NODULATION, GROWTH AND YIELD OF MUNGBEAN AND BLACKGRAM AS AFFECTED BY FERTILIZER MATERIALS

BY

RAZIA SULTANA RATNA

REGISTRATION NO. 27617/00760

A Thesis

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

IN

AGRONOMY

SEMESTER: JULY-DECEMBER, 2007

Approved by:

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

(Prof. Dr. Prasanta C. Bhowmik)
Co-supervisor

(Prof. Dr. Parimal Kanti Biswas)
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled, **"Nodulation, growth and yield of mungbean and blackgram as affected by fertilizer materials"** submitted to faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY**, embodies the result of a piece of *bona fide* research work carried out by **Razia Sultana Ratna**, Registration No. **27617/00760** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

Dated: 26/12/07

Dhaka, Bangladesh

Dedicated

To

Those Who:

Work for humanity

Struggle against poverty

Fight against superstitions

ACKNOWLEDGEMENT

All praises to Almighty Allah, the Supreme Ruler of the universe who enables the author to complete this present piece of work.

The author would like to express her heartiest gratitude, sincere appreciation and immense indebtedness to her supervisor ***Prof. Dr. Parimal Kanti Biswas****, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his scholastic guidance, planning, valuable suggestions, continuous encouragement and all kinds of support and help throughout the period of research work and preparation of this manuscript of thesis.*

Heartiest gratitude is due to the respectable co-supervisor ***Prof. Dr. Prasanta Chitta Bhowmik****, Fulbright Scholar, faculty of Plant, Soil, and Insect Sciences, University of Massachusetts, Amherst, USA, for his valuable suggestions, kind co-operation and dynamic guidance throughout the study and research work.*

The Author expresses her profound gratitude to her most honorable teachers ***Prof. Dr. A. K. M. Ruhul Amin*** *for his valuable advice, encouragement, proper assistance and keen supervision during the period of research work.*

*The Author wishes to record deep appreciation to her other course teachers (****Prof. Dr. Fazlul Karim, Prof. Dr. Hazrat Ali, Prof. Sadrul Anam Sardar, Md. Obaidul Islam,*** *Assistant Professor and* ***Md. Abdullahil Baque,*** *Assistant Professor) Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation and constant encouragement.*

The author is grateful to ***Quazi Nasim Ahamed****, Lecturer, Department of Agronomy, SAU, Dhaka whose accompany and constant encouragement with co-operation in innumerable aspects made it possible to complete the study in a peaceful state of mind.*

The author wishes to acknowledge her indebtedness to farm division of SAU and other staff of the Department of Agronomy for their co-operation in the implementation of research work.

The author expresses her cordial thanks to all her friends especially Albely, Wazed, Nazia, Kumkum, Mosheur, Mahbub, Babu, Sumit, Tomal, Jewel, Noman, Sajeeb and Runu for their constant encouragement.

At last but not the least, the Author feels indebtedness to her beloved parents whose sacrifice, inspiration, encouragement and continuous blessing paved the way to her higher education. The Author is also grateful to her Uncle Engr. Anisur Rahman Hero, younger brother Enamul Kabir Rana and little sister Ratry and other members of the family for their forbearance, inspirations, sacrifices and blessings.

Date: *The Author*

NODULATION, GROWTH AND YIELD OF MUNGBEAN AND BLACKGRAM AS AFFECTED BY FERTILIZER MATERIALS

ABSTRACT

An experiment was carried out at the Sher-e-Bangla Agricultural University farm; Dhaka to investigate the nodulation, growth and yield of mungbean and blackgram as affected by fertilizer materials during the period from March 2007 to June 2007. The trial comprised of two crops and five fertilizer treatments such as C_1 = mungbean and C_2= blackgram, F_1 = no fertilizer (control), F_2 = chemical fertilizer (NPKB), F_3 = inoculum, F_4 = cowdung, F_5 = PK+ inoculum. The experiment was laid out in a split plot design with three replications where two crops were assigned in the main plot and five fertilizer materials as the sub-plot. Plant height, nodulation, root length, root dry weight, total dry matter production, number of branches plant^{-1}, pods plant^{-1}, number of seeds pod^{-1},1000-seeds weight, shelling percentage, seed yield, stover yield, biological yield and harvest index were tested for different treatments. Results revealed that inoculum and PK+ inoculum influenced significantly on the growth, yield parameters and yield of mungbean and blackgram. Plant height, root length, number of branches plant^{-1} and pods plant^{-1} were higher in blackgram than mungbean. Number of nodules plant^{-1}, total dry matter production, pod length, number of seeds pod^{-1} and yield were higher in mungbean than blackgram. inoculum alone or in combination with PK increased plant height, total dry matter production, leaf area index, number of branches plant^{-1}, number of seeds pod^{-1} and yield. The highest seed yield (1.59 t ha^{-1}) was given by mungbean with inuculum treatment that was similar to mungbean with PK+inoculum (1.43 t ha^{-1}) and chemical fertilizer (NPKB) (1.33 t ha^{-1}) and blackgram with inoculum (1.35 t ha^{-1}). The higher dry matter eventually supported the plant to produce maximum number of branches and pods per plant, which resulted in maximum seed yield.

LIST OF CONTENTS

Contd.

Contd.

Contd.

Contd.

Contd.

Contd.

Contd.

Contd.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

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

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Pulses are important crops in Bangladesh. They occupy an area of about 0.47 million ha (>5% of the total cropped area) and contribute about 2% of the total grain production of the country (BBS, 2001). The major pulses grown in Bangladesh are: Khesari *(Lathyrus sativus* L.), Lentil (*Lens culinaris* Medic), Chickpea (*Cicer arietinum* L.), Blackgram (*Vigna mungo* L.), Mungbean (*Vigna radiata* L.) and Fieldpea (*Pisum sativum*)/ Among these khesari, lentil, chickpea and fieldpea are grown during winter (November-March) and contribute about 82% of total pulses. Blackgram is grown in late summer (August-December). Mungbean is grown both in early summer (February-April) and in late summer.

Pulse plays a vital role in national economy and in the diet.Pulses, a common item in the daily diet of the people of Bangladesh, is the edible seed of legumes. Pulses have been considered poor men's meat since they are the cheapest source of protein for the underprivileged people who can not afford animal protein and it is taken mostly in the form of soup. Many of the pulse seeds are consumed raw when they are in green stage. Generally there is no complete dish without "dail" in this county. The green plants can also be used as animal feed and the residues as manure. It is also best source of protein for domestic animals. Pluses contain a remarkable amount of minerals, vitamins, fats and carbohydrates. Pluse protein is rich in amino acids like isoleucine, leucine, lysine, valine etc. FAO (1999) recomends a minimum pluse intake of 80 g/head/day whereas; it is only 14.19 g in Bangladesh (BBS, 2006).This is because of the fact that production of the pulses is not adequet to meet the national demand.The crop is potentially useful in improving cropping system as it can be grown as a cash crop due to its rapid growth with easily maturing characteristics. Moreover, pulse is considered as soil building crop as it has the remarkable quality of helping the symbiotic root rhizobia to fix atmospheric nitrogen.

Mungbean (*Vigna radiata* L.) and Blackgram (*Vigna mungo* L.) are important world food crops for providing an inexpensive source of vegetable protein. Mungbean and blackgram are sub-tropical, kharif crops, well adapted to semi arid and sub-humid zones with annual rainfall between 600-1000 mm. requiring an optimum mean temperature of 30°C. It grows successfully on sandy loam to clay loam soil. Usually grown on low to medium elevations in the tropics as a rain-feed crop (Andeshna *et al.,* 1993). Expandtion of mungbean cultivation in such non traditional areas depends largely on its competive ability witg other crops (Hamid, 1996) as well as its adaptability over a wide range of environmental conditions (Popalghat *et al.*, 2001).Among the environmental factors, excess rain at the time of reproductive period causes enormous loss of both seed yield and seed quality of mungbean (Williams *et al.*, 1995).

Mungbean (*Vigna radiata* L.) ranks second both in acreage (555243 ha) and production (33880 mton) (BBS, 2001) and Blackgram (*Vigna mungo* L.) ranks fourth among the pulses with an area of about 82000 ha (BBS, 2006). Among the pulses, mungbean the is one of the best in nutritional value, having 51% carbohydrate, 26% protein, 4% mineral and 3% vitamins and blackgram is also contains 59% carbohydrate, 24% protein, 10% moisture, 4% mineral and 3% vitamins (Khan *et al.*,1982; Kaul, 1982). It is an excellent source of digestible protein. It has well digestibility and flavor.

The farmers of Bangladesh generally grow mungbean and blackgram by one ploughing but with almost no fertilizer. There is ample scope of increasing the yield of mungbean and blackgram per unit area with improved management practices and by using proper fertilizer. Mungbean and blackgram are highly responsive to fertilizer. But the farmers of Bangladesh hardly use fertilizer due to their poor socio-economic condition. As a result, the yield is low although it has great potential for higher yield. Adequate nutrition from chemical fertilizers and bio-fertilizers is essential for normal growth and yield of a crop. In Bangladesh, most of the lands are increasingly deficient in organic matter. The imbalanced applications of chemical fertilizers may have detrimental effects to the environment. Yield of legumes in farmers' field is usally less than 1 t ha^{-1} as compared to the potential yield of 2 to 4 t ha^{-1} (Ramakrishna *et al.*, 2000), suggesting a large yield gap. Much of the yield gap may be narrowed down by adopting improved agronomic practices.

The yield of mungbean and blackgram can be increased by using high yielding varieties and fertilizer. Fertilizers (N and P) may increase significantly mungbean yield (Paikera *et al.*, 1988) by increasing leaf area and total dry matter. Application of N fertilizer has been reported to have significant effect on seed yield (Watanabe *et al.*, 1988). Seed yield and harvest index of mungbean also increased by P application (Khamparia, 1996).

Soil organic matter is an important factor to be considered in improving crop productivity. Because of the tropical climate, organic matter decomposition in Bangladesh soil is high. Moreover, the rural population has little chance to add organic residues to soil through farmyard manure, composts and organic residues since the major portion of these materials are being used as fuel. Most soils of Bangladesh contain very low amount of organic matter, usually less than 2% (Panaullah *et a*l., 1999; Bhuiyan, 1999; Jahiruddin *et al.*, 2000).The proper soil organic matter management needs due attention in view of the low organic matter status of our soil (Ali *et al.*, 1997). Inclusion of a legume crop in between cereals may contribute to maintain or increase in soil organic matter.

Variation types of fertilizer materials can increase nodulation and increase legume crops yield differently. But bio-fertilizers can add 20-200 kg N ha^{-1} $year^{-1}$ (by fixation) liberate growth promoting substances and increase yield by 10-50% (Bachbha *et al.*, 1994).These are cheaper, pollution free based on renewable energy sources and also improve soil tilth (FAO, 1999). Limited information is available on the combined effect of different bacterial inoculation and combined effect of N and P with bacterial inoculation on summer mungbean.

Previous studies showed that *Rhizobium* inoculums increased the dry matter accumulation, number of nodules plant^{-1}, nodule weight plant^{-1}, nutrient uptake and yield attributes (Shukla and Dixit, 1996). In Bangladesh, inoculation with *Rhizobium* increased 57% effective nodule, 77% dry matter production, 64% grain yield and 40% hay yield as compared to the uninoculated control in mungbean (Chanda *et al.*,1991).

The use of chemical fertilizers and bio-fertilizers in crop production can play a vital role in improving soil environment and sustainable agriculture. In Bangladesh, few studies have been conducted on the effects of chemical fertilizer and bio-fertilizer on mungbean and blackgram. Hence, an experiment was conducted to examine nodulation, growth and yield of *kharif-1* mungbean and blackgram as affected by fertilizer materials. The experiment was conducted with the following objectives:

i) to determine the nodulation, growth, crop characters and yield of mungbean and blackgram.

ii) to determine the effect of fertilizer materials on nodulation, growth and yield mungbean and blackgram.

iii) to study the interaction effect between fertilizer materials and variety on the nodulation, growth and yield of mungbean and blackgram.

Chapter 2
Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Mungbean and blackgram are important pulse crops of global economic importance. Extensive research work on these crops has been done in several countries, especially in the South East Asia for the improvement of its yield and quality. In Bangladesh, little attention has so far been given for the improvement of mungbean and blackgram. Recently, Bangladesh Agricultural Research Institute and Bangladesh Institute of Nuclear Agriculture have started research on varietals development and various agronomic management of the crop.

Limited information is available regarding the effect of fertilizer materials of mungbean and blackgram on the seed yield and its quality. Although this idea was not a recent one but research findings in this regard was scanty. Some of the pertinent works on these technologies have been highlighted in this chapter.

2.1 Effect on growth parameters

2.1.1. Plant height

Asaduzzaman (2006) found that plant height of mungbean was significantly increased by the application of nitrogen fertilizer at 30 kg ha^{-1}.

Patil *et al*. (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varieties and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, and fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced plant height significantly.

In a field experiment on *Vigna radiata* Sardar (2002) found reported that application of phosphorus at the rate of 40 kg ha^{-1}enhanced the plant height significantly. Singh *et al.* (1999) observed that increasing level of P significantly increased plant height up to 26.40 kg P ha^{-1} in mungbean. Sharma and Singh (1997) also found in a field experiment that to *Vigna rediata* application of phosphorus at the rate of 50 kg ha^{-1} enhanced the plant height significantly.

Solaiman (2002), Roy (2001) and Hasanuzzaman (2001) observed in a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculum significantly increased plant height as compared to uninoculated control. But Kavathiya and Pandey (2000) observed in a pot experiment with *Bradyrhizobium* on seed inoculation of mungbean. They found that *Bradyrhizobium* inoculum significantly increased plant height compared with uninoculated control. Mozumder (1998) and Rahman (1993) also reported that mungbean produced significantly increased plant height when inoculated with *Rhizobium* compared to uninoculated control. Another field experiment Sattar and Ahmed (1995) found on *Vigna radiata* studied the response of inoculation with *Bradyrhizobium* inoculants incorporating (BINA 403, BINA 407.RCR 3824 and RCR 3828 strains) as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased plant height significantly. In a field trail where *Vigna radiata* cv. Pusa-105 and PS-16 were treated seed inoculation with VAM fungal or a combination of both, Thakur and Panwar (1995) found that inoculation either singly or combined increased plant height compared with no inoculation.

Saini and Thakur (1996) stated that nitrogen at 30 and 40 kg ha^{-1} significantly increased the plant height of blackgram as compared to no N and Jamro *et al.* (1990) observed that application of 90 kg N ha^{-1} is significantly increased the plant height o blackgram.

2.1.2 Number and dry weight of nodule

Solaiman (2002), Hasanuzzaman (2001), Roy (2001) and Bhuiyan and Obaidullah (1992) observed in a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculum significantly increased the number of nodules; nodules dry weight compared to uninoculated control. But Kavathiya and Pandey (2000) observed in a pot experiment with *Bradyrhizobium* on seed inoculation of mungbean. They found that *Bradyrhizobium* inoculum significantly increased the number of nodules and nodule dry weight compared with uninoculated control.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced the plant height, crop growth rate, number of nodules $plant^{-1}$ and dry weight of nodules $plant^{-1}$ significantly.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the higher number of nodules and nodule dry weight compared with uninoculated control in mungbean cultivars.

Ram and Dixit (2000) found in a field trail during summer 1987 at Faisabad, Uttar Pradesh, India, where mungbean cv. 1851 was sown on 20 or 30 March or 9 April and given 0, 20 and 40 of 60 kg P ha^{-1} and observed that nodulation increased with the increasing P rates. Singh *et al.* (1999) also observed that increasing level of P significantly increased number of nodules, fresh and dry weights of nodules up to 26.40 kg P ha^{-1} in mungbean.

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 revealed that nodulation was greatest with inoculation in B 105 and Hoogly local.

Mozumder (1998) reported that mungbean produced significantly increased higher number (17.36) and weight of nodule (135 g) per plant when inoculated with *Rhizobium* compared to uninoculated (13.16, 58 g) control.

Provorov *et al.* (1998) observed that seed inoculation of mungbean (*Vigna radiata*) with Strain CLAM 1901 of *Bradyrhizobium* increased number of 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}.

Mozumder (1998) found in 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 levels on two varieties of summer mungbean and reported that nitrogen produced negative effect on nodule production and starter dose of nitrogen (40 kg ha^{-1}) gave the maximum seed yield (1607 kg ha^{-1}).

Poonam and Khurana (1997) conducted a field experiment to study the effect of single and multi-strain inoculants *Rhizobium* in summer mungbean variety SML 32. Number of nodules was superior in multi strain inoculants. Yadav and Sanoria (1996) also found that inoculums increased the number and dry weight of nodule compared to uninoculated control in mungbean.

Sattar and Ahmed (1995) found in a field experiment on mungbean (*Vigna radiata*) studied the response of inoculation with *Bradyrhizobium* inoculants incorporating (BINA 403, BINA 407, RCR 3824 and RCR 3828 strains) as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the nodules number and weight significantly.

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

Santos *et al.* (1993) observed on mungbean cv. Berken, grown in pots in podzolic soil using 7 levels 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. Plants grown at 400 and 500 kg ha^{-1} failed to nodulated.

Rahman (1993) reported that seed inoculation of *Rhizobium* to *Vigna radiata* cv. Kanti increased nodule number and dry weight of nodules respectively. Sangakhara and Marambe (1989) also observed that inoculation significantly increased nodulation of *Vigna radiata* at 21 days after sowing.

Hoque and Barrow (1993) conducted a field trails 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.

Prasad and Ram (1992) reported that green gram (cv. Pusa Baishakhi) on alluvial soil *Bradyrhizobium* strain M_5 inoculation and 2.5 ppm both Zn and Cu gave highest nodule dry matter $plant^{-1}$ compared to 0.86 t ha^{-1} in uninoculated control.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1}on mungbean progressively and significantly increased nodulation, shoot and root length.

Hoque (1991) reported that Bangladesh Agricultural University, Mymensingh, *Rhizobium* bacteria was the best strain for producing highest nodule number of mungbean.

Pandher *et al.* (1991) reported that inoculation of *Vigna radiata* cv. M 2131 with single and multiple strains of *Rhizobium* increased root nodule number. Multiple strain inoculation did not increased dry weight (OW) of plants and nodule compared to uninoculation control.

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.

Ahmed (1989) studied the effect of inoculation with *Bradvrhizobium* inoculants (BINA 403, BINA 407, RCR 3824 and RCR 3825 strain) as single and mixed cultures in presence of 4 levels of phosphorus (0, 30, 60 and 90 kg ha^{-1} from triple superphosphate) with a basal dose of potassium at the rate of 30 kg K_2O ha^{-1} from muriate of potash on growth, root nodulation, yield and yield contributing characters and protein and phosphorus content of mungbean. *Bradyrhizobium* inoculation increased significantly the number of nodules and nodule weight which become 63% over uninoculated control.

Maiti *et al.* (1988) in trials with green gram (*Vigna radiata*) grown Ion soils given (a) 60 or (b) 100 kg ha^{-1} each of P_2O_5 and K_20, seed inoculation with *Brardyrhizobium* increased nodule nitrogen activity by 36-54 % and seed yields by 15-20 % in *Vigna radiata,* respectively.

Penaranda *et al.* (1988) observed in an experiment on the effect of *Rhizobium* strain and phosphorus fertilizer on mungbean and reported that highest nodule count was 52 per plant with strain BGM1 is mungbean.

Gupta *et al*. (1988) observed in a pot trail with *Vigna radiata* seed inoculated with *Bradyrhizobium*. They found that formation of total nodule and dry weight of plant increased due to seed inoculation of *Bradyrhizobium*.

Patel *et al*. (1986) found that response of *Bradvrhizobium* in respect of nodulation of mungbean was found to be significantly higher over uninoculated control. Vaishya *et al.* (1983) also reported that seed inoculation with *Rhizobium* strain M1 significantly increased the number and weight of nodules in 12 *Vigna radiata* cultures.

Bhuiya *et al.* (1984) found in a field experiment at Bangladesh Agricultural University farm and observed that the inoculation of mungbean gave the higher dry weight of nodules and shoot per plant compared to control. They also reported that large size nodules were produced due to inoculation.

2.1.3 Shoot length and weight

Solaiman (2002), Roy (2001) and Hasanuzzaman (2001) observed in a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculum significantly increased the shoot dry weight plant^{-1} compared to uninoculated control.

Mozumder (1998) reported that mungbean produced significantly increased shoot dry weight when inoculated with *Rhizobium* compared to uninoculated (13.16, 58 g) control. Patra and Bhattacharyya (1998) also observed that seed inoculated plants exhibited significantly greater fresh and dry weight of shoot compared with uninoculated control in mungbean plants. Mand and Chahal (1987) found that *Bradyrhizobium* inoculation along with 40 ppm N gave maximum dry weight of shoot in mungbean plants.

Das *et al.* (1997) conducted in field trials where *Vigna radiata* cv. Nayagrah local seeds were inoculated with *Rhizobium* and/or VAM culture which was applied at 15 kg ha-1. They found that shoot lengths were increased with dual interaction compared with uninoculated control.

Yadav and Sanoria (1996) found that inoculums increased shoot weight compared to uninoculated control in mungbean. Rahman (1993) reported that seed inoculation of *Rhizobium* to *Vigna radiata* cv. Kanti increased shoot dry weight.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1}on mungbean progressively and significantly increased shoot length.

Hoque (1991) reported that Bangladesh Agricultural University, Mymensingh, *Rhizobium* bacteria was the best strain for producing highest shoot weight of mungbean. Samantary *et al.* (1990) also observed that shoot length and total dry weight of shoot was the highest in the control with *Rhizobium* inoculum of mungbean.

Ahmed (1989) studied the effect of inoculation with *Bradvrhizobium* inoculants (BINA 403, BINA 407, RCR 3824 and RCR 3825 strain) as single and mixed cultures in presence of 4 levels of phosphorus (0, 30, 60 and 90 kg ha^{-1} from triple superphosphate) with a basal dose of potassium at the rate of 30 kg K_2O ha^{-1} from muriate of potash on growth, root nodulation, yield and yield contributing characters and protein and phosphorus content of mungbean. *Bradyrhizobium* inoculation increased significantly the highest shoot weight (5.5 f plant) which becomes 63% over uninoculated control.

2.1.4 Root length and weight

Mozumder (1998) reported that mungbean produced significantly increased root dry weight when inoculated with *Rhizobium* compared to uninoculated (13.16, 58 g) control but Das *et al.* (1997) conducted in field trials where *Vigna radiata* cv. Nayagrah local seeds were inoculated with *Rhizobium* and/or VAM culture which was applied at 15 kg ha^{-1}. They found that root lengths were increased with dual interaction compared with uninoculated control.

Patra and Bhattacharyya (1998) observed that seed inoculated plants exhibited significantly greater fresh and dry weight of root compared with uninoculated control in mungbean plants.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1}on mungbean progressively and significantly increased root length

Samantary *et al.* (1990) observed that shoot length and total dry weight of root was the highest in the control with *Rhizobium* inoculum of mungbean. Mand and Chahal (1987) also found that *Bradyrhizobium* inoculation along with 40 ppm N gave maximum dry weight of root in mungbean plants.

2.1.5 Dry matter production

Chowdhury *et al.* (2000) conducted a field experiment during *Kharif* season of 1995 with mungbean and seed inoculation with *Bradyrhizobium* strains. They found that seed yield and dry matter production was increased by about 50%.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the higher plant dry weights compared with uninoculated control in mungbean cultivars.

Tomar *et al.* (1996) observed that leaf number, branch number, and dry weight per plants of summer mungbean *(Vigna radiata)* were highest with 60 kg P_2O_5 ha^{-1}.

Tomar *et al.* (1995) found in a tier experiment and observed that absolute growth rate, relative growth rate, net assimilation rate and dry matter at all the growth stages and crop growth rate at 65 days recorded significantly higher with application of phosphorus at 60 kg P_2O_5 ha^{-1} as compared to the other level of phosphorus in mungbean cultivars.

Leelavathi *et al.* (1991) reported that different levels of nitrogen showed significant difference in seed and dry matter production up to a certain level (60 kg N ha^{-1}) but Agbenin *et al.* (1991) found that applied N significantly increased growth components, dry matter yield and nutrient uptake over the control.

Pandher *et al.* (1991) reported that inoculation of *Vigna radiata* cv. M 2131 with single and multiple strains of *Rhizobium* increased root nodule number and seed yield. Multiple strain inoculation did not increased dry weight (OW) of plants and nodule compared to uninoculation control butChanda *et al.* (1991) observed 77 % higher dry matter production with *Bradyrhizobium* inoculation over control in mungbean cultures.

2.2 Effect on yield attributing characters

2.2.1 Number of branches plant^{-1}

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced number of branches significantly.

Singh *et al.* (1999) observed that increasing level of P significantly increased number of primary branches up to 26.40 kg P ha^{-1} in mungbean. Sharma and Singh (1997) also found in a field experiment on *Vigna rediata* and reported that application of phosphorus at the rate of 50 kg ha^{-1} enhanced branches plant^{-1} significantly. Another experiment Tomar *et al.* (1996) observed that branch number per plants of summer mungbean *(Vigna radiata)* were highest with 60 kg P_2O_5 ha^{-1}.

Ansari *et al.* (1990) found that soaking of *Vigna radiata* on K 851 in 0.1-0.5% pyridoxine solution significantly enhanced leaf N, P and concentration at different growth stages and seed protein content at harvest.

