INFLUENCE OF *Azolla* AND UREA ON NODULATION, GROWTH AND YIELD OF MUNGBEAN

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INFLUENCE OF *Azolla* AND UREA ON NODULATION, GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

*This is to certify that the thesis entitled, "**INFLUENCE OF Azolla AND UREA ON NODULATION, GROWTH AND YIELD OF MUNGBEAN**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the results of a piece of bona-fide research work carried out by **Rakhi Banerjee**, Registration No. 09-03624 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.

Dated:

Dhaka, Bangladesh

Prof. Dr. Parimal Kanti Biswas

Supervisor

DEDICATED TO MY ADORED PARENTS

List of Abbreviations

Abbreviations	Full word
AEZ	Agro ecological zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
cm	Centimeter
cv.	Cultivar
CV	Coefficient of Variation
DAS	Days After Sowing
EC	Emulsifiable concentrate
et al.	And others (*et alibi*)
FAO	Food and Agriculture organization
g	Gram
ha	Hectare
HI	Harvest Index
kg	Kilogram
L	Liter
LAI	Leaf Area Index
LSD	Least Significance Difference
m^2	Square Meter
mL	milliliter
MP	Muriate of potash
N	Nitrogen
No.	Number
NPK	Nitrogen phosphorus potassium
NS	Non Significant
%	Percent
pH	Hydrogen ion concentration
$plant^{-1}$	per plant
Seeds pod^{-1}	Seeds per pod
t ha^{-1}	Ton (s) per hectare
TSP	Triple super phosphate

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ABSTRACT

A field experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period of March to June 2014 to study the influence of *Azolla* and urea on nodulation, growth and yield of mungbean. The treatments were two mungbean (*Vigna radiata*) varieties viz. BARI mung-5 (V_1) and Chaiti mung (V_2) and five fertilizer materials viz. 100% urea (F_1), 75% urea+ 25% *Azolla* (F_2), 50% urea+ 50% *Azolla* (F_3), 25% urea+ 75% *Azolla* (F_4) and 100% *Azolla* (F_5). The experiment was laid out into Split-plot design with three replications where varieties were assigned in the main plot and fertilizer materials in the sub-plot. The purpose of this experiment was to evaluate variations between the local and modern variety of mungbean and to study the possibility of substituting chemical fertilizer by biofertilizer (*Azolla*). Results revealed that plant height, number of leaflets plant^{-1}, number of branches plant^{-1}, number of nodules plant^{-1} and shoot length was higher in BARI mung-5 at early stage but from 45 DAS to harvest these values were higher in Chaiti mung as it is an indeterminate variety of mungbean. Significantly higher economic yield (1.35 t ha^{-1}) was obtained from the BARI mung-5 compared to the Chaiti mung (0.98 t ha^{-1}). The modern variety (BARI mung-5) showed higher harvest index (22.30) and 1000-seed weight (42.74 g) compared to the local variety (Chaiti mung). Varieties had no significant influence on SPAD value and seeds pod^{-1} of mungbean. Fertilizer materials and the interaction of variety and fertilizer materials had no significant effect on 1000-seed weight, economic yield, biological yield and harvest index of mungbean that reflects the positive indication of replacing chemical fertilizer by *Azolla*.

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CHAPTER 1

INTRODUCTION

Pulses are the most important protein source in the diet of majority people of Bangladesh. It contains about twice as much protein as cereals. It also contains amino acid isoleucine, leucine, lysine, valine etc. which are generally deficit in food grains (Islam *et al*., 2007). The green plants can also be used as animal feed and the residues as manure. It is the also best source of protein for domestic animals. Pluses contain a remarkable amount of minerals, vitamins, fats and carbohydrates. Generally there is no complete dish without “dhal” in Bangladesh. Moreover, adding of legumes in cereal based cropping system can improve soil structure, nutrient exchange capacity and maintain healthy sustainable soil system. Grain legumes are believed to add 20-60 kg N ha^{-1} to the succeeding crop (Becker *et al*., 1995).

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 field pea (*Pisum sativum*). Among these khesari, lentil, chickpea and field pea 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 (March-June) and in late summer. In Bangladesh, among pulses, mungbean ranks 3rd in acreage and production and first in market price (BBS, 2013). Traditionally, mungbean was grown in the winter season due to favorable agro-ecological condition of Bangladesh although it is now cultivated in both summer and winter seasons in many countries of the world. With the technological progress, most of the growers have shifted mungbean to the Kharif-1 season instead of winter (Bose, 1982).

FAO (1999) recommends a minimum pulse intake of 80 g $head^{-1}$ day^{-1} whereas it is only 14.19 g in Bangladesh. This is because of fact that production of the pulses is not adequate 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 and 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. The area under mungbean cultivation in Bangladesh in 2011-2012 was 91 thousand acres with a total production of 26 thousand tons (BBS, 2013). In Bangladesh, most of the mungbean area (~65%) is located in the southern part of the country where mungbean is fitted in T. aman rice - mungbean - fallow or Aus rice - T. aman rice – mungbean cropping system (Haque *et al*., 2002).

It is recognized that pulses offer the most practical means of solving protein malnutrition in Bangladesh but there is an acute shortage of grain legumes in relation to its requirements, because the yield of legumes in farmers' field is usually less than 1 t ha^{-1} against the potential yield of 2 to 4 t ha^{-1} (Ramakrishna *et al*., 2000). Low yields of grain legumes including mungbean make the crop less competitive with cereals and high value crops (Saha *et al*., 2002).

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 as 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% (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.

The reasons for low yield of mungbean are manifold: some are varietal and some are agronomic management especially improper fertilizer application. Among the fertilizer elements, nitrogen plays a key role in mungbean production. It affects the vegetative growth, development and yield. The important role of nitrogenous fertilizers in increasing mungbean yield has been widely recognized (Asad *et al*., 2004). In the less developed countries, many farmers cannot afford inorganic fertilizers. This has led to interest in biofertilization with emphasis on biological nitrogen fixation (Wagner, 1997).

Mungbean yield may be increased by 20 to 45% by proper utilization of nitrogenous fertilizers. Costly and environmentally risky chemical fertilizers causes continuous problem for increasing mungbean production in Bangladesh. Biological nitrogen fixation resulting from symbiosis between legume crops and root nodule bacterium can ameliorate this problem by reducing the chemical N fertilizer input required to ensure productivity (Hayat *et al*., 2004). Currently, a real challenge for the workers in the field of agricultural research is to stop the use of expensive agrochemicals/chemical fertilizers, which negatively affect the environment as well as human health. Chemical fertilizers are used to replenish soil N, in large quantities, they are highly costly and contaminate environment severely (Dai *et al*., 2004). Biofertilizers fix the atmospheric nitrogen in the available form for plants (Chen, 2006). Biofertilizers are low cost, renewable sources of plant nutrients which supplement chemical fertilizers. Use of Biofertilizer is of great importance because they are components of integrated nutrient management, and they are also cost effective and renewable source of energy for plants and to help in reducing the use of chemical fertilizers for sustainable agriculture (Rana and Kapoor, 2013).

Azolla is a free floating water fern that fixes N in association with the N fixing Blue green algae and considered to be a potential biofertilizer in terms of N contribution. The application of *Azolla* as a biofertilizer on agricultural crops in order to provide a natural source of the crucial nutrient N can be very beneficial of our planet. Besides the environmental appropriateness of the use of *Azolla* for multitudes of farmers in many parts of the world who cannot afford chemical fertilizers, *Azolla* application can enhance their economic status, increasing yields while minimizing costs (Wagner, 1997).

The Genus *Azolla* was established by Lamarck in the year 1783 and placed in the monotypic family Azollaceae and there are seven species of *Azolla*. *Azolla* is categorized into two sub-genus viz. *Euazolla* and *Rhizosperma. The* sub-genus *Euazolla* is characterized by the presence of three floats of megasporocarps and consists of Species such as *A. caroliniana*, *A. filiculoides*, *A. mexicana*, *A. rubra* and *A. microphylla*. In contrast, the sub-genus *Rhizosperma* consists of nine megaspore floats. *A. pinnata* and *A. nilotica* belong to this sub-genus. The trichomes are important in the identification of the organism at the Species level (Konar and Kapoor, 1972).

The use of chemical fertilizers and *Azolla* 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 *Azolla* and urea on mungbean. Therefore, it is a necessity to examine the influence of *Azolla* and urea on nodulation, growth and yield of mungbean. With this aim in view, an experiment was conducted with the following objectives:

I) To evaluate variations between the modern and local variety cv. BARI mung-5 and Chaiti mung

II) To determine the influence of *Azolla* and urea on nodulation, growth and yield of mungbean

III) To study the interaction effect between variety and fertilizer materials on the nodulation, growth and yield of mungbean

IV) To study the possibility of substituting chemical fertilizer by biofertilizer (*Azolla*)

CHAPTER 2

REVIEW OF LITERATURE

Research on mungbean is being carried out extensively in many countries including Bangladesh and the South East Asian countries specially Pakistan, India for its improvement of yield and quality. More recently the Pulse Research Centre at Iswardi, Bangladesh Agricultural Research Institute (BARI), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and Bangladesh Institute of Nuclear Agriculture (BINA) have started research for improvement of this crop. The influence of *Azolla* and urea on mungbean (*Vigna radiata* L.) have been reviewed below in this chapter.

2.1 Effect of Variety

Ghosh (2007) conducted an experiment using BARI mung-6 and Sona mung as planting materials and found that seed yield was higher in BARI mung-6 with harvesting the crop at 35 days after anthesis. Weight of thousand seed and pod length was higher in BARI mung-6 with harvesting the crop at 20 and 25 days after anthesis respectively. Shelling percentage, pods plant^{-1} and primary branches plant^{-1} was highest in Sona mung with harvesting at 15, 20 and 30 days after anthesis respectively.

Sarkar *et al.* (2004) reported that in Bangladesh condition, BARI mung-2 contributed higher seed yield than BARI mung-5. Binamoog-2 had the highest number of branches plant^{-1}. The highest number of pods plant^{-1} was recorded for BARI mung-3. Pod length was greatest in BARI mung-5. **B**ARI mung-2 produced the highest seed yield and harvest index. The lowest seed yield and harvest index were recorded for BARI mung-3. The highest 1000-seed weight was obtained from BARI mung-5.

Ahmed *et al.* (2003) conducted a pot experiment on the growth and yield of mungbean cultivars Kanti, BARI mung-4, BARI mung-5, BU mung-1 and Binamoog-5. The seed yield of Kanti, BARI mung-4 and BARI mung-5 were higher than rest of the cultivars. In a field experiment, carried out by Nayak and Patra (2000), eight improved and four local mungbean cultivars were evaluated. Results of their study revealed that yield was 0.45-0.63 t ha^{-1} in the local cultivars and 0.61-1.01 t ha^{-1} in the improved cultivars.

Mohanty *et al.* (1998) observed that among nine mungbean (*Vigna radiata*) cultivars, Kalamung was the best performing cultivar, with a potential seed yield of 793.65 kg ha^{-1}, the highest number of pods $plant^{-1}$ (18.67) and highest number of seeds pod^{-1} (10.43). Mitra and Bhattacharya (1999) conducted a field experiment in India during the kharif (rainy) seasons of 1996 and 1997 to study the effects of cultivars on the growth and seed yield of mungbean. They observed that mungbean cv. GM 9002 had greater dry matter (at harvest), number of pods $plant^{-1}$ and number of seeds pod^{-1}, 1000-seed weight, seed yield and total biomass yields than cv. UPM-12 or MH-309.

Singh *et al.* (1996) conducted a field experiment in Bihar with 40 mungbean cultivars. They found that significant variation existed among the cultivars for plant height, pods $plant^{-1}$ and single plant yield.

Farrag (1995) reported from a field trial with 23 mungbean accessions the seed yield, number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight varied among the tested accessions. He also obtained that some cultivars like VC 2711 A, KPSI and UTT showed better performance under late sown condition. This indicates that all varieties have not equal potentiality to perform better under similar condition.

In an experiment under Bangladesh condition with four varieties of mungbean, Islam (1983) found the highest number of branches $plant^{-1}$ from the variety Faridpur-1 followed by Mubarik, BM-7715 and BM-7704. The maximum number of pods plant^{-1} was produced by Mubarik followed by BM-7704, BM-7715 and Faridpur-1. He mentioned that pods plant^{-1} were a useful agronomic character contributing to higher yield in mungbean. Masood and Meena (1986) reported that mungbean variety 'PDM 11' gave significantly higher seed yield than the other varieties. He also found that number of pods plant^{-1} varied significantly with genotypes. Jain *et al*. (1988) from an experiment with four mungbean varieties observed that 'ML 131' produced the highest seed yield compared with other varieties.

2.2 Effect of Fertilizer Materials

An experiment was conducted by Yaqub *et al.* (2010) to evaluate the induction of short-duration (maturity period, 55-70 days) mungbean (*Vigna radiata* L.) as a grain legume in the pre-rice niche of the rice-wheat annual double cropping system. He found that the mungbean crop (grown without mineral N fertilizer) produced 1166 kg ha^{-1} of grain in addition to 4461 kg ha^{-1} of the manure biomass (containing 52 kg N ha^{-1}) that was ploughed under before planting rice with urea-N applied in the range of 0-160 kg N ha^{-1}. Averaged across urea - N treatments, manuring significantly increased the number of tillers plant^{-1} (11% increased), rice grain yield (6% increased), grain N content (4% increased) and grain N uptake (9% increased). He observed significant residual effects of manuring on the subsequent wheat crop showing higher grain yield (21% increased), grain N uptake (29% increased) and straw yield (15% increased). The results suggested the feasibility of including mungbean in the pre-rice niche to improve the productivity of the annual rice-wheat double cropping system.

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

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

Mozumder (1998) conducted a field trail at the Agronomy field laboratory, Bangladesh Agricultural University, Mymensingh 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}).

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 seventy eight mungbean cultivar was 0-100% at 33 DAS and 76% in all cultivars at 60 DAS. The author suggested that these cultivars might respond more to applied N than high fixing cultivars.

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

An experiment was conducted by Rahman *et al.* (2012) at Bangladesh Institute of Nuclear Agriculture (BINA) farm, Mymensingh to study the effect of *Rhizobial* inoculant (Biofertilizer) on the yield and yield contributing characters of mungbean cultivars. Experimental treatments included two varieties of mungbean namely Binamoog-5 and Binamoog-7 and six inoculant treatments namely control, *Bradyrhizobium* Inoculant (I), Inoculant + P, NPK, Inoculant + PK + B and Inoculant + PK + CD. Inoculant + PK + B gave the highest grain yield of mungbean (1.49 t ha^{-1}) while Inoculant + PK + CD showed the highest straw yield. NPK application showed significantly higher grain and straw yield over un-inoculated control and parallel to inoculation but statistically inferior to I+PK+CD in respect of grain yield. He recommended I + PK + CD or I + PK + B for summer mungbean production where I + PK + CD was preferable.

Bhuiyan *et al.* (2008b) carried out a field experiment with five mungbean varieties with or without *Bradyrhizobium* inoculation at BAU Farm to observe shoot dry matter production and nitrogen uptake by mungbean at different growth stages. Significant influences of the mungbean varieties were observed on dry matter production and nitrogen uptake. *Bradyrhizobium* inoculant significantly increased dry matter production. The highest dry matter production $plant^{-1}$ at 77 DAS was recorded in *Bradyrhizobium* inoculated plots. Inoculated BARI mung-2 produced the highest shoot weight.

An experiment was carried out by Islam *et al.* (2006) in the field laboratory of the department of crop Botany, Bangladesh Agricultural University, Mymensingh to evaluate the effect of biofertilizer (*Bradyrhizobium)* and plant growth regulators (GA_3 and IAA) on growth of summer mungben. Among the mungbean varieties Binamoog-5 performed better than that of Binamoog-2 and Binamoog-4. They reported that most of the growth parameters like number of leaves $plant^{-1}$, number of branches $plant^{-1}$, root dry weight $plant^{-1}$, number of nodules $plant^{-1}$ was higher due to application of biofertilizer. On the other hand, plant height, leaf dry weight $plant^{-1}$ and shoot dry weight $plant^{-1}$ was higher due to application of plant growth regulators (GA_3 and IAA). However biofertilizer (*Bradyrhizobium)* and plant growth regulators (GA_3 and IAA) showed identical performance on Crop Growth Rate (CGR) and Relative Growth Rate (RGR).

Ashraf and Warrick (2003) conducted a field experiment to observe the effects of seed inoculation of a biofertilizer and NPK application on the performance of mungbean cv. NM-98 studied in Faisalabad, Pakistan. The treatments consisted of the seed inoculation of *Bradyrhizobium phaseoli* singly or in combination with 20:50:0, 40:50:0, 50:50:0 or 50:50:50 kg NPK ha^{-1} (urea), P (single super phosphate), and K (potassium sulphate) was applied during sowing. Seed inoculation + 50:50:0 or 50:50:50 kg ha^{-1} resulted in the highest number of pods plant^{-1} (28.97, 56.00, 63.90 and 32.56 respectively) and seed yield (1053, 1066, 1075 and 1072 kg ha^{-1}). Harvest index was the highest with seed inoculation in combination along with NPK and 40:50:0 (25.23), 50:50:0 (24.70) or 50:50:50 (27.5). Seed inoculation with NPK at 30:50:0 kg ha^{-1}) was optimum for the production of high seed yield by mungbean cv. NM-98. The tallest plant (69.93 cm) was obtained with seed inoculation + 50:50: 0 kg NPK ha^{-1}.

Palm and Bhattacharya (1997) carried out a field trial with *Bradyrhizobium* (Biofertilizer) and urea (25 kg ha^{-1}) on *Vigna radiata* cv. B-I. They found that all treatments increased nodulation compared control. They also reported that the highest nodules were given by *Bradyrhizobium* compared control. They also reported that the highest nodules were given by *Bradyrhizobium* + urea.

Sattar and Ahmed (1995) carried out a field experiment on mungbean (*Vigna radiata* L.) to study the response of inoculation with *Bradyrhizobium* inoculants incorporating BINA 403, BINA 407, RCR 3824 and RCR 3825 strains as single and mixed culture. They observed that *Bradyrhizobium* inoculation increased the number of nodules, nodule weight, seed, hay and total protein yield significantly compared to un-inoculated treatments.

Kavathiya and Pandey (2000) conducted a pot experiment with *Rhizobium* on mungbean (*Vigna radiata* cv. K 851) and found that nodule plant^{-1} increased significantly over uninoculated control. They also reported that maximum seed germination (96.6%), plant height (24.6 cm), fresh shoot weight (5.33 g), fresh root weight (4.42 g) and nodulation (69 healthy nodules plant^{-1}) was recorded in the *Rhizobium* treatment. Sharma and Khurana (1997) studied the effectiveness of single and multistrain inoculants in a field experiment with summer mungbean variety SML 32. They found that number of nodules, nodule dry biomass and grain yield were better in multistrain inoculants. On an average, single strain and multistrain *Rhizobium* inoculants increased the seed yield by 10.4% and 19.3% respectively compared to the uninoculated control.

An experiment was conducted by Pramanik *et al.* (2014) at the Agronomy field laboratory, Bangladesh Agricultural University, Mymensingh from February to June 2010 to study the effect of biofertilizer and weeding on the growth characters and yield of summer mungbean (cv. Binamoog-7). Experimental treatments comprised of (a) five levels of biofertilizer: 0, 1, 2, 3, 4 kg ha^{-1} and (b) four levels of weeding: no weeding, one weeding, two weedings, and three weedings. They reported that the highest plant height (58.83 cm) was obtained at 60 DAS from 4 kg biofertilizer ha^{-1} and the highest dry weight plant^{-1} (17.78 g) at 60 DAS was produced from 2 kg biofertilizer ha^{-1}. Three times weeding produced highest plant height (41.69 cm) and dry weight plant^{-1} (18.09 g) at 60 DAS and seed yield (1.96 t ha^{-1}) was attained significantly at maximum level from the application of 2 kg ha^{-1} biofertilizer. Application of 2 kg biofertilizer ha^{-1} with three times weeding was proved to be the best possible combination.

Wagner (1997) reported that *Azolla* is suitably called as green gold because it is economically important as an animal feed, medicine, hydrogen fuel, biogas producer, weed controller as well as a biofertilizer. According to Speelman *et al*. (2009), *Azolla* plants in huge numbers sequestered significant quantities of atmospheric CO_2 and converted it directly into biomass of *Azolla*.

Singh (1989) said that *Azolla* is a fern of agronomic importance due to its ability to fix atmospheric nitrogen. The presence of the algal symbiont *Anabaena– Azollae* in its leaf cavities helps in N fixation and in turn increases soil organic content in terms of total N after death of the *Azolla* plant.

Yadav *et al.* (2014) reported that the nitrogen fixing aquatic pteridophyte *Azolla* has the ability to fix atmospheric nitrogen at cheaper and faster rates due to the presence of a symbiotic cyanobacterium *Anabaena Azollae*. Because of this property it has been exploited widely as biofertilizer for rice plants. In addition to this it has several other uses such as food, feed, biogas producer and hyperaccumulator of heavy metals etc. Because of the multifaceted uses the promotion and use of *Azolla-Anabaena* system would be ideal and environment friendly in sustainable agriculture.

Bhuvaneshwari and Kumar (2013) conducted an experiment at Banaras Hindu University, Varanasi and found beneficial effects of *Azolla* in the cultivation of rice. They observed that application of *Azolla* significantly improved the physical and chemical properties of the soil especially nitrogen, organic matter and other cations such as magnesium, calcium and sodium released into the soil.

Watanabe *et al*. (1977) said that the aquatic pteridophyte *Azolla* is an excellent biofertilizer and green manure having global distribution. Ability of *Azolla-Anabaena* system to fix atmospheric nitrogen at faster rates makes it an outstanding agronomic choice for the cultivation of rice under tropical conditions. Nitrogen fixation potential of the *Azolla-Anabaena* system has been estimated to be 1.1 kg N ha^{-1} day^{-1} and one crop of *Azolla* provided 20-40 kg N ha^{-1} to the rice crop in about 20- 25 days.

Singh *et al.* (1992) reported that increase in yield due to application of *Azolla* was demonstrated by several studies conducted in the past at several locations in the country. Similar results have been obtained with *Azolla* along with the application of chemical nitrogenous fertilizers.

Singh (2000) said that highest grain yield in rice plants is observed when a comparison of *Azolla* application is made with other biofertilizers. Suppression of weeds and reduction in the volatilization of ammonia in rice fields due to the formation of a thick mat in rice fields by *Azolla* is observed.

Mahapatra and Sharma (1989) observed beneficial effects of *Azolla* on subsequent wheat crop with increase in grain yield. Application of 20 tons of *Azolla* along with 60 Kg nitrogen recorded highest yield of wheat.

Maximum population of bacteria, fungi and actinomycetes and high urease and dehydrogenase activities due to organic farming using *Azolla* as one of the components was reported by Krishnakumar *et al*. (2005).

