yield plant^{-1} (g)

v. Seed yield (t ha^{-1})

vi. Straw yield (t ha^{-1})

vii. Harvest index (%)

3.13 Outline of data recording

A brief outline on data recording is gives below:

A. Nodulation and growth parameters

i. Plant height (cm)

The data of plant height was recorded from sampled plants at an interval of 15 days which was started from 25 DAS to harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

ii. Number of nodules plant^{-1}

From the inner side of all the border rows excluding the plants those were kept for recording final data (yield data), 5 plants were selected randomly at 45 DAS (Flowering stage) and uprooted carefully for counting the nodules plant^{-1}. Nodules from the lateral and taproots were counted and the mean was found out.

iii. Weight of oven dried nodules plant^{-1} (g)

Nodules from 5 plants were collected and dried in the electric oven maintaining a temperature of 85^0 C ± 5^0 C for 24 hours and dry weight was recorded with an electric balance.

iv. Leaf area index (LAI)

The sum of leaf area of whole leaves/ unit area is calculated leaf area index. It was calculated by using the following formula (Hunt, 1978), at 45 DAS (Flowering stage).

$$LAI = \frac{\text{Sum of the leaf area of all the leaves of plant}}{\text{Ground area of field where the leaves have been collected}}$$

B. Yield and yield components

i. Number of pods plant^{-1}

The number of pods from 5 randomly selected plants from each plot was determined at the time of harvesting to find out the number of pods/ plant.

ii. Number of seeds pod^{-1}

Pods were separated and 10 pods plot^{-1} were taken randomly and the seed were separated and counted. Then the average seed number was calculated.

iii. Weight of 1000 seeds (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

iv. Seed yield plant^{-1} (g)

The seed yield of 5 randomly selected plants plot^{-1} was taken at harvest by using electrical balance and per plant yield was calculated from average weight and expressed in gram.

v. Seed yield (t ha^{-1})

Plants of selected 1 m^2 plot^{-1} were harvested at complete maturity. The seeds of each pod were separated manually from the plants and dried in the sun to a constant weight. Seeds were recorded plot wise and yields were then converted to ton per hectare basis.

vi. Straw yield (t ha^{-1})

After pod separation the plants were sundried for several days to a constant weight. Then the straw yield expressed in ton per hectare.

vii. Harvest index (%)

Harvest index was calculated with the following formula:

$$\text{Harvest Index} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.14 Statistical analysis

Data recorded for different parameters were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done following computer package MSTAT programme. Mean differences among the treatments were tested with Least Significant Differences (LSD) at 5% level.

CHAPTER 4

Results and discussion

RESULTS AND DISCUSSION

The experimental results regarding the effect of inoculation, plant population and their interaction on the growth, yield and yield components of summer mungbean have been presented and discussed in this chapter. The effects of inoculation and plant population and their interaction on growth, yield and yield contributing characters have been shown in Fig. 1 to Fig. 8 and in Table 1 to Table 17.

Effects of Inoculation and plant population on growth, yield and other crop characters of mungbean

Effect of inoculation and plant population on different vegetative growth parameters, yield and yield contributing characters are discussed below.

4.1 Plant height

4.1.1 Effect of inoculation

The result showed that the effect of inoculation on plant height was significant at all stages of growth such as 25, 40, 55, 70 DAS and at harvest (Fig 1). BINA-MB 441 gave the significantly highest plant height at all stages of growth and at harvest (56.66 cm). was found in same inoculation. On the other hand, the lowest plant height was obtained from without inoculation condition at all stages of growth and finally it was 54.12 cm at harvest. The result was in agreement with the findings of Thakuria and Saharia (1990) who reported the plant height differed among varieties.

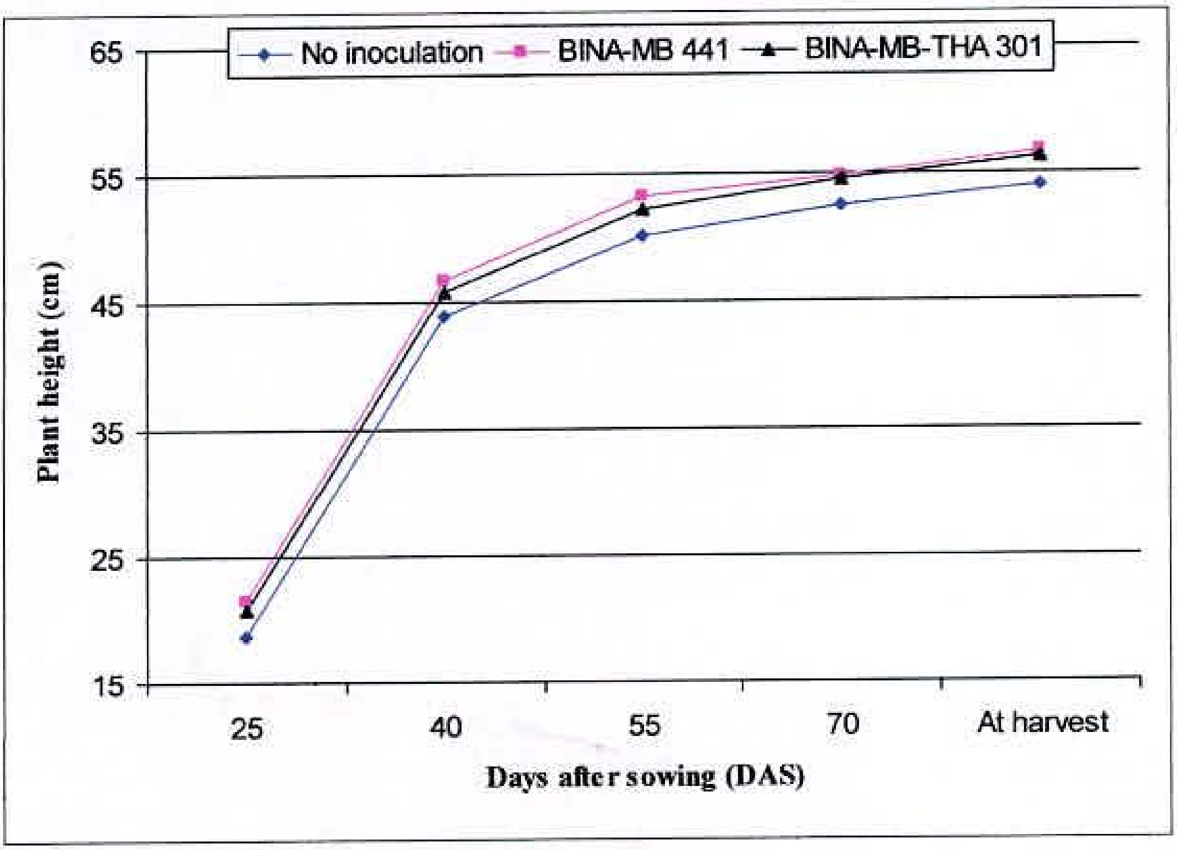

Fig. 1: Effect of Inoculation on plant height of mungbean at different days after sowing (DAS)

4.1.2 Effect of plant population

The plant height was significantly influenced by plant population for 25, 40, 55, 70 DAS and at harvest. The increasing plant population significantly increased plant height. At all stages of growth (25, 40, 55, 70 DAS and at harvest), the highest plant height (21.85, 47.85, 55.35, 57.49 and 58.70 cm) respectively was recorded in 50 plants m^{-2} and the lowest (19.17, 43.42, 49.08, 50.74 and 52.83 cm) respectively in 10 plants m^{-2} (Fig 2). Intermediate plant height was obtained from 30 plants m^{-2}.

