STUDY OF FLOWERING PATTERN AND REPRODUCTIVE EFFICIENY IN MUNGBEAN

A Thesis
By

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Submitted to the Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka-1207
In partial fulfilment of requirements
for the degree of

MASTER OF SCIENCE (M.S.)

IN

AGRICULTURAL BOTANY

Department of Agricultural Botany
Sher-e-Bangla Agricultural University
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ABSTRACT

A pot experiment was conducted at the Bangladesh Institute of Nuclear Agriculture, Mymensingh, during September to November 2007 to investigate flower production, flowering pattern, reproductive efficiency, yield attributes and their relationship with seed yield in 10 mungbean genotypes. The experiment was laid out in a Completely Randomized Design with four replications. High yielding genotypes produced greater number of opened flowers (range 34.2-45.0 plant^{-1}) having longer flowering duration (range 15-18 days) than the low yielding ones. In contrast, low yielding genotypes produced fewer opened flowers (range 16.1-21.0 plant^{-1}) and also showed shorter flowering duration (range 11-15 days) except MB-46 (21 days). High yielding genotypes had higher flower production rate over time than the low yielding ones and maximum flower production occurred within 10-12 days after flowering started. However, high yielding genotypes had inferior performance in reproductive efficiency (range 52.6-61.4%) than in low yielding ones (59.5-81.2%) indicating that there was a scope of increasing yield by improving the reproductive efficiency in high yielding genotypes in mungbean. High yielding genotypes maintained increased leaf area, TDM, increased flowers and pod numbers plant^{-1}. In contrast, low yielding genotypes produced shorter and narrower plant canopy, fewer flowers and pods plant^{-1}. Seed yield had highly significant and positive correlation with pod number (r = 0.89**) and pod number depended on leaf area (r = 0.75**), TDM plant^{-1} (r = 0.84**), raceme (r = 0.76**) and flower number (r = 0.87**). Genotypes MB-17 and MB-35 showed better performance in respect of growth, reproductive, yield and yield contributing characters.

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Introduction

CHAPTER I

INTRODUCTION

Mungbean [*Vigna radiata* (L) Wilczek] is one of the most important pulse crops of global economic importance. It belongs to the family Leguminosae and sub-family Papilionaceae. It is originated in the South and Southeast Asia (India, Mayanmar, Thailand) (Poehlman, 1991). It is widely grown in India, Pakistan, Bangladesh, Mayanmar, Thailand, Philippinnes, China and Indonesia (FAO, 2005). It ranks 3rd in acreage, 5th in production and 3rd in protein content among the pulses grown in Bangladesh. Pulses cover an area of about 5,60,036 hectares, where mungbean occupies 65,129 hectares (BBS, 2008). Mungbean has raceme type of inflorescence, with asynchronous flowering and poding. This leads to double harvest of the crop lengthening it at least up to two weeks. Mungbean requires about 70-85 days to mature. It is mostly grown in dry season following T. aman and winter crops (Dutta, 2001) but it can be grown almost throughout the year (Afzal *et al.*, 2008).

Bangladesh is a developing country and there is a serious nutritional crisis because of cereal-based diet. Mungbean is an excellent supplemental protein source for rice diet. The protein content of mungbean is more than cereals. Seeds contain 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamins (Afzal *et al.*, 2008). Besides providing valuable protein in the diet, mungbean has the remarkable quality of helping the symbiotic root rhizobia to fix atmospheric nitrogen and enrich the soil (Anonymous, 2005).

The principal constraint of mungbean production is its low yield potential. About 70 to 95% of mungbean flowers do not develop mature pods (Mondal, 2007) indicating that potential fruit or seed number is usually much larger than the number actually produced by the plant. The number of fruits with developing seeds increases at fruit setting stage and reaches the maximum at maximum seed growth stages (Hamid *et al.*, 1989) but during this period the plant continues to grow vegetatively. Therefore, developing reproductive sinks compete for assimilates with vegetative sinks. Unlike cereal, researches on grain legume especially flower and pod production and interrelationship in mungbean are inadequate and hence the understanding of the physiological basis of yield is limited. Many researchers reported that seed yield plant^{-1} is determined by the number of flowers formed plant^{-1}, the per cent pod set, the number of seeds pod^{-1} and seed size (Begum *et al.*, 1997; Fakir and Biswas, 2001; Mondal, 2007). In legume crops, lots of flowers are produced but a few of them set pods. One of the important reasons is abscission of flowers and immature pods. If abscission could be prevented or decreased, yield of leguminous crops might be increased. For example, extent of flower shedding may be 60-87% in soybean (*Glycin max*) (Nahar and Ikeda, 2002), 79-95% in mungbean [*Vigna radiata* (L) Wilczek] (Mondal, 2007), 80-91% in *Vigna unguiculata* (Fakir and Biswas, 2001) and 80-95% in *Cajanus cajan* (Fakir *et al.*, 1998). The high percentage of flower abscission is due to most of the later formed flowers abscise in mungbean. On the other hand, the genotypes, which produced more flowers within shorter time, also had a greater likelihood of setting pods and retaining them to maturity (Biswas *et al.*, 2005). Seventy per cent and more pods produced plant^{-1} originate from the first 10 days of flowering in determinate type and from fifteen days in indeterminate type of soybean (Yoshida *et al.*, 1983). Similarly, the plants which produced maximum flowers within 15 days after flowering also showed higher pod yield in mungbean (Mondal, 2007). Therefore, an understanding of the pattern of flowering may help in selection of superior genotypes. So, morpho-physiological basis of flower production and flowering pattern that ultimately lead to more mature pods and final yield need to be assessed.

Keeping all these information in mind, an experiment was conducted with ten mungbean mutants/cultivar with the following objectives:

i) To assess the magnitude and pattern of flower production;

ii) To investigate the relationship between flower production and morpho- physiological characters and seed yield; and

iii) To study correlation coefficient among different quantitative characters in mungbean genotypes.

Chapter 2

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

Mungbean is an important grain legume crop in the tropical and subtropical countries of the world. For yield augmentation, extensive research in varietal improvement and crop management practices has been performed quite satisfactorily. Some of the important research findings relevant to the present study have been reviewed in the following sections.

2.1 Morpho-physiological characters

2.1.1 Plant height

Plant height is an important morphological character and is influenced by growing condition such as plant density. Increased plant densities increase plant height and decrease stem diameter and pod number plant^{-1} (Lam-Sanches and Velosa, 1974). Prodhan (2004) studied comparative performance in respect of growth and yield in four mungbean genotypes and reported that high yielding genotypes had higher plant height compared to low yielding ones. Similar result was reported by Sadi (2004) and Mondal *et al.* (2004) by studying comparative performances of 15 mungbean genotypes.