Wagner (1997) reported that in Asia, *Azolla* has been long used as green manure for crop production and a supplement to diets for pig and poultry. Some strains of *Azolla* can fix as much as 2-3 kg of nitrogen ha^{-1} day^{-1}. *Azolla* doubles its biomass in 3-10 days, depending on conditions, and easily reaches a standing crop of 8-10 t ha^{-1} fresh weight in Asian rice fields, 37.8 t ha^{-1} fresh weight (2.78 t ha^{-1} dry weight) has been reported for *Azolla pinnata* in India.

Cisse and Vlek (2003) reported that *Azolla* helps to sustain soil nitrogen supply by returning N to the soil in quantities roughly equal to those extracted from soil by the rice plants. Studies conducted by Li *et al.* (1982) showed that the lignin content of dry *Azolla* was 21%, and this was higher than fresh *Azolla* lignin of 18%, making the mineralization of dried *Azolla* more difficult.

Raja *et al.* (2012) said that the *Azolla-Anabaena* association is important agronomically owing to its capacity to fix atmospheric nitrogen at cheaper and faster rates and making it available to crop plants. *Azolla* seems to help sustain the soil nitrogen supply by returning nitrogen to quantities roughly equal to those extracted from the soil by the rice plant.

Ramesh and Chandrasekaran (2004) observed that *Azolla* can fix about 1.1 kg N ha^{-1} day^{-1} when used as a green manure and in 30 days, under favorable environmental condition, about 30 kg N ha^{-1} would have been fixed. Apart from *Azolla* being used as a green manure for rice and other such crops, it significantly improves the soil organic carbon content, thus sequestering carbon in soils.

Increase in yield due to application of *Azolla* was demonstrated by Singh (1977) through several studies conducted at several locations. He found that a single crop of *Azolla* provides 20-40 kg N ha^{-1}. Similar results have been obtained by Singh *et al*. (1992) with integrated application of *Azolla* and chemical nitrogen fertilizers. When a comparison of *Azolla* is made with other biofertilizers highest grain yield in rice is observed.

Singh and Singh (1990) said that *Azolla* is used to increase soil fertility. *Azolla* application improves soil fertility by increasing total nitrogen, organic carbon and available phosphorus in soil and these findings were supported by Kannaiyan *et al*. (1997). They found that *Azolla* improves soil structure.

Adhikary and Thakur (2013) reported that an extensive survey on *Azolla* was conducted in Nepal where *Azolla pinnata* was found widely occurring in all the mid hills and terai of Nepal. Experimental results indicated that *Azolla* application increased the rice yield by 25%, equivalent to 30 kg urea N ha^{-1}. Rice yield were found increased by 40% over control when the *Azolla* was incorporated twice during the rice growing period.

Ram *et al.* (1994) found that incorporation of 6,12,18 and 24 t ha^{-1} of fresh *Azolla* into the soil significantly increased water holding capacity, organic carbon, ammonium nitrogen, nitrate-nitrogen and its available phosphorus, potassium, calcium and magnesium, while it decreased pH and bulk density, such incorporation significantly raised the yield of mungbean.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the Kharif-1 season of March to June, 2014 to study the influence of *Azolla* and urea on nodulation, growth and yield of mungbean. The materials used and methodology followed in the investigation have been presented details in this chapter.

3.1 Description of the Experimental Site:

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 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 5.6-6.5 and had organic matter 1.10-1.99%. The experimental area was flat having available irrigation and drainage system and above flood level.

3.1.4 Climate

The area has subtropical 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).

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 varieties of mungbean namely BARI mung-5 and local (Chaiti mung) and the second set consisted of five treatments of fertilizer materials. Two sets of treatments were as follows:

A. Main plot (Variety): 2

1. BARI mung-5 (MV) - V_1
2. Chaiti mung (Local) - V_2

B. Sub-plot (Fertilizer materials): 5

1. 100% urea (F_1)
2. 75% urea + 25% *Azolla* (F_2)
3. 50% urea + 50% *Azolla* (F_3)
4. 25% urea + 75% *Azolla* (F_4)
5. 100% *Azolla* (F_5)

3.2.2 Experimental design and layout

The experiment was laid out into Split-plot design with three replications having varieties in the main plot and fertilizer materials in the sub-plot. Each replication had ten unit plots to which the treatment combinations were assigned randomly. The total numbers of unit plots were thirty. The size of unit plot was 7.2 m^2 (3.0 m x 2.4 m). The distances between replication to replication and plot to plot were 1m and 0.75 m respectively. The layout of the experiment has been shown in Appendix II.

3.2.3 Planting materials

The seeds of BARI mung-5, a modern mungbean variety and Chaiti mung, a local variety were used as experimental material. BARI mung-5 was developed by Bangladesh Agricultural Research Institute (BARI) characterized as 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 approximately 10 cm long and contains 8-10 seeds. Seeds are green in color and drum shaped. On the other hand, the plants of the local variety collected from Satkhira district are 60-70 cm in height, life cycle lasts for 75-80 days and asynchronous type. The plants are erect and branched. Each plant contains 25-30 pods and the pods are around 6-7 cm long. Each pod contains 10-12 seeds. The seeds are small and light green in color. The seed yield of BARI mung-5 ranges from 1.3 to 1.5 t ha^{-1}, while Chaiti mung gives yield around 1.0 t ha^{-1}.

3.2.4 Collection of *Azolla*

The *Azolla* used in the study was collected from an experimental Boro Rice field of Sher-e Bangla Agricultural University then spreaded in the threshing floor and sun dried. The dried *Azolla* were used in the experiment.

3.2.5 Preparation of experimental land

A pre-sowing irrigation was given on 12 March, 2014. The land was opened with the help of a tractor drawn disc harrow on 14 March, 2014, and 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 16, 2014 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.2.6 Fertilizer application

During final land preparation, the land was fertilized with 100 and 55 kg ha^{-1} of TSP and MoP respectively as basal dose. After preparation of field the plots were fertilized with urea and *Azolla* @ 40 kg ha^{-1} and 5 t ha^{-1} respectively according to experimental treatments following the recommendations.

3.2.7 Seed sowing

The seeds of BARI mung-5 and Chaiti mung were sown by hand in 30 cm apart lines continuously at about 3 cm depth at the rate of 50 kg ha^{-1} on March 16, 2014.

3.2.8 Intercultural operations

3.2.8.1 Thinning

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

3.2.8.2 Weeding

The crop field 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.

3.2.8.3 Application of irrigation water

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

3.2.8.4 Drainage

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

3.2.8.5 Plant protection measures

The crops were infested by insects and diseases. The insecticide Marshall 20 EC @30 mL/10L water was sprayed during the later stage of crop to control pests.

3.2.8.6 Harvesting and post-harvest operations

Maturity of crop was determined when 80-90% of the pods become blackish in color. Four harvesting was done while the first harvesting of BARI mung-5 was done on 10 May and the others on 16 May, 24 May and 10 June. The harvesting of Chaiti mung was started on 16 May and the following harvesting was done on 24 May, 10 June and 13 June. The harvesting was done by picking pods from central four lines for avoiding the boarder effects. The collected pods were sun dried, threshed and weighted to a control moisture level. The seed weight of harvesting pods plot^{-1} was added and converted into t ha^{-1}.

3.3 Recording of data

Experimental data were determined from 15 days of growth duration and continued until harvest. Dry weight of plants 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

1. Germination percentage
2. Plant height (cm) at 15 days interval
3. No. of leaflets plant^{-1} at 15 days interval
4. Root length (cm) plant^{-1} at 15 days interval
5. Shoot length (cm) plant^{-1} at 15 days interval
6. Shoot/root ratio plant^{-1} at 15 days interval
7. Number of nodules plant^{-1} at 15 days interval
8. Dry matter production of different plant parts at 15 days interval
9. SPAD value
10. Leaf area index (LAI)

B. Yield and other crop characters

1. Number of branches plant^{-1} at 15 days interval
2. Number of pods plant^{-1}
3. Length (cm) of pod
4. Breadth (cm) of pod
5. Number of seeds pod^{-1}
6. Nodal performance (%)
7. 1000-seed weight (g)
8. Seed yield (t ha^{-1})
9. Biological yield (t ha^{-1})
10. Harvest index (%)

3.4 Detailed procedures of recording data

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

3.4.1. Crop growth characters

3.4.1.1 Germination percentage

Numbers of seeds germinated per m^2 from each plot were counted at 4, 5, 6 and 7days after sowing (DAS) when maximum seeds are germinated and the mean values were determined in percentage.

3.4.1.2 Plant height (cm)

Plant heights of five randomly selected plants from each plot were measured at 15, 30, 45, 60 days after sowing (DAS) and at harvest. The heights of the plants were determined by measuring the distance from the soil surface to the tip of the leaf of main shoot.

3.4.1.3 Number of leaflets plant^{-1}

Numbers of leaflets of five randomly selected plants from each plot were recorded at 15, 30, 45, 60 days after sowing and at harvest and the means were determined.

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

Five plants plot^{-1} were uprooted continuously from second line and root lengths were counted at 35, 40, 55 DAS and at harvest and the mean values were determined.

3.4.1.5 Shoot length (cm) plant^{-1}

The shoot lengths were counted from same five plants those were collected for root length measurement at 35, 40, 55 DAS and at harvest and the mean values were determined.

3.4.1.6 Shoot/root ratio plant^{-1}

The sub-samples of five plants plot^{-1} were uprooted from second line and root and shoot lengths were counted at 25, 40, 55 DAS and at harvest and the mean values of the ratio of shoot/root were determined.

3.4.1.7 Number of nodules plant^{-1}

The five plants plot^{-1} from second line were uprooted and total number of nodules were counted at 25, 40 and at 55 DAS and the mean values were determined.

3.4.1.8 Dry weight plant^{-1} (g)

Five plants from each plot were collected for each recording data. The plant parts were separated and packed in separate paper packets then kept in the oven at 80^0 C for two days to reach a constant weight. Then dry weight of different plant parts were taken separately with an electric balance. The mean values were determined.

3.4.1.9 SPAD value

The SPAD value of three leaves from three plants of each plot were measured with the help of a chlorophyll meter (SPAD 502 plus) and the mean values were determined.

3.4.1.10 Leaf area index (LAI)

Leaf area index were estimated manually by the total number of leaves plant^{-1} and measuring the length and average width of leaf and multiplying by a factor of 0.65 (Keulen and Wolf, 1986).

3.4.2 Yield and other crop characters

3.4.2.1 Number of branches plant^{-1}

The number of branches plant^{-1} from five randomly selected plants of each plot were counted at 30, 45, 60 days after sowing (DAS) and at harvest and mean values were taken.

3.4.2.2 Number of pods plant^{-1}

The total numbers of pods of five selected plants plot^{-1} at harvest were counted and the average values were recorded.

3.4.2.3 Pod length (cm)

Lengths of pods were measured from the ten randomly selected plants of each plot. Then the average values were recorded.

3.4.2.4 Pod breadth (cm)

Breadth of pods were measured from ten randomly selected pods plot^{-1} and averaged.

3.4.2.5 Number of seeds pod^{-1}

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

3.4.2.6 Nodal performance (%)

The pods from bearing nodes of five randomly selected plants from each plot were counted and their average values were determined to know their performance.

3.4.2.7 1000-seed weight (g)

A sub sample of seeds was taken from each plot from which 1000 seeds were counted manually. One thousand seeds thus counted were weighed at 12% moisture level in a digital balance to obtain 1000-seed weight (g).

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

The pods from harvested area (central four lines, 3.6 m^2) were harvested as per experimental treatments and were threshed. Seeds were cleaned and properly dried under sun. Then seed yield $plot^{-1}$ was recorded at 12% moisture level and converted into t ha^{-1}.

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

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

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

3.4.2.10 Harvest index (%)

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

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.5 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTAT-C computer package program developed by Russel (1986). Mean difference among the treatments were tested with Least Significant Difference Test (LSD) at 5% level of significance.

CHAPTER 4

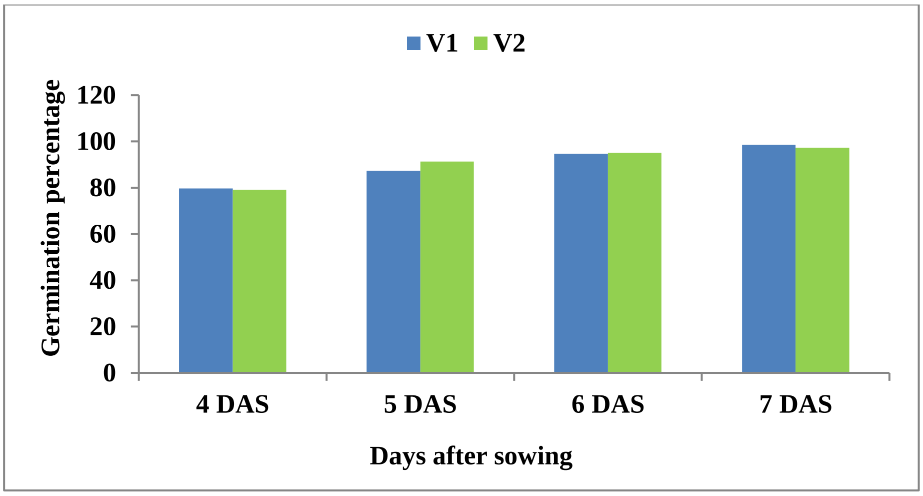
RESULTS AND DISCUSSION

4.1 Crop growth characters

4.1.1 Germination percentage

4.1.1.1 Effect of variety

Germination percentage of mungbean was not significantly influenced by varieties at 4, 6 and 7 days after sowing (DAS) but effect was significant at 5 DAS (Appendix III and Figure 1). At 4 DAS, germination percentage of BARI mung-5 and Chaiti mung was statistically similar. But at 5 DAS, germination percentage was higher in Chaiti mung (91.32%) compared to BARI mung-5 (87.26%). At 6 and 7 DAS, the germination percentages of the two varieties were statistically similar. These results were compared with the findings of Ghosh (2007) who found that germination percentage was significantly influenced by varieties. He also found the highest germination percentage in Sona mung (100%) and the lowest in BARI mung-6 (94.66%).

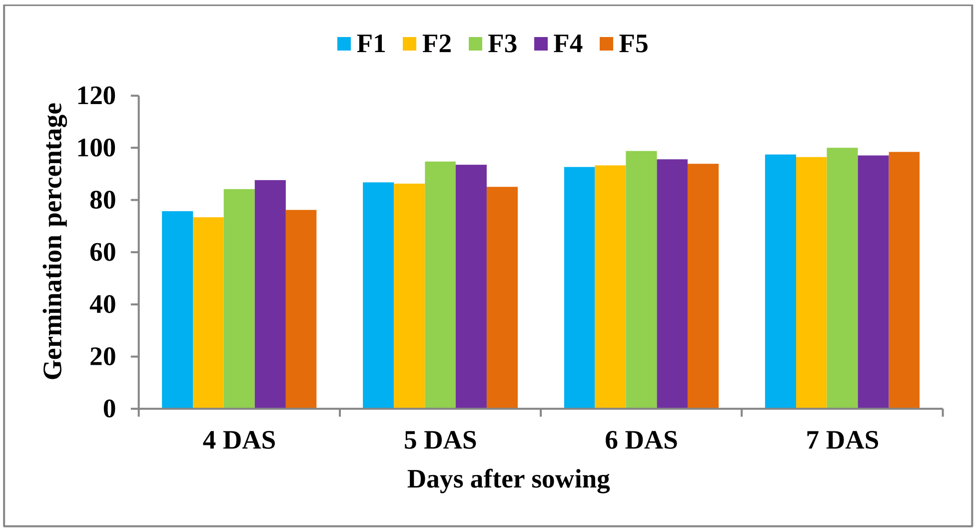


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 1. Germination percentage of mungbean as influenced by variety ($LSD_{(0.05)}$ at 5 DAS=2.84)

4.1.1.2 Effect of fertilizer materials

Fertilizer materials showed significant effect on germination percentage of mungbean at 4 and 5 DAS but effect was not significant at 6 and 7 DAS. At 4 DAS, the germination percentage was higher (87.66%) in F_4 treatment (25% urea+75% *Azolla*) but the result was statistically similar with F_3 treatment (50% urea+50% *Azolla*) (84.21%). The lowest (73.40%) germination percentage was found in F_2 treatment (75% urea+25% *Azolla*) but the result was statistically similar with F_1 (100% urea) (75.79%) and F_5 (100% *Azolla*) (76.19%) treatments. At 5 DAS, the highest germination percentage (94.78%) was recorded in F_3 treatment (50% urea +50% *Azolla*) but the result was statistically similar with F_4 (25% urea+75% *Azolla*) (93.49%), F_1 (100% urea) (86.78%) and F_2 (75% urea+25% *Azolla*) (86.33%) treatments. Germination percentage was lower (85.06%) in F_5 treatment (100% *Azolla*) which was statistically similar with F_2 (75% urea+25% *Azolla*) (86.33%), F_1 (100% urea) (86.78%) and F_4 (25% urea+75% *Azolla*) (93.49%) treatments. At 6 and 7 DAS, the results were statistically similar, so fertilizer materials had no significant effect on germination percentages of mungbean after 5 DAS (Figure 2).



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 2. Germination percentage of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at 4 and 5 DAS=8.75 and 8.87 respectively)

4.1.1.3 Interaction effect of variety and fertilizer materials

Interaction of variety and fertilizer materials showed significant effect on germination percentage of mungbean at 4 DAS but effect was not significant at 5, 6 and 7 DAS (Table 1). At 4 DAS, the highest germination percentage (92.41%) was recorded in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea + 75% *Azolla*) which was statistically similar with V_2F_3 (Chaiti mung fertilized by 50% urea + 50% *Azolla*) (90.79%), V_2F_4 (Chaiti mung fertilized by 25% urea+75% *Azolla*) (82.91%) and V_1F_1 (BARI mung-5 fertilized by 100% urea) (81.74%) treatments. Germination percentage was lower (69.84%) in V_2F_1 (Chaiti mung fertilized by 100% urea) which was statistically similar with V_1F_2 (BARI mung-5 fertilized by 75% urea + 25% *Azolla*) (70.51%), V_2F_5 (Chaiti mung fertilized by 100% *Azolla*) (75.8%), V_2F_2 (Chaiti mung fertilized by 75% urea + 25% *Azolla*) (76.29%), V_1F_5 (BARI mung-5 fertilized by 100% *Azolla*) (76.51%), V_1F_3 (BARI mung-5 fertilized by 50% urea + 50% *Azolla*) (77.62%) and V_1F_1 (BARI mung-5 fertilized by 100% urea) (81.74%) treatments. At 5, 6 and 7 DAS, no significant variation in germination percentage of mungbean was observed due to the interaction of variety and fertilizer materials.

Table 1. Interaction effect of variety and fertilizer materials on germination percentage of mungbean at different days after sowing

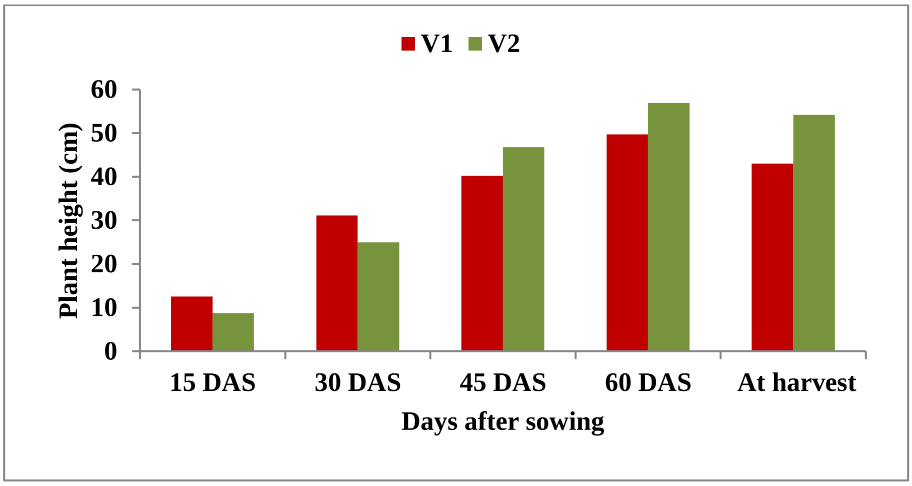
Treatments	Germination percentage at			
	4 DAS	5 DAS	6 DAS	7 DAS
V_1F_1	81.74 a-c	84.74	90.40	97.00
V_1F_2	70.51 c	83.60	92.60	97.44
V_1F_3	77.62 bc	91.90	97.62	100.00
V_1F_4	92.41 a	94.17	96.39	98.25
V_1F_5	76.51 bc	81.90	96.19	100.00
V_2F_1	69.84 c	88.83	94.95	97.98
V_2F_2	76.29 bc	89.06	94.06	95.58
V_2F_3	90.79 a	97.66	100.00	100.00
V_2F_4	82.91 ab	92.82	94.88	95.99
V_2F_5	75.80 bc	88.21	91.54	96.88
$LSD_{(0.05)}$	12.37	NS	NS	NS
CV (%)	8.99	8.11	4.11	2.81

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level
DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.2 Plant height (cm) at different growth stages

4.1.2.1 Effect of variety

The plant height of mungbean was significantly influenced by varieties at 15, 30, 60 days after sowing (DAS) and at harvest but at 45 DAS varieties had no significant effect because plant height of BARI mung-5 and Chaiti mung were statistically similar at 45 DAS (Appendix IV and Figure 3). The result revealed that at 15 DAS, the higher plant height (12.55 cm) was obtained from BARI mung-5 (V_1) and the lowest (8.76 cm) at Chaiti mung (V_2). The higher plant height (31.14 cm) was recorded at 30 DAS from BARI mung-5 followed by Chaiti mung (24.93 cm). But at 45 DAS, the numerically higher plant height (46.74 cm) was obtained from Chaiti mung and the minimum height (40.22 cm) from BARI mung-5. Similar trend of plant height was observed at 60 DAS and at harvest. Plant height of BARI mung-5 decreased at harvest over 60 DAS because BARI mung-5 is a determinate variety of mungbean. But as Chaiti mung is indeterminate type so its vegetative growth continues until harvest. These results were similar with the findings of Aguilar and Villarea (1989) and Thakuria and Saharia (1990) who reported that varieties differ significantly in respect of plant height of mungbean.



