GROWTH AND YIELD RESPONSE OF MUNGBEAN TO THE APPLICATION OF NITROGEN AND BIOFERTILIZER

S. M. M. SHAHRIAR TONMOY

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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By

S. M. M. SHAHRIAR TONMOY

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Approved by:

(Prof. Dr. Md. Fazlul Karim)	**(Prof. Dr. Parimal Kanti Biswas)**
Supervisor	**Co-supervisor**

(Prof. Dr. Md. Fazlul Karim)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled " ***GROWTH AND YIELD RESPONSE OF MUNGBEAN TO THE APPLICATION OF NITROGEN AND BIOFERTILIZER"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***S. M. M. SHAHRIAR TONMOY,*** *Registration. No.* ***08-03047*** *under my supervision and guidance. No part of this 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:

Dhaka, Bangladesh

(Prof. Dr. Md. Fazlul Karim)
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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THE GROWTH AND YIELD RESPONSE OF MUNGBEAN TO THE APPLICATION OF NITROGEN AND BIOFERTILIZER

ABSTRACT

An experiment was carried out at Sher-e-Bangla Agricultural University farm, Dhaka to investigate the growth and yield response of mungbean *(Vigna radiata* L.*)* as affected by nitrogen and biofertilizer management during the period from September to November, 2014. The experiment consisted of two factors. Factor A: Nitrogen fertilizer (4 levels); N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal application, N_2: 20 kg N ha^{-1} at branching stage and N_3: 20 kg N ha^{-1} at flowering stage, and factor B: *Rhizobium* inoculum (3 levels); R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}. The variety, BARI Mung-6 was used in this experiment as the test crop. The experiment was laid out in split-plot design with three replications where levels of nitrogen were assigned in the main plot and doses of *Rhizobium* inoculum in the sub-plot. Plant height, leaf area $plant^{-1}$, dry weight $plant^{-1}$, branches $plant^{-1}$, nodules $plant^{-1}$, pods $plant^{-1}$, pod length, seeds pod^{-1}, weight of 1000 seed, seed yield, stover yield, biological yield and harvest index were tested under different treatments. Results revealed that, N_2 and R_2 treatment influenced significantly on most of the growth, yield parameters and yield of mungbean. N_2 gave the higher yield (1.37 t ha^{-1}) which was 77.92% higher than N_0 (0.77 t ha^{-1}). Application of *Rhizobium* inoculums greatly influenced the seed yield and R_2 produced (1.28 t ha^{-1}) which was 28.00% higher than R_0 (1.00 t ha^{-1}). The highest seed yield (1.69 t ha^{-1}) was recorded from the treatment combination of N_2R_2 and the minimum (0.73 t ha^{-1}) was recorded from the interaction of N_0R_1. The maximum yield might be attributed to higher pods $plant^{-1}$, seeds $pod^{-1}$and 1000-seeds weight. Application of 20 kg N ha^{-1} at branching stage as split and *Rhizobium* inoculums @ 8 kg ha^{-1} could be the best fertilizer and inoculum management for cultivation of mungbean for higher yield.

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LIST OF ACRONYMS

AEZ	= Agro-Ecological Zone
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
BBS	= Bangladesh Bureau of Statistics
Co	= Cobalt
CV%	= Percentage of coefficient of variance
cv.	= Cultivar
DAE	= Department of Agricultural Extension
DAS	= Days after sowing
et al.	=And others
FAO	= Food and Agriculture Organization
g	= gram(s)
ha^{-1}	= Per hectare
HI	= Harvest Index
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
mg	= milligram
Min	= Minimum
MoP	= Muriate of Potash
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
TSP	= Triple Super Phosphate
wt.	= Weight
%	= Percent
^0C	= Degree Celsius

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an ancient and well known legume crop in Asia, particularly in the Indian subcontinent. It is one of the important pulse crops of Bangladesh, as it is an excellent source of easily-digestible protein of low flatulence, which complements the staple rice diet in the country. It contains amino acid, lysine which is generally deficit in food grains (Elias *et al*., 1986). It holds the 3^{rd} in protein content and 5^{th} in acreage and production and first in market price (BBS, 2008). It is grown three times in a year covering 35313 ha with an average yield of 0.70 t ha^{-1} (BBS, 2013). It is produced for both human consumption and as fodder. Its seed contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamin (Afzal *et al*., 2008). This legume is known to have high nutrient values with excellent source of vegetable protein (seeds and sprouts contain to 28% of proteins). Sprout is rich in vitamins, minerals and amino acids (especially lizin). Mungbean is considered as a substitute of animal protein and forms a balanced diet when used with cereals (Khan and Malik, 2001; Anjum *et al.*, 2006; Mansoor, 2007).

Mungbean is usually grown at low to medium elevations in the tropics as a rainfed crop. It ranks second to drought resistance after soybean (Ali *et al*., 2001). Mungbean can be grown as manure, hay, cover crop and forage or intercropped in cereals, sugarcane, sunflower or jute. On an average, it fixes atmospheric nitrogen @ 300 kg ha^{-1} annually (Sharar *et al*., 2001).The agro ecological condition of Bangladesh is favorable for growing this crop.

Since it is a short duration legume (maturing in 55 to 70 days), it fits well into many cropping systems, including rice and sugarcane under both rainfed and irrigated conditions. It increases small farmer’s income and improves soil conditions. On an average in Bangladeshi diet only 8 to 10% of the protein intake originates from animal sources, the rest can be met from plant sources by increasing the consumption of pulses. Hence from the point of nutritional value, mungbean is perhaps the best of all other pulses. However, the average yield of mungbean in the country is about 625 kg ha^{-1}, which is much lower than that of India and some other countries of the world. This poor yield may be attributed due to climatic condition, adaptation of varieties, disease and insect problems, poor crop management practices and judicious application of fertilizer especially nitrogenous fertilizers/bio-fertilizers as nitrogen is the most important element for crop.

In Bangladesh, most of the soils are deficient in organic matter and nitrogen. To fulfill the demand of nitrogen, usually urea is being used. Nitrogen (N) is the most essential nutrient element and its adequate supply increases growth and yield of crop. Without an adequate underlying of the dry matter production and the underlying physiological process of crop growth, development and yield of mungbean under different N treatments, any attempt to improve the yield potential of mungbean may not be successful. It alters leaf area and net photosynthetic rate because its usage strongly affects plant growth and productivity; therefore, the application of N fertilizer is very important to obtain maximum potential of crops (Novoa and Loomis, 1981).

Pulses although fix nitrogen from the atmosphere, there is evident that application of nitrogenous fertilizers becomes helpful in increasing the yield (Ardeshana *et al*., 1993) Nitrogen is most useful for pulse crops because it is the component of protein (BARC, 2005). High yielding variety with proper nitrogen management is inadequate in farmer's field which is burning cause for lower yield. The lower amount of nitrogen is to be given at proper time for increasing growth and yield of mungbean with maximum utilization of nutrient. The important role of nitrogenous fertilizer in increasing mungbean yield has been widely recognized (BINA, 2003). Mungbean yield may be increased by 30 to 60% by proper utilization of nitrogen fertilizer (Patel *et al.*, 2003).Undoubtedly, higher yield can be obtained by the application of chemical fertilizers as they are instant source of nutrients for crops, but during the last couple of years, the stagnant yields have been obtained and no more increase in crop yields were observed even when fertilizers were applied at optimum level. Moreover, high cost energy inputs required for manufacturing of chemical fertilizers and their shortage in markets diverts the attention of farmers to other cheap fertilizer sources (i.e. bio-fertilizers).

In mungbean, at flowering stage abortion of flower is a major problem due to the lack of proper N_2 supply to the plant. As N_2 is a rapid release fertilizer, the basal applied N_2 and N_2 fixed by bacterial inoculums could not last to the flowering period. So, to minimize this abortion of flower split application of nitrogen at branching stage could be effective. The integrated use of organic, inorganic and bio-fertilizers may be an alternative approach to increase stagnant yield of legumes in Bangladesh. *Bradyrhizobium* bio-fertilizer inoculation increased mungbean seed yield from 4.3% to 162% (BINA, 2004). In Bangladesh, inoculation with *Bradyrhizobium* increased 77% dry matter production, 64% grain yield and 40% hay yield over non-inoculated control (Chanda *et al*., 1991). It has been reported that combined application of N and *Bradyrhizobium* increased yield of mungbean (Mozumder *et al*., 2003). Moreover, the combined use of N fertilizers at the rate of 50 kg ha^{-1} and *Rhizobium* inoculum produced highest grain yield of legumes (Ashraf *et al*., 2003). The significant increase in grain yield of beans in response to the application of manures and N fertilizer was reported (Otieno *et al*., 2007). Keeping in view the above discussion, it is obligatory to search out innovative alternatives to improve crop productivity on sustainable basis. Considering the above facts the present work was conducted to evaluate the response of nitrogen and bio-fertilizer on mungbean production with the following objectives:-

1. To examine the effect of bio-fertilizer on the plant characters, yield and yield attributes of mungbean.
2. To determine the time of application of nitrogen fertilizer on the growth and yield of mungbean.
3. To study the combined effect of nitrogen and bio-fertilizer on mungbean production.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

The growth and yield response of mungbean towards application of nitrogen and bio-fertilizer. Following review of literature includes reports as studied by several investigators who were engaged in understanding the problems that may help in the explanation and interpretation of results of the present investigation. In this chapter, an attempt has been made to review the available information in home and abroad regarding the growth and yield response of mungbean towards application of nitrogen and bio-fertilizer.

2.1 Effect of Nitrogen application

2.1.1 Plant height

Achakzai *et al.* (2012) conducted a study was to evaluate the growth response of mungbean cultivars subjected to different rate of applied N fertilizer. The different N fertilizers exerted significant on plant height of Mungbean. The plants of T_2 (20 kg ha^{-1} N) gained maximum height (36.81 cm), whereas the short stature plants (29.64 cm) obtained in plots either receiving no fertilizer.

Asaduzzaman (2008) found that plant height of mungbean was significantly increased by the application of nitrogen fertilizer at 30 kg ha^{-1}.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*Vigna radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (pods $plant^{-1}$ and seeds pod^{-1}) of greengram were augmented significantly due to foliar nutrition. The foliar application of 2% diammonium phosphate + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield attributes.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mung bean cv. AEM 96 in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.25 cm.

In a pot experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Masud (2003) observed the highest plant height with the application of 30 kg N ha^{-1}

Saini and Thakur (1996) stated that nitrogen at 30 and 40 kg ha^{-1} significantly increased the plant height of blackgram compared with no N.

Quah and Jaafar (1994) noted that plant height of mungbean was significantly increased by the application of nitrogen fertilizer 50 kg ha^{-1}.

Suhartatik (1991) in a study observed that increased application of NPK fertilizers significantly increased the plant height of mungbean.

Jamro *et al*. (1990) observed that application of 90 kg N ha^{-1} significantly increased the plant height of blackgram.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increase in plant height of mungbean.

Trung and Yoshida (1983) conducted a field trial on mungean in nutrient soil containing 0-100 ppm N in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulphate. They observed that maximum plant height was obtained by 25 ppm N at all the stages of development.

2.1.2 Leaf area plant^{-1}

Mondal *et al.* (2014) conducted a field experiments with mungbean (*Vigna radiata* L. Wilczek) in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India and found that leaf area plant^{-1} of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS.

Achakzai *et al.* (2012) conducted a study was to evaluate the growth response of mungbean cultivars subjected to different rate of applied N fertilizer. The plants grown with 80 kg N ha^{-1} treatment numerically attained maximum leaf area (33.19 cm^2). Whereas, the minimum leaf area (24.36 cm^2) recorded for treatment receiving no added fertilizer.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University,Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher leaves plant^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that leaves plant^{-1} was significantly affected by varying level of nitrogen.

2.1.3 Nodules plant^{-1}

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean (*Vigna unguiculata*) and mungbean (*Vigna radiata*) response to fertilization and found that mungbean grown without fertilizer produced the highest nodules per plant.

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean (*Vigna radiata* L.*)* and found that foliar application of urea and organic manure substantially improved number and dry weight of nodule.

Mozumder (1998) conducted a field trail at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994 to study the effects of five nitrogen level 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}).

Santos *et al.* (1993) observed on mungbean cv. Berken, grown in pots in podzolic soil using 7 level of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1} as NH_4NO_3. They noted that nodule number increased strongly, between flowering and maturity; in plants grown at 100 kg 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 leaves at the maturity stages. Plants grown at 400 and 500 kg ha^{-1} N failed to nodulation.

Hoque and Barrow (1993) conducted a field trail at various locations in Bangladesh and found that the, inoculants markedly increased nodule number and nodule dry weight of soybean, lentil and mungbean compared to uninoculated control and urea-N treatments.

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 applied N, but fixation per unit nodule weight was similar in both N treatments. The percentage N derived from the air of 78 mungbean cultivar was 0-100% at 33 DAS and 760% in all cultivars at 60 DAS. The author suggested that these cultivars might respond more to applied N than high fixing cultivars.

2.1.4 Dry matter production

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher dry matter production.

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean (*Vigna radiata* L.) to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) significantly improved dry matter accumulation of mungbean.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in dry matter content in above ground part.

Santos *et al.* (1993) carried out an experiment on mungbean cv. Berken grown in pots in podzolic soil with 7 level of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1}), applied as NH_4NO_3 and noted that application of N up to 200 kg ha^{-1} increased the total dry matter, higher rates decreased it.

Chowdhury and Rosario (1992) studied the effects of 0, 30, 60 or 90 kg N ha^{-1} on the growth and yield performance of mungbcan at Los Banos, Philippines in 1988. They observed that N @ 30 kg ha^{-1} showed significant difference in dry matter yield of mungbean up to a certain level (60 kg N ha^{-1}).

Leelavathi *et al.* (1991) reported that different rate of nitrogen showed significant difference in seed and dry matter production up to a certain level (60 kg N ha^{-1}).

Agbenin *et al.* (1991) found that applied N significantly increased growth components, dry matter yield and nutrient uptake over the control.

Yein (1982) carried out two year field experiment in Assam. India on mungbean (*Vigna radiata* L.) and reported that combined application of nitrogen and phosphorus significantly increased the dry weight of the plants.

2.1.5 Branches $plant^{-1}$

Achakzai *et al.* (2012) conducted a study was to evaluate the growth response of mungbean cultivars subjected to different rate of applied N fertilizer. Results regarding number of branches $plant^{-1}$ exhibited that there was a significant difference among various treatments of N fertilizer when compared it with their control treatment (no fertilizer). The plants of T_6 (100 kg h^{-1} N) produced the maximum number of branches $plant^{-1}$ (3.83), whereas minimum recorded for (3.17) in no fertilizer use.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly more number of branches (1.67) $plant^{-1}$.

Malik *et al.* (2003) conducted a study to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that number of branches $plant^{-1}$ was found to be significantly higher by 25 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer. The number of branches increased with increasing N rates.

Ansari and Afridi (1990) found that soaking of *V. radiata* on K 851 in 0.1-0.5% pyridoxine solution significantly enhanced leaf N, P concentration at different growth stages and number of branches increased with increasing N concentration.

2.1.6 Pods plant^{-1}

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean (*Vigna unguiculata*) and mungbean (*Vigna radiata*) response to fertilization and they found that mungbean grown without fertilizer produced the highest number of pods plant $^{-1}$.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher pods plant $^{-1}$.

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest values for number of pods plant $^{-1}$ (38.3).

Kulsum (2003) reported that different level of nitrogen showed significantly increased pods plant $^{-1}$ of blackgram up to N 60 kg ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer and reported that the number of pods plant $^{-1}$ increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) and observed that the number of pods plant $^{-1}$ was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N.

Tank *et al*. (1992) observed when mungbean was fertilized with 20 kg N along with level of 40 kg P_2O_5 ha^{-1} increased seed yield significantly over the unfertilized control. They also reported that mungbean fertilized with 20 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} significantly increased the number of pods plant $^{-1}$.

Patel and Parmar (1986) conducted an experiment on the response of green gram to varying level of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of pods plant $^{-1}$.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N level (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. In that experiment, it was found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods plant $^{-1}$.

2.1.7 Length of pod

Mondal *et al.* (2014) conducted a field experiments with mung bean (V*igna radiata* L. Wilczek) in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India. They found that pod length of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS.

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest pod length was obtained at 150 kg ha^{-1} urea.

2.1.8 Seeds pod^{-1}

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2 % foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest seeds pod^{-1} (7.67).

Malik *et al*. (2003) investigated the effect of varying level of nitrogen (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 during 2001. It was found that number seeds pod^{-1} was significantly affected by varying level of nitrogen and phosphorous.

Quah and Jaafar (1994) noted that seed yield of mungbean increased significantly by the application of nitrogen fertilizer at 50 kg ha^{-1}.

Patel and Parmar (1986) conducted an experiment on the response of green gram to varying level of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of seeds pod^{-1}.

2.1.9 Weight of 1000 seeds

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and observed 1000-seeds weight increased with increasing rates of N up to 40 kg ha^{-1}.

Mahboob and Asghar (2002) studied the effect of seed inoculum at different nitrogen level on the yield and yield components of mungbean at the agronomic research station, Farooqabad in Pakistan durin the year of 2000 and 2001. They revealed that with the application of NPK at the rate of 50-50-0 kg ha^{-1} significantly affected the 1000 grains weight.

Bali *et al.* (1991) conducted a field trail on mungbean in kharif season on silty clay loam soil. They revealed that 1000 seeds weight increased with 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increases in 1000 seeds weight of mungbean.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N level (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. They observed that application of 40 kg P_2O_5 ha^{-1} along with 20 kg N ha^{-1} significantly increased the 1000-seeds weight of mungbean.

2.1.10 Seed yield

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest seed yield and pod length was obtained at 150 kg ha^{-1} urea.

Akbar *et al.* (2013) conducted an experiment on the interactive effect of cobalt and nitrogen on growth, nodulation, yield and protein content of field grown pea and observed that the highest seed yield in the treatment the 60 kg N ha^{-1} and 10 g Co ha^{-1}.

Sadeghipour *et al. (*2010) conducted an experiment on the production of mungbean (*Vigna radiata* L.) by nitrogen and phosphorus fertilizer application and they found that the maximum seed yield was obtained when 90 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} was applied.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher seed yield ha^{-1} (1982.05 kg).

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean (*Vigna radiata* L.) to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) gave significantly maximum seed yield $plant^{-1}$ (5.53 g).

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest grain yield (9.66 q ha^{-1}).

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher grain yield (1.63 t ha^{-1}) compared to cv. Pusa 105.

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*V. radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (number of pods per plant and number of seeds per pod) of green gram augmented significantly due to foliar nutrition. The foliar application of urea + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield. The highest grain yield of 1529 kg ha^{-1} was recorded with this treatment.

A field study conducted by Sharma and Sharma (2006) for two years at the Indian Agricultural Research Institute, New Delhi on a sandy clay loam soil showed that the application of NP increased the total grain production of a rice-wheat-mungbean cropping system by 0.5-0.6 t ha^{-1}, NK by 0.3-0.5 t ha^{-1} and NPK by 0.8-0.9 t ha^{-1} compared to N alone, indicating that the balanced use of primary nutrients was more advantageous than their imbalanced application.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording the highest seed yield of 1205.2 kg ha^{-1}.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculum and different level of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5

ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that a fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that grain yield increased with increasing rates of up to 40 kg N ha^{-1} only.