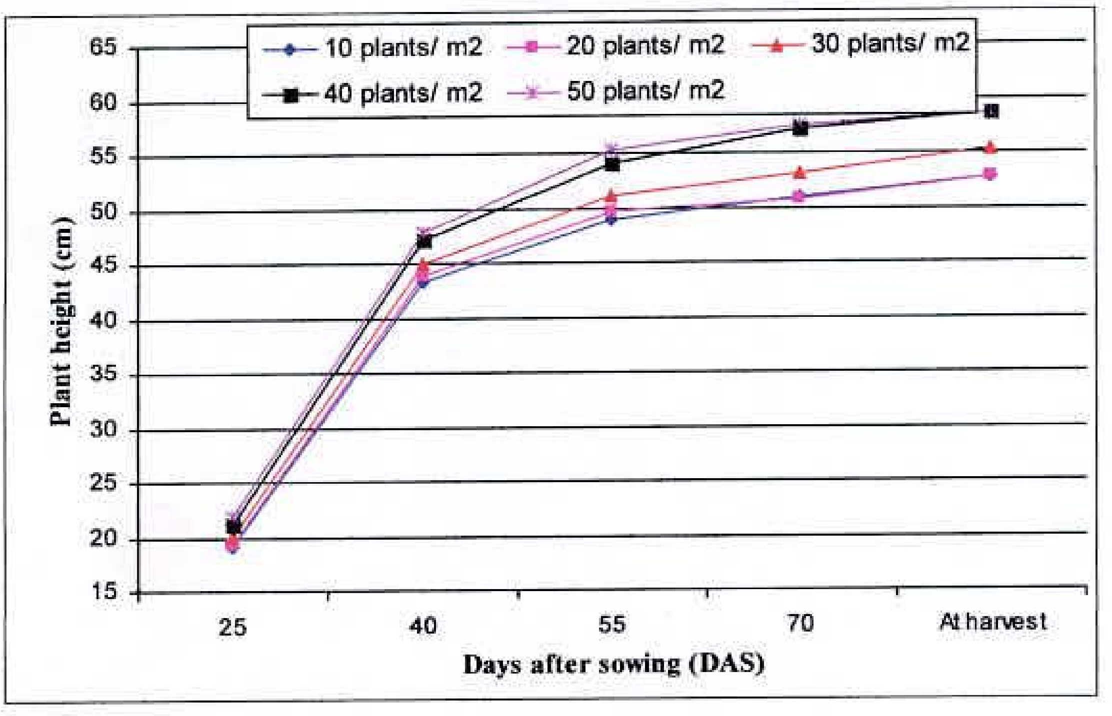

Fig. 2: Effect of plant population on plant height of mungbean at different days after sowing (DAS)

4.1.3 Interaction effect of inoculation and plant population

Interaction between inoculation and plant population exerted significant effect on plant height (Table 1). The highest plant height (23.43, 49.49, 57.00, 58.21 and 60.06 cm) was observed in the 50 plants m^{-2} inoculated with BINA-MB 441 in 25, 40, 55, 70 DAS and at harvest respectively while, the lowest one (17.90, 42.25, 48.90 and 50.60 cm) was observed in 20 plants m^{-2} with un-inoculated condition at 25, 40, 70 DAS and at harvest respectively, except 55 DAS. At 55 DAS significantly the lowest plant height (47.76 cm) was produced in 10 plants m^{-2} without inoculation which was statically similar with 20 plants m^{-2} at same condition.

Table 1: Interaction effect of inoculation and plant population on plant height of mungbeans at different days after sowing (DAS)

Treatment	Plant height (cm)				
	25 DAS	40 DAS	55 DAS	70 DAS	At harvest
P_1I_0	18.17	42.59	47.76	50.12	51.81
P_1I_1	20.23	44.17	50.47	51.57	53.49
P_1I_2	19.10	43.49	49.01	51.23	53.17
P_2I_0	17.90	42.25	47.95	48.90	50.60
P_2I_1	20.49	45.29	51.02	52.14	53.99
P_2I_2	19.92	44.06	50.01	51.19	54.00
P_3I_0	18.14	43.10	49.20	50.74	52.41
P_3I_1	21.43	46.53	53.23	54.23	56.81
P_3I_2	20.66	45.10	51.03	54.73	56.98
P_4I_0	19.60	45.47	52.48	55.69	57.85
P_4I_1	22.30	48.21	54.86	58.00	58.94
P_4I_2	21.88	47.78	55.21	57.90	58.89
P_5I_0	19.76	45.82	53.31	57.00	57.93
P_5I_1	23.43	49.49	57.00	58.21	60.06
P_5I_2	22.36	48.25	55.75	57.25	58.10
$LSD_{(0.05)}$	0.542	0.770	0.880	0.863	0.537

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.2 Number of nodules plant^{-1}

4.2.1 Effect of inoculation

Results presented in Table 2, showed that inoculation has significant effect on nodulation. Significantly the highest number of nodules plant^{-1} (10.71) was produced when inoculated with BINA-MB 441 compared to no inoculation (5.12). Intermediate number of nodules plant^{-1} (8.89) was obtained from BINA-MB-THA 3301. This result was similar with the results of Provorov *et al.* (1998); Poonam and Khurana (1997); Pandhar *et al.* (1991) and Vaishya *et. al.* (1993). They observed that *Rhyzobium* inoculation generally initiated the early nodule formation in the crown root system. For that reason nodulation was better in inoculated plant.

Table 2: Effect of Inoculation on number of nodules plant^{-1} and dry weight of nodules plant^{-1}

Inoculation	Number of nodules plant^{-1}	Dry weight of nodules plant^{-1}
I_0	5.12	34.73
I_1	10.71	46.17
I_2	8.89	43.44
$LSD_{(0.05)}$	0.343	3.535

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.2.2 Effect of plant population

The effect of plant population on nodule production was significant (Table 2). Significantly the highest number of nodules plant (10.44) was produced when 10 plants m^{-2} was grown. The second highest (9.33) was in 20 plants m^{-2}. The lowest number of nodules plant^{-1} (6.16) was obtained from 50 plants m^{-2}. In general, number of nodules plant^{-1} increased at lower plant population and it might probably due to availability of more space, nutrition, air, water and light to the plant.

Table 3: Effect of plant population on number of nodules plant^{-1} and dry weight of nodules plant^{-1}

Plant population	Number of nodules plant^{-1}	Dry weight of nodules plant^{-1}
P_1	10.44	42.30
P_2	9.33	43.69
P_3	8.55	42.56
P_4	6.71	39.55
P_5	6.16	39.12
$LSD_{(0.05)}$	0.4425	4.563

P_1=10 plants m^{-2}, P_2=20 plants m^{-2}, P_3=30 plants m^{-2}, P_4=40 plants m^{-2}, P_5=50 plants m^{-2}

4.2.3 Interaction effect of inoculation and plant population

Table 4 showed that the interaction effect between inoculation and plant population on nodule production was significant. It was revealed from the table that significantly the highest number of nodules plant^{-1} (13.32) was produced from 10 plants m^{-2} when inoculated with BINA-MB 441 and the lowest (3.15) from 50 plants m^{-2} without inoculation condition. The second highest number of nodules plant^{-1} (11.95) was obtained from 20 plants m^{-2} inoculation with BINA-MB 441 condition and intermediate (8.70) was from 40 plants m^{-2} with same condition.

Table 4: Interaction effect of Inoculation and plant population on number of nodules plant^{-1} and dry weight of nodules plant^{-1}

Treatment	Number of nodules plant^{-1}	Dry weight of nodules plant^{-1}
P_1I_0	7.21	38.79
P_1I_1	13.32	47.47
P_1I_2	10.78	40.63
P_2I_0	5.93	31.13
P_2I_1	11.95	47.70
P_2I_2	10.10	52.25
P_3I_0	5.21	27.10
P_3I_1	11.13	51.57
P_3I_2	9.32	49.00
P_4I_0	4.11	37.87
P_4I_1	8.70	42.90
P_4I_2	7.32	36.60
P_5I_0	3.15	38.73
P_5I_1	8.43	41.21
P_5I_2	6.91	38.70
$LSD_{(0.05)}$	0.766	7.903

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.3 Dry weight of nodules plant^{-1}

4.3.1 Effect of inoculation

Inoculation had a significant influence on dry weight of nodules plant^{-1}. Results presented in Table 2, showed that significantly the highest dry weight of nodules plant^{-1} (46.17 mg) was produced when inoculated with BINA-MB 441 and it was statistically similar with BINA-MB-THA 301 (43.44 mg). The lowest dry weight of nodules plant^{-1} (34.73 mg) was obtained from no inoculation condition. This result was similar with the results of Sattar and Ahmed (1995) and Bhuiyan and Obidullah (1992). They observed that *Rhyzobium* inoculation increased nodule weight significantly.