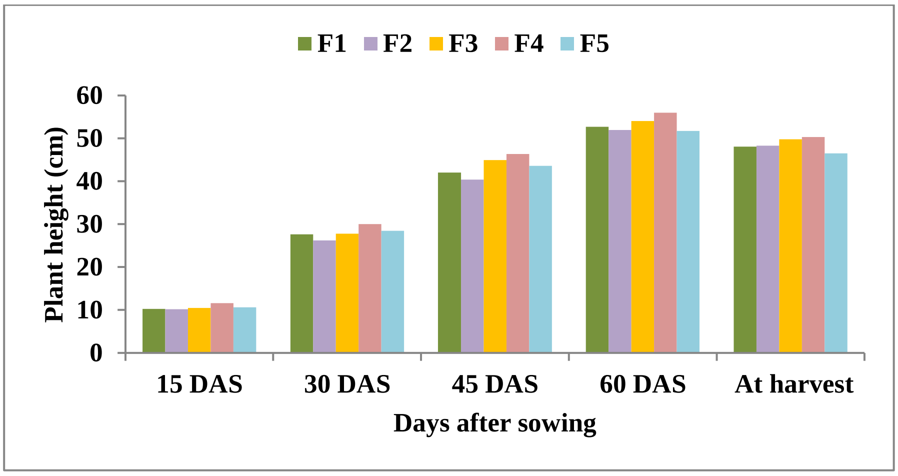
V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 3. Plant height (cm) of mungbean as influenced by variety ($LSD_{(0.05)}$ at 15, 30, 60 DAS and at harvest=3.78, 2.94, 6.83 and 5.60 respectively)

4.1.2.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on plant height at 15 and 30 DAS (Appendix IV and Figure 4). At 45 DAS, the highest plant height (46.39 cm) was obtained from 25% urea+75% *Azolla* (F_4 treatment) which was statistically similar with the height of (F_3 treatment) 50% urea+50% *Azolla* (44.95 cm) and (F_5 treatment) 100% *Azolla* (43.62 cm) treatments. The lowest plant height (40.39 cm) was obtained from (F_2 treatment) 75% urea + 25% *Azolla* which was statistically similar with the height of (F_1 treatment) 100% urea (42.02 cm). At 60 DAS, the highest plant height (56.00 cm) was obtained from (F_4 treatment) 25% urea + 75% *Azolla*. The lowest plant height (51.72 cm) was obtained from (F_5 treatment) 100% *Azolla*, which was statistically similar with the height of (F_2 treatment) 75% urea + 25% *Azolla* (51.99 cm) and (F_1 treatment) 100% urea (52.69 cm).

At harvest the highest plant height (50.34 cm) was obtained from (F_4 treatment) 25% urea + 75% *Azolla* which was statistically similar with the height of (F_3) 50% urea + 50% *Azolla* (49.83cm), (F_2) 75% urea + 25% *Azolla* (48.27 cm) and (F_1) 100% urea (48.08 cm). The lowest plant height (46.53 cm) was obtained from (F_5 treatment) 100% *Azolla*, which was statistically similar with the height of (F_2) 75% urea + 25% *Azolla* (48.27 cm) and (F_1) 100% urea (48.08 cm).



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 4. Plant height (cm) of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at 45, 60 DAS and at harvest=3.92, 1.48 and 2.36 respectively)

4.1.2.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on plant height observed at 15, 30, 45, 60 DAS and at harvest (Appendix IV and Table 2). At 15 DAS, the highest plant height was observed in V_1F_2 treatment (BARI mung-5 fertilized by 75% urea + 25% *Azolla)*. At 30 DAS, the highest plant height was observed in V_1F_5 treatment (BARI mung-5 fertilized by 100% *Azolla*). But at 45 and 60 DAS, plant height was highest in V_2F_4 treatment (Chaiti mung fertilized by 25% urea + 75% *Azolla*). At harvest, the highest plant height was found in V_2F_3 treatment. But the results were statistically similar in each case. So interaction effect of variety and fertilizer materials was not significant in respect of plant height.

Table 2. Interaction effect of variety and fertilizer materials on plant height (cm) of mungbean at different growth stages

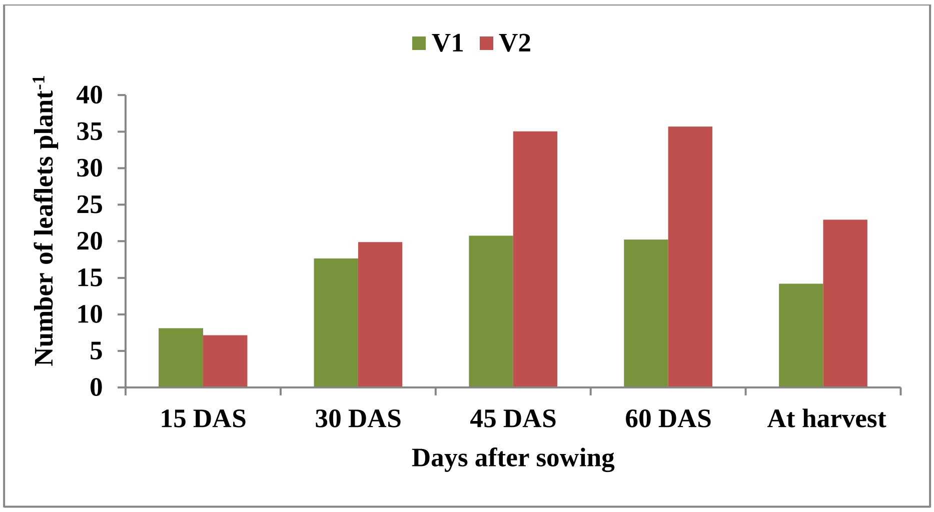
Treatments	Plant height (cm) at				
	15 DAS	30 DAS	45 DAS	60 DAS	At harvest
V_1F_1	12.24	30.37	40.10	49.83	43.13
V_1F_2	13.44	31.47	39.94	48.87	43.46
V_1F_3	11.03	30.01	40.53	50.06	42.55
V_1F_4	13.24	31.83	41.33	51.43	44.50
V_1F_5	12.67	32.01	39.17	48.31	41.49
V_2F_1	8.24	24.89	43.95	55.56	53.03
V_2F_2	6.96	21.03	40.85	55.13	53.09
V_2F_3	9.99	25.60	49.37	58.00	57.11
V_2F_4	10.03	28.15	51.45	60.57	56.19
V_2F_5	8.59	24.97	48.07	55.14	51.58
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	13.66	10.75	7.37	2.27	3.96

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*, F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.3 No. of leaflets plant^{-1} at different growth stages

4.1.3.1 Effect of variety

Number of leaflets plant^{-1} of mungbean was significantly influenced by varieties at 30, 45, 60 days after sowing (DAS) and at harvest but at 15 DAS, varieties had no significant effect because number of leaflets plant^{-1} of BARI mung-5 and Chaiti mung were statistically similar at 15 DAS (Appendix V and Figure 5). The result revealed that at 30 DAS, number of leaflets plant^{-1} was higher in Chaiti mung (V_2) compared to BARI mung-5 (V_1). Similar trend of number of leaflets plant^{-1} was observed at 45, 60 DAS and at harvest. Chaiti mung is indeterminate type so its vegetative growth continues until harvest and the number of branches plant^{-1} was higher in Chaiti mung than BARI mung-5. In Chaiti mung, as the number of branches was higher, the number of leaflets plant^{-1} was also higher. Ansary (2007) reported that varieties differ significantly in respect of number of leaflets plant^{-1}. He found two varieties BARI mung-6 and BU mung-2 had significant effect on number of leaflets plant^{-1} at 30 and 45 DAS.

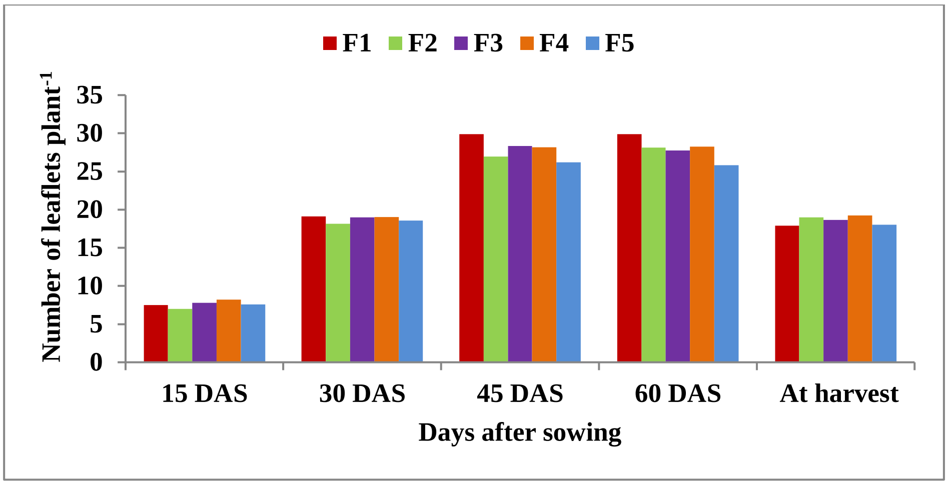


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 5. Number of leaflets plant^{-1} of mungbean as influenced by variety ($LSD_{(0.05)}$ at 30, 45, 60 DAS and at harvest=1.06, 2.22, 4.03 and 6.85 respectively)

4.1.3.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on number of leaflets plant^{-1} of mungbean at 15, 30, 45, 60 DAS and at harvest (Appendix V and Figure 6). At 15 DAS and at harvest, the number of leaflets plant^{-1} was higher in F_4 treatment (25% urea + 75% *Azolla*). At 30, 45 and 60 DAS, number of leaflets plant^{-1} was higher in F_1 treatment (100% urea) but the results were statistically similar in each case as no significant variation observed on number of leaflets plant^{-1} due to application of fertilizer materials.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 6. Number of leaflets plant^{-1} of mungbean as influenced by fertilizer materials

4.1.3.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on number of leaflets plant^{-1} observed at 15, 45, 60 DAS and at harvest but significant variation observed at 30 DAS (Appendix V and Table 3). At 15 DAS, all the results were statistically similar. At 30 DAS, the highest number of leaflets plant^{-1} was observed in V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) but the result was statistically similar with V_2F_4 treatment (Chaiti mung fertilized by 25% urea+ 75% *Azolla*) and V_2F_1 treatment (Chaiti mung fertilized by 100% urea). Number of leaflets plant^{-1} was lower in V_1F_3 treatment (BARI mung-5 fertilized by 50% urea+ 50% *Azolla*) which was statistically similar with V_1F_4 (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*), V_1F_5 (BARI mung-5 fertilized by 100% *Azolla*), V_1F_1 (BARI mung-5 fertilized by 100% urea), V_1F_2 (BARI mung-5 fertilized by 75% urea+ 25% *Azolla*) and V_2F_2 (Chaiti mung fertilized by 75% urea+ 25% *Azolla*) treatments. At 45, 60 DAS and at harvest, number of leaflets plant^{-1} was higher inV_2F_1 treatment (Chaiti mung fertilized by 100% *Azolla*) but the result was statistically similar in all case. These might due to higher number of branches plant^{-1} of Chaiti mung compared to BARI mung-5.

Table 3. Interaction effect of variety and fertilizer materials on number of leaflets plant^{-1} of mungbean at different gowth stages

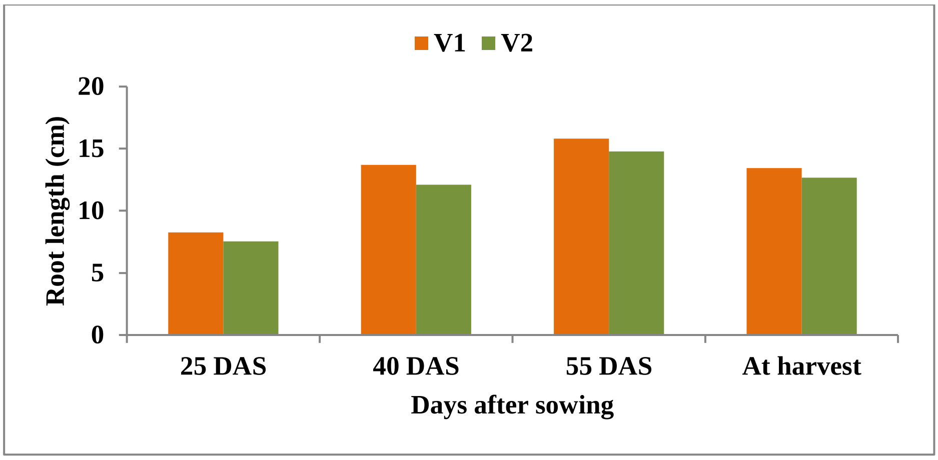
Treatments	Number of leaflets plant^{-1} at				
	15 DAS	30 DAS	45 DAS	60 DAS	At harvest
V_1F_1	8.20	18.00 cd	20.93	20.47	11.27
V_1F_2	8.00	18.00 cd	20.60	20.33	13.60
V_1F_3	7.60	16.80 d	20.80	18.73	14.93
V_1F_4	8.80	17.67 cd	20.07	21.33	15.80
V_1F_5	8.00	17.87 cd	21.40	20.33	15.27
V_2F_1	6.80	20.27 ab	38.80	39.33	24.53
V_2F_2	6.00	18.27 cd	33.33	35.93	24.40
V_2F_3	8.00	21.20 a	35.87	36.73	22.40
V_2F_4	7.60	20.40 ab	36.27	35.20	22.67
V_2F_5	7.20	19.27 bc	30.97	31.33	20.80
$LSD_{(0.05)}$	NS	1.86	NS	NS	NS
CV (%)	13.10	5.72	9.96	10.60	14.10

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*, F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.4 Root length (cm) at different growth stages

4.1.4.1 Effect of variety

Root length of mungbean was significantly influenced by varieties at 55 days after sowing (DAS) and at harvest (Appendix VI and Figure 7). But no significant variation of root length was observed between BARI mung-5 and Chaiti mung at 25 DAS and at 40 DAS because the results were statistically similar. At 55 DAS, BARI mung-5 produced the higher root length (15.82 cm) and Chaiti mung gave the shorter root length (14.79 cm). The same trend of root length was observed at harvest. The result agreed with the findings of Ratna (2007) who observed varieties differ significantly in respect of root length.

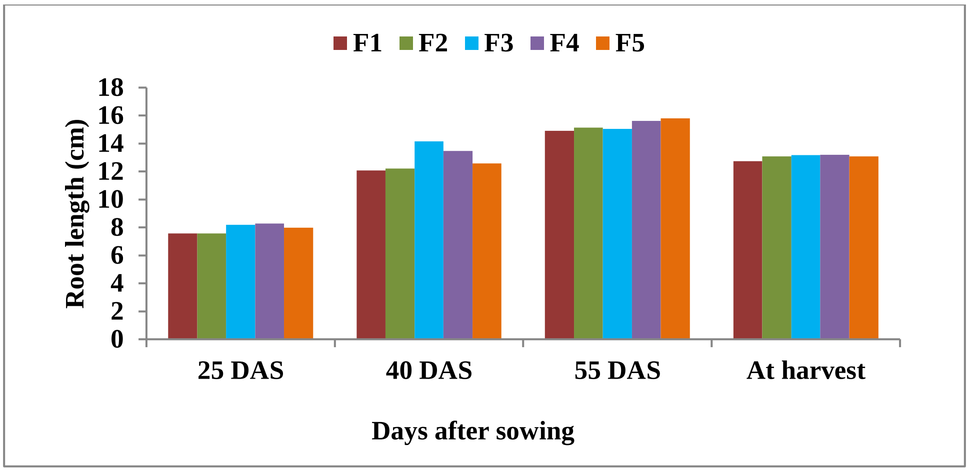


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 7. Root length (cm) of mungbean as influenced by variety ($LSD_{(0.05)}$ at 55 DAS and at harvest=0.89 and 0.29 respectively)

4.1.4.2 Effect of fertilizer materials

Fertilizer materials had significant effect on root length at 25 DAS and at 40 DAS. At 25 DAS, the highest root length (8.27 cm) was obtained in F_4 treatment (25% urea+ 75% *Azolla*) but the result was statistically similar with F_3 (50% urea+ 50% *Azolla*) and F_5 (100% *Azolla*) treatments. The shortest root length (7.57 cm) was obtained from F_1 treatment (100% urea) but it was statistically similar with F_2 (75% urea+ 25% *Azolla*) (Appendix VI and Figure 8). At 40 DAS, root length was higher (14.15 cm) in F_3 treatment (50% urea+ 50% *Azolla*) and it was statistically similar with F_4 (25% urea+ 75% *Azolla*) treatment. Root length was lower (12.08 cm) in F_1 (100% urea) but the result was statistically similar with F_2 (75% urea+ 25% *Azolla*) and F_5 (100% *Azolla*) treatments. So root length was unaffected by the different fertilizer materials at 55 DAS and at harvest.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 8. Root length (cm) of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at 25 and 40 DAS =0.53 and 1.37 respectively)

4.1.4.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on root length observed at 25, 40, 55 DAS and at harvest. At 25 and 40 DAS, the highest root length was observed in V_1F_3 treatment (BARI mung-5 fertilized by 50% urea+ 50% *Azolla*) (Table 4). But at 55 DAS and at harvest root length was higher in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*). But the results were statistically similar at different growth stages of both BARI mung-5 and Chaiti mung. This revealed that use of only urea, only *Azolla* or their different combinations, root lengths were statistically similar in case of BARI mung-5 and Chaiti mung.

Table 4. Interaction effect of variety and fertilizer materials on number of leaflets plant^{-1} of mungbean at different gowth stages

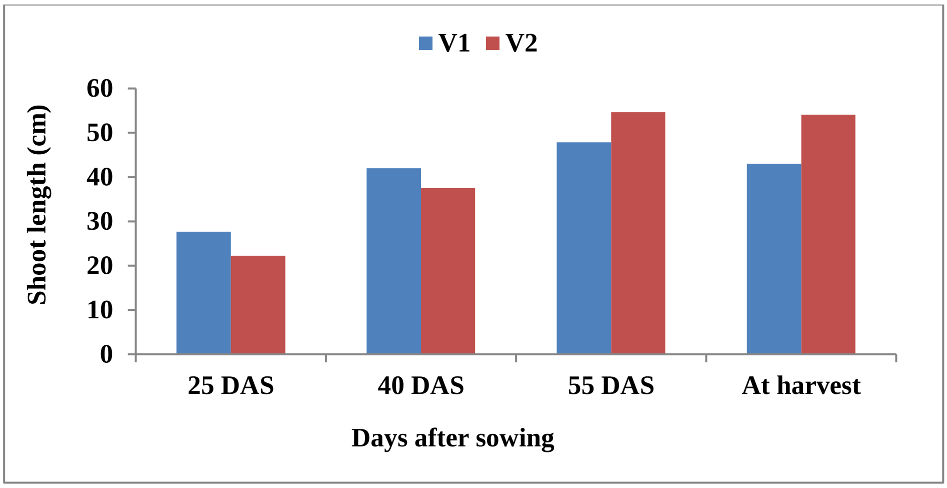
Treatments	Root length (cm) at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	7.73	12.67	15.83	13.05
V_1F_2	8.23	13.27	16.18	13.70
V_1F_3	8.50	14.58	15.33	13.57
V_1F_4	8.43	13.58	16.29	13.78
V_1F_5	8.47	14.34	15.49	13.08
V_2F_1	7.40	11.75	14.01	12.40
V_2F_2	6.93	10.89	14.08	12.46
V_2F_3	7.87	13.72	14.76	12.75
V_2F_4	8.10	13.35	14.95	12.59
V_2F_5	7.47	10.80	16.13	13.07
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	5.48	8.66	8.87	8.35

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.5 Shoot length (cm) at different growth stages

4.1.5.1 Effect of variety

Varieties had significant influence on shoot length of mungbean at 25, 55 days after sowing (DAS) and at harvest but at 40 DAS, varieties had no significant effect because shoot length of BARI mung-5 and Chaiti mung were statistically similar at 40 DAS (Appendix VII and Figure 9). At 25 DAS, BARI mung-5 produced the higher shoot length (27.67 cm) and Chaiti mung gave the smaller shoot length (22.23 cm). But at 55 DAS, the higher shoot length was observed in Chaiti mung (54.67 cm) than BARI mung-5 (47.83 cm). At harvest shoot length was also higher in Chaiti mung (54.08 cm) because Chaiti mung is a local variety and it is indeterminate type whose vegetative growth continues at reproductive stage also. The shoot length varies with the variation in variety was reported by Ahmed *et al.* (2003).

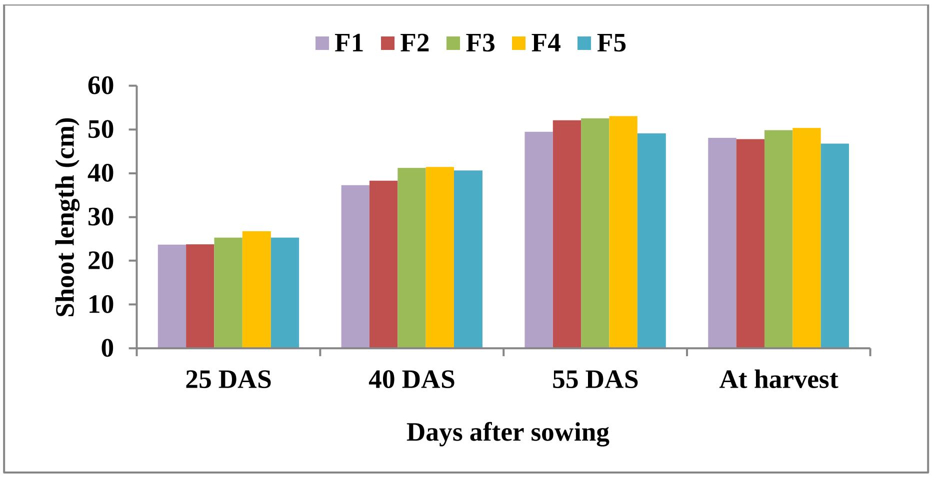


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 9. Shoot length (cm) of mungbean as influenced by variety ($LSD_{(0.05)}$ at 25, 55 DAS and at harvest=4.34, 5.38 and 10.46 respectively)

4.1.5.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on shoot length at 25, 40 and 55 DAS but significant effect observed at harvest. At 25 DAS, the highest shoot length (26.75 cm) was obtained in F_4 treatment (25% urea+ 75% *Azolla*) but the result was statistically similar with other treatments. Similar trend was also observed in 40 and 55 DAS. At harvest, the shoot length was higher (50.35 cm) in F_4 treatment (25% urea+ 75% *Azolla*) and it was statistically similar with F_3 (50% urea+ 50% *Azolla*) and F_1 (100% urea) treatments. Shoot length was lower (46.74cm) in F_5 (100% *Azolla*) but the result was statistically similar with F_1 (100% urea) and F_2 (75% urea+25% *Azolla*) treatments (Appendix VII and Figure 10). Shoot length was unaffected by the different fertilizer materials at 25, 40 and 55 DAS.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 10. Shoot length (cm) of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at harvest =2.35)

4.1.5.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had insignificant effect in shoot length observed at 25, 40, 55 DAS and at harvest. At 25 and 40 DAS, the highest shoot length was observed in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*) but the results were statistically similar with other treatments. At 55 DAS and at harvest shoot length was higher in V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) and it was also statistically similar with other treatments. After attaining certain height the shoot length of BARI mung-5 decrease or remain constant but as Chaiti mung is indeterminate type so its shoot length increases until harvest (Appendix VII and Table 5).