Mahboob and Asghar (2002) studied the effect of seed inoculum at different nitrogen level on mungbean at the agronomic research station, Farooqabad in Pakistan. They revealed that seed inoculum + 50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Kamal *et al.* (2001) conducted an experiment at the BARI farm during rainy season for 2000-2001 to determine the effect of various level of fertilizer and weeding of mungbean. Superior grain yield (1430 kg ha^{-1}) was found when fertilized @ 20-60-30 NPK kg ha^{-1}with two hand weeding at 20 and 30 DAE were used. This was followed by that obtained (1368 kg ha^{-1}) by using inoculum + 60-30 PK kg ha^{-1} with two hand weeding at 20 and 30 DAE. This result showed that application of fertilizer @ 20-60-30 kg ha^{-1} combine with two hand weeding at 20 and 30 DAE was economical for yield as well as quality seed production of mungbean.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India where mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmer's practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Karle and Pawar (1998) examined the effect of varying level of N and P fertilizers on summer mungbean. They reported higher seed yield in mungbean with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Patel *et al.* (1992) conducted a field trial to evaluate the response of mungbean to sulphur fertilization under different level of nitrogen and phosphorus. Greengram cv. Gujrarat 2 and K 851 were given 10 kg N + 20 kg P ha^{-1}, 20kg N + 40 kg P ha^{1} and 0, 10, 20 or 30 kg S ha^{-1} as gypsum. Seed yield was 1.2 and 1.24 t ha^{-1} in Gujrarat 2 K 851 respectively 20 kg N + 40 kg P ha^{-1}.

A field experiments was conducted by Sarkar and Banik (1991) to study the effect of N and P on yield of mungbean. Results showed that application of N along with P significantly increased the seed yield of mungbean. The maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_2O_5 ha^{-1}.

Arya and Kalra (1988) reported that application of N at the rate of 50 kg ha^{-1} along with 50 kg P ha^{-1} increased mungbean yield. Another experimental result from field experiments conducted by Mahadkar and Saraf (1988) of mungbean revealed that the application of N with P and K at 20:25 kg ha^{-1} gave higher seed yield.

Pongkao and Inthong (1988) applied N at the rate of 0-60 kg ha^{-1} on mungbean and reported that application of 15 kg N ha^{-1} was found to be superior giving 23% higher seed yield over the control. However 60 kg N ha^{-1} tended to produced seed yield which was at par of 15 kg N ha^{1}.

An experiment was conducted by Trung and Yoshida (1983) using 0-100 ppm N as treatment in the form of ammonium nitrate or 10 or 100 ppm N as urea, sodium nitrate, ammonium nitrate or ammonium sulphate. They found that seed yield of mungbean increased with the increase in N up to 50 ppm.

2.1.11 Stover yield

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Stover yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer and reported that straw yield increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and stated that the stover yield increased with increasing N up to 40 kg ha^{-1}.

2.1.12 Biological yield

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India. Cultivar Pusa Vishal recorded higher biological (3.66 1.63 t ha^{-1}) compared to cv. Pusa 105.

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Biological yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect biological yield.

Results of an experiment conducted by Sardana and Verma (1987) in Delhi, India and stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in biological yield of mungbean.

2.1.13 Harvest index

In a field experiment carried out by Mozumder (1998) at the Agronomy field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994 studied with five nitrogen level (0. 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer munghean *viz*. Binamoog-2 and Kanti, results revealed that nitrogen produced negative effect of harvest index. Harvest index (%) was decreased by higher nitrogen level.

2.2 Effect of *Rhizobium* dose

2.2.1 Plant height

Malik *et al.* (2014) conducted an experiment to synergistic use of *rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiate* L.). The maximum significant ($p<0.05$) increase in plant height was observed by the combined application of compost, *Rhizobium* and nitrogen compared to other treatments.

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean (*Vigna radiata* L.) affected by foliar application of urea and bio-organic fertilizers. They found that foliar application of urea and organic manure substantially improved the plant height.

2.2.2 Leaf area $plant^{-1}$

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mung bean (*Vigna radiata* L.) affected by foliar application of urea and bio-organic fertilizers. They found that foliar application of urea and organic manure substantially improved leaf area $plant^{-1}$.

2.2.3 Nodule plant^{-1}

Malik *et al.* (2014) conducted an experiment on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.*)* and found that the combined application of *Rhizobium*, compost and 75% of the recommended mineral nitrogen (RMN) gave maximum nodules and dry weight.

A field experiment was conducted by Nazmun *et al.* (2009) at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest effective nodules plant^{-1} (34.9) was recorded in combined application of *Bradyrhizobium* and *Azotobacter* inoculants and the lowest (23.1) was found in uninoculated control. The use of *Bradyrhizobium* inoculants alone gave the second highest nodule plant^{-1} in F_2 (31.2 plant^{-1}) followed by *Azotobacter* inoculants (29.8 plant^{-1}) and application of 20kg N ha^{-1} (25.1 plant^{-1}).

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2. *Bradyrhizobium* inoculum and observed that nitrogen negatively affected on nodulation.

Maldal and Ray (1999) observed in a field experiment where mungbean cv. B 105, B1 and Hooghly local were untreated, seed inoculated with *Rhizobium* and 20, 30 or 40 kg N ha^{-1} as urea were given. They reported that nodulation was greatest with inoculum in B 105.

Provorov *et al.* (1998) observed that seed inoculum of mungbean (*Vigna radiate* L.) with Strain CLAM 1901 of *Bradyrhizobium* increased root nodules by 24 %, herbage by 46.6%, seed mass by 39.2%, 1000-seeds weight by 16% and seed N by 30%. These results were equivalent to applying 120 kg N ha^{-1}.

Tripathi *et al*. (1994) conducted an experiment regarding soybean, mungbean and groundnut grown on a clay soil in 1985 and 1986. Five N treatments were applied through 2 sources: No N sources (control), 20 N kg ha^{-1}, *Rhizobium* seed inoculum alone, inoculum with 10 kg N ha^{-1}, and inoculum with 20 kg N ha^{-1}. The combination of inoculants + 20 kg N ha^{-1}gave the highest crop yield and the maximum root nodules. Soybeans and groundnuts gave comparatively higher yields than *V. mungo* and *V. radiata*

2.2.4 Pods $plant^{-1}$

Nazmun *et al*. (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest number of pods $plant^{-1}$ (20.5) was found in F_4 *(Bradyrhizobium + Azotobacter).* The use of *Bradyrhizobium,* or *Azotobacter* inoculants alone also recorded higher number of pods $plant^{-1}$over control and 20 kg N ha^{-1}.

Basu and Bandyopadhyay (1990) conducted a field trail 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 0-40 kg N ha^{-1}. Inoculum increased number of pods plant $^{-1}$ and seeds pod^{-1} and N uptake. Jca_1 was superior to M-10. Number of pods plant $^{-1}$ and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

2.2.5 Length of pod

Nazmun *et al*. (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. Pod length of mungbean increased significantly due to use of bacterial fertilizers. The longest pod (34.1cm) was found in F_4 (*Bradyrhizobium +Azotobacter)*. The pod length found due to *Azotobacter* (F_3) inoculant was comparable to those found in F_2 (*Bradyrhizobium*), F_5 (20 kg N ha^{-1}) and F_1 (control).

2.2.6 Seeds pod^{-1}

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest number of seeds pod^{-1} was produced in F4 (*Bradyrhizobium*+*Azotobacter*). The use of *Bradyrhizobium* (F_2) or *Azotobacter* (F_3) alone or 20 kg Nha^{-1} (F_5) and control (F_1) recorded statistically identical number of seeds plant^{-1}.

2.2.7 Weight of 1000 seeds

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on 1000-seed weight of Mungbean. The highest 1000 seed weight (34.1 g) was produced in F_4 (*Bradyrhizobium* + *Azotobacter*) followed by F_2 (33.1 g) and F_3 (30.8 g), F_5 (30.0 g) and the lowest 1000 seed weight (29.4g) was found in control (F_1).

Basu and Bandyopadhyay (1990) conducted a field trail 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 0-40 kg N ha^{-1}. Inoculum increased number of pods plant^{-1} and seeds plant^{-1} and N uptake. Jca_1 was superior to M-10. 1000 seeds weight and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

2.2.8 Seed yield

Hossain *et al.* (2014) conducted an experiment to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculum *Bradyrhizobium* (1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI mung-5 and BARI mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher seed yield than BARI Mung-5.

Malik *et al.* (2014) conducted an experiment on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.) and found that the combined application of *Rhizobium,* compost and 75% of the recommended mineral nitrogen (RMN) gave maximum grain yield plant^{-1}.

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2. *Bradyrhizobium* inoculum increased dry matter production, nodulation, pod production, seed yield and harvest index and observed that increase of nitrogen fertilizer increased seed yield up to 40 kg N ha^{-1} and straw yield up to 60 kg N ha^{-1}.

2.2.9 Stover yield

Hossain *et al.* (2014) conducted an experiment to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculum *Bradyrhizobium* (1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI mung-5 and BARI mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher stover yield than BARI Mung-5.

Nazmun *et al.* (2009) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on stover yield of Mungbean. The highest (3754 kg ha^{-1}) and the lowest stover yield (2644 kg ha^{-1}) was found in F_4 (*Bradyrhizobium* +*Azotobacter*) and in control (F_4), respectively.

2.2.10 Biological yield

Hossain *et al.* (2014) found that nitrogen and *Bradyrhizobium* inoculants showed significant increase the biological yield of Mungbean. The *Bradyrhizobium* inoculated plants showed the highest seed yield (876 kg ha^{-1}) which was statistically superior to other treatments. The lowest seed yield (716 kg ha^{-1}) was showed in non-inoculated plant.

Malik *et al.* (2014) found that biological yield increased by the addition of compost, mineral N and *Rhizobium* inoculum. Lowest number of biological yield was recorded in control while it was being nourished by recommended mineral NPK fertilizers.

2.2.11 Harvest index

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2 *Bradyrhizobium* inoculum and observed that nitrogen negatively affected on harvest index.

From the above study of above reviewed literature it might be concluded that mungbean can itself be able to fix atmospheric nitrogen but supplemental use of nitrogen (at vegetative stage @ 30-40 kg ha^{-1}) may increase the yield. Bacterial inoculations that are present in the soil are not sufficient for proper atmospheric nitrogen fixation. So additional application of *Rhizobium* inoculation as a source of biofertilizer might be helpful for increasing the growth, yield and yield attributes of mungbean.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to study the effect of nitrogen (N) and bio-fertilizer (*Rhizobium*) on the growth and yield of mungbean (cv. BARI Mung-6). Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

Geographically the experimental field was located at 23° 77' N latitude and 90° 33' E longitudes at an altitude of 9 m above the mean sea level. The soil belonged to the Agro-ecological Zone - Modhupur Tract (AEZ -28). The land topography was medium high and soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-I and II.

3.1.2 Climate and weather

The climate of the locality is subtropical which is characterized by high temperature and heavy rainfall during Kharif season (April-September) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The prevailing weather conditions during the study period have been presented in Appendix-III.

3.2 Plant materials

BARI mung-6 was used as planting material. BARI mung-6 was released and developed by BARI in 2003. Plant height of the cultivar ranges from 40 to 45 cm. It is resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus. Its life cycle is about 55 to 60 days after emergence. One of the main characteristics of this cultivar is synchronization of pod ripening. Average yield of this cultivar is about 1.5-1.6 t ha^{-1}. The seeds of BARI Mung-6 for the experiment were collected from BARI, Joydepur Gazipur. The seeds were drum-shaped, dull and greenish and free from mixture of other seeds, weed seeds and extraneous materials.

3.3 Treatments under investigation

There were two factors in the experiment namely nitrogen rate and *Rhizobium* dose as mentioned below:

A. Factor-1: Nitrogen application (4)

a) N_0= No nitrogen (Control)
b) N_1= 20 kg N ha^{-1} as basal
c) N_2= 20 kg N ha^{-1} at branching stage as split
d) N_3= 20 kg N ha^{-1} at flowering stage as split

B. Factor-2: *Rhizobium* dose (3)

a) R_0= No *Rhizobium* (Control)
b) R_1= *Rhizobium* at 5 kg ha^{-1}
c) R_2 = *Rhizobium* at 8 kg ha^{-1}

Treatment combination: Twelve treatment combinations

N_0R_0	N_1R_0	N_2R_0	N_3R_0
N_0R_1	N_1R_1	N_2R_1	N_3R_1
N_0R_2	N_1R_2	N_2R_2	N_3R_2

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. There are 12 treatment combinations and 36 unit plots. The unit plot size was 5.25 m^2 (3.5 m × 1.5 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. A layout of the experiment has been shown in Appendix IV.

3.5 Land preparation

The experimental land was opened with a power tiller on 05th September 2014. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 10th September 2014 and was ready for sowing seeds.

3.6 Fertilizer application

The fertilizers were applied as basal dose at final land preparation where K_2O, P_2O_5, Ca and S were applied @ 33 kg ha^{-1}, 48 kg ha^{-1}, 3.3 kg ha^{-1} and 1.8 kg ha^{-1} respectively in all plots. All fertilizers were applied by broadcasting and mixed thoroughly with soil. Nitrogen fertilizer was applied as per treatment variables (Afzal *et al*., 2003).

3.7 Sowing of seeds

Seeds were sown at the rate of 25 kg ha^{-1} in the furrow on 11th September 2014 and the furrows were covered with the soils soon after seeding. Row to row distance is 30 cm and in rows seed to seed distance 10 cm were maintained. In *Rhizobium* treatment, seeds were mixed thoroughly with *Rhizobium* strain and then treated seeds were shown.

3.8 Intercultural operations

3.8.1 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.8.2 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and other two were given 2-3 days after weeding.

3.8.3 Plant protection measures

The crop was infested by insects and diseases. Ripcord 10 EC @ 1 ml L^{-1} was applied two times at an interval of 1 week to control insect. On the other hand Diazinon 60 EC @ 2 ml L^{-1} was applied two times at an interval of 1 week to control disease.

3.9 Harvesting and sampling

The crop was harvested at 70 DAS. The crop was harvested plot wise when about 80% of the pods became mature. Samples were collected from different places of each plot leaving undisturbed very small in the center. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.10 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Seeds 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 a constant level. The dried seeds and straw were cleaned and weighed.

3.12 Recording of data

The data were recorded on the following parameters

a. Plant height (cm)

b. Leaf area plant $^{-1}$ (cm^2)

c. Branches plant^{-1} (no.)

d. Dry matter weight plant^{-1} (g)

e. Nodules plant^{-1} (no.)

f. Pods plant^{-1} (no.)

g. Pod length (cm)

h. Seeds pod^{-1} (no.)

i. 1000 seed weight (g)

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

k. Stover yield (t ha^{-1})

l. Biological yield (t ha^{-1})

m. Harvest index (%)

3.13 Procedure of recording data

i. Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 10, 20, 30, 40, 50 DAS and harvest.

ii. Leaf area $plant^{-1}$ (cm^2)

Leaf area was measured by destructing method using CL-202 Leaf Area Meter (USA). All the leaves of the sampled plants were collected and measured leaf area and expressed in cm^2. Then the mean was calculated.

iii. Branches $plant^{-1}$ (no.)

The branches $plant^{-1}$ was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants then the average data were recorded.

iv. Dry matter content $plant^{-1}$ (g)

Ten plants were collected randomly from each plot at 10, 20, 30, 40, 50 DAS and harvest. The sample plants were oven dried for 72 hours at 70°C and then dry matter content $plant^{-1}$ was determined.

v. Nodules $plant^{-1}$ (no.)

The 10 plants $plot^{-1}$ from second line was uprooted and total number of nodules from ten plants was counted at 10, 20, 30, 40, 50 DAS and harvest and the mean value was determined.

vi. Pods plant^{-1} (no.)

Pods plant^{-1} was counted from the 10 selected plant sample and then the average pod number was calculated.

vii. Pod length (cm)

Length of pod was measured by meter scale from 20 pods of plants and then the average seed number was calculated.

vi. Seeds pod^{-1} (no.)

Seeds pod^{-1} was counted from 20 selected pods of plants and then the average seed number was calculated.

vii. Weight of 1000 seeds (g)

1000 seeds were counted, which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

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

Seed yield was recorded on the basis of total harvested seeds plot^{-1} and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 12% moisture content.

ix. Stover yield (t ha^{-1})

After separation of seeds from plant, the straw and shell harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

x. Biological yield (t ha^{-1})

The summation of seed yield and above ground stover yield was the biological yield. Biological yield =Grain yield + Stover yield.

xi. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula.

Harvest index (HI %) = $\frac{Seed\ yield}{Biological\ \ yield} \times 100$

Here, Biological yield = Grain yield + stover yield

3.14 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of probability (Gomez & Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER 4

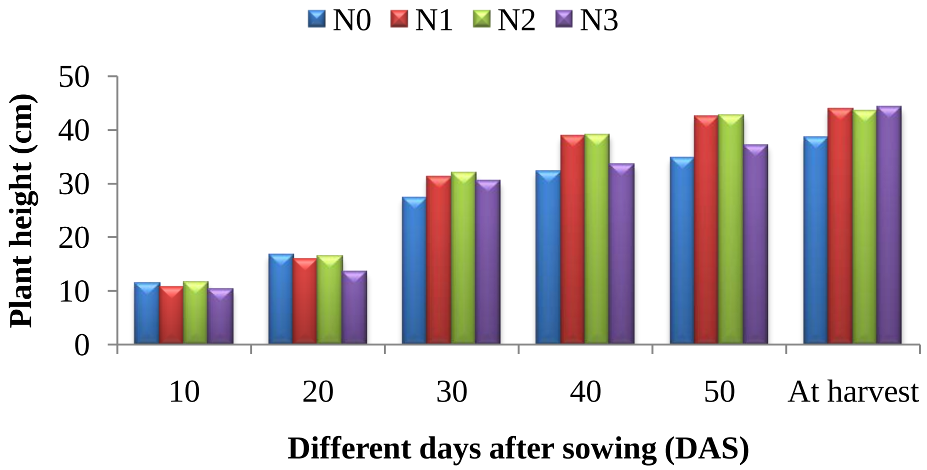
RESULTS AND DISCUSSION

The study was conducted to determine the effect of nitrogen (N) and bio-fertilizer (*Rhizobium*) on the growth and yield of mungbean. Data on different yield contributing characters and yield were recorded to find out the optimum rate of nitrogen and bio-fertilizer on mungbean. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height (cm)

4.1.1 Effect of nitrogen on the plant height (cm)

Plant height (cm) of mungbean varied significantly due to the application of different level of nitrogen (Figure 1). Plant height (cm) rapidly increased from 20 DAS to 40 DAS thereafter a slower rate of increase in plant height (cm) was recorded up to harvest. The highest plant height (16.38, 31.88, 39.15 and 42.74 cm at 20, 30, 40 and 50 DAS, respectively) was obtained from treatment N_2 which was statistically similar with N_1; similar with N_0 at 20 DAS. At harvest, the tallest plant (44.23 cm) was recorded under N_3 (20 kg N ha^{-1} at flowering stage) treatment which was statistically similar with N_1 and N_2 treatment. The lowest plant height (13.55 cm at 20 DAS) was obtained from N_3 which was statistically similar with N_1; (27.36, 32.36, 34.77 and 38.52 cm at 30, 40, 50 DAS and harvest, respectively) was obtained from N_0 which was statistically similar with N_3. Saini and Thakur (1996) found similar results and Yein (1982) found increased plant height of mungbean with nitrogen application.