2.1.2 Branching

Several workers reported that seed yield was significantly and positively correlated with number of primary and secondary branches plant^{-1} (Ahmed *et al.*1978; Hassan *et al.*, 1995; Sadi, 2004). A positive association of number of branches was observed with pods plant^{-1} (Mondal *et al.*, 2004). Further, Mondal (2007) stated that high yielding genotypes had greater branch number plant^{-1} than low yielding ones in mungbean. Similar result was reported by Hossain *et al.* (2002) in blackgram. Shibley and Weber (1986) studied 25 mungbean genotypes and observed a wide range of variability in branch number (range 1.0-4.5 plant^{-1}). Similar results were reported by Anonymous (2007) in mungbean.

2.1.3 Leaf area

Leaf is the most important part of field crop. It is directly related with photosynthesis, which influences other morpho-physiological traits also. Increase leaf area also produces increase photosynthates, which become converted into higher economic yield of a crop plant (Gautom and Sharma, 1987). Grain yield is positively correlated with leaf area in mungbean (Prodhan, 2004; Sadi, 2004), lentil (Maola, 2005; Rahman, 2005) and chickpea (Mishra *et al.*, 1988). Mondal (2007) studied 45 mungbean genotypes in relation to morpho-physiological characters and reported that there was a wide range of variability in leaf area (range 400-1037 cm^{-2} $plant^{-1}$) and he further noted that high yielding genotypes always produced greater leaf area than in low yielding ones.

2.1.4 Total Dry matter

Total dry matter (TDM) production and distribution are economically useful to determine the crop yield (Evans, 1975). Total dry matter of a crop depends on the size of leaves, its activity as well as the duration of its growth period during which photosynthesis continues. Dutta (2001) stated that total dry matter production was largely dependent on the solar radiation interception over the growing season and also indicated that total grain yield was influenced by photosynthesis and the distribution of photosynthates within the plant.

Hamid *et al.* (1990) reported that total dry matter production was positively correlated with the amount of foliage displayed in the upper 50% of canopy. It seemed that the foliage developed in the lower part of the canopy had little or negative contribution to dry matter production in mungbean.

Pulse crops either in winter or summer always had steady increase in dry matter before flowering (Matsunaga *et al.*, 1989). In a legume, the initial growth was very slow during the early vegetative phase and relatively smaller amount of total dry matter was produced before flower initiation (Pandey *et al.*, 1978; Osumi *et al.*, 1998) and a maximum dry matter was produced around physiological maturity (Prodhan, 2004). Many researchers reported that grain yield was positively and significantly correlated with total dry matter production (Hamid *et al.*, 1989; Mondal *et al.*, 2004; Prodhan, 2004; Maola, 2005).

2.1.5 Chlorophyll content in leaf

The chlorophyll content is central to photosynthesis phenomenon. With this widely conceived physiological standpoint, the yielding ability (biological and economic) depends upon photosynthesis (Nathvant. 1975). Yield was shown to have positive correlation with chlorophyll content in plant leaf (Lee *et al.* 1990; Singh *et al.*, 1990; Mondal *et al.*, 2004). However, some workers reported just positive but not significant correlation between chlorophyll content and yield (Ashraf *et al.*, 1995; Dewan, 2005; Jewel, 2005).

2.1.6 Harvest index

Harvest index (HI) is the ratio of the grain yield to the biological yield (Donald, 1963). It is a measure of the efficiency of conversion of photosynthate into economic yield of a crop plant (Gautom and Sharma, 1987). Increased HI results in increased crop yield, probably because of improved partitioning of dry matter to reproductive parts (Poehlman, 1991). Grain yield is positively correlated with HI in lentil (Dutta and Mondal, 1998; Maola, 2005), mungbean (Prodhan, 2004; Mondal, 2007), blackgram (Hossain *et al.*, 2002) and in chickpea (Mishra *et al.*, 1988).

2.2 Flowering behaviour

2.2.1 Flower production and floral abscission

Hamid (1991) reported that mungbean produces a number of flowers but the greater portion of them abscise without forming pods. Abscission of reproductive organ might be one of the possible reasons for the lower yield. Several reports indicated alarmingly high rates of flower abscission in mungbean (Savithri *et al.*, 1978). AVRDC (1974) reported that mungbean flowers abundantly but a large proportion of flowers and pods abscise. Sinha (1974) stated that mungbean normally produces a large number of flowers but most of them abscise (75-95%). Similar result was reported by Mondal (2007) in mungbean. Chowdhury (2001) reported that cowpea produced 205 flowers plant^{-1} with 80.4% abscission. Again, Chowdhury (1999) noted that it produced 695 flowers with 91.3% abscission. The authors also reported that there was a negative correlation between percentage of floral abscission and pod yield in cowpea. Anonymous (2006) studied 15 genotypes of mungbean and reported that total number of flowers plant^{-1} varied between 12 and 32 while percentage flower abscission varied between 60 and 88%. However, Fakir (1997) studied 45 genotypes of pigeonpea and observed that genotypic variation in flower production and wide ranges of flower abscission (70-95%) exist. The author estimated floral abscission to almost 100% after node 8 in a raceme of pigeonpea.

Saitoh *et al.* (2004) reported about 70-92% of flowers were lost by abscission in four genotypes of soybean. The high percentage of flower abscission is due to most of the later-formed flowers abscised in legumes (Isobe *et al.*, 1995; Kuroda *et al.*, 1998). On the other hand, the genotypes, which produced increased number of flowers within shorter time also had a greater likelihood of setting pods and retaining them to maturity (Fakir, 1997; Miah *et al.*, 2006). A couple of postgraduate students in the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh studied flower production, flowering pattern in mungbean genotypes and reported that total flower production plant^{-1} varied between 86 and 245 with abscission percentage which varied between 79 and 95% (Rahman, 2001; Haque, 2001: Prodhan, 2004). In mungbean, Mondal (2007) further reported that the plants, which produced increased number of flowers within first 15 days after commencement of flowering, also showed higher yield.

An experiment with genotypes of country bean, Fakir *et al.* (2000) found that floral abscission varied between 73 and 83%. Matsunaga *et al.* (1989) reported that the extent of flower abscission varied depending on the growing season in mungbean. The authors observed that the rate of pod set was less than 30% in summer while it was about 85% and 41% in autumn and rainy seasons, respectively.