Table 5. Interaction effect of variety and fertilizer materials on shoot length (cm) at different crop growth stages of mungbean

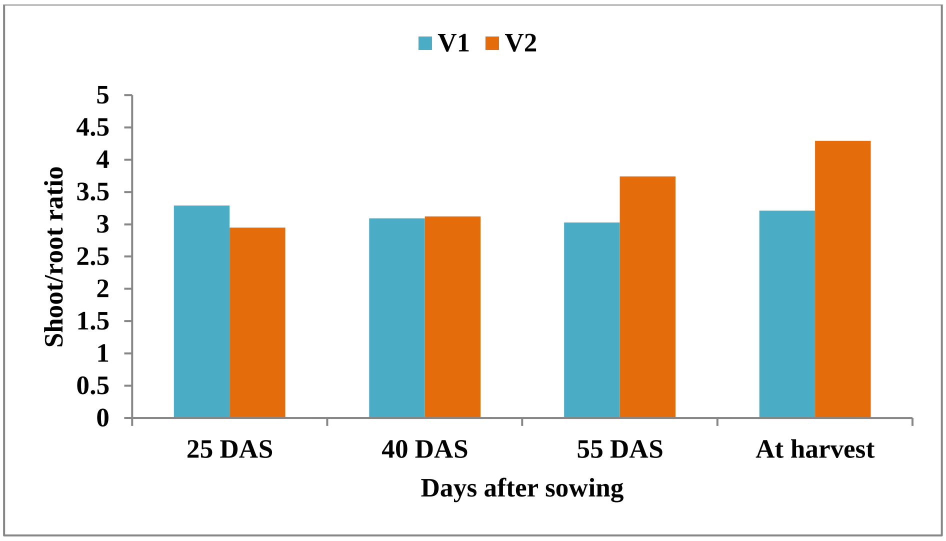
Treatments	Shoot length (cm) at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	25.8	39.81	46.98	43.13
V_1F_2	28.59	45.36	48.93	43.46
V_1F_3	26.51	41.73	47.69	42.55
V_1F_4	28.96	42.07	50.29	44.50
V_1F_5	28.42	41.02	45.28	41.49
V_2F_1	21.55	34.66	51.96	53.03
V_2F_2	18.89	31.27	55.22	52.09
V_2F_3	24.08	40.65	57.38	57.11
V_2F_4	24.55	40.76	55.77	56.19
V_2F_5	22.10	40.31	53.01	51.98
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	11.48	12.44	6.04	3.95

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.6 Shoot /root ratio at different growth stages

4.1.6.1 Effect of variety

Significant influence of varieties on shoot/root ratio of mungbean was found at 55 days after sowing (DAS) and at harvest but at 25 and 40 DAS, varieties had no significant effect. At 25 DAS, the numerically higher shoot/root ratio was observed on BARI mung-5 and at 40 DAS, it was higher in Chaiti mung but the results were statistically similar in both case. Shoot/root ratio was higher in Chaiti mung (3.74) at 55 DAS than BARI mung-5 (3.03). At harvest, shoot/root ratio was also higher in Chaiti mung (4.29) than BARI mung-5 (3.21) (Appendix VIII and Figure 11).

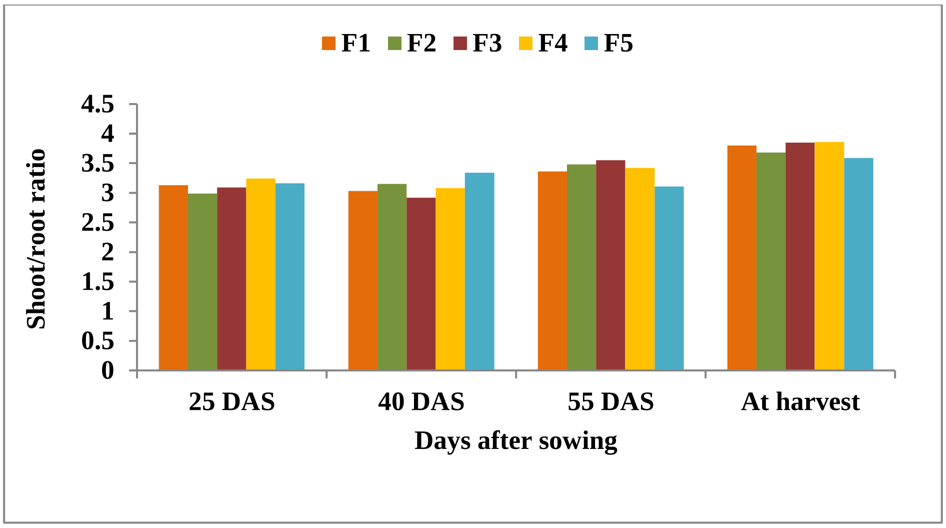


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 11. Shoot/root ratio of mungbean as influenced by variety ($LSD_{(0.05)}$ at 55 DAS and at harvest=0.43 and 0.31 respectively)

4.1.6.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on shoot/root ratio at 25, 40, 55 DAS and at harvest (Appendix VIII and Figure 12). At 25 DAS, the maximum shoot/root ratio (3.24) was obtained in F_4 treatment (25% urea+ 75% *Azolla*) but the result was statistically similar with other treatments. At 40 DAS, the shoot/root ratio was higher (3.34) in F_5 treatment (100% *Azolla*). At 55 DAS, it was higher (3.55) in F_3 treatment (50% urea+50% *Azolla*) and at harvest shoot/root ratio was higher (3.86) in F_4 treatment (25% urea+ 75% *Azolla*) than other treatments but there was no significant variation as the results were statistically similar.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 12. Shoot/root ratio of mungbean as influenced by fertilizer materials

4.1.6.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on shoot/root ratio observed at 25, 55 DAS and at harvest but significant effect observed at 40 DAS Appendix VIII and Table 6). At 25 DAS, the maximum shoot/root ratio was observed in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*) but the result was statistically similar with other treatments. At 40 DAS, the shoot/root ratio was higher (3.79) in V_2F_5 treatment (Chaiti mung fertilized by 100% *Azolla*) but it was statistically similar with V_1F_1 (BARI mung-5 fertilized by 100% urea) and V_1F_2 (BARI mung-5 fertilized by 75% urea+ 25% *Azolla*) treatments. Shoot/root ratio was lower in V_1F_3 (BARI mung-5 fertilized by 50% urea+ 50% *Azolla*) and V_2F_2 (Chaiti mung fertilized by 25% urea+ 75% Azolla) treatments but the results were statistically similar with other treatments except V_2F_5 treatment (Chaiti mung fertilized by 100% *Azolla*) which gave the maximum shoot/root ratio. At 55 DAS and at harvest shoot/root ratio was higher in V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) and it was also statistically similar with other treatments.

Table 6. Interaction effect of variety and fertilizer materials on shoot/root ratio at different growth stages of mungbean

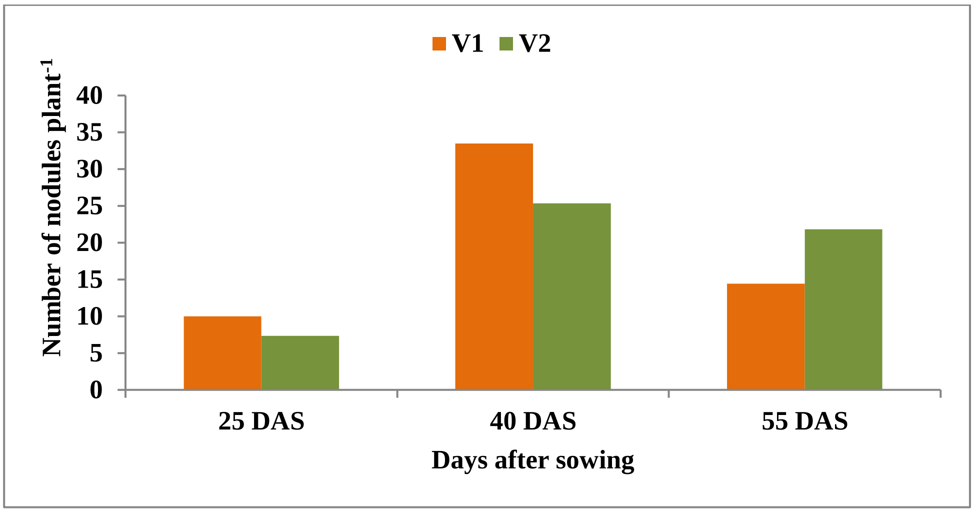
Treatments	Shoot/root ratio at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	3.35	3.15 ab	2.99	3.32
V_1F_2	3.23	3.43 ab	3.03	3.18
V_1F_3	3.11	2.87 b	3.12	3.16
V_1F_4	3.43	3.09 b	3.09	3.23
V_1F_5	3.36	2.88 b	2.93	3.19
V_2F_1	2.92	2.91 b	3.73	4.28
V_2F_2	2.74	2.87 b	3.92	4.18
V_2F_3	3.07	2.97 b	3.99	4.54
V_2F_4	3.04	3.06 b	3.76	4.48
V_2F_5	2.96	3.79 a	3.29	3.99
$LSD_{(0.05)}$	NS	0.66	NS	NS
CV (%)	10.23	12.31	12.00	9.34

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.7 Number of nodules plant^{-1} at different growth stages

4.1.7.1 Effect of variety

No significant influence of varieties on number of nodules plant^{-1} of mungbean was found at 25 and 40 days after sowing (DAS) but at 55 DAS, the total number of nodules plant^{-1} was significantly influenced by varieties (Appendix IX and Figure 13). At 25 DAS and at 40 DAS, more number of nodules plant^{-1} was found in BARI mung-5 compared to Chaiti mung but the results were statistically similar at both growth stages. At 55 DAS, Chaiti mung produced more number of nodules plant^{-1} (21.81) than BARI mung-5 (14.43). The number of total nodules plant^{-1} increased with the advancement of growth up to 45 DAS, thereafter started declining. It appeared that the peak nodulation in mungbean occurred between pre-flowering and pod filling stage. This might be due to peak nodulation in mungbean at 50% flowering stage and degeneration of nodules after pod filling stage. Patel and Patel (1994) reported that significantly 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.

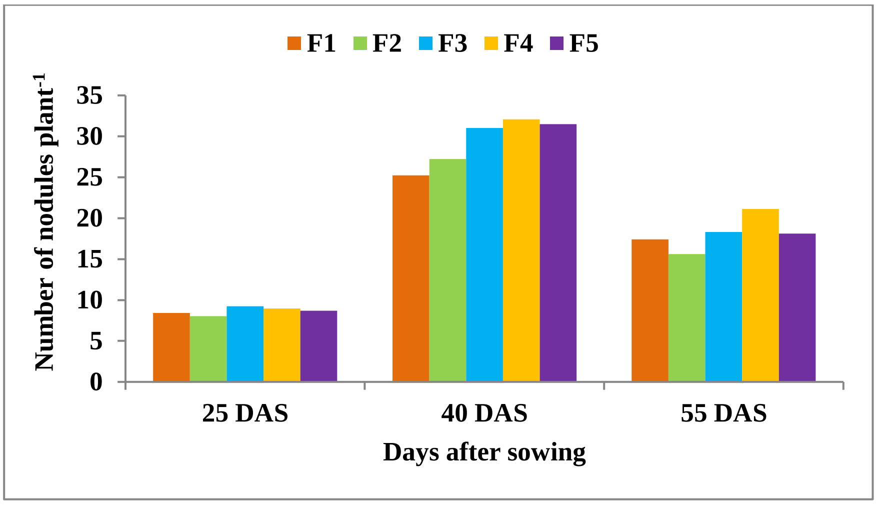


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 13. Number of nodules plant^{-1} of mungbean as influenced by variety (LSD$_{(0.05)}$ at 55 DAS =6.89)

4.1.7.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on number of nodules plant^{-1} at 25 and 40 DAS. At 25 DAS, the maximum number of nodules plant^{-1} (9.23) was obtained in F_3 treatment (50% urea+ 50% *Azolla*) and at 40 DAS, number of nodules plant^{-1} was higher (32.08) in F_4 treatment (25% urea+75% *Azolla*) but the results were statistically similar with other treatments in both growth stages. The different fertilizer materials had highly significant effect in formation of total number of nodules plant^{-1} recorded at 55 DAS, it was highest (21.13) in F_4 treatment (25% urea+75% *Azolla*) and the result was statistically similar with F_3 (50% urea+ 50% *Azolla*) (18.30) and F_5 (100% *Azolla*) (18.13) treatments. The minimum number of nodules plant^{-1} (15.63) was recorded in F_2 (75% urea+25% *Azolla*) treatment but it was statistically similar with F_1 (100% urea) (17.40), F_5 (100% *Azolla*) (18.13) and F_3 (50% urea+ 50% *Azolla*) (18.30) treatments (Appendix IX and Figure 14). This might be due to the high requirement of N at flowering and pod filling stage (Rennie and Kemp, 1984).



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 14. Number of nodules plant^{-1} of mungbean as influenced by fertilizer materials (LSD$_{(0.05)}$ at 55 DAS =3.12)

4.1.7.3 Interaction effect of variety and Fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on number of nodules plant^{-1} observed at 25, 40 and 55 DAS. At 25 DAS, maximum number of nodules plant^{-1} was observed in V_1F_3 treatment (BARI mung-5 fertilized by 50% urea+ 50% *Azolla*) but the result was statistically similar with other treatments. At 40 DAS, number of nodules plant^{-1} was highest in V_1F_5 treatment (BARI mung-5 fertilized by 100% *Azolla*) and at 55 DAS, maximum number of nodules plant^{-1} was found in V_2F_4 (Chaiti mung fertilized by 25% urea+75% *Azolla*) and V_2F_5 (Chaiti mung fertilized by 100% *Azolla*) treatments but the results were statistically similar with other treatments (Appendix IX and Table 7). So no significant variation was found due to interaction of variety and fertilizer materials on number of nodules plant^{-1}.

Table 7. Interaction effect of variety and fertilizer materials on number of nodules plant^{-1} at different growth stages, SPAD value and leaf area index (LAI) of mungbean

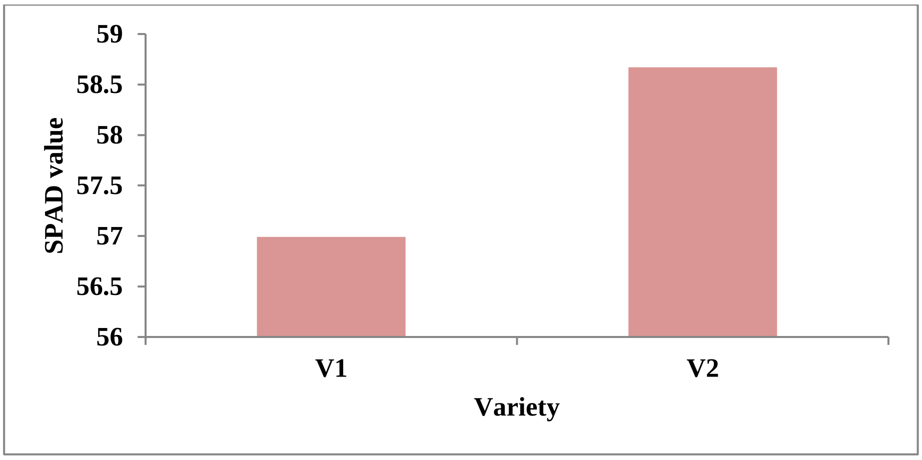
Treatments	Number of nodules plant^{-1}			SPAD value	Leaf area index (LAI)
	25 DAS	40 DAS	55 DAS		
V_1F_1	8.80	30.07	14.13	55.62	4.96
V_1F_2	9.67	31.07	11.00	56.89	4.87
V_1F_3	10.67	34.07	15.80	56.31	5.01
V_1F_4	10.60	33.63	15.40	58.99	4.92
V_1F_5	10.33	38.60	15.80	57.17	5.20
V_2F_1	8.07	20.40	20.67	59.97	5.73
V_2F_2	6.37	23.40	20.27	58.70	5.14
V_2F_3	7.80	28.00	20.80	57.81	5.50
V_2F_4	7.33	30.53	26.87	58.37	5.64
V_2F_5	7.067	24.33	26.87	58.22	5.46
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	16.18	16.67	14.09	3.58	7.15

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level,
DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.8 SPAD value

4.1.8.1 Effect of variety

Varieties had no significant effect on SPAD value of mungbean (Appendix IX and Figure 15). SPAD value was higher (58.67) in Chaiti mung compared to BARI mung-5 (56.99) but the values were statistically similar.

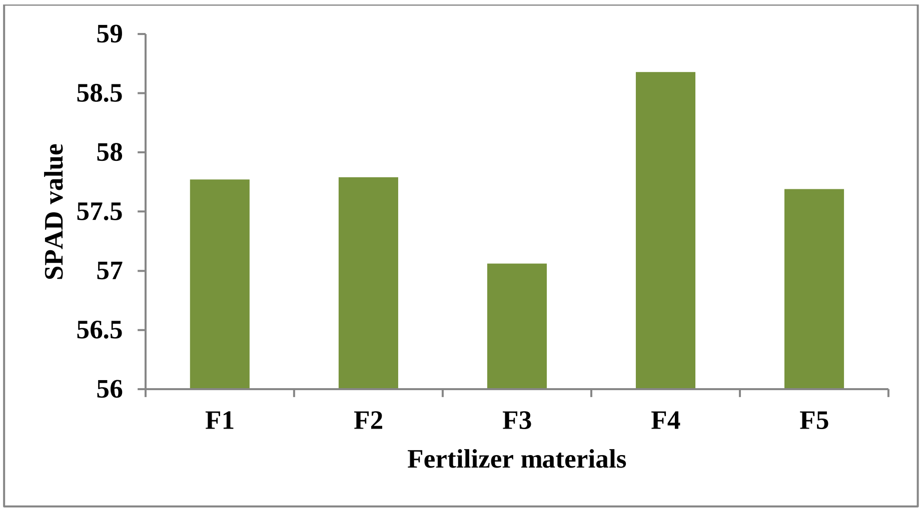


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 15. SPAD value of mungbean as influenced by variety

4.1.8.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on SPAD value of mung bean (Appendix IX and Figure 16). SPAD value was highest (58.68) in F_4 (25% urea+75% *Azolla*) treatment but the result was statistically similar with other treatments. So chlorophyll content of mungbean was not affected by fertilizer materials.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 16. SPAD value of mungbean of mungbean as influenced by fertilizer materials

4.1.8.3 Interaction effect of variety and fertilizer materials

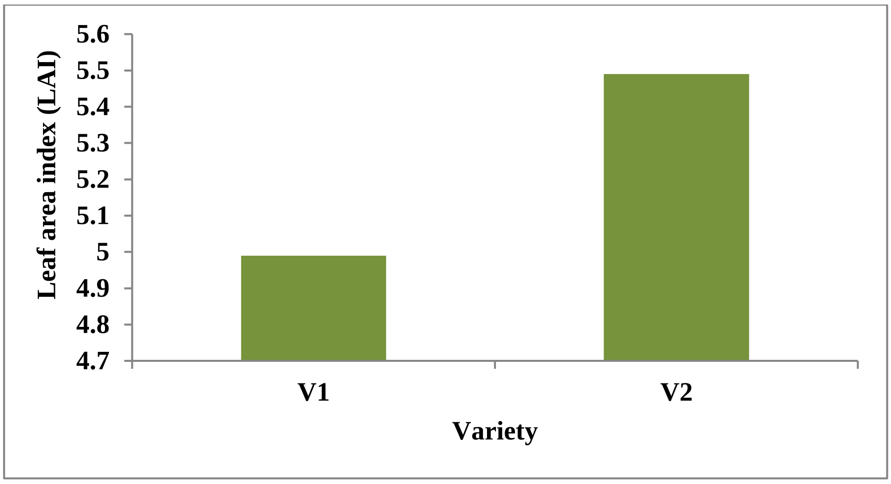
Interaction effect between variety and fertilizer materials was found insignificant in respect of SPAD value (Appendix IX and Table 7). Maximum SPAD value (59.97) was observed in V_2F_1 treatment (Chaiti mung fertilized by 100% urea) but it was statistically similar with all other treatments. This revealed that use of only urea, only *Azolla* or their different combinations, chlorophyll content were statistically similar in case of both BARI mung-5 and Chaiti mung.

4.1.9 Leaf Area Index (LAI)

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 and it is the functional size of the standing crop on unit land area. It depends on the growth, number of leaves plant^{-1}, population density and leaf senescence. The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of crop photosynthesis depends on the LAI. LAI increase after germination reaches the peak levels and thereafter declines due to increased senescence (Katiya, 1980).

4.1.9.1 Effect of variety

Significant effect of varieties was found on Leaf area index (LAI) of mungbean at 45 DAS (Appendix IX and Figure 17). Leaf area index was higher (5.49) in V_2 (Chaiti mung) and lower (4.99) in V_1 (BARI mung-5). The finding was similar with Ghosh (2007) who reported that Leaf area index (LAI) of mungbean was significantly influenced by varieties.



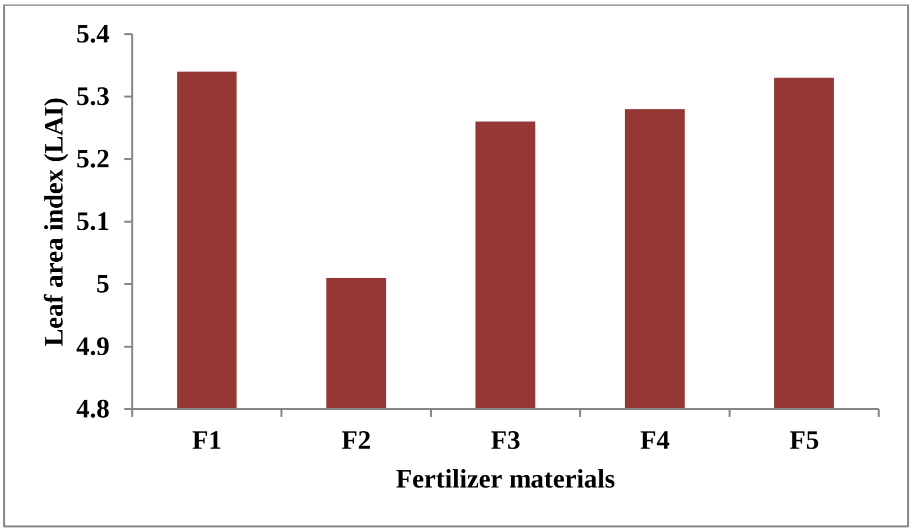
V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 17. Leaf area index (LAI) of mungbean as influenced by variety

4.1.9.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on Leaf area index (LAI) of mung bean (Appendix IX and Figure 18). Leaf area index (LAI) was higher in F_1

(100% urea) treatment (5.34) but the result was statistically similar with other treatments. So Leaf area index (LAI) of mungbean was not affected by fertilizer materials.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 18. Leaf area index (LAI) of mungbean of mungbean as influenced by fertilizer materials

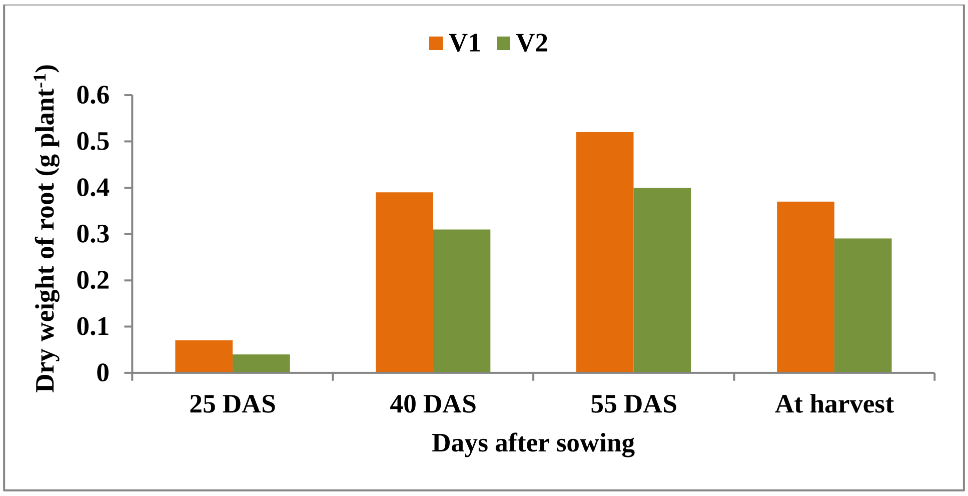
4.1.9.3 Interaction effect of variety and fertilizer materials

Interaction effect between variety and fertilizer materials was found insignificant in respect of Leaf area index (LAI) (Appendix IX and Table 7). Leaf area index (LAI) was higher in V_2F_1 treatment (Chaiti mung fertilized by 100% urea) (5.73) but it was statistically similar with all other treatments.