Gill *et al.* (1985) reported that inoculation significantly increased number of branches plant^{-1}, in *Vigna radiata.*

2.2.2 Number of pods plant^{-1}

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced pods plant^{-1}, number of seeds pod^{-1} significantly.

Mosamma Uttma Kulsum (2003) reported that different levels of nitrogen showed significantly increased pods per plant of blackgram upto N 60 kg ha^{-1}. Srinivas *et al.* (2002) also examined the effect of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and P (0, 25, 50 and 75 kg ha^{-1}) on the growth of munbeann.They objerved that the number of pods per plant was increased with the increasing rate of N upto 4 kg/ha followed by decrease with further increase in N.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced mature pods plant^{-1}significantly. Sharma and Singh (1997) also found in a field experiment on *Vigna rediata* and reported that application of phosphorus at the rate of 50 kg ha^{-1} enhanced pods plant^{-1} significantly.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the pod number plant^{-1} compared with uninoculated control in mungbean cultivars.

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}. Inoculation increased number of pods/plant and seeds/pod and N uptake. Jca_1 was superior to M-10. Number of pods/plant and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate. But Gill *et al.* (1985) reported that inoculation significantly increased pods $plant^{-1}$ in *Vigna radiata*.

2.2.3 Seeds pod^{-1}

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced number of seeds pod^{-1} significantly.

Malik *et al.* (2003) investigated the effect of varying levels 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 per pod were signicantly affected by varying levels of nitrogen and phosphorous. But Quah and Jaafar (1994) noted that seed yield of mungbean increased significantly by the application of nitrogen fertilizer at 50 kg ha^{-1}.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced number of seeds pod^{-1} significantly. But Sharma and Singh (1997) found in a field experiment on *Vigna rediata* and reported that application of phosphorus at the rate of 50 kg ha^{-1} enhanced grains $plant^{-1}$ and grains yields significantly. Patro and Sahoo (1994) also reported that application of 60 kg P_2O_5 ha^{-1} gave the highest seed yield (1254 kg ha^{-1}) in mungbean.

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}. Inoculation increased number of pods/plant and seeds/pod and N uptake. Jca_1 was superior to M-10. Number of pods/plant, seeds/pod and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate. But Gill *et al.* (1985) reported that inoculation significantly increased seeds $pods^{-1}$ in *Vigna radiata*.

2.2.4 1000 seeds weight

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced 1000-seed weight significantly.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels 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 signicantly affected the 1000 grain weight.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced weight of 1000 seed (g) significantly. But Singh *et al.* (1999) observed that increasing level of P significantly increased test weight and gram and straw yields up to 26.40 kg P ha^{-1} in mungbean.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the higher 1000 seed weight compared with uninoculated control in mungbean cultivars.

Provorov *et al.* (1998) observed that seed inoculation of mungbean (*Vigna radiata*) with Strain CLAM 1901 of *Bradyrhizobium* increased number of 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}.

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}. Inoculation increased number of pods/plant and seeds/pod and N uptake. Jca_1 was superior to M-10. 1000 seed 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.

2.2.5 Seed yield

Solaiman (2002), Roy (2001) and Hasanuzzaman (2001) observed in a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculum significantly increased grain yield and stover yield compared to uninoculated control.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced seed yield $plant^{-1}$ and yield significantly.

Shivesh and Sharma (2001) reported that crop growth rate, relative growth rate, days to 50% flowering, days to maturity and grain yield were at maximum when mungbean seeds were treated with the local isolate.

Kamal *et al.* (2001) Studies were conducted 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 (1430kg/ha) was found when fertilizer @20-60-30 NPK kg $ha^{-1}$with two hand weedings at 20 and 30 DAE were used. This was followed by that obtained (1368 kg/ha) by using inoculum+ 60-30 PK kg ha^{-1} with two hand weedings 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.

Yadav and Jakhar (2001) found that grain and straw yields of mungbean increased up to 60 kg P_2O_5 application ha^{-1}. But Ram and Dixit (2000) found in a field trail during summer 1987 at Faisabad, Uttar Pradesh, India, where mungbean cv. 1851 was sown on 20 or 30 March or 9 April and given 0, 20, 40 of 60 kg P ha^{-1} and observed that seed yield increased with the increasing P rates.

Chowdhury *et al.* (2000) conducted a field experiment during *Kharif* season of 1995 with mungbean and seed inoculation with *Bradyrhizobium* strains. They found that seed yield and dry matter production was increased by about 50%. Mozumder (1998) also reported that mungbean produced significantly increased grain yield when inoculated with *Rhizobium* compared to uninoculated (13.16, 58 g) control.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the higher grain and straw yield compared with uninoculated control in mungbean cultivars.

Upadhyay *et al.* (1999) found that seed yield of mungbean was higher with seed inoculation of *Rhizobium* (2.02 vs.1.87 t/ha) and increased with up to 40 kg P_2O_5 /ha (2.01 t/ha).

Provorov *et al.* (1998) observed that seed inoculation of mungbean (*Vigna radiata*) with Strain CLAM 1901 of *Bradyrhizobium* increased number of 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}.

Paul (1998) observed in a pot experiment where mungbean cv. Ps -16 were seed inoculated singly with 5 *Rhizobium* strains and exposed to 3 water regimes. She found that seed yield was not increased by inoculation under excess water or normal irrigation condition. But water stress conditions seed yield was increased by inoculation, particularly with strains N_{11} and D_4.

Mozumder (1998) found in 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 levels on two varieties of summer mungbean and reported that nitrogen produced negative effect on nodule production and starter dose of nitrogen (40 kg ha^{-1}) gave the maximum seed yield (1607 kg ha^{-1}).

Ramamoorthy and Raj (1997) conducted a field experiment in 1993-94 at Pudukottai, Tamil Nadu, India and found that seed yield of green gram (*Vigna radiata*) was 517 kg/ha without applied P and the highest (1044 kg/ha) with 25 kg P_2O_5 ha^{-1} as Mussoorie rock phosphate and seed inoculation with phosphobacteria.

Sharma and Khurana (1997) studied the effectiveness of single and multistrain inoculants in field experiment with summer mungbean variety SmL32 and found that grain yield was superior in multistrain inoculants. On an average, single strain and multi strain *Rhizobium* inoculants increased the grain yield by 10.4% and 14.3% over uninoculated control respectively.

Sharma and Singh (1997) found in a field experiment on *Vigna rediata* and reported that application of phosphorus at the rate of 50 kg ha^{-1} enhanced grains and straw yields significantly.

Poonam and Khurana (1997) conducted a field experiment to study the effect of single and multi-strain inoculants *Rhizobium* in summer mungbean variety SML 32. *Rhizobium* inoculum increased the yield by 10.4% and 19.3% over uninoculated control, respectively.

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

Yadav and Sanoria (1996) found that inoculums increased the grain yield compared to uninoculated control in mungbean.

In a field experiment observed by Satyanarayanamma *et al.* (1996) in 1992-93 at Lam, Guntur, Andhra Pradesh, India, 5 mungbean cultivars were sprayed with 2 % urea at pre-flowering, flowering, pod development or at all the combinations or two of' three growth stages. They followed that spraying urea at flowering and pod development stages produced the highest seed yield of 1.59 t ha^{-1}.

Ardeshna *et al.* (1993) reported that seed yield of *Vigna radiata* increased with the application of nitrogen up to 20 kg N ha^{-1} (0.75 t ha^{-1}) as urea up to 40 kg P_2O_5 (0.77 t ha^{-1}) as single super phosphate and seed inoculation with *Rhizobium* (0.76 t ha^{-1}).

Sharma *et al.* (1993) observed that in pot experiments seed and straw yield of *Vigna radiata* cv. Pusa Baishakhi increased with increase of P up to or equivalent of 60 kg p / ha and with *Rhizobium* inoculum and with a starter dose of nitrogen.

Khurana and Poonam (1993) studied with *Rhizobium* strains (LMR 107, KM 1, M 10, GMBS I and MO 5) and *Vigna radiata* cv. ML 207 and P 516. Under field condition seed inoculation with R strain increased the seed yield by 21.5% and 35.1% over uninoculation control.

Dubey *et al.* (1993) studied a micro plot (2m x 2m) field experiment In the farm of the Indian Agricultural Research Institute with the application of P as basal through DAP @ 0,25 and 50 kg P_2O_5 $ha^{-1}$and found that application of 50 kg P_2O_5 ha^{-1}gave the highest grain yield ha^{-1} of mungbean.

Mathan *et al.* (1993) conducted an experiment during rainy season of 1991 and 1992 to study the influence ok fertilizer, manure and *Rhizobium* inoculation of seeds on seed yield of (*Vigna mungo*) and N,P and K uptake by blackgram. Application of 25 kg N/ha +50kg P/ha as enriched farmyard manure (FYM) in 750+ 6.25 t/ha as basal dose and diammonium phosphate spray 25 kg/ha twice at flower initiation and15 days after FC to the crop sown with *Rhizobium* inoculated seeds was found optimum and recorded 75 and 54.5% more seed yield than control.

Satter and Ahmed (1992) reported that *Bradyrhizobium* inoculation gave better yield performances of mungbean at different levels of phosphatic fertilizer and did best at 60 kg P_20_5 /ha.

Prasad and Ram (1992) reported that green gram (cv. Pusa Baishakhi) on alluvial soil *Bradyrhizobium* strain M_5 inoculation and 2.5 ppm both Zn and Cu gave highest seed yield (1.27 t ha^{-1}) compared to 0.86 t ha^{-1} in uninoculated control.

Rajput *et al.* (1992) conducted a field experiment under irrigated conditions on a P-deficient soil to determine the response of mungbean cv. BRM 23 and BRM 41 to different combinations of N, P and K. Average seed yield was 553 kg ha^{-1} without fertilizers and the highest (803 kg) with 34 kg N + 67 kg P. BRM 23 had higher seed yield (728 kg ha^{-1}) than cultivar BRM 41 (682 kg ha^{-1}).

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1}on mungbean progressively and significantly increased grain, hay and total protein yield and grain and hay phosphorus content. Higher dose of phosphorus decreased the grain and hay yield and other studied parameters.

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

Sarkar and Banik (1991) observed in a field experiment to study the response of green gram to nitrogen, phosphorus and molybdenum. They reported that application of N and P improved plant productivity and enhanced the grain yield of green gram significantly. They also reported that response to P_2O_5 was recorded up to 60 kg ha^{-1}.

Trivedi *et al.* (1991) conducted a field experiment during the rainy seasons (1990-1991) to study the response of blackgram to nitrogen, phosphorus and sulphur. They reported that application of N, P_2O_5 and S significantly increased the grain yield and stover yield up to their maximum levels.

Hoque (1991) reported that *Rhizobium* bacteria were the best strain for producing seed yield of mungbean. These results and other studies showed 20-60 % increased in seed yield of mungbean.

Pandher *et al.* (1991) reported that inoculation of *Vigna radiata* cv. M 2131 with single and multiple strains of *Rhizobium* increased root nodule number and seed yield.

Ansari *et al.* (1990) found that soaking of *V. radiata* on K 851 in 0.1-0.5% pyridoxine solution significantly enhanced leaf N, P and concentration at different growth stages and seed protein content at harvest.

Singh and Kumari (1990) reported that *Vigna radiata* seed when inoculated with *Rhizobium* increased Mn and P content in seeds and straw. But Gill *et al.* (1985) reported that inoculation significantly increased grain yield in *Vigna radiata*.

Ahmed (1989) studied the effect of inoculation with *Bradvrhizobium* inoculants (BINA 403, BINA 407, RCR 3824 and RCR 3825 strain) as single and mixed cultures in presence of 4 levels of phosphorus (0, 30, 60 and 90 kg ha^{-1} from triple superphosphate) with a basal dose of potassium at the rate of 30 kg K_2O ha^{-1} from muriate of potash on yield and yield contributing characters and protein and phosphorus content of rnungbean. *Bradyrhizobium* inoculation increased significantly grain and hay yield over uninoculated control.

Patel *et al.* (1988) in a trial with green gram (*Vigna radiata*) grown in summer season and found seed yield of 1.01, 1.20 and 1.24t ha^{-1} respectively. The application of 20 kg N ha^{-1} or seed inoculation with *Rhizobium*+10 kg N/ha gave similar yields of 1.21-1.25 t ha^{-1} compared with 1.02 t/ha without inoculation.

Khade *et al.* (1988) showed that green gram (*Vigna radiata*) in the winter season gave higher yields with 50 and 75 kg P_2O_5 ha^{-1} than with 25 kg P_2O_5 or no phosphorus application.

Dixit and Swain (1987) found in an experiment with 5 greengram (*Vigna radiata*) cultivars at 0 to 60 kg P_2O_5 $ha^{-1}$and observed that K851 and Pusa Baishakhi gave the highest seed yield of 1.21 and 1.08 t ha^{-1} respectively. Yield at 40 and 60 kg PROS ha^{-1}were 1.03 and 4.06 t ha^{-1} respectively compared with 0.86 t ha^{-1} without application of phosphorus.

Ahmed *et al.* (1986) reported that application of phosphorus up to 60 kg P_2O_5 ha^{-1} significantly enhanced the growth and yield parameters and increased the grain and straw protein of mungbean (*Vigna radiata*).

2.2.6 Stover yield

Solaiman (2002), Roy (2001) and Hasanuzzaman (2001) observed in a field experiment with *Bradyrhizobium* on seed inoculation of mungbean and found that seed inoculum significantly increased grain yield and stover yield compared to uninoculated control.

Yadav and Jakhar (2001) found that grain and straw yields of mungbean increased up to 60 kg P_2O_5 application ha^{-1}. Singh *et al.* (1999) also observed that increasing level of P significantly increased test weight and gram and straw yields up to 26.40 kg P ha^{-1} in mungbean.

Deb (2000) reported that *Rhizobium* inoculation along with fertilizer application including Mo significantly increased the higher straw yield compared with uninoculated control in mungbean cultivars.

Sharma and Singh (1997) found in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 50 kg ha^{-1} enhanced straw yield significantly.

Yadav and Sanoria (1996) found that inoculums increased straw yield compared to uninoculated control in mungbean. Sattar and Ahmed (1995) also found in a field experiment on mungbean (*Vigna radiata*) studied the response of inoculation with *Bradyrhizobium* inoculants incorporating (BINA 403, BINA 407.RCR 3824 and RCR 3828 strains) as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased hay and total protein yield significantly.

Behari *et al.* (1995) conducted an experiment with *Vigna radiata* cv. B1, K 851 and B165. Seeds were treated with 10 different *Bradyrhizobium* strains before sowing in field trails and found that a significant interaction between different strain mixtures. Seed yield was generally improved by using multi- strain inoculation.

Sharma *et al.* (1993) observed that in pot experiments seed and straw yield of *Vigna radiata* cv. Pusa Baishakhi increased with increase of P up to or equivalent of 60 kg P / ha and with *Rhizobium* inoculum and with a starter dose of nitrogen.

Satter and Ahmed (1992) reported that phosphorus application up to 60 kg P_2O_5 ha^{-1} on mungbean progressively and significantly increased hay and total protein yield and grain and hay phosphorus content. Higher dose of phosphorus decreased the grain and hay yield and other studied parameters.

Trivedi *et al.* (1991) conducted a field experiment during the rainy seasons (1990-1991) to study the response of blackgram to nitrogen, phosphorus and sulphur. They reported that application of N, P_2O_5 and S significantly increased the grain yield and stover yield up to their maximum levels.

Singh and Kumari (1990) reported that *Vigna radiata* seed when inoculated with *Rhizobium* increased Mn and P content in seeds and straw and N content in straw only.

Ahmed (1989) studied the effect of inoculation with *Bradvrhizobium* inoculants (BINA 403, BINA 407, RCR 3824 and RCR 3825 strain) as single and mixed cultures in presence of 4 levels of phosphorus (0, 30, 60 and 90 kg ha^{-1} from triple superphosphate) with a basal dose of potassium at the rate of 30 kg K_2O ha^{-1} from muriate of potash on growth, yield and yield contributing characters and protein and phosphorus content of mungbean. *Bradyrhizobium* inoculation increased significantly grain and hay yield over uninoculated control.

Chahal and Chahal (1987) reported that *Rhizobium* strain R-1 produced the greatest yield of mungbean plants. Gill *et al.* (1985) also reported that inoculation significantly increased straw yield in *Vigna radiata*.

2.2.7 Biological yield

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals (El), only recommended dose of fertilizers (E2), and fertilizer- and pesticide- free conditions (E3) in Dharwad, Karnataka, India. Observations were recorded for enhanced biological yield significantly.

2.2.8 Harvest index

Patil *et al.* (2003) studied genetic diversity among 36 genotypes of mungbean, consisting of both released varities and advance lines selected for tolerance to different stress conditions. The genotypes were grown in three distinct environments with recommended dose of fertilizers and plant protection chemicals, only recommended dose of fertilizers, fertilizer and pesticide free conditions in Dharwad, Karnataka, India. Observations were recorded for enhanced harvest index significantly.

Sardar (2002) observed in a field experiment on *Vigna radiata* and reported that application of phosphorus at the rate of 40 kg ha^{-1} enhanced harvest index significantly.

Gill *et al.* (1985) reported that inoculation significantly increased harvest index in *Vigna radiata*.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from late March to mid June, 2007. Detailes of the experimental materials and methods for the study are presented in this chapter.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 9 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area has sub-tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity and rainfall prevailed at the experimental site during the study period were presented in Appendix II.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 5.6 to 6.5 and had organic matter 1.10 to 1.99%. The experimental area was flat having available irrigation and drainage system and above flood level. Pre-experiment soil samples from 0 to 15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The physico-chemical properties of the soil are presented in Appendix III.

3.2 Details of the experiment

3.2.1 Treatments

Two sets of treatment factors included in the experiment; the first set comprised of two crops namely Mungbean (BARI mung 6) and Blackgram (BARI mash 1) and the second set consisted of five treatments of fertilizer materials. Two sets of treatments were as follows:

Factor A. Crop (2):

1. Mungbean
2. Blackgram

Factor B. Fertilizer materials (5):

1. No fertilizer (Control)
2. Chemical fertilizer (NPKB)
3. Inoculum
4. Cowdung and
5. PK+ Inoculum

3.2.2 Experimental design and layout

The experiment was laid out in a split-plot design with three replications having crops as the main plots and fertilizer materials as the sub-plots. There were 10 treatment combinations. The total numbers of unit plots were 30. The size of unit plot was 4.0 m by 3.0 m. The distances between plot to plot and replication to replication were 1 m and 1.5 m, respectively. The layout of the experiment has been shown in Appendix IV.

3.3 Crop/Planting Material

Mungbean (BARI mung 6) and Blackgram (BARI mash 1) were used as plant material.

3.3.1 Description of crop: Mungbean (BARI mung 6)

The seeds of BARI mung 6, a modern mungbean variety were used as experimental material. BARI mung 6 was developed by Bangladesh Agricultural Research Institute (BARI). The plants of this variety are of 40-45 cm in height, life cycle lasts for 55-58 days and synchronous type. The plants are erect, stiff and less branched. Each plant contains 15-20 pods. Each pod is around 10 cm long and contains 8-10 seeds. Seeds are large and green in colour and drum shaped. The seed yield of BARI mung 6 range from 1.4-1.5 t ha^{-1} (Hussain *et al.*, 2006).

3.3.2 Description of crop: Blackgram (BARI mash 1)

The seeds of BARI mash 1, a modern blackgram variety were used as experimental material. BARI mash 1 was developed by Bangladesh Agricultural Research Institute (BARI). The plants of this variety are of 32-36 cm in height, life cycle lasts for 65-70 days and synchronous type. The plants are erect, stiff and more branched. Each plant contains 35-45 pods. Each pod is around 5 cm. long and contains 5-6 seeds. Seeds are large and blackish-brown in colour and drum shaped. The seed yield of BARI mash 1 ranges from 1.4-1.5 t ha^{-1} (Hussain *et al.*, 2006).

3.3.3 Description of fertilizer materials: Chemical fertilizer (NKPB)

The recommended chemical fertilizer dose was 45, 100, 55 and 1 kg/ha of Urea, TSP (Triple super phosphate), MP (Muriate of potash) and BA (Boric acid) respectively (Hussain *et. al.*, 2006). All the fertilizers were applied as broadcast and were mixed with soil thoroughly at the time of final land preparation.

3.3.4 Description of fertilizer materials: Inoculum

Before sowing, the seeds of inoculated treatment were mixed with inoculum (BARI RISI-403) as per specification given by BARI.

3.3.5 Description of fertilizer materials: Cowdung

The specific plot was manured with cowdung @ 10 t/ha. All the amount of cowdung was applied as broadcast and was mixed with soil thoroughly at the time of final land preparation after making plot.

3.4 Crop management

3.4.1 Seed collection

Seeds of BARI mung 6 and BARI mash 1 were collected from Pulse Seed Section, BARI, Joydebpur, Gazipur, Bangladesh.

3.4.2 Seed sowing

The seeds (BARI mung 6 and BARI mash 1 having more than 80% germination) were sown by hand in 30 cm apart lines continuously at about 3 cm depth at the rate of 60 g/plot (BARI mung 6) and 50 g/plot (BARI mash 1) on 25 March, 2007.

3.4.3 Collection and preparation of initial soil sample

The soil sample of the experimental field was collected two times, first before fertilizer application and then after harvesting of the crops. The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.4.4 Preparation of experimental land

A pre sowing irrigation was given on 17 March, 2007. The land was open with the help of a tractor drawn disc harrow on 20 March, 2007, then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on March 25, 2007 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.4.5 Fertilizer application

The specific plots area were fertilized @ 45, 100, 55 and 1 kg/ha of Urea, TSP (triple super phosphate), MP (muriate of potash), BA (boric acid) and 10 t/ha cowdung respectively. The entire amounts of urea, TSP, MP, BA and cowdung were applied as basal dose at final land preparation. Inoculum was mixed with seed applied just before seed sowing.

3.4.6 Intercultural operations

3.4.6.1 Thinning

The plots were thinned out on 15 days after sowing to maintain a uniform plant stand.

3.4.6.2 Weeding

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

3.4.6.3 Application of irrigation water

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

3.4.6.4 Drainage

There was a heavy rainfall during the experimental period. Drainage channles were properly prepared to easy and quick drained out of excess water.

3.4.6.5 Plant protection measures

The crops were infested by insects and diseases. Marshal @ 0.2% and Ripcord @ 30 ml. in 10 litre water (60ml.) were applied in the experimental field to control white fly on 19th April, 2007 and 4th May, 2007 respictively. Cu-fungicide (Curavite) applied in the experimental field to control fungal diseases @ 0.2% at the later stage of the plants.

3.4.7 Harvesting and post harvest operation

Maturity of crop was determined when 80-90% of the pods become blackish in color. The harvesting of BARI mung 6 was done on 3 June, 2007. The harvesting of BARI mash 1 was done on 22 June, 2007. Ten pre-selected plants per plot from which different yield attributing data were collected and 6m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using pedal thresher. The grains were cleaned and sun dried to a moisture content of 14%. Straw was also sun dried properly. Finally, grain and straw yields plot^{-1} were determined and converted to ton ha^{-1}.

3.4.8 Recording of data

Experimental data were determined from 15 days of growth duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of plants at different specific dates from the inner rows leaving border rows and harvest area for grain. The following data were recorded during the experimentation.

A. Crop growth characters

i. Plant height (cm) at 15 days interval
ii. Root length (cm) plant^{-1} at 15 days interval
iii. Number of nodules plant^{-1} at 15 days interval
iv. Dry weight of nodules plant^{-1} at 15 days interval
v. Leaf area index at 15 days interval
vi. Dry matter production at 15 days interval
vii. Days to flowering

B. Yield and other crop characters

i. Number of branches plant^{-1}
ii. Number of pods plant^{-1}
iii. Length of pod
iv. Number of seeds pod^{-1}
v. Weight of 1000-seeds
vi. Seed yield
vii. Stover yield
viii. Biological yield
ix. Harvest index
x. Shelling percentage

3.4.9 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

A. Crop growth characters

3.4.9.1 Plant height (cm)

Plant height of ten selected or random plants from each plot was measured at15, 30, 45 days after sowing (DAS) and at harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf of main shoot.

3.4.9.2 Root length (cm) plant^{-1}

The sub-samples of 5 plant plot^{-1} uprooted from second line and root length from five plants was measured at 15, 30, 45 DAS and at harvest and the mean value was determined.

3.4.9.3 Number of nodule

The 5 plants plot^{-1} from second line was uprooted and total number of nodules from five plants was counted at 15, 30, 45 DAS and at harvest and the mean value determined.

3.4.9.4 Leaf area index (LAI)

Leaf area index were estimated manually by the total number of leaves per plant and measuring the length and average width of leaf and multiplying by a factor of 0.65 (Keulen and Wolf, 1986).

3.4.9.5 Dry weight of plant (g)

The sub-samples of 5 plant plot^{-1} uprooted from second row were oven dried until a constant moisture level, from which the weights of above ground dry matter were recorded at 15 day intervals and at harvest.

3.4.9.6 Days to flowering

Time of flowering (days) was recorded when about 50% of the plants within a plot flowered.

B. Yield and other crop characters

3.4.9.7 Number of branches plant^{-1}

Branch number was counted from ten pre-seleted plants and the mean value was determined.

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

Pods of ten selected plants were counted and the average pods for each plant was determined.