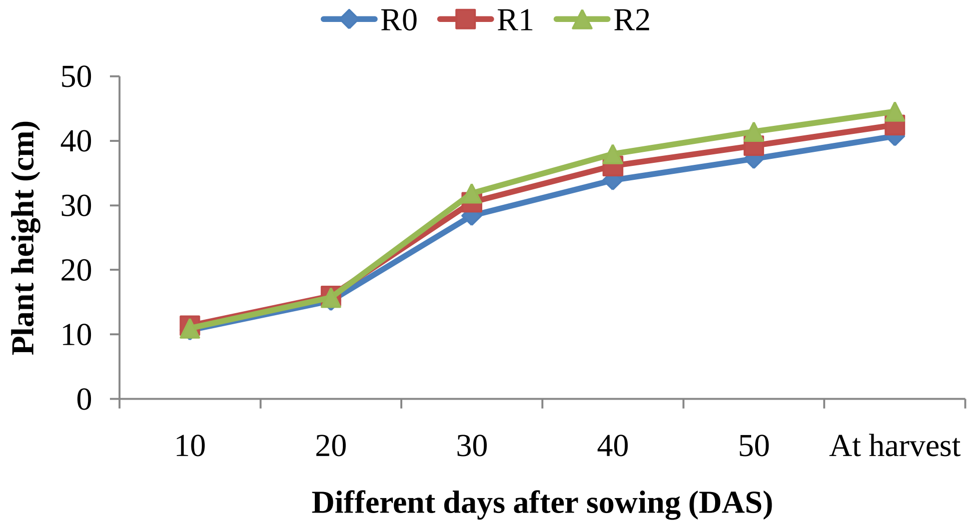


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 01. Effect of nitrogen application on plant height (cm) of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 2.42, 3.78, 4.82, 5.25 and 4.67 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.1.2 Effect of *Rhizobium* inoculum on the plant height (cm)

The effects of *Rhizobium* on the plant height (cm) of mungbean are presented in figure 2. Significant variation was observed on the plant height (cm) of mungbean when the seed was inoculated with different doses of *Rhizobium*. Among the different doses of *Rhizobium*, R_1 showed the highest plant height (11.36 cm at 10 DAS) which was identical with R_2 ; R_2 showed the highest plant height (31.86, 37.96, 41.42 and 44.54 cm at 30, 40, 50 DAS and harvest, respectively) which was followed by R_1. On the other hand, the lowest plant height (10.65, 28.39, 33.91, 37.23 and 40.74 cm at 10, 30, 40, 50 DAS and harvest, respectively) was observed in R_0 which was identical with R_2 at 10 DAS; R_1 at 30, 40, 50 DAS and harvest.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 02. Effect of *Rhizobium* doses on plant height (cm) of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.65, NS, 2.25, 2.25, 2.72 and 2.69 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.1.3 Combined effect of nitrogen and *Rhizobium* on the plant height (cm)

Combined application of different doses of nitrogen and *Rhizobium* had significant effect on the plant height (cm) of mungbean (Table 1). The highest plant height (12.15 cm at 10 DAS) was observed in N_2R_1 which was identical with N_0R_0, N_0R_1, N_0R_2, N_1R_1, N_1R_2 and N_2R_2; (17.43 cm at 20 DAS) was observed in N_0R_1 which was identical with all other combinations except N_1R_0, N_2R_0, N_3R_0, N_3R_1 and N_3R_2; (34.80, 42.86, 46.70 and 47.68 cm at 30, 40, 50 DAS and harvest, respectively) was recorded from N_2R_2 which was identical with all other combinations except N_0R_0, N_0R_1, N_0R_2, N_2R_0 and N_3R_0 at 30 DAS; identical with N_1R_1, N_1R_2 and N_2R_1 at 40 DAS; identical with N_1R_0, N_1R_1, N_1R_2 and N_2R_1 at 50 DAS; identical with N_1R_1, N_1R_2, N_2R_1, N_3R_0, N_3R_1 and N_3R_2 at harvest. On the other hand, the lowest plant height (9.71 and 13.02 cm at 10 and 20 DAS, respectively) was observed in N_3R_2 which was identical with N_1R_0, N_1R_1, N_2R_0, N_3R_0 and N_3R_1 at 10 DAS; N_2R_0, N_3R_0 and N_3R_1 at 20 DAS; (26.12, 30.80, 33.18 and 37.37 cm at 30, 40, 50 DAS and harvest, respectively) was observed in N_0R_0 which was identical with N_0R_1, N_0R_2, N_1R_0, N_2R_0 and N_3R_0 at 30 DAS; N_0R_1, N_0R_2, N_2R_0, N_3R_0 and N_3R_1 at 40 DAS; N_0R_1, N_0R_2, N_3R_0 and N_3R_1 at 50 DAS; N_0R_1, N_0R_2, N_1R_0 and N_2R_0 at harvest. Malik *et al.* (2014) found that the maximum significant ($p<0.05$) increase in plant height was observed by the combined application of compost, *Rhizobium* and nitrogen compared to other treatments.

Table 01. Combined effect of different nitrogen application and *Rhizobium* inoculum on plant height (cm) of mungbean at different days after sowing

Treatment combination	Plant height (cm)					
	Different days after sowing (DAS)					
	10	**20**	**30**	**40**	**50**	**At harvest**
N_0R_0	11.46 a-d	16.62 ab	26.12 e	30.80 f	33.18 e	37.37 d
N_0R_1	11.65 a-c	17.43 a	27.32 de	32.56 ef	34.76 de	37.79 d
N_0R_2	11.06 a-d	16.24 a-c	28.65 b-e	33.73 d-f	36.36 c-e	40.40 b-d
N_1R_0	10.27 de	15.19 bc	30.45 a-e	37.60 b-d	41.35 a-c	42.03 b-d
N_1R_1	10.98 a-e	15.94 a-c	31.00 a-d	39.26 a-c	43.00 ab	44.49 a-c
N_1R_2	11.01 a-d	16.29 a-c	32.36 a-c	39.66 ab	43.10 ab	45.40 ab
N_2R_0	10.40 c-e	14.50 cd	28.12 c-e	34.93 c-f	38.81 b-d	39.60 cd
N_2R_1	12.15 a	17.38 a	32.72 ab	39.68 ab	42.70 ab	43.47 a-c
N_2R_2	11.97 ab	17.25 a	34.80 a	42.86 a	46.70 a	47.68 a
N_3R_0	10.49 c-e	14.60 cd	28.87 b-e	32.31 ef	35.56 de	43.98 a-c
N_3R_1	10.68 b-e	13.04 d	30.87 a-d	32.90 ef	36.55 c-e	44.04 a-c
N_3R_2	9.707 e	13.02 d	31.63 a-d	35.61 b-e	39.52 b-d	44.67 a-c
$LSD_{(0.05)}$	**1.29**	**1.93**	**4.49**	**4.50**	**5.43**	**5.38**
CV (%)	**6.79**	**7.14**	**8.58**	**7.23**	**7.99**	**7.30**

Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

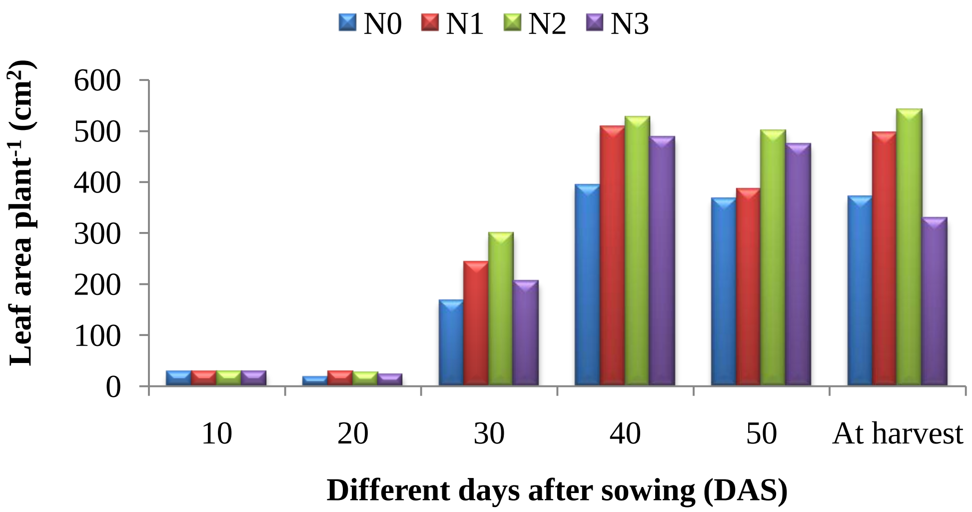
R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.2 Leaf area plant^{-1} (cm^2)

4.2.1 Effect of nitrogen on leaf area plant^{-1} (cm^2)

Leaf area plant^{-1} (cm^2) of mungbean varied significantly due to the application of different level of nitrogen (Figure 3). Leaf area plant^{-1} (cm^2) rapidly increased from 20 DAS to 40 DAS thereafter a slower rate of increase in leaf area plant^{-1} (cm^2) was recorded up to harvest. The maximum leaf area plant^{-1} (299.2, 527.7, 500.3 and 542.0

cm^2 at 30, 40, 50 DAS and harvest, respectively) was obtained from treatment N_2 which was statistically similar with N_1 at 40 DAS and harvest; similar with N_3 at 40 and 50 DAS. The minimum leaf area $plant^{-1}$ (168.0, 393.8, 366.8 and 370.1 cm^2 at 30, 40, 50 DAS and harvest, respectively) was obtained from N_0 which was statistically similar with N_1 at 50 DAS and harvest. Mondal *et al.* (2014) found that leaf area $plant^{-1}$ of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS. Khalilzadeh *et al.* (2012) also found the similar results.

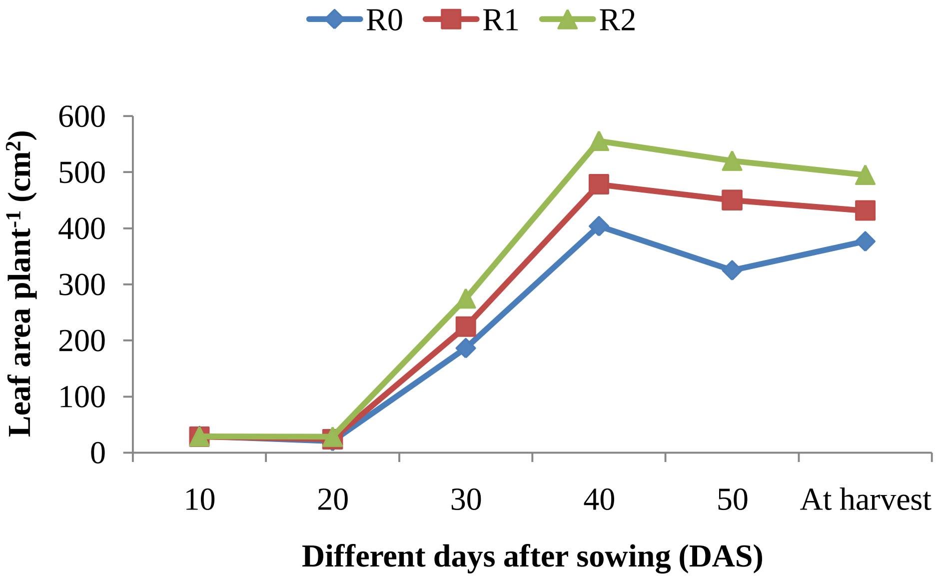


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 03. Effect of nitrogen application on leaf area $plant^{-1}$ (cm^2) of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 3.85, 18.64, 57.12, 70.54 and 54.66 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.2.2 Effect of *Rhizobium* inoculum on leaf area $plant^{-1}$ (cm^2)

Significant variation was observed on leaf area $plant^{-1}$ (cm^2) of mungbean due to the application of *Rhizobium* (Figure 4). Leaf area $plant^{-1}$ rapidly increased from 20 DAS to 40 DAS thereafter a slower rate of increase in leaf area $plant^{-1}$ was recorded up to harvest. Among the different doses of *Rhizobium*, R_2 (8 kg ha^{-1}) showed the maximum leaf area $plant^{-1}$ (275.0, 556.0, 520.6 and 495.4 cm^2 at 30, 40, 50 DAS and harvest, respectively) which was statistically different from all other treatments. On the other hand, the minimum leaf area $plant^{-1}$ (186.2, 403.8, 325.0 and 376.7 cm^2 at 30, 40, 50 DAS and harvest, respectively) was observed in the R_0 treatment where *Rhizobium* was not applied.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 04. Effect of *Rhizobium* doses on leaf area plant^{-1} (cm^2) of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 2.375, 24.05, 36.67, 46.32 and 40.14 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.2.3 Combined effect of nitrogen and *Rhizobium* inoculum on leaf area plant^{-1} (cm^2)

Combined application of different doses of nitrogen and *Rhizobium* had significant effect on the leaf area plant^{-1} (cm^2) of mungbean (Table 2). The minimum leaf area plant^{-1} (152.2, 320.0, 282.8 and 274.6 cm^2 at 30, 40, 50 DAS and harvest, respectively) was observed in the treatment combination of N_0R_0 which was statistically similar with N_0R_1, N_0R_2, N_1R_0 and N_3R_0 at30 DAS; N_0R_1 and N_3R_0 at 40 DAS; N_0R_1, N_1R_0, N_2R_0 and N_3R_0 at 50 DAS; N_3R_0 and N_3R_1 at harvest. On the other hand, the maximum leaf area plant^{-1} (366.7, 600.3, 613.3 and 619.5 cm^2 at 30, 40, 50 DAS and harvest, respectively) was recorded with N_2R_2 (20 kg N ha^{-1} at branching stage + 8 kg ha^{-1} *Rhizobium*) treatment. Combined treatment N_2R_2 was statistically similar with N_1R_2, N_2R_1, N_3R_1 and N_3R_2 at 40 DAS; N_2R_1, N_3R_1 and N_3R_2 at 50 DAS.

Table 2. Combined effect of different nitrogen application and *Rhizobium* inoculum on leaf area plant^{-1} (cm^2) of mungbean at different days after sowing

Treatment combination	Leaf area plant^{-1} (cm^2)					
	Different days after sowing (DAS)					
	10	20	30	40	50	At harvest
N_0R_0	27.35	13.64 f	152.2 h	320.0 f	282.8 e	274.6 f
N_0R_1	27.51	17.82 ef	155.7 h	363.8 f	362.3 de	385.8 de
N_0R_2	29.93	20.14 de	196.2 e-h	497.8 b-e	455.2 bc	450.0 cd
N_1R_0	28.73	24.33 cd	174.9 f-h	493.5 c-e	303.0 de	443.8 cd
N_1R_1	28.63	27.80 bc	235.3 de	463.6 de	382.4 cd	509.0 bc
N_1R_2	28.70	37.05 a	316.9 b	567.3 ab	472.8 bc	538.3 b
N_2R_0	29.38	21.80 de	244.6 cd	449.7 e	354.3 de	496.2 bc
N_2R_1	28.43	26.83 c	286.3 bc	533.0 a-d	533.2 ab	510.5 bc
N_2R_2	29.85	32.39 ab	366.7 a	600.3 a	613.3 a	619.5 a
N_3R_0	32.17	21.75 de	173.3 gh	352.0 f	359.8 de	292.3 f
N_3R_1	28.83	23.45 cd	222.0 d-f	553.3 a-c	523.0 ab	321.0 ef
N_3R_2	27.86	24.04 cd	220.0 d-g	558.5 a-c	541.1 ab	374.4 de
$LSD_{(0.05)}$	**NS**	**4.75**	**48.10**	**73.34**	**92.63**	**80.27**
CV (%)	**10.22**	**11.31**	**12.15**	**8.84**	**12.39**	**10.67**

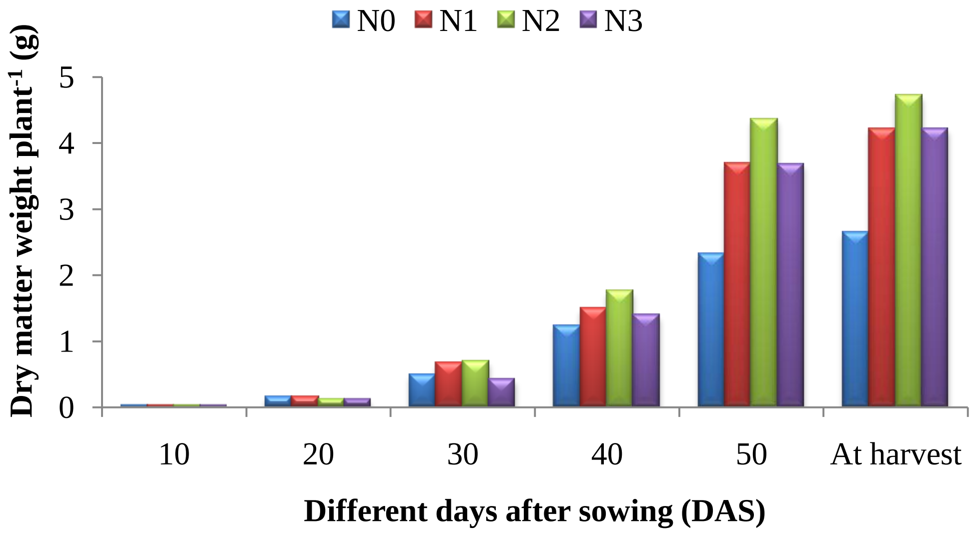
Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.3 Dry matter weight plant^{-1} (g)

4.3.1 Effect of nitrogen on dry matter weight plant^{-1} (g)

The dry matter weight plant^{-1} (g) was significantly influenced by different rate of nitrogen (Figure 5). The dry matter weight plant^{-1} rapidly increased from 20 DAS to 50 DAS thereafter a slower rate of increase in dry matter weight plant^{-1} was recorded up to harvest. The maximum dry weight plant^{-1} (0.16 g at 20 DAS) was obtained from treatment N_0 which was statistically similar with N_1 and N_2; (0.701, 1.758, 4.366 and 4.72 g at 30, 40, 50 and harvest, respectively) was obtained from treatment N_2 which was statistically similar with N_1 at 30 DAS. The minimum dry weight plant^{-1} (0.11 and 0.43 g at 20 and 30 DAS, respectively) was obtained from treatment N_3 which was statistically similar with N_2 at 20 DAS; (1.24, 2.32 and 2.65 g at 40, 50 DAS and harvest, respectively) was obtained from N_0 which was statistically similar with N_3 at 40 DAS. Similar result was found by Mozumder *et al*. (2003); Yein (1982) and Agbenin *et al*. (1991). They found that application of N increased the total dry weight of mungbean plant.