4.1.10 Dry weight of root (g plant^{-1})

4.1.10.1 Effect of variety

Dry weight of root plant^{-1} of mungbean was significantly affected by varieties at 40, 55 DAS and at harvest but unaffected at 25 DAS (Appendix X and Figure 19). At 40 DAS, dry weight of root plant^{-1} was higher in V_1 (BARI mung-5) (0.39 g plant^{-1}) compared to V_2 (Chaiti mung) (0.31 g plant^{-1}). Similar trend of dry weight of root plant^{-1} was observed at 55 DAS and at harvest. These results supported the findings of Ghosh (2007) who reported that varieties differ significantly in respect of dry weight of root plant^{-1} of mungbean at different growth stages.

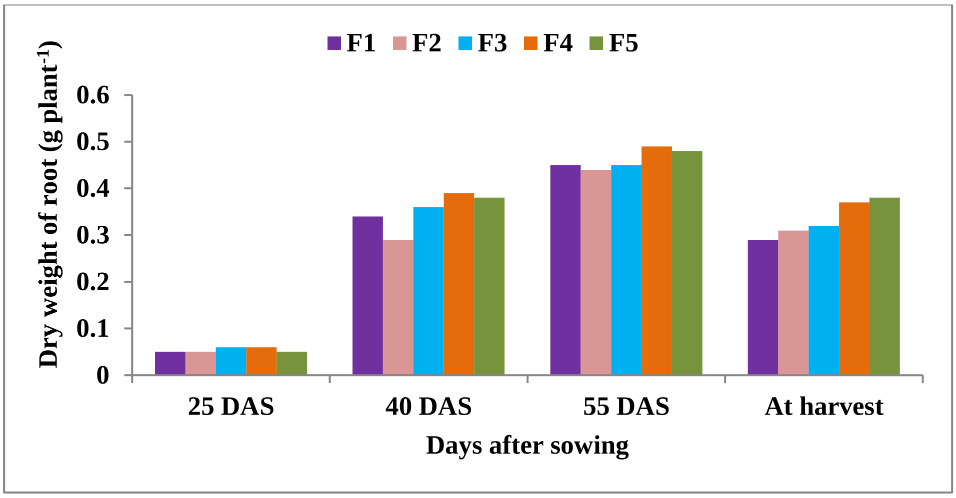


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 19. Dry weight of root (g plant^{-1}) of mungbean as influenced by variety (LSD$_{(0.05)}$ at 40, 55 DAS and at harvest=0.05, 0.06 and 0.04 respectively)

4.1.10.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on dry weight of root plant^{-1} of mungbean at 25, 40 and 55 DAS but significant effect found at harvest (Appendix x and Figure 20). At 25, 40 and 55 DAS, all the treatments were statistically similar so effect was insignificant. But at harvest, dry weight of root was highest (0.38 g plant^{-1}) in F_5 treatment (100% *Azolla*) which was statistically similar with F_4 (25% urea+75% *Azolla*) (0.37 g plant^{-1}) treatment and root dry weight was lowest (0.29 g plant^{-1}) in F_1 treatment (100% urea) which was statistically similar with F_2 (75% urea+25% *Azolla)* (0.32 g plant^{-1}) and F_3 (50% urea+50% *Azolla*) (0.31 g plant^{-1}) treatments. These might be due to *Azolla* application because it is a beneficial biofertilizer and due to its application root penetrates into deeper length and root dry weight increases to some extent compared to application of chemical fertilizer.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 20. Dry weight of root (g plant^{-1}) of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at harvest=0.06)

4.1.10.3 Interaction effect of variety and fertilizer materials

Interaction effect between variety and fertilizer materials was found insignificant in respect of dry weight of root plant^{-1} of mungbean at 25, 40, 55 DAS and at harvest (Appendix X and Table 8). The results were statistically similar in all case. This revealed that use of only urea, only *Azolla* or their different combinations, dry weight of root plant^{-1} would be statistically similar in case of both BARI mung-5 and Chaiti mung.

Table 8. Interaction effect of variety and fertilizer materials on dry weight of root plant^{-1} of mungbean at different growth stages

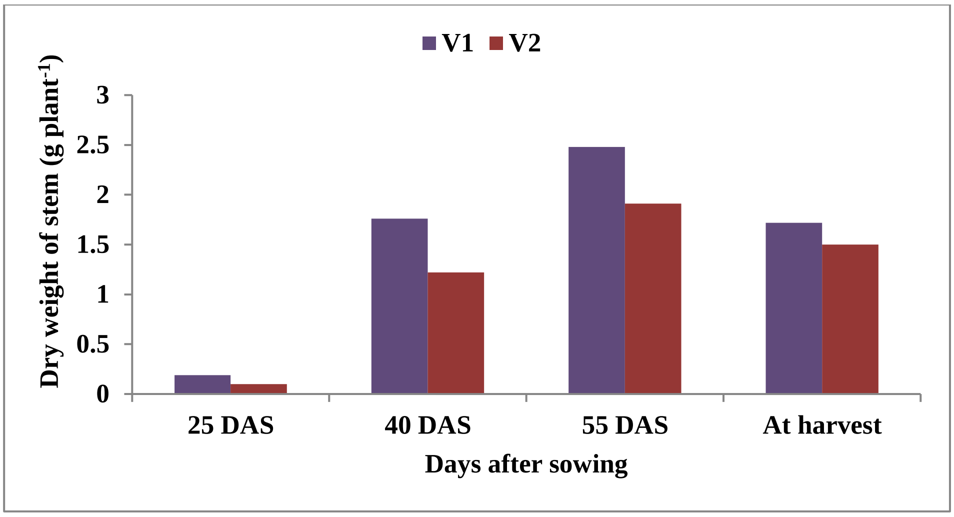
Treatments	Dry weight of root (g plant^{-1}) at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	0.06	0.39	0.49	0.33
V_1F_2	0.07	0.34	0.52	0.35
V_1F_3	0.07	0.37	0.46	0.30
V_1F_4	0.07	0.46	0.56	0.45
V_1F_5	0.07	0.41	0.55	0.41
V_2F_1	0.04	0.29	0.41	0.27
V_2F_2	0.03	0.24	0.35	0.26
V_2F_3	0.05	0.35	0.43	0.32
V_2F_4	0.05	0.31	0.42	0.29
V_2F_5	0.03	0.34	0.40	0.34
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	24.85	17.97	11.88	13.47

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.11 Dry weight of stem (g plant^{-1})

4.1.11.1 Effect of variety

Dry weight of stem plant^{-1} of mungbean was significantly influenced by varieties at 25 days after sowing (DAS) but at 40 DAS, 55 DAS and at harvest, variety had no significant effect. At 25 DAS, dry weight of stem was higher (0.19 g plant^{-1}) in V_1 (BARI mung-5) compared to V_2 (Chaiti mung) (0.10 g plant^{-1}). Dry weight of stem plant^{-1} of BARI mung-5 and Chaiti mung were statistically similar at 40, 55 DAS and at harvest (Appendix XI and Figure 21).

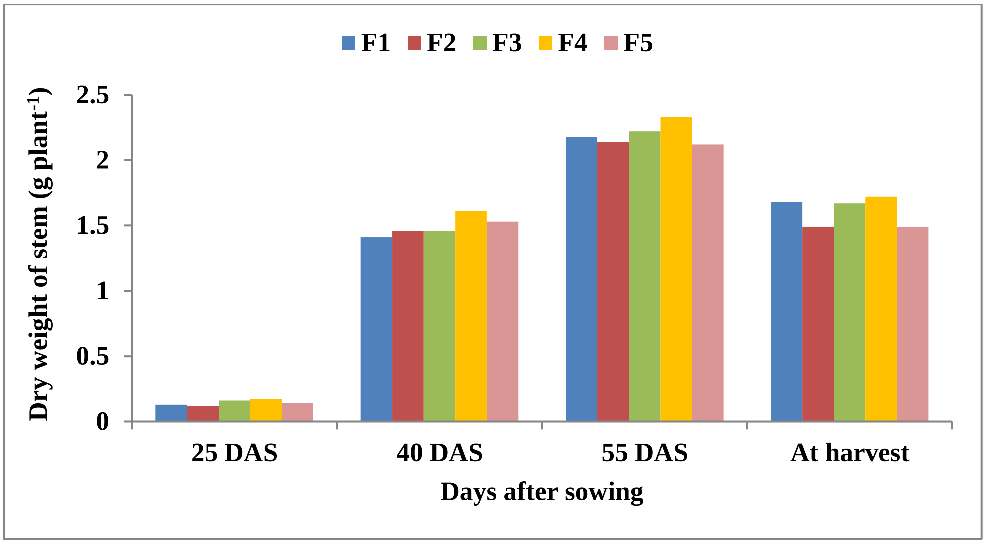


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 21. Dry weight of stem (g plant^{-1}) of mungbean as influenced by variety ($LSD_{(0.05)}$ at 25 DAS =0.07)

4.1.11.2 Effect of fertilizer materials

Fertilizer materials had significant effect on dry weight of stem plant^{-1} of mung bean at 25 DAS but no significant effect found at 40, 55 DAS and at harvest (Appendix XI and Figure 22). At 25 DAS, the highest dry weight of stem (0.17 g plant^{-1}) was found in F_4 (25% urea+75% *Azolla*) treatment which was statistically similar with F_3 (50% urea+50% *Azolla*) (0.16 g plant^{-1}) and F_5 (100% *Azolla*) (0.14 g plant^{-1}) treatments. Dry weight of stem was lowest (0.12 g plant^{-1}) in F_2 treatment (75% urea+25% *Azolla*) which was statistically similar with F_1 (100% urea) (0.13 g plant^{-1}) and F_5 (100% *Azolla*) (0.14 g) treatments. At 40, 55 DAS and at harvest all the treatments were statistically similar and so effect was insignificant.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 22. Dry weight of stem (g plant^{-1}) of mungbean as influenced by fertilizer materials (LSD$_{(0.05)}$ at 25 DAS=0.04)

4.1.11.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on dry weight of stem plant^{-1} of mungbean at 25, 40, 55 DAS and at harvest (Appendix XI and Table 9). At 25 and 40 DAS, stem dry weight plant^{-1} was highest in V_1F_4 Treatment (BARI mung-5 fertilized by 25% urea+75% *Azolla*). At 55 DAS and at harvest dry weight of stem plant^{-1} was found highest in V_1F_1 Treatment (BARI mung-5 fertilized by 100% urea) but the results were statistically similar in all case. This revealed that use of only urea, only *Azolla* or their different combinations, dry weight of stem plant^{-1} would be statistically similar in case of both BARI mung-5 and Chaiti mung.

Table 9. Interaction effect of variety and fertilizer materials on dry weight of stem plant^{-1} of mungbean at different growth stages

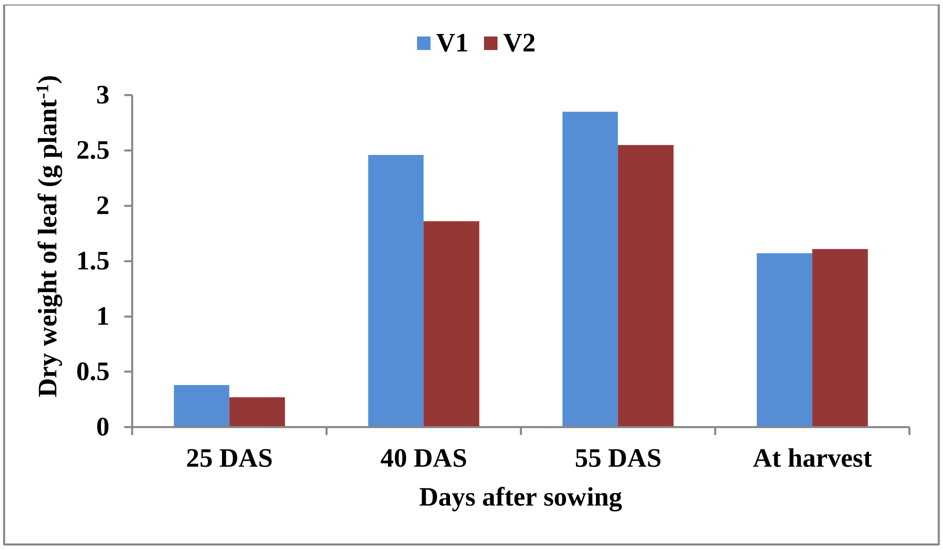
Treatments	Dry weight of stem (g plant^{-1}) at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	0.17	1.67	2.64	1.87
V_1F_2	0.17	1.84	2.48	1.73
V_1F_3	0.19	1.63	2.41	1.69
V_1F_4	0.21	1.89	2.56	1.73
V_1F_5	0.18	1.76	2.33	1.57
V_2F_1	0.08	1.15	1.71	1.48
V_2F_2	0.07	1.08	1.79	1.25
V_2F_3	0.12	1.28	2.03	1.64
V_2F_4	0.12	1.32	2.11	1.70
V_2F_5	0.09	1.29	1.91	1.41
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	22.27	15.58	8.87	13.35

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.12 Dry weight of leaf (g plant^{-1})

4.1.12.1 Effect of variety

Significant influence of varieties was found on dry weight of leaf plant^{-1} of mungbean at 25 and 40 days after sowing (DAS) but at 55 DAS and at harvest leaf dry weight was not significantly influenced by varieties (Appendix XII and Figure 23). At 25 DAS, leaf dry weight was found higher (0.38 g plant^{-1}) in BARI mung-5 compared to Chaiti mung (0.27 g plant^{-1}). Similar trend of leaf dry weight was found at 40 DAS. At 55 DAS and at harvest the results were statistically similar for two varieties of mungbean.

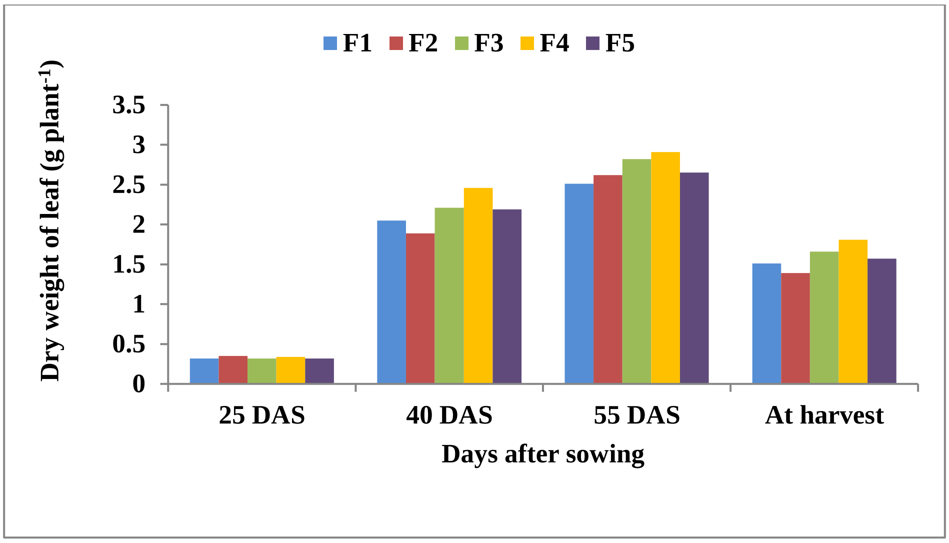


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 23. Dry weight of leaf (g plant^{-1}) of mungbean as influenced by variety ($LSD_{(0.05)}$ at 25 and 40 DAS =0.09 and 0.52 respectively)

4.1.12.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on dry weight of leaf plant^{-1} of mung bean at 25 and 55 DAS but significant effect found at 40 DAS and at harvest (Appendix XII and Figure 24). At 25 and 55 DAS, all the treatments were statistically similar so effect was insignificant. But at 40 DAS, dry weight of leaf was highest (2.46 g plant^{-1}) in F_4 treatment (25% urea+75% *Azolla*) and lowest (1.89 g plant^{-1}) in F_2 (75% urea+25% *Azolla*) which was statistically similar with F_1 treatment (100% urea) (2.05 g plant^{-1}). At harvest, dry weight of leaf was higher (1.81 g plant^{-1}) in F_4 (25% urea+75% *Azolla*) which was statistically similar with F_3 treatment (50% urea+50% *Azolla*) (1.66 g plant^{-1}) and lower (1.39 g plant^{-1}) in F_2 (75% urea+25% *Azolla*) which was statistically similar with F_1 (100% urea) (1.51 g plant^{-1}) and F_5 (100% *Azolla*) treatments (1.57 g plant^{-1}).



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 24. Dry weight of leaf (g plant^{-1}) of mungbean as influenced by fertilizer materials ($LSD_{(0.05)}$ at 40 DAS and at harvest=0.23 and 0.22 respectively)

4.1.12.3 Interaction effect of variety and fertilizer materials

Interaction effect between variety and fertilizer materials was found insignificant in respect of dry weight of leaf plant^{-1} of mungbean at 25, 40, 55 DAS and at harvest (Appendix XII and Table 10). In all growth stages, leaf dry weight plant^{-1} was highest in V_1F_4 Treatment (BARI mung-5 fertilized by 25% urea+75% *Azolla*) but the results were statistically similar in all case.

Table 10. Interaction effect of variety and fertilizer materials on dry weight of leaf plant^{-1} of mungbean at different growth stages

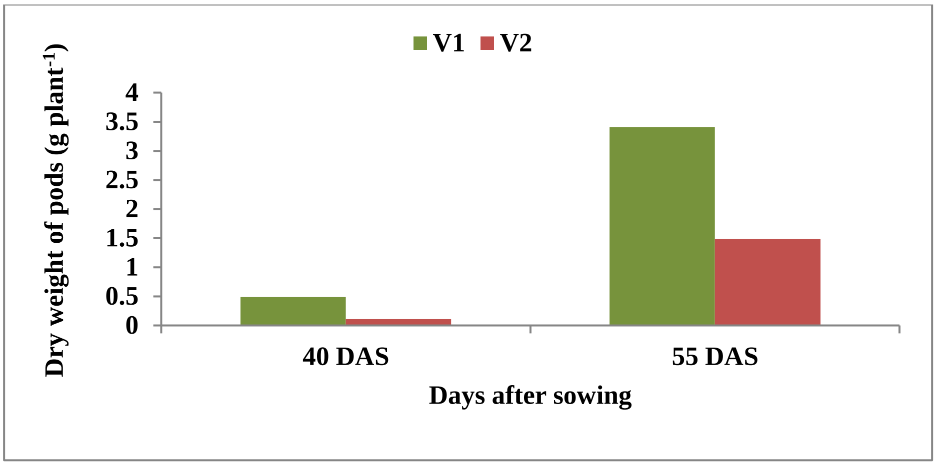
Treatments	Dry weight of stem (g plant^{-1}) at			
	25 DAS	40 DAS	55 DAS	At harvest
V_1F_1	0.36	2.28	2.69	1.44
V_1F_2	0.41	2.18	2.90	1.34
V_1F_3	0.38	2.50	2.73	1.59
V_1F_4	0.40	2.81	3.03	1.85
V_1F_5	0.36	2.50	2.89	1.62
V_2F_1	0.27	1.82	2.33	1.58
V_2F_2	0.29	1.60	2.33	1.43
V_2F_3	0.26	1.92	2.91	1.72
V_2F_4	0.27	2.11	2.79	1.78
V_2F_5	0.27	1.87	2.41	1.52
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	19.26	8.54	10.21	11.27

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.13 Dry weight of pods (g plant^{-1})

4.1.13.1 Effect of variety

Varieties had no significant influence on dry weight of pod plant^{-1} of mungbean at 40 DAS but significant influence found at 55 DAS. At 55 days after sowing, dry weight of pods was higher (3.41 g plant^{-1}) in BARI mung-5 (V_1) and lower in Chaiti mung (V_2) (Appendix XIII and Figure 25). At earlier (40 DAS), the results were statistically similar but at 55 DAS, number of pods plant^{-1} in BARI mung-5 was higher than local variety (Chaiti mung), so pod dry weight was higher. Ratna (2007) in her experiment also found that dry weight of pods plant^{-1} varies with varieties of mungbean.

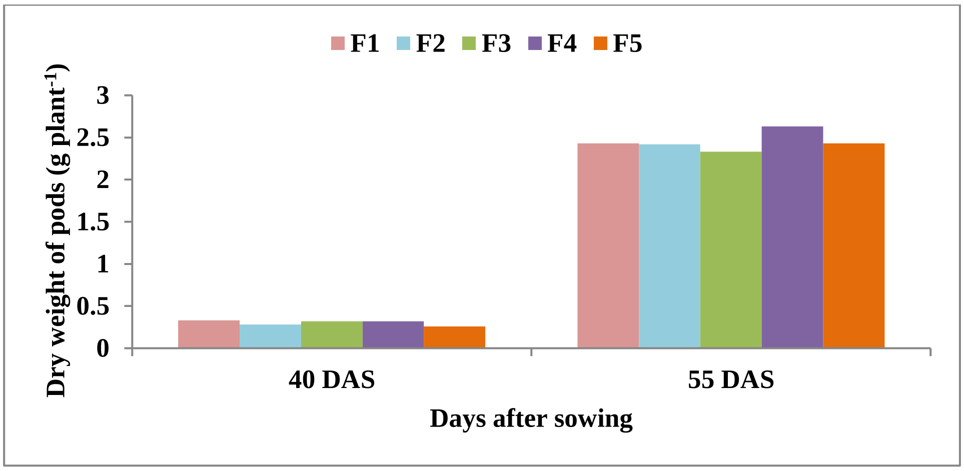


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 25. Dry weight of pods (g plant^{-1}) of mungbean as influenced by variety (LSD$_{(0.05)}$ at 55 DAS =0.64)

4.1.13.2 Effect of fertilizer materials

No significant variation on dry weight of pods plant^{-1} of mungbean was found at 40 DAS due to fertilizer materials but effect was significant at 55 DAS. At 55 DAS, pods dry weight was higher (2.63 g plant^{-1}) in F_4 treatment (25 % urea + 75% *Azolla*) and lower in F_3 treatment (50 % urea + 50 % *Azolla*) (2.33 g plant^{-1}) but the result was statistically similar with F_2 (75 % urea + 25 % *Azolla*) (2.42 g plant^{-1}), F_1 (100% urea) (2.43 g plant^{-1}) and F_5 (100 % *Azolla*) (2.43 g plant^{-1}) treatments (Appendix XIII and Figure 26).