2.2.2 Pattern of flowering

In mungbean, flowering occurred from lower to higher order racemes in the canopy and flowering within the raceme started from the lower order nodes up to the higher nodes. Haque (2001) studied flowering pattern in six genotypes of mungbean and reported that 45% of the total flowers were produced in the mainstem alone whereas 55% flowers were produced in the branches. Heindl and Brun (1984) suggested that flower production at different levels within the canopy was variable and was affected by genotypes, growth habit and cultural conditions in soybean. Weibold *et al.* (1981) observed that substantially fewer flowers were produced in the bottom of the canopy than in the middle and top in soybean.

Krisna *et al.* (1985) reported that flowering reached a peak within 50-60 days after sowing in groundnut. Reddy *et al.* (1994) observed two distinct peaks in flowering pattern of groundnut in normal sown crop whilst it was erratic in late sown crop. The authors observed that the first flush lasted up to 2-3 weeks after commencement of flowering and maximum flowering period was observed during 38-44 days after sowing. The second spell of flowering occurred 12-15 days after the first flush. The second flush produced more total flowers and lasted longer duration than the first flush, with maximum during 50-62 days after sowing. Cheong *et al.* (1997) observed maximum flowering between 68-80 days and 81-86 days in two different flushes in groundnut. Further, Mondal (2007) studied flowering pattern in 15 and 10 mungbean genotypes and reported that in most cases, the number of opening flowers day^{-1} increased till 10-15 days and flowering ceased within 20-25 days after flowering start.

2.3 Yield contributing characters

2.3.1 Pod number

The number of pods plant^{-1}, the prime yield attribute is an important criterion for the visual selection of high yielding genotypes (Dutta, 2001). Sadi (2004) reported that seed yield in mungbean depends on pod number, seeds/pod and seed size. Dutta (2001) further recommended that pods plant^{-1}, plant height and number of productive branches were criteria for the visual selection of high yielding genotypes. Similar result was also reported by Anonymous (2006) in mungbean who observed that high yielding genotypes had high number of pods plant^{-1} in mungbean. Sadi (2004) further observed a wide variation in case of pod/plant in mungbean. Similar result was observed by Mondal *et al.* (2004) in mungbean. However, most of the researchers reported that seed yield was strongly dependent on pod number plant^{-1} (Hassan *et al.*, 1995; Hossain *et al.*, 2002; Dutta and Mondal, 1998; Prodhan, 2004; Sadi, 2004).

2.3.2 Pod length

Anonymous (2006) studied 15 mungbean genotypes for flowering pattern and yield contributing characters and found that there was a high variation in pod length. Khattak *et al.* (2002) conducted an experiment on mungbean cultivars *viz.*, NM92, NM6601, NM51, NM89, Pak22, RC71-27 and ML5 and found that pod length was the highest in NM92. The authors further reported that pod lengths were greater in 1st flush than in 2nd flush in mungbean.

2.3.3 Number of seeds pod^{-1}

Sadi (2004) studied 15 mungbean genotypes for yield contributing characters and found that there was a high variation in seeds pod^{-1}. Khattak *et al.* (2002) conducted an experiment on mungbean cultivars *viz.* NM92, NM6601, NM51, NM89, Pak22, RC71-27 and ML5 and found that seeds pod^{-1} was the highest in NM92. They further reported that seeds pod^{-1} was greater in 1st flush than in 2nd flush in mungbean. However, most of the researchers reported that the number of seeds pod^{-1} was positively correlated with seed yield and negatively associated with seed size (Hossain *et al.*, 2002; Prodhan, 2004; Sadi, 2004; Mondal, 2007).

2.3.4 Thousand seed weight

Khattak *et al.* (2002) conducted an experiment on mungbean cultivars *viz.*, NM92, NM6601, NM51, NM89, Pak22, RC71-27 and ML5 and found that 1000-seed weight varied significantly among the tested cultivars and 1000-seed weight was the highest in NM92. They further reported that 1000-seed weight was greater in 1st flush than in 2nd flush in mungbean. Similar result was reported by Bhadra (2004) and Sadi

(2004) in mungbean. Hassan *et al.* (1995) reported that seed yield was positively correlated with 100-seed weight in mungbean. On the other hand, Prodhan (2004) reported that seed size had no significant influence on seed yield in mungbean.

2.4 Varietal performance

Many workers have studied yield performance of mungbean across the world. Kalita and Shah (1988) studied 19 cultivars of mungbean and found that seed yield was the highest in PMS-1 (890 kg ha^{-1}) and the lowest in PS-11/99 (520 kg ha^{-1}). Saharia and Dholi (1984) reported that there was significant variation in pods $plant^{-1}$ and seed yield in 25 mungbean genotypes and the yield range was 0.81-1.45 t ha^{-1}. Sadi (2004) observed that plant height, 1000-seed weight and harvest index were significantly influenced by variety. In an experiment with 15 genotypes in mungbean, the highest seed yield was obtained in MB45 (Hasan, 2004). Mondal *et al.* (2004) working with modern varieties of mungbean observed that there were significant differences in all plant characters among the varieties of the same species.

2.5 Correlation coefficient

Ahmed *et al.* (1978) conducted an experiment with seventy strains of mungbean and found significant positive correlation of yield with number of branchs $plant^{-1}$ and pods $plant^{-1}$. An experiment with 357 exotic and indigenous strains of mungbean was conducted by Pundir *et al.* (1992) and found that seed yield was positively associated with branches $plant^{-1}$, flowers $plant^{-1}$, pods $plant^{-1}$, pod length, seeds pod^{-1} and 100-seed weight.

Vikas *et al.* (1999) raised 63 genotypes over eight environments and studied the genotypic and phenotypic correlation among twelve quantitative characters of mungbean and found that seed yield showed positive association with number of raceme $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, 100-seed weight and TDM.

Malik *et al.* (1987) studied correlation using data of seed yield/plant and 12 related traits in 40 elite genotypes of mungbean and found that seed yield was positively correlated with plant height, branches $plant^{-1}$, pods $plant^{-1}$, flower clusters plant^{-1} and TDM plant^{-1}. Similar results were also reported by many researchers (Hassan *et al.*, 1995; Sadi, 2004, Prodhan, 2004; Mondal, 2007)

From the review of different plant characters studied by various scientists, it appears that in most of the cases the primary yield contributing characters like pods plant^{-1}, seeds pod^{-1} and 100-seed weight were directly related to the grain yield in mungbean and morpho-physiological characters influence indirectly the yield attributes and yield.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

In this chapter the details of different materials used and methodologies followed during the experimental period are presented under the following heads:

3.1 Experimental site

A pot experiment was carried out at the pot yard of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from 20 September to 20 November 2007. Geographically the experimental area is located at $24^{0}75$ N latitude and $90^{0}50$ E longitude at the elevation of 18 m above the sea level (FAO, 1988).