4.3.2 Effect of plant population

The effect of plant population was significant on dry weight of nodules plant^{-1}. Table 3 showed that the highest number of dry weight of nodules plant^{-1} (43.69 mg) was produced when 20 plants m^{-2} was grown which was followed by the second highest in 30 plants m^{-2} (42.56 mg) and the third highest in 10 plants m^{-2} (42.30 mg). The lowest nodule weight (39.12 mg) was obtained from 50 plants m^{-2}. In general, dry weight of nodules plant^{-1} increased at lower plant population, might probably due to availability of more space, nutrition, air, water and light to the plant which might help to produce more dry matt

4.3.3 Interaction effect of inoculation and plant population

The interaction effect between inoculation and plant population on dry weight of nodules plant^{-1} was significant. From Table 4, it was revealed that maximum dry weight of nodules plant^{-1} (52.25 mg) was obtained from BINA-MB-THA 301 inoculated plants with 20 plants m^{-2} and it was statistically similar with 30 plants m^{-2} (51.57 mg) inoculated with BINA-MB 441. The lowest one (27.10 mg) was produced from 30 plants m^{-2} without inoculation which was also statistically similar to 20 plants m^{-2} (31.13 mg) in same condition. Nodule dry weight increased with inoculation at wider spacing was also reported by (Shukla and Dixit, 1996) whose result was in conformity with the present investigation.

4.4 Leaf area index (LAI)

4.4.1 Effect of inoculation

Bradyrhizobium inoculation influenced LAI significantly. Significantly the highest (1.91) LAI was found in plant inoculated with BINA-MB-THA 301 which was statistically similar with BINA-MB 441 (1.88). The lowest (1.58) was produced from not inoculated plant. The inoculated plant produced higher leaf area than uninoculated plant. Similar result was reported by Shukla and Dixit (1996).

Table 5: Effect of inoculation on leaf area index of mungbean

Inoculation	Leaf area index
I_0	1.58
I_1	1.88
I_2	1.91
$LSD_{(0.05)}$	0.2256

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.4.2 Effect of plant population

Plant population had significant effect on leaf area Index (LAI). Significantly the highest LAI (2.31) was obtained from 50 plants m^{-2} and the lowest (1.47) from 10 plants m^{-2} and it was similar with 20 and 30 plants m^{-2}. Intermediate (1.97) LAI was obtained from 40 plants m^{-2} (Table 6). The highest plant population produced more leaf area and ultimately showed higher LAI. It was in agreement with the results of Trung and Yoshida (1985); AVRDC (1981) and Sprent *et al.* (1977).

Table 6: Effect of plant population on leaf area index

Plant population	Leaf area index
P_1	1.47
P_2	1.55
P_3	1.66
P_4	1.97
P_5	2.31
$LSD_{(0.05)}$	0.2913

P_1=10 plants m^{-2}, P_2=20 plants m^{-2}, P_3=30 plants m^{-2}, P_4=40 plants m^{-2}, P_5=50 plants m^{-2}

4.4.3 Interaction effect of inoculation and plant population

The interaction effect between inoculation and plant population on leaf area index was significant. From Table 7, it was revealed that the highest LAI (2.99) was obtained from BINA-MB 441 inoculated with 50 plants m^{-2} which was followed by BINA-MB-THA 301 with same condition (2.83). The lowest LAI (1.10) was found from 50 plants m^{-2} without inoculation.

Table 7: Interaction effect of inoculation and plant population on leaf area index

Treatments	Leaf area index
P_1I_0	1.67
P_1I_1	1.60
P_1I_2	1.15
P_2I_0	1.69
P_2I_1	1.48
P_2I_2	1.47
P_3I_0	1.50
P_3I_1	1.51
P_3I_2	1.96
P_4I_0	1.94
P_4I_1	1.83
P_4I_2	2.13
P_5I_0	1.10
P_5I_1	2.99
P_5I_2	2.83
$LSD_{(0.05)}$	0.5045

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.5 Number of pods plant^{-1}

4.5.1 Effect of inoculation

Inoculation showed significant difference in number of pods plant^{-1}. From the Fig. 3, it revealed that plant inoculated with BINA-MB 441 produced the highest number of pods plant^{-1} (13.55) whereas, uninoculated plant produced the lowest one (7.01). Intermediate pods plant^{-1} (12.08) was produced when plant inoculated with BINA-MB-THA 301. This result was in conformity with the findings of Basu and Bandyopadhyay (1990). Inoculation enhanced plant growth and development through maximum N and P uptake, which might resulted in increased number of pods plant^{-1}.

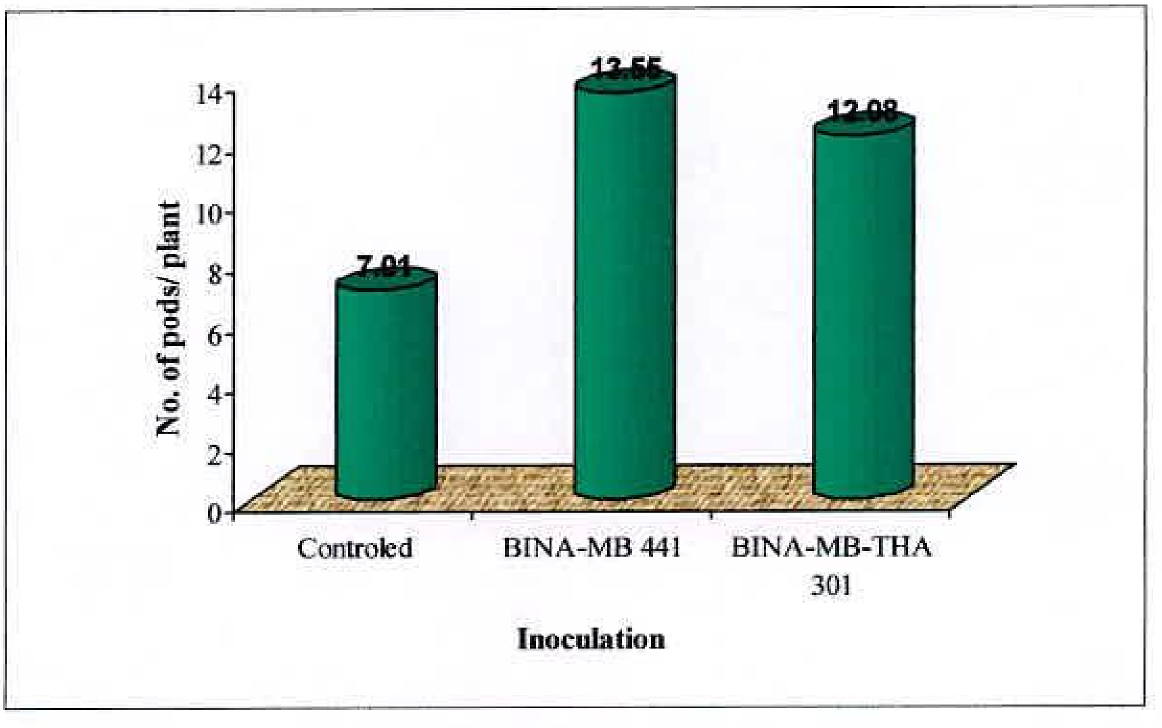

Fig 3: Effect of Inoculation on number of pods plant^{-1} ($LSD_{5\%}$ = 0.2983) of mungbean

4.5.2 Effect of plant population

Number of pods $plant^{-1}$ was significantly affected by plant population. There was inverse trend on number of pods $plant^{-1}$ due to plants m^{-2} (Fig. 4). Significantly the highest number of pods $plant^{-1}$ (14.26) was produced at 10 plants m^{-2} and the second highest was in 20 plants m^{-2} (12.78). The lowest (7.60) was found in 50 plants m^{-2}. Availability of more space, nutrition, air, water and light in the thinly populated crop resulted in the production of more pods $plant^{-1}$. A similar result was also found by Trung and Yoshida (1985) and El-Habbasha *et al.* (1996).