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

Pods from each of ten plants per plot were separated and ten pods were selected randomly. The number of seeds pod^{-1} was counted and average number of seeds pod^{-1} was determined.

3.4.9.10 Weight of 1000-seeds (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

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

Grain yield was determined from the central 6.0 m^2 area of each plot and expressed as t ha^{-1} and adjusted with 14% moisture basis. Moisture content was measured by using a digital moisture tester.

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

Straw yield was determined from the central 6 m^2 area of each plot. After separation of seeds, the sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

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

Seed yield and straw yield were combined together as biological yield. Biological yield was calculated with the following formula:

Biological yield (t ha^{-1}) = Seed yield (t ha^{-1}) + Stover yield (t ha^{-1})

3.4.9.14 Harvest index (%)

Harvest index denotes the ratio of economic yield (seed yield) to biological yield and was calculated with following formula (Donald, 1963; Gardner *et al.*, 1985).

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

3.4.9.15 Shelling percentage

The shells of the harvested pods from each plot were collected and dried under the sun. The weight of the shells was recorded from which shelling percentage was calculated as per following formula:

$$\text{Shelling (\%)} = \frac{\text{Shell yield}}{\text{Seed yield} + \text{shell yield}} \times 100$$

3.4.10 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of the SRDI, Farmgate, Bangladesh. The properties studied included pH, organic matter, total N, available P and exchangeable K. The soil was analyzed following standard methods. Particle-size analysis of soil was done by Hydrometer method and soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5.

3.4.11 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using IRRISTAT package and the mean differences were adjudged by LSD technique (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the present study regarding the effects of fertilizer materials and their interactions on the yield and yield components of summer mungbean and blackgram have been presented, discussed and compared in this chapter. The analytical results have been presented in Table 1 through Table 8, Figure 1 through 19 and Appendix V through Appendix XI. A general view of the experimental plots and treatments has been shown in plate I through plate 4.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of crops

The plant heights of mungbean and blackgram were significantly influenced by different crop varieties at 15, 30 and 45 DAS, but it was insignificant at harvest (Appendix V and Table 1).

The results revealed that at 15 DAS, the crop mungbean produced the tallest plant (17.25 cm) and the blackgram gave the shortest plant (10.89 cm) and the same trend of plant height was also observed at 30 and 45 DAS. At harvest, no significant variation of plant height was observed between the two crops, through numerically the tall plant height (73.62 cm) was found in blackgram and short plant height (70.38 cm) was found in mungbean, there was no significant difference in plant height due to different crop was observed. In the initial stage of growth, the increase of plant height was very slow and then the crop remained in vegetative stage. The rapid increase of plant height was observed from 15 to 45 DAS. After reaching the maximum vegetative stage, the growth of plant became very slow. Plant height increased over blackgram to mungbean was 42.4, 45.26 and 18.13% at 15, 30 and 45 DAS respetively.

But blackgram was about 5.4% taller at harvest compared to mungbean. These results were in agreement with the findings of Thakuria and Shaharia (1990) who found similar plant height of mungbean varieties.

Table 1. Influence of fertilizer materials on plant height at different crop growth stages of mungbean and blackgram

Treatments	Plant height (cm) at different days after sowing			
	15	30	45	At harvest
Crop				
C_1	17.25	43.51	65.93	70.38
C_2	10.89	29.93	57.77	73.62
$LSD_{(0.05)}$	0.994	2.354	4.434	NS
Fertilizer materials				
F_1	12.11	32.89	56.69	64.64
F_2	13.48	36.55	64.78	79.11
F_3	14.09	38.75	64.37	79.80
F_4	14.72	36.84	61.16	65.45
F_5	15.97	38.56	62.23	71.01
$LSD_{(0.05)}$	1.572	3.722	7.012	NS
CV (%)	9.12	8.28	9.26	17.25

C_1 =BARI mung 6, C_2 = BARI mash 1, F_1 =No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.1.1.2 Effect of fertilizer materials

Fertilizer materials had significant effect on plant height (Appendix V and Table 1). Plant height was affected by the different fertilizer materials at 15, 30, 45 DAS and at harvest. At 15 DAS, the tallest plant height (15.97 cm) was obtained in PK+inoculum treatment and shortest plant height (12.11 cm) was obtained from no fertilizer (Control) treatment. At 30 DAS, the tallest plant height (38.75 cm) was obtained from inoculum and shortest plant height (32.89

cm) was obtained from no fertilizer material (Control). At 45 DAS, the tallest plant height (64.68 cm) was obtained from chemical fertilizer (NPKB) and shortest plant height (56.69 cm) was obtained from no fertilizer material (Control). At harvest, no significient variation of plant height objerved among the fertilizer materials through numerically the maximum plant height (79.80 cm) was obtained from inoculum treatment and minimum plant height (64.64 cm) was obtained from no fertilizer material (Control). The result was similar to the findings of Mathan *et al.* (1992), Shukla and Dixit (1990), Yadav (1985), Kavathiya and Pandey (2000), Roy (2001) Akhtaruzzaman (1998). Similar effect of fertilizer material on plant height was found in groundnut as reported by Ferdous *et al.* (1999).

4.1.1.3 Interaction effect of crops and fertilizer materials

Significant interaction effect between the crop and fertilizer materials was observed at 15, 30, 45 DAS and at harvest in plant height (Appendix V and Figure 1). At 15 DAS, the tallest plant was obtained from the mungbean with PK+ inoculum (19.37 cm) which was statistically similar with the interaction of cowdung in mungbean (18.42cm). The shortest plant height (8.50 cm) was found with no fertilizer (Control) treatment with blackgram. At 30 DAS, the tallest plant was obtained from the mungbean with inoculum (47.12 cm) which was statistically similar with the interaction of cow dung, inoculum and PK+ inoculum (42.83 cm). The shortest plant height (26.79 cm) was with no fertilizer (Control) with blackgram which was similar to the other fertilizer. At 45 DAS, the tallest plant height was recorded at the mungbean with chemical fertilizer (69.67 cm) which was statistically similar with the interaction of cowdung, inoculum and PK+inoculum and no fertilizer (Control) with mungbean and chemical fertilizer (NPKB) and inoculum with blackgram (59.90 cm). The shortest plant height (52.73 cm) was when no fertilizer with blackgram which was statistically similar to the cowdung and PK+ inoculum interaction with blackgram. At harvest, the tallest plant (85.53 cm) was obtained from the blackgram with Inoculum which was statistically similar with the interaction of cow dung, inoculum and PK+ inoculum, chemical fertilizer (NPKB) and no fertilizer (Control) with mungbean and chemical fertilizer (NPKB), PK+ inoculum, cowdung and no fertilizer (Control) with blackgram (64.80 cm) and the shortest plant (63.89 cm) was recorded from the blackgram with cowdung.

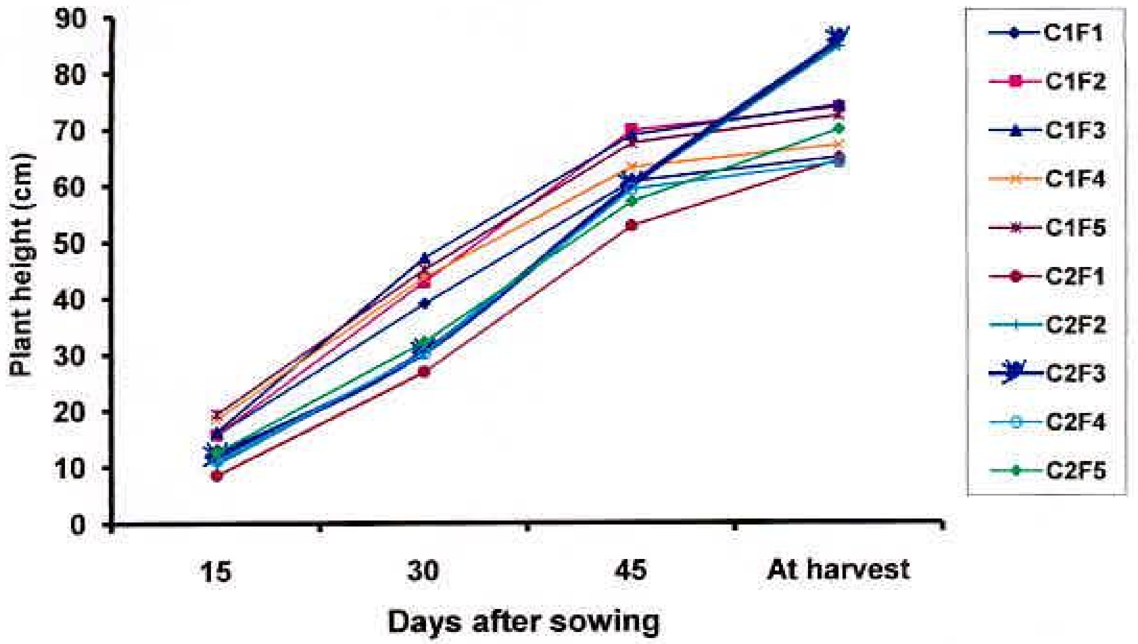


Figure 1. Interaction effect of crop and fertilizer materials on plant height (cm) crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS and at harvest was 2.22, 5.26, 9.92 and 21.49 respectively)

4.1.2 Root length at different growth stages of crops

4.1.2.1 Effect of crops

The root length of mungbean and blackgram were significantly different at 15, 30, 45 DAS and at harvest (Appendix VI and Table 2).

At 15 DAS, the crop mungbean produced the longest root (8.26 cm) and the crop blackgram gave the shortest root (7.35 cm). At 30 DAS, blackgram produced the longer root (11.67 cm) and the shorter root length was found with mungbean (8.26 cm), and the same trend of root length was observed at harvest although no variation of root length observed at 45 DAS. Root length increased over mungbean to blackgram was 11.37, 2.33 and 7.43% at 30, 45 DAS and at harvest. But mungbean was about 6.06% taller at 15 DAS compared to blackgram.

4.1.2.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on root length except at harvest (Appendix VI and Table 2). Root length was unaffected by the different fertilizer materials at 15, 30 and 45 DAS. At harvest, the longest root length (16.05 cm) was obtained in chemical fertilizer (NPKB) which was statistically similar of PK+ inoculum and no fertilizes (control) and the shortest root length (11.62 cm) was obtained from inoculum.

Table 2. Influence of fertilizer materials on root length at different crop growth stages of mungbean and blackgram

Treatments	Root length (cm) at different days after sowing			
	15	30	45	At harvest
Crop				
C_1	8.26	8.26	11.70	12.99
C_2	7.35	11.67	12.75	17.45
LSD $_{(0.05)}$	0.797	0.789	NS	1.667
Fertilizer materials				
F_1	7.73	11.91	12.69	15.04
F_2	8.06	11.66	12.64	16.05
F_3	7.73	11.75	11.62	11.62
F_4	7.56	11.36	12.04	13.91
F_5	7.94	11.48	12.16	15.27
LSD $_{(0.05)}$	NS	1.249	1.396	2.635
CV (%)	13.19	8.77	9.33	14.15

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 = No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.1.2.3 Interaction effect of crops and fertilizer materials

Significant interaction effect between the crops and fertilizer materials were observed at 15, 30, 45 DAS and at harvest on root length (Appendix VI and Figure 2).

At 15 DAS, the longest root length was obtained from the mungbean with no fertilizer (9.26 cm) which was statistically similar with the interaction of cowdung, inoculum, PK+ inoculum and recommended chemical fertilizer and blackgram with cowdung, PK+inoculum and chemical fertilizer (NPKB). The shortest root length (6.19 cm) was found of blackgram with no fertilizer (control). At 30 DAS, the longest root length was

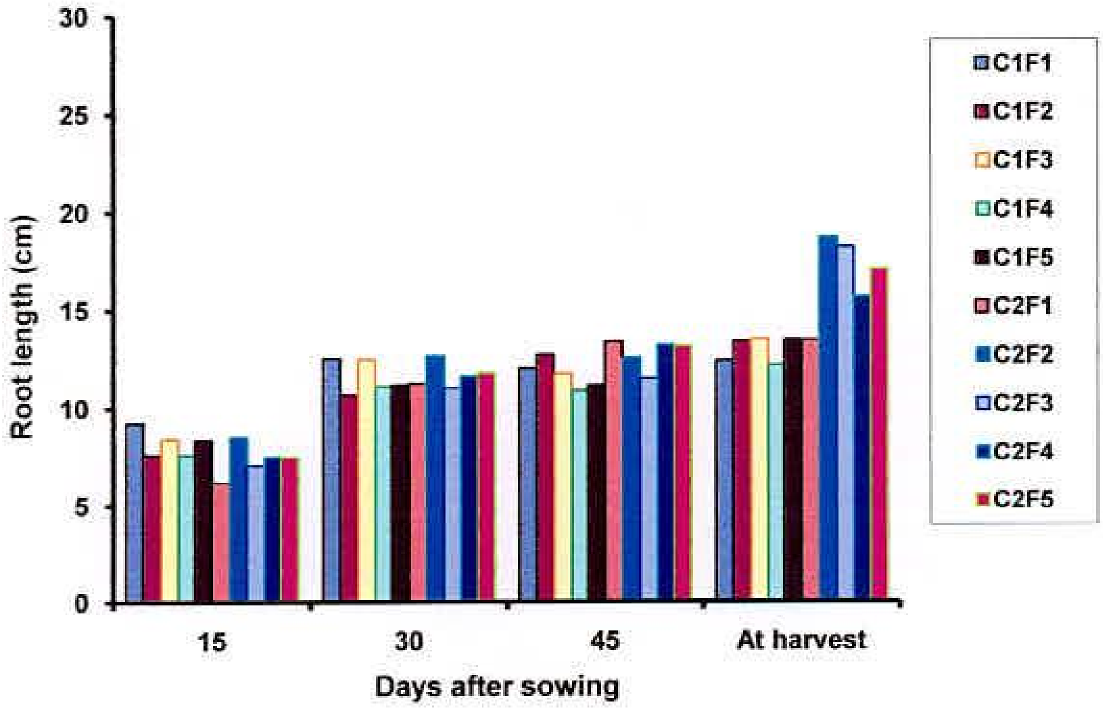


Figure 2. Interaction effect of fertilizer materials on root length (cm) at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS and at harvest was 1.78, 1.76, 1.97 and 1.98 respectively)

obtained from the blackgram with chemical fertilizer (12.65 cm) which was statistically similar with the interaction of cowdung, inoculum, PK+ inoculum and no fertilizer (control) with blackgram and mungbean with cowdung, inoculum, PK+ inoculumand and no fertilizer (control). The shortest root length (10.67 cm) was found in chemical fertilizer (NPKB) with mungbean. At 45 DAS, the longest root length was recorded at the blackgram with no fertilizer (13.37 cm) which was statistically similar with the interaction of cowdung, inoculum, PK+inoculum and chemical fertilizer (NPKB) with blackgram and inoculum, chemical fertilizer (NPKB) and no fertilizer (control) with mungbean (11.51 cm). The shortest root length (10.87 cm) was in inoculum with mungbean. At harvest, the tallest root length (18.68 cm) was obtained from the blackgram with chemical fertilizer (NPKB) which was statistically similar with the interaction of cowdung, inoculum and PK+ inoculum of blackgram. The shortest root length (10.87 cm) of mungbean was found with no fertilizer (control).

4.1.3 Number of nodules at different growth stages of crops

4.1.3.1 Effect of crops

Mungbean and blackgram plants recorded significant number of nodules at 15 DAS, but no variations were observed at 30 and 45 DAS (Appendix VII and Table 3).

At 15 DAS, the mungbean plants produced the maximum total number of nodules plant^{-1} (5.87) and the blackgram plants gave the lowest total number of nodules plant^{-1} (3.67). Similar result has been reported by Maldal and Roy (1999) and Singh *et al.* (1991). At 30 and 45 DAS, there was no significant differences objerved for total number of nodules between mungbean and blackgram. Observation on total number of nodules plant^{-1} revealed that crops differed significantly between themselves. This result confirmed that nodule production varied from crop to crop (Murakami *et al.*, 1990; Patel and Patel, 1994; Pal and Lal, 1993 Akao *et al.*, 1990).

The number of total nodules $plant^{-1}$ increased various growth stages up to 45 DAS, followed by a decline. It appeared that the peak nodulation in mungbean and blackgram occurred between pre-flowering and pod filling stage. This might be due to peak nodulation in mungbean and blackgram at 50% flowering stage and degeneration of nodules after pod filling stage. Patel and Patel (1991) reported that significantlly higher number of nodules $plant^{-1}$ in mungbean was observed at 30 DAS followed by 45 and 15 DAS. Pal and Lal (1993) also reported that nodules were higher at 45 DAS than 60 DAS in mungbean. Akhtaruzzaman (1998) also observed maximum nodulation at 40 DAS than at 30 and 20 DAS in mungbean.

Table 3. Influence of fertilizer materials on number of nodules at different crop growth stages of mungbean and blackgram

Treatments	Number of nodules at different days after sowing		
	15	30	45
Crop			
C_1	5.87	9.47	16.33
C_2	3.67	8.33	19.07
$LSD_{(0.05)}$	1.344	NS	NS
Fertilizer materials			
F_1	4.83	8.00	17.33
F_2	3.67	7.67	14.00
F_3	3.50	8.33	17.33
F_4	6.00	9.17	18.17
F_5	5.83	11.33	21.67
$LSD_{(0.05)}$	2.126	NS	5.263
CV (%)	36.43	34.66	24.29

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 = No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.1.3.2 Effect of fertilizer materials

The different fertilizer materials had highly significant effect in formation of total number of nodules plant^{-1} recorded at 15 and 45 DAS, but at 30 DAS no significant variations observed for total number of nodules plant^{-1} (Appendix VII and Table 3). Cowdung and PK+inoculum gave more nodules than chemical fertilizer (NPKB), inoculum and no fertilizer (control).

At 15 DAS, the maximum total number of nodules plant^{-1} (6.00) was produced by cowdung, which was statistically similar to PK+inoculum and no fertilizer (control) and the lowest number of nodules was produced by inoculam (3.50 plant^{-1}). At 30 DAS, there was no significant variation observed in the total number of nodule production for different fertilizer materials. At 45 DAS, the highest total number of nodules (21.67 plant^{-1}) was produced by PK+inoculum, which was similar to cowdung, inoculum and no fertilizer (17.33 plant^{-1}) and the lowest number of nodules (14 plant^{-1}) was produced by chemical fertilizer (NPKB). Similar results also reported by Sarkar *et al.* (1991), Bhuiyan *et al.* (1994), Hossain and Hamid (1998). Datt and Bhardwaj (1995) reported that the nodule number and nodule dry weight of cowpea increased significantly by *Rhizobium* inoculation at 45 DAS followed by 55, 30 and 15 DAS. This might be due to the high requirement of N at flowering and pod filling stage (Rennie and Kemp, 1984). Chowdhury *et al.* (1997) observed higher nodule number in inoculated mungbean at flowering stage than at pod filling or pre-flowering stage. Application of phosphorus fertilizer increased the nodule number and their dry weight, which was expected in phosphorus deficient soil, since phosphorus is reported to enhance multiplication and activity of nodule bacteria in legume rhizosphere and to increase root density which was important for producing more nodule.

4.1.3.3 Interaction effect of crops and fertilizer materials

Significant interactions effect between the crops and fertilizer materials were observed at 15, 30 and 45 DAS on total number of nodules produced $plant^{-1}$ (Appendix VII and Figure 3).

At 15 DAS, mungbean plants produced the highest number of nodules was produced from the mungbean with PK+inoculum (8.00 $plant^{-1}$) which was statistically similar with the interaction of cowdung and no fertilizer (6.67 $plant^{-1}$). The lowest number of nodule was produced in no fertilizer (control) with blackgram (3.00 $plant^{-1}$). At 30 DAS, the maximum number of nodules (13.00 $plant^{-1}$) was obtained from the mungbean with PK+inoculum which was statistically similar with the interaction of inoculum, cowdung, chemical fertilizer (NPKB) and no fertilizer (Control) with mungbean and PK+inoculum,

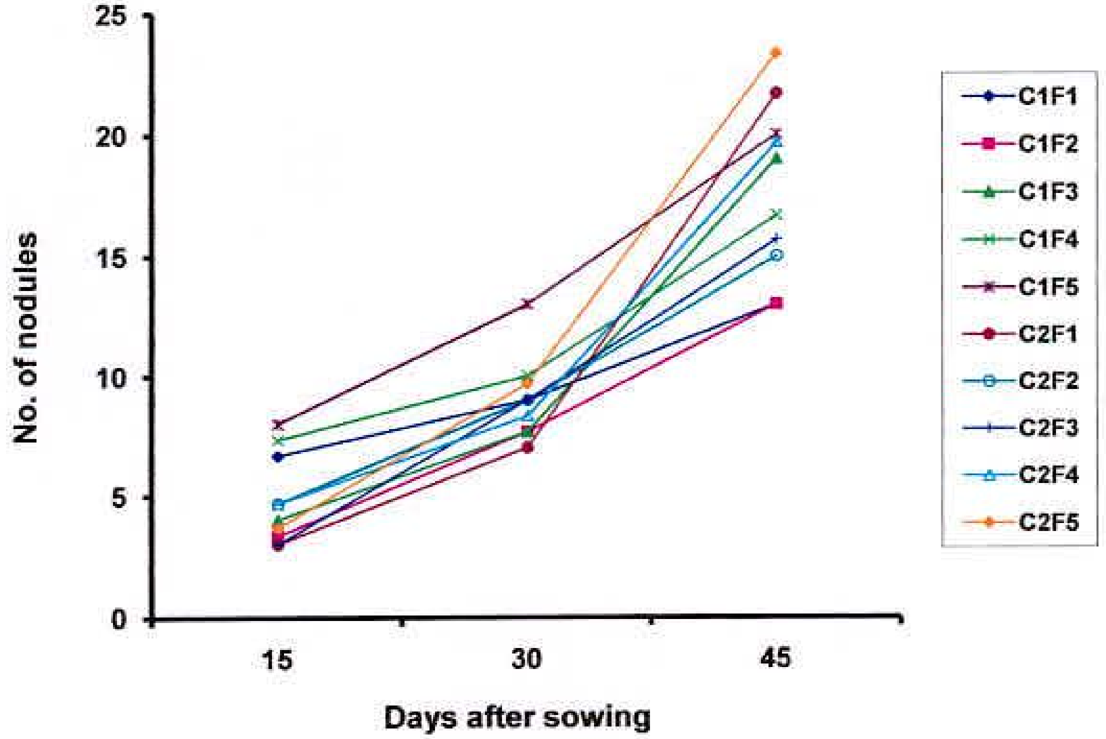


Figure 3. Interaction effect of fertilizer materials on number of nodules at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS was 3.00, 5.34 and 7.44 respectively)

cowdung, inoculum and chemical fertilizer (NPKB) with blackgram (7.67 plant^{-1}). The lowest number of nodule was produced in no fertilizer (control) with blackgram (7.00 plant^{-1}). At 45 DAS, the maximum nodule was recorded at the blackgram with PK+inoculum (23.33 plant^{-1}) which was statistically similar with the interaction of cowdung and no fertilizer (control) with blackgram (19.67 plant^{-1}) and PK+inoculum, cowdung and inoculum with mungbean (16.67 plant^{-1}). The lowest number of nodules was produced from the mungbean with no fertilizer (13.00 plant^{-1}). These result indicated that boi-fertilizer had influence on nodule production in mungbean and blackgram. Similar results have been reported by Naher (2000), Kavathiya and Panday (2000). The order of total number of nodules production was as per: 45DAS> 30DAS> 15DAS> harvest. Similar results have been reported by Gupta *et al.* (1988) and Pandher *et al.* (1991). Who reported that at 42 DAS (i.e. at 50% flowering stage), the number of total nodules was higher in all the crops studied.

4.1.4. Dry weight of nodules at different growth stages of crops

4.1.4.1 Effect of crops

The dry weights of nodule plant^{-1} were not different for mungbean and blackgram at different days after sowing (Appendix VII and Table 4).

At 15 DAS, the nodule weight produced by mungbean and blackgram was not measurable. At 30 DAS, there was no significant difference of nodule dry weightobjerved for two crops. At 45 DAS, the crop blackgram produced the maximum dry weight of nodules (0.064 g plant^{-1}) and the crop mungbean gave the minimum weight (0.034 g plant^{-1}) though was statistically similar. Nodule dry weight increased almost exponentially with progress of crop growth up to 45 or 50 DAS. The results was similar with those of Bhuiya *et al.* (1984) who reported that inoculation of mungbean seeds gave the highest dry weight of nodules plant^{-1}. Similar results were also reported in soybean by Bhuiyan *et al.*

(1994), Solaiman (1983), Islam *el al.* (1987), Bhuiyan *et al.* (1998) and Akao *et al.* (1990).

4.1.4.2 Effect of fertilizer materials

The different fertilizer materials had no significant effect of dry weight of nodules plant^{-1} at 30 DAS and 45 DAS (Appendix VII and Table 4). Though cowdung and PK+inoculum gave more nodules than chemical fertilizer (NPKB), inoculum and no fertilizer (control) treatments.