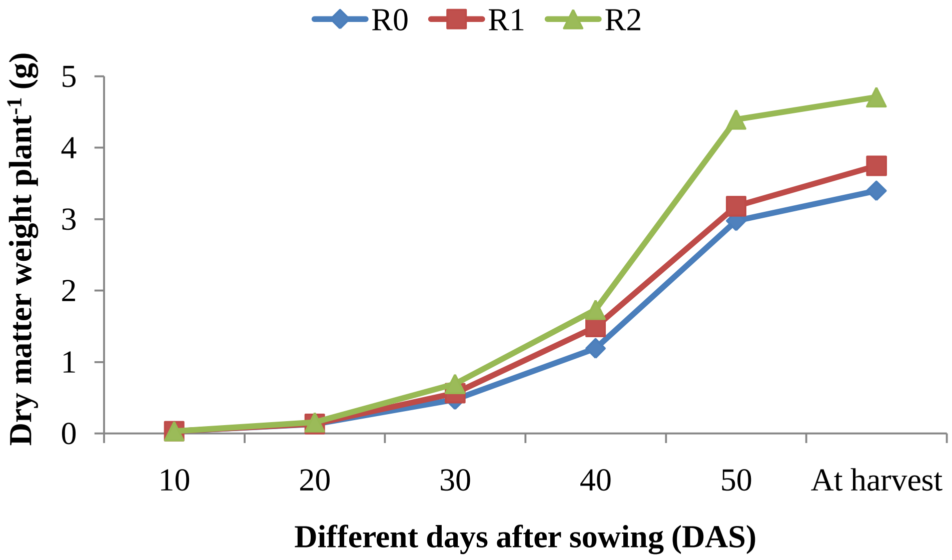


N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal, N_2: 20 kg N ha^{-1} at branching stage and N_3: 20 kg N ha^{-1} at flowering stage

Figure 05. Effect of nitrogen application on dry matter weight plant^{-1} (g) of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 0.04, 0.07, 0.20, 0.64 and 0.40 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.3.2 Effect of *Rhizobium* inoculum on dry matter weight plant^{-1} (g)

The dry matter weight plant^{-1} (g) rapidly increased from 20 DAS to 50 DAS thereafter a slower rate of increase in dry matter weight plant^{-1} was recorded up to harvest due to application of *Rhizobium* inoculum (Figure 6). The maximum dry weight plant^{-1} (0.16, 0.70, 1.73, 4.40 and 4.71 g at 20, 30, 40, 50 and harvest, respectively) was obtained from treatment R_2 which was statistically similar with R_1 at 20 DAS. The minimum dry weight plant^{-1} (0.13, 0.47, 1.19, 2.97 and 3.40 g at 20, 30, 40, 50 DAS and harvest, respectively) was obtained from R_0 which was statistically similar with R_1 at 20 DAS.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 06. Effect of *Rhizobium* doses on dry matter weight $plant^{-1}$ (g) of mungbean at different days after sowing ($LSD_{(0.05)}$ = NS, 0.03, 0.07, 0.13, 0.44 and 0.56 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.3.3 Combined effect of nitrogen and *Rhizobium* inoculum on dry matter weight $plant^{-1}$ (g)

Combined application of different doses of nitrogen and *Rhizobium* inoculum had significant effect on dry matter weight $plant^{-1}$ (g) of mungbean except 10 DAS (Table 3). The maximum dry matter weight $plant^{-1}$ (0.88, 2.25, 5.62 and 5.72 g at 30, 40, 50 and harvest, respectively) was obtained from N_2R_2 which was statistically similar with N_1R_2 but different from other treatment combinations. The minimum dry matter weight $plant^{-1}$ was obtained from N_3R_0 (0.35 g at 30 DAS) which was statistically similar with N_0R_0 and N_3R_1; from N_0R_0 (1.04, 1.79 and 1.72 g at 40, 50 DAS and harvest, respectively) which was statistically similar with N_0R_1, N_2R_0 and N_3R_0 at 40 DAS; N_0R_1 at 50 DAS; N_0R_1 at harvest.

Table 03. Combined effect of different nitrogen application and *Rhizobium* inoculum on dry matter weight plant^{-1} (g) of mungbean at different days after sowing

Treatment combination	Dry matter weight plant^{-1} (g) — Different days after sowing (DAS)					
	10	20	30	40	50	At harvest
N_0R_0	0.03	0.14 a-c	0.46 e-g	1.04 g	1.79 g	1.72 d
N_0R_1	0.03	0.14 a-c	0.49 ef	1.20 fg	2.32 fg	2.40 d
N_0R_2	0.03	0.19 a	0.56 de	1.47 c-e	2.86 ef	3.82 bc
N_1R_0	0.03	0.14 a-c	0.57 de	1.33 d-f	3.06 d-f	3.59 c
N_1R_1	0.03	0.15 a-c	0.63 cd	1.49 cd	3.17 d-f	4.12 bc
N_1R_2	0.03	0.18 ab	0.83 ab	1.67 bc	4.85 ab	4.95 ab
N_2R_0	0.03	0.13 bc	0.51 d-f	1.17 fg	3.60 c-e	4.23 bc
N_2R_1	0.03	0.12 c	0.72 bc	1.85 b	3.88 cd	4.18 bc
N_2R_2	0.03	0.13 bc	0.88 a	2.25 a	5.62 a	5.72 a
N_3R_0	0.03	0.11 c	0.35 g	1.21 e-g	3.45 c-e	4.02 bc
N_3R_1	0.02	0.11 c	0.42 fg	1.42 c-f	3.36 de	4.29 bc
N_3R_2	0.03	0.12 bc	0.51 d-f	1.54 cd	4.26 bc	4.33 bc
$LSD_{(0.05)}$	**NS**	**0.05**	**0.13**	**0.26**	**0.87**	**1.12**
CV (%)	**10.3**	**10.81**	**12.99**	**10.25**	**14.35**	**16.45**

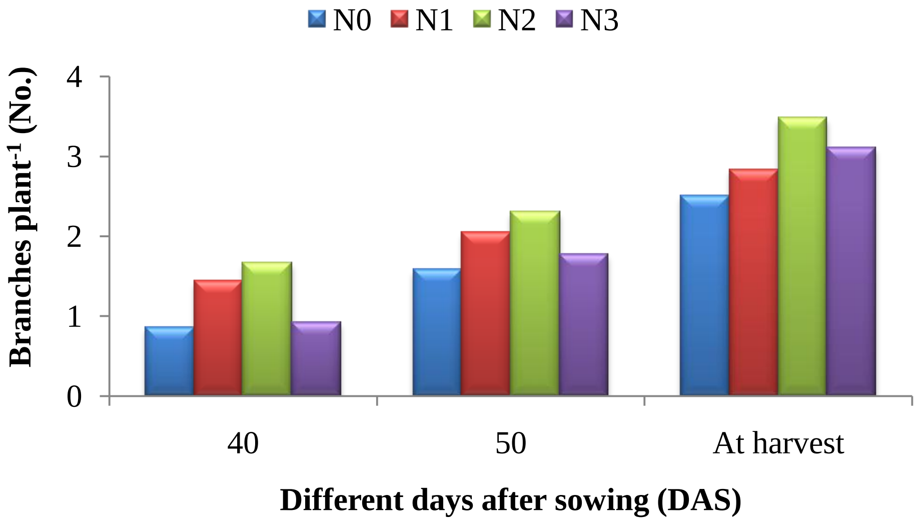
Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.4 Branches plant^{-1} (No.)

4.3.1 Effect of nitrogen on the branches plant^{-1} (No.)

Significant variation was observed in the branches plant^{-1} (No.) of mungbean when different doses of nitrogen were applied (Figure 7). The highest branches plant^{-1} (1.60, 2.30 and 3.49 at 40, 50 DAS and harvest, respectively) was recorded from N_2 which was statistically different from all other treatments. The lowest branches plant^{-1} (0.86, 1.582 and 2.513 at 40, 50 DAS and harvest, respectively) was recorded in N_0 which was statistically similar with N_3 at 40 DAS. Similar results were noticed in mungbean by Achakzai *et al.* (2012).

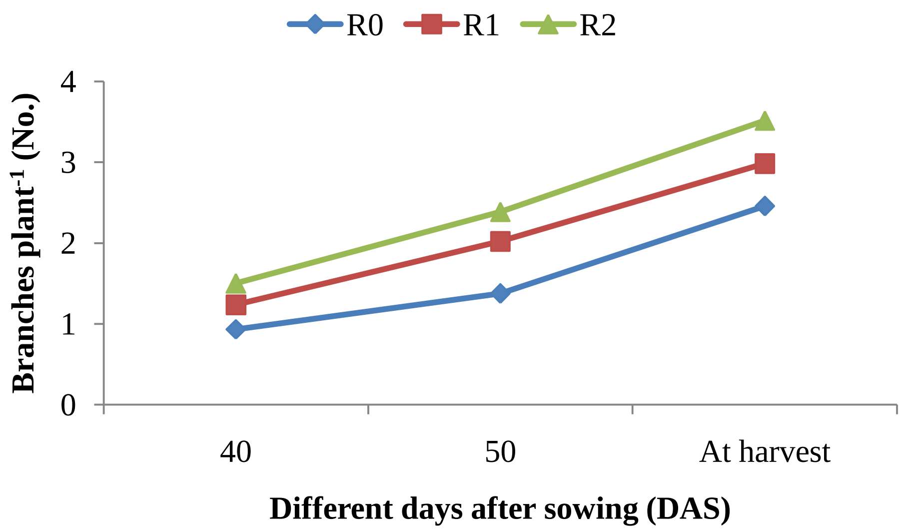


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 07. Effect of nitrogen application on branches plant^{-1} (No.) of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.13, 0.17 and 0.24 at 30, 50 DAS and harvest, respectively)

4.4.2 Effect of *Rhizobium* inoculum on the branches plant^{-1} (No.)

Significant variation was observed in the branches plant^{-1} (No.) of mungbean when different doses of *Rhizobium* were applied (Figure 8). The highest branches plant^{-1} (1.502, 2.338 and 3.517 at 40, 50 DAS and harvest, respectively) were recorded from R_2 which was statistically similar with R_1 at 40 DAS but different from all other treatments. The lowest branches plant^{-1} (0.931, 1.375 and 2.457 at 40, 50 DAS and harvest, respectively) was recorded in R_0 treatment where no *Rhizobium* inoculum was applied.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1}, R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 08. Effect of *Rhizobium* doses on branches $plant^{-1}$ (No.) of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.28, 0.15 and 0.20 at 30, 50 DAS and harvest, respectively)

4.4.3 Combined effect of nitrogen and *Rhizobium* inoculum on the branches $plant^{-1}$ (No.)

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the branches $plant^{-1}$ (No.) of mungbean was significant (Table 4). The highest branches $plant^{-1}$ (2.38, 2.95 and 4.17 at 40, 50 DAS and harvest, respectively) was recorded with the treatment combination of N_2R_2. On the other hand, the lowest branches $plant^{-1}$ (0.73, 1.26 and 2.16 at 40, 50 DAS and harvest, respectively) was found in N_0R_0 which was statistically similar with N_0R_1, N_0R_2, N_1R_0, N_2R_0, N_3R_0, N_3R_1 and N_3R_2 at 40 DAS; N_1R_0, N_2R_0 and N_3R_0 at 50 DAS; N_0R_1, N_1R_0 and N_3R_0 at harvest.

Table 04. Combined effect of different nitrogen application and *Rhizobium* inoculum on branches plant^{-1} (No.) of mungbean at different days after sowing

Treatment combination	Branches plant^{-1} (No.)		
	Different days after sowing (DAS)		
	40	50	At harvest
N_0R_0	0.73 e	1.26 g	2.16 g
N_0R_1	0.89 de	1.69 ef	2.48 fg
N_0R_2	0.96 de	1.80 ef	2.90 de
N_1R_0	1.23 b-e	1.38 g	2.37 g
N_1R_1	1.30 b-d	2.11 d	2.84 ef
N_1R_2	1.78 b	2.65 b	3.30 b-d
N_2R_0	1.01 de	1.54 fg	2.86 ef
N_2R_1	1.62 bc	2.41 bc	3.40 bc
N_2R_2	2.38 a	2.95 a	4.17 a
N_3R_0	0.76 de	1.31 g	2.43 g
N_3R_1	1.13 c-e	1.87 de	3.21 c-e
N_3R_2	0.88 de	2.15 cd	3.69 b
$LSD_{(0.05)}$	**0.56**	**0.29**	**0.40**
CV (%)	**26.36**	**8.76**	**7.78**

Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

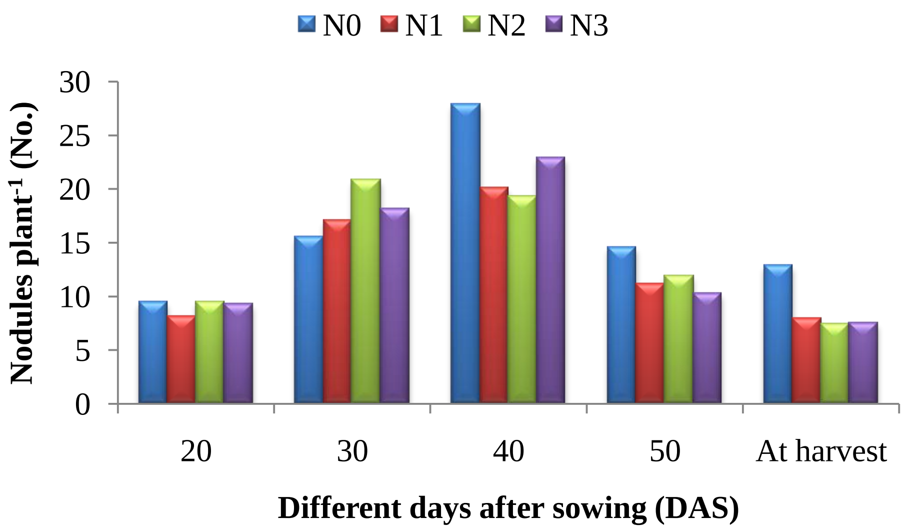
R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.5 Nodules plant^{-1} (No.)

4.5.1 Effect of nitrogen on the nodules plant^{-1} (No.)

Significant variation was observed in nodules plant^{-1} (No.) of mungbean when different doses of nitrogen were applied (Figure 9). Nodules plant^{-1} rapidly increased from 20 DAS to 40 DAS thereafter rapidly decreased from 50 DAS up to harvest. The highest nodules plant^{-1} (27.92, 14.59 and 12.89 at 40, 50 DAS and harvest, respectively) was recorded in N_0 (control) which was statistically similar with N_1 and N_2 at 50 DAS. At 20 and 30 DAS, the highest nodules plant^{-1} was recorded (9.52 and 20.82, respectively) from N_2 treatment which was statistically at par with N_0 and N_3 at 20 DAS; N_3 at 30

DAS. At 20 DAS, the lowest nodules plant^{-1} (8.15) was recorded in the N_1 treatment which shown similarity with N_3. At 30 DAS, the lowest nodules plant^{-1} (15.56) was recorded in the N_0 treatment which was statistically similar with N_1 and N_3. At 40 DAS, the lowest number of nodules plant^{-1} (19.33) was recorded in the N_2 which was statistically similar with N_1 and N_3. At 50 DAS, the lowest nodules plant^{-1} (10.33) was recorded in the N_3 which was statistically similar with N_1 and N_2. At harvest, the lowest nodules plant^{-1} (7.44) was recorded in the N_2 which was statistically similar with N_1 and N_3. Similar results were found in mungbean by Nursu'aidah *et al.* (2014).

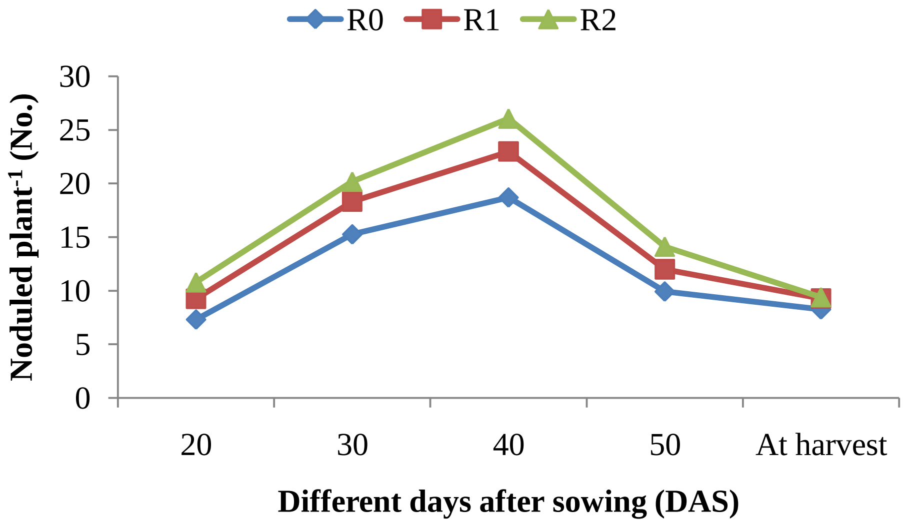


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 09. Effect of nitrogen application on nodules plant^{-1} (No.) of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 2.57, 3.28, 3.95, 3.41 and 1.58 at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.5.2 Effect of *Rhizobium* inoculum on the nodules plant^{-1} (No.)

The nodules plant^{-1} (No.) of mungbean varied significantly due to the application of *Rhizobium* inoculum except at harvest (Figure 10). Nodules plant^{-1} rapidly increased from 20 DAS to 40 DAS thereafter rapidly decreased from 50 DAS up to harvest. The highest nodules plant^{-1} (10.78, 20.17, 26.06 and 14.11 at 20, 30, 40 and 50 DAS, respectively) was recorded in R_2 which was statistically similar with R_1 at 30 DAS. The lowest nodules plant^{-1} (10.78, 15.25, 18.69, 9.91 and 8.25 at 20, 30, 40 and 50 DAS, respectively) was recorded in R_0 where no *Rhizobium* inoculums were applied.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 10. Effect of *Rhizobium* doses on nodules plant^{-1} (No.) of mungbean at different days after sowing (LSD $_{(0.05)}$ = 1.31, 1.23, 1.88, 2.88, 1.67 and NS at 10, 20, 30, 40, 50 DAS and harvest, respectively)

4.5.3 Combined effect of nitrogen and *Rhizobium* inoculum on the nodules plant^{-1} (No.)

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the nodules plant^{-1} of mungbean was significant (Table 5). At 20 DAS, the highest and lowest nodules plant^{-1} (12.11 and 6.67) was recorded with the treatment combination of N_2R_2 and N_1R_0, respectively. N_1R_0 was statistically similar with N_2R_0 and N_3R_0. At 30 DAS, the highest and lowest nodules plant^{-1} (24.11 and 12.11) was recorded with the treatment combination of N_2R_1 and N_0R_0, respectively. N_2R_1 was statistically similar with N_0R_2 and N_2R_2; N_0R_0 was statistically similar with N_0R_1 and N_2R_0. At 40 DAS, the highest and lowest nodules plant^{-1} (32.55 and 13.33) was recorded with the treatment combination of N_0R_2 and N_2R_0, respectively. N_2R_0 was statistically similar with N_1R_0 and N_3R_0. At 50 DAS, the highest and lowest nodules plant^{-1} (17.11 and 7.66) was recorded with the treatment combination of N_0R_2 and N_3R_0, respectively. N_0R_2 was statistically similar with N_2R_2; N_3R_0 was statistically similar with N_1R_0, N_2R_0 and N_3R_1. At harvest, the highest and lowest nodules plant^{-1} (14.33 and 5.77) was recorded with the treatment combination of N_0R_2 and N_2R_2, respectively. N_0R_2 was statistically similar with N_0R_0 and N_0R_1; N_2R_2 was statistically similar with N_1R_0, N_1R_1, N_2R_0, N_3R_0 and N_3R_1. Malik *et al.* (2014) found the similar results in mungbean.