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 26. Dry weight of pods (g plant^{-1}) of mungbean as influenced by fertilizer materials (LSD$_{(0.05)}$ at 55 DAS =0.18)

4.1.13.3 Interaction of Variety and fertilizer materials

Interaction effect between variety and fertilizer materials was not found significant in respect of dry weight of pods plant^{-1} of mungbean at 40 and 55 DAS (Appendix XIII and Table 11). At 40 DAS, dry weight of pods plant^{-1} was highest in V_1F_4 Treatment (BARI mung-5 fertilized by 25% urea+75% *Azolla*) but the value was same as V_1F_1Treatment (BARI mung-5 fertilized by 100% urea). At 55 DAS, dry weight of pods plant^{-1} was also highest in V_1F_4 Treatment (BARI mung-5 fertilized by 25% urea+75% *Azolla*) but there was no statistical difference among the treatments.

Table 11. Interaction effect of variety and fertilizer materials on dry weight of pods (g plant^{-1}) and dry weight of nodules (mg plant^{-1}) of mungbean at different growth stages

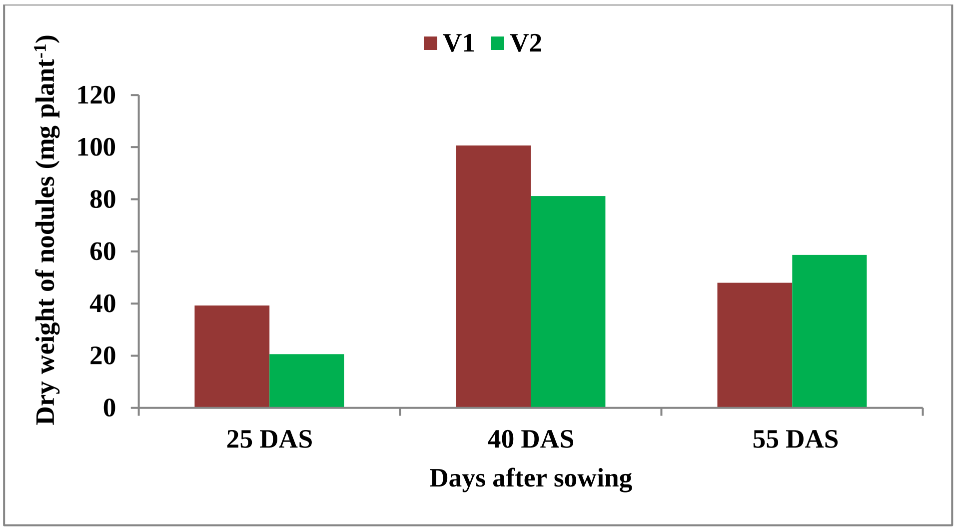
Treatments	Dry weight of pods (g plant^{-1})		Dry weight of nodules (mg plant^{-1})		
	40 DAS	55 DAS	25 DAS	40 DAS	55 DAS
V_1F_1	0.53	3.44	36.67	96.67	46.67
V_1F_2	0.47	3.33	43.33	96.67	33.33
V_1F_3	0.51	3.24	40.00	103.33	53.33
V_1F_4	0.53	3.71	40.00	106.67	53.33
V_1F_5	0.42	3.34	36.67	100.00	53.33
V_2F_1	0.12	1.42	23.33	76.67	56.67
V_2F_2	0.09	1.51	20.00	80.00	56.67
V_2F_3	0.12	1.42	26.67	86.67	60.00
V_2F_4	0.12	1.56	16.67	90.00	63.33
V_2F_5	0.10	1.52	16.67	73.33	56.67
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	18.26	6.06	35.36	13.46	16.68

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.1.14 Dry Weight of nodules (mg plant^{-1})

4.1.14.1 Effect of variety

Varieties had no significant influence on dry weight of nodules plant^{-1} of mungbean at 40 and 55 DAS but significant influence found at 25 DAS. At 25 days after sowing, dry weight of nodules was higher (39.33 mg plant^{-1}) in BARI mung-5 (V_1) and lower (20.6 mg plant^{-1}) in Chaiti mung (V_2). At 40 DAS, dry weight of nodules plant^{-1} was also higher in BARI mung-5 than local variety (Chaiti mung) but both the values were statistically similar. But at 55 DAS, dry weight of nodules plant^{-1} was higher in Chaiti mung than BARI mung-5 although they were statistically similar. Ratna (2007) in her experiment also found that dry weight of nodules plant^{-1} varies with varieties of mungbean. Nodule dry weight increased almost exponentially with progress of crop growth up to 40 or 45 DAS and later decreased as number of nodules plant^{-1} disappears after peak nodulation (Appendix XIII and Figure 27).

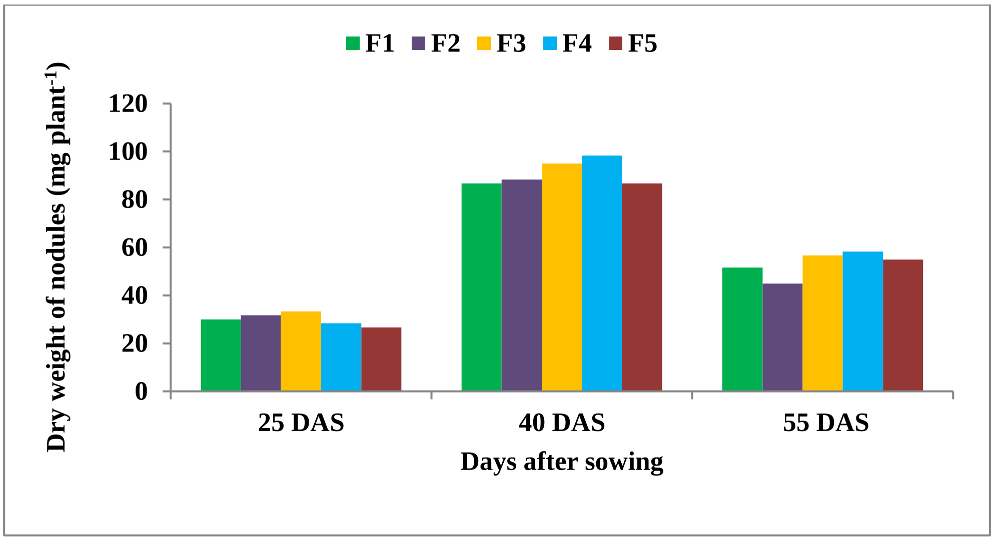


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 27. Dry weight of nodules (mg plant^{-1}) of mungbean as influenced by variety (LSD$_{(0.05)}$ at 25 DAS =17.81)

4.1.14.2 Effect of fertilizer materials

No significant variation on dry weight of nodules plant^{-1} of mungbean was found at 25, 40 and 55 DAS due to fertilizer materials. At 25 DAS, dry weight of nodules plant^{-1} was highest in F_3 treatment (50 % urea+50% *Azolla*) but at 40 and 55 DAS, nodules dry weight plant^{-1} was higher in F_4 treatment (25 % urea+75% *Azolla*) but the results were statistically similar with other treatments in every case. So dry weight of nodules (mg plant^{-1}) was unaffected by fertilizer materials at different growth stages of mungbean.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 28. Dry weight of nodules (mg plant^{-1}) of mungbean as influenced by fertilizer materials

4.1.14.3 Interaction effect of variety and fertilizer materials

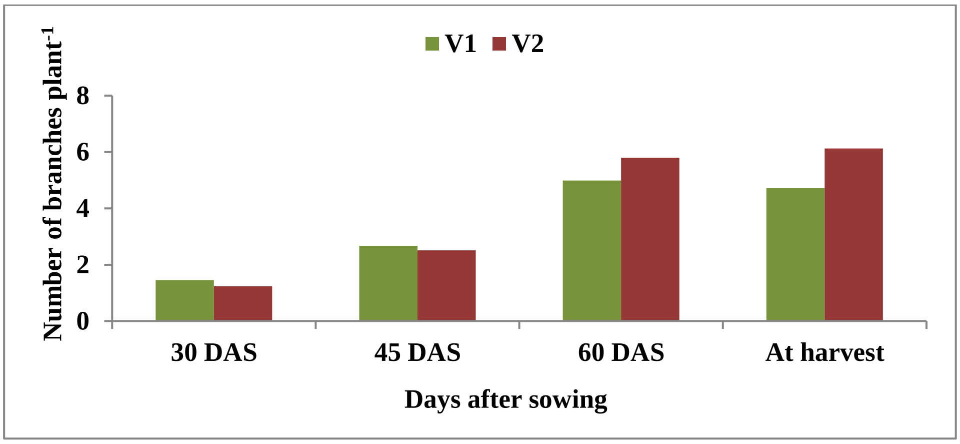
Interaction effect between variety and fertilizer materials had no significant effect on dry weight of nodules plant^{-1} of mungbean at 25, 40 and 55 DAS (Appendix XIII and Table 11). At 25 DAS, highest dry weight of nodules Plant^{-1} was found in V_1F_2 treatment (BARI mung-5 fertilized by 75% urea+ 25% *Azolla*). At 40 DAS, it was highest in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*) and at 55 DAS, dry weight of nodules Plant^{-1} was highest in V_2F_4 treatment (Chaiti mung fertilized by 25% urea+ 75% *Azolla*) but there were no statistical difference among the treatments.

4.2 Yield and other crop characters

4.2.1 Number of branches plant $^{-1}$

4.2.1.1 Effect of variety

The number of branches plant^{-1} was not significantly influenced by variety at 30 and 45 DAS but at 60 DAS and at harvest the number of branches plant^{-1} varied significantly for the two varieties (Appendix XIV and Figure 29). At 60 DAS, the maximum number of branches plant^{-1} was observed in Chaiti mung (5.80) and the minimum number of branches plant^{-1} (4.99) was observed in BARI mung-5). Similar trend of number of branches plant^{-1} was also observed at harvest. Number of branches plant^{-1} of BARI mung-5 decreased at harvest over 60 DAS because BARI mung-5 is determinate variety of mungbean. But as Chaiti mung is indeterminate type so the number of branches plant^{-1} increased until harvest. The result agreed with Islam (1983) who observed significant variation of branch number plant^{-1} in different studied varieties of mungbean and the highest number of branches plant^{-1} was in the variety Faridpur 1 followed by Mubarik, BM-7715 and BM-7704. The result also agreed with the findings of Ghosh (2007) who observed varieties differ significantly in respect of number of branches plant^{-1}. He found highest number of branches plant^{-1} in Sona mung and the lowest number of branches plant^{-1} in BARI mung-6.

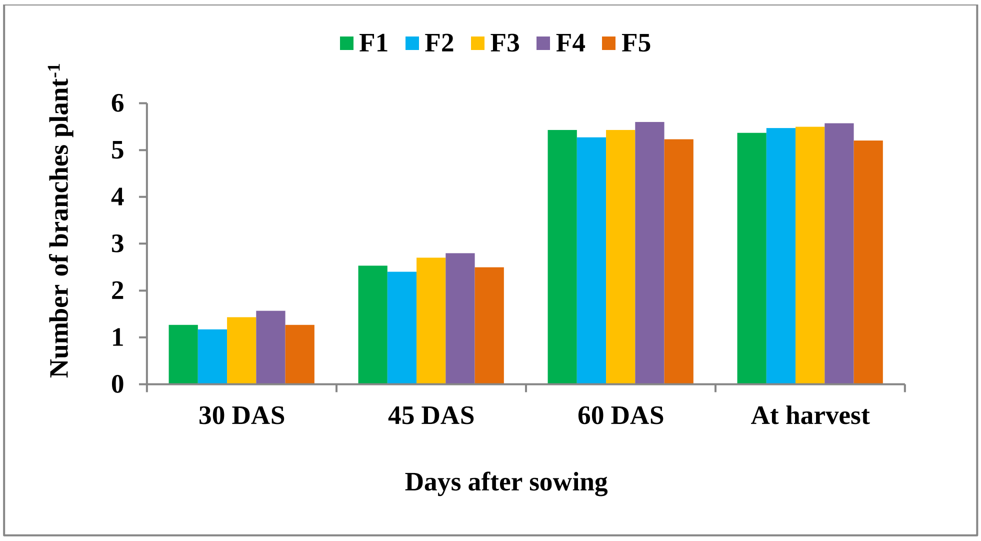


V_1 = BARI mung-5, V_2 = Chaiti mung

Figure 29. Number of branches plant^{-1} of mungbean as influenced by variety ($LSD_{(0.05)}$ at 60 DAS and at harvest =0.46 and 1.23 respectively)

4.2.1.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on number of branches plant^{-1} at 30, 45, 60 DAS and at harvest (Appendix XIV and Figure 30). At all growth stages, the maximum number of branches plant^{-1} was obtained from F_4 treatment (25% urea+75% *Azolla*) which was statistically similar with other treatments. So number of branches plant^{-1} was unaffected by the different fertilizer materials at 30, 45, 60 DAS and at harvest.



F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*,
F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 30. Number of branches plant^{-1} of mungbean as influenced by fertilizer materials

4.2.1.3 Interaction effect of variety and fertilizer materials

Interaction effect between variety and fertilizer materials was not significant in respect of number of branches plant^{-1} at 30, 45, 60 DAS and at harvest (Appendix XIV and Table 12). At 30 and 45 DAS, number of branches plant^{-1} was found highest in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*). But at 60 DAS, it was highest in V_2F_4 treatment (Chaiti mung fertilized by 25% urea+ 75% *Azolla*) and at harvest number of branches plant^{-1} was highest in V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) but the results were statistically similar in each case. This revealed that use of only urea, only *Azolla* or their different combinations, number of branches plant^{-1} were statistically similar in case of both BARI mung-5 and Chaiti mung.

Table 12. Interaction effect of variety and fertilizer materials on number of branches plant^{-1} at different crop growth stages of mungbean

Treatments	Number of branches plant^{-1} at			
	30 DAS	45 DAS	60 DAS	At harvest
V_1F_1	1.47	2.60	4.93	4.53
V_1F_2	1.40	2.60	5.07	4.87
V_1F_3	1.40	2.60	4.87	4.73
V_1F_4	1.67	2.87	5.13	4.93
V_1F_5	1.33	2.67	4.93	4.47
V_2F_1	1.07	2.47	5.93	6.20
V_2F_2	0.93	2.20	5.47	6.07
V_2F_3	1.47	2.80	6.00	6.27
V_2F_4	1.47	2.73	6.07	6.20
V_2F_5	1.20	2.33	5.53	5.93
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	18.43	9.86	5.41	5.05

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.2.2 Pod length (cm)

4.2.2.1 Effect of variety

The pod length varied significantly for the two varieties (Appendix XV and Table 13). The maximum (9.10 cm) and minimum (6.73 cm) pod length was observed in BARI mung-5 and Chaiti mung respectively. The result agreed with the findings of Farghali and Hossain (1995) who observed varieties differ significantly in respect of pod length.

4.2.2.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on pod length (Appendix XV and Table 13). The maximum (7.98 cm) pod length was recorded from F_3 treatment (50% urea+ 50% *Azolla*). But the result was statistically similar with F_1 (100% urea), F_2 (75% urea+25% *Azolla*), F_4 (25% urea+75% *Azolla*) and F_5 (100% *Azolla*) treatments.

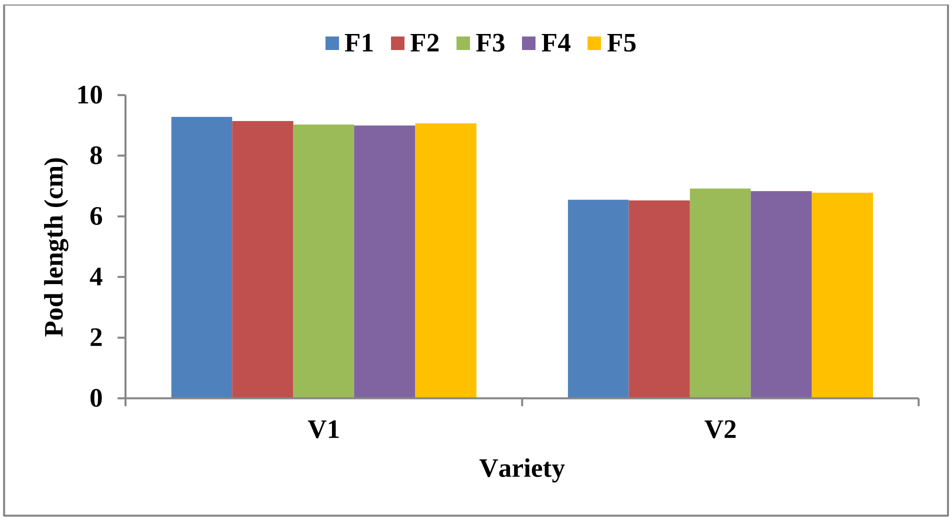
Table 13. Influence of variety and fertilizer materials on yield and other crop characters of mungbean

Treatments	Pod length (cm)	Pod breadth (cm)	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	1000 seed weight (g)
Variety					
V_1	9.10 a	0.50 a	11.37 b	11.23	42.74 a
V_2	6.73 b	0.33 b	23.27 a	11.52	14.93 b
$LSD_{(0.05)}$	0.45	0.05	3.02	NS	1.46
CV (%)	3.64	7.60	11.07	11.92	3.25
Fertilizer materials					
F_1	7.92	0.41	17.78	11.43	28.83
F_2	7.84	0.42	16.42	11.10	28.85
F_3	7.98	0.43	18.23	11.73	28.95
F_4	7.92	0.42	17.53	11.43	28.77
F_5	7.93	0.40	16.65	11.18	28.77
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	3.81	7.60	6.93	4.15	0.51

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$=Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*, F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.2.2.3 Interaction effect of variety and fertilizer materials

Interaction effect of variety and fertilizer materials had no significant effect on pod length (Appendix XV and Figure 31). The maximum pod length (9.28 cm) was obtained from BARI mung-5 fertilized by 100% urea (V_1F_1 treatment) but the result was statistically similar with other treatments.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 31. Pod length (cm) of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.3 Pod breadth (cm)

4.2.3.1 Effect of variety

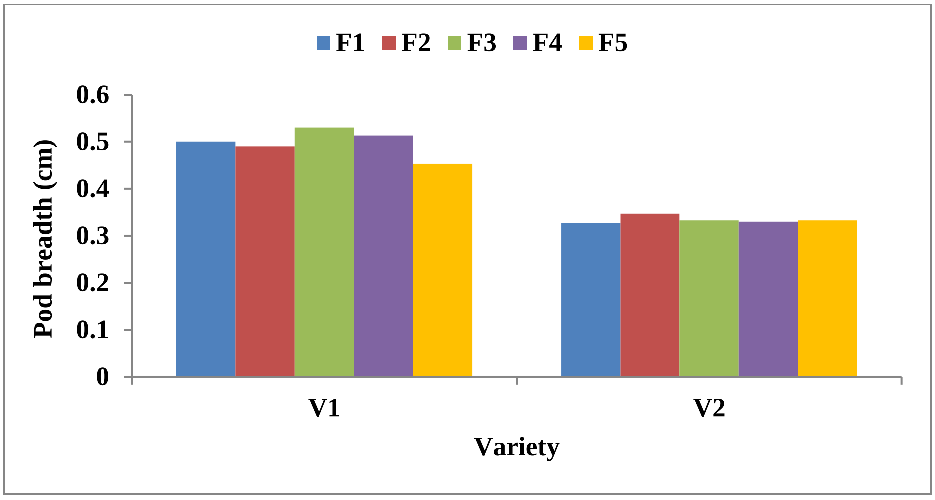
The pod breadth varied significantly for the two varieties (Appendix XV and Table 13). The maximum (0.50 cm) and minimum (0.33 cm) pod breadth was observed in BARI mung-5 and Chaiti mung respectively. The result agreed with the findings of Farghali and Hossain (1995) who observed varieties differ significantly in respect of pod breadth.

4.2.3.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on pod breadth (Appendix XV and Table 13). The maximum (0.43 cm) pod breadth was recorded from F_3 treatment (50% urea+ 50% *Azolla*). But the result was statistically similar with F_1 (100% urea), F_2 (75% urea+25% *Azolla*), F_4 (25% urea+75% *Azolla*) and F_5 (100% *Azolla*) treatments.

4.2.3.3 Interaction effect of variety and fertilizer materials

Interaction effect of variety and fertilizer materials had no significant effect on pod breadth (Figure 32). The maximum pod breadth (0.53 cm) was obtained from BARI mung-5 fertilized by 50% urea+50% *Azolla* (V_1F_3 treatment), but the result was statistically similar with other treatments.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 32. Pod breadth (cm) of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.4 Number of pods plant^{-1}

4.2.4.1 Effect of variety

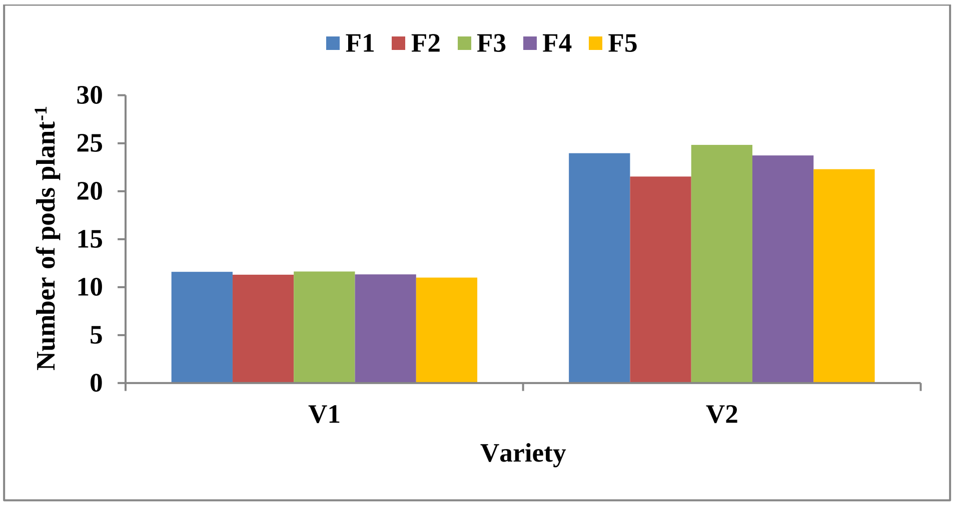
The total number of pods plant^{-1} differed significantly due to varietal variation (Appendix XV and Table 13). The higher number of pods plant^{-1} (23.27) was recorded in Chaiti mung and the lower number of pods plnat^{-1} (11.37) was recorded in BARI mung-5. The result agreed with Pahlwan and Hossain (1983) who observed the highest number of pods plant^{-1} from variety Mubarik but the result disagreed with Pookpadi *et al*. (1980) who observed the lowest number of pods plant^{-1} in local variety. Masood and Meena (1986) reported that number of pods plant^{-1} varied significantly with genotypes. Islam (1983), Haque *et al*. (2002) also opined that pods plant^{-1}is a useful agronomic character contributing to higher yield of mungbean and there was a significant positive correlation between the number of pods plant^{-1} and yield plant^{-1}.