Table 4. Influence of fertilizer materials on dry weight of nodules at different crop growth stages of mungbean and blackgram

Treatments	Dry weight of nodules at different days after sowing		
	15	30	45
Crop			
C_1	Trace	0.015	0.034
C_2	Trace	0.027	0.064
LSD $_{(0.05)}$	Teace	NS	NS
Fertilizer materials			
F_1	Trace	0.009	0.031
F_2	Trace	0.012	0.037
F_3	Teace	0.021	0.036
F_4	Trace	0.023	0.044
F_5	Trace	0.040	0.095
LSD $_{(0.05)}$	Trace	NS	0.0502

C_1= BARI mung 6, C_2= BARI mash 1, F_1 = No fertilizer, F_2 = Chemical fertilizer (NPKB), F_3= Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

At 15 DAS, the different fertilizer materials had produced trace amount of nodules with negligible weights. At 30 DAS, the maximum dry weight of nodules (0.04 g plant^{-1}) was produced by PK+inoculum; the minimum dry weight of nodules (0.009 g plant^{-1}) was produced in the no fertilizer or control plot. At 45 DAS, the highest dry weight of nodule (0.095 g plant^{-1}) was produced by PK+inoculum, which was significantly similar to cowdung (0.044 g plant^{-1}) and the lowest dry weight of nodules (0.031 g plant^{-1}) was produced with no fertilizer (control) treatment. Similar results were also reported by Sairam *et al.* (1989); Datt and Bhardwaj (1995); Yadav and Sanoria (1996), Sharma and Khurana (1997); Kavathiya and Pandey (2000); Deb (2000) and Roy (2001).

4.1.4.3 Interaction effect of crops and fertilizer materials

Significant interaction effect between the crops and fertilizer materials were observed at 30 and 45 DAS on dry weight of nodules produced plant^{-1} (Appendix VII and Figure 4).

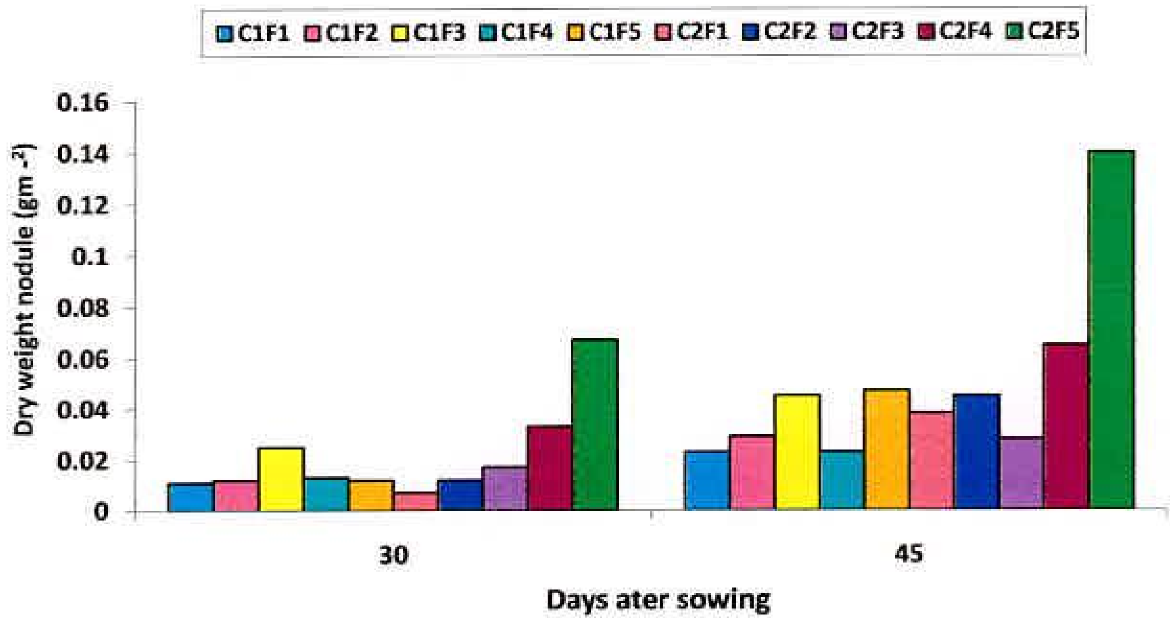


Figure 4. Interaction effect of fertilizer materials on dry weight of nodules at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 30 and 45 DAS was 0.04 and 0.07 respectively)

At 15 DAS, the different fertilizer materials with mungbean and blackgram produced the nodule not measurable. At 30 DAS, the maximum dry weight of nodules (0.067 g plant^{-1}) was obtained from the blackgram with PK+ inoculum which was statistically similar with the interaction of blackgram with cowdung and inoculum with the interaction of mungbean (0.025 g plant^{-1}). The lowest dry weight of nodule was produced in no fertilizer (control) with blackgram (0.007 g plant^{-1}). At 45 DAS, the maximum dry weight of nodule was recorded at the blackgram with PK+ inoculum (0.14 g plant^{-1}). The lowest dry weight of nodules was produced in mungbean with no fertilizer (0.023 g plant^{-1}). Similar results were also reported by Ghosh and Poi (1998) who found that *Rhizobium* and phosphorus solubilizing organism increased nodule dry weight of mungbean.

4.1.5 Leaf area index (LAI) at different days after sowing

The leaf area of plant is one of the major determinants of its growth. It is the ratio of leaf area to its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the growth, number of leaves plant^{-1}, population density and leaf senescence (Khan, 1981). The higher productivity of a crop depends on the persistence of high LAI over a longer period of its vegetative phase. The rate of crop photosynthesis depends on the LAI. LAI increase after germination, reaches the peak level and thereater declines due to increased senescence (Katiya, 1980).

4.1.5.1 Effect of crops

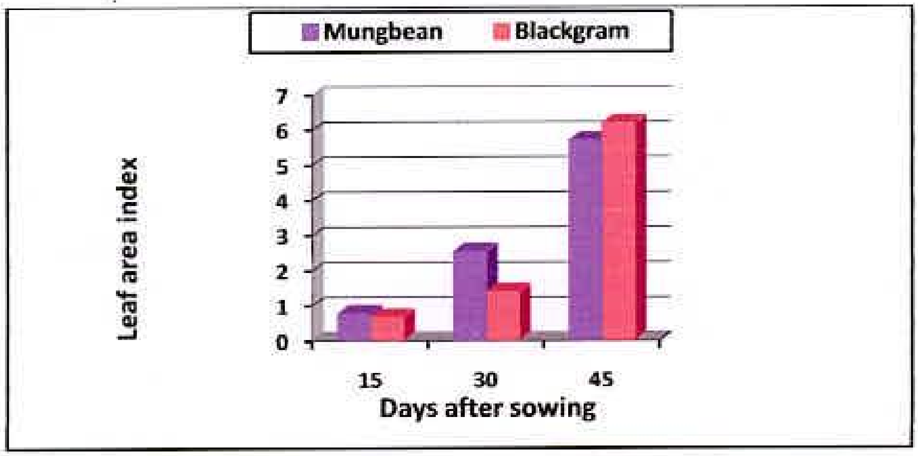
Mungbean and blackgram had different LAI at 15 and 30 DAS but insignificant at 45 DAS (Appendix VIII and Figure 5).

At 15 DAS, the highest LAI (0.77) was found in the mungbean and the lowest leaf area index (0.67) was found in blackgram. Significantly maximum (2.54) and lower (1.39) LAI at 30 DAS were found in the mungbean and blackgram respectively. At 45 DAS, there was no significant variation of LAI observed for mungbean and blackgram.

4.1.5.2 Effect of fertilizer materials

Leaf area index of mungbean and blackgram had significantly influenced by different fertilizer materials at 15 and 30 DAS, but not significant at 45 DAS (Appendix VIII and Figure 5).

At 15 DAS, the maximum LAI (0.83) followed in the PK+inoculum treatement and no fertilizer (control) produced the minimum leaf area index (0.49). At 30 DAS, Inoculum produced the maximum LAI (2.40) that was followed by the PK+inoculum and cowdung and no fertilizer (control) produced the minimum LAI (1.33). At 45 DAS, there was no significant variation of LAI observed among the fertilizer materials.



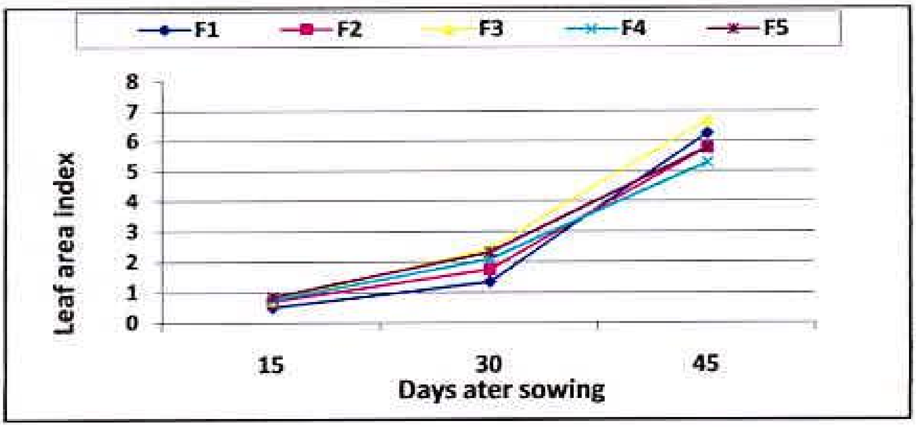


Figure 5. Changes of leaf area index for different fertilizer materials at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS was 0.072, 0.31 and 1.07 crops and 0.038, 0.49 and 1.69 fertilizer Materials, respectively)

4.1.5.3 Interaction effect of crops and fertilizer materials

Significant effects of crops and different fertilizer materials were observed with LAI at 15, 30 and 45 DAS (Appendix VIII and Figure 6). At 15 DAS, the mungbean with PK+inoculum was produced the maximum LAI (0.94) followed by the same crop with cowdung and inoculum and the minimum LAI produced by blackgram with no fertilizer (0.46). At 30 DAS, mungbean produced the maximum LAI (3.01) with PK+inoculum which was statistically similar with the cowdung and inoculum with mungbean and the minimum LAI produced by blackgram with the interaction of no fertilizer (0.86). At 45 DAS, mungbean produced the maximum LAI (6.83) with inoculum which was statistically similar with all the treatment combinations except blackgram with cowdung. The blackgram with cowdung interaction produced the minimum LAI (4.38).

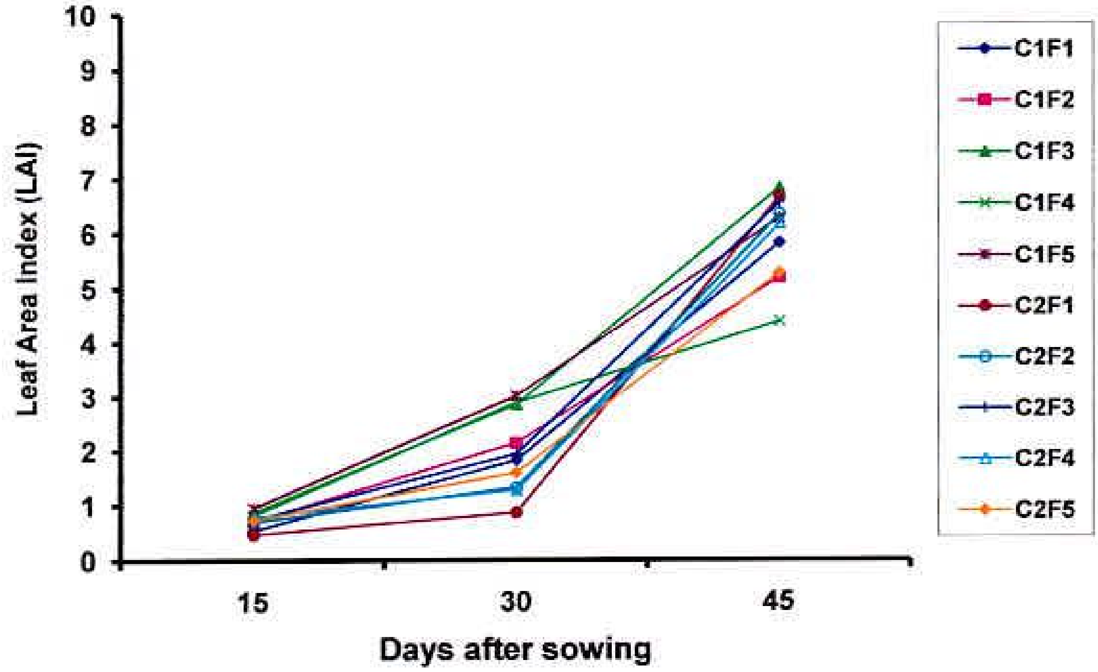


Figure 6. Interaction effect of fertilizer materials on leaf area index at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS was 0.16, 0.70 and 2.40 respectively)

4.1.6 Dry matter production

4.1.6.1 Effect of crops

Mungbean and blackgram significantly different total dry matter production at 15, 30, 45 DAS, and at harvest (Appendix IX and Table 5).

At 15 DAS, the mungbean produced higher dry weight (9.97 g m^{-2}) as compared to the blackgram (5.40 g m^{-2}). At 30 DAS, the maximum dry weight was produced by mungbean (45.29 g m^{-2}) as compared to the blackgram (36.40 g m^{-2}). At 45 DAS, the mungbean produced higher dry weight (314.19 g m^{-2}) compared to the blackgram (236.84 g m^{-2}). At harvest, mungbean produced the maximum dry weight (860.14 g m^{-2}) which was 18.09% higher than the blackgram (704.55 g m^{-2}).

The dry matter production of different plant parts at harvesting time was recorded in which all partitioned components were statistically different for each crop (Appendix X) The dry matter production of different plant parts of two crops statistically maximum except leaf in the mungbean compared to the blackgram (Figure 7).

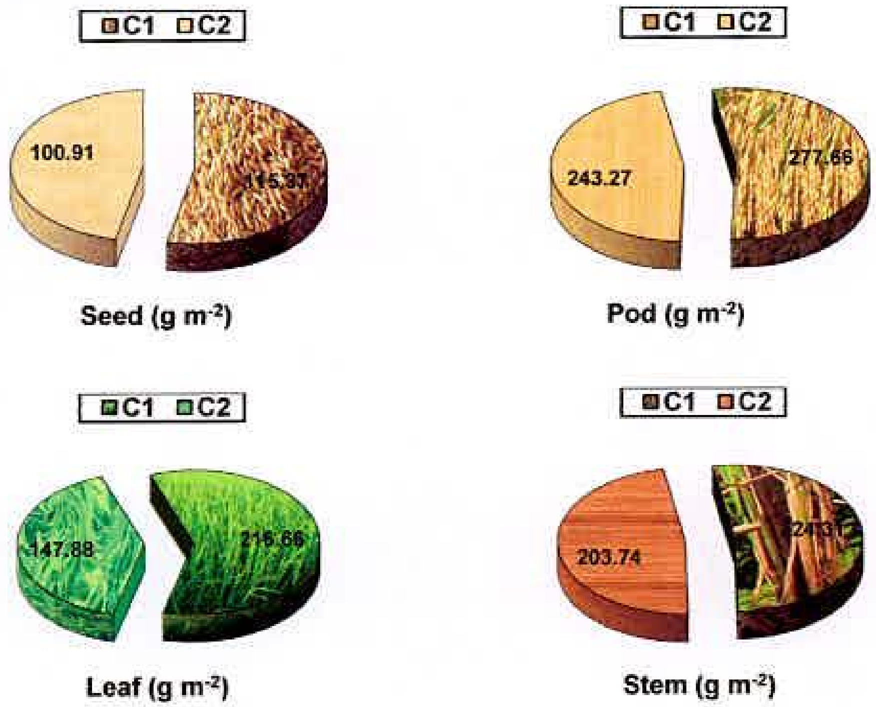


Figure 7. Influence of crop on dry matter production of different plant parts at harvest ($LSD_{0.05}$ stem, leaf, pod and seed was 41.19, 49.59, 15.39 and 67.71 respectively)

4.1.6.2 Effect of fertilizer materials

Various fertilizer materials significantly influenced the total dry weight of plants at 15, 30, 45 DAS, and at harvest (Appendix IX and Table 5). At 15 DAS, the maximum dry weight (9.53 g m^{-2}) was recorded in PK+inoculum and the minimum dry weight (6.85 g m^{-2}) was recorded in no fertilizer (control) and cowdung. At 30 DAS, the maximum dry weight (52.74 g m^{-2}) was recorded in inoculum and the minimum dry weight (35.30 g m^{-2}) was recorded in cowdung. Delowara *et al.* (1991) reported that inoculums alone and P_{50} K_{50}+Inoculum gave significantly higher straw yields as compared to others.

Table 5. Influence of fertilizer materials on total dry matter at different crop growth stages of mungbean and blackgram

Treatments	Total dry weight (g m^{-2}) at different days after sowing			
	15	30	45	At harvest
Crop				
C_1	9.97	45.29	314.19	860.14
C_2	5.40	36.40	236.84	704.55
LSD $_{(0.05)}$	1.665	6.224	41.611	108.268
Fertilizer materials				
F_1	6.85	38.47	213.65	692.55
F_2	7.68	40.65	303.25	612.75
F_3	7.54	52.74	301.35	964.70
F_4	6.85	35.30	284.00	823.03
F_5	9.53	37.08	275.33	818.70
LSD $_{(0.05)}$	2.633	9.840	65.792	171.186
CV (%)	27.99	19.68	19.51	17.88

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 = No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

At 45 DAS, chemical fertilizer (NPKB) produced the maximum dry weight (303.25 g m^{-2}) which was similar with the inoculum, PK+inoculum and cowdung (275.33 g m^{-2}). The lowest dry weight (213.65 g m^{-2}) was obtained with the no fertilizer (control) treatment. At harvest, the maximum dry weight (964.70 g m^{-2}) was obtained from the inoculum which was similar to

PK+inoculum (818.70 g m^{-2}) and cowdung (8.23.03 g m^{-2}). The lowest dry weight (612.75 g m^{-2}) was obtained from the chemimical fertilizer (NPKB). Shukla and Dixit (1990) also reported that inoculated seeds increased the dry matter production of mungbean by 12, 10, 10 and 10.5% at 30, 45, 60 DAS and harvest stages respectively over the uninoculated seeds. Das, *et al.* (1999) reported higher dry matter yield in inoculated treatment over the uninoculated seeds. *Bradyrhizobium* inoculation promoted nodulation and fixed more nitrogen, which was also expressed through dry matter production (Raunt and Kohire, 1991). The dry matter production of different plant parts at harvesting time was recorded in which dry weight of all parts were influenced by fertilizer materials (Appendix X and Figure 8). The highest dry weight of seeds, stem, leaf and pod was produced by the inoculum. The lowest dry weight of all plant parts except seed was obtained from the chemical fertilizer (NPKB).

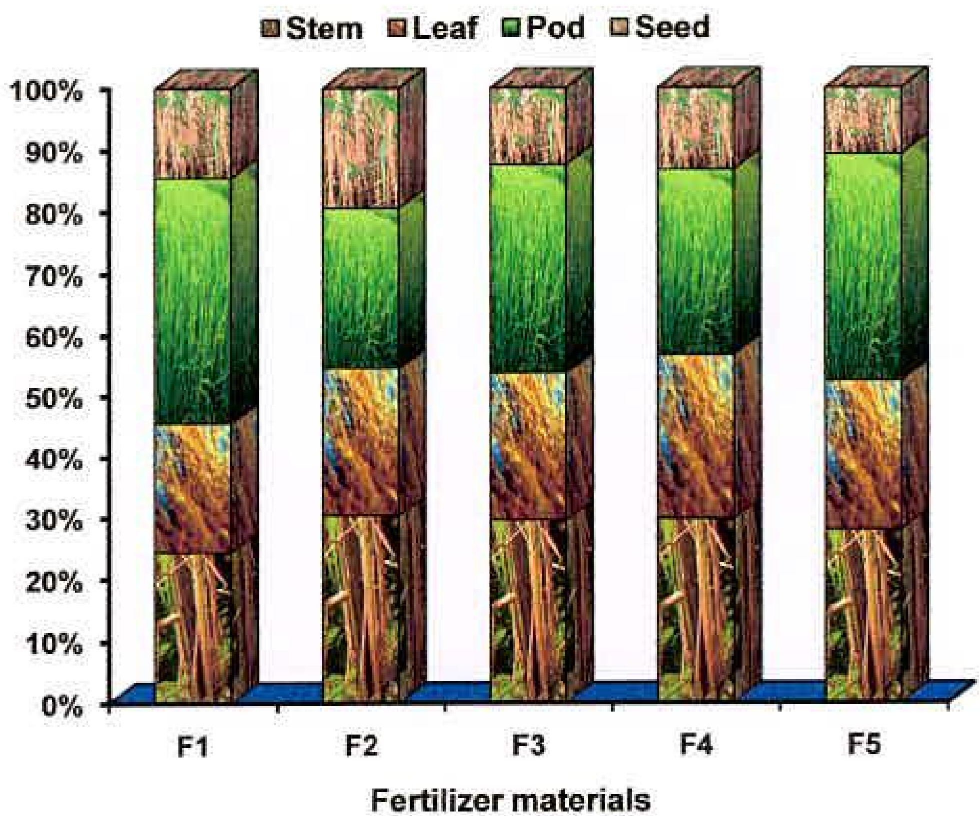


Figure 8. Influence of fertilizer materials on dry matter production in different plant parts at harvest ($LSD_{0.05}$ stem, leaf, pod and seed was 65.12, 78.42, 107.05 and 24.33 respectively)

4.1.6.3 Interaction effect of crops and fertilizer materials

Crop and fertilizer materials influenced the dry matter production of mungbean and blackgram at 15, 30, 45 DAS and at harvest (Appendix IX and Figure 9).

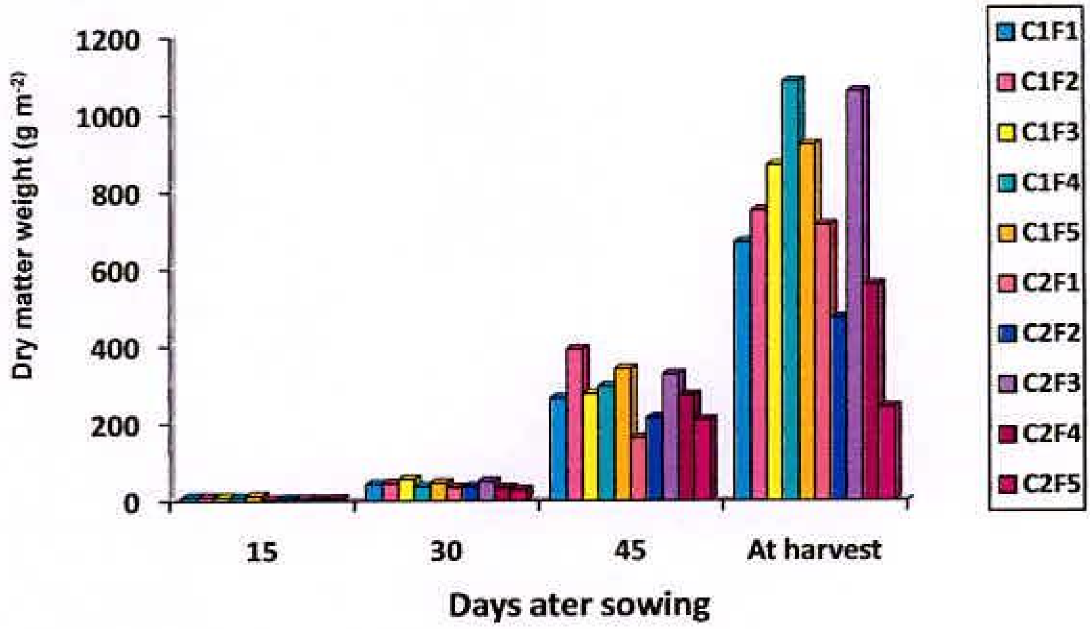


Figure 9. Interaction effect of fertilizer materials on dry matter production at different crop growth stages of mungbean and blackgram ($LSD_{0.05}$ 15, 30 and 45 DAS and at harvest 3.72, 13.92, 93.04 and 242.09 respectively)

At 15 DAS, the highest dry weight (13.05 g m^{-2}) was observed in the mungbean with PK+inoculum and lowest dry weight (13.05 g m^{-2}) was observed in the blackgram with no fertilizer (control). However, at 30 DAS, the highest dry weight (55.50 g m^{-2}) was obtained from the mungbean with inoculum which was similar to blackgram with inoculum (49.98 g m^{-2}). Lowest dry weight (13.05 g m^{-2}) was observed in the blackgram with PK+inoculum. Again at 45 DAS, maximum dry weight (392.10 g m^{-2}) was produced by the mungbean with chemical fertilizer (NPKB) which was similar to mungbean with the interaction of PK+ inoculum and blackgram with inoculum (49.98 g m^{-2}) and lowest dry weight (13.05 g m^{-2}) was observed in the blackgram with no fertilizer (control). At harvest, mungbean with cowdung produced the highest dry weight (1085.80 g m^{-2}) which was similar to the dry matter proudced by blackgram with inoculum (1059.90 g m^{-2}). The lowest dry weight was produced by the blackgram with chemical fertilizer (473.10 g m^{-2}).

4.1.7 Days to flowering

4.1.7.1 Effect of crops

There was no difference between the duration of flowering of the crops (Appendix VI and Table 6). The mungbean and blackgram needed statistically similar duration for flowering (30.40 days for mungbean and 30.13 days or blackgram, respectively).

4.1.7.2 Effect of fertilizer materials

The different fertilizer materials had affected flowering time (Appendix VI Table 6). Cowdung and no fertilizer needed the similared longest duration for flowering (31 days). Inoculum and PK+ inoculum needed the shortest duration for flowering (29.33 days).