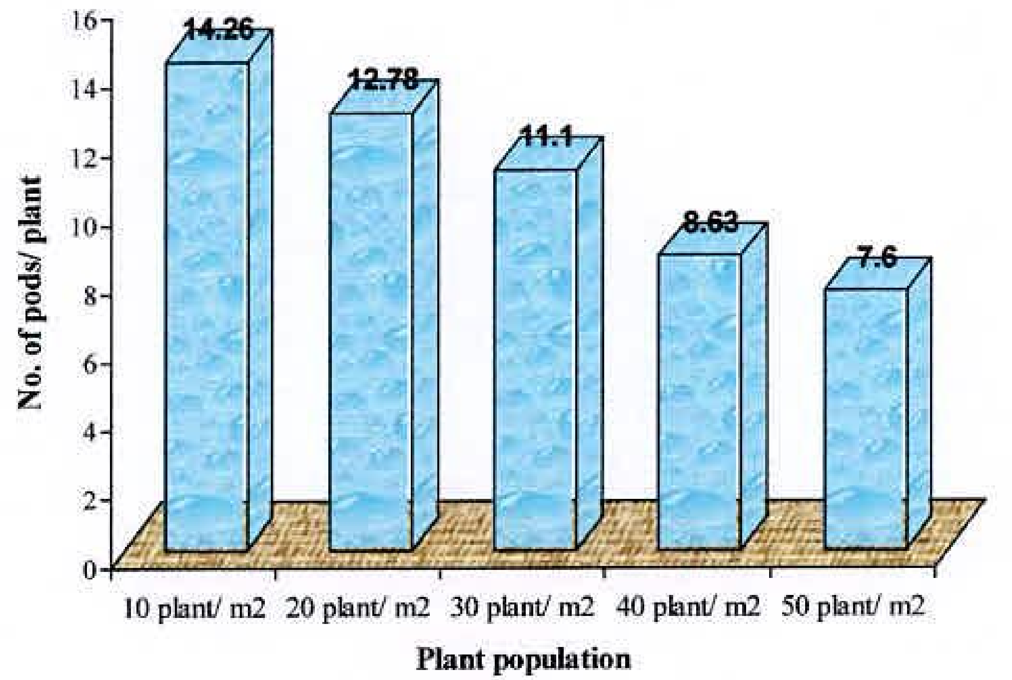

Fig 4: Effect of plant population on number of pods $plant^{-1}$ ($LSD_{5\%}$ = 0.3850) of mungbean

4.5.3 Interaction effect of plant population and inoculation

The interaction effect between inoculation and plant population was significant in number of pods plant^{-1}. From the Table 10, the highest number of pods plant^{-1} (16.69) was found in BINA-MB 441 inoculated condition when 10 plants m^{-2} were grown. The second highest was in 20 plants m^{-2} (15.32) inoculated with BINA-MB 441 which was identical with 10 plants m^{-2} when inoculated with BINA-MB-THA 301 (15.10). The lowest (4.99) was obtained from 50 plants m^{-2} without inoculation which was statistically identical with 40 plants m^{-2} (5.01) and 30 plants m^{-2} in same condition.

4.6 Number of seeds pod^{-1}

4.6.1 Effect of inoculation

Inoculation showed significant difference in number of seeds pod^{-1}. Inoculated plant with BINA-MB 441 produced the highest number of seeds pod^{-1} (10.12) and the lowest (8.88) from without inoculation (Table 8). It is in agreement with the result of Basu and Bandyopadhyay (1990). The variation might be due to *Bradyrhyzobium* inoculum enhanced P uptake which produced longer pod and ultimately produced higher number of seeds pod^{-1}.

Table 8: Effect of inoculation on number of seeds pod^{-1}

Inoculation	Number of seeds pod^{-1}
I_0	8.88
I_1	10.12
I_2	9.62
$LSD_{(0.05)}$	0.2435

I_0 = Control (No inoculation), I_1 = BINA-MB 441, I_2 = BINA-MB-THA 301

4.6.2 Effect of plant population

Number of seeds pod^{-1} was significantly affected by plant population. Table 9 shows that significantly the highest number of seeds pod^{-1} (10.07) was produced by 10 plants m^{-2} which was similar with the second highest in 30 plants m^{-2} (10.03). The lowest number of seeds pod^{-1} (8.38) was produced by 50 plants m^{-2}. Number of seeds pod^{-1} decreased gradually with the increased plant population probably due to hard competition of space, nutrition, air, water and light to the plant. This result is in agreement with the result of Miranda *et. al.* (1997).

Table 9: Effect of plant population on number of seeds pod^{-1}

Plant population	number of seeds pod^{-1}
P_1	10.07
P_2	9.91
P_3	10.03
P_4	9.18
P_5	8.38
$LSD_{(0.05)}$	0.3144

P_1=10 plants m^{-2}, P_2=20 plants m^{-2}, P_3=30 plants m^{-2}, P_4=40 plants m^{-2}, P_5=50 plants m^{-2}

4.6.3 Interaction effect of inoculation and plant population

The interaction effect between inoculation and plant population was significant in number of seeds pod^{-1}. From Table 10, it is evident that 10 plants m^{-2} produced the highest number of seeds pod^{-1} (10.74) inoculated with BINA-MB 441, which was similar to the second highest in 30 plants m^{-2} (10.71) with same condition. The lowest number of seeds pod^{-1} (7.67) was found in 50 plants m^{-2} without inoculation. Intermediate was 40 plants m^{-2} (9.31) inoculation with BINA-MB-THA 301. Different effect of different factors might be the cause of significance of interaction effect of factors.

Table 10: Interaction effect of inoculation and plant population on number of pods plant^{-1} and number of seeds pod^{-1}

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}
P_1I_0	10.99	9.45
P_1I_1	16.69	10.74
P_1I_2	15.10	10.03
P_2I_0	8.84	9.23
P_2I_1	15.32	10.41
P_2I_2	14.19	10.09
P_3I_0	5.19	9.26
P_3I_1	14.14	10.71
P_3I_2	13.97	10.13
P_4I_0	5.01	8.40
P_4I_1	11.66	9.82
P_4I_2	9.29	9.31
P_5I_0	4.99	7.67
P_5I_1	9.93	8.94
P_5I_2	7.87	8.53
$LSD_{(0.05)}$	0.6669	0.5445

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0= Control (No inoculation)
I_1= BINA-MB 441
I_2= BINA-MB-THA 301

4.7 Weight of 1000 seeds

4.7.1 Effect of inoculation

Difference between inoculated and uninoculated plants was significant in 1000 seeds weight. Table 11 shows that the highest 1000 seeds weight (48.51 g) was obtained in inoculated plants with BINA-MB 441 and the second highest (46.62 g) was in BINA-MB-THA 301. The lowest (42.49 g) was obtained from without inoculation. The present result is similar to the report of Podder *et al.* (1999).

Table 11: Effect of inoculation on weight of 1000 seeds

Inoculation	Weight of 1000 seeds(g)
I_0	42.49
I_1	48.51
I_2	46.62
$LSD_{(0.05)}$	0.344

I_0 = Control (No inoculation)
I_1 = BINA-MB 441
I_2 = BINA-MB-THA 301

4.7.2 Effect of plant population

Table 12 shows that the weight of 1000 seeds of mungbean was significantly affected by plant population. Significantly the highest 1000 seeds weight (47.54 g) was found in 10 plants m^{-2} but it was identical with the result when 30 plants m^{-2} (47.25 g) and 20 plants m^{-2} (47.12 g) were grown. The lowest 1000 seeds weight (42.64 g) was recorded in 50 plants m^{-2}. However, this yield attribute appeared to be increased perhaps due to less number of plant population m^{-2}, which provided scope for increased photosynthetic activities and translocation of more metabolites to the seed skin. Trung and Yoshida (1985) observed a similar result in mungbean.

Table 12: Effect of plant population on weight of 1000 seeds

Plant population	Weight of 1000 seeds
P_1	47.54
P_2	47.12
P_3	47.25
P_4	44.83
P_5	42.64
$LSD_{(0.05)}$	0.4436

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

4.7.3 Interaction effect of inoculation and plant population

The interaction effect between inoculation and plant population was significant on 1000 seeds weight. From Table 13, it is revealed that the highest 1000 seeds weight (50.71 g) was recorded in 10 plants m^{-2} inoculated with BINA-MB 441 and the second highest (49.91 g) was obtained from 30 plants m^{-2} in same condition, which was similar with 20 plants m^{-2} (49.82 g) with same condition. The lowest (40.01 g) 1000 seeds weight was produced in 50 plants m^{-2} without inoculation.

