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Flowering Pattern and Reproductive Efficiency in Mungbean

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ABSTRACT

A large proportion of flowers abort during development due to vascular tissue limitation in the distal part of rachis resulting in lower yield in mungbean [*Vigna radiata* (L.) Wilczek]. Flowering pattern and its relationships with pod retention, reproductive efficiency and yields in 10 local mungbean genotypes were assessed at Mymensingh, Bangladesh in two consecutive years of 2006 and 2007. The number and pattern of flower production, pod retention and reproductive efficiency (RE, percent pod set to opened flowers) varied among the genotypes. Results revealed that the genotypes, which produced higher number of flowers within a shorter period (10–15 days) after commencement of flowering also produced higher yields, attributed from higher number of flowers and pods. In contrast, low yielding genotypes showed reverse trends. However, low yielding genotypes had higher RE than high yielding ones. It further revealed that the genotype with early-formed flowers had higher podset and retention capacity than later-formed ones. The implication of relationships between flower production and RE for mungbean seed yield is also discussed. © 2011 Friends Science Publishes

Key Words: *Vigna radiata*; Flowering pattern; Pod set percent; Pod retention pattern

INTRODUCTION

Seed yield per plant is determined by the number of flowers per plant, the percent podset, the number of seeds per pod and seed size in mungbean [*Vigna radiata* (L.) Wilczek] (Mondal, 2011c). In legume crops, many flowers are produced, but only a few set pods. Degree of flower shedding varies between 60–92% in soybean (Nahar & Ikeda, 2002; Saitoh *et al*., 2004), 70-90% in mungbean (Kumari & Verma, 1983; Mondal *et al.,* 2011a), 80–91% in *Vigna unguiculata* (Hossain *et al*., 2006) and 80–95% in *Cajanus cajan* (Fakir *et al*., 1998; Begum *et al*., 2007). The high proportion of reproductive abscission is due to most of the later-formed flower that mostly abscise in legumes (Isobe *et al*., 1995; Kuroda *et al*, 1998; Mondal *et al.,* 2011a). Because of the flowers and pods of the raceme may not receive enough assimilates from the leaf due to inadequate phloem tissue development in distal (top) part of the raceme (Wiebold & Panciera, 1990; Begum *et al*., 2007; Mondal *et al.,* 2011a) resulting abscission of flowers and immature pods in legumes (Nahar & Ikeda, 2002; Hossain *et al*., 2006). It is widely accepted that yield of leguminous crops can be increased, if abscission could be reduced. There has been much debate as to whether yield in legume is source or sink limited and most of the arguments favour the former as earlier-formed pods were heavier than the later-formed ones (Kuroda *et al*., 1998; Begum *et al*., 2007; Mondal *et al.,* 2011a) indicating inadequate assimilate supply to later formed pods. Moreover, genotypes, which produce more flowers within shorter time also have higher pod sets capacity and retention till maturity (Togun & Tayo, 1990; Biswas *et al*., 2005). Apart from the magnitude, duration of flowering also appeared equally important since more than 70% pods per plant are originated from the first 10 days of flowering in determinate type and 15 days in indeterminate type of soybean (Yoshida *et al*., 1983). Similarly, the plants that produce maximum flowers within two to three weeks after first flowering shows higher pod yield in groundnut and mungbean (Mondal & Hamid, 1998; Mondal, 2011c). This suggests an understanding of flowering pattern is important for selection of high yielding genotypes. There is little information in this aspect for mungbean (Mondal, 2011c). However, seed yield of soybean was closely correlated with the number of flowers opened, but not with the rate of pod set or reproductive efficiency (Saitoh *et al*., 1998). This suggests the potential of flower production appears more important than the rate of abortion for increased seed yield. Therefore, morpho-physiological basis of flower production and flowering pattern that ultimately leads to more mature pods and final yield need to be properly assessed in mungbean for future varietal development program. This experiment focused on investigating flower production, flowering pattern and reproductive efficiency (podset percent) in 10 mungbean genotypes discriminated for yields to assess yield determining factors.