Table 05. Combined effect of different nitrogen application and *Rhizobium* inoculum on nodules plant^{-1} (No.) of mungbean at different days after sowing

Treatment combination	Nodules plant^{-1} (No.)				
	Different days after sowing (DAS)				
	20	30	40	50	At harvest
N_0R_0	8.33 d-f	12.11 f	24.89 bc	13.22 b	12.00 ab
N_0R_1	9.44 cd	14.00 ef	26.33 b	13.44 b	12.33 a
N_0R_2	10.67 b	20.55 ab	32.55 a	17.11 a	14.33 a
N_1R_0	6.67 h	16.89 b-e	17.56 ef	9.777 cd	7.78 c-f
N_1R_1	8.11 e-g	16.44 c-e	20.44 c-e	10.89 bd	7.22 d-f
N_1R_2	9.67 bc	18.00 b-d	22.33 b-e	12.89 bc	9.00 cd
N_2R_0	7.22 f-h	15.33 d-f	13.33 f	9.00 d	6.67 d-f
N_2R_1	9.22 c-e	24.11 a	21.11 b-e	12.78 bc	9.89 bc
N_2R_2	12.11 a	23.00 a	23.56 b-d	14.00 ab	5.778 f
N_3R_0	7.00 gh	16.67 c-e	19.00 d-f	7.667 d	6.56 ef
N_3R_1	10.22 bc	18.67 b-d	24.00 b-d	10.89 bd	7.61 c-f
N_3R_2	10.67 b	19.11 bc	25.78 bc	12.45 bc	8.45 c-e
$LSD_{(0.05)}$	**1.223**	**3.76**	**5.75**	**3.34**	**2.41**
CV (%)	**7.75**	**12.12**	**14.71**	**16.08**	**15.52**

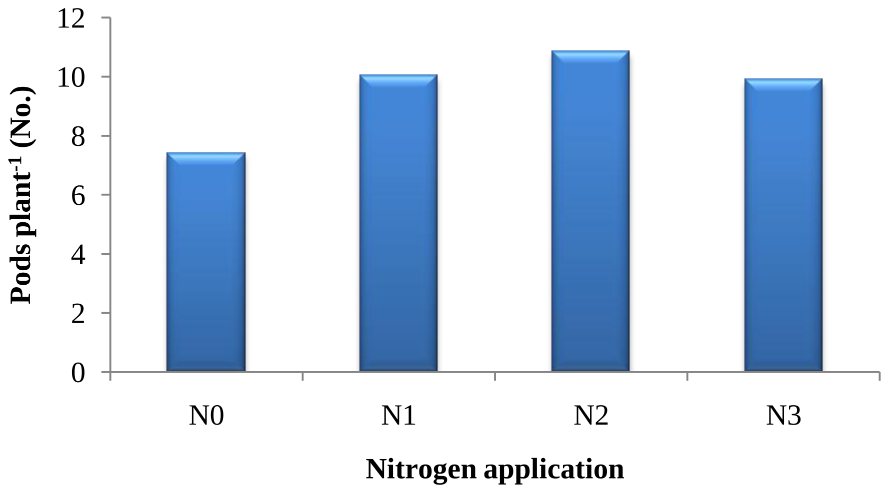
Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.6 Pods plant^{-1} (No.)

4.6.1 Effect of nitrogen on the pods plant^{-1} (No.)

Significant variation was observed in pods plant^{-1} (No.) of mungbean when different rates of nitrogen were applied (Figure 11). The highest pods plant^{-1} (10.84) was recorded in N_2 which was statistically similar with N_1 and N_3 but different from other treatment. The lowest pods plant^{-1} (7.40) was recorded in the N_0 treatment where no nitrogen was applied. Probably optimum nitrogen restricted flower and pod dropping, which might have contributed to more pods per plant as reported by Kulsum (2003) in blackgram.

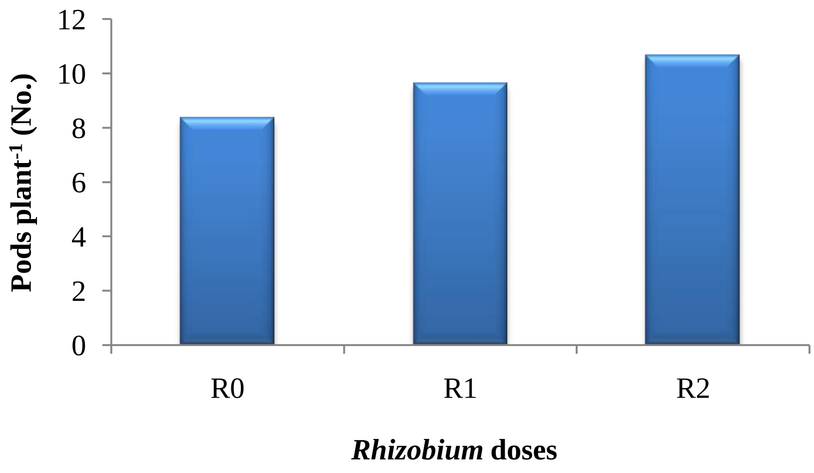


N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal, N_2: 20 kg N ha^{-1} at branching stage and N_3: 20 kg N ha^{-1} at flowering stage

Figure 11. Effect of nitrogen application on pods plant^{-1} (No.) of mungbean (LSD $_{(0.05)}$ = 1.80)

4.4.2 Effect of *Rhizobium* inoculum on the pods plant^{-1} (No.)

Different doses of *Rhizobium* inoculum showed significant variations in respect of pods plant^{-1} (No.) (Figure 12). Among the different doses of *Rhizobium*, R_2 showed the highest pods plant^{-1} (10.66) which was statistically different from other treatment. On the contrary, the lowest pods plant^{-1} (8.35) was observed with R_0. Nazmun *et al.* (2009) found the similar results in mungbean.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 12. Effect of *Rhizobium* doses on pods plant^{-1} (No.) of mungbean (LSD $_{(0.05)}$ = 0.59)

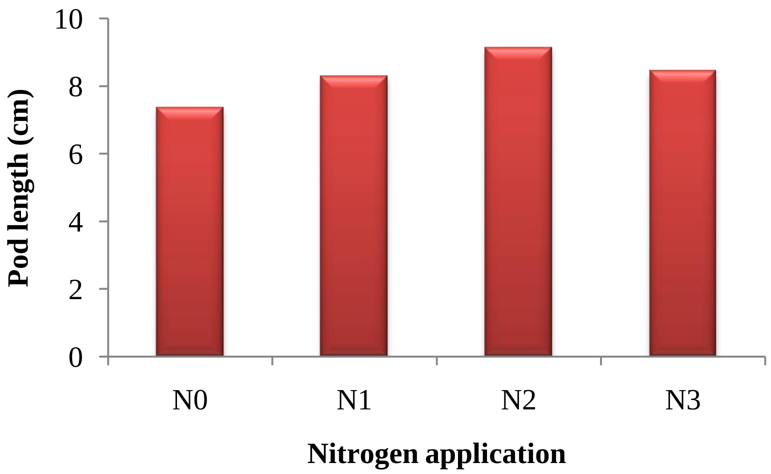
4.6.3 Combined effect of nitrogen and *Rhizobium* inoculum on the pods plant^{-1} (No.)

The combined effect of different rates of nitrogen and *Rhizobium* inoculum on pods plant^{-1} of mungbean was significant (Table 6). The highest pods plant^{-1} (12.68) was recorded with the treatment combination of N_2R_2 which were statistically different from the rest of the treatment combinations. On the other hand, the lowest pods plant^{-1} (6.36) was found in N_0R_0 which was statistically similar with N_0R_1.

4.7 Pod length (cm)

4.7.1 Effect of nitrogen on pod length (cm)

The pod length (cm) as affected by different rate of nitrogen showed statistically significant variation (Figure 13). Among the different doses of N the highest pod length (9.14 cm) was observed in N_2 which was statistically different from other treatment. The lowest pod length (7.36 cm) was recorded in the N_0 treatment where no nitrogen was applied. Azadi *et al.* (2013) also found that the highest pod length was obtained due to the application of higher amount of nitrogen.



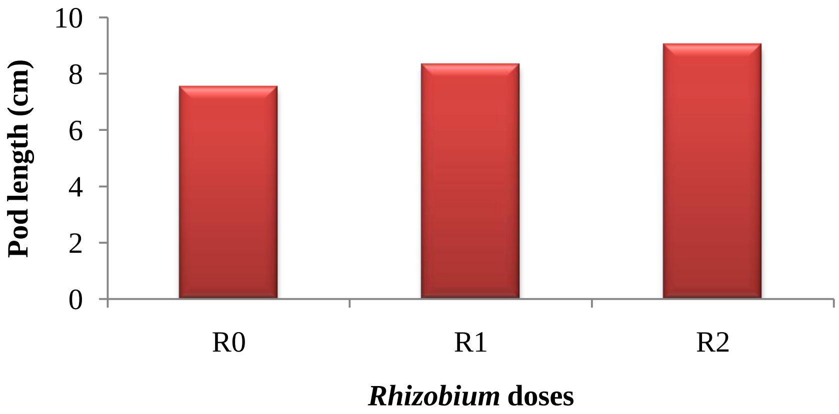
N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 13. Effect of nitrogen application on pod length (cm) of mungbean (LSD $_{(0.05)}$ = 0.33)

4.7.2 Effect of *Rhizobium* inoculum on pod length of mungbean (cm)

Application of *Rhizobium* inoculum at different doses showed significant variation on the pod length (cm) of mungbean (Figure 14). Among the different *Rhizobium* doses, R_2

showed the highest pod length (9.03 cm), which was statistically different from other treatment. The lowest pod length (7.55 cm) was recorded in the R_0 treatment where no *Rhizobium* inoculums were applied. Nazmun *et al.* (2009) found similar results in mungbean.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 14. Effect of *Rhizobium* doses on pod length (cm) of mungbean (LSD $_{(0.05)}$ = 0.49)

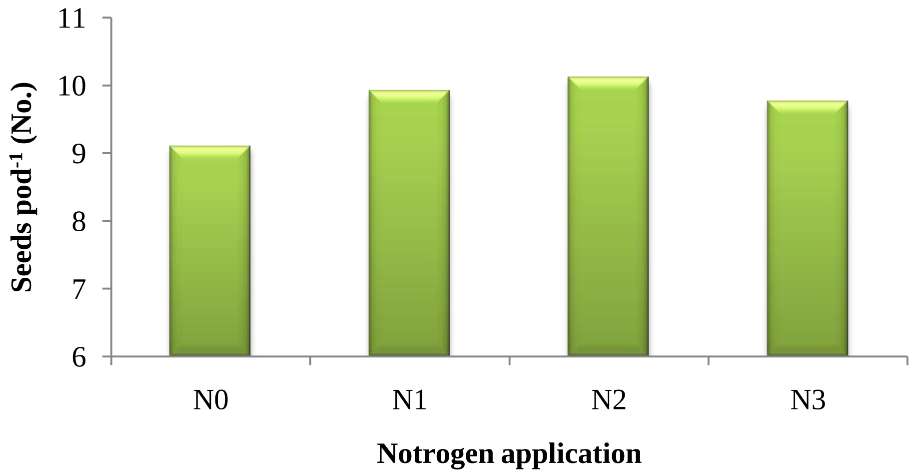
4.7.3 Combined effect of nitrogen and *Rhizobium* inoculum on pod length (cm)

Combined effect of different doses of nitrogen and *Rhizobium* inoculum on pod length (cm) showed a statistically significant variation (Table 06). The highest pod length (10.33 cm) was recorded in the treatment combination of N_2R_2 which was statistically different from other treatment combinations. On the other hand, the lowest pod length (6.0 cm) was found in N_0R_0.

4.8 Seeds pod^{-1} (No.)

4.8.1 Effect of nitrogen on the seeds pod^{-1} (No.)

Significant variation was observed in seeds pod^{-1} (No.) of mungbean when different doses of nitrogen were applied (Figure 15). The highest seeds pod^{-1} (10.11) was recorded in N_2 which was statistically similar with N_1 and N_3. The lowest seeds pod^{-1} (9.09) was recorded in the N_0 treatment where no nitrogen was applied. This finding was partly supported by Singh *et al.* (1993) who stated that application of nitrogen increased the seeds per pod.

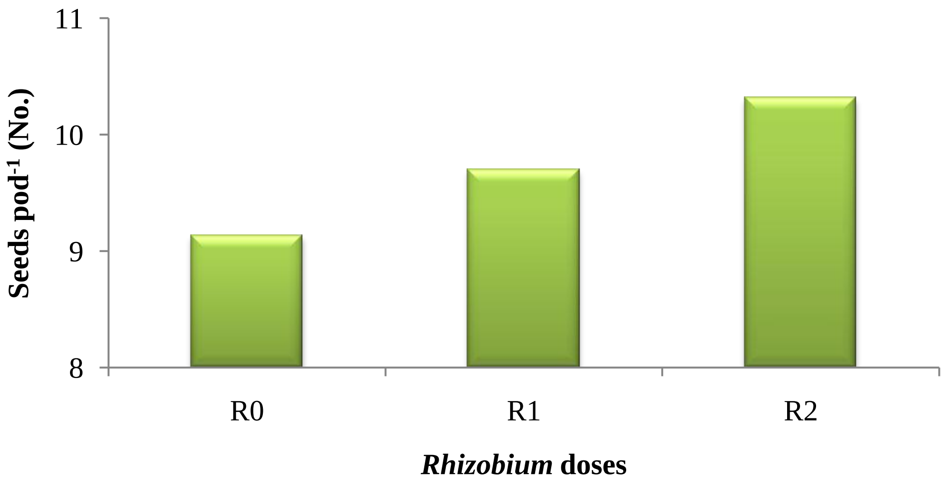


N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal, N_2: 20 kg N ha^{-1} at branching stage and N_3: 20 kg N ha^{-1} at flowering stage

Figure 15. Effect of nitrogen application on seeds pod^{-1} (No.) of mungbean (LSD $_{(0.05)}$ = 0.59)

4.8.2 Effect of *Rhizobium* inoculum on the seeds pod^{-1} (No.)

Different doses of *Rhizobium* inoculum showed significant variations in respect of seeds pod^{-1} (No.) (Figure 16). Among the different doses of *Rhizobium*, R_2 showed the highest seeds pod^{-1} (10.32) which was statistically different from other treatment. On the contrary, the lowest seeds pod^{-1} (9.13) was observed with R_0, where no *Rhizobium* inoculums were applied.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 16. Effect of *Rhizobium* doses on seeds pod^{-1} (No.) of mungbean (LSD $_{(0.05)}$ = 0.41)

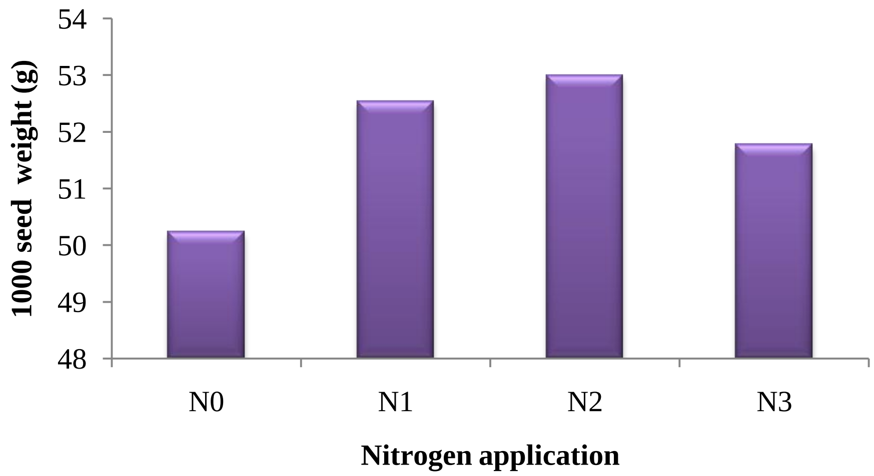
4.8.3 Combined effect of nitrogen and *Rhizobium* inoculum on the seeds pod^{-1} (No.)

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on seeds pod^{-1} (No.) of mungbean was significant (Table 6). The highest seeds pod^{-1} (10.69) was recorded with the treatment combination of N_2R_2 which was statistically similar with N_0R_2, N_1R_0, N_1R_2, N_2R_1 and N_3R_2 treatment. On the other hand, the lowest seeds pod^{-1} (7.90) was found in N_0R_0 treatment (control).

4.9 Weight of 1000 seed (g)

4.9.1 Effect of nitrogen on weight of 1000 seed (g)

The weight of 1000 seed (g) of mungbean was varied non-significantly with the different doses of nitrogen application (Figure 17). The highest weight of 1000 seed (53.0 g) was recorded in N_2 and the lowest was recorded (50.23 g) in the N_0 treatment where no nitrogen was applied. Mahboob and Asghar (2002) revealed that the application of nitrogen fertilizer was significantly affected the 1000 seed weight of mungbean.

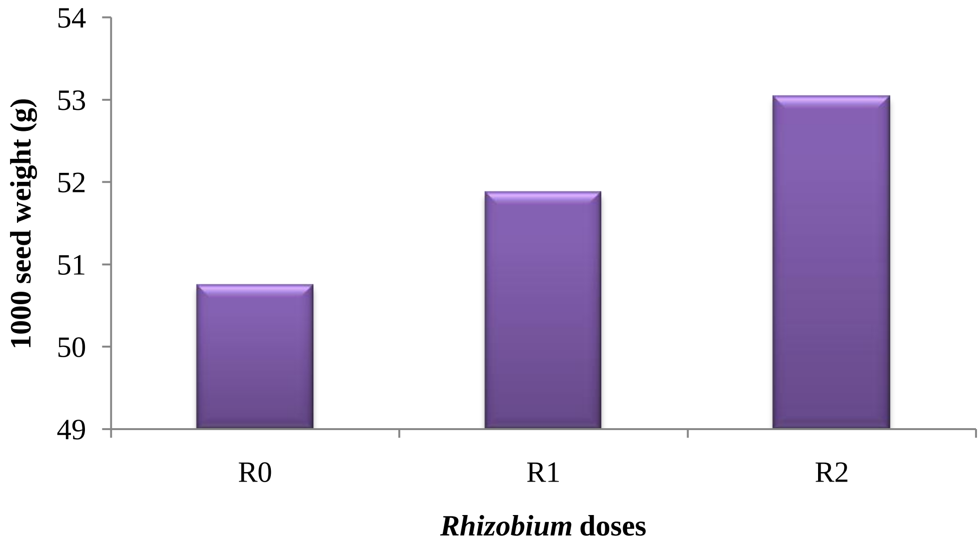


N_0: No nitrogen (Control), N_2: 20 kg N ha^{-1} at branching stage and
N_1: 20 kg N ha^{-1} as basal, N_3: 20 kg N ha^{-1} at flowering stage

Figure 17. Effect of nitrogen application on 1000 seed weight (g) of mungbean (LSD $_{(0.05)}$ = NS)

4.9.2 Effect of *Rhizobium* inoculum on weight of 1000 seed (g)

Different doses of *Rhizobium* inoculum showed significant variations in respect of the weight of 1000 seed (g) of mungbean (Figure 18). Among the different doses of *Rhizobium*, R_2 showed the highest weight of 1000 seed (53.04 g) and it was identical with R_1 treatment. On the contrary, the lowest weight of 1000 seed (50.75 g) was observed with R_0 which was identical with R_1.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 18. Effect of *Rhizobium* doses on 1000 seed weight (g) of mungbean (LSD $_{(0.05)}$ = 1.65)

4.9.3 Combined effect of nitrogen and *Rhizobium* inoculum on weight of 1000 seed (g)

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the weight of 1000 seed (g) of mungbean was significant (Table 6). The highest weight of 1000 seed (55.16 g) was recorded with the treatment combination of N_2R_2 which was statistically similar with N_1R_1, N_1R_2, N_2R_1 and N_3R_2. On the other hand, the lowest weight of 1000 seed (48.42 g) was found in N_0R_0 which was statistically similar with N_0R_1, N_0R_2, N_2R_0, N_3R_0 and N_3R_1.