Table 13: Interaction effect of inoculation and plant population on weight of 1000 seeds

Treatments	Weight of 1000 seeds(g)
P_1I_0	43.84
P_1I_1	50.71
P_1I_2	48.06
P_2I_0	43.55
P_2I_1	49.82
P_2I_2	47.98
P_3I_0	43.69
P_3I_1	49.91
P_3I_2	48.14
P_4I_0	41.36
P_4I_1	47.23
P_4I_2	45.91
P_5I_0	40.01
P_5I_1	44.90
P_5I_2	43.00
$LSD_{(0.05)}$	0.7683

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0= Control (No inoculation)
I_1= BINA-MB 441
I_2= BINA-MB-THA 301

4.8.1 Effect of inoculation

4.8 Seed yield plant^{-1}

Effect of *Bradyrhyzobium* inoculum on seed yield plant^{-1} was significant. From the Fig 5, it was revealed that highest seed yield plant^{-1} (4.70 g) was obtained from inoculated plants with BINA-MB 441 and it was lowest (3.29 g) in without inoculation. Intermediate seed weight plant^{-1} (3.87 g) was produced from BINA-MB-THA 301. Higher number of seeds pod^{-1} and 1000 seeds weight might be the cause of higher seed yield plant^{-1} in inoculated plant over the control. This result was similar with the report of Provorov *et al.* (1998) and Gill *et al.* (1985) that inoculation significantly increased seed yield plant^{-1} of mungbean.

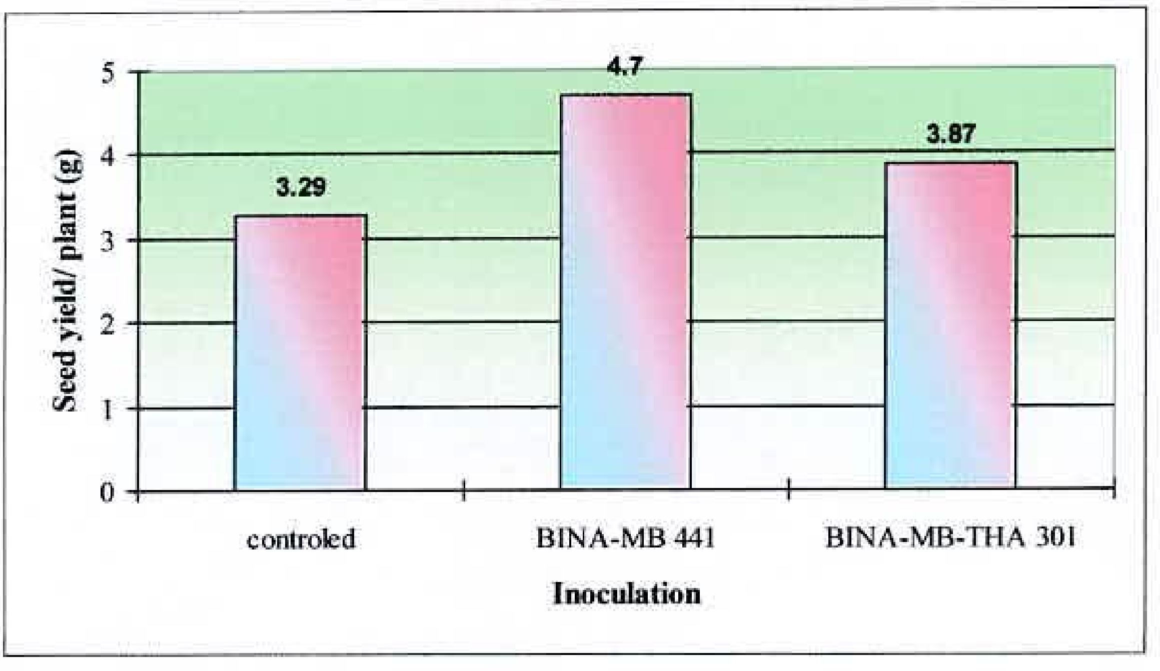

Fig 5: Effect of Inoculation on seed yield plant^{-1} (LSD $_{5\%}$ = 0.3944)

4.8.2 Effect of plant population

Seed yield plant^{-1} was significantly differed by plant population. From the Fig 6, it is revealed that there was inverse trend between seed yield plant^{-1} and plants m^{-2}. Significantly the highest seed yield plant^{-1} (5.61 g) was obtained from 10 plants m^{-2} and the second highest (4.81 g) was in 20 plants m^{-2}. The lowest seed yield plant^{-1} (2.26) was recorded in 50 plants m^{-2}. Seed yield plant^{-1} increased with the decrease of plant population m^{-2}. This trend was similar with the report of Muesca and Oria (1981). It might be attributed to more number of pods plant^{-1}, seeds pod^{-1} and 1000 seeds weight in lowest plant population.

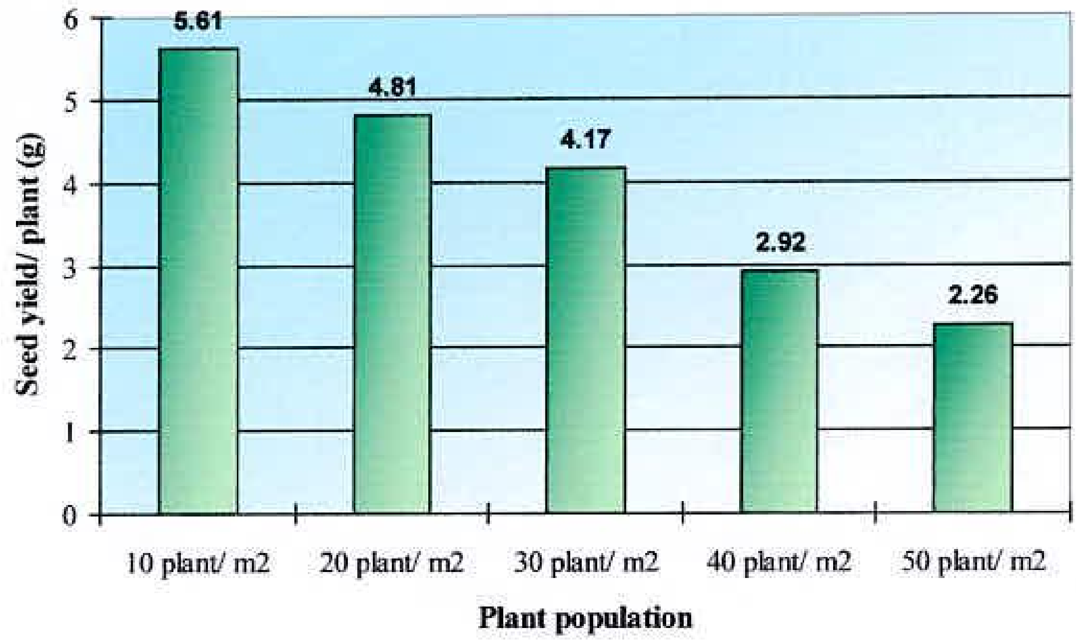

Fig 6: Effect of plant population on seed yield plant^{-1} (LSD $_{5\%}$ = 0.5091)

4.8.3 Interaction effect of inoculation and plant population

The interaction effect between inoculation and plant population was highly significant in respect of seed yield plant^{-1}. From the Table 14, it was evident that significantly the highest seed yield plant^{-1} (6.98 g) was recorded in 10 plants m^{-2} inoculated with BINA-MB 441. The second highest (5.51 g) was obtained in BIMA-MB 441 inoculation with 20 plants m^{-2}, which was statistically identical with 10 plants m^{-2} (5.01 g) and 30 plants m^{-2} (5.00 g) when inoculated with BINA-MB-THA 301 and BINA-MB 441 respectively. The lowest seed yield plant^{-1} (1.95 g) was produced by 50 plants m^{-2} without inoculation, which was also statistically identical to 50 plants m^{-2} (2.10 g) inoculated with BINA-MB-THA 301. These findings might be due to dissimilar response of plant population with inoculation.