MATERIALS AND METHODS

Two field experiments were conducted with 10

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genotypes (five high & five low yielding, Table I) of mungbean in 2006 and 2007 at the Field Laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh (24°8′ N 90°0′ E), Bangladesh. The soil of the experimental area is silty loam having a total nitrogen 0.06%, organic matter 1.15%, available phosphorus 18.5 ppm, exchangeable potassium 0.28 meq/100g, sulphur 18 ppm and pH 6.8. The weather data during the experimental period is shown in Table I.

A randomized complete block design with three replications was used. The unit plot size was 2 m × 2 m with plant spacing of 30 cm × 10 cm. Seeds were sown on 28 February, 2006 and 04 March, 2007. Recommended cultural practices were followed in both seasons (Mondal, 2011a). Total 15 plants, five from each of the three replications were randomly selected and tagged for daily count of opened flowers. Flower count began from the date of opening of first flower and continued every day until flowering ceased for first flush. Number of flowers produced at each day was averaged over 5 days interval. Flower production or flowering pattern at 5 days interval and flowering duration were calculated from the collected data. The yield and yield attributes were also recorded. Per cent podset to opened flowers (reproductive efficiency, RE) was estimated as: percent pod set = (Number of pods plant^{-1} ÷ Number of opened flowers plant^{-1}) × 100. The collected data were statistically analyzed following Dancans Multiple Range Test.

Table I: Monthly temperature and rainfall at experimental area, Mymensingh, Bangladesh during the experiment period

Months	Year: 2006				Year: 2007			
	Temperature (°C)			Total rainfall (mm)	Temperature (°C)			Total rainfall (mm)
	Maxi-mum	Mini-mum	Average		Maxi-mum	Mini-mum	Average	
March								
01–07	28.80	17.80	23.30	0.00	30.57	16.86	23.71	0.00
08–15	26.50	16.40	21.45	19.0	28.88	14.75	21.32	08.62
16–23	28.50	18.45	23.48	2.10	30.12	19.31	24.72	15.90
24–31	29.44	20.02	24.73	92.9	31.38	20.88	26.13	40.38
April								
01–07	31.41	21.33	26.37	0.00	33.71	23.07	28.39	0.00
08–15	32.84	23.01	27.93	22.0	37.53	24.69	31.11	25.45
16–22	30.56	22.14	26.35	51.8	34.21	22.14	28.18	1.00
23–30	31.56	22.62	27.09	22.4	34.00	23.44	28.72	10.00
May								
01–07	30.54	22.73	26.64	39.0	36.50	24.40	30.45	18.20
08–15	32.80	23.71	28.25	20.4	35.60	23.30	29.45	24.00
16–23	32.84	23.34	28.09	102	36.00	24.60	30.30	68.60
24–31	32.55	23.50	28.03	104	37.23	24.70	30.96	54.00

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

Table II: Flowering pattern in 10 mungbean genotypes in 2006

Genotypes	Number of open flowers at 5 days interval (absolute)					
	Days after first opened flower					
	1–5	6–10	11–15	16–20	21–25	26–30
High yielding						
E_4I 913	3.50 e	10.3 b	13.3 b (27.1)†	4.0 d	3.5 b	3.5 a
BARI moog2	10.5 a	10.0 b	4.90 e (25.4)	3.0 de	1.0 d	0
BMX 942-8	6.30 b	10.3 b	14.3 b (30.9)	2.7 de	2.0 c	1.7 b
BMX 953-9	6.00 b	10.5 b	6.50 d (23.0)	7.2 ab	5.2 a	3.0 a
VC 6173	4.70 d	16.7 a	21.5 a (42.9)	5.5 c	2.0 c	1.0 c
Average	6.10	11.6	12.3 (30.0)	4.7	2.7	1.8 b
Low yielding						
MB 300	5.5 c	10.0 b	5.00 e (20.5)	0	0	0
BMX 967-1	4.5 d	6.3 c	6.70 d (17.5)	2.5 e	0	0
VC 6144C	5.8 c	2.8 e	10.3 c (18.9)	8.3 a	2.5 c	0
VC 3960	7.0 b	4.8 d	4.70 e (16.5)	5.8 c	0	0
VC 6173A	6.3 b	4.2 d	7.00 d (17.5)	2.0 e	4.0 b	0
Average	5.8	5.6	6.74 (18.1)	3.7	1.3	0
LSD (0.05)	1.01	1.33	1.41	1.23	0.66	0.70