Table 06. Combined effect of different nitrogen application and *Rhizobium* inoculum on pods plant^{-1} (No.), pod length (cm), seeds pod^{-1} (No.), 1000 seed weight (g) of mungbean

Treatment combination	Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)
N_0R_0	6.36 g	6.00 d	7.90 e	48.42 c
N_0R_1	7.39 fg	7.57 c	9.36 cd	50.67 bc
N_0R_2	8.47 ef	8.51 bc	10.04 a-c	51.60 bc
N_1R_0	9.17 c-e	8.03 bc	9.97 a-d	51.75 b
N_1R_1	10.06 b-d	8.41 bc	9.64 b-d	52.54 ab
N_1R_2	10.87 b	8.45 bc	10.11 a-c	53.35 ab
N_2R_0	8.93 de	8.09 bc	9.49 cd	51.25 bc
N_2R_1	10.91 b	9.00 b	10.17 a-c	52.59 ab
N_2R_2	12.68 a	10.33 a	10.69 a	55.16 a
N_3R_0	8.94 c-e	8.12 bc	9.190 d	51.57 bc
N_3R_1	10.11 bc	8.38 bc	9.65 b-d	51.67 bc
N_3R_2	10.65 b	8.86 b	10.44 ab	52.06 ab
$LSD_{(0.05)}$	**1.17**	**0.99**	**0.82**	**3.31**
CV (%)	**7.08**	**6.85**	**4.9**	**3.68**

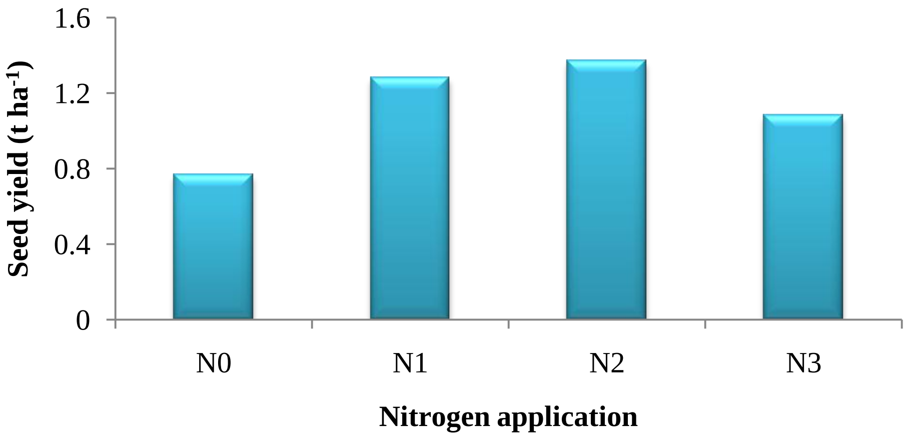
Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

4.10 Seed yield (t ha^{-1})

4.10.1 Effect of nitrogen on the seed yield (t ha^{-1})

Significant variation was observed on the seed yield (t ha^{-1}) of mungbean when different doses of nitrogen were applied (Figure 19). The highest seed yield of mungbean (1.37 t ha^{-1}) was recorded in N_2 which was statistically similar with N_1 but different from other treatments. The lowest seed yield of mungbean (0.77 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied. N_2 produced the highest yield due to maximum production of crop characters like plant height, branches plant^{-1}, leaves plant^{-1}, pods plant^{-1} and seeds pod^{-1}. Similar results were observed in mungbean by Azadi *et al.* (2013), Saini and Thakur (1996).

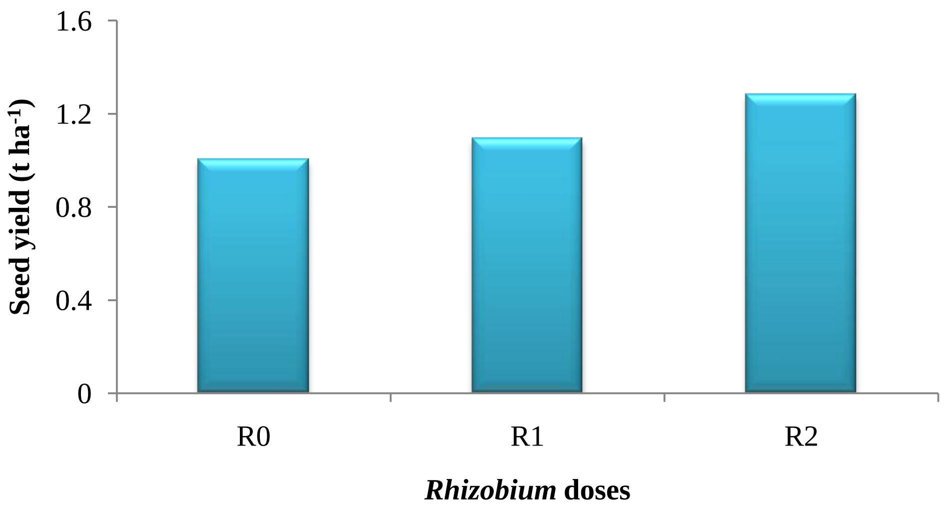


N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal, N_2: 20 kg N ha^{-1} at branching stage and N_3: 20 kg N ha^{-1} at flowering stage

Figure 19. Effect of nitrogen application on seed yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.1)

4.10.2 Effect of *Rhizobium* inoculum on the seed yield (t ha^{-1})

Different doses of *Rhizobium* inoculum showed significant effect of seed yield (t ha^{-1}) of mungbean (Figure 20). Among the different doses of *Rhizobium*, R_2 showed the highest seed yield of mungbean (1.28 t ha^{-1}). On the contrary, the lowest seed yield of mungbean (1.00 t ha^{-1}) was observed with R_0 where no *Rhizobium* inoculums were applied. Similar results were observed in mungbean by Hossain *et al.* (2014) and Malik *et al.* (2014).



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 20. Effect of *Rhizobium* doses on seed yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.07)

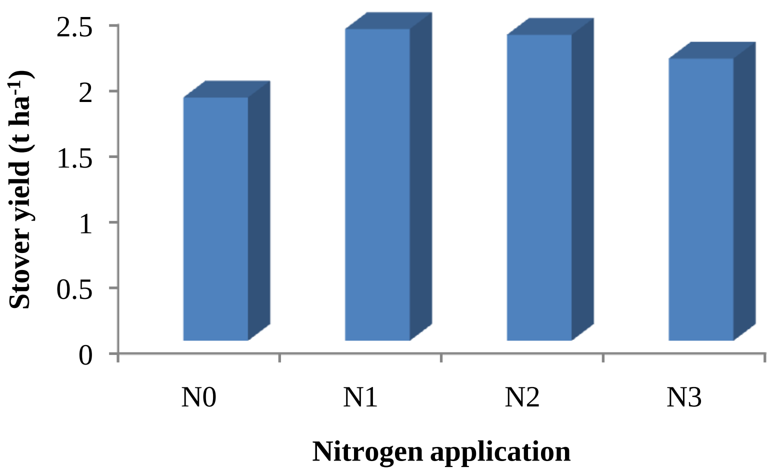
4.10.3 Combined effect of nitrogen and *Rhizobium* inoculum on seed yield (t ha^{-1})

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the seed yield (t ha^{-1}) of mungbean was significant (Table 7). The highest grain yield of mungbean (1.69 t ha^{-1}) was recorded with the treatment combination of N_2R_2 which was statistically different from all other treatments. On the other hand, the lowest grain yield of mungbean (0.73 t ha^{-1}) was found in N_0R_1 treatment combination which was statistically similar with N_0R_0 and N_0R_2. Malik *et al.* (2014) found that the combined application of *Rhizobium*, compost and 75% of the recommended mineral nitrogen (RMN) gave maximum grain yield plant^{-1}.

4.11 Stover yield (t ha^{-1})

4.11.1 Effect of nitrogen on the stover yield (t ha^{-1})

Significant variation was observed on the stover yield (t ha^{-1}) of mungbean when different doses of nitrogen were applied (Figure 21). The highest stover yield of mungbean (2.37 t ha^{-1}) was recorded in N_1, which was statistically similar with N_2 but different from other treatments. The lowest stover yield (1.85 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied. Rajender *et al*. (2003) and Srinivas *et al.* (2002) also found the similar results in mungbean.

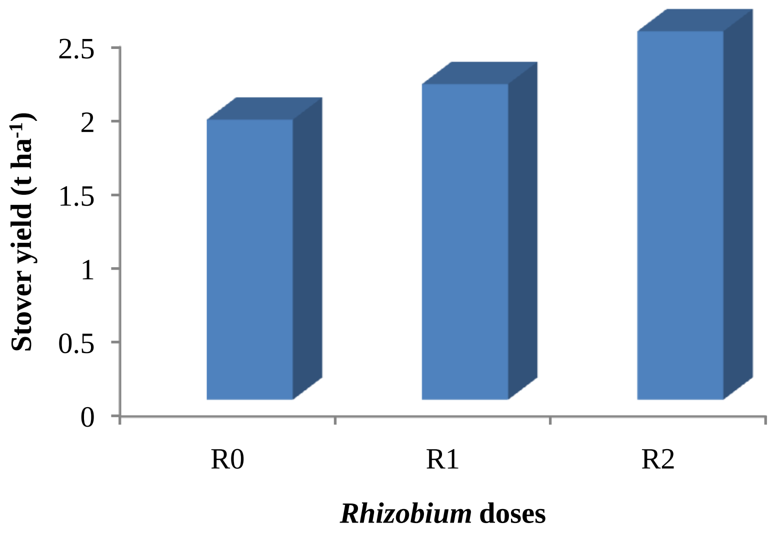


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 21. Effect of nitrogen application on stover yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.13)

4.11.2 Effect of *Rhizobium* inoculum on the stover yield (t ha^{-1})

Different doses of *Rhizobium* inoculum showed significant variations in respect of stover yield (t ha^{-1}) of mungbean (Figure 22). Among the different doses of *Rhizobium*, R_2 showed the highest stover yield (2.49 t ha^{-1}), which was statistically different from other treatments. On the contrary, the lowest stover yield (1.89 t ha^{-1}) was observed with R_0 treatment. Nazmun *et al.* (2009) were observed that the different *rhizobium* inoculum exerted significant on stover yield of Mungbean.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1}, R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 22. Effect of *Rhizobium* doses on stover yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.12)

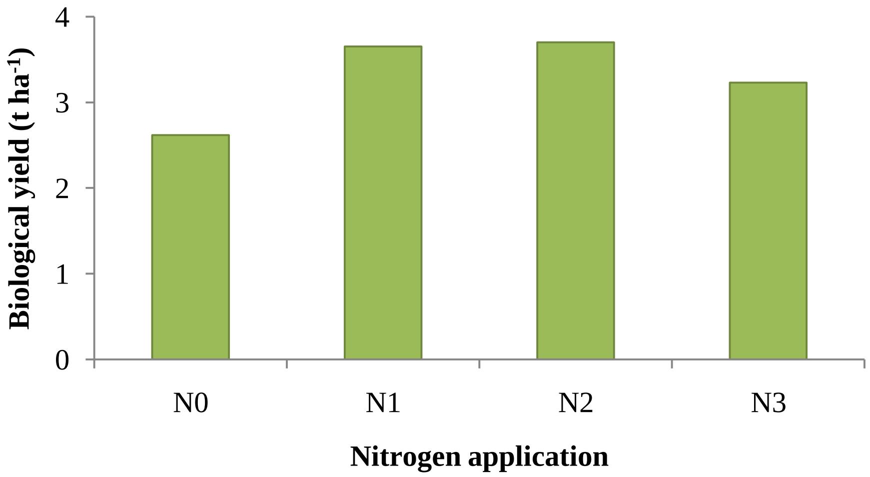
4.11.3 Combined effect of nitrogen and *Rhizobium* inoculum on stover yield (t ha^{-1})

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the stover yield (t ha^{-1}) was significant (Table 7). The highest stover yield (2.67 t ha^{-1}) was recorded with the treatment combination of N_2R_2 which were statistically similar with N_1R_1, N_1R_2 and N_3R_2 but different from other treatments. On the other hand, the lowest stover yield (1.60 t ha^{-1}) was found in N_0R_0 which was statistically similar with N_0R_1.

4.12 Biological yield (t ha^{-1})

4.12.1 Effect of nitrogen on the biological yield (t ha^{-1})

Significant variation was observed on the biological yield (t ha^{-1}) of mungbean when different doses of nitrogen were applied (Figure 23). The highest biological yield of mungbean (3.70 t ha^{-1}) was recorded in N_2, which was statistically similar with N_1 but different from other treatments. The lowest biological yield (2.61 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied.

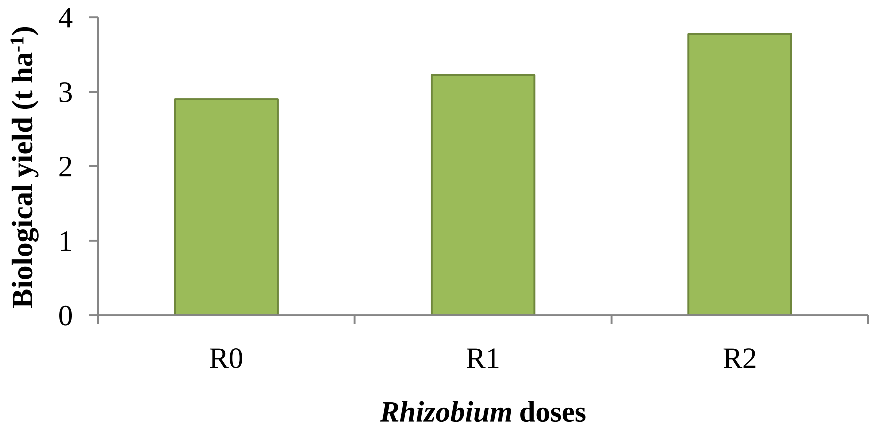


N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as basal,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

Figure 23. Effect of nitrogen application on biological yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.16)

4.12.2 Effect of *Rhizobium* inoculum on the biological yield (t ha^{-1})

Different doses of *Rhizobium* inoculum showed significant variations in respect of biological yield (t ha^{-1}) of mungbean (Figure 24). Among the different doses of *Rhizobium*, R_2 showed the highest biological yield (3.77 t ha^{-1}), which was statistically different from other treatments. On the contrary, the lowest biological yield (2.89 t ha^{-1}) was observed with R_0 treatment.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 24. Effect of *Rhizobium* doses on biological yield (t ha^{-1}) of mungbean (LSD $_{(0.05)}$ = 0.13)

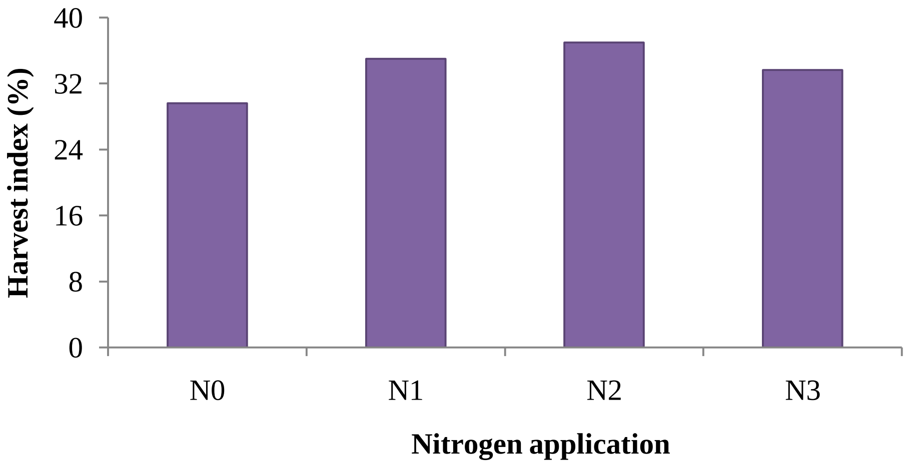
4.12.3 Combined effect of nitrogen and *Rhizobium* inoculum on biological yield (t ha^{-1})

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the biological yield was significant (Table 07). The highest biological yield (4.36 t ha^{-1}) was recorded with the treatment combination of N_2R_2 which were statistically different from other treatments. On the other hand, the lowest biological yield (2.36 t ha^{-1}) was found in N_0R_0 which was statistically similar with N_0R_1. Malik *et al.* (2014) found that biological yield increased by the addition of compost, mineral N and *Rhizobium* inoculum.

4.13 Harvest index (%)

4.13.1 Effect of nitrogen on the harvest index (%)

Significant variation was observed on the harvest index (%) of mungbean when different doses of nitrogen were applied (Figure 25). The highest harvest index (%) of mungbean (36.99%) was recorded in N_2, which was statistically similar with N_1 but different from other treatments. The lowest harvest index (29.60%) was recorded in the N_0 treatment where no nitrogen was applied.

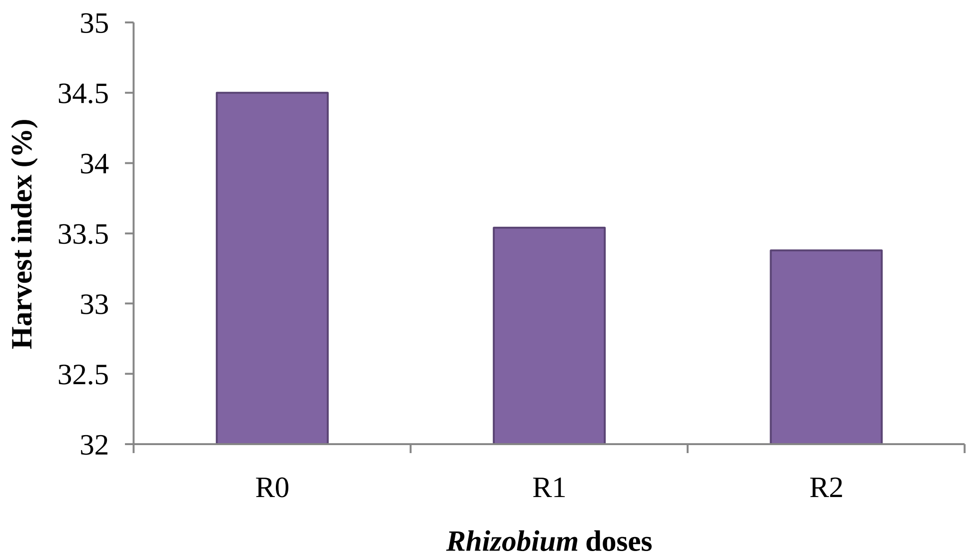


N_0: No nitrogen (Control), N_2: 20 kg N ha^{-1} at branching stage and
N_1: 20 kg N ha^{-1} as basal, N_3: 20 kg N ha^{-1} at flowering stage

Figure 25. Effect of nitrogen application on harvest index (%) of mungbean (LSD $_{(0.05)}$ = 2.87)

4.13.2 Effect of *Rhizobium* inoculum on the harvest index (%)

Different doses of *Rhizobium* inoculum showed non-significant variations in respect of harvest index (%) of mungbean (Figure 26). Among the different doses of *Rhizobium*, R_0 showed the highest harvest index (34.50%) and the lowest was observed (33.38%) with R_2 treatment.



R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}

Figure 26. Effect of *Rhizobium* doses on harvest index (%) of mungbean (LSD $_{(0.05)}$ = NS)

4.13.3 Combined effect of nitrogen and *Rhizobium* inoculum on harvest index (%)

The combined effect of different doses of nitrogen and *Rhizobium* inoculum on the harvest index (%) was significant (Table 7). The highest harvest index (38.75%) was recorded with the treatment combination of N_2R_2 which were statistically similar with N_1R_0, N_1R_1, N_1R_2, N_2R_0, N_2R_1 and N_3R_0 but different from other treatments. On the other hand, the lowest harvest index (26.16%) was found in N_0R_2 treatment combination which was statistically similar with N_0R_1.