3.2 Soil

The soil of the experiment was collected from BINA farm, Mymensingh. The collected soil belongs to the agro-ecological zone of Old Brahmaputra Floodplain (AEZ-9) (BARC, 2005). Description of the soil is presented in Appendix-I.

3.3 Climate and weather

The experimental field was under subtropical climates characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March (Anonymous, 2006). The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours received at the experimental site during the period between September to November, 2007 are presented in the Appendix II.

3.4 Treatment of the experiment

The experiment consisted of ten mungbean genotypes which were collected from Crop Physiology Division, BINA, Mymensingh. The genotypes were MB-16, MB-17, MB-23, MB-35, MB-44., MB-45, MB-46, MB-47, BARImung-4 and

BINAmoog-4. Among these. BARImung-4 and BINAmoog-4 were released varieties and the rests were advanced mutants.

3.5 Preparation of pots and fertilizer applications

Silty loam soils were collected from BINA farm, Mymensingh. The collected soil was well pulverized and dried in the sun. Plant propagules, inert materials, visible insects and pests were removed from this soil. The dry soil was thoroughly mixed with well rotten cow dung. This prepared medium was used in filling the pots after mixing thoroughly with given amounts of urea, triple super phosphate, muriate of potash and gypsum at the rate of 2.18, 4.36, 3.27 and 2.18 g pot^{-1} corresponding to 40, 80, 60 and 40 kg ha^{-1}, respectively. Earthen pots of 30 cm diameter and 35 cm height were used for the experiment. The pots of the experiment were filled with 12 kg of soils.

3.6 Experimental design and sowing of seeds

The experiment was laid out in a Completely Randomized Design (CRD) with 4 replications. Each pot contained two plants and denotes a replication.

Ten seeds were sown in each pot on 20 September, 2007 at a depth of 3 cm. Finally they were thinned to two seedlings after 20 days of emergence.

3.7 Intercultural operations

Weeding and soil loosening were done as and when necessary. Water was supplied as and when needed to ensure sufficient moisture for the normal growth of the crops. Plant protection measures were taken at 35 and 50 DAS against fruit and shoot borer by spraying Sypermethrin 50 EC @ 0.25%.

3.8 Harvesting

All the plants of the given genotypes under four replications were harvested at a time on 29 November 2007, when most of the pods became mature (about 90% pods were became brown in colour). The mature pods were collected by hand.

3.9 Collection of data

3.9.1 Data on reproductive efficiency as recorded from the experiment were:

i) Number of flowers $plant^{-1}$ day^{-1}: Daily flower count was done & recorded from days to first flowering until flowering was ceased.

ii) Number of total flowers $plant^{-1}$: The total number of flowers produced on every plant of the given genotypes through the crop life was recorded.

iii) Reproductive efficiency: Ratio of pods to opened flowers in percentage.

$$\text{i.e. \% pods to opened flowers} = \frac{\text{Total number of pods plant}^{-1}}{\text{Total number of opened flowers plant}^{-1}} \times 100$$

3.9.2 Morpho-physiological parameters

i) Plant height (cm): Plant height was measured from the base of the plant to the tip of the main stem.

ii) Number of branches: Number of branch was counted from each plant at harvest.

iii) Leaf area: Leaf area per plant was measured by leaf area meter (LICOR 3000, USA).

iv) Total dry matter: The total dry matter was recorded by drying the plants at 80 $^{0}C\pm$ 2 for 48 hours and calculated from summation of leaves, stem, roots and pods weight as observed in an electronic balance.

v) Raceme number: Number of raceme, the pod bearing organ was counted from each plant at harvest.

vi) Chlorophyll: Chlorophyll was extracted in 80% acetone from the leaves of upper two nodes of a plant and the chlorophyll was determined by following the method of Yoshida *et al.* (1976).

3.9.3 Yield and yield contributing characters

i) Number of pods plant^{-1}: Number of pods was counted from each plant at harvest

ii) Seeds pod^{-1}: Number of seeds were recorded from the randomly selected 10 competitive pods.

iii) Single pod weight: Ten randomly selected pods from each of the plants were weighed and then were divided by ten to get single pod weight.

iv) 100-seed weight: One hundred clean sun dried seeds were counted from the seed stock obtained from the sample plants and weighed by using electronic balance.

v) Seed yield: The seeds were separated from pod by threshing manually and then sun dried and weighed.

vi) Harvest index: Harvest index (HI) was calculated by dividing economic yield to biological yield of plant by multiplying with 100 and expressed in percentage.

$$\text{Harvest index (HI)} = \frac{\text{Economic yield (seed yield)/plant}}{\text{Biological yield/plant}} \times 100$$

3.10 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell, 1986).

Chapter 4

Results and Discussions

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study on the genotypic effect on morpho-physiological characters, flowering pattern, yield and yield contributing characters of mungbean are presented and possible interpretations have been made in this chapter.

4.1 Morpho-physiological characters

4.1.1 Plant height

Plant height was significantly different among the genotypes (Table 1). The highest plant height (54.1 cm) was recorded in MB-46 which was significantly different from the others. On the other hand, BINAmoog-4 was the shortest one (32.5 cm). These results were in agreement with the result of Prodhan (2004) who stated that plant height differed significantly among the studied genotypes in mungbean. The results of the present study were also supported by the results of Sadi (2004) in mungbean.

4.1.2 Number of branches plant^{-1}

Number of branches plant^{-1} had significant variation among the genotypes (Table 1). BINA moog-4 produced the highest number of branches plant^{-1} (3.32). In contrast, MB-16 produced the lowest number of branches plant^{-1} (1.11) followed by MB-23 (1.30), MB-44 (1.50) and MB-45 (1.40). Sadi (2004) studied morpho-physiological parameters of 15 mungbean genotypes and reported that there had been a wide variation in number of branches plant^{-1}, which supported the present experimental results.