Table 6. Influence of fertilizer materials on flowering of mungbean and blackgram

Treatments	Days to flowering (days)
Crop	
C_1	30.40
C_2	30.13
LSD $_{(0.05)}$	NS
Fertilizer materials	
F_1	31.00
F_2	30.66
F_3	29.33
F_4	31.00
F_5	29.33
LSD $_{(0.05)}$	0.974
Interaction of Crop and Fertilizer materials	
C_1F_1	31.33
C_1F_2	31.00
C_1F_3	29.33
C_1F_4	31.00
C_1F_5	29.33
C_2F_1	30.67
C_2F_2	30.33
C_2F_3	29.33
C_2F_4	31.00
C_2F_5	29.33
LSD $_{(0.05)}$	1.377
CV (%)	2.62

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 = No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.1.7.3 Interaction effect of crops and fertilizer materials

Interaction effect of crops and fertilizer materials were observed the flowering dates (Appendix VI and Table 6). Mungbean plants in the no fertilizer or control plot required the longest time for flowering (31.33 days). Similar trend was observed in other interactions of mungbean and blackgram with fertilizer materials. Inoculum and PK+inoculum treatment of mungbean and blackgram were resulted in the shortest time for flowering (29.33 days).

4.2 Yield and other crop characters

4.2.1 Number of branches plant^{-1}

The number of branches plant^{-1} of mungbean and blackgram was affected by fertilizer materials and their interaction effects were observed.

4.2.1.1 Effect of crops

Each crop produced significantly different number of branches plant^{-1} (Appendix XI and Table 7). Results showed that, the blackgram produced maximum number of branches (3.23 plant^{-1}) and the minimum was obtained from the mungbean (0.57 plant^{-1}). The variation in the production of branches plant^{-1} might be due to genetic constituents of the crops.

4.2.1.2 Effect of fertilizer materials

Fertilizer materials significantly influenced the number of branches plant^{-1} (Appendix XI and Table 7). The maximum number of branches (2.23 plant^{-1}) was obtained from the Inoculum which was statistically similar to PK+inoculum, chemical fertilizer (NPKB) and no fertilizer (control). The lowest number of branches (1.17 plant^{-1}) was obtained from the control plot (no fertilizer).

4.2.1.3 Interaction effect of crops and fertilizer materials

The interaction effects of crops and fertilizer materials were observed with the number of branches plant^{-1} (Appendix XI and Figure 10). The maximum number of branches plant^{-1} (4.00) was obtained from the blackgram with inoculum, which was similar to the interactions of PK+inoculum, chemical fertilizer (NPKB) and no fertilizer (control) with blackgram (3.33 plant^{-1}). The lowest number of branches plant^{-1} (0.47) was obtained from the mungbean with no fertilizer (control).

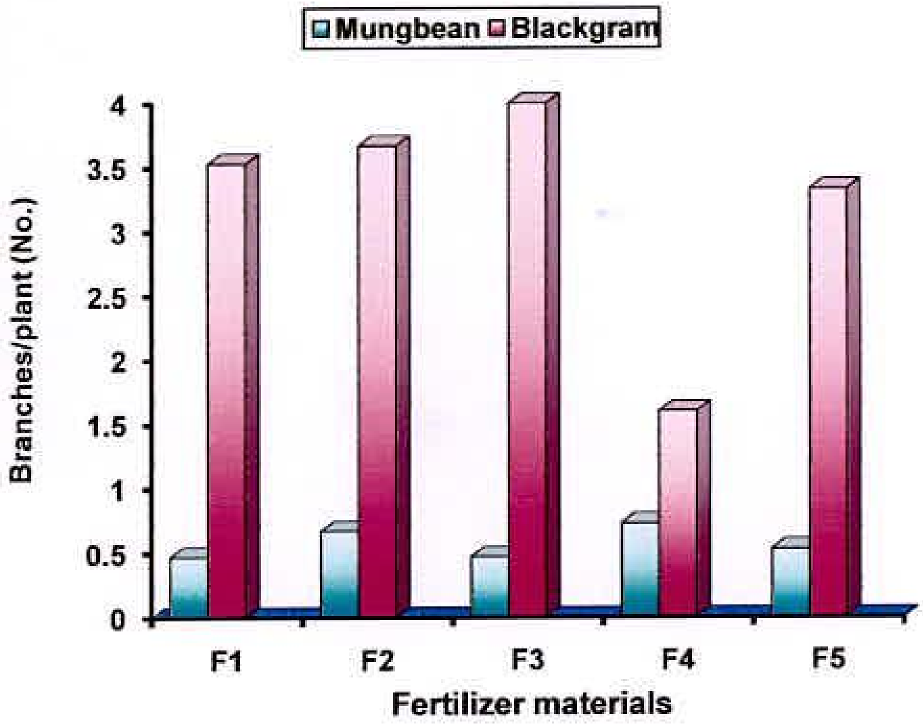


Figure 10. Interaction effect of fertilizer materials on branches plant^{-1} of mungbean and blackgram ($LSD_{0.05} = 1.36$)

4.2.2 Number of pods plant^{-1}

4.2.2.1 Effect of crops

The number of pods plant^{-1}was significantly differenent with two crops (Appendix XI and Table 7). Results showed that the blackgram produced maximum number of pods (44.56 plant^{-1}) and the minimum was obtained from the mungbean (20.52 plant^{-1}). The variation in the production of pods plant^{-1} as related to genetic constituents of the crops.

4.2.2.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on the number of pods plant^{-1} (Appendix XI and Table 7). The maximum and minimum number of pods plant^{-1}were recorded from the no fertilizer (35.93) and inoculum (29.47plant^{-1}) though the difference was not statistically different.

Table 7. Influence of fertilizer materials on different crop characters of mungbean and blackgram

Treatments	Branches/ plant (No.)	Pods/ plant (No.)	Pod length (cm)	Seeds/ pod (No.)	1000-seed weight (g)
Crop					
C_1	0.57	20.52	9.22	10.87	50.95
C_2	3.23	44.56	4.06	6.13	40.82
LSD $_{(0.05)}$	0.607	7.797	0.274	1.074	1.628
Fertilizer materials					
F_1	2.00	35.93	6.98	8.67	45.83
F_2	2.17	29.47	6.16	8.17	45.82
F_3	2.23	32.83	6.97	9.00	45.30
F_4	1.17	31.90	6.39	8.50	45.75
F_5	1.93	32.57	6.68	8.17	46.71
LSD $_{(0.05)}$	0.959	NS	0.434	NS	NS
CV (%)	41.11	30.95	5.34	16.32	4.58

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 =No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.2.2.3 Interaction effect of crops and fertilizer materials

The number of pods plant^{-1} was significantly different with two crops and fertilizer materials (Appendix XI and Figure 11). The maximum number of pods plant^{-1} (51.27) was obtained from the blackgram with no fertilizer (control), which was similar to PK+inoculum, cowdung, chemical (NPKB) fertilizer and inoculum with blackgram (41.73 plant^{-1}). The lowest number of pods plant^{-1} (18.33) was obtained from the mungbean with PK+inoculum.

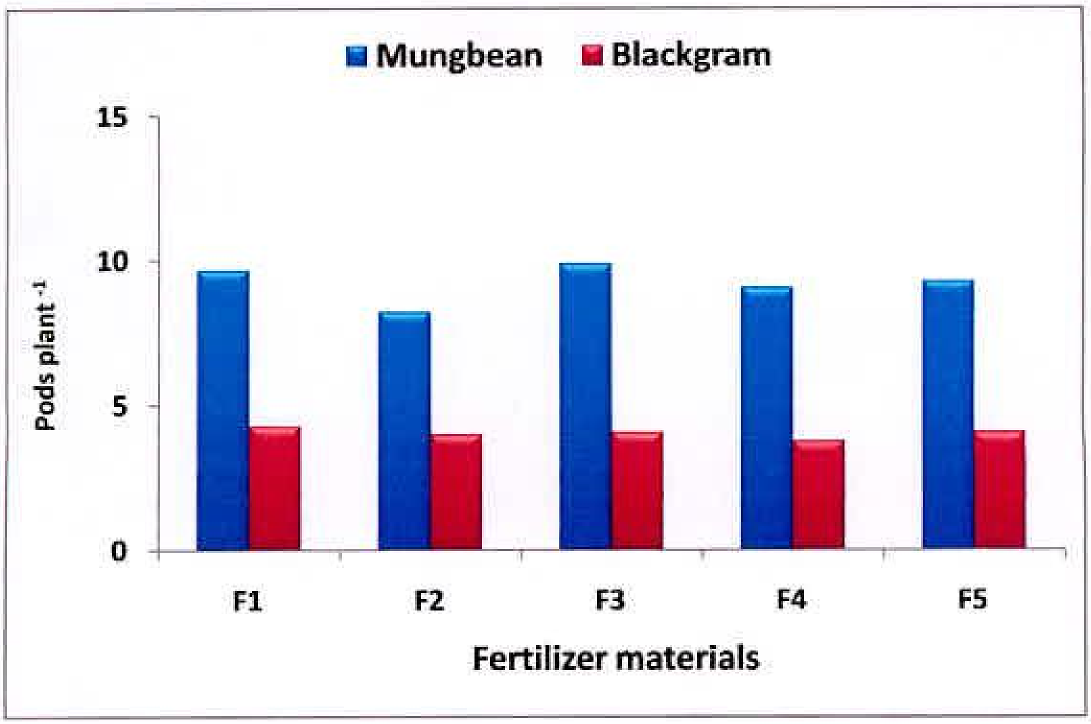


Figure 11. Interaction effect of fertilizer materials on pods plant^{-1}of mungbean and blackgram ($LSD_{0.05}$ = 17.43)

4.2.3 Pod length

4.2.3.1. Effect of crops

The pod length of mungbean and blackgram were significantly different (Appendix XI and Table 7). The maximum (9.22 cm) and minimum (4.06 cm) pod length was recorded from mungbean and blackgram, respectively.

4.2.3.2. Effect of fertilizer materials

Various fertilizer materials significantly effected pod length (Appendix XI and Table 7). The maximum pod length was (6.98 cm) observed in no fertilizer which was statistically similar to inoculum and PK+ inoculum treatments. The minimum pod length was (6.16 cm) observed with chemical fertilizer treatments.

4.2.3.3 Interaction effect of crops and fertilizer materials

The pod length was significantly influenced by the interaction effects of crops and fertilizer materials (Appendix XI and Figure 12). The highest pod length (9.88 cm) was recorded from the mungbean with inoculum treatment which was was statistically similar to no fertilizer (control) treatment and PK+inoculum treatment. The lowest pod length (3.76) was obtained from the blackgram with cowdung.

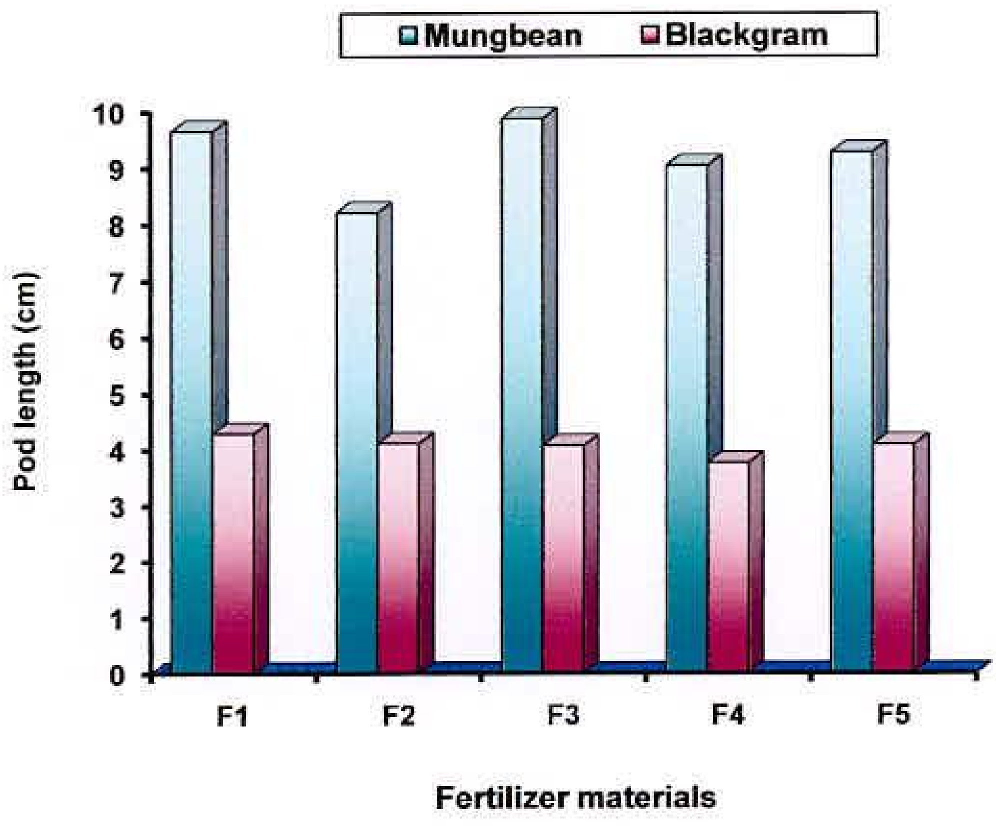


Figure 12. Interaction effect of fertilizer materials on pod length of mungbean and blackgram ($LSD_{0.05}$ = 0.613)

4.2.4 Number of seeds pod^{-1}

4.2.4.1. Effect of crops

Each crop produced significantly different number of seeds pod^{-1} (Appendix XI and Table 7). Mungbean produced the maximum number of seeds pod^{-1} (10.87) and blackgram produced the lowest number of seeds pod^{-1} (6.13). The number of seeds pod^{-1} was 43.61% higher in blackgram as compared to mungbean.

4.2.4.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on the number of seeds pod^{-1} (Appendix XI and Table 7). The maximum number of seeds pod^{-1} was recorded from the inoculum (9.00) and the minimum number of seeds pod^{-1} was recorded from PK+inoculum and chemical fertilizer (8.17) though the difference was statistically similar. The result was in agreement with Shukla and Dixit (1990), Mozumder (1998) and Naher (2000), who reported that *Bradyrhizobium* inoculation did not significantly increase the number of mature seeds pod^{-1}.

4.2.4.3 Interaction effect of crops and fertilizer materials

The number of seeds pod $^{-1}$ was significantly influenced by the interaction of crop and fertilizer materials (Appendix XI and Figure 13). The maximum number of seeds pod^{-1} (12.00) was obtained from mungbean with the interaction of inoculum, which was similar with the interaction of PK+inoculum, cowdung, chemical fertilizer (NPKB) and no fertilizer (control) with mungbean (9.67). The lowest number of seeds pod^{-1} (6.00) was obtained from blackgram with the interaction of inoculum, cowdung, chemical fertilizer (NPKB) and no fertilizer (control).

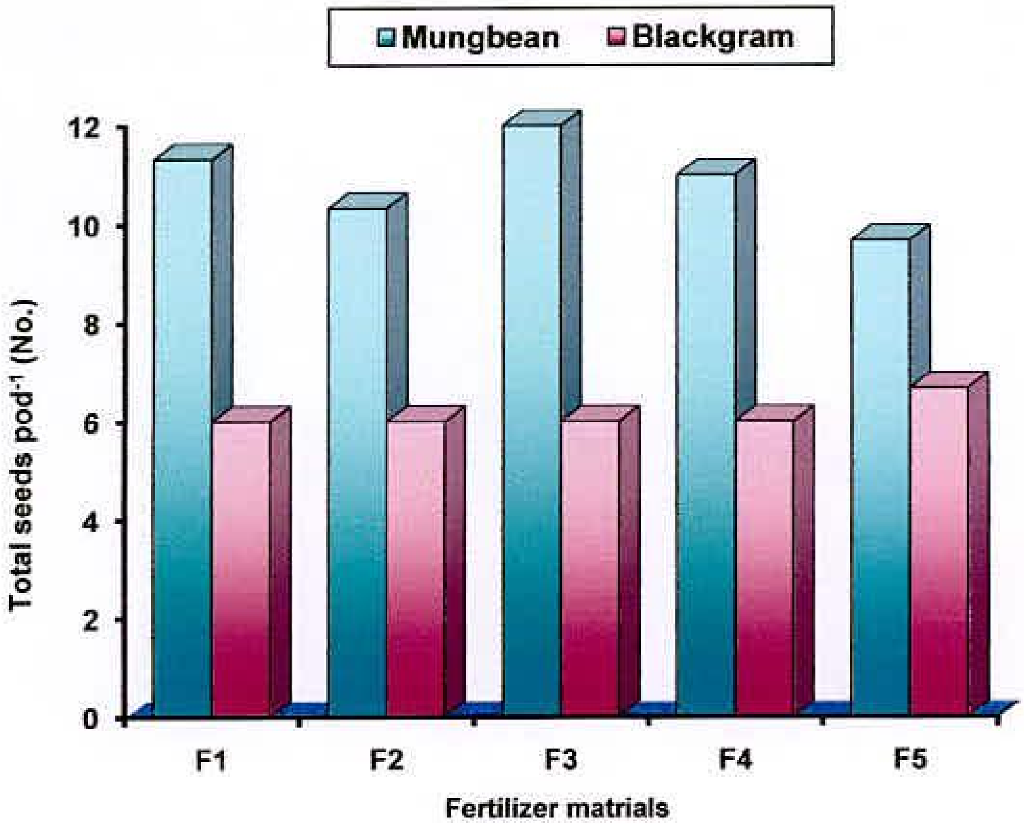


Figure 13. Interaction effect of fertilizer materials on number of seeds pod^{-1} of mungbean and blackgram ($LSD_{0.05} = 2.40$)

4.2.5 Weight of 1000-seeds

4.2.5.1 Effect of crops

The weight of 1000-seeds was significantly influenced by the crop (Appendix XI and Table 7). The highest weight of 1000-seeds (50.95 g) was obtained from mungbesn and the lowest weight of 1000-grains (40.82 g) was obtained from blackgram. The variation of 1000-seeds weight between two crops might be due to genetic constituents of the crops.

4.2.5.2 Effect of fertilizer materials

There was no significant variation observed among the fertilizer materials in respect to weight of 1000-seeds (Appendix XI and Table 7).The maximum weight of 1000-seeds (46.71 g) was obtained from the PK+inoculum and the minimum weight of 1000-seeds (45.30 g) was obtained from the inoculum treatment.

4.2.5.3 Interaction effect of crops and fertilizer materials

Interaction effects between crops and fertilizer materials were found significant in respect of weight of 1000-seeds (Appendix XI and Figure 14). The highest weight of 1000-seeds (51.54 g) was obtained from mungbean with the interaction of cowdung, which was similar with the interaction of PK+inoculum, inoculum, chemical fertilizer (NPKB) and no fertilizer (control) with mungbean (49.76 g). The lowest weight of 1000-seeds (39.48 g) was obtained from blackgram with the interaction of inoculum.

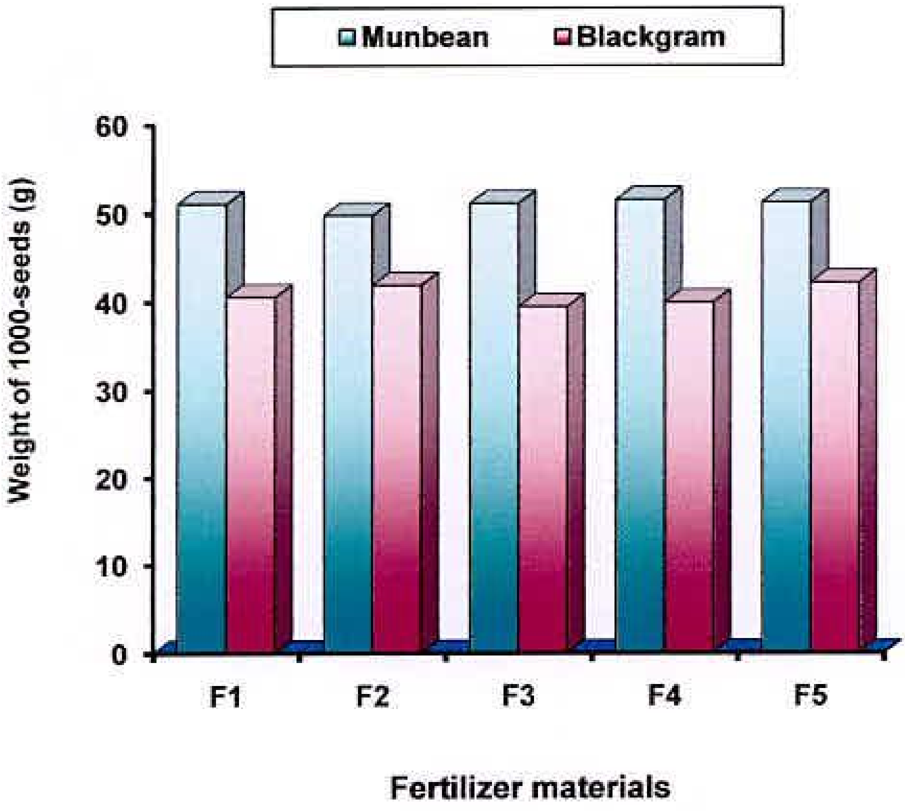


Figure 14. Interaction effect of fertilizer materials on weight of 1000-seeds of mungbean and blackgram ($LSD_{0.05}$ = 3.64)

4.2.6 Seed yield

4.2.6.1. Effect of crops

Seed yield was not significantly influenced by the crop (Appendix XI and Table 8). The maximum seed yield (1.30 t ha^{-1}) was obtained from the mungbean compared to the yield (1.24 t ha^{-1}) of blackgram. Mungbean gave 4.61% higher yield than blackgram. Mungbean produced higher number of seeds pod^{-1} and seed weight but lower number of pods $plant^{-1}$which resulted in similar seed yield. Similar yields of BARI mung 6 and BARI mash 1 was also reported by Hussain *et al*., (2006).

4.2.6.2. Effect of fertilizer materials

Fertilizer materials had significant effect on seed yield (Appendix XI and Table 8). Inoculum treatment produced significantly the highest seed yield (1.47 t ha^{-1}) which was similar with the PK+inoculums and chemical fertilizer (NPKB). The lowest seed yield (1.10 t ha^{-1}) was obtained from cowdung. Ashraf *et al.* (2003) showed that seed inoculation with *Bradyrhizobium* strain significantly in mungbean seed yield. Similar results were also reported by Shukla and Dixit (1996), Sharma and Khurana (1997), Chowdhury *et al.* (2000) and Solaiman (2002).

4.2.6.3 Interaction effect of crops and fertilizer materials

Interaction effect between crops and fertilizer materials was found significant in respect of seed yield (Appendix XI and Figure 15). The highest seed yield (1.59 t ha^{-1}) was obtained from mungbean with the interaction of inoculum and which was similar with the interaction of PK+inoculum, chemical fertilizer (NPKB) and no fertilizer (control) with mungbean (1.33 t ha^{-1}) and blackgram with the interaction of Inoculum and no fertilizer (1.32 t ha^{-1}). The lowest seed yield (1.02 t ha^{-1}) was obtained from mungbean with cowdung. Mungbean with inoculum gave 35.85% higher yield than mungbean with cowdung. The yield increase due to inoculation alone was 68% in lentil as reported by Delowara *et* *al*. (1991). Subba Rao and Tilak (1977) also obtained 32.2% higher yield in lentil with inoculation over the uninoculated control. Herreara and Longeri (1985) recorded 114% higher grain yield of lentil due to inoculation.

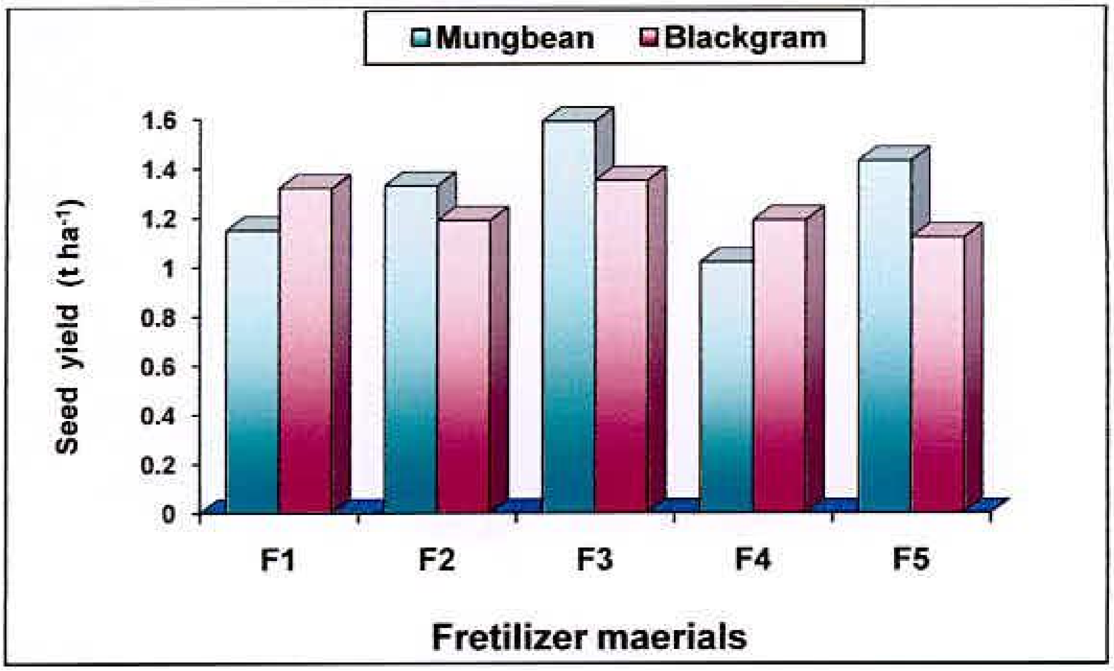


Figure 15. Interaction effect of fertilizer materials on seed yield of mungbean and blackgram ($LSD_{0.05}$ = 0.32)

4.2.7 Stover yield

4.2.7.1. Effect of crop

Stover yield was significantly for each crop (Appendix XI and Table 8). The highest stover yield (8.82 t ha^{-1}) was obtained from the mungbean as compared to the yield (6.69 t ha^{-1}) of blackgram. Mungbean gave 24.15% higher yield than blackgram. Saini and Jaiswal (1991), and Samanta *et al.* (1999) reported that temperature had tremendous influence on mungbean growth and observed that high temperature favored vegetative growth and consequently increased in stover yield.