Table 07. Combined effect of different nitrogen application and *Rhizobium* inoculum on seed yield (t ha^{-1}), stover yield (t ha^{-1}), Biological yield (t ha^{-1}), harvest index (%) of mungbean

Treatment combination	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0R_0	0.76 f	1.61 f	2.36 g	32.08 bc
N_0R_1	0.73 f	1.66 f	2.39 g	30.55 cd
N_0R_2	0.81 f	2.29 bc	3.10 e	26.16 d
N_1R_0	1.12 de	2.12 cd	3.24 e	34.59 a-c
N_1R_1	1.25 cd	2.43 ab	3.68 c	34.03 a-c
N_1R_2	1.47 b	2.57 a	4.04 b	36.41 ab
N_2R_0	1.15 cd	2.04 de	3.19 e	36.34 ab
N_2R_1	1.27 c	2.27 b-d	3.55 d	35.89 ab
N_2R_2	1.69 a	2.67 a	4.36 a	38.75 a
N_3R_0	0.98 e	1.82 ef	2.80 f	34.99 a-c
N_3R_1	1.11 de	2.18 cd	3.29 de	33.71 bc
N_3R_2	1.16 cd	2.44 ab	3.60 c	32.19 bc
$LSD_{(0.05)}$	**0.14**	**0.24**	**0.26**	**4.86**
CV (%)	**7.3**	**6.57**	**4.61**	**8.31**

Here, N_0: No nitrogen (Control),
N_1: 20 kg N ha^{-1} as,
N_2: 20 kg N ha^{-1} at branching stage and
N_3: 20 kg N ha^{-1} at flowering stage

R_0: No *Rhizobium* (Control),
R_1: *Rhizobium* @ 5 kg ha^{-1} and
R_2: *Rhizobium* @ 8 kg ha^{-1}

Chapter 5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during September to November, 2014 to study the effect of nitrogen and *Rhizobium* inoculum on the growth and yield of mungbean. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors split plot design. Factor A: Nitrogen fertilizer (4 application); N_0: No nitrogen (Control), N_1: 20 kg N ha^{-1} as basal, N_2: 20 Kg N ha $^{-1}$ at branching stage and N_3: 20 kg N ha^{-1} at flowering stage, and factor B: *Rhizobium* inoculum (3 doses); R_0: No *Rhizobium* (Control), R_1: *Rhizobium* @ 5 kg ha^{-1} and R_2: *Rhizobium* @ 8 kg ha^{-1}. The variety, BARI Mung-6 was used in this experiment as the test crop. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 5.25 m^2 (3.5 m × 1.5 m). N, K_2O, P_2O_5, Ca and S were applied during the final land preparation at the rate of 20 kg ha^{-1}, 33 kg ha^{-1}, 48 kg ha^{-1}, 3.3 kg ha^{-1} and 1.8 kg ha^{-1}, respectively following BARI recommendation. Data on different yield contributing characters & yield were recorded to find out the optimum rate of nitrogen and *Rhizobium* inoculum for higher yield of mungbean.

Different plant and yield parameters were significantly influenced by different rate of nitrogen. The highest plant height (16.38, 31.88, 39.15 and 42.74 cm at 20, 30, 40 and 50 DAS, respectively) was obtained from treatment N_2 treatment. At harvest, the tallest plant (44.23 cm) was recorded under N_3 (20 kg N ha^{-1} at flowering stage) treatment. The shortest plant height (27.36, 32.36, 34.77 and 38.52 cm at 30, 40, 50 DAS and harvest, respectively) was obtained from N_0 treatment. The maximum and minimum leaf area $plant^{-1}$ (299.2, 527.7, 500.3 and 542.0 cm^2 at 30, 40, 50 DAS and harvest, respectively) and (168.0, 393.8, 366.8 and 370.1 cm^2 at 30, 40, 50 DAS and harvest, respectively) was obtained from treatment N_2 and N_0 treatment, respectively. The maximum and minimum dry weight $plant^{-1}$ (0.70, 1.76, 4.37 and 4.72 g at 30, 40, 50 and harvest, respectively) and (0.50, 1.24, 2.32 and 2.65 g at 30, 40, 50 DAS and harvest, respectively) was obtained from N_2 and N_0 treatment, respectively. The highest and lowest branches $plant^{-1}$ (1.60, 2.30 and 3.48 at 40, 50 DAS and harvest, respectively) and (0.86, 1.582

and 2.513 at 40, 50 DAS and harvest, respectively) was recorded in N_2 and N_0 treatment, respectively. The maximum nodules plant^{-1} (15.44, 27.92, 14.59 and 12.89 at 20, 40, 50 DAS and harvest, respectively) was recorded in N_0 and (20.82 at 30 DAS) in N_2 treatment. The minimum nodules plant^{-1} was recorded (11.26 at 20 DAS) in N_1, (15.56 at 30 DAS) in N_0, (19.33 at 40 DAS) in N_2, (10.33 at 50 DAS) in N_3 and (7.44 at harvest) in the N_2 treatment. The highest and lowest pods plant^{-1} (10.84 and 7.40), pod length (9.14 cm and 7.36 cm), seeds pod^{-1} (10.11 and 9.09), weight of 1000 seed (53.0 g and 50.23 g), seed yield (1.372 t ha^{-1} and 0.766 t ha^{-1}), biological yield (3.70 t ha^{-1} and 2.61 t ha^{-1}) and harvest index (36.99% and 29.60%) was recorded in N_2 and N_0 treatment, respectively. The highest and lowest stover yield of mungbean (2.37 t ha^{-1}) and (1.85 t ha^{-1}) was recorded in N_1 and N_0 treatment, respectively.

Different plant and yield parameters were significantly influenced by different rate of *Rhizobium* inoculum. The highest plant height (31.86, 37.96, 41.42 and 44.54 cm at 30, 40, 50 DAS and harvest, respectively) was observed in R_2 (8 kg ha^{-1}). The lowest plant height (28.39, 33.91, 37.23 and 40.74 cm at 30, 40, 50 DAS and harvest, respectively) was observed in the R_0 treatment. The maximum and minimum leaf area plant^{-1} (275.0, 556.0, 520.6 and 495.4 cm^2 at 30, 40, 50 DAS and harvest, respectively) and (186.2, 403.8, 325.0 and 376.7 cm^2 at 30, 40, 50 DAS and harvest, respectively) was observed in the R_2 and R_0 treatment, respectively. The maximum and minimum dry weight plant^{-1} (0.157, 0.70, 1.73, 4.40 and 4.71 g at 20, 30, 40, 50 and harvest, respectively) and (0.13, 0.47, 1.19, 2.97 and 3.40 g at 20, 30, 40, 50 DAS and harvest, respectively) was obtained from treatment R_2 and R_0 treatment, respectively. The highest and lowest branches plant^{-1} (1.50, 2.34 and 3.52 at 40, 50 DAS and harvest, respectively) and (0.93, 1.38 and 2.46 at 40, 50 DAS and harvest, respectively) was recorded in R_2 and R_0 treatment, respectively. The maximum and minimum nodules plant^{-1} (10.83, 16.25, 20.17, 26.06, 14.11 and 9.38 at 10, 20, 30, 40, 50 DAS and harvest, respectively) and (7.58, 10.92, 15.25, 18.69, 9.91 and 8.25 at 10, 20, 30, 40, 50 DAS and harvest, respectively) was recorded in R_2 and R_0 treatment, respectively. The highest and lowest pods plant^{-1} (10.66 and 8.35), pod length (9.03 cm and 7.55 cm), seeds pod^{-1} (10.32 and 9.13), weight of 1000 seed (53.04 g and 50.75 g), seed yield (1.283 t ha^{-1} and 1.002 t ha^{-1}), stover yield (2.49 t ha^{-1} and 1.89 t ha^{-1}) and biological yield (3.77 t ha^{-1} and 2.89 t ha^{-1}) was recorded in R_2 and R_0 treatment, respectively. Among the different doses of

Rhizobium, R_0 showed the highest harvest index (34.50%) and the lowest was observed (33.38%) with R_2 treatment.

Seed yield of mungbean responded significantly to the combined application of nitrogen and *Rhizobium* inoculum. The highest and lowest seed yield (1.69 t ha^{-1} and 0.73 t ha^{-1}) was recorded in N_2R_2 and N_0R_1 treatment combinations, respectively. The highest and lowest stover yield (2.67 t ha^{-1} and 1.60 t ha^{-1}) was recorded in N_2R_2 and N_0R_0 treatment combinations, respectively. The lowest plant height (26.12, 30.80, 33.18 and 37.37 cm at 30, 40, 50 DAS and harvest, respectively) was observed in the treatment combination of N_0R_0 and the highest plant height (34.80, 42.86, 46.70 and 47.68 cm at 30, 40, 50 DAS and harvest, respectively) was recorded with N_2R_2. The maximum and minimum leaf area $plant^{-1}$ (366.7, 600.3, 613.3 and 619.5 cm^2 at 30, 40, 50 DAS and harvest, respectively) and (152.2, 320.0, 282.8 and 274.6 cm^2 at 30, 40, 50 DAS and harvest, respectively) was recorded with N_2R_2 and N_0R_0, respectively. The maximum dry weight $plant^{-1}$ (0.88, 2.25, 5.62 and 5.72 g at 30, 40, 50 and harvest, respectively) was obtained from N_2R_2. The minimum dry weight $plant^{-1}$ was obtained from N_3R_0 (0.35 g at 30 DAS) and N_0R_0 (1.04, 1.79 and 1.72 g at 40, 50 DAS and harvest, respectively). The highest and lowest branches $plant^{-1}$ (2.38, 2.95 and 4.17 at 40, 50 DAS and harvest, respectively) and (0.73, 1.26 and 2.16 at 40, 50 DAS and harvest, respectively) was recorded with the treatment combination of N_2R_2 and N_0R_0, respectively. The highest and lowest nodules $plant^{-1}$ was recorded (12.22 and 6.55 at 10 DAS) in N_2R_2 and N_3R_0, respectively. At 20 DAS, the highest and lowest nodules $plant^{-1}$ (17.78 and 9.0) was recorded with N_3R_2 and N_1R_0, respectively. At 30 DAS, the highest and lowest nodules $plant^{-1}$ (24.11 and 12.11) was recorded with N_2R_1 and N_0R_0, respectively. At 40 DAS, the highest and lowest nodules $plant^{-1}$ (32.55 and 13.33) was recorded with N_0R_2 and N_2R_0, respectively. At 50 DAS, the highest and lowest nodules $plant^{-1}$ (17.11 and 7.66) was recorded with N_0R_2 and N_3R_0, respectively. At harvest, the highest and lowest nodules $plant^{-1}$ (14.33 and 5.77) was recorded with N_0R_2 and N_2R_2, respectively. The highest and lowest pods $plant^{-1}$ (12.68 and 6.36), pod length (10.33 cm and 6.0 cm), seeds pod^{-1} (10.69 and 7.90), weight of 1000 seed (55.16 g and 48.42 g) and biological yield (4.36 t ha^{-1} and 2.36 t ha^{-1}) was recorded with N_2R_2 and N_0R_0, respectively. The highest and lowest harvest index (38.75%) and (26.16%) was recorded with the treatment combination of N_2R_2 and N_0R_2, respectively.

The results in this study indicated that the plants performed better in respect of grain yield in N_2R_2 treatment than the control treatment (N_0R_0), which was poor. It can be therefore, concluded from the above study that the treatment combination (application of 20 kg N ha^{-1} at branching stage and *Rhizobium* @ 8 kg ha^{-1}) was found to the most suitable combination for the highest yield of mungbean in AEZ 28 soils of Bangladesh.

However, to reach a specific conclusion and recommendation, more research work on mungbean should be done in different Agro-ecological zones of Bangladesh to fit in cropping system for rich diet and improve the soil health.

References

REFERENCES

Achakzai, A. K. K., Habibullah, Shah, B. H. and Wahid, M. A. (2012). Effect of Nitrogen Fertilizer on the Growth of Mungbean [*Vigna radiata* (L.) Wilczek] Grown in Quetta. *Pakistan J. Bot*. **44**(3): 981-987.

Afzal, M. A., Bakar, M. A., Luna, N. K., Rahman, M. M., Hamid, A., Haque, M. M. and Shanmungasudaram, S. (2003). Registration of 'Barimungs' Mungbean. *Crop Sci*. **43**: 930-931.

Afzal, M. A., Murshad, A. N. M., Bakar, M. A., Hamid, A. and Salahuddin, A. B. M. (2008). Mungbean Cultivation in Bangladesh. Gazipur, Bangladesh: Pulse Research Station, Bangladesh Agricultural Research Institute.

Agbenin, J. O., Lombin, G. and Owonubi, J. J. (1991). Direct and interactive effect of boron and nitrogen on selected agronomic parameters and nutrient uptake by (*Vigna radiata* L.) under glasshouse conditions. *Trop. Agric*. (Trinidad and Tobago) **68**(4): 357-362.

Akbar, F. M., Zafar, M., Hamid, A., Ahmed, M., Khaliq, A., Khan, M. R., and Rehman, Z. (2013). Interactive effect of cobalt and nitrogen on growth, nodulation, yield and protein content of field grown pea. *Horticulture, Environ. Biotech*. **54**(6): 465-474.

Ali, A., Nadeem, M. A. , Tayyab, M., Tahir, M. and Sohail, M. (2001). Determining suitable planting geometry for two mungbean (*Vigna radiata* L.) cultivars under Faisalabad conditions. *Pakistan J. Biol. Sci.* **4**: 344-450.

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

Ansari, S. A. S. and Afridi, M. M. R. K. (1990). Enhancement of leaf nitrogen, phosphorus and potassium and seed protein in *Vigna radiata* by Pyridoxine application. *Plant Soil. India*. **125**(2): 296-298.

Ardeshana, R. B., Modhwadia, M. M., Khanparal, V. D. and Patel, J. C. (1993). Response of greengram (*Phaseoulus radiatus*) to nitrogen, phosphorus and Rhizobium inoculum. *Indian J. Agron*. **38**(3): 490-492.

Arya, M. P. S. and Kalra, G. S. (1988). Effect of phosphorus doses on growth, yield and quality of summer mungbean (*Vigna radiata* L.) and soil nitrogen. *Indian J. Agric. Res.* **22**(1): 23-30.

Asaduzzaman, M. (2008). Effect of nitrogen and irrigation management on the yield attributes and yield of mungbean (*Vigna radita* L.) M.S thesis, Dept. Agron. Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Asaduzzaman, M., Karim, M. F., Ullah, M. J., and Hasanuzzaman, M. (2008). Response of mungbean (*Vigna radiata* L.*)* to nitrogen and irrigation management. *American -Eurasian J. Sci. Res.* **3**: 40-43.

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

Azadi, E., Rafiee, M. and Nasrollahi, H. (2013). The effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad. *Annal. Bio. Res*. **4** (2): 51-55.

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

BARC (Bangladesh Agricultural Research Council), (2005). Fertilizer Recommendation Guide 2005. Bangladesh Agricultural Research Council, Farmgate , Dhaka.

Basu, T. K. and Bandyopadhyay, S. (1990). Effects of *Rhizobium* inoculum and nitrogen application on some yield attributes of mungbean. *Env. Eco*. **8**(2): 650-654.

BBS (Bangladesh Bureau of Staistic). (2008). Major and minor crops statistics. wwbbs.gov.bd.

BBS (Bangladesh Bureau of Statistics). (2013). Statistical Yearbook of Bangladesh. Stat. Div., Minis. Plan., Govt. People's Repub.Bangladesh, Dhaka.

BINA. (2003). Role of biofertilizer on stoveryield production in mungbean. Annual report of 2002-03. Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. p.75.

BINA. (2004). Annual Repoat of 2003-2004. Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. p.42.

Chanda, M. C., Satter, M. A., Solaiman, A. R. M. and Podder, A. K. (1991). Effect of *Rhizobium* inoculation on mungbean varieties as affected by chemical fertilizers. Intl. Bot. Conf., 10-12 January 1991. Dhaka, Bangladesh. p.9.

Chowdhury, M. K. and Rosario, E. (1992). Utilization efficiency of applied nitrogen as related to yield advantage in maize mungbean intcrcropping. *Field Crops Res.* **30**(1-2): 41-51.

Elias, S. M., Hossain, M. S., Sikder, F. S., Ahmed, J. and Karim, M. R. (1986). Identification of constraints to pulse production with special reference to present farming systems. Annual Report of the Agricultural Economics Division, BARI, Joydebpur. p.1.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hoque, M. S. and Barrow, N. J. (1993). *Bradyrhizobium* technology: a promising substitute for chemical nitrogen fertilizer in Bangladesh agriculture. Proc. Twelfth International Plant Nutrition coloquim, Sept. 21-26, Western Australia, pp. 447-450.

Hossain, M. E., Chowdhury, I. F., Hasanuzzaman, M., Mazumder, S., Matin, M. A. and Jerin, R. (2014). Effect of Nitrogen and *Bradyrhizobium* on Growth and Yield of Mungbean. *J. Bio. Agri. Res.* **01**(02): 79-84.

Jamro, Shinde, C. P. and Singh, V. (1990). Effect of various level of nitrogen, phosphorous and sulphur on the yield and quality of mustard in blackgram mustard cropping sequence. Department of soil science & Agricultural

Chemistry, College of Agriculture, Gwalior, Madhya Pradesh, India. Crop Research Hisar. pp. 265-270.

Kamal, M. M., Hossain, M. A., Islam, F. and Khan, M. S. A. (2001). Response of mungbean to management practices for yield and quality seed production. *Bangladesh J. Agric. Res*. **28**(4): 501-511.

Karle, A. S. and Pawar, G. G. (1998). Effect of legume residue incorporation and fertilizer in mungbean-safflower cropping system. *J. Maharastha Agril. Univ*. **23**(3): 333-334.

Khalilzadeh, R. H., Tajbakhsh, M. J., and Jalilian, J. (2012). Growth characteristics of mungbean (*Vigna radiata* L.) affected by foliar application of urea and bio-organic fertilizers. *Intl. J. Agric. Crop Sci*. **4**(10): 637-642.

Khan, A. and Malik, M. A. (2001). Determing biological yield potential of different mungbean cultivars. *J. Biol. Sci*. **1**: 575-576.

Kulsum, M. U. (2003). Growth, yield and nutrient uptake in blackgram at different nitrogen level. M.S thesis. Bangabandhu Sheikh Mujibur Rahman Agri. Univ. Gazipur-1706.

Leelavathi, G. S. N. S., Subbaiah, G. V. and Pillai, R. N. (1991). Effect of different level of nitrogen on the yield of greengram [*Vigna radiata* L. Wilczek). *Andhra Agric. J. (India)*. **38** (1): 93-94.

Mahboob, A. and Asghar, M. (2002). Effect of seed inoculum and different nitrogen level on the grain yield of mungbean. *Asian J. Plant Sci*. **1**(4): 314-315.

Maldal, A. B. and Ray, R. (1999). Effect of *Bradyrhizobium* inoculum and nitrogenous fertilizer on the performance of mung. *J. Interacademicia*. **3**(3-4): 259-262.

Malik, M. A., Saleem, M. F., Asghar, A. and Ijaz, M. (2003). Effect of nitrogen and phophorus application on growth, yield and quality of mungbean (*Vigna radiata* L.). *Pakistan J. Agric. Sci*. **40**(3/4): 133-136.

Malik, M. M. R., Akhtar, M. J., Ahmad, I., and Khalid, M. (2014). Synergistic use of rhizobium, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.) *Pakistan J. Agric. Sci.* **51**(1): 383-388.