.4.1.3 Leaf area plant^{-1}

Significant variations among the genotypes were observed in case of character leaf area per plant (Table 1). The genotypes MB-35 and MB-44 produced the higher leaf area and the highest was noted in MB-44 (655 cm^2 plant^{-1}). In contrast, BINAmoog-4 had the lowest leaf area

Table 1. Morpho-physiological parameters of 10 mungbean genotypes

Genotypes	Plant height (cm)	Branches plant^{-1} (no.)	Leaf area plant^{-1} (cm^2)	Total dry mass plant^{-1} (g)	Chlorophyll (mg g^{-1}fw)	Racemes plant^{-1} (no.)	Harvest index (%)	Days to maturity
MB-16	39.0 e	1.11 f	481 e	13.00 e	1.60	8.40 e	30.9 a	60 f
MB-17	44.6 c	1.98 c	550 d	20.17 b	1.70	10.8 cd	30.3 a	61 ef
MB-23	45.7 c	1.30 ef	540 d	13.90 e	1.60	8.53 e	26.1 bcd	62 e
MB-35	45.5 c	1.85 d	648 a	20.50 b	1.80	12.7 b	29.7 ab	65 d
MB-44	49.4 b	1.50 ef	666 a	19.93 bc	1.71	8.30 e	26.9 bc	69 b
MB-45	47.0 bc	1.40 ef	466 ef	17.90 cd	1.60	11.2 c	27.1 b	62 e
MB-46	54.1 a	1.55 de	460 ef	16.55 d	1.85	7.90 e	24.7 d	75 a
MB-47	42.8 d	2.86 b	600 b	23.77 a	1.80	13.5 a	25.8 d	74 a
BARImung-4	49.1 b	2.20 c	420 f	13.88 e	1.67	7.90 e	27.7 b	60 f
BINAmoog-4	32.5 f	3.32 a	418 f	13.63 e	1.70	10.0 c	27.9 ab	67 c
F-test	**	**	**	**	NS	**	*	**
CV (%)	4.00	9.11	5.72	7.22	8.10	5.42	6.00	1.96

In a column same letter (s) do not differ significantly at $P \leq 0.05$ as per DMRT; NS = Not significant
*, **, indicate significant at 5 and 1% level of probability, respectively

(418 cm ^{2} plant^{-1}) whilst showing similarity with BARImung-4 (420 cm^2 plant^{-1}), MB-45 (466 cm^2 plant^{-1}) and MB-46 (460 cm^2 plant^{-1}). This result of variability in leaf area agreed with the result observed by Mondal *et al.* (2004) in mungbean. Again, higher leaf area producing genotypes also showed higher TDM. On the other hand, low yielding genotypes had lower leaf area as well as lower TDM indicating insufficiency in source leaf in low yielding genotypes.

4.1.4 Total dry mass plant^{-1}

Total dry mass (TDM) plant^{-1} had significant variation among the genotypes (Table 1). The highest TDM plant^{-1} was recorded in MB-47 (23.77 g) followed by MB-35 (20.50 g). In contrast, the lower TDM plant^{-1} was recorded in four genotypes *viz.*, MB-16, MB-23, BARImung-4 and BINAmoog-4 (range 13.00-13.90 g). Results further revealed that high yielding genotypes produced high TDM plant^{-1} compared to low yielding ones indicating that the seed yield is positively correlated with TDM production in mungbean. Sadi (2004) and Mondal *et al.* (2004) studied 15 mungbean genotypes and reported that high yielding genotypes also had higher TDM plant^{-1} than in low yielding ones, which supported the present experimental results.

4.1.5 Chlorophyll content

The effect of genotypes on chlorophyll content variation in leaf was non-significant (Table 1). However, the results indicated that high yielding genotypes possessed greater chlorophyll content in leaf than in low yielding ones. The above results indirectly agreed with those of many workers. Anonymous (2006) reported just positive but no significant correlations between chlorophyll content and seed yield in mungbean. Similar results was reported by Sadi (2004) in mungbean.

4.1.6 Number of racemes plant^{-1}

Racemes, the pod bearing organ had significant differences among the genotypes studied (Table 1). MB 47 produced the highest number of racemes plant^{-1} (13.5). In contrast, MB-46 and BARImung-4 produced the lowest number of racemes plant^{-1} (7.90) which was statistically similar to MB-44, MB-23 and MB-16 ranging from 8.30 to 8.53. Genotypic variation in raceme number was also observed by Prodhan (2004).

4.1.7 Harvest index

Harvest index (HI) had significant variation among the genotypes (Table 1). The highest HI was recorded in MB-16 (30.9%) which was statistically similar with other three genotypes, such as MB-17 (30.3%), MB-35 (29.7%) and BINAmoog-4 (27.9%). In contrast, MB-46 showed the lowest HI (24.7%) followed by MB-47 (25.8%). The above result of variability fully agrees with Mondal (2007) who also observed large variation in HI within the genotypes in mungbean.

4.1.8 Days to maturity

Days required to maturity had significant variability amongst the genotypes (Table 1). MR-46 and MB-47 required longer days to reach maturity (74-75 days). On the other hand, MB-16 and BARImung-4 required the shortest days to reach maturity (60 days) followed by MB-17 (61 days). This result is in full agreement with Anonymous (2004) who reported that mutant lines took shorter days to reach maturity than the mother cultivars.

4.2 Flowering characters

4.2.1 Pattern of opened flower production

Significant variation in periodical flower production at 3 days interval in 10 mungbean genotypes is shown in table 2. Five genotypes *viz.*, MB 16, MB-23, MB- 46, BARImung-4 and BINAmoog-4 had shown peak flowering within 4-6 days after flowering initiation (DAF) while two genotypes *viz.*, MB-35 and MB-44 showed peak at 7-9 DAF. The rest of three genotypes (MB-17, MB-45 and MB-47) had shown peak within 10-12 DAF. Concerning yield versus flowering peak, most of the high yielding genotypes had shown peak flowering within 10-12 DAF except MB-35. The genotype MB-35 produced higher yield with flowering peak within 7-9 DAF (Table 2).