In a column, figures with common letter (s) do not differ significantly at P ≤ 0.05 by DMRT. † †Figures in parenthesis indicate the cumulative flower production up to 15 days after commencement of flowering

RESULTS

Flower production and flowering pattern: Variation in flowering pattern at 5 days interval, total flower production and seed yield showed significant variations in 10 mungbean genotypes (Tables II, III & IV). The duration of flowering was 5 days longer in 2007 than 2006 (Tables II & III). Moreover, in both years, the flowering duration was greater in high yielding genotypes (20-30 days) than in low yielding ones (10–25 days). For high yielding genotypes, the duration of flowering varied between 20 and 25 days in 2007 and between 25 and 30 days in 2006. Contrarily, for low yielding genotypes, flowering duration was 15–25 days in 2006 and 10–20 days in 2007. These results indicated genotypic versus year responses on flowering duration and yields. Among the high yielding genotypes, BARI moog2 had the shortest flowering duration (20-21 days) in the both year. Remainder high yielding genotypes, the flowering duration varied from 21–25 days in 2007 and 26–30 days in 2006. In contrast, of the low yielding genotypes, MB 300 had the shortest flowering duration as it terminated at 10 days in 2007 and 15 days in 2006, which was earlier than remainders.

Synchronous and shorter flowering duration appeared in 2007 compared to 2006, reaching peak flower production within 10 days after the beginning of flower opening in the latter year and 15 days in the former year. In general, high yielding genotypes produced greater number of flowers per plant (average 37.8) than low yielding ones (average 18.2) (Table IV). Interestingly, those genotypes that produced more number of flowers within 10–15 days after commencement of flowering (DAF) in both years also produced higher seed yield. In both years, the genotypes, E_4I 913, BARI moog2, BMX 942-8, BMX 953-9 and VC 6173 produced higher number of flowers within 10–15 DAF also produced higher seed yields. In contrast, the genotypes MB 300, BMX 967-1, VC 6144C, VC 3960 and VC 6173A produced fewer flowers within the above given time and also showed lower seed yields (Table IV).

Reproductive efficiency (RE) and yield: In general, both genotypes and years had affected flower production and RE

Table III: Flowering pattern in 10 mungbean genotypes in 2007

Genotypes	Number of open flowers at 5 days interval (absolute)					
	Days after first opened flower					
	1–5	6–10	11–15	16–20	21–25	26–30
High yielding						
E_4I 913	12.8 abc	15.2 a (28.0)†	2.4 d	5.8 a	2.4 b	0
BARI moog2	12.8 abc	14.0 ab (26.8)	4.2 bc	3.0 b	0	0
BMX 942-8	14.0 a	10.7 cd (24.7)	4.7 b	2.7 b	4.0 a	0
BMX 953-9	14.4 a	12.2 c (26.6)	2.8 d	1.2 c	1.0 c	0
VC 6173	12.0 bcd	14.8 ab (26.8)	6.0 a	3.5 b	0.5 c	0
Average	13.2	13.4 (26.6)	4.0	3.2	1.6	0
Low yielding						
MB 300	8.20 f	6.00 e (14.2)	0	0	0	0
BMX 967-1	10.5 de	11.8 cd (22.3)	1.5 e	0.2 d	0	0
VC 6144C	10.5 de	4.00 f (14.5)	4.5 b	0.5 d	0	0
VC 3960	10.2 e	6.40 e (16.6)	1.2 e	0	0	0
VC 6173A	9.00 ef	5.00 ef (14.0)	0.3 f	0	0	0
Average	9.68	6.64 (16.3)	1.5	0.14	0	0
LSD (0.05)	1.65	1.52	0.83	0.65	0.58	

