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RELATIONSHIPS BETWEEN FLOWERING BEHAVIOR AND SEED YIELD IN MUNGBEAN MUTANTS

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Abstract

Flower is the prime sink that produces pods and yield depends on numbers and size of pods in legume crops. Flowering behavior affects the synchrony of pod maturity, which is crucial for efficient harvesing that regulates the yield. Thus, it is essential to study the relationship between flowering behavior and pod yield in mungbean mutants. This experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications at the BINA headquarters physiology pot yard. The aim was to assess the relationship between flowering patterns, flowering duration, and seed yield in ten mungbean mutants/varieties. Results indicated that high-yielding mutant (MM-1) produced more opened flowers (38.0 flowers per plant) and had a longer flowering duration (12 days) compared to low-yielding varieties/mutants (13.1-18.0 flowers per plant and 7-9 days). Additionally, high-yielding varieties exhibited higher flower production rates over time, with peak flower production occurring within 5-8 days, while low-yielding varieties peaked within 3-4 days. High-yielding mungbean mutants/varieties exhibit lower pod set and reproductive efficiency (48.7-55.0%) compared to low-yielding ones (63.2-70.9%), indicating potential for yield improvement in high-yielding genotypes through enhanced pod set. Pod number, a key yield parameter, has a significant positive correlation with flower number (r = 0.56**), while pod number is also dependent on flowers per plant (r = 0.68**). Additionally, seed yield shows a strong positive relationship with the harvest index (r = 0.62**). These findings suggest that future breeding efforts should focus on synchronizing flower production to increase mungbean yield.

Keywords: Mungbean, flowering pattern, flowering duration, pod set, seed yield

The primary limitation of mungbean production is its low yield potential, with legume crops like mungbean often producing numerous flowers but setting only a few pods, resulting in reduced yields (Ong *et al.* 2023). A significant proportion, ranging from 55% to 85%, of mungbean flowers fail to mature into pods, highlighting that the potential fruit or seed count often exceeds the actual production within the plant community (Mondal *et al*., 2013a). The higher proportion of reproductive abscission is due to most of the later-formed flowers abscise in the legume (Mondal *et al*, 2011b, Wien *et al.* 2020). It is widely accepted that the yield of leguminous crops can be increased if abscission can be reduced.

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Moreover, the genotypes that produced more flowers within a shorter time also had a greater likelihood of setting pods (Fakir *et. al.*, 2011a and Labua. H. 2012). Apart from the magnitude, the duration of flowering is equally important. Seventy percent and more pods produced by plants originated from the first 10 days of flowering in the determinate type, and from the fifteen days in the indeterminate type of soybean (Kim *et. al.*, 2020 and Wang *et al*., 2023). Therefore, an understanding of the pattern of flowering may help in the selection of superior genotypes. There is little information on this aspect mutants of mungbean.

However, the seed yield of legume crops showed a strong correlation with flower numbers, rather than with pod setting rate or reproductive efficiency (Mondal *et al*., 2013c; Suso *et. al*., 2013). This suggests the potential flower production appears more important than the abortion rate for increased legume seed yield. Is there any relation between flowering duration and flower production in mungbean, it needs investigation. Therefore, the morpho-physiological basis of flower production which ultimately leads to more mature pods and final yield needs to be assessed in mungbean mutants for future varietal development programs. This experiment focused on investigating flowering behavior duration, and flower production in twelve modern mungbean varieties discriminated for yields to assess yield determining factors in mungbean.

The experiment was conducted at the BINA pot yard in Mymensingh, Bangladesh (2408´ N 9000´ E), from March to May 2019 to evaluate the flowering pattern and its correlation with seed yield using 7 mungbean mutants and 3 varieties listed in Table 1. The soil used in the experiment was silty loam. The study was arranged in a Completely Randomized Design with four replications, with pots filled with 10 kg of soil and fertilized with urea, TSP, MoP, gypsum, zinc sulfate, and boric acid at specified rates (Armin *et al*., 2016). Each pot was initially sown with three seeds, and after 30 days, one plant was retained per pot. Standard intercultural practices were followed, and insecticide (Ripcord 50 EC at 0.025%) was applied during flowering and fruiting stages (45 and 55 DAS) to manage shoot and fruit borer infestations. But flowering pattern or number was not affected by the infestation. The flower count commenced from the initiation of the first flower opening and was documented daily until the end of flowering. The average number of flowers produced per day was calculated over 2 days. Flower production, flowering pattern at 2-day interval, and flowering duration were determined based on the data collected. Reproductive efficiency (RE), expressed as the percentage of pod set to open flowers was calculated as % pod set (Reproductive efficiency) = (Number of pods plant^{-1} ÷ Number of opened flowers plant^{-1}) × 100. Seed yield and yield components were assessed at harvest. The plants were partitioned into roots, stems, leaves, and pods, and their respective dry weights were measured after oven drying at 80 ± 2^{o} C for 72 hours. Statistical analysis was conducted using Duncan's Multiple Range Test with the MSTAT statistical software package (Russell, 1986).