Table 2. Effect of genotypes on pattern of flower production, flowering duration and reproductive efficiency in 10 mungbean

Genotypes	Production of opened flowers plant^{-1} (no.)						Total flowers plant^{-1} (no.)	Flowering duration (days)	Reproductive efficiency (%)	Seed yield plant^{-1} (g)†
	Days to flowering start									
	1-3	4-6	7-9	10-12	13-15	16-19				
MB-16	4.65 a	8.81 c	6.67 d	0.35 g	0.00	0.00	20.7 e	11 e	61.3 de	5.80 e
MB-17	1.10 h	4.57 g	10.0 b	15.7 a	10.7 a	3.00 a	45.0 a	17 b	52.6 f	8.79 a
MB-23	3.83 bc	7.67 c	4.50 f	1.83 e	0.50 e	0.00	18.3 fg	13 d	76.5 b	4.90 f
MB-35	3.13 d	12.9 a	14.7 a	5.17 d	0.70 de	0.00	36.5 b	15 c	60.3 e	8.67 ab
MB-44	2.30 e	4.50 ef	8.33 c	1.33 f	3.67 c	0.00	20.1 ef	15 c	62.2 d	7.33 c
MB-45	2.33 e	5.00 e	6.82 d	7.50 c	6.70 b	0.70 c	28.6 d	18 b	45.8 g	6.65 d
MB-46	1.61 g	6.67 d	3.30 f	2.33 e	0.83 d	1.33 b	16.1 k	21 a	81.2 a	5.43 ef
MB-47	4.00 b	4.33 f	9.31 b	10.0 b	6.53 b	0.20	34.2 c	16 c	61.4 de	8.27 b
BARImung-4	3.33 d	6.83 d	5.00 e	1.67 f	0.50 e	0.00	17.3 g	14 d	71.7 c	5.31 ef
BINAmoog-4	4.17 b	9.17 b	6.67 e	0.67 g	0.33 e	0.00	21.0 e	15 c	59.5 e	5.28 ef
F-test	**	**	**	**	**	**	**	**	**	**
CV (%)	7.20	7.14	8.64	9.00	10.41	30.47	5.66	7.00	5.04	6.01

In a column, same letter (s) do not differ significantly at $P \leq 0.05$ as per DMRT; †: For comparison with other reproductive characters

**, indicate significant at 1% level of probability

On the other hand, the low yielding genotypes viz., MB-16, MB-23, MB-46, BARImoog-4 and BINAmoog-4 had shown peak within 4-6 days after anthesis and also produced fewer number of flowers ranging from 16.1 to 21.0 and flowering ceased within 13-15 DAF in most of the low yielding genotypes. It seems that flowering pattern may have a relation with seed yield. Similar result was also reported by Mondal (2007) in mungbean.

4.2.2 Number of total flowers plant^{-1} and flowering duration

The total cumulative flower production also showed significant difference amongst the genotypes (Table 2). The genotypes MB-17, MB-35 and MB-47 had higher yield (range 8.27-879 g plant^{-1}) and also produced greater number of flowers plant^{-1} ranging from 34.2 to 45.0 plant^{-1} (Table 2). In contrast, low yielding genotypes, in general, produced fewer flowers plant^{-1} (range 16.1-21.0 plant^{-1}). This result indicates that in mungbean, cumulative increased flower production may be desirable in achieving high yield.

Considering flowering duration, in general, high yielding genotypes required more time (15-21 days) compared to low yielding ones (11-15 days). MB-16 took the shortest duration of flowering (11 days). On the other hand, MB-17, MB-45 and MB-46 took longer flowering duration (17-21 days) and also showed higher seed yield except MB-47. It seems that flowering duration has a relation with seed yield. The present result was in agreement with Mondal (2007) who reported that the genotypes of longer flowering duration produced higher flowers which resulted with higher seed yield in mungbean. However the present result has the disagreement with Haque (2001) who reported that earlier flower production within shorter period of time produced higher seed yield in mungbean.

4.2.3 Reproductive efficiency

Significant variation in reproductive efficiency (% pod set to opened flowers, RE) was also observed in mungbean genotypes (Table 2). In general, high yielding genotypes showed lower RE (range 52.6-61.4%) compared to low yielding ones (range 59.5-81.2%) except MB-45 (45.8%). The highest reproductive efficiency was recorded in MB-46 (81.2%) followed by MB-23 (76.5%). In contrast, the lowest reproductive efficiency was observed in MB-45 (45.8%). This result was consistent with the results of Hasan (2004) and Mondal (2007) in mungbean who reported that high yielding genotypes had inferior RE than in low yielding ones in mungbean.

4.3 Yield and yield contributing characters

4.3.1 Number of pods plant^{-1}

Pod number, one of the most important yield attributes varied significantly among the genotypes (Table 3). MB-17 produced the highest number of pods plant^{-1} (23.7) followed by MB-35 (22.0) and MB-47 (21.0). In contrast, four genotypes, MB-16, MB-44, BARI mung-4 and BINAmoog-4 produced fewer number of pods plant^{-1} (range 12.4-12.7) and showed similarity with each other. Genotypic variation in pod number was also observed by many workers in mungbean (Dutta, 2001; Anonymous, 2004; Mondal *et al.*, 2004; Mondal, 2007).

4.3.2 Pod length

Pod length showed significant variability among the genotypes studied with MB-44 being the highest (9.97 cm) of all followed by other 4 genotypes (Table 3). On the other hand, MB-23 produced the shortest pod (6.39 cm), which was statistically identical with MB-35 (6.85 cm). The above results of variability in pod length were in full agreement with many workers. Prodhan (2004), Sadi (2004) and Uddin (2001) observed quite high degree of variability in pod length in their studies with mungbean.

4.3.3 Number of seeds pod^{-1}

The effect of genotypes on seed number pod^{-1} was significant (Table 3). MB-17 showed the highest number of seeds pod^{-1} (12.2). In contrast, MB- 16 produced the lowest number of seeds pod^{-1} (9.20) followed by MB-46 (9.44). Other genotypes were intermediate in respect of seeds pod^{-1}. This result of variability in seed number

Table 3. Genotypic effect on yield and yield contributing characters of mungbean

Genotypes	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Single pod weight (mg)	100-seed weight (g)	Seed yield plant^{-1} (g)
MB-16	11.5 cd	8.40 bcd	9.20 h	602 c	4.97 bc	5.80 e
MB-17	22.4 a	8.00 d	12.2 a	580 d	4.30 d	8.79 a
MB-23	12.8 c	6.39 f	11.5 bc	490 g	3.30 g	4.90 f
MB-35	20.6 b	6.85 ef	11.7 b	507 f	4.11 e	8.67 ab
MB-44	11.3 cd	9.97 a	10.4 e	796 a	5.87 a	7.33 c
MB-45	12.1 cd	8.90 b	10.0 f	692 b	5.82 a	6.65 d
MB-46	11.8 cd	8.16 cd	9.44 g	690 b	5.83 a	5.43 ef
MB-47	19.8 b	8.53 bc	11.0 d	786 a	5.21 b	8.27 b
BARImung-4	11.1 d	7.10 e	11.4 bc	551 e	3.90 f	5.31 ef
BINAmoog-4	11.3 cd	8.67 bc	11.5 bc	566 de	4.96 c	5.28 ef
F-test	**	**	**	**	**	**
CV (%)	6.66	4.34	3.20	2.55	2.15	6.01

In a column, same figure (s) do not differ significantly at $P \leq 0.05$ as per DMRT;
**, indicate significant at 1% level of probability

pod^{-1} agreed with the results of Sadi (2004) and Hasan (2004) in mungbean.