Table 14: Interaction effect of inoculation and plant population on seed yield $plant^{-1}$ and seed yield

Treatments	Seed yield $plant^{-1}$ (g)	Seed yield
P_1I_0	4.83	0.50
P_1I_1	6.98	0.69
P_1I_2	5.01	0.50
P_2I_0	4.08	0.68
P_2I_1	5.51	1.10
P_2I_2	4.83	0.97
P_3I_0	3.01	0.90
P_3I_1	5.00	1.50
P_3I_2	4.51	1.35
P_4I_0	2.59	1.04
P_4I_1	3.30	1.32
P_4I_2	2.88	1.15
P_5I_0	1.95	0.98
P_5I_1	2.73	1.37
P_5I_2	2.10	1.05
$LSD_{(0.05)}$	0.8818	0.09161

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0= Control (No inoculation)
I_1= BINA-MB 441
I_2= BINA-MB-THA 301

4.9 Seed yield

4.9.1 Effect of inoculation

Seed yield differed significantly by *Bradyrhyzobium* inoculation. Fig 7 revealed that inoculated plants with BINA-MB 441 produced significantly the highest seed yield (1.120 t ha^{-1}) compared with uninoculated plants (0.82 t ha^{-1}). Intermediate seed yield (1.00 t ha^{-1}) was obtained from BINA-MB-THA 301 inoculated plant. This might be due to better performance of inoculated plants over control. Similar result was found by Poonam and Khurana (1997), Pandher *et al.* (1991) and Gill *et al.* (1985).

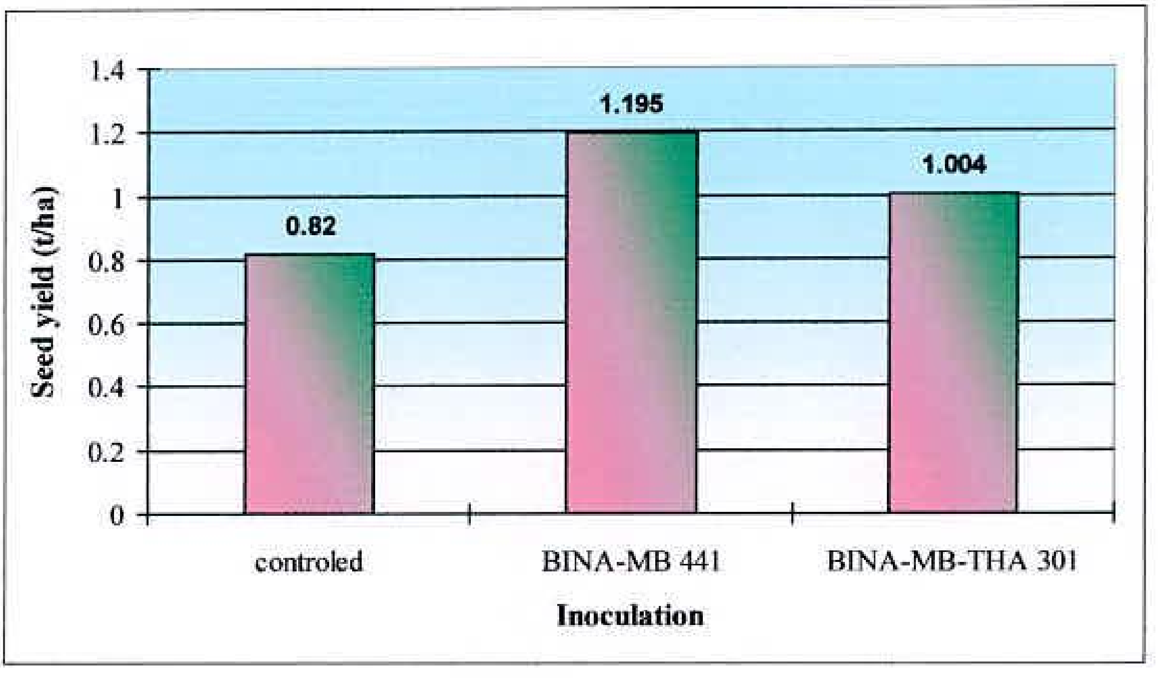

Fig 7: Effect of Inoculation on seed yield (LSD $_{5\%}$ = 0.04097) of mungbean

4.9.2 Effect of plant population

Plant population was significant in respect of seed yield. From the Fig 8, it was revealed that a gradual increase of plant population $unit^{-1}$ area up to a tolerable limit, increased the seed yield, thereafter it decrease with increase plant population. The highest seed yield

(1.25 t ha^{-1}) was obtained by 30 plants m^{-2} and the second highest (1.17 t ha^{-1}) was in 40 plants m^{-2} and the lowest one (0.56 t ha^{-1}) was recorded in 10 plants m^{-2}. It might be attributed due to more number of plants and more number of total pods $unit^{-1}$ area also reported by Mimber (1993), Trung and Yoshida (1985) and Beech and Wood (1978).

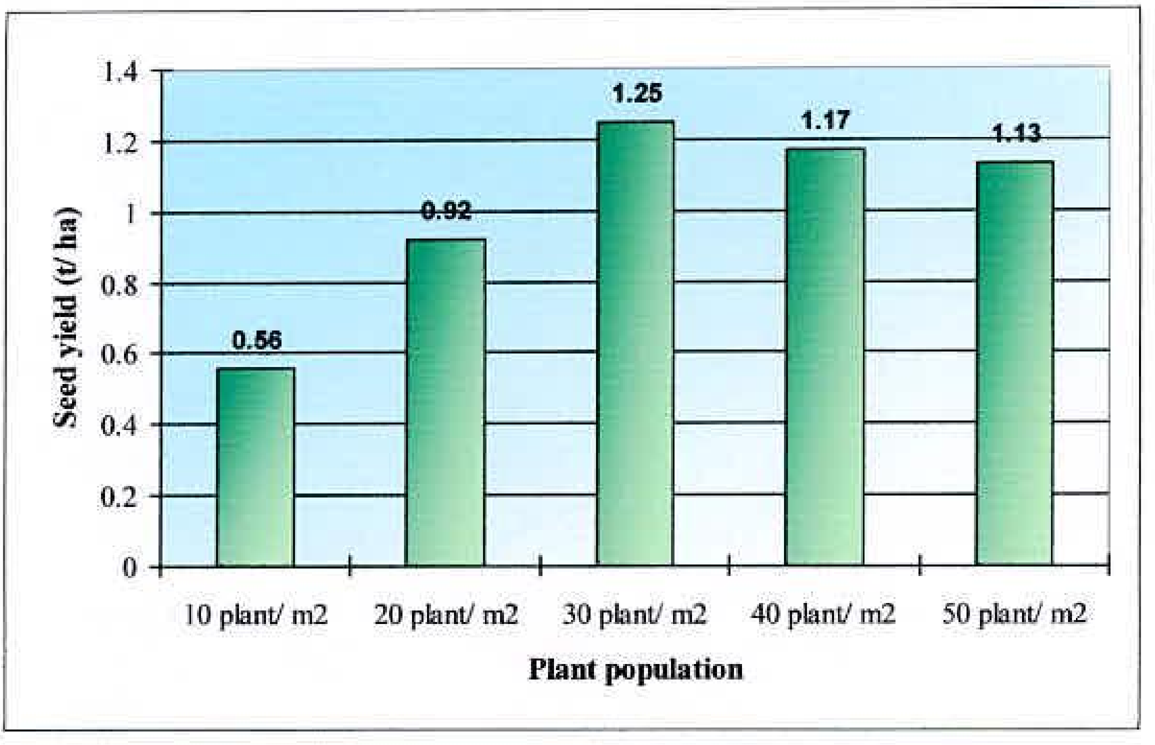

Fig 8: Effect of plant population on seed yield (t ha^{-1}) (LSD $_{5\%}$ = 0.05289)

4.9.3 Interaction effect of inoculation and plant population

Seed yield was significantly affected by inoculation and plant population interaction. Table 14 shows that significantly the highest seed yield (1.50 t ha^{-1}) was obtained in 30 plants m^{-2} inoculated with BINA-MB 441 and the lowest (0.50 t ha^{-1}) was recorded in 10 plants m^{-2} both in without inoculation and inoculated with BINA-MB-THA 301. The second highest (1.37 t ha^{-1}) was produced by 50 plants m^{-2} inoculated with BINA-MB

441, which was statistically identical with 30 plants m^{-2} (1.35 t ha^{-1}) in same condition and 40 plants m^{-2} (1.32 t ha^{-1}) inoculated with BINA-MB-THA 301. This might be due to different response of plant density with inoculation; similar result was reported by Shukla and Dixit (1996).