Table 8. Influence of fertilizer materials on yield and harvest index of mungbean and blackgram

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Shelling percentge
Crop					
C_1	1.30	8.82	9.97	14.26	30.96
C_2	1.24	6.69	7.71	16.40	39.87
LSD $_{(0.05)}$	NS	1.243	1.202	NS	2.338
Fertilizer materials					
F_1	1.24	6.93	7.99	16.07	34.84
F_2	1.26	6.13	7.26	19.39	34.73
F_3	1.47	9.31	10.46	13.67	36.60
F_4	1.10	8.19	9.20	14.25	36.68
F_5	1.27	8.24	9.29	13.26	34.21
LSD $_{(0.05)}$	0.226	1.965	1.900	5.854	3.697
CV (%)	14.56	20.69	17.56	31.26	8.53

C_1 = BARI mung 6, C_2 = BARI mash 1, F_1 = No fertilizer (Control), F_2 = Chemical fertilizer (NPKB), F_3 = Inoculum, F_4 = Cowdung and F_5 = PK+Inoculum

4.2.7.2. Effect of fertilizer materials

Fertilizer materials had significant effect on stover yield (Appendix XI and Table 8). Inoculum produced significantly the highest stover yield (9.31 t ha^{-1}) which was similar to the PK+inoculum and cow dung (8.19 t ha^{-1}). The lowest stover yield (6.13 t ha^{-1}) was obtained from chemical fertilizer (NPKB) that similar to no fertilizer (contol) application. Increased nodulation due to seed inoculation resulting in increase in the vegetative growth, which had gave increase seed yield as well as stover yield. The result obtained was in agreement with Shukla and Dixit (1996) and Solaiman (1999). Similar result was reported by Gill *et al.* (1985) who reported that inoculation significantly increased seed and straw yield.

4.2.7.3 Interaction effect of crops and fertilizer materials

Interaction effect between crops and fertilizer materials was found significant in respect to stover yield (Appendix XI and Figure 16). The highest stover yield (10.85 t ha^{-1}) was obtained from mungbean with the interaction of cowdung, which was similar to the interaction of PK+inoculum and inoculum with mungbean (9.33 t ha^{-1}) and blackgram with inoculum (8.92 t ha^{-1}). The lowest stover yield (4.73 t ha^{-1}) was obtained from blackgram with chemical fertilizer (NPKB).

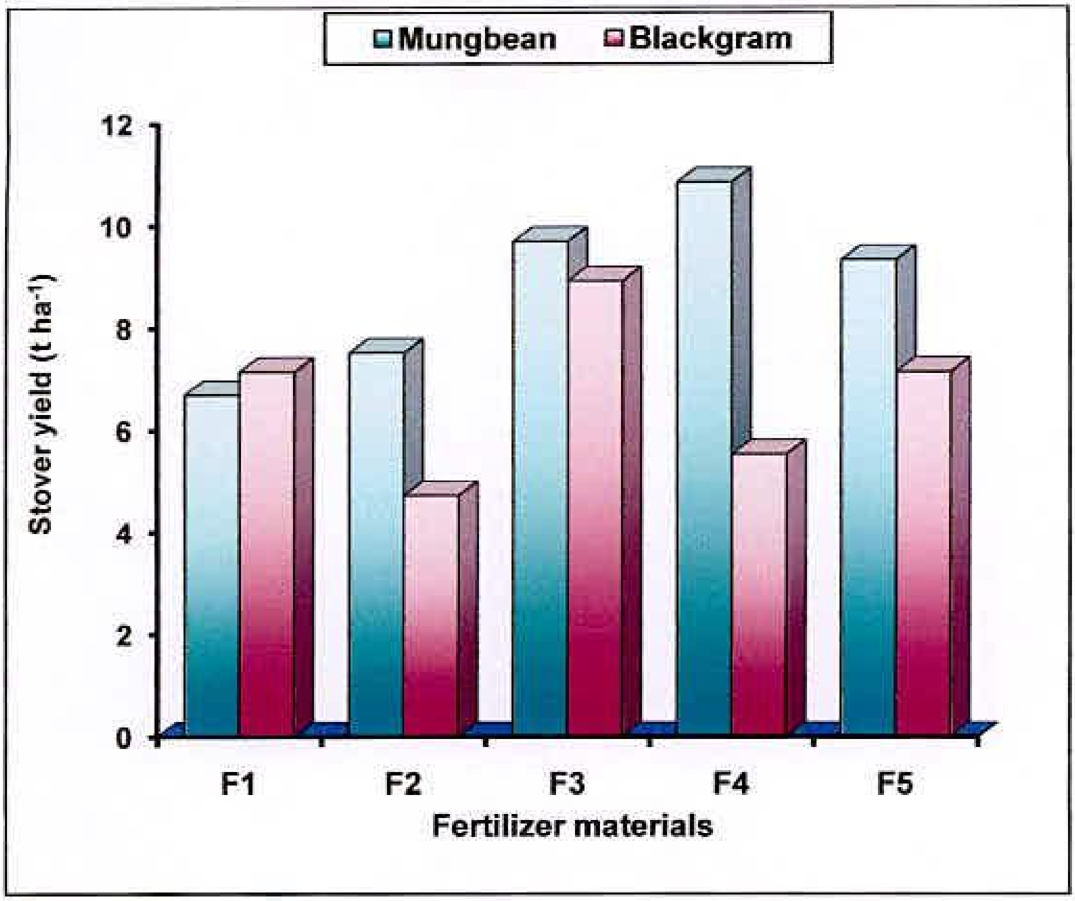


Figure 16. Interaction effect of fertilizer materials on stover yield of mungbean and blackgram ($LSD_{0.05}$ = 2.77)

4.2.8 Biological yield

4.2.8.1. Effect of crops

Biological yield was significantly influenced by the crop (Appendix XI and Table 8). The maximum biological yield (9.97 t ha^{-1}) was obtained from the mungbean compared to the yield (7.71 t ha^{-1}) of blackgram. Mungbean gave 22.67% higher biological yield than blackgram.

4.2.8.2. Effect of fertilizer materials

Fertilizer materials had significant effect on biological yield (Appendix XI and Table 8). Inoculum produced significantly the highest biological yield (10.46 t ha^{-1}) which was similar to the PK+inoculums (9.29 t ha^{-1}) and cowdung (9.20 t ha^{-1}). The lowest biological yield (7.26 t ha^{-1}) was obtained from chemical fertilizer (NPKB) thus similar to no fertilizer (control) application.

4.2.8.3 Interaction effect of crops and fertilizer materials

Interaction effect between crops and fertilizer materials was found significant in respect of biological yield (Appendix XI and Figure 17). The maximum biological yield (11.77 t ha^{-1}) was obtained from mungbean with cowdung, which was similar to inoculum with mungbean (10.49 t ha^{-1}). The lowest biological yield (5.66 t ha^{-1}) was obtained from blackgram with chemical fertilizer (NPKB).

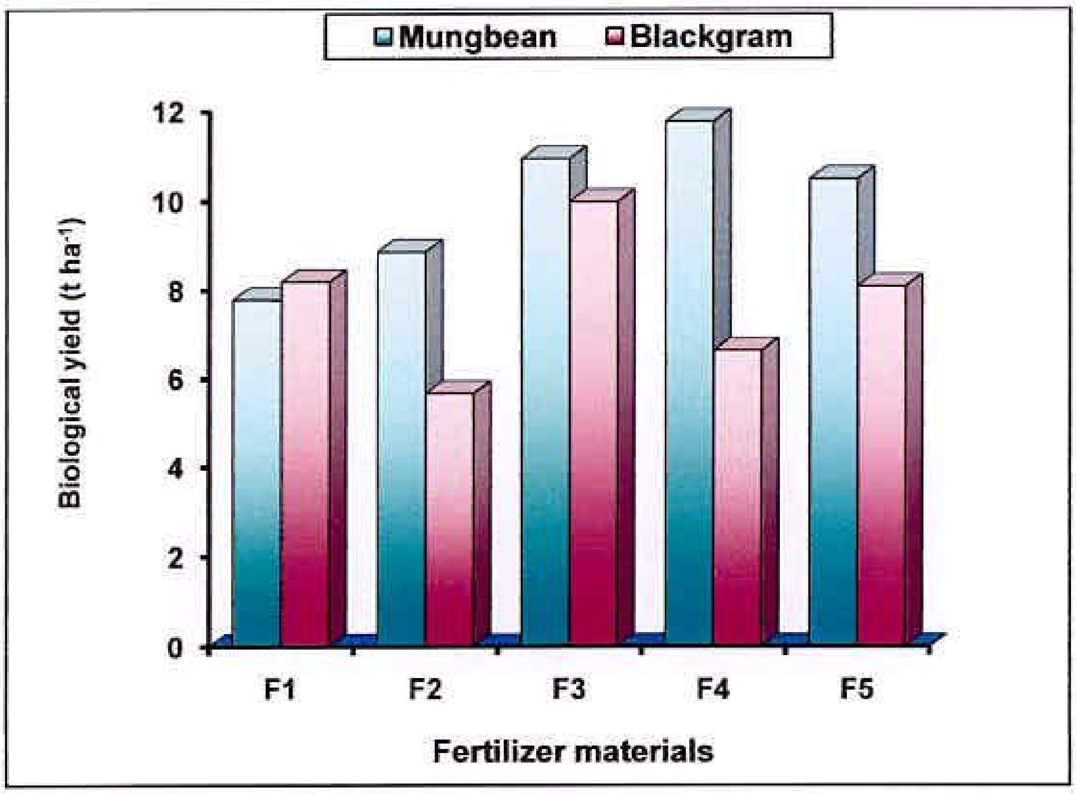


Figure 17. Interaction effect of fertilizer materials on biological yield of mungbean and blackgram ($LSD_{0.05}$ = 2.68)

4.2.9 Harvest index

4.2.9.1 Effect of crops

Harvest index was not significantly affected by the crop (Appendix XI and Table 8). The maximum harvest index (16.40%) was found from blackgram and the minimum harvest index (14.26%) was found from mungbean. The harvest index was 13.05% higher in the mungbean as compared to blackgram. Comperativity higher seed yield and lower biological yield might be the probable reason for the maximum harvest index of blackgram.

4.2.9.2 Effect of fertilizer materials

Fertilizer materials had significant effect on harvest index (Appendix XI and Table 8). Chemical fertilizer (NPKB) produced significantly the highest harvest index (19.39%) which was similar to no fertilizer (16.07%), cowdung (14.25%) and inoculum (13.67%) reatments. The lowest harvest index (13.26) was obtained from PK+inoculum.

4.2.9.3 Interaction effect of crops and fertilizer materials

Interaction effect between crops and fertilizer materials was found significant in respect to harvest index (Appendix XI and Figure 18). The maximum harvest index (19.99%) was obtained from blackgram with the interaction of cowdung, which was similar to the interaction of all other fertilizer materials except the control (no fertilizer) with mungbean and blackgram. The lowest harvest index (8.51%) was obtained from mungbean with cowdung.

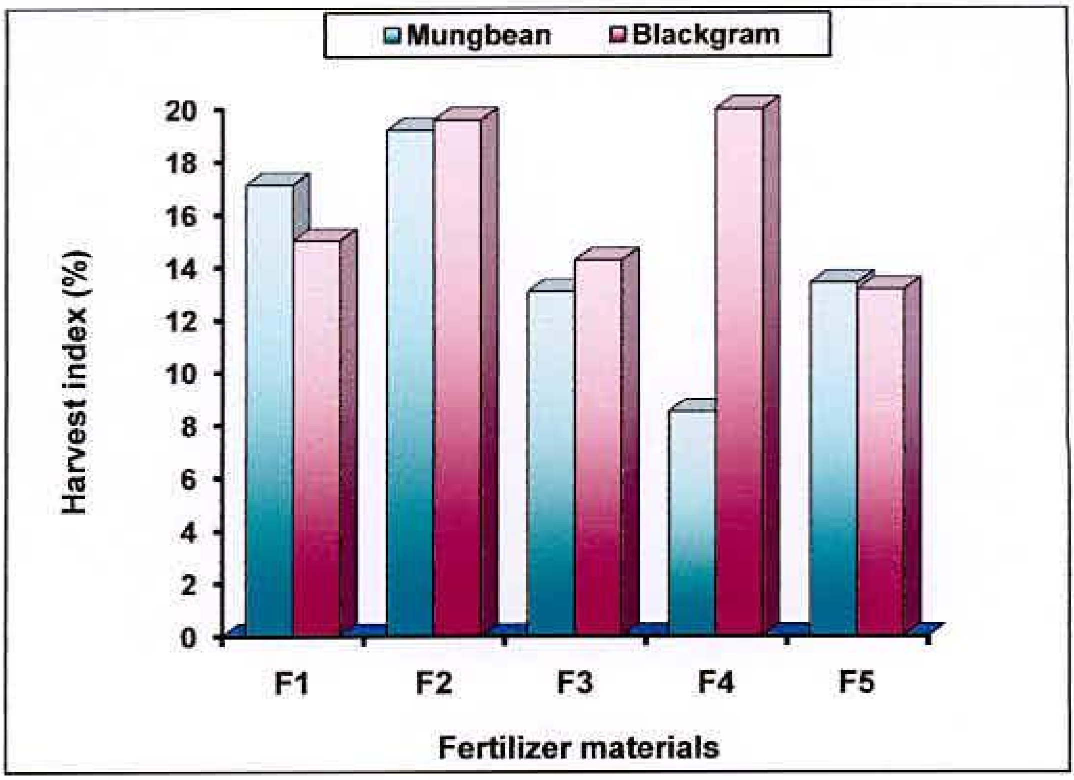


Figure 18. Interaction effect of fertilizer materials on harvest index of mungbean and blackgram ($LSD_{0.05}$ = 8.29)

4.2.10 Shelling percentage

4.2.10.1 Effect of crops

Shelling percentage was significant effect by the crop (Appendix XI and Table 8). The highest shelling percentage (39.87) was found from blackgram and the lowest shelling percentage (30.96) was found from mungbean. The shelling percentage was 22.35% higher in the blackgram as compared to mungbean.

4.2.10.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on shelling percentage (Appendix XI and Table 8). Cowdung produced significantly the highest shelling percentage (36.68) and the lowest harvest index (34.21) was obtained from PK+inoculum.

4.2.10.3 Interaction effect of crops and fertilizer materials

Interaction effect between crops and fertilizer materials was found significant in respect to shelling percentage (Appendix XI and Figure 19). The maximum shelling percentage (43.24) was obtained from blackgram with cowdung, which was similar with the interaction of blackgram with inoculum and no fertilizer (40.26). The lowest shelling percentage (29.41) was obtained from mungbean with the interaction of no fertilizer (control).

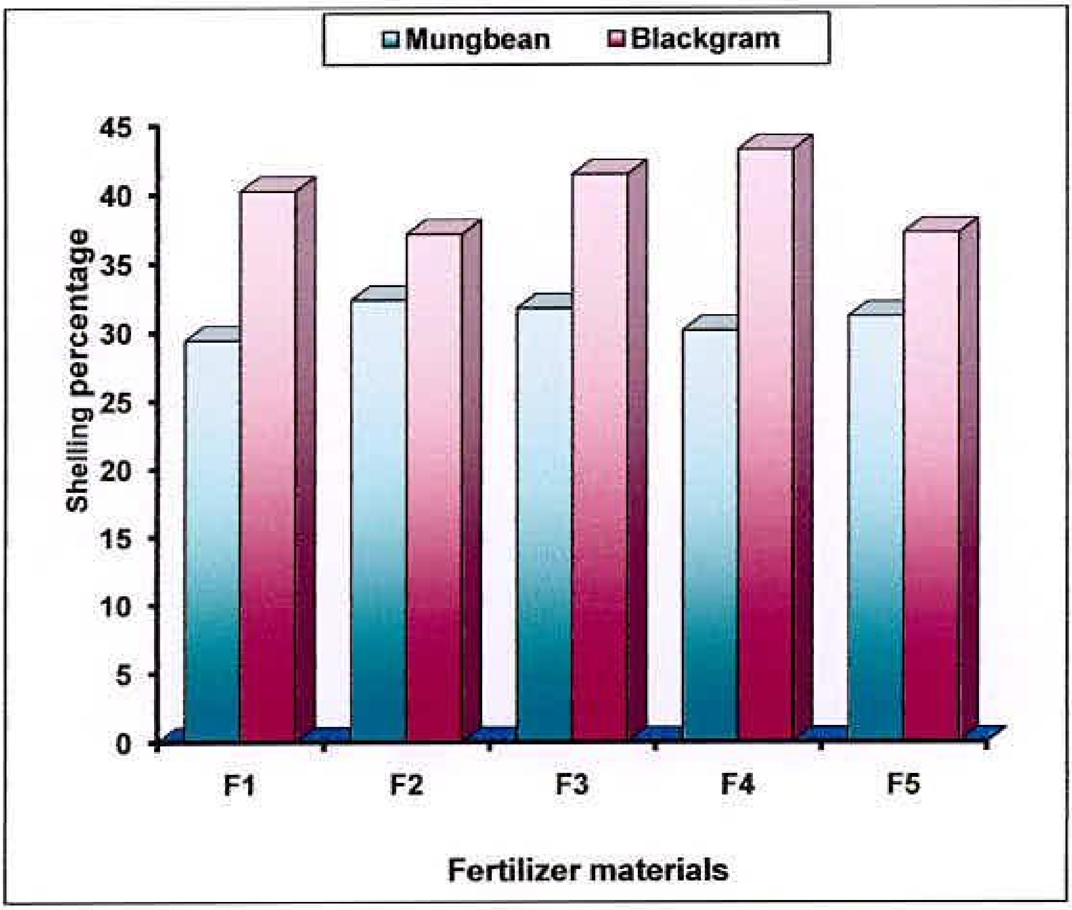


Figure 19. Interaction effect of fertilizer materials on Shelling percentage of mungbean and blackgram ($LSD_{0.05}$ = 5.23)

Chapter 5
Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from March 2007 to June 2007 to study the performance of different fertilizer materials on mungbean and blackgram in Kharif 1 season under the Modhupur Tract (AEZ-28). The experiment was comprised with two crops viz. BARI mung 6 (C_1) and BARI mash 1 (C_2) and five fertilizer materials viz. No fertilizer (F_1), Chemical fertilizer (NPKB) (F_2), Inoculum (F_3), Cowdung (F_4) and PK+ Inoculum (F_5).The experiment was laid out in a split-plot design with three replications having crops as the main plots and fertilizer materials as the sub-plots.

The data on crop growth parameters like plant height, number of nodule plant^{-1}, leaf area index, dry matter and time of flowering were recorded at different growth stages. Yield and other crop chaeacters like number of branches plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seeds weight, seed and stover yield were recorded after harvest. Data were analyzed using IRRISTAT package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Results showed that each crop had significant effect on its growth parameters except pod length, number of nodule plant^{-1}, seed yield and harvest index. The rapid increase of plant height and dry weight was observed from 30 days to 45 days of growth stages which was higher in the mungbean compared to the blackgram; however, at harvest it was higher in the blackgram. The higher root length at all growth stages except 15 DAS was found in blackgram. The higher LAI at all the growth stages except 45 DAS was found in mungbean. Again, blackgram needed longer duration for flowering and maturity compared to that of mungbean. Blackgram produced maximum number of branch plant^{-1} and maximum number of pod plant^{-1} compare to mungbean. The higher number of seeds pod^{-1} (10.87) was obtained from mungbean and the lower number of seeds pod^{-1} (6.13) was obtained from blackgram. The higher weight of 1000-seeds (50.95 g) was obtained from mungbean and the lower weight of 1000-seeds (40.82 g) was obtained from blackgram. Mungbean produced the higher seed yield (1.30 t ha^{-1}), the higher stover yield (8.82 t ha^{-1}) and the higher biological yield (9.97 t ha^{-1}) whereas, blackgram produced the lower seed yield (1.24 t ha^{-1}), the lower stover yield (6.69 t ha^{-1}) and the lower biological yield (7.71 t ha^{-1}). Mungbean seed yield was higher by 4.62% as compared to yield of blackgram. The maximum harvest index (25.86) was found from mungbean and the lower harvest index (20.58) was found from blackgram. The harvest index was 20.42% higher in mungbean as compared to blackgram. The maximum shelling percentage (39.87) was found from blackgram and the lower shelling percentage (30.96) was found from mungbean. The shelling percentage was 22.2% higher in blackgram as compared to mungbean.

Fertilizer materials significantly influenced all growth and yield attributes except number of nodule, nodule dry weight, pods plant^{-1}, number of seeds pod^{-1}, 1000-seeds weight and shelling percentage. The results revealed that the inoculums and PK+inoculum produced the highest plant height at all the growth stages, however, at harvest the highest plant height was found in the blackgram. In case of number of branch plant^{-1}, the inoculum secured the highest position at harvest. At 15 and 30 days of crop stage the maximum leaf area index was obtained from the PK+inoculum and inoculum but at harvest LAI was insignificant. The inoculum produced maximum dry weight at 30, 45 days of crop stage and at harvest; however the PK+inoculum produced maximum dry weight at 15 DAS. Plants with no fertilizer (control) and cowdung needed the longest duration for flowering and maturity, whereas, the lowest duration for flowering and maturity was observed in the inoculum and Pk+inoculum. The highest pod length (6.98 cm) obtain from no fertilizer (control) and number of seeds pod^{-1} (9.00) was obtained from the inoculum and the lowest pod length (6.16 cm) number of seeds pod^{-1} (8.17) was recorded from the chemical fertilizer (NPKB). The highest weight of 1000-seeds (46.71g) was obtained from the PK+inoculum whereas the lowest weight of 1000-seeds (45.30 g) was obtained from the inoculum. The inoculum produced the significantly maximum seed yield (1.47 t ha^{-1}) than the other fertilizer and the minimum seed yield (1.24 t ha^{-1}) was obtained from no fertilizer (control). The inoculum produced the maximum stover yield (9.31 t ha^{-1}) and biological yield (10.46 t ha^{-1}), however, the minimum stover yield (6.13 t ha^{-1}) and biological yield (7.26 t ha^{-1}) were obtained from chemical fertilizer (NPKB). The highest harvest index (19.39) was found from the chemical fertilizer (NPKB) and the lowest harvest index (13.26) was found from the PK+inoculum.

Interaction effect of crop and fertilizer also significantly affected growth as well as yield and yield contributing characters except pod length. The tallest mungbean plant height was initially found with the PK+inoculum but at later tallest plant height was observed in the ioculum of blackgram. In the later stages, the maximum number of nodule plant^{-1} was obtained from the PK+inoculum with blackgram and the highest leaf area index was observed in the PK+inoculum with mungbean. At harvest, the cowdung treatment produced highest dry weight of mungbean. The no fertilizer (control) of mungbean needed the longest duration for flowering, whereas, the lowest duration for flowering was observed in the PK+inoculum and inoculum of mungbean and blackgram respectively.

The maximum number of branches plant^{-1} (4.00) was obtained from the inoculum of blackgram; however the lowest number of branches plant^{-1} (0.47) was obtained from the no fertilizer (control) of mungbean. The maximum number of pods plant^{-1} (51.27) was obtained from the no fertilizer (control) of blackgram and the minimum number of pods plant^{-1} (18.33) was obtained from the PK+inoculum of mungbean. The highest weight of 1000-seeds (51.54 g) was obtained from the cowdung of mungbean, which was similar with the other fertilizer materials of the same crop. The lowest weight of 1000-seeds (39.48 g) was obtained from the inoculum of blackgram. Among the treatments, the maximum seed yield was observed in inoculam with mungbean (1.59 t ha^{-1}) that was similar with PK+ioculum and chemical fertilizer (NPKB) of mungbean or in inoculam with blackgram and the minimum yield (1.02 t ha^{-1}) was observed in cowdung with mungbean. The highest stover yield (10.85 t ha^{-1}) was recorded in the cowdung with mungbean and the lowest straw yield (4.72 t ha^{-1}) was found in the chemical fertilizer (NPKB) with blackgram. The highest biological yield (11.77 t ha^{-1}) was recorded in the cowdung with mungbean and the lowest biological yield (5.66t ha^{-1}) in the chemical fertilizer (NPKB) with blackgram. The highest harvest index (19.99) was recorded in the cowdung with blackgram and the lowest harvest index (8.51) in the in the cowdung with mungbean. The highest shelling percentage (43.24) was recorded in the cowdung with blackgram and the lowest harvest index (29.41) in the in the no fertilizer (control) with mungbean.