4.3.4 Single pod weight

Single pod weight varied significantly among the genotypes under study (Table 3). MB-44 had the highest single pod weight (796 mg). In contrast, MB-23 had the lowest single pod weight (490 mg) followed by MB-35 (507 mg). This result of variability in single pod weight agreed with the results of Prodhan (2004) in mungbean.

4.3.5 Hundred-seed weight

Hundred seed weight, an important yield attribute, varied significantly among the genotypes (Table 3). Three genotypes *viz.*, MB-44, MB-45 and MB-46 showed higher 100-seed weight (range 5.82-5.87 g) and the highest was found in MB-44 (5.87 g). On the other hand, MB-23 had the lowest 100-seed weight (3.30 g). This result of variability in 100-seed weight agreed with the results of Sadi (2004) in mungbean.

4.3.6 Seed yield plant^{-1}

Seed yield plant^{-1} varied significantly among the genotypes (Table 3). The higher seed yield was recorded in MB-17 (8.79 g plant^{-1}) and MB-35 (8.67 g plant^{-1}) followed by MB-47 (8.27 g plant^{-1}). The yield was higher in those genotypes because of producing higher number of pods plant^{-1} and seeds pod^{-1}. The lower seed yield was recorded in MB-23 (4.90 g plant^{-1}), MB-46 (5.43 g plant^{-1}), BARI mung-4 (5.31 g plant^{-1}) and BINAmoog-4 (5.28 g plant^{-1}) due to production of lower number of pods plant^{-1}. However, MB-44 produced fewer pods plant^{-1} but showed moderate yield due to production of bold size pods and seeds. This result is consistent with the result of Prodhan (2004) and Mondal *et al.* (2004) in mungbean who observed that there was significant variation among the studied genotypes for seed yield.

4.4 Correlation coefficients

Seed yield had shown highly significant positive correlation with raceme number, flower number, pod number, total dry mass and leaf area plant^{-1} (Table 4). These results indicated that yield could be improved by increasing sink (raceme, flower and pod). On the other hand, raceme, flower and pod production depend on leaf area (r = 0.55 **, 0.62** and 0.0.75**. respectively), branch number (r = 0.63**, 0.53** and 0.55**, respectively) and TDM (r = 0.73**, 0.82** and 0.84**, respectively). It means to increase sink production, photosynthetic apparatus (leaf area) should be increased in mungbean. "These results were consistent with the results of many workers (Choudhary *et al.*, 1988; Hassan *et al.*, 1995; Hasan, 2004; Mondal. 2007). On the other hand, 100-seed weight and single pod weight had no influence on seed yield. Most of the workers reported that pod and seed size had negative association with seed yield in mungbean (Choudhary *el al.*, 1988; Poehlman, 1991; Prodhan, 2004; Mondal, 2007).

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Table 4. Simple correlation coefficient among different quantitative characters of 10 mungbean genotypes

Characters	Racemes plant^{-1} (no.)	Flowers plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Total dry mass plant^{-1} (g)	Plant height (cm)	Branches plant^{-1} (no.)	Leaf area plant^{-1} (cm^2)	Chlorophyll content in leaf (mg g^{-1}fw)	Single pod weight (mg)
Seed yield	0.70 **	0.91 **	0.89**	0.36 *	0.07	0.94 **	0.06	0.42 *	0.73 **	0.42 *	0.25
Raceme number		0.80 **	0.76**	0.24	0.003	0.73 **	0.26	0.63 **	0.55 **	0.30	0.28
Flower number			0.87**	0.53 **	- 0.15	0.82 **	0.15	0.53 **	0.62 **	0.70 **	- 0.24
Pod number				0.53 *	- 0.29	0.84 **	0.02	0.55 **	0.75 **	0.43 *	- 0.22
Seeds pod^{-1}					- 0.60**	0.30	- 0.23	0.42 *	0.32	0.06	- 0.43 *
100-seed weight						0.19	0.18	- 0.04	- 0.36 *	0.26	0.84 **
Total dry mass							0.39 *	0.41 *	0.78 **	0.53 **	0.45 *
Plant height								- 0.42 *	0.45 *	0.34 *	0.27
Branch number									0.52 **	0.37 *	0.04

n = 40 ; ** and * indicate significant at 1% and 5% level of probability.

Chapter 5
Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at Bangladesh Institute of Nuclear Agriculture, Mymensingh, during the period from September to November, 2007 to investigate flower production, flowering pattern, reproductive efficiency, yield attributes and their relationship with seed yield in 10 mungbean genotypes. The genotypes were MB-16, MB-17, MB-23, MB-35, MB-44, MB-45. MB-46, MB-47, BARImung-4 and BINAmoog-4. The experiment was laid out in a completely randomized design with four replications.

High yielding genotypes produced increased number of opened flowers and longer flowering duration than the low yielding ones. The genotypes, MB-17, MB-35 and MB-47 produced increased number of opened flowers (45.0, 36.5 and 34.2 plant^{-1}, respectively) and also showed higher seed yield. In contrast, low yielding genotypes (MB-16, MB-23, MB-46, BARImung-4 and BINAmoog-4) produced fewer number of opened flowers (range 16.1-21.0 plant^{-1}) and also showed shorter flowering duration (12-15 days) except MB-46. High yielding genotypes had higher flower production rate over time than the low yielding ones and maximum flowers production occurred within 10-12 days after flowering starts. This suggests that early maximum flowers within 10-12 days after flowering start could be the selection criteria of yield improvement in mungbean. For reproductive efficiency (RE), high yielding genotypes had inferior performance in RE (range 52.6-61.4%) than in low yielding ones (59.5-81.2%). MB-46 showed the highest RE (81.2°%) and MB-45 showed the lowest (45.8%). This result indicates that there is a scope of increasing yield by improving the RE in high yielding genotypes in mungbean.

In case of morpho-physiological characters, high yielding genotypes maintained moderate plant height, greater raceme number, increased leaf area and TDM plant^{-1}. In contrast, low yielding genotypes produced lower leaf area, stem diameter, TDM and raceme number plant^{-1}. The highest harvest index was recorded in MB-16 (30.9%) and the lowest was recorded in MB-46 (24.7%).