Pattern of flower production

Significant genotypic variation in the case of days to flowering, number of opened flowers at 2-day interval, and total flower plant^{-1} was observed (Table 1). Daily flowering converted to 2-day intervals had shown a differential peak period (Table 1). The flowering duration ranges from 8 to 12 days after flowering starts. The shortest flowering duration was recorded in MM-9, MM-11, and MM-12 (8 DAF, days after flowering started), and the longest was recorded in Binamoog-5 and MM-1 (12 DAF). The mutant MM-1 produced the highest number of flowers (38 plant^{-1}) followed by Binamoog-8 (32 plant^{-1}). In contrast, MM-9 produced the fewest flowers (13.1 plant^{-1}). Results further indicated that the genotypes that had longer flower duration also produced a greater number of flower plant^{-1} than short duration flowering mungbean plants. Results revealed that the high-yielding varieties/mutants produced a greater number of opened flowers (range 24.3-38.0 plant^{-1}) having longer flowering duration (range 10-12 days) than the low-yielding ones (number of opened flowers range 13.1-18.0 plant^{-1} and flowering duration range 7-9 days). It also appeared that high-yielding varieties had higher flower production percentage over time than the low-yielding ones and maximum flower production occurred within 5-8 days in the high-yielding varieties and within 3-4 days in the low-yielding varieties. It seems that flowering patterns may have a relation with seed yield.

Table 1. Flowering pattern at two-day intervals of ten mungbean varieties/mutants

Mutants/ Varieties	Days to flowering	Number of opened flowers at 2- day interval						Total flowers plant^{-1} (no.)
		Days after flowering start						
		0-2	3-4	5-6	7-8	9-10	11-12	
MM-1	39 b	3 c	7 b	9 a	10 b	8 a	1 b	38.0 a
MM-2	42 a	4 b	5 c	5 d	4 b	1 c	0	19.0 ef
MM-5	38 c	2 d	5 c	6 c	3.3 c	1 c	0	17.3 g
MM-8	37 c	4 b	9 a	5 d	1 e	1 c	0	20.0 de
MM-9	35 d	3 c	5 c	3.1 f	2 d	0	0	13.1 h
MM-11	35 d	6 a	6 bc	4 e	2 d	0	0	18.0 fg
MM-12	35 d	4 b	6 bc	5 d	2 d	0	0	17.0 g
Binamoog-5	40 b	4 b	5 c	4 e	4 b	3 b	2 a	22.0 cd
Binamoog-8	38 c	4 b	6 bc	8 b	13 a	1c	0	32.0 b
Binamoog-9	36 d	7 a	9 a	5.3	2 d	1 c	0	24.3 c
CV (%)	1.13	9.76	15.33	7.58	11.90	20.21	16.40	13.58

Figures followed by same letter(s) in a column indicates do not differ significantly at P≤ 0.05. (Binamoog-5, Binamoog-8 and Binamoog-9 act as control over the mutant lines).

Interestingly, those genotypes that produced an increased number of flowers within 4-8 DAF also showed higher seed yield. In contrast, the mutants MM-5, MM-9, MM-11, and MM-12 produced fewer flowers (range 13.1-18.0 plant^{-1}) within the above given times and also showed lower seed yields (range 2.85-4.87g plant^{-1}) (Table 2) . This suggests that higher yield in mutants/ cultivars could be achieved if an increased rate of flower production is ensured within 8-10 DAF.

However, it is well conceived that the genotypes of mungbean that exhibit a higher number of flowers within a condensed timeframe, especially during early flowering stages, enable more time for assimilate accumulation, resulting in increased sink strength compared to those with delayed flower formation (Mondal *et al*., 2013c and Seo *et. al.,* 2023). This helps in producing a high rate of pod set thereby high yield. That is why, the higher rates of flower production within 8-10 DAF in this study possibly had shown higher pod and seed yields.

Seed yield and yield attributes

The findings suggested that genotypes with shorter flowering durations exhibited increased reproductive efficiency (Table 2). Interestingly, high-yielding varieties demonstrated lower reproductive efficiency (ranging from 48.7% to 55.6%) compared to low-yielding ones (ranging from 63.2% to 70.9%). This implies that enhancing the reproductive efficiency in high-yielding genotypes of mungbean could potentially boost yields. This result is consistent with the result of Mondal *et al.* (2009) and Fakir *et al.* (2011b) in mungbean who reported that high-yielding genotypes had lower RE than low-yielding ones. Low-yielding genotypes with higher pod set or RE produced lower yields because of fewer sink (flowers) plant^{-1}. This phenomenon can be elucidated by the reduced competition for assimilates among flowers and pods in low-yielding genotypes due to their lower flower count, enabling the maximum pod-to-flower ratio (Mondal *et al.* 2009 and Fakir *et al.* 2011). Conversely, high-yielding genotypes exhibited an extended time to mature alongside increased biological yield and seed yield (Table 2).