Based on the results of the present study, the following conclusions may be drawn-

- The munbean (BARI mung 6) showed higher yield potential as compared to the crop blackgram (BARI mash 1).
- Though the highest yield was observed with the inoculum treatment, other treatments like chemical fertilizer (NPKB), PK+inoculum also showed higher yield which was important in socio-economic aspect.
- Although cowdung failed to produce better yield, it provided an early harvest and it needs further research to utilize its maximum potential.
- Inoculum, chemical fertilizer (NPKB) and PK+inoculum showed similar yield potential that may encourage practicing inoculum or PK+inoculum rather depending only on chemical fertilizer as well as cultivating the crops with no fertilizer (control) treatment.

However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones.

References

REFERENCE

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.

Ahmed, I. U., Rahman, S., Begum, N. and Islam, M. S. (1986). Effect of phosphorus and zinc application on the growth, yield and P, Zn and protein content of mungbean. *J. Indian Soc. soil Sci.* **34**(2):305-308.

Ahmed, S. U. 1989. Response of Mungbean (*Vigna radiata*) to inoculation with *Rhizobium* as affected by phosphorus levels. An M.Sc. thesis in Soil Science, BAU, Mymensingh. p.56.

Akao, S., Takahashi, T., Itoh, A. Saito, M., Ishh, K. and Iohiki, H. (1990). Effectiveness of inoculation with some strains of *Bradyrhizobium japonicum* and their persistence in siol. *Bull. Tohoku National Agril.Expt. Station*. **82**: 47-61 (Cited from Soyabean Abastracts. 1993. **16**(1): 29).

Akhtaruzzaman, Md. Abu. (1998). Influnce o rates of nitrogen and phosphorus fertilizers on the productivity of mungbean (*Vigna radiate* [L] Wilczek). Ph. D. thesis, Dept. Agron. Institute of Postgradute Studies in Agriculture, Gazipur.

Ali, M. M., Shadheed, S. M. and Kubota, D. (1997). Soil degradation during the period 1967-1995 in Banglaladesh. II. Seleceted chemical characters. *Soil Sci. Plant Nutr.* **43**: 879-890.

Anonymous. (1988a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (1988b). Land Resources Appraisal of Bangladesh for Agricultural Development. Report No. 2. Agroecological Regions of Bangladesh, UNDP and FAO. pp. 472-496.

Anonymous. (2004). Annual Internal Review for 2000-2001. Effect of seedling throwing on the grain yield of water land rice compared to other planting methods. Crop Soil Water Mang. Prog. Agron. Div. BRRI, Gazipur-1710.

Ansari., S. A. Sammiulla 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.

Ardeshna, R. B., Modhwadia, M. M., Khanpara, V. D. and Patel, J. C. (1993). Response of greengram to nitrogen, phosphorus and *Rhizobium* inoculation. *Indian J. Agron.* **38**(3): 490-492.

Asaduzzaman (2006). 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.

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

Bachbha, S. M., Jadhav, A. S., Naidu. T. R. V. and Bachlav, (1994) Effects of nitrogen and nitrogen on Leaf area, nodulation and dry matter production in summer green gram. *J. Maharastgo Agrol. Univ.* **19**(2): 211-213.

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

BBS (Bangladesh Bureau of Statisticl). (2001). Statistical Yearbook of Bangladesh. Statistics Division, Ministry of planning, Government of the people's Republic of Bangladesh. Dhaka. pp. 63-591.

BBS (Bangladesh Bureau of Statistics) (2006). Monthly Statistical Bulletin. Statistics Diision. Ministry of planning. Government of the Peoples Republic of Bangladesh. Dhaka. p. 57.

Behari, K., Kani, M. C. and Poi, S. C. (1995). Potentiality of using multistrain inoculants for improved yield in greengram (*Vigna radiata* L. wilczek). *Indian Agric*. **39**(3): 165-172.

Bhuiya, Z. H., Hoque, M. S. and Mian, M. H. (1984). Field trial at BAU Farm on the effect of *Rhizobium* inoculation on mungbean. 1st Ann. Report on B. N. F. under irrigated and rainfed condition. pp. 11-14.

Bhuiyan, A. T. M. and Obaidullah. (1992). Response of groundnut (*Arachis hypogaea* L.) to *Rhizobium* inoculum as affected by plant genotypes. M. S. thesis, Ag. Soil Sci. BAU, Mymensingh. p. 63.

Bhuiyan, M. A. H., Khanam, D., Rahman, M. M. and Ali, M. M. (1998).Variation in the symbiotic effectiveness of *Bradyrhizobium* strain of soybean. *Bangladesh J. Microbial*. **15**(1): 25-30.

Bhuiyan, M. A. H., Khanam, D., Rahman, M. M. and Talukder, M. Z. (1994). Respons of soyabean to inoculation with different srarins of *Bradyrhizobium. Bangladesh J. Agril. Res*. **26**(4): 529-534.

Bhuiyan, N. I. (1999). Overview of soil fertility and crop productivity situations in Bangladesh. BRRI-IRRI joint workshop on Long-term Experiments on Soil ertility in Rice-Based Copping Systems. BRRI., 8-11 Mar, 1999. pp. 1-18.

Chahal, P. P. K. and Chahal, V. P. S. (1987). Inter-relationship between strains of *Rhizobium*, root knot nematodes and moog (*Vigna radiata* L. Wilczek). Zentralblattfur Mikrobiologie (India). **142**(2): 129-132.

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

Chowdhury, M. M. U., Haider, J., Karim, A. J. M. S. and Hossain, T. (1997). Nitrate reductase activity in mungbean (*Vigna radiata* L. Wilczek) leaves, roots and nodules in relation to *Bradyrhizobium* inoculation and phosphorus application. Annals Banaladesh Agric. 7(2): 145-148.

Chowdhury, M. M. U., Ullah, M. I. and Mahmmud, Z. U. (2000). Dry matter production in mungbean (*Vigna radiata* L. wilczek) as influenced by *Bradyrhizobium* inoculation and phosphorus application. Institute of Post Graduate Studies in Agriculture, Salna, Gazipur 1703, *Bangladesh. Legume Res.* **23**(1): 15-20.

Das, P. K., Sahoo, P. N. and Jena, M. K. (1997). Effect of VA-mycarrhiza and *Rhizabium* inoculation nutrient uptake. *Environ. Ecol.* **15**(4): 830-833.

Das, P. K., Sethi, A. K., Jena, M. K. and Patra, R. K. (1999). Effect of P sourses and dual inoculation of VA-mycorrhiza and *Rhizobium* on dry matter yield and nutrient uptake by greengram (*Vigna radiata* L.). *J. Indian Soc. Soil Sci.* **47**(3): 466-470.

Datt, N. and Bhardwaj, K. K. R. (1995). Nitrogen contribution and soil improemrnt by legume green-manuring in Rice-Wheat cropping on an Acid Clay Loam soil. *J. Indian Soc. Sci.* **43**(4): 603-607.

Deb, P. (2000). Response of molybdenum on the growth and yield of summer mungbean with and without inoculation. M.S. thesis, Soil Sci. BAU, Mymensingh, Bangladesh. p. 72.

Delowara, K., Rahman, M. H. H., Bhuiyan, M. A. H., Hossain, A. K. M. and Rahman, A. F. M. (1991).Efect of Rhizobial inoculation and chemical fertilizers on the growth and yield of lentil at two agroecologial zones of Bangladesh. *Bangladesh J. Agril. Res.* **18**(2): 196-200.

Dixit, L. and Swain, N. (1987). Response of greengram varieties to phosphate fertilization. *Indian J. Agron.* **32**(3): 284-285.

Donald, C.M. (1963). Competition among crops and pasture plants. *Adv. Agon.* **15**: 11-18.

Dubey, S. K., Sinha, A. K. and Yadav, B. R. (1993). Effect of Sodic water and applied phosphorus on uptake of phosphorus and grain yield of greengram. *J. Indian Soc. Soil Sci.* **41**(1): 208-209.

FAO (Food and Agricurltural Organization) 1999. FAO Production Yearbook. Basic Data Unit. Statistic Division, FAO, Rome, Italy.

Ferdous, A. K. M., Khaliq, Q. A., Moynul, H. M., Shirajul, K. A. J. M. and Bhuiyan, M. K. A. (1999). Effet of nitrogen fertilizer on growth, nitrogen and phosphorus uptake and yield in edible podded pea. *Bangladesh Agron. J.* 2004, **10**(1 & 2): 133-140.

Gardner, F.P., Pearce, R.B. and Mistechell, R.L. (1985). Physiology of Crop Plants. Iowa State Univ. Press, Powa. p. 66.

Ghosh, G. and Poi, S. C. (1998). Response of *Rhizobium*, phosphate solubilizing bacteria and micorhizal organisms on some legume crops. *Environ. Ecol.* **16**(3): 607-610.

Gill, M. A., Naimat, A. and Nayyer, M. M. 1985. Relative effect of phosphorus combined with potash and Rhizobium Phaseoli on the yield of *Vigna radiata* (mung). *J. Agril. Res.*, Pakistan. **23**(4): 279-282.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nd Ed. John Wiley and Sons, New York. pp. 643-654.

Gupta, R. P., Bhandari, S. C., Pandher, M. S. and Sedha, R. K. (1988). Symbiotic efficiency in presence of mycorrhiza and fertilizer application in mungbean. Res. Dev. Rep. **5**(1-2): 1-5.

Gupta, S. C. (2000). Response of gram (*Cicer arietinum*) to types and methods of microbial inoculation. *Indian J. Agril. Sci.* **74**(2): 73-75.

Hamid, A. (1988). Nitrogen and carbofuran effects on the growth and yield performance of mungbean (*Vigna radiata* L. Wilczek). *J. Agron. Crop Sci. Bangladesh.* **161**(1): 11-16.

Hamid, A. (1996). Growth and yield performance of munbean (*Vigna radiate* L.) at a mid range of population densities. A. N. Asthana and K. D. Hwan. Recent Adv. mungbean res. (eds.), pp. 92-100. Indian Society of Pulse Research, IIPR, Kanpur, India.

Hasanuzzaman, M. (2001). Effect of plant population and. Bio-fertilizer of growth and yield performance of two summer mungbean cultivars. M.S. thesis, Agron. BAU, Mymensingh, Bangladesh. p.148.

Herreara, A. and Longeri, L. (1985). Response of lentil to inoulation with *Rhizobium leguminosarum*. *Ciencias a investigation Agraria*. **12**(1): 49-53.

Hoque, M. S. (1991). Collection and characterization of Rhizobium bacteria and their effectiveness on some important food legume crops. *Proc. BAU. Res. Prog.* **5**: 91-97.

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. A. and Hamid, A. (1998). Phosphorus fertilizer effect on nitrogen fixation, dry matter accumulation, yield and oil content of groundnut (*Arachis hypogaea* L.). *Bangladesh Agron. J. 2004*. **10**(1): 99-108.

Hunt, R. (1978). The fitted curve in plant growth studies. Mathematics and Plant Physiology. D. A. Rose and D. A. C. Edwards, (eds.). Aca. Press. London. pp. 283-298.

Hussain, M. S., Rahman, M. M., Harun-ur-rashid, M., Farid, A. T. M., Quyyum, M. A., Ahamed, M., Alam, M. S. and Salahuddin, K. M. (2006). Krishi Projukti Hatboy (Handbook on Agro-tecnology), 4th edition, Bangladesh Aricultural Researh Institute, Gazipur 1701.pp. 123-142.

Islam, A. B. M. S., Hoque, M. S. and Bhuiya, Z. H. (1987). Effect of different *Rhizobium* inoculants on soybean. *Bangladesh J. Agric.* **12**(2): 129-134.

Jahiruddin, M., Islam, M. R. and Islam, M. F. (2000). Effect of some secondary and micronutrients on mustard, lentil, chickpea, wheat and rice. Proc. Inter. Conf. on Manaing Natural Resources for Sustainable Agricultural Production in the 21st Century held at New Delhi, India during 14-18 Feb,2000.

Jamro, Shinde, C. P. and Singh, V. (1990). Effect of various levels 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. 103, p: 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. Agril. Res.* **28**(4): 501-511.

Katiya, R.P. (1980). Development changes in LAI and growth parameters in chickpea. *Indian J. Agric. Sci.* **50**: 684-691.

Kaul, A. (1982). Pulses in Bangladesh. BARC, Farmgate, Dhaka, p. 27.

Kavathiya, Y. A. and Pandey, K. N. (2000). Interaction studies on *Meloidogyne, javanica, Bradyrhizobiaum* species and *Macrophomaina phaseolina* in Mungbean. *J. Mycol. Plant Pathol.* **30**(1): 9 1-93.

Khade, V. N., Patel, B. P., Khanwilkar, S. A. and Dongale, J. I-I. 1988. Irrigation and phosphorus requirement of rabi greengram. *J. Maharastra Agril. Univ.* **13**(1):99.

Khamparia, N. N. K. (1996).Yield abd yield attributing characters of soyabean as affected by levels of phosphorus and zinc and their interactions of ertisol. *Crop Res.* **12**(3): 275-282.

Khan, M. R. L, Shaikh, M. A. Q. and Dutta, P. C. (1982). Nutritional quality characters in pulses. *Proc. Natl. Workshop on Pulses*. Aug. 18-19, 1981. BARI, Joydebpur, Gazipur. pp. 199-206.

Khan, M. A. A. (1981). The Effect of CO_2 environment on the pattern of growth and development in rice and mustard. Ph.D. Dissertation. Royal Vet. and Agril. Univ. Copenhagen. p. 104.

Khurana, A. S., Poonam, S. (1993). Interaction between Mungbean varieties and *Bradyrhizobium* strains. *J. Res., Punjab April. Univ.* **30**(1/2): 44-49.

Kluen, h. and Wolf, J. (1986). Modelling of agricultural production: weather, soils and crops. Pudoc, Wageningen. p. 23.

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

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

Maiti, S., Das, C. C., Chatterjee, B. N. and Sengupta, K. (1988). Response of greengram and lentil to *Rhizobium* inoculation. *Indian J. Agron.* **33**(1):92-94.

Maldal, A. B. and Ray, R. (1999). Effect of *Bradyrhizobium* inoculation 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 phosphorus application on growth, yield and quality of mungbean (*Vigna radiata* L.). *Pakistan J. Agril. Sci.* **40**(3/4): 133-136.

Mand, S. and Chahal, V. P. S. (1987). Effect of nitrate application and Rhizobium inoculation on symbiotic effectively in *Vigna radiata* (L). Wilczek. *Annals Biol., India.* **3**(1): 92-96.

Mathan, K. K., Honora, J. F. and Ramanathan, S. P. (1993). Respons of blackgram (*Phaseolus mungo*) to fertilization and rhizobium inoculation. *Indian J. Agron.* **41**(1): 74-77.

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

Mozumder, S. N. (1998). Effect of nitrogen and Rhizobial biofertilizer on two varieties of summer mungbean. M.S. thesis, Agron. BAU, Mymensingh, Bangladesh. p. 78.

Murakami, T., Siripin, S., Wadisirisuk, P., Boondend, N., Yoneyama, T., Yokoyama, T. and Imai, 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. 187-198.

Naher, S. (2000). Comparative performance of bio-fertilizer and chemical fertilizer on the yield and yield contributing characters of mungbean. M.S. thesis, Dept. Agron., BAU, Mymensingh, Bangladesh. pp. 1-62.

Paikera, A., Mishra, M. and Misra, S. N. (1988). Response of soybean varieties to nitrogen and phosphorus. *Indian J. Agron.* **33**(3): 320-322.

Pal, G. and Lal, B. (1993). Nodulation and rooting pattern of summer greengram (*Phaseolus raditus*) as influenced by irrigation variables. *Indian J. Agri. Sci.* **38**(1): 129-131.

Panaullah, G. M., Saleque, M. A. Abedin, M. J. and Ishaque, M. (1999). Intergated nutrient management with inorganic fertilizers, crop residues and organic manure for Wheat –Mungbean-T.Aman rice cropping pattern. In: Proc. Nat. Workshop on Intergated nutrient management for crop production and Soil Fertility. 24-25 Mar,1998, Gazipur. pp. 171-182.

Pandher, M. S., Sedha, R. K., Gupta, R. P. and Sharma, S. R. (1991). Response of mungbean (*Vigna radiata* L. Wilczek) inoculation with single and multi-strain Rhizobial inoculants. *Indian J. Eco.* **18**(2): 113-117.

Patel, F. M. and Patel, L. R. (1991). Response of greengram varieties to phosphorus and *Rhizobium* inoculation . *Indian J. Agron.* **36**(2): 295-297.

Patel, H. R., Patel, R. G. and Raman, S. (1988). Response of summer greengram to moisture regimes and nitrogen fertilization. *India J. Agron*. **33**(1): 102-103.

Patel, J. R. and Patel, Z. G. (1994). Effect of foliar fertilization of nitrogen and phosphorus on growth and yield of summer greengram (*Phaseolus radiatus*). *Indian J. Agron*. **39**(4): 578-580.

Patel, K. S., Thakur, N. P., Chandhari, S. M. and Shah, R. M. (1986). Response of chickpea to rhizobial inoculation in soil sustaining a high native *Bradyrhizobium* population. *INC.* **14**: 22-23.

Patil, B. L., Heged, V. S. and Salimath, P. M. (2003). Studies on genetic divergence over stress and non-stress environment in mungbean [*Vigna radiata* (L.) Wilczek]. *Indian Gen. Breed.* **63**(1): 77-78.

Patra, D. K. and Bhattacharyya, P. (1998). Response of cowpea rhizobia on nodulation and yield of Mungbean (*Vigna radiata* L. wilczek). *J. Mycopathol. Res.* **36**(1): 17-23.

Patro, H. and Sahoo, P. N. (1994). Response of Mungbean genotypes to phosphorus. *Indian J. Pulses Res.* 7(2): 191-192.

Paul, S. (1998). Symbiosis between mungbean and rhizobia: influence on water stress. *Indian J. Plant Physiol.* **3**(l): 1 1-16.

Penaranda, F. I., Mendoza, H. T., Sanlao, G. R., Rod, T., Canday, L. S. and Bongolan, F. F. (1988). Sefeening of different strains of *Rhizobium* Soybean, Mungbean and Peanut under Zambonga delsur conditions. *Philippines J. Crop Sci.* **13**: 11.

Poonam, S. and Khurana, A. S. (1997). Effect of single and multi-strain *Rhizobium* inoculants on biological nitrogen fixation in summer mungbean (*Vigna radiata* L. Wilczek). *Res. and Dev. Reporter.* **14**(1-2): 8-11.

Popalghat, G., Patil, J. U., Deshmukh, R. B. and Mhase, L. B. (2001). Genotype and environment interaction for seed yield and seed quality parameters in chickpea. *Legume Res.* **24**: 248-251.

Prasad, J. and Ram, H. (1992). Effect of zinc and copper and *Rhizobium* inoculation on microbial population of soil and yield of greengram (*Vigna radiata*). *Intl. J. Tropic. Agric.* **10**(2): 157-160.

Provorov, N. A., Saimnazarov, U. B., Bahromoy, L. U., Pulatova, D., Kozhemyakov, A. P. and Kurbanov, G. A. (1998). Effect of *Rhizobium* inoculation 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 Mungbean. Applied biology beyond the year 2000: Proceedings of the third Symposium of Malaysia Society of Applied Biology. pp. 72-74.

Radford, P. J. (1967). Growth analysis formulae, their use and abuse. *Crop Sci.* **7**: 181-175.

Rahman, M. F. (1993). Effect of *Bradyrhizobium* inoculant on the yield of Mungbean (*Vigna radiata* L., variety Kanti) grown in ganges tidal floodplain soil. M.S. thesis, Soil Science. BAU, Mymensingh, Bangladesh. p. 73.

Rajput, H. A., Masood, T., Jamil, M. and Afzal, C. M. (1992). Response of mungbean (*Vigna radiates*) to NPK fertilizers under irrigated conditions. *J. Agril. Res. Lahore*. **30**(4): 485-488.

Ram, S. N. and Dixit, R. S. (2000). Effect of dates of sowing and phosphorus on modulation; uptake of nutrients and yield of summer mungbean (*Vigna radiata* L. Wilczek). *Crop Res. Hisar*. **19**(3): 414-417.

Ramakrishna, A., Gowda, C. L. L and Johansen, C. (2000). Management factors affecting legumes production in the Indo- Genetic plain. In: Legumes in rice and wheat cropping systems of the Indo- Genetic plain – constrains and opportunities. pp. 156-165.

Ramamoorthy, K. and Raj, A. A. (1997). Studies on phosphorus economy in rainfed greengram. *Current Res*. **26**(11): 208-209.

Raut, R. S. and Kohire, O. D. (1991). Phosphorus response in chickpea (*Cicer arietinum* L.) with *Rhizobium* inoculation. *Legume Res.* **14**(2): 78-82.

Rennie, R. J. and Kemp, G. A. (1984). ^{15}N determined time course for N_2-fixation in two cultivars of field bean. *Agron. J.* **76**: 146-154.

Roy, A. K. (2001). Response of biofertilizer to nodulation, growth and yield of different varieties of summer mungbean (*Vigna rudiata* L.). M.S. thesis, Soil Science. BAU, Mymensingh, Bangladesh. p.59.

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.

Saini, S. S. and Jaiswal, V. P. (1991). Response of summer greengram (*Phaseolus radiatus*) to date of planting. *Indian J. Agron.* **36**(3): 427-428.

Sairam, R.K., Tomar, P.S., Harika, A. S. and Ganguly, T. K. (1989). Effect of phosphorus levels and inoculation with Rhizobial on nodulation, leghaemoglobin content and nitrogen uptake in fodder cawpea. *Legume Res.* **12**(1): 27-30.

Samanta, S. C., Rashid, M. H., Biswas, P. and Hasan, M. A. (1999). Performance of five cultivars of mungbean under different dates of sowing. *Bangladesh J. Agril. Res.* **24**(3): 521-527.

Samantaray, S., Mallic, U. C. and Das, P. (1990). Effect of Rhizobium on growth and biomass yield of mungbean (*Vigna radiata* L.) on chromite minewaste. *Orissa J. Agric. Res.* **3**(3-4): 252-257.

Sangakhara. U. R. and Marambe, B. (1989). Effect of method of inoculation and nitrogen fertilizer of nodulation and yield of selected tropical legumes. *J. Agron. Sci.* **162**(5): 305-309.

Santos, P. J. A., Edwards, D. G., Asher, C. J., Dart, P. J. and Barrow, N. J. (1993). Response of *Bradyrhizobium*-inoculated Mungbean (*Vigna radiata* L. wilczek) to applied nitrogen. Plant nutrition from genetic engeneering to field practice: Proceedings of the Twelfth International Plant Nutrition Colloquium, 21-22 Sept., Perth, Western Australia. pp. 443-446.

Sardar, M. S. U. (2002). Influence of plant density and phosphorus and inoculation on the growth and yield of mungbean (cv. BINA moog-2). M.S. thesis, Agron. BAU, Mymensingh. p. 52.

Sarkar, R. K., Karmakar, S. and Chakraborty, A. (1991). Response of summer greengram (*Phaseolus raditus*) to nitrogen, phosphorus application and bacterial inoculation. *Indian J. Agron.* **38**(4): 578-581.

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

Sattar, M. A. and Ahmed, S. U. (1995). Response of mungbean *(Vigna radiata* L.Wilczek) to inoculation with *Bradyrhizobium* as affected by phosphorus levels. Proc. Int. Coog. Coom. IV. pp. 419-423.

Satter, M. A. and Ahmed, S. U. (1992). Response of mungbean *(Vigna radiata* L. Wilczek) to inoculation *with Bradyrhizobium* as affected by phosphorus levels. Proc.Commission IV Conference, Bangladesh 1-3 December, 1992. pp. 419-423.

Satyanarayanamma, M., Pillai, R. N. and Satyanarayana, A. (1996). Effects of foliar application of urea on yield and nutrient uptake by mungbean. *J. Maharastra Agril. Univ.* **21**(2): 315-316.

Sharma, P. and Khurana, A. S. (1997). Effect of single and multistrain Rhizobium inoculants on biological nitrogen fixation in summer Mungbean (*Vigna radiata* L. wilczek). *Res. and Development Reporter*. **14**(1-2): 8-11.

Sharma, Y. M., Diskshit, P. R. Turkar, O. R. and Sharma, A. M. (1993). Effect of *Rhizobium* culture with different starter doses of nitrogen and phosphorus on yield, nutrition and nodulation of summer mung (*Vigna radiata* L.). *Bharatia Krishi Pattrika*. **8**(2): 106-114.

Sharma. M. P. and Singh. R. (1997). Effect of phosphorus and sulphur on greengram (*Vigna radiata* L.). *Indian J. Agron.* **42**(3-4): 650-652.

Shivesh and Sharma, S. (2001). Growth, physiological and yield aspects of mungbean (*Vigna radiata*) as affected by inoculation treatment by different strains of *Bradyrhizobium* culture. *Res. Crops*. **2**(2): 112-115.

Shukla, S. K. and Dixit, R. S. (1990). Nutrient and plant-population management in summer greengram (*Phaseolus radiates*). *Indian J. Agron.* **4l**(4): 78-83.

Shukla, S. K. and Dixit, R. S. (1996). Effect of Rhizobium inoculation, plant population and phosphorus on growth and yield of summer greengram (*Phaseolus radiates*). *Indian J. Agron.* **4l**(4): 611-615.