4.10 Straw yield

4.10.1 Effect of inoculation

Bradyrhyzobium inoculation played significant role on straw production. Table 15 shows that inoculated plants with BINA-MB 441 produced the highest straw (3.27 t ha^{-1}) compared with without inoculated (2.69 t ha^{-1}). This Finding follows the result of Gill *et. al.* (1985) that inoculation significantly increased seed and straw yield.

Table 15: Effect of Inoculation on straw yield and harvest index

Inoculation	Straw yield(t/ha)	Harvest index
Control	2.69	23.61
BINA-MB 441	3.27	27.65
BINA-MB-THA 301	2.97	25.67
$LSD_{(0.05)}$	0.222	0.341

4.10.2 Effect of plant population

Straw production significantly differed by plant population. From the Table 16, it was evident that straw yield increasd with increasing plant population m^{-2}. Significantly the highest straw yield (3.65 t ha^{-1}) was produced from 50 plants m^{-2} and the lowest (2.16 t

ha^{-1}) from 10 plants m^{-2}. The second highest (3.27 t ha^{-1}) was in 40 plants m^{-2}. This result might be due to more number of plant $unit^{-1}$ area.

Table 16: Effect of plant population on straw yield and harvest index of mungbean

Plants/m^2	Straw yield(t/ha)	Harvest index
10	2.16	25.24
20	2.81	24.35
30	2.98	29.28
40	3.27	26.31
50	3.65	23.04
$LSD_{(0.05)}$	0.287	0.440

P_1=10 plants m^{-2}, P_2=20 plants m^{-2}, P_3=30 plants m^{-2}, P_4=40 plants m^{-2}, P_5=50 plants m^{-2}

4.10.3 Interaction effect of plant inoculation and population

The interaction effects of inoculation and plant population played significant role on straw production (Table 17). Significantly the highest straw yield (3.97 t ha^{-1}) was produced from 50 plants m^{-2} when plant inoculated with BINA-MB 441 and it was statistically similar with 40 plants m^{-2} (3.54 t ha^{-1}) and 50 plants m^{-2} (3.52 t ha^{-1}) BINA-MB 441 and no inoculation condition. The lowest (1.80 t ha^{-1}) was produced from 10 plants m^{-2} when inoculated with BINA-MB-THA 301, which was also similar with 10 plants m^{-2} without inoculation condition.

Table 17: Interaction effect of Inoculation and plant population on straw yield and harvest index

Treatment	Straw yield(t/ha)	Harvest index
P_1I_0	2.06	21.85
P_1I_1	2.63	28.22
P_1I_2	1.80	25.64
P_2I_0	2.44	21.79
P_2I_1	3.05	26.51
P_2I_2	2.95	24.74
P_3I_0	2.45	26.87
P_3I_1	3.15	32.26
P_3I_2	3.35	28.72
P_4I_0	3.00	25.74
P_4I_1	3.54	27.16
P_4I_2	3.27	26.02
P_5I_0	3.52	21.78
P_5I_1	3.97	24.12
P_5I_2	3.47	23.23
$LSD_{(0.05)}$	0.496	0.763

P_1 = 10 plants m^{-2}
P_2 = 20 plants m^{-2}
P_3 = 30 plants m^{-2}
P_4 = 40 plants m^{-2}
P_5 = 50 plants m^{-2}

I_0= Control (No inoculation)
I_1= BINA-MB 441
I_2= BINA-MB-THA 301

4.11 Harvest index

4.11.1 Effect of inoculation

Bradyrhyzobium inoculation played an effective role on straw production. Significantly the highest harvest index (27.65) was recorded in inoculated plant with BINA-MB 441 and the lowest one (23.61) from uninoculated (Table 15). Intermediate (25.67) was in

BINA-MB-THA301. This result was similar with the report of Gill *et al.* (1985) that inoculation significantly increased harvest index.

4.11.2 Effect of plant population

Plant population $unit^{-1}$ area exerted significant difference on harvest index. From the Table 16, it is revealed significantly the highest harvest index (29.28) from 30 plants m^{-2} and the second highest (26.31) in 40 plants m^{-2} and the lowest (23.04) was in 50 plants m^{-2}. This result is in agreement with the result of Tsuing (1978).

4.11.3 Interaction effect of inoculation and plant population

The interaction effect of inoculation and plant population was significant on harvest index. Table 17 shows that significantly the highest harvest index (32.26) was recorded from 30 plants m^{-2} inoculated with BINA-MB 441 and the second highest (28.72) was in 30 plants m^{-2} inoculated with BINA-MB-THA 301 which was statistically similar with 10 plants m^{-2} (28.22) inoculated with BINA-MB 441. The lowest one (21.78) was obtained from 50 plants m^{-2} at no inoculation condition which was also statistically similar with 10 plants m^{-2} (21.85) and 20 plants m^{-2} (21.79) with same condition.

CHAPTER 5

Summary and conclusion

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from March to June, 2006 in *kharif* -1 season by using BARI mung-5 variety to study the "Influence of Bio-fertilizer and Plant Population on Growth and Yield of Summer Mungbean". The experiment comprised of two different factors viz. A. Inoculation (Three): i. not inoculation (I_0), ii. BINA-MB 441 (I_1), iii. BINA-MB-THA 301 (I_2) and B. Plant population (Five): 10, 20, 30, 40 and 50 plants m^{-2} (P_1, P_2, P_3, P_4 and P_5 respectively). The experiment was laid out in Randomized Complete Block Design (Factorial) with three replications. The unit plot size was 8 m^2 (4 m x 2 m). The distance mentioned between two unit plots was 0.5 m and blocks were 1.0 m. Chemical fertilizer (Urea, TSP and MP) were applied as per their recommended dose. Intercultural operations viz. weeding, water management and pest management were done as and when necessary.

The data for measuring different parameters like plant height, number of nodules $plant^{-1}$, dry weight of nodules $plant^{-1}$, leaf area index, number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000 seeds weight, seed yield $plant^{-1}$, seed yield, straw yield and harvest index were recorded. The recorded and calculated data were analyzed statistically and mean differences were adjudged by Least Significant Difference (LSD) Test at 5% level of significance.

Results revealed that bio-fertilizer had significant influence on all the crop characters. Plant height at all sampling dates varied significantly due to inoculation. Among the inoculation BINA-MB 441 produced the highest plant height (56.66 cm) whereas control produced the lowest (54.12 cm). BINA-MB 441 also produced significantly the highest number of nodules plant', dry weight of nodules plant', number of pods plant', number of seeds pod'', weight of 1000 seeds, seed yield plant', seed yield, straw yield and harvest index, except leaf area index (LAI). LAI was the highest in BINA-MB-THA 301. In case of not inoculation condition, value of all characters was significantly the lowest. Intermediate value of all characters was observed in BINA-MB-THA 301 condition.

There was a significant influence of plant population on all of the parameters at all sampling dates. The tallest plant (58.70 cm) was obtained from 50 plants m^{-2} and the shortest ones from 10 plants m^{-2} (52.83 cm). At harvest all the crop characters were influenced by plant population significantly. The highest number of nodules plant-^{1} (10.44), number of pods plant'' (14.26), number of seeds pod-^{1} (10.07), weight of 1000 seeds (47.54 g) and seed yield plant-^{1} (5.61 g) but the lowest LAI (1.47), seed yield (0.56 t ha^{-1}) and straw yield (2.16 t ha^{-1}) were found in 10 plants m^{-2}. On the contrary, 50 plants m^{-2} showed the lowest number of nodules $plant^{-1}$ (6.16), dry weight of nodules $plant^{-1}$ (39.12 mg), number of pods $plant^{-1}$ (7.6), number of seeds pod^{-1} (8.38), weight of 1000 seeds (42.64 g), seed yield $plant^{-1}$ (2.26 g) and harvest index (23.04%) but the highest LAI (2.31) and straw yield (3.65 t ha^{-1}). The highest dry weight of nodules $plant^{-1}$ (43.69 g) and seed yield (1.25 t ha^{-1}) were produced by 20 plants m^{-2} and 30 plants m^{-2} respectively.