Table 2. Variation in reproductive efficiency, biological and seed yield in 10 mungbean varieties/mutants

Mutants/ Varieties	Reproductive efficiency (%)	Days to maturity	Biological yield (g plant^{-1})	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight. (g)	Seed weight plant^{-1} (g)	Harvest index (%)
MM-1	48.7 d	68 b	18.95 a	18.5	10.9 ab	4.95 cd	7.99 a	42.16 c
MM-2	63.2 b	65 c	10.81 e	12.0	10.8 ab	4.60 ef	4.77 cd	44.12 bc
MM-5	51.0 d	65 c	11.91 d	8.67	10.6 b	4.44 fg	3.66 f	30.73 f
MM-8	55.0 c	65 c	12.50 c	11.0	9.40 cd	4.85 de	4.21 e	33.68 e
MM-9	70.9 a	60 e	11.48 d	10.5	10.7 b	5.31 b	4.87 c	42.42 c
MM-11	55.6 c	60 e	10.90 e	10.0	9.11 e	5.11 bc	3.82 f	34.98 e
MM-12	64.7 b	60 e	8.50 f	11.0	8.20 f	3.82 h	2.85 g	33.53 e
Binamoog-5	63.6 b	70 a	12.20 c	14.0	9.70 cd	4.15 g	4.61 cd	37.78 de
Binamoog-8	53.1 c	66 c	14.55 b	17.0	9.80 c	5.15 bc	6.96 b	47.83 b
Binamoog-9	55.6 c	63 d	13.40 b	13.5	11.2 a	5.45 a	6.70 b	50.00 a
CV (%)	17.28	1.55	8.23	8.71	3.84	2.58 b	7.96	6.54

[Figures followed by same letter (s) in a column indicate not to differ significantly at $P \leq 0.05$.

High-yielding genotypes, in general, showed higher harvest index with few exceptions. The highest seed yield was recorded in MM-1 (7.99g plant^{-1}) due to higher pod production followed by Binamoog-8 (6.96g plant^{-1}). Binamoog-9 showed the third higher seed yield with the fewer pods plant^{-1} might be due to good dry matter partitioning to economic yield and larger seed size (Mondal *et al.*, 2009). Three mutants, MM-9, MM-11, and MM-12 matured earlier (60 days after sowing) and Binamoog-5 that required the longest days to maturity (70 days after sowing).

Correlation coefficient

Pod number is the prime yield attribute in mungbean and pod number showed significant and positive correlations with flower number (r = 0.56**), flowering duration (r = 0.68**), biological yield (r = 0.81**) and harvest index (r = 0.62**), thereby strongly correlating these parameters to seed yield (Table 3). In contrast, pod number and seed yield had a negative association with RE (r = -0.37*, -0.44*). Increasing sink (pod number) production would increase seed yield and pod production depends on flower number, not on reproductive efficiency (Mondal *et al.*, 2012). Again, a positive and significant correlation of yield was observed with opened flowers (r = 0.86**). Still, the number of opened flowers was negatively and significantly correlated (r = 0.41*) with RE (Table 3).

Table 3. Simple correlation coefficient between yield attributes and reproductive characters of 10 mungbean mutants/cultivars

Characters	Pods/ plant (no.)	Total flowers/ plant (no.)	Flowering duration	RE (%)	BY (g/plant)	100-seed weight (g)	Harvest index (%)	Seed yield/ plant (g)	Seeds/ pod (no.)
Seed yield/ plant (g)	0.87**	0.86**	0.57**	-0.44**	0.89**	0.60**	0.78**	---	0.62**
Pods/plant (no.)	---	0.56**	0.68**	-0.37*	0.81**	0.22	0.62**	0.87**	0.26
seeds/pod (no.)	0.26	0.27	0.37*	-0.18	0.53**	0.55**	0.58**	0.62**	---
100-seed weight (g)	0.22	0.24	-0.09	-0.23	0.45**	---	0.62**	0.60**	0.55**

N = 40, * and ** indicate significance at 5% and 1% level of probability, respectively; RE, reproductive efficiency; BY, biological yield.

This suggests that selection for higher RE and thereby high yield could be misleading since it might be difficult to get higher flower production with increased RE simultaneously. Similar results were also reported by Mondal *et al.*, (2011b) in soybeans that it would be difficult to incorporate high flower production capacity and low flower abortion (FA) into one strain because of a positive correlation between FA and flower number, which supports the present results. Further, seed yield strongly and positively correlated with flowering duration (r = 0.57**), biological yield (r = 0.89**), seed size (r = 0.60**), seed number pod^{-1} (r = 0.62**) and harvest index (r = 0.78**). These results agree with the results of many workers in mungbean and lentil, who also observed that seed yield increased with the increased number of flowers and pods per plant (Fakir *et al.*, 2011; Mondal *et al.*, 2013a; Mondal *et al.*, 2011a, Kritika 2017, Kadam *et al.*, 2023). This aspect may be necessary for future plant breeding programs of mungbean yield improvement.

From the results, high-yielding genotypes had longer flowering duration, and higher rates of flower production with larger seed sizes while reverse trends hold for the low-yielders.

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