Singh, A.K., Choudhary, R.K. and Sharma, R. P.R. (1991).Effect of inoculation and fertilizer levels on yield, yield attributes and nutrient uptake of greengram (*Phaseolus raditus*) and blackgram (*P. mungo*). *Indian J. Agron.* **38**(4): 663-665.

Singh, B. and Kumari, M. (1990). Potassium, magnesium and Rhizobium Interactions in mung (*Vigna radiata* L) *Legume Res*. **13**(3): 139-145.

Singh, O. P., Tripathi, P. N., Room Singh and Singh, R. (1999). Effect of phosphorus and sulphur nutrition on summer greengram (*Phaseolus radiatus*). *Indian. J. Agric. Sci.* **9**(11): 798-799.

Solaiman, A. R. M. (1999). Response of mungbean to *Bradyrhizobium* sp. (*Vigna*) inoculation with and without phosphorus and potassium fertilization. *Bangladesh J. Sci. Res*. **17**(2): 125-132.

Solaiman, M.N. 2002. Effect of nitrogen fertilizer and biofertilizer and yield of summer mungbean (*Vigna radiata* L.) M.S. thesis, Soil Science. BAU, Mymensingh. p. 42.

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

Subba Rao, N. S. and Talik, K. U. B. R. (1977). *Rhizobium* culture-their role in pulse production. Souvenier Bell Directorate of Pulses, Department of Agriculture, Government of India, Lucknow. pp 31-34.

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

Thakuria, A. and Saharia, P. (1990). Response of greengram genotypes to plant density and phosphorus levels in summer. *Indian J. Agron*. **35**(4): 431-432.

Tomar, S. S., Sharma. R. K., Verma. O. P., Bhadouria, S. S. and Tomar A. S (1996). Effect of seed rate, irrigation and phosphorus levels on the growth attributes and net return of summer mung (*Vigna radiata*). *Bhartiy Krishi Anusandhan Patrika*. **11**(3): 136-140.

Tomar, S. S., Shrivastava. U. K., Sharma, R. K., Bhadouria, S. S. and Tome, A. S. (1995). Physiological parameters of summer moong (*Vigna radiata* L.) as affected by seed rate, moisture regime and phosphorus levels. *Legume Res*. **18**(2): 125-128.

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.

Trivedi, S.K., Vijay, S. and Shinde, C. P. (1991). Effect of nitrogen phosphorus and sulphur on yield and chemical composition of blackgram (*Phaseolus mungo*). *GAU Res. J.* **22**(2): 46-50.

Upadhyay, R. G., Sharma, S. and Daramwal, N. S. (1999). Effect of *Rhizobium* inoculation and graded levels of phosphorus on the growth and yield of summer greengram (*Phuseolus radiatus* L.). *Legume Res*. **22**(4): 277-279.

Vaishya, U.K., Gajendragadkar, G.R. and Pandey, R.L. (1983). Effect of *Rhizobium* inoculation nodulation and grain yield of mungbean (*Vigna radiata* L. Wilczek). *Indian. J. Microbio*. **23**(4): 228-230.

Watanabe, I., Tabuchi, K. and Nakano, H. (1988). Response of soybean to supplemental nitrogen after flowering. National Agriculture Research Centre, Yatabe, Tsukuba, Ibarki. 305. Japan. pp. 301-308.

Williams, R. W., Lawn, R. J., Imrie, B. C. and Byth, D. E. (1995). Studies on weather damage in mungbean. I. Effect of weathering on seed quality and viability. *Aust. J. Agril.* Res. **46**: 887-900.

Yadav, B. L. and Jakhar, S. R. (2001). Effect of tillage and phosphorus fertilization on yield and water expense efficiency of rainfed mungbean. *J. Indian Soc. Soil Sci*. **49**(1): 193-194.

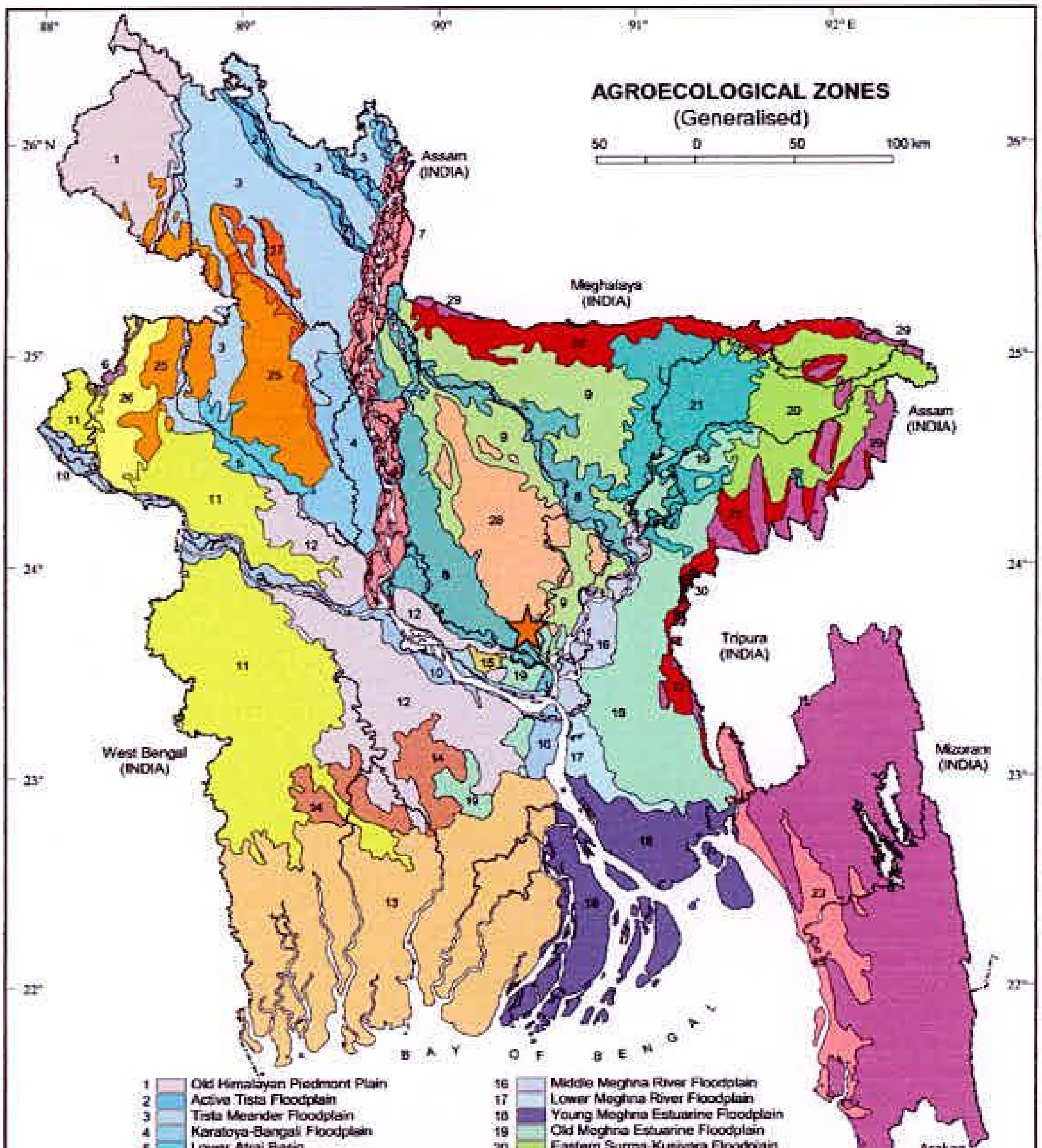
Yadav, J. and Sanoria, C. L. (1996). Field study on inoculation of Zaid and Kharif mungbean (*Vigna radiata* L.) with exotic rhizobial strains in *Varanasi alluvium*. *J. Indian Soc. Soil. Sci.* **44**(3 & 4): 521-522.

Yadav, M. (1985). Performance of summer planted moongbean (*Vigna radiata* L.) varieties in relation to irrigation and plant density. M.S. thesis, Agri. Narendra Deva University of Agriculture and Technology Faizabad, Uttar Pradesh.

Appendices

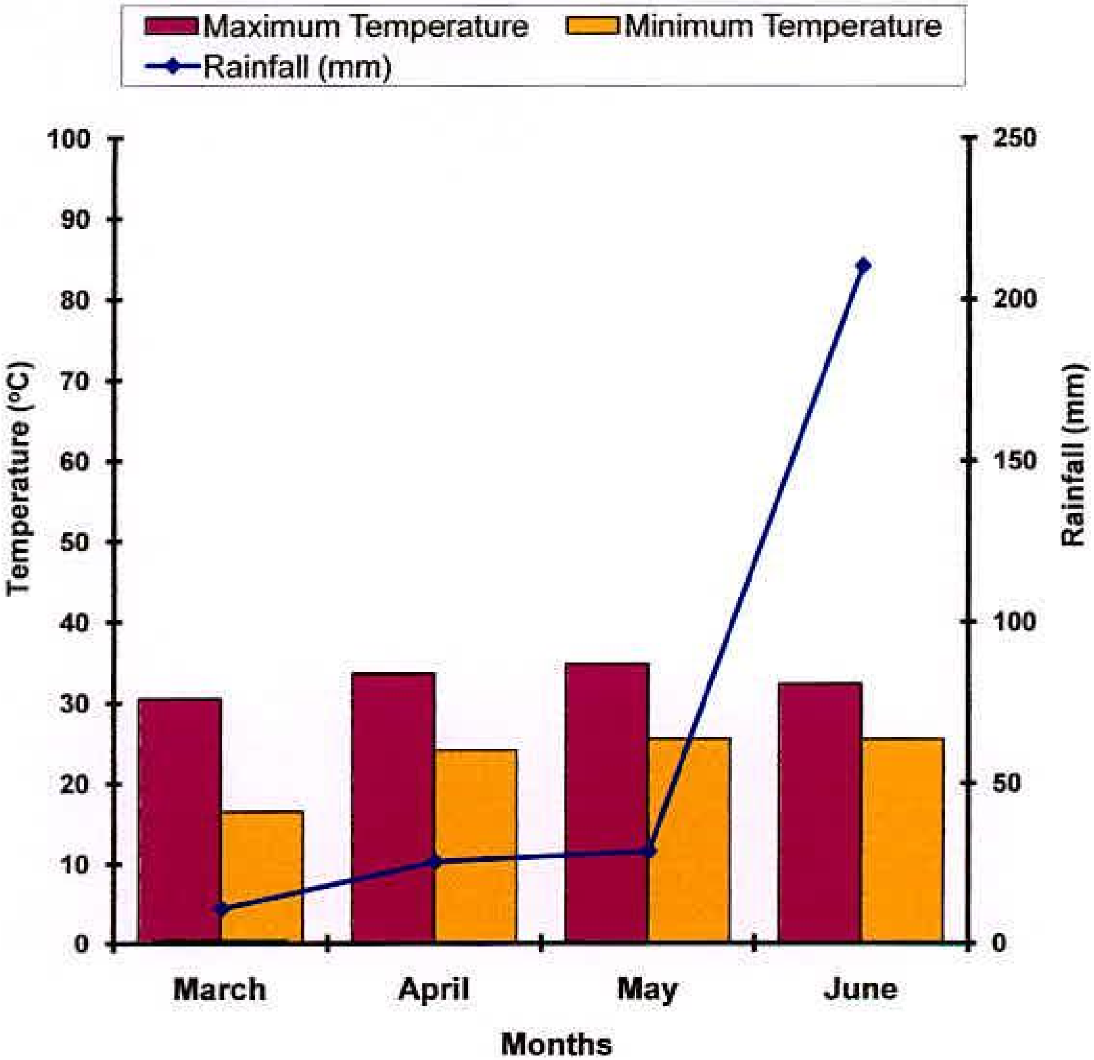
APPENDICES

Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from March to June 2007 [Source: Bangladesh Meteorological Department, Agargoan, Dhaka-1212]



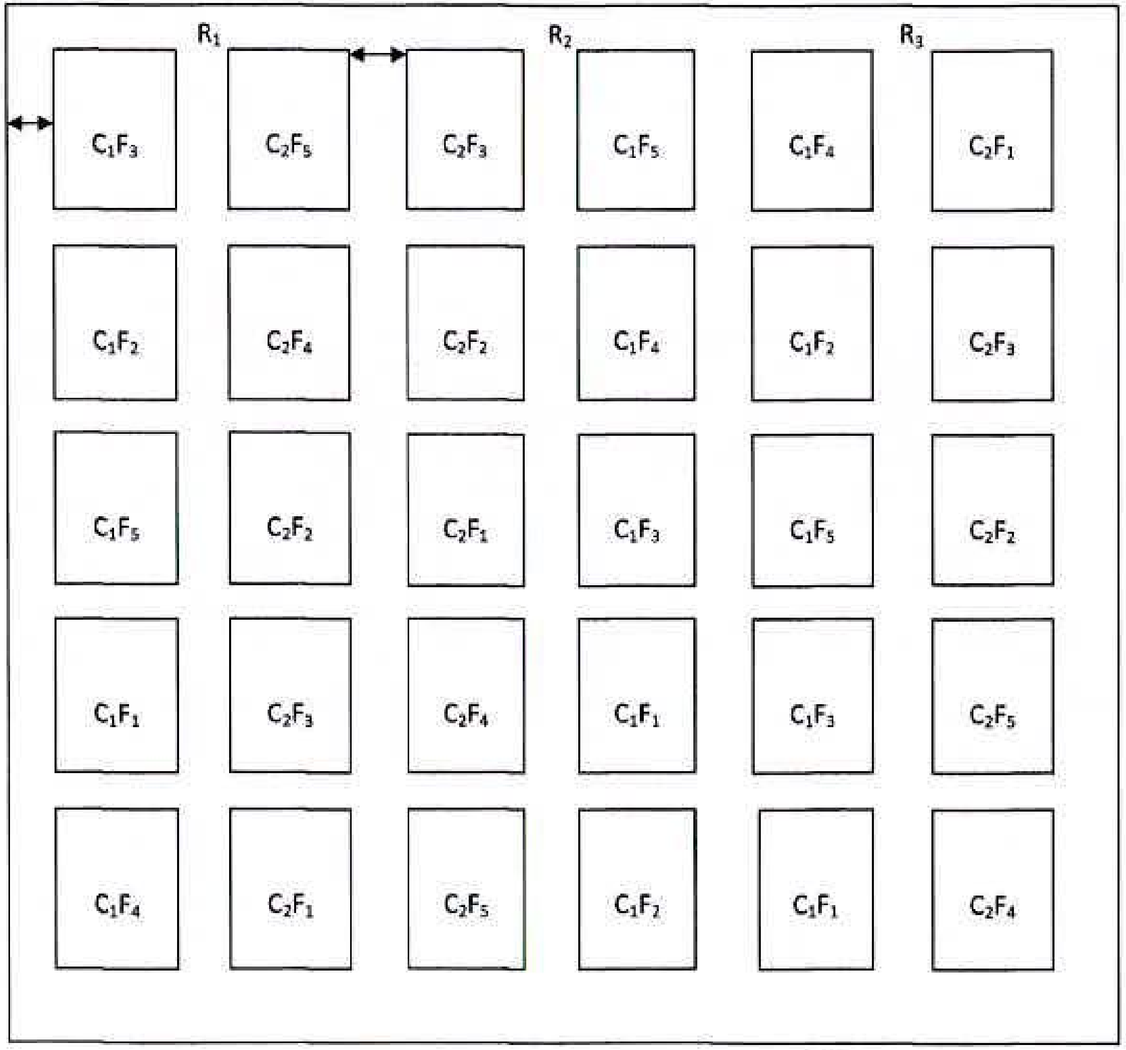
Appendix IIIa. Physicochemical properties of the soil

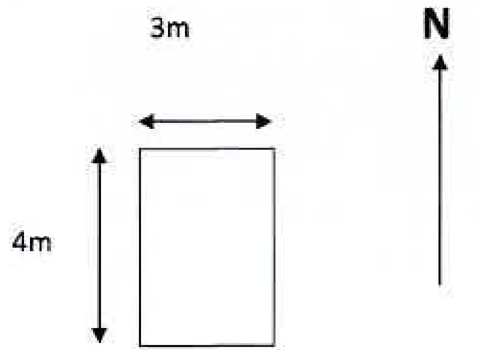
Soil sample	pH	Organic matter (%)	Total Nitrogen (%)	Exchangeable potassium (ml/100 g soil)	Available Phosphorus (ppm)
Initial	6.6	2.20	0.110	0.19	88.53
Crop					
C_1	6.06	1.51	0.075	0.16	14.07
C_2	6.20	1.43	0.071	0.20	12.14
Fertilizers					
F_1	6.05	1.41	0.071	0.14	11.32
F_2	6.15	1.14	0.057	0.17	13.27
F_3	6.35	1.58	0.079	0.32	12.04
F_4	6.05	1.65	0.080	0.12	13.54
F_5	6.05	1.58	0.079	0.15	13.36

Appendix IIIb. Physicochemical properties of the soil

Soil sample	pH	Organic matter (%)	Total Nitrogen (%)	Exchangeable potassium (ml/100 g soil)	Available Phosphorus (ppm)
C_1F_1	5.6	1.10	0.055	0.10	10.88
C_1F_2	5.9	1.24	0.062	0.13	13.02
C_1F_3	6.5	1.99	0.099	0.28	12.94
C_1F_4	6.3	1.58	0.074	0.13	18.74
C_1F_5	6.0	1.65	0.083	0.15	14.77
C_2F_1	6.5	1.72	0.086	0.17	11.75
C_2F_2	6.4	1.03	0.051	0.21	13.52
C_2F_3	6.2	1.17	0.059	0.36	11.14
C_2F_4	5.8	1.72	0.086	0.11	12.33
C_2F_5	6.1	1.51	0.075	0.15	11.95
Mean	6.13	1.47	0.073	0.18	13.104

Appendix-IV: Experimental Layout





Plot Size: 4m x 3m

Between Plot: 1m

Between replication: 1.5m

Appendix V. Mean square values for plant height of mungbean and blackgram at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing			
		15	30	45	At harvest
Replication	2	8.28*	78.82**	193.00**	27.89
Crop	1	183.45**	1381.76**	499.39**	78.93
Error (a)	2	4.35*	64.22**	257.48**	494.22
Fertilizer materials	4	12.31**	33.27*	63.26	314.22
Crop × Fertilizer materials	4	2.41	5.05	9.70	79.07
Error (b)	16	1.65	9.25	32.82	154.19

* Significant at 5% level

** Significant at 1% level

Appendix VI. Mean square values for root length at different days after sowing and days to flowering mungbean and blackgram

Sources of variation	Degrees of freedom	Mean square values at different days after sowing				
		15	30	45	At harvest	Days to flowering
Replication	2	0.47	3.92*	1.55	0.16	0.63
Crop	1	6.20*	0.038	8.30*	149.00**	0.53
Error (a)	2	0.95	1.66	0.42	6.40	0.63
Fertilizer materials	4	0.23	0.29	1.18	4.20	4.47**
Crop×Fertilizer materials	4	3.23*	3.11*	2.13	1.13	0.20
Error (b)	16	1.06	1.04	1.30	4.64	0.63

* Significant at 5% level

** Significant at 1% level

Appendix VII. Mean square values for number and dry weight of nodules at different days after sowing of mungbean and blackgram

Sources of variation	Degrees of freedom	Mean square values at different days after sowing				
		15	30	45	30	45
		Nodule number			Nodule dry weight	
Replication	2	3.43	5.70	53.20	0.00022	0.00081
Crop	1	36.30**	9.63	56.03	0.00114	0.0068
Error (a)	2	9.10	15.83	82.53*	0.00081	0.00069
Fertilizer materials	4	8.22	12.97	44.87	0.00086	0.0042
Crop × Fertilizer materials	4	6.22	4.97	27.37	0.0010	0.0026
Error (b)	16	3.02	9.52	18.49	0.00067	0.0017

* Significant at 5% level

** Significant at 1% level

Appendix VIII. Mean square values for leaf area index of mungbean and blackgram at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing		
		15	30	45
Replication	2	0.0083	2.46**	1.10
Crop	1	0.058*	9.84**	1.87
Error (a)	2	0.0096	0.73*	1.10
Fertilizer materials	4	0.111**	1.15**	1.74
Crop × Fertilizer materials	4	0.011	0.19	1.91
Error (b)	16	0.0087	0.16	1.92

* Significant at 5% level

** Significant at 1% level

Appendix IX. Mean square values for total dry matter of mungbean and blackgram at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing			
		15	30	45	At harvest
Replication	2	5.42	142.83	413.79	4417.91
Crop	1	157.00**	592.29**	44872.7**	181562**
Error (a)	2	4.44	74.54	1021.85	40382.9
Fertilizer materials	4	7.20	288.28**	8003.98	109583**
Crop × Fertilizer materials	4	4.14	45.95	12407.4*	118114**
Error (b)	16	4.63	64.64	2889.58	19562.3

* Significant at 5% level

** Significant at 1% level

Appendix X. Mean square values for dry matter weight of different parts of mungbean and blackgram at harvest

Sources of variation	Degrees of freedom	Mean square values			
		Stem	Leaf	Pod	Seed
Replication	2	1984.68	4253.22	4189.37	552.79
Variety	1	3172.41	35480.2**	8868.32	1566.89
Error (a)	2	1850.31	8725.38	31927.9*	421.81
Fertilizer materials	4	9626.41*	7149.74	33997.8**	256.18
Crop × Fertilizer materials	4	4830.86	6692.53	15097.4	698.25
Error (b)	16	2830.91	4104.98	7650.37	395.23

* Significant at 5% level

** Significant at 1% level

Appendix XI. Summary of analysis of variance for crop characters, yield and yield components of mungbean and blackgram at harvest

Source of variation	Degrees of freedom	Mean square values									
		Branch plant^{-1} (no.)	Pod plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seeds weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Shelling percentage
Replication	2	2.42*	97.82	0.71**	0.40	3.02	0.032	0.19	0.068	10.76	22.85
Crop	1	52.80**	4334.41**	199.12**	168.03**	770.03**	0.033	33.81*	38.26**	34.24	595.32**
Error (a)	2	0.93	150.12	0.32	0.533	8.85	0.076	9.94*	8.64*	80.68*	18.49
Frtilizer materials	4	1.09	32.18	0.77**	0.75	1.57	0.10*	9.27*	9.28*	37.81	7.89
Crop× Fertilizer materials	4	1.60	39.36	0.60**	1.95	4.05	0.077	7.16	6.75	43.22	17.70
Error (b)	16	0.61	101.46	0.13	1.92	4.42	0.034	2.58	2.41	22.96	9.12

* Significant at 5% level

** Significant at 1% level

PLATES

Plate 1. Field view of the experiment

(C_1F_1)

(C_2F_1)

(C_1F_2)

(C_2F_2)

Mungbean (C_1F_3)

Blackgram (C_2F_3)

Plate 2. Effect of fertilizer materials on vegetative stages of mungbean and blackgram

(C_1F_4) (C_2F_4)

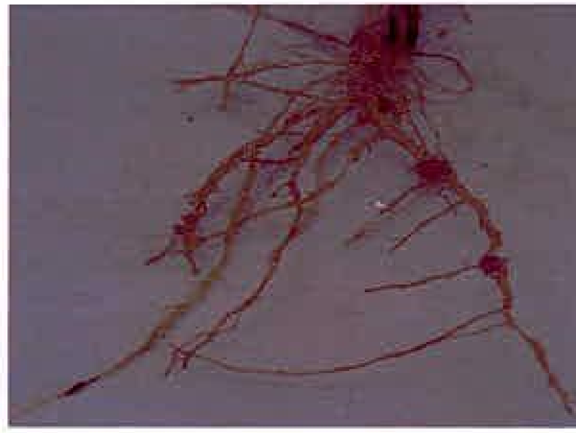
Mungbean (C_1F_5) **Blackgram (C_2F_4)**

Plate 2. Continued

Mungbean (C_1F_1) **Blackgram (C_2F_1)**

Plate 3. Nodulation at different fertilizer materials of mungbean and blackgram at 30 DAS

(C_1F_2)



(C_2F_2)

(C_1F_3)

(C_2F_3)

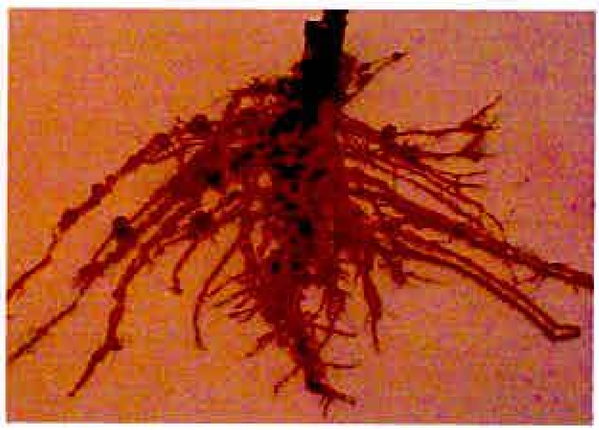
Mungbean (C_1F_4)

Blackgram (C_2F_4)

Plate 3. Continued

Mungbean (C_1F_5) **Blackgram (C_2F_5)**

Plate 3. Continued



Mungbean (C_1F_5) **Blackgram (C_2F_5)**

Plate 4. Maximum nodules at 45 DAS of mungbean and blackgram