Interaction effect between inoculation and plant population was significantly influence all characters of mungbean. Combination of BINA-MB 441 with 10 plants m^{-2} was found the best in respect of number of nodules plant^{-1} (13.32), number of pods plant^{-1} (16.69), number of seeds pod^{-1} (10.74), weight of 1000 seeds (50.71 g) and seed yield plant-' (6.98 g) whereas, significant plant height, leaf area index (2.99) and straw yield (3.97 t ha^{-1}) were found in BINA-MB 441 with 50 plants M-2. Besides, seed yield (1.5 t ha^{-}) and harvest index (32.26 %) were the highest in the combination of BINA-MB 441 with 30 plants m^{-2}. Significant dry weight of nodules plant^{-1} (52.25 mg) was found in BINA-MB-THA 301 with 20 plants m^{-2}. The lowest plant height, number of nodules plant^{-1} (3.15), leaf area index (1.10), number of pods plant^{-1} (4.99), number of seeds pod^{-1} (7.67), 1000 seeds weight (40.01 g), seed yield plant^{-1} (1.95 g) and harvest index (21.78 %) were found in 50 plants m^{-2}. In case of seed yield (0.5 t ha^{-1}) and dry weight of nodule plant^{-1} (27.10 mg) were found at 10 plants m^{-2} and 30 plants m^{-2}. The lowest straw yield (1.80 t ha^{-1}) was found in 20 plants m^{-2} inoculated with BINA-MB-THA 301.

Overall result of the field experiment showed that bio-fertilizer *(Bradyrhizobium)* was beneficial in growth, yield and yield contributing characters of mungbean. Bio-fertilizer appears to be an effective method of successful mungbean production which may also improve the soil health. For determination of effectiveness of bio-fertilizer and making any recommendation further should be performed in different locations for more conformation. From the above discussion, we conclude that BINA-MB 441 inoculums and 30 plants m^{-2} were the best to produce better mungbean during summer season.

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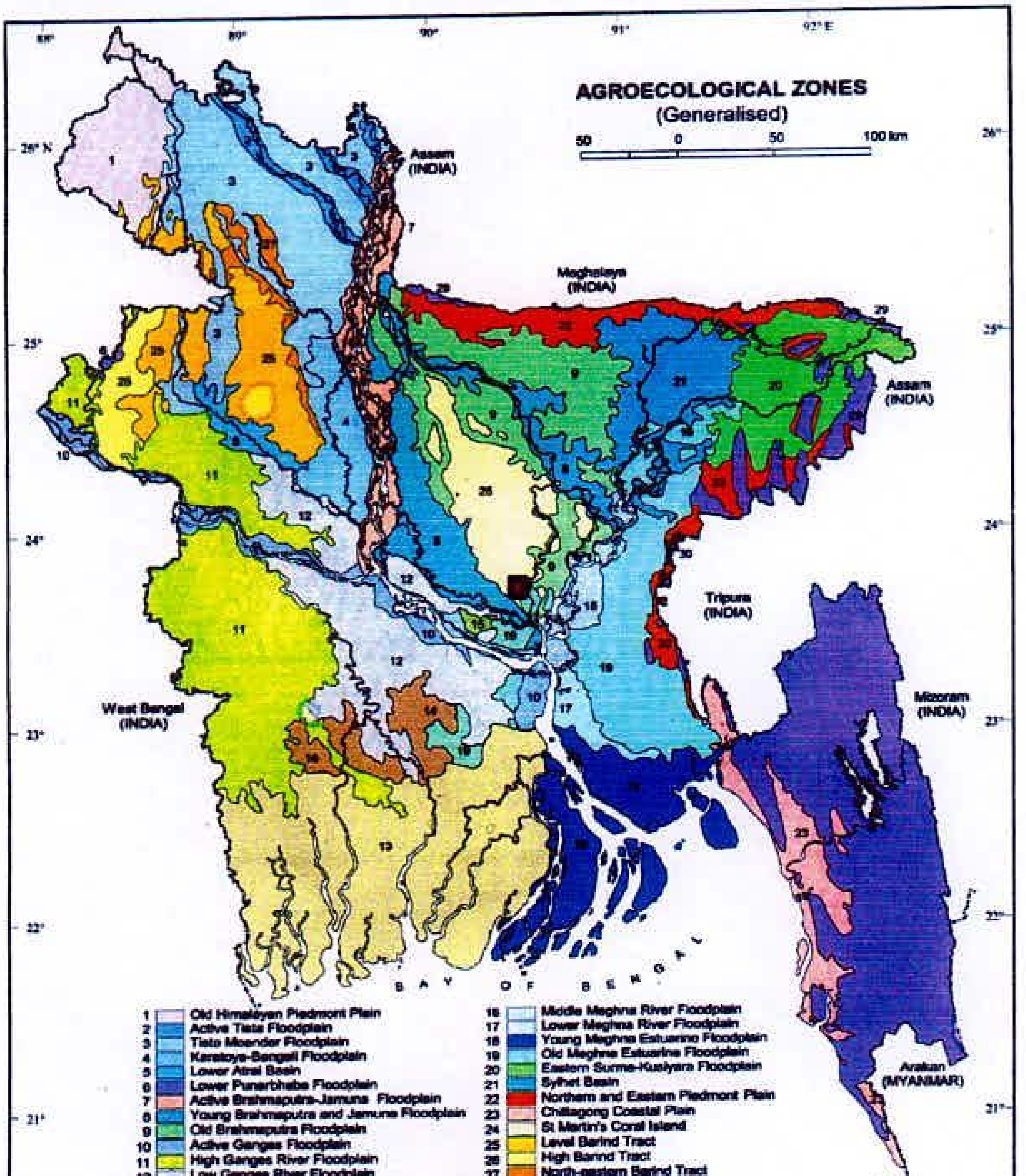
Appendices

APPENDICES

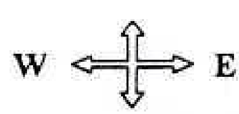
Appendix I. Map showing the experimental site under study



■ **The experimental site under study**

Appendix II. Lay out of experimental field

P_1I_0	P_3I_2	P_4I_1
P_1I_1	P_3I_1	P_4I_0
P_1I_2	P_3I_0	P_4I_2
P_2I_0	P_5I_2	P_1I_1
P_2I_1	P_5I_1	P_1I_2
P_2I_2	P_5I_0	P_1I_0
P_3I_0	P_4I_2	P_2I_1
P_3I_1	P_4I_1	P_2I_0
P_3I_2	P_4I_0	P_2I_2
P_4I_0	P_1I_2	P_5I_1
P_4I_1	P_1I_1	P_5I_0
P_4I_2	P_1I_0	P_5I_2
P_5I_0	P_2I_2	P_3I_1
P_5I_1	P_2I_1	P_3I_2
P_5I_2	P_2I_0	P_3I_0
R_1	R_2	R_3



Appendix III: Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	*Characteristics*
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	*Value*
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from February 2006 to May 2006.

Month	Sunshine hour	*RH (%)*	*Air temperature (°C)*			*Rainfall (mm)*
			Max.	*Min.*	*Mean*	
February	148	51.27	21.26	19.43	20.34	0
March	155	46.13	36.2	22	29.1	0
April	253	61.4	33.74	23.81	28.77	185
May	96	64.27	32.5	24.95	28.72	180

Source: Bangladesh Meterological Department (Climatic Division), Agargaon, Dhaka-1207.

PLATES

Plate 1. Field view of experimental plots at 15 days after sowing of mungbean

Plate 2. Field view of experimental plots at vegetative stage of mungbean

Plate 3. Field view of experimental plots at flower initiation stage of mungbean

Plate 4. Field view of experimental plots at pod initiation stage of mungbean