Considering correlation coefficient between yield and yield related traits, result revealed that seed yield had high significant positive correlation with raceme number (r = 0.75**), flower number (r = 0.91 **), pod number (r = 0.89"), leaf area (r = 0.73**) and TDM plant^{-1} (r = 0.94**). Again, pod number was highly correlated with leaf area (r = 0.75 **), TDM (r = 0.84 **), raceme number (r = 0.76**) and flower number plant^{-1} (r = 0.87**) indicating the dependence of pod production on leaf area, TDM, racemes and number of opened flowers. On the other hand, pod and seed size had no significant influence on seed yield.

The genotypes, MB-17, MB-35 and MB-47 produced higher seed yield plant^{-1} (8.79, 8.67 and 8.27 g, respectively) due to the production of higher number of pods plant^{-1} and seeds pod^{-1}. In contrast, MB-16, MB-23, MB-46, BARI mung-4 and BINA moog-4 showed lower seed yield (5.80, 4.90, 5.43, 5.31 and 5.28 g plant^{-1}, respectively) due to lesser number of pods plant^{-1}. These results indicated that a genotype with increased sink (pod) production might give higher yield in mungbean.

From the results above, it may be concluded that

i) high yielding genotypes have higher number of flowers than the low yielders in mungbean and total opened flowers is more important than reproductive efficiency to get higher yield;

ii) the flower production depends on branch number, leaf area and total dry mass production in mungbean; and

iii) among different quantitative characters TDM and flower number plant^{-1} possess maximum correlation with seed yield (r = 0.94 ** and 0.91**, respectively).

Two mungbean genotypes *viz.*, MB-17 and MB-35 performed better in respect of growth (LA and TDM), reproductive (raceme and flower number) yield and yield contributing characters. It needs further trials in field conditions to have a concrete decision regarding their performance to a greater extent.

Recommendation

1. Extensive study is necessary in field condition to have more clear and practical results.

2. Source-sink ratio should be studied extensively covering all parts of the plant.

3. Influence of responsible genes could be found out to find out flowering pattern and reproductive efficiency in mungbean.

4. Reproductive biology covering stigma receptivity, pollen germination, pollen tube growth, fertilization and pod set can be studied extensively.

5. Mobilization pattern of food through the phloem tissue to the flower could be examined thoroughly.

6. Regulation of hormones can be observed extensively.

7. Anatomical changes in the petiole and gynoecium before and after fertilization could be observed keenly.

Chapter 6

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Appendices

APPENDICES

Appendix I. Physical and chemical properties of soil (0-15 cm) of the experimental field

A. Physical properties of soil	
% sand (0.2-.02 mm)	21.75
% silt (0.02-.002 mm)	66.60
% clay (< 0.002 mm)	11.65
Textural class	Silty loam
Consistency	Granular
B. Chemical properties of soil	
Soil pH	6.4
Organic carbon (%)	1.30
Organic matter (%)	1.28
Total nitrogen (%)	0.11
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12
Available sulphur (ppm)	9.00

Source: Soil Science Division, BINA, Mymensingh-2202

Appendix II. Monthly recorded of air temperature, rainfall, relative humidity and sunshine hours of the experimental site during the period from September to November 2007

Months	Air temperature (^{0}C)			Rainfall (mm)	Relative humidity (%)	Sunshine (hrs)
	Maximum	Minimum	Average			
<u>September</u>						
01-07	31.67	26.09	28.90	46.1	89.71	1.90
08-15	29.81	25.85	27.83	142	92.63	2.63
16-22	30.54	25.41	27.98	21.1	90.57	3.47
23-28	30.29	24.98	27.64	60.7	92.00	2.81
<u>October</u>						
01-07	29.73	24.60	27.17	426	91.29	4.49
08-15	29.66	23.39	26.52	62.1	89.25	4.55
16-23	30.46	21.42	25.94	0.00	83.75	8.80
24-31	29.57	20.22	24.90	0.00	84.38	7.83
<u>November</u>						
01-07	28.38	17.90	23.14	0.00	82.71	8.09
08-15	28.08	16.70	22.39	0.00	81.00	7.81
16-22	28.07	17.00	22.53	0.00	84.70	6.46
23-30	28.62	15.78	22.20	0.00	82.00	7.55

Source: Weather Yard, Department of Irrigation and Water Management, BAU, Mymensingh

Appendix III. Analysis of variance (mean square) of some morpho-physiological characters in 10 mungbean genotypes

Source of variation	df	Plant height (cm)	Branches plant^{-1} (no.)	Leaf area plant^{-1} (cm^2)	Total dry mass plant^{-1} (g)	Chlorophyll (mg g^{-1}fw)	Racemes plant^{-1} (no.)	Harvest index (%)	Days to maturity
Genotypes	9	133.6 **	1.91 **	39362 **	66.9 **	0.03 ^{ns}	16.96 **	6.75 **	106.7 **
Error	30	3.04	0.027	1023	1.35	0.015	0.277	1.87	1.35

**, indicate significant at 1% level of probability; ns = Not significant

Appendix IV. Analysis of variance (mean square) of floral characters in 10 mungbean genotypes

Source of variation	df	Flowers at 1-3 DAF (no. plant^{-1})	Flowers at 4-6 DAF (no. plant^{-1})	Flowers at 7-9 DAF (no. plant^{-1})	Flowers at 10-12 DAF (no. plant^{-1})	Flowers at 13-15 DAF (no. plant^{-1})	Flowers at 16-19 DAF (no. plant^{-1})	Total flowers plant^{-1}	Flowerin g duration (days)	Repro-ductive efficiency †
Genotypes	9	5.05 **	28.13 **	54.91 **	45.79 **	135.7 **	3.87 **	388.2 **	40.18 **	338.5 **
Error	30	0.043	0.141	0.341	0.095	0.166	0.022	1.56	1.135	3.14

**, indicate significant at 1% level of probability

Appendix V. Analysis of variance (mean square) of some yield contributing characters and yield in 10 mungbean genotypes

Source of variation	df	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Single pod weight (mg)	100-seed weight (g)	Seed yield plant^{-1} (g)
Genotypes	9	81.95 **	4.47 **	4.16 **	48374.9 **	3.36 **	9.10 **
Error	30	0.898	0.117	0.055	210.8	0.011	0.11

**, indicate significant at 1% level of probability