4.2.4.2 Effect of fertilizer materials

The number of pods plant^{-1} did not differ significantly at different fertilizer doses (Appendix XV). The maximum number of pods plant^{-1} (18.23) was observed in F_3 treatment (50% urea+ 50% *Azolla*) followed by F_1 (100% urea), F_4 (25% urea+ 75% *Azolla*), F_5 (100% *Azolla*) and F_2 (75% urea+ 25% *Azolla*) treatments which were statistically similar (Table 13).

4.2.4.3 Interaction effect of variety and fertilizer materials

Interaction of variety and fertilizer materials had no significant effect on pods plant^{-1} (Appendix XV and Figure 33). The maximum number of pods plant^{-1} (24.83) was obtained in Chaiti mung fertilized by 50% urea+ 50% *Azolla* (V_2F_3 treatment) and it was statistically similar with other treatments. As the number of branches plant^{-1} of Chaiti mung was higher than BARI mung-5, the number of pods plant^{-1} was higher in Chaiti mung. So interaction effect of variety and fertilizer materials in respect of number of pods plant^{-1} was not found significant.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 33. Number of pods plant^{-1} of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.5 Number of seeds pod^{-1}

4.2.5.1 Effect of variety

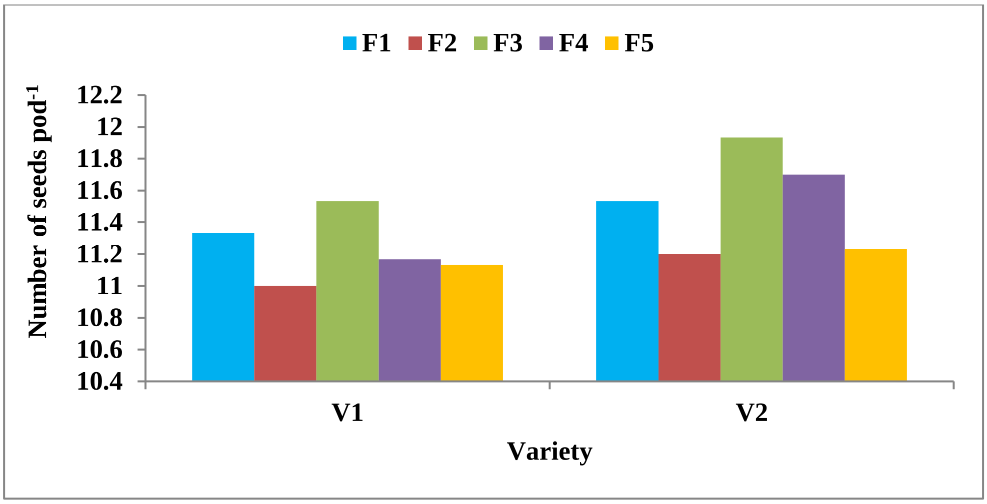
The number of seeds pod^{-1} did not differ significantly between the two varieties of mungbean (Appendix XV and Table 13). The numerically maximum number of seeds pod^{-1} (11.52) was found in Chaiti mung and the minimum number of seeds pod^{-1} (11.23) in BARI mung-5. The result did not support the findings of Pahlwan and Hossain (1983) and Pookpakdi *et al*. (1980) who found the highest yield from two mungbean cultivars Mubarik and CES 14 with the highest number of seeds pod^{-1}. But the result supported the findings of Ghosh (2007). He found that number of seeds pod^{-1} did not differ significantly between BARI mung-6 and Sona mung.

4.2.5.2 Effect of fertilizer materials

The number of seeds pod^{-1} did not differ significantly at different fertilizer doses (Appendix XV and Table 13). The maximum number of seeds pod^{-1} (11.73) was observed in F_3 treatment (50% urea+ 50% *Azolla*) followed by F_4 (25% urea+ 75% *Azolla),* F_1 (100% urea), F_5 (100% *Azolla*) and F_2 (75% urea+ 25% *Azolla*) treatments which were statistically similar.

4.2.5.3 Interaction effect of variety and fertilizer materials

Interaction effect of variety and fertilizer materials was found insignificant in respect of seeds pod^{-1} (Appendix XV and Figure 34). The highest number of seeds pod^{-1} (11.93) was obtained in Chaiti mung fertilized by 50% urea+ 50% *Azolla* and it was statistically similar with other treatments. So interaction effect of variety and fertilizer materials had no significant effect on number of seeds pod^{-1}.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 34. Number of seeds pod^{-1} of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.6 Weight of 1000-seed (g)

4.2.6.1 Effect of variety

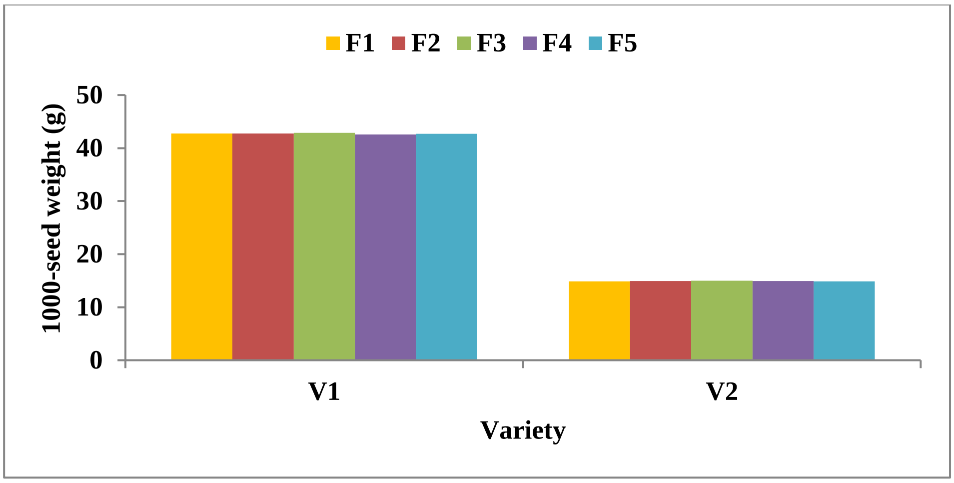
The weights of 1000-seed were significantly influenced by variety (Appendix XV and Table 13). The higher 1000-seed weight (42.74 g) was obtained from BARI mung-5 and the lower 1000-seed weight (14.93 g) was recorded in Chaiti mung. The result was agreed with the findings of Katial and Shah (1998) and Ghosh (2007) who reported that 1000-seed weight was significantly influenced by variety.

4.2.6.2 Effect of fertilizer materials

The weight of 1000-seeds did not differ significantly at different fertilizer doses (Appendix XV). The maximum 1000 seed weight (28.95 g) was observed in F_3 treatment (50% urea+ 50% *Azolla*) followed by F_2 (75% urea+ 25% *Azolla*), F_1 (100% urea), F_5 (100% *Azolla*) and F_4 (25% urea+ 75% *Azolla*) treatments which were statistically similar (Table 13). This revealed that use of only urea, only *Azolla* or their different combinations, 1000-seed weights would be statistically similar in case of mungbean.

4.2.6.3 Interaction effect of variety and fertilizer materials

Interaction effect of variety and fertilizer materials was found insignificant in respect of 1000-seed weight (Appendix XV and Figure 35). The highest 1000-seed weight (5.47 g) was obtained in BARI mung-5 fertilized by 50% urea+ 50% *Azolla* (V_1F_3 Treatment) and it was statistically similar with other treatments. So interaction of variety and fertilizer materials had no significant effect on 1000-seed weight of mungbean.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*,
F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 35. 1000-seed weight (g) of mungbean as influenced by interaction of variety and fertilizer materials

4.2.7 Performance (%) of bearing nodes

4.2.7.1 Effect of variety

Significant influence of varieties was found on the performance of 1st bearing node and 4th to rest bearing nodes but no significant variation on the performance of 2nd bearing node and 3rd bearing node of mungbean was observed as the results were statistically similar (Appendix XVI and Table 14). Performance of 1st bearing node was higher (23.96 %) in BARI mung-5 (V_1) and lower (22.04%) in Chaiti mung (V_2). But performance of 4th to rest bearing nodes were higher (21.91%) in Chaiti mung compared to BARI mung-5 (16.94%).

4.2.7.2 Effect of fertilizer materials

No significant variation on the performance (%) of bearing nodes of mungbean was found due to fertilizer materials. So use of singly urea, singly *Azolla* or their different combinations, there was no statistical difference on performance (%) of all bearing nodes of mungbean (Table 14).

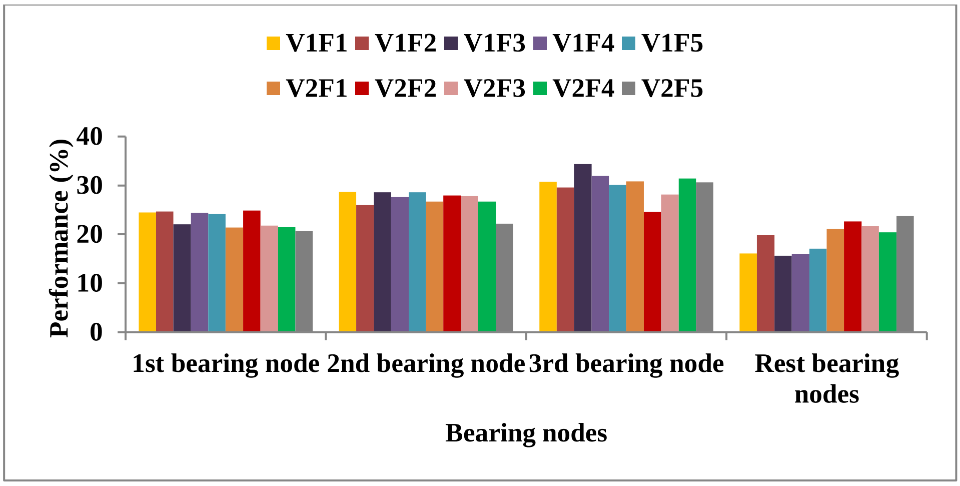
Table 14. Influence of variety and fertilizer materials on performance (%) of bearing nodes of mungbean

Treatments	Performance of bearing nodes (%)			
	1st bearing node	2nd bearing node	3rd bearing node	4th to rest bearing nodes
Variety				
V_1	23.96 a	27.90	31.34	16.94 b
V_2	22.04 b	26.27	29.11	21.91 a
$LSD_{(0.05)}$	1.09	NS	NS	2.88
CV (%)	3.00	18.11	15.79	9.44
Fertilizer materials				
F_1	22.95	27.68	30.77	18.60
F_2	24.77	26.95	27.07	21.22
F_3	21.91	28.23	31.24	18.64
F_4	22.93	27.16	31.68	18.24
F_5	22.43	25.41	30.36	20.44
$LSD_{(0.05)}$	NS	NS	NS	NS
CV (%)	7.21	18.74	8.82	12.14

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ =Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*,
F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.2.7.3 Interaction effect of variety and fertilizer materials

Interaction effect between variety and fertilizer materials had no significant effect on performance (%) of all bearing nodes of mungbean (Appendix XVI and Figure 36) because there was no statistical difference among the treatments. In case of both varieties, bearing percentage of 3rd node was higher than other nodes.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 36. Performance (%) of bearing nodes of mungbean as influenced by interaction of variety and fertilizer materials

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

4.2.8.1 Effect of variety

Seed yield of mungbean was significantly influenced by variety (Appendix XVII and Table 15). The higher seed yield (1.35 t ha^{-1}) was obtained from BARI mung-5 and lower seed yield (0.98 t ha^{-1}) was obtained from Chaiti mung. The higher seed yield in BARI mung-5 might be due to the contribution of more number of pods plant^{-1} and individual seed weight. The finding was similar with Singh and Singh (1988) who reported that cultivars played a key role in increasing yield. Pahlwan and Hossain (1983) reported that the highest yield from the variety Mubarik was attributed to the highest number of pods plant^{-1} and seeds plant^{-1}. Though Chaiti mung had more pods plant^{-1} over BARI mung-5 the probable cause of yield reduction in Chaiti mung might be due to heavy rainfall during harvesting as well as lower seed weight. The result agreed with Lassim *et al*. (1984) and Saha *et al*. (2002) who reported that field weathering caused reduction in seed yield and quality of pulses. Yield loss was caused due to reduction in seed weight and threshing percentage.

4.2.8.2 Effect of fertilizer materials

Seed yield was not significantly influenced by fertilizer materials (Appendix XVII). The numerically higher Seed yield (1.23 t ha^{-1}) was recorded in F_4 treatment (25% urea+ 75% *Azolla*) followed by F_3 (50% urea+ 50% *Azolla*), F_2 (75% urea+ 25% *Azolla*) and F_1 (100% urea) treatments. The lowest Seed yield (1.11 t ha^{-1}) was recorded in F_5 (100% *Azolla*) treatment, but there was no statistical difference among these results. This revealed that use of sole urea, sole *Azolla* or their different combinations, Seed yield would be statistically similar in case of mungbean.

Table 15. Influence of variety and fertilizer materials on the yield and other parameters of mungbean

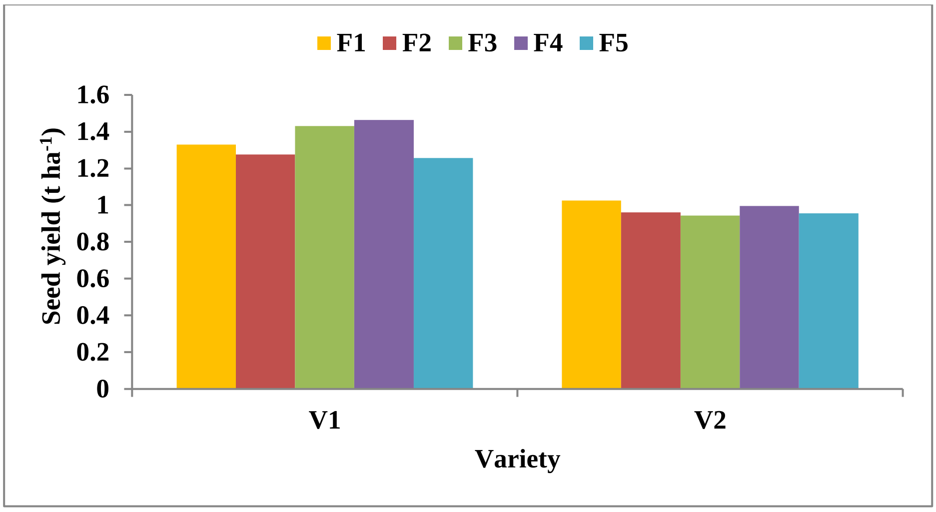
Treatments	Seed yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
Variety			
V_1	1.35 a	6.06 a	22.30 a
V_2	0.98 b	5.74 b	16.99 b
$LSD_{(0.05)}$	0.09	0.21	2.33
CV (%)	5.33	2.32	7.52
Fertilizer materials			
F_1	1.18	5.94	19.77
F_2	1.12	5.88	18.96
F_3	1.19	5.92	19.91
F_4	1.23	5.91	20.71
F_5	1.11	5.86	18.87
$LSD_{(0.05)}$	NS	NS	NS
CV (%)	6.78	1.39	6.34

In a column, the means having the same letter (s) do not differ significantly
NS = Not significant, CV = Coefficient of variation, $LSD_{(0.05)}$ =Least significant difference at 5% level, DAS = Days after sowing
V_1= BARI mung-5, V_2= Chaiti mung, F_1=100 % urea, F_2=75% urea+25% *Azolla*, F_3=50% urea+ 50% *Azolla*, F_4=25% urea+ 75% *Azolla*, F_5=100% *Azolla*

4.2.8.3 Interaction effect of variety and fertilizer materials

Interaction of variety and fertilizer materials had no significant effect on Seed yield of mungbean (Figure 37). The maximum Seed yield (1.46 t ha^{-1}) was obtained in BARI mung-5 fertilized by 25% urea+ 75% *Azolla* (V_1F_4 Treatment) and it was statistically similar with other treatments. The minimum

Seed yield (0.94 t ha^{-1}) was found from Chaiti mung fertilized by 25% urea +75% *Azolla* (V_2F_3 treatment) but the result was statistically similar with the treatment combination that gave highest economic yield. This revealed that interaction effect of variety and fertilizer materials had no significant effect on Seed yield of mungbean.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 37. Seed yield (t ha^{-1}) of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.9 Biological yield (t h^{-1})

4.2.9.1 Effect of variety

Biological yield of mungbean was significantly influenced by variety (Appendix XVII and Table 15). The higher biological yield (6.06 t ha^{-1}) was obtained from BARI mung-5 and lower biological yield (5.74 t ha^{-1}) was obtained from Chaiti mung. The higher biological yield in BARI mung-5 might be due to the contribution of more number of pods $plant^{-1}$ and individual seed yield.

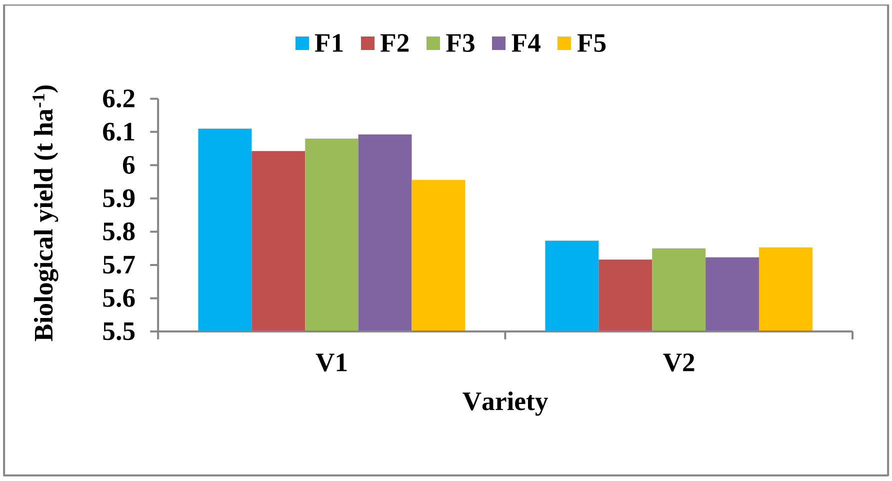
4.2.9.2 Effect of fertilizer materials

Biological yield was not significantly influenced by fertilizer materials (Appendix XVII). The maximum biological yield (5.94 t ha^{-1}) was recorded in F_1 treatment (100% urea) followed by F_3 (50% urea+ 50% *Azolla*), F_4 (25%

urea+ 75% *Azolla*) and F_2 (75% urea+ 25% *Azolla)* treatments. The minimum biological yield (5.86 t ha^{-1}) was recorded in F_5 (100% *Azolla*) treatment, but there was no statistical difference between these results.

4.2.11.3 Interaction effect of variety and fertilizer materials

Interaction of variety and fertilizer materials had insignificant effect on biological yield of mungbean (Figure 38).The maximum biological yield (6.11 t ha^{-1}) was obtained in BARI mung-5 fertilized by 100% urea (V_1F_1) and it was statistically similar with other treatments. The minimum biological yield (5.71 t ha^{-1}) was found from Chaiti mung fertilized by 75% urea+ 25% *Azolla* (V_2F_2) but the result was statistically similar with the treatment combination that gave the maximum biological yield. This revealed that interaction effect of variety and fertilizer materials had no significant effect on biological yield of mungbean.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*,
F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 38. Biological yield (t ha^{-1}) of mungbean as influenced by interaction effect of variety and fertilizer materials

4.2.10 Harvest index (%)

4.2.10.1 Effect of variety

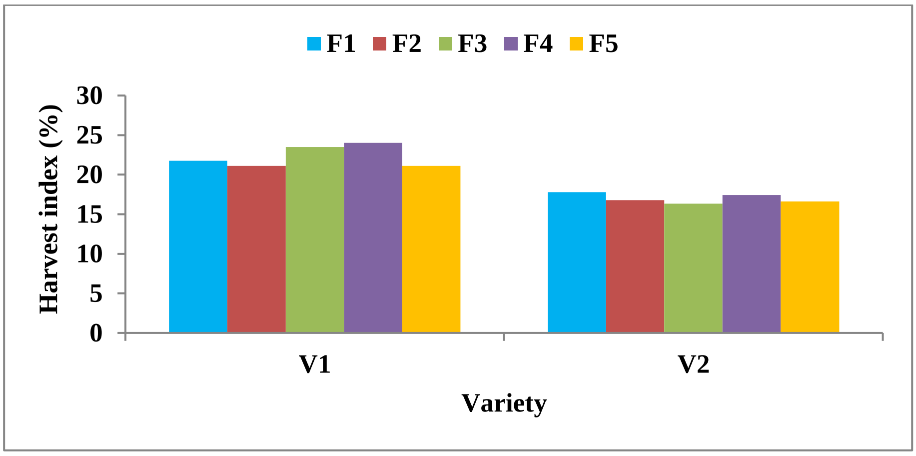
The harvest index was significantly influenced by variety (Appendix XVII and Table 15). The higher harvest index (22.30) was found in BARI mung-5 and the lower harvest index (16.99) was in Chaiti mung. The result was agreed with the findings of Aguliar and Villarea (1989) and Ghosh (2007) who reported that the harvest index of mungbean was significantly influenced by the variety.

4.2.10.2 Effect of fertilizer materials

Fertilizer materials had no significant effect on harvest index of mung bean (Appendix XVII and Table 15). Harvest index was higher (20.71) in F_4 (25% urea+75% *Azolla*) treatment compared to F_1 (100% urea) (19.77), F_3 (50% urea+ 50% *Azolla*) (19.91), F_2 (75% urea+25% *Azolla*) (18.96) and F_5 (100% *Azolla*) (18.87) treatments but there was no statistical difference among the treatments. So harvest index of mungbean was not affected by fertilizer materials

4.2.10.3 Interaction effect of variety and fertilizer materials

Interaction between variety and fertilizer materials had no significant effect on harvest index of mungbean (Appendix XVII and Figure 39). Due to the interaction, maximum harvest index (24.01) was observed in V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+ 75% *Azolla*) and minimum (16.32) in V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) but the results were statistically similar.



V_1 = BARI mung-5, V_2 = Chaiti mung, F_1 = 100 % urea, F_2 = 75% urea + 25% *Azolla*, F_3 = 50% urea + 50% *Azolla*, F_4 = 25% urea + 75% *Azolla*, F_5 = 100% *Azolla*

Figure 39. Harvest index of mungbean as influenced by interaction effect of variety and fertilizer materials

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was conducted at the research field, Sher-e-Bangla Agricultural University, Dhaka from March, 2014 to June, 2014 to find out the influence of *Azolla* and urea on nodulation, growth and yield of two mungbean varieties. The treatment of the experiment consists of two varieties viz. BARI mung-5 and Chaiti mung and five fertilizer materials viz. 100% urea, 75% urea+25% *Azolla*, 50% urea+50% *Azolla*, 25% urea+75% *Azolla*, 100% *Azolla*. The experiment was laid out in Split-plot design following the principles of randomization with three replications. The sowing date was on March 16, 2014.