Mansoor, M. (2007). Evaluation of various agronomic management practices for increased productivity of Mungbean (*Vigna radiata* L. Wilczek). PhD thesis. Department of Agronomy Faculty of Agriculture Gomal University, Dera Ismail Khan: 1-163 http://eprints.hec.gov.pk/2430/1/2285.htm.

Masud, A. R. M. (2003). Effects of different doses of nitrogen fertilizer on growth, nitrogen assimilation and yield in four mungbean genotypes. M.S. Thesis, Dept. of Crop Botany, Bangladesh Agricultural University, Mymensingh. pp. 22-40.

Mondal, N. K., Datta, J. K. and Banerjee, A. (2014). Impact of reduction dose, time and method of application of chemical fertilizer on Mungbean under old alluvial soil, West Bengal, India. *Com. Plant. Sci.* **4**(3-4): 63-71.

Mozumder, S. N. (1998). Effect of nitrogen and rhizobiumbio-fertilizer on two varieties of summer mungbean *(Vigna radiata* L.). M.S. Thesis. Department of Agronomy. Bangladesh Agricultural University. Mymensingh. pp. 51-64.

Mozumder, S. N., Salim , M., Islam , N., Nazrul M. I. and Zaman, M. M. (2003). Effect of *Bradyrhizobium* Inoculum at Different Nitrogen Level on Summer Mungbean. *Asian J. Plant Sci.* **2**: 817-822.

Murakami, T., Siripin, S., Wadisirisuk, P., Boondend, N., Yoneyama, T., Yokoyama, T. and lmai, H. (1990). The nitrogen fixing ability of mungbean (*Vigna radiata* L. Wilczek). Proceding of the mungbean meeting. Ching mai, Thailand February 23-24 Soil Sci. Div. Dept. A Bangladesh, Bankok 10900. Thailand. pp. 187-198.

Nadeem, M. A., Ahmad, R. and Ahmad, M. S. (2004). Effect of seed inoculum and different fertilizer level on the growth and yield of mungbean (*Vigna radiata* L.). *Indian J. Agron*. **3**(1): 40-42.

Nazmun, A., Rokonuzzaman, M. and Hasan, M. N. (2009). Effect of *Bradyrhizobium* and *Azotobacter* on growth and yield of mungbean varieties. *J. Bangladesh Agril. Univ*. **7**(1): 7-13.

Nigamananda, B. and Elamathi, S. (2007). Studies on the time of nitrogen, application foliar spray of DAP, and growth regulator on yield attributes, yield and economics of greengram (*Vigna radiata* L.). *Intl. J. Agric. Sci*. **3**(1): 168-169.

Novoa, R. and Loomis, R. S. (1981). Nitrogen and plant production. *Plant Soil* **58**:177-204.

Nursu'aidah, H., Motior, M. R., Nazia, A. M. and Islam, M. A. (2014). Growth and photosynthetic responses of longbean (*Vigna unguiculata)* and mungbean (*Vigna radiata*) response to fertilization. *J Anim Plant Sci.* **24**(2): 573-578.

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

Otieno, P. E., Muthomi, J. W., Cheminingwa, G. N. and Nderitu, J. H. (2007). Effect of *Rhizobium* inoculum, farmyard manure and nitrogen fertilizer on growth, nodulation and yield of selected food grain legumes. *Proc. African Crop Sci. Conf.* **8**: 305-312.

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

Patel, J. S and Parmar, M. T. (1986). Response of greengram to varing level of nitrogen and phosphorus. *Madras Agric. J.* **73**(6): 355-356.

Patel, L. R., Salvi, N. M. and Patel, R. H. (1992). Response of greengram (*Phaseolus vulgaris*) varieties to sulphur fertilization under different level of nitrogen and phosphorus. *Indian J. Agron.* **37**(4): 831-833.

Patel, R. G., Palel, M.P., Palel, H. C. and Palel, R. B. (1984). Effect of graded level of nitrogen and phosphorus on growth, yield and economics of summer mungbean. *Indian J. Agron.* **29**(3): 42-44.

Pongkao, V. C. and Inthong, M. A. (1988). Effect of nitrogen fertilizer on mungbean. *J. Agric. Sci*. **33**(3): 14-19.

Provorov, N. A., Saimnazarov, U. B., Bahromoy, L. U., Pulatova, D., Kozhemyakov, A. P. and Kurbanov, G. A. (1998). Effect of *Rhizobium* inoculum on the seed (herbage) production of mungbean (*Phaseolus raditus*) grown at Uzbekistan. *J. Arid Environ.* **39**(4): 569-575.

Quah, S. C. and Jaafar, N. (1994). Effect of nitrogen fertilizer on seed protein of munghean. Applied biology beyond the year 2000: Proceedings of the third symposium of Malaysian Society of Applied Biology. 13-18 March. Kehansaan. Malaysia. pp. 72-74.

Rajender, K., Sing, V. P., Sing, R. C. and Kumar, R. (2003). Monetary analysis on mungbean during summer season. *Annl. Biol*. **19**(2): 123-127.

Rajender, K., Singh, V. P. and Singh, R. C. (2002). Effect of N and P fertilization on summer planted mungbean (*Vigna radiata* L.). *Crop Res. Hisar*. **24**(3): 467-470.

Raman, R. and Venkataramana, K. (2006). Effect of foliar nutrition on NPK uptake, yield attributes and yield of greengram (*Vigna radiata* L.) *Crop Res. Hisar*. **32**(1): 21-23.

Sadeghipour, O., Monem, R., and Tajali, A. A. (2010). Production of mungbean (*Vigna radiata* L.) as affected by nitrogen and phosphorus fertilizer application. *J. Appl. Sci.* **10**(10): 843-847.

Saini and Thakur (1996). Effect of nitrogen, phosphorous and sulphur on the micronutrient content of blackgram. Department of Soil Science, JN Krishi Vishwa Vidyalaya, Gwalior 474002, Madhya Pradesh, India. SO: *Crop Res. Hisar.* **9**(1): 54-58.

Santos, P. J. A., Edwards, D. G., Asher, C. J. and Barrow, J. J. (1993). Response of *Bradyrhizobium*- inoculated mungbean to applied nitrogen. Plant nutrition from genetic engineering to field practice: Proceedings of the Twelfth International Plant Nutrition Collloquum. 21-26 September. Perth, Western Australia. pp. 443-446.

Sardana, H. R. and Verma, S. (1987). Combined effect of insecticide and fertilizers on the growth and yield of mungbean (*Vigna radiata* L.). *Indian J. Entom*. **49**(1): 64-68.

Sarkar, R. K. and Banik, P. (1991). Response of mungbean (*Vigna radiata*) to nitrogen, phosphorus and molybdeum. *Indian J. Agron*. **36**(1): 91-94.

Sharar, M. S., Ayub, M., Nadeem, M. A. and Noori, S. A. (2001). Effect of different row spacing and seeding densities on the growth and yield of gram (*Cicer arietinum* L.). *Pakistan J. Agri. Sci.* **38**: 51-53.

Sharma, C. K. and Sharma, H. K. (1999). Effect of different production factors on growth, yield and economics of mungbean (*Vigna radiata* L. Wilezeck). *Hill Farming*. **12**(1-2): 29-31.

Sharma, S. K. and Sharma, S. N. (2006). Effect of different combinations of inorganic nutrients and farmyard manure on the sustainability of a rice-wheat-mungbean cropping system. *Acta Agronomica Hungarica*. **54**(1): 93-99.

Singh, A. K., Choudhary, R. K. and Sharma, R. P. R. (1993). Effect of inoculum and fertilizer rate on yield, yield attributes and nutrient uptake of greengram (Phaseolus radiatus) and blackgram (P. mungo).Tirhut College of Agriculture, Rajendra Agricultural University, Dholi 843121, Bihar, India. *Indian J Agron*. **38**(4): 663-665.

Srinivas, M., Shaik, M. and Mohammad, S. (2002). Performance of greengram (*Vigna radiata* L. Wilczek) and response functions as influenced by different level of nitrogen and phosphorus. *Crop Res. Hisar.* **24**(3): 458-462.

Suhartatik, E. (1991). Residual effect of lime and organic fertilizer on mungbean (*Vigna radiata* L. Wilczek) in red yellow podzolic soil: Proceedings of the seminar of food crops Research Balittan Bogor (Indonesia). **2**: 267-275.

Sultana, S., Ullah, J., Karim, F., and Asaduzzaman, J. (2009). Response of Mungbean to Integrated Nitrogen and Weed Managements. *American-Eurasian J. Agron.* ***2***(2): 104-108.

Tank, U. N., Damor, U. M., Patel, J. C. and Chauhan, D. S. (1992). Response of summer mungbean (*Vigna radiata*) to irrigation, nitrogen and phosphorus. *Indian J. Agron*. **37**(4): 833-835.

Tickoo, J. L., Naresh, C., Gangaiah, B. and Dikshit, H. K. (2006). Performance of mungbean (*Vigna radiata*) varieties at different row spacings and nitrogen-phosphorus fertilizer level. *Indian J. Agric. Sci*. **76**(9): 564-565.

Tripathi, M. L., Namdeo, K. N., Tiwari, K. P. and Kurmvanshi, S. M. (1994). Relative efficiency of nitrogen and *Rhizobium* inoculum on growth and yield of Kharif pulses and oilseeds. *Crop Res*. **7**(3): 33-35.

Trung, B. C. and Yoshida, S. (1983). Significance and nitrogen nutrition on the productivity of mungbean (*Vigna radiata* L.) *Japanese J. Crop Sci.* **52**(4): 493-499.

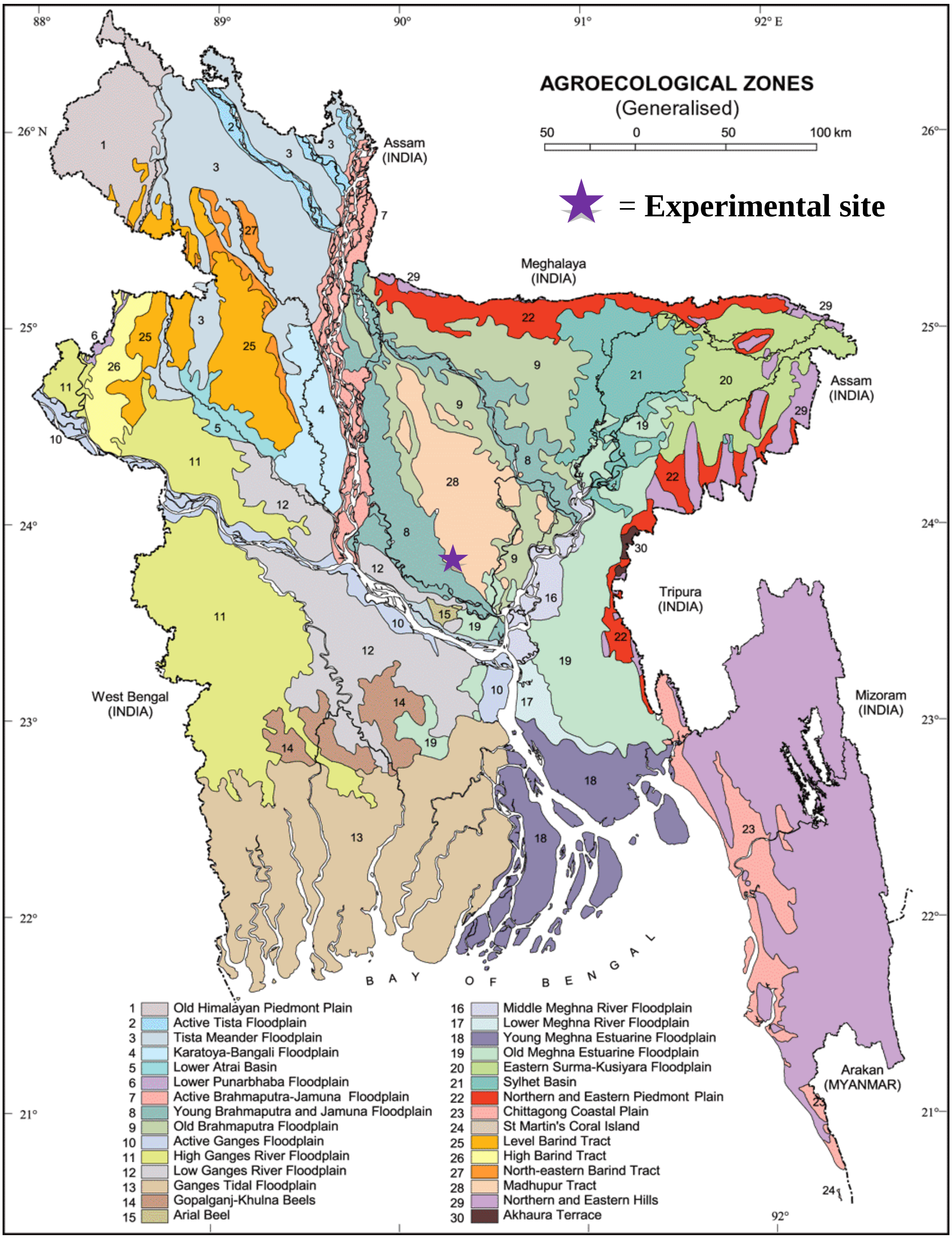
Yakadri, M., Thatikunta, R., Rao, L. M. and Thatikunta, R. (2002). Effect of nitrogen and phosphorus on growth and yield of greengram (*Vigna radiata* L.) *Legume Res.* **25**(2): 139 - 141.

Yein, B. R. (1982). Effect of carbofuran and fertilizers on the incidence of insect, pests and on growth and yield of mungbean. *J. Res. (Assam Agric. Univ*.). **3**(2): 197-203.

Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical characteristics	
Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly meteorological information during the period from September to December, 2014

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2014	September	31.46	14.82	73.20	161
	October	30.18	14.85	67.82	137
	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	0

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout for experimental field.

Total number of unit plots: 12 × 3 = 36
Unit plot size: 3.5 m×1.5 m = 5.25m^2
The blocks and unit plots were separated by 1m and 0.5m, respectively.

Replication 1	N_OR_O	N_1R_2	N_2R_1	N_3R_2
	N_OR_1	N_1R_1	N_2R_2	N_3R_O
	N_OR_2	N_1R_O	N_2R_O	N_3R_1
Replication 2	N_3R_O	N_OR_2	N_1R_1	N_2R_2
	N_3R_1	N_OR_1	N_1R_2	N_2R_O
	N_3R_2	N_OR_O	N_1R_O	N_2R_1
Replication 3	N_2R_O	N_3R_2	N_OR_1	N_1R_2
	N_2R_1	N_3R_1	N_OR_2	N_1R_O
	N_2R_2	N_3R_O	N_OR_O	N_1R_1

Appendix V. Analysis of variance of the data on plant height (cm) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square of plant height (cm) at different days after sowing					
		10	20	30	40	50	At harvest
Replication	2	26.12	20.47	40.32	25.70	93.04	92.89
Nitrogen rate(A)	3	2.91^{NS}	18.56*	36.23*	110.88*	140.65*	66.47*
Error	6	2.78	4.39	10.72	17.44	20.73	16.39
Rhizobium inoculum rate (B)	2	1.53*	1.60^{NS}	36.65*	49.39*	52.79*	43.35*
Nitrogen (A) X *Rhizobium* (B)	6	0.95*	3.61*	4.08*	5.92*	5.71*	7.78*
Error	16	0.56	1.25	6.73	6.77	9.85	9.65

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on leaf area plant^{-1} (cm^2) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square of leaf area plant^{-1} (cm^2) at different days after sowing					
		10	20	30	40	50	At harvest
Replication	2	13.61	13.942	3443.84	20779.49	3490.45	5659.48
Nitrogen rate(A)	3	3.20^{NS}	265.97*	28181.59*	31647.82*	38510.63*	92105.25*
Error	6	28.89	11.17	261.09	2452.09	3740.11	2245.23
Rhizobium inoculum rate(B)	2	3.53^{NS}	193.91*	23759.85*	69484.61*	117836.74*	42452.02*
Nitrogen (A) X *Rhizobium* (B)	6	6.56^{NS}	18.93*	2375.59*	7823.54*	2944.90*	2353.81*
Error	16	8.76	7.53	772.21	1795.11	2864.18	2150.70

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on dry matter weight plant^{-1} (g) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square of dry matter weight plant^{-1} (g) at different days after sowing					
		10	20	30	40	50	At harvest
Replication	2	0.000	0.000	0.000	0.089	0.267	0.079
Nitrogen rate(A)	3	0.000^{NS}	0.005*	0.161*	0.430*	6.612*	7.295*
Error	6	0.000	0.001	0.004	0.029	0.311	0.119
Rhizobium inoculum rate(B)	2	0.000^{NS}	0.003*	0.150*	0.889*	7.071*	5.500*
Nitrogen (A) X *Rhizobium* (B)	6	0.000^{NS}	0.000*	0.012*	0.107*	0.377*	0.568*
Error	16	0.000	0.001	0.006	0.023	0.255	0.422

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on nodules plant^{-1} (No.) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square of nodules plant^{-1} (No.) at different days after sowing				
		20	30	40	50	At harvest
Replication	2	3.20	14.81	27.93	6.21	2.52
Nitrogen rate(A)	3	3.79*	44.03*	135.98*	30.49*	62.03*
Error	6	1.16	8.09	11.71	8.76	1.87
Rhizobium inoculum rate(B)	2	36.33*	73.88*	163.97*	52.84*	4.68^{NS}
Nitrogen (A) X *Rhizobium* (B)	6	1.55*	20.18*	8.57*	2.39*	6.44*
Error	16	0.50	4.71	11.03	3.73	1.94

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on branches plant^{-1} (No.) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square of branches plant^{-1} (No.) at different days after sowing		
		40	**50**	**At harvest**
Replication	2	0.11	0.01	0.10
Nitrogen rate(A)	3	1.40*	0.89*	1.51*
Error	6	0.01	0.02	0.05
***Rhizobium* inoculum rate(B)**	2	0.98*	3.16*	3.37*
Nitrogen (A) X *Rhizobium* (B)	6	0.29*	0.12*	0.07*
Error	16	0.10	0.03	0.05

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on pods plant^{-1} (No.), pod length (cm), seeds pod^{-1} (No.) and 1000 seed weight (g) of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square value			
		Pods plant^{-1} (No.)	**Pod length (cm)**	**Seeds pod^{-1} (No.)**	**1000 seed weight(g)**
Replication	**2**	1.59	0.66	2.21	1.79
Nitrogen rate(A)	**3**	19.82*	4.83*	1.74*	13.27^{NS}
Error	**6**	2.43	0.08	0.26	6.96
***Rhizobium* inoculum rate(B)**	**2**	16.15*	6.56*	4.19*	15.77*
Nitrogen (A) X *Rhizobium* (B)	**6**	0.73*	0.88*	0.61*	2.06*
Error	**16**	0.46	0.33	0.23	3.65

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Analysis of variance of the data on seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index of mungbean as influenced by combined effect of different nitrogen and *Rhizobium* inoculum application

Source of variation	df	Mean square value			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
Replication	**2**	0.03	0.04	0.33	2.49
Nitrogen rate(A)	**3**	0.65*	0.50*	2.27*	87.98*
Error	**6**	0.01	0.01	0.02	6.17
***Rhizobium* inoculum rate(B)**	**2**	0.25*	1.08*	2.36*	4.40^{NS}
Nitrogen (A) X *Rhizobium* (B)	**6**	0.04*	0.04*	0.08*	13.87*
Error	**16**	0.01	0.02	0.02	7.89

*Significant at 5% level of significance

^{NS} Non significant