Observation were made on germination percentage, plant height, number of leaflets plant^{-1}, root length, shoot length, shoot/root ratio, SPAD value, leaf area index (LAI), dry mater production, number of branches plant^{-1}, number of nodules plant^{-1}, number of pods plant^{-1}, pod length, pod breadth, number of seeds pod^{-1}, weight of 1000 seeds, economic yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index and performance (%) of bearing nodes. Germination percentage was recorded upto hundred percent germination from 1m^{2} area. Five plants were randomly selected from each unit plot for taking observations on plant height, number of leaflets plant^{-1} and number of branches plant^{-1} with 15 days interval at 15, 30, 45, 60 days after sowing and at harvest. Pods plant^{-1}, pod length, pod breadth, number of seeds pod^{-1}, SPAD value, leaf area index (LAI) and nodal performance (%) were recorded from the selected plants. Root length, shoot length, shoot root ratio, number of nodules plant^{-1}, dry weight of nodules and dry weight of different plant parts were taken from 25 DAS upto harvest. Central four lines from each plot were harvested for economic yield, biological yield and harvest index (%). Thousand seed weight was measured from sampled seed. Data were analyzed using MSTST-C package. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Among the growth parameters, germination percentage was unaffected by varieties of mungbean except at 5 DAS, which was higher in Chaiti mung. Plant height of BARI mung-5 was higher upto 30 DAS, statistically similar at 45 DAS and higher in Chaiti mung from 60 DAS until harvest. Number of leaflets plant^{-1}, leaf area index (LAI) and number of pods plant^{-1} was higher in Chaiti mung. Shoot length and shoot/root ratio was higher in BARI mung-5 at early stages but after 45 DAS and upto harvest, the values were higher in Chaiti mung. Dry weight of different plant parts and root lengths were higher in BARI mung-5 compared to Chaiti mung. Number of nodules plant^{-1} was higher in BARI mung-5 but at 55 DAS, Chaiti mung gave the higher values. Among the yield parameters, 1000-seed weight, pod length, pod breadth, economic yield, biological yield and harvest index was higher in BARI mung-5 compared to Chaiti mung. Nodal performance (%) was higher in BARI mung-5 upto 3rd bearing nodes but from 4th to rest bearing nodes the values were higher in Chaiti mung. SPAD value and number of seeds pod^{-1} was unaffected by varieties of mungbean.

The findings showed that fertilizer materials influenced germination percentages of mungbean at 4 and 5 days after sowing but later the effect was not significant. Plant height was significantly influenced by fertilizer materials from 45 DAS and upto harvest. The highest plant height was obtained from F_4 treatments (25% urea+75% *Azolla*). Number of nodules plant^{-1} was significantly influenced by fertilizer materials at 55 DAS and the highest values was recorded from F_4 treatment (25% urea+75% *Azolla*). At 25 and 40 DAS, effect was not significant. Fertilizer materials had significant effect on root length at 25 and 40 DAS and shoot length at harvest but other values were statistically similar. At harvest, the highest shoot length was recorded from 25% urea+75% *Azolla* (F_4). No significant variation observed due to fertilizer materials in number of leaflets plant^{-1}, number of branches plant^{-1}, shoot/root ratio, SPAD value and leaf area index (LAI) of mungbean. Fertilizer materials influenced root dry weight at harvest. The highest dry weight of root was recorded from F_5 treatment (100% *Azolla*) and the lowest from F_1 treatment (100% urea). Effect of fertilizer materials was observed on dry weight of stem, the highest value was recorded from F_4 treatment (25% urea+75% *Azolla*) and the lowest from F_2 treatment (75% urea+25% *Azolla*). Dry weight of leaf was influenced by fertilizer materials at 40 DAS and at harvest and the highest values were recorded in F_4 treatments (25% urea+75% *Azolla*). At 55 DAS, pod dry weight was higher in F_4 (25% urea+75% *Azolla*) treatment. The yield and yield contributing parameters like pod length, pod breadth, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, economic yield, biological yield and harvest index were unaffected by fertilizer materials.

The interaction of variety and fertilizer materials had significant effect on germination percentages of mungbean at 4 days after sowing and the highest value was recorded from V_1F_4 treatment (BARI mung-5 fertilized by 25% urea+75% *Azolla*) and the lowest from V_2F_1 treatment (Chaiti mung fertilized by 100% urea) but from 5 DAS to later, the effect was not significant. At 30 days after sowing, number of leaflets plant^{-1} was affected by interaction of variety and fertilizer materials. The highest number of leaflets plant^{-1} was recorded from V_2F_3 treatment (Chaiti mung fertilized by 50% urea+ 50% *Azolla*) and the lowest from V_1F_3 treatment (BARI mung-5 fertilized by 50% urea+50% *Azolla*). Other growth parameters like plant height, number of branches plant^{-1}, number of nodules plant^{-1}, root length, shoot length, dry weight, SPAD value and leaf area index was unaffected by interaction of variety and fertilizer materials. Effect was found on shoot/root ratio at 40 DAS, the highest value was recorded from V_2F_5 treatment (Chaiti mung fertilized by 100% *Azolla*) and the lowest value from V_1F_3 treatment (BARI mung-5 fertilized by 50% urea+ 50% *Azolla*). Interaction of variety and fertilizer materials had no significant effect on different yield and yield contributing parameters like pod length, pod breadth, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, economic yield, biological yield and harvest index. Performance (%) of bearing nodes was also unaffected by interaction of variety and fertilizer materials.

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

- Plant height, number of leaflets plant^{-1} and number of branches plant^{-1} was higher in BARI mung-5 at early stage but after 45 DAS, these values were higher in Chaiti mung as it is an indeterminate variety of mungbean.

- Number of nodules plant^{-1} increased in treatments where *Azolla* was applied and F_4 treatment (25% urea+ 75% *Azolla*) gave more number of nodules.

- The variety BARI mung-5 showed higher yield potential than the local variety (Chaiti mung).

- Interaction of variety and fertilizer materials had no significant effect on yield characters of mungbean. So use of different fertilizer combinations for BARI mung-5 and Chaiti mung would be statistically similar.

- Costly and environmentally risky chemical fertilizer urea can be supplemented by biofertilizer *Azolla* in case of both BARI mung-5 and Chaiti mung.

However, to reach a specific conclusion and recommendation, more research work of biofertilizer *Azolla* on other crops should be done over different Agro-ecological zones.

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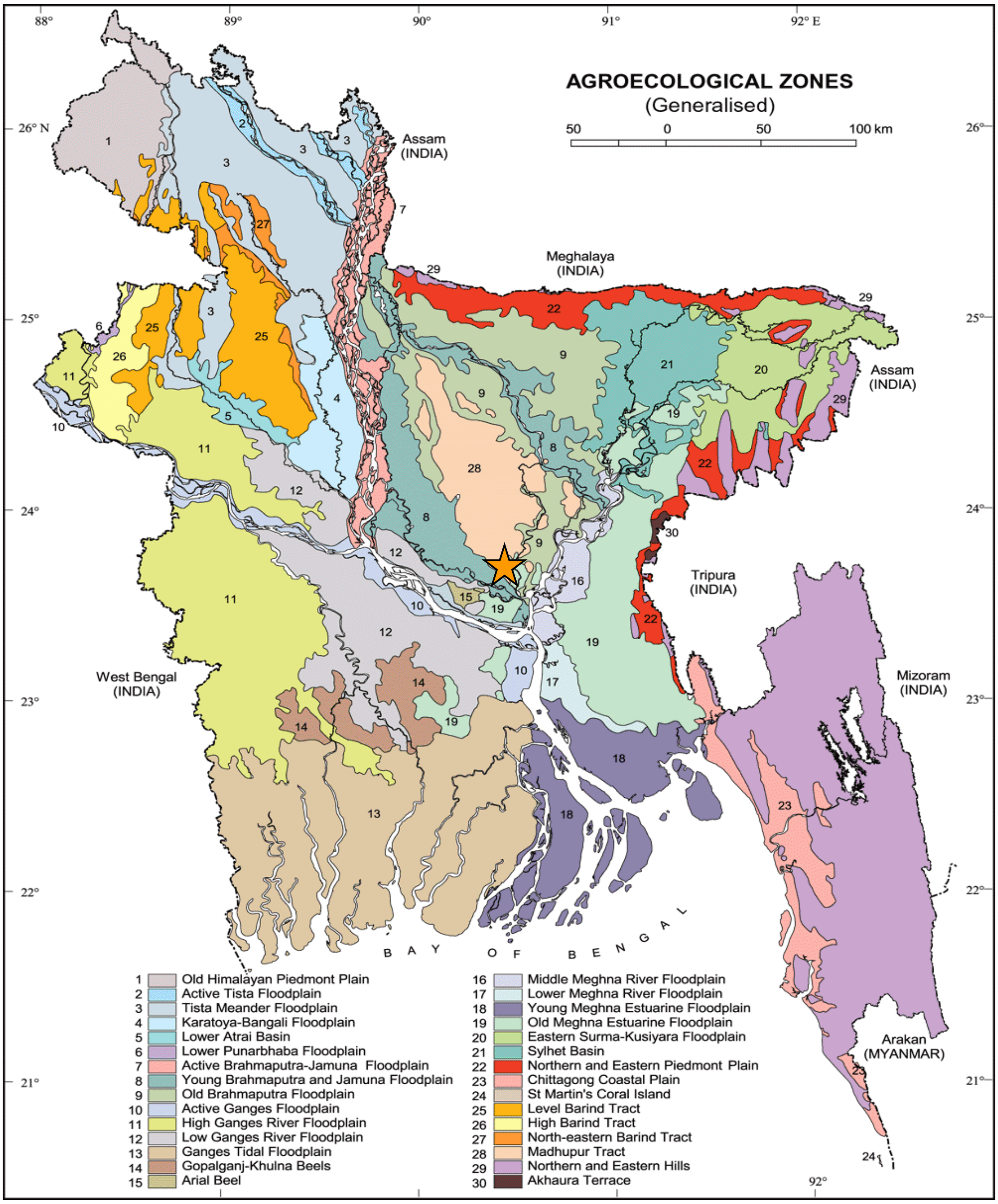
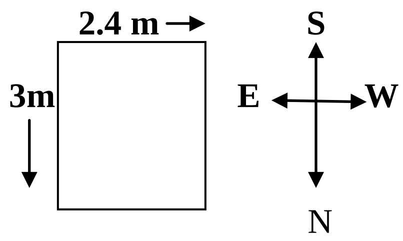
APPENDICES

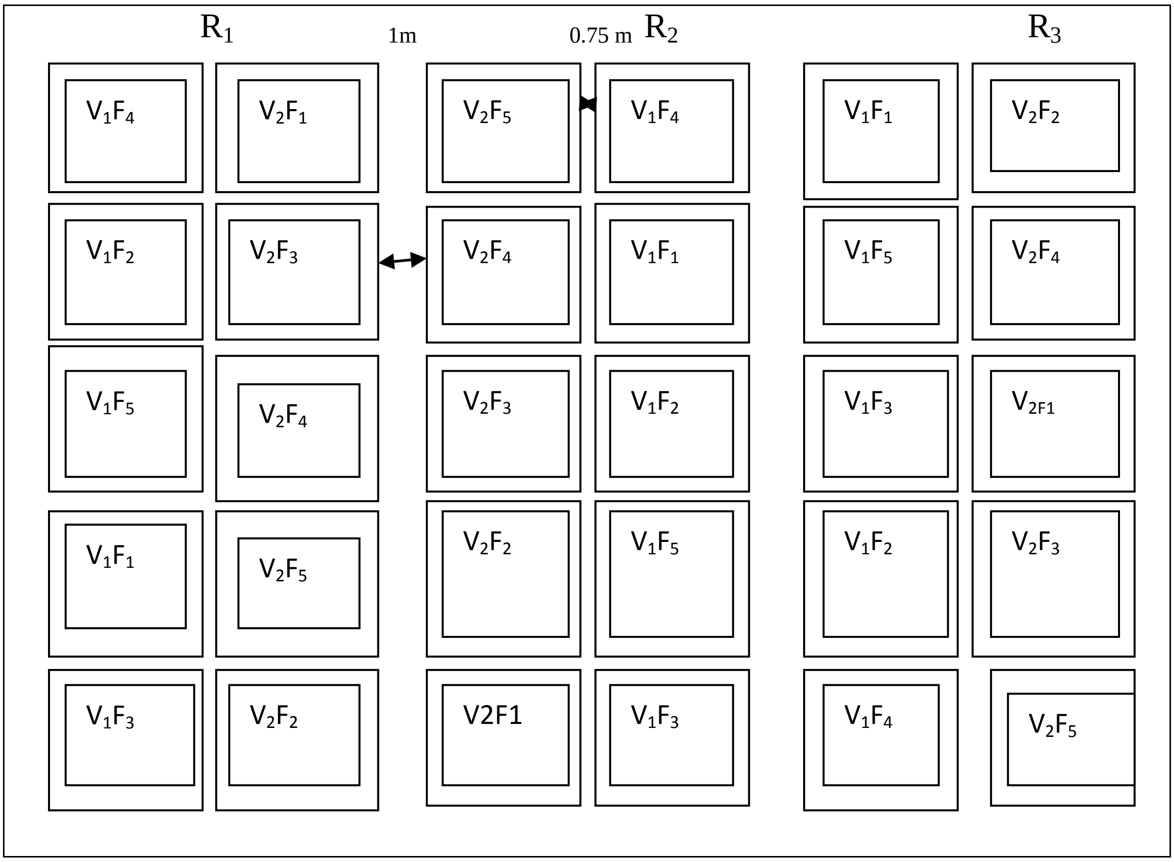
Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Layout of the experiment





Appendix III. Means square values for germination percentage of mungbean at different days after sowing

Sources of variation	Degrees of freedom	Means square values			
		4 DAS	5 DAS	6 DAS	7 DAS
Replication	2	222.943	65.050	71.102	9.464
Variety (V)	1	2.864	123.140*	1.501	11.706
Error (a)	2	92.500	3.270	19.392	24.998
Fertilizer materials (F)	4	226.057**	121.172*	36.454	11.124
V X F	4	164.070*	14.697	19.260	4.273
Error (b)	16	51.094	52.487	15.174	7.550
CV (%)		8.99	8.11	4.11	2.81

* Significant at 5% level, ** Significant at 1% level

Appendix IV. Means square values for plant height (cm) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values				
		15 DAS	30 DAS	45 DAS	60 DAS	At harvest
Replication	2	5.467	18.979	68.696	16.341	11.534
Variety (V)	1	106.18*	289.045**	318.958	386.930*	936.772**
Error (a)	2	5.791	3.510	33.438	18.876	12.683
Fertilizer materials (F)	4	2.039	11.169	33.431*	18.569* *	13.787*
V X F	4	5.706	10.775	23.441	2.820	6.360
Error (b)	16	2.113	9.078	10.278	1.469	3.707
CV (%)		13.66	10.75	7.37	2.27	3.96

* Significant at 5% level, ** Significant at 1% level

Appendix V. Means square values for number of leaflets plant^{-1} of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values				
		15 DAS	30 DAS	45 DAS	60 DAS	At harvest
Replication	2	1.812	3.137	16.490	5.209	98.657
Variety (V)	1	7.500	36.741**	1530.816**	1794.133**	579.041*
Error (a)	2	2.100	0.457	1.994	6.577	19.025
Fertilizer materials (F)	4	1.152	1.051	11.917	12.691	2.057
V X F	4	1.200	3.565*	15.666	15.190	15.051
Error (b)	16	0.996	1.154	7.726	8.792	6.858
CV (%)		13.10	5.72	9.96	10.60	14.10

* Significant at 5% level, ** Significant at 1% level

Appendix VI. Means square values for root length (cm) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	1.204	11.241	1.420	0.365
Variety (V)	1	3.888	18.913	8.091*	4.555**
Error (a)	2	0.687	5.502	0.318	0.033
Fertilizer materials (F)	4	0.644*	4.683*	0.902	0.204
V X F	4	0.271	2.719	1.823	0.373
Error (b)	16	0.188	1.247	1.841	1.186
CV (%)		5.48	8.66	8.87	8.35

* Significant at 5% level, ** Significant at 1% level

Appendix VII. Means square values for shoot length (cm) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	35.063	138.0777	17.782	8.397
Variety (V)	1	221.300*	149.901	350.277*	916.764**
Error (a)	2	7.631	20.615	11.739	8.324
Fertilizer materials (F)	4	9.755	21.084	19.646	13.455*
V X F	4	11.401	48.242	5.461	7.598
Error (b)	16	8.197	24.467	9.569	3.684
CV (%)		11.48	12.44	6.04	3.95

* Significant at 5% level, ** Significant at 1% level

Appendix VIII. Means square values for shoot /root ratio of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	1.067	0.259	0.281	0.107
Variety (V)	1	0.922	0.009	3.759*	8.759*
Error (a)	2	0.252	0.080	0.074	0.040
Fertilizer materials (F)	4	0.052	0.147	0.168	0.082
V X F	4	0.049	0.453*	0.068	0.082
Error (b)	16	0.102	0.146	0.165	0.123
CV (%)		10.23	12.31	12.00	9.34

* Significant at 5% level, ** Significant at 1% level

Appendix IX. Means square values for number of nodules plant^{-1} at different growth stages, SPAD Value and Leaf area index (LAI) of mungbean

Sources of variation	Degrees of freedom	Means square values				
		No. of Nodules/Plant			SPAD Value	Leaf area index (LAI)
		25 DAS	40 DAS	55 DAS		
Replication	2	15.141	18.991	1.744	0.045	0.114
Variety (V)	1	54.136	498.576	409.221*	19.441	1.890*
Error (a)	2	6.466	66.212	19.205	8.316	0.052
Fertilizer materials (F)	4	1.334	54.291	23.722*	1.997	0.113
V X F	4	1.836	26.171	12.751	4.739	0.089
Error (b)	16	1.969	24.048	6.515	4.293	0.146
CV (%)		16.18	16.67	14.09	3.58	0.114

* Significant at 5% level, ** Significant at 1% level

Appendix X. Means square values for dry weight of root (g plant^{-1}) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	2.333	0.015	0.004	0.008
Variety (V)	1	0.003	0.052*	0.097*	0.031*
Error (a)	2	0.004	0.001	0.001	0.004
Fertilizer materials (F)	4	0.001	0.008	0.003	0.005*
V X F	4	0.001	0.003	0.006	0.002
Error (b)	16	0.001	0.004	0.003	0.002
CV (%)		24.85	18.16	12.23	13.47

* Significant at 5% level, ** Significant at 1% level

Appendix XI. Means square values for dry weight of stem (g plant^{-1}) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	0.003	0.142	0.456	0.006
Variety (V)	1	0.061**	2.160	2.460	0.363
Error (a)	2	0.002	0.125	0.237	0.091
Fertilizer materials (F)	4	0.003 **	0.035	0.044	0.072
V X F	4	0.000	0.033	0.080	0.060
Error (b)	16	0.001	0.054	0.038	0.046
CV (%)		22.27	15.58	8.87	13.35

* Significant at 5% level, ** Significant at 1% level

Appendix XII. Means square values for dry weight of leaf (g plant^{-1}) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		25 DAS	40 DAS	55 DAS	At harvest
Replication	2	0.000	0.530	0.151	0.596
Variety (V)	1	0.087 *	2.628 *	0.666	0.012
Error (a)	2	0.003	0.111	0.180	0.166
Fertilizer materials (F)	4	0.001	0.266**	0.158	0.154 **
V X F	4	0.001	0.012	0.128	0.021
Error (b)	16	0.004	0.03	0.076	0.032
CV (%)		19.26	8.54	10.21	11.27

* Significant at 5% level, ** Significant at 1% level

Appendix XIII. Means square values for dry weight of pods (g plant^{-1}) and nodules (mg plant^{-1}) of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values				
		Dry weight(g) of pod plant^{-1}		Dry weight of nodule (mg) plant^{-1}		
		40 DAS	55 DAS	25 DAS	40 DAS	55 DAS
Replication	2	0.083	0.860	390.000	120.000	63.333
Variety (V)	1	0.114	27.840**	2613.333*	2803.333	853.333
Error (a)	2	0.007	0.167	143.333	813.333	203.333
Fertilizer materials (F)	4	0.004	0.074 *	41.667	171.667	166.667
V X F	4	0.003	0.035	38.333	28.333	86.667
Error (b)	16	0.003	0.022	112.500	150.000	79.167
CV (%)		18.26	6.06	35.36	13.46	16.68

* Significant at 5% level, ** Significant at 1% level

Appendix XIV. Means square values for number of branches plant^{-1} of mungbean at different growth stages

Sources of variation	Degrees of freedom	Means square values			
		30 DAS	45 DAS	60 DAS	At harvest
Replication	2	2.196	0.025	0.277	0.100
Variety (V)	1	0.385	0.192	4.961*	15.265*
Error (a)	2	0.089	0.124	0.085	0.609
Fertilizer materials (F)	4	0.151	0.155	0.131	0.122
V X F	4	0.069	0.082	0.138	0.055
Error (b)	16	0.061	0.065	0.085	0.075
CV (%)		18.43	9.86	5.41	5.04

* Significant at 5% level, ** Significant at 1% level

Appendix XV. Means square values for yield and other crop characters of mungbean

Sources of variation	Degrees of freedom	Means square values				
		Pod length	Pod breadth	Pods plant^{-1}	Seeds pod^{-1}	Wt. of 1000 seeds
Replication	2	0.018	0.000	4.743	0.762	0.382
Variety (V)	1	42.459*	0.200**	1062.075	0.616	5802.979
Error (a)	2	0.083	0.001	3.679	1.840	0.879
Fertilizer materials (F)	4	0.015	0.001	3.538	0.371	0.036
V X F	4	0.115	0.001	1.988	0.046	0.017
Error (b)	16	0.091	0.001	1.448	0.223	0.020
CV (%)		3.81	7.60	6.932	4.15	0.506

*Significant at 5% level, ** Significant at 1% level

Appendix XVI. Means square values for performance (%) of bearing nodes of mungbean

Sources of variation	Degrees of freedom	Means square values			
		1st bearing node	2nd bearing node	3rd bearing node	Rest bearing nodes
Replication	2	18.593	77.925	2.135	19.952
Variety (V)	1	27.629 *	0.021	37.565	185.207*
Error (a)	2	0.477	22.576	22.785	3.365
Fertilizer materials (F)	4	6.968	13.503	20.121	10.391
V X F	4	4.561	40.254	14.799	3.399
Error (b)	16	2.744	24.174	7.109	5.565
CV (%)		7.20	18.74	8.82	12.14

* Significant at 5% level, ** Significant at 1% level

Appendix XVII. Means square values for yield and other crop characters of mungbean

Sources of variation	Degrees of freedom	Seed yield (t/ha)	Biological yield (t/ha)	Harvest Index
Replication	2	0.009	0.019	1.555
Variety (V)	1	0.002**	0.733*	211.897**
Error (a)	2	0.008	0.016	2.189
Fertilizer materials (F)	4	0.016	0.007	3.446
V X F	4	0.011	0.001	3.217
Error (b)	16	1.058	0.006	1.555
CV (%)		6.78	1.39	6.34

* Significant at 5% level, ** Significant at 1% level

Plate 1. Experimental field under study at 25 days after sowing

Plate 2. Experimental field under study at 55 days after sowing

Plate 3. Field view of BARI mung-5 fertilized by 50% urea+ 50% *Azolla*

Plate 4. Field view of Chaiti mung fertilized by 25% urea+ 75% *Azolla*