In a column, figures with common letter (s) do not differ significantly at P ≤ 0.05 by DMRT. †Figures in parenthesis indicate the cumulative flower production up to 10 days after commencement of flowering

Table IV: Total flower production, reproductive efficiency and seed yield in 10 mungbean genotypes in 2006 and 2007

Genotypes	2006			2007		
	Open flowers $plant^{-1}$	Pod set to opened flowers (%)	Seed yield $plant^{-1}$ (g)	Open flowers $plant^{-1}$ (no.)	Pod set to opened flowers (%)	Seed yield $plant^{-1}$ (g)
High yielding						
E_4I 913	38.1 b	84.9 ab	5.17 b	38.6 a	73.1 bc	6.45 a
BARI moog2	35.4 c	84.7 b	5.03 b	34.5 b	77.2 b	5.02 c
BMX 942-8	37.3 bc	87.0 ab	6.60 a	36.1 ab	58.3 e	6.15 ab
BMX 953-9	38.4 b	80.3 cd	5.65 ab	31.6 c	66.9 cd	5.15 bc
VC 6173	51.4 a	77.0 cd	6.00 ab	36.8 a	63.6 de	5.71 abc
Average	39.3	82.8	5.69	35.5	67.8	5.70
Low yielding						
MB 300	20.5 ef	84.7 b	3.89 c	14.2 g	74.3 bc	3.33 d
BMX 967-1	20.0 f	90.3 a	3.73 c	24.0 d	69.2 cd	3.37 d
VC 6144C	29.7 d	87.1 ab	3.71 c	19.5 e	86.7 a	3.35 d
VC 3960	21.4 ef	84.1 bc	3.03 c	17.8 ef	77.3 b	3.83 d
VC 6173A	23.5 e	81.2 cd	3.55 c	15.3 f	71.9 c	3.91 d
Average	23.0	85.5	3.58	18.2	75.9	3.56
LSD (0.05)	2.55	5.56	0.98	2.62	5.20	1.06

In a column, figures with common letter (s) do not differ significantly at P ≤ 0.05 by DMRT

(Table IV). Increased flower production and RE were observed in 2006 compared to 2007 although RE was greater in low yielding genotypes yet with fewer total numbers of opened flowers than high yielding ones (Table IV). Low yielding genotypes with higher RE produced lower yield because of fewer sink (flowers) per plant. In contrast, high yielding genotypes produced flower almost double (37.8 $plant^{-1}$, average over years) compared to low yielding ones (20.6 $plant^{-1}$) yet showed lower RE.

Pod retention pattern: Variation in per cent podset or pod retention pattern was significant (Fig. 1). During 2007, pod retention percentage appeared higher within 5 days after commencement of flowering (DAF) in both high and low yielding genotypes followed by a decline to almost zero at 20–25 DAF in high and 11–15 DAF in low yielding genotypes (Fig. 1). During 2006, pod retention percentage was higher up to 10 DAF and became almost nil at 26–30 DAF in high and 21–25 DAF in low yielding genotypes, except BARI moog2 and MB 300. In BARI moog2 and MB 300, it decreased to nil at 16-20 and 11–15 DAF, respectively. The results indicated that for both years, genotypes with earlier borne flowers had a higher podset.

Table V: Simple correlation coefficient between reproductive characters and yield of 10 mungbean genotypes (averaged over two years)

Characters	Flowering duration (days)	Flowers $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Reproductive efficiency (%)
Seed yield	0.70**	0.86**	0.74**	- 0.42**
Flowering duration		0.82**	0.84**	0.08
Flower number			0.94**	- 0.36**
Pod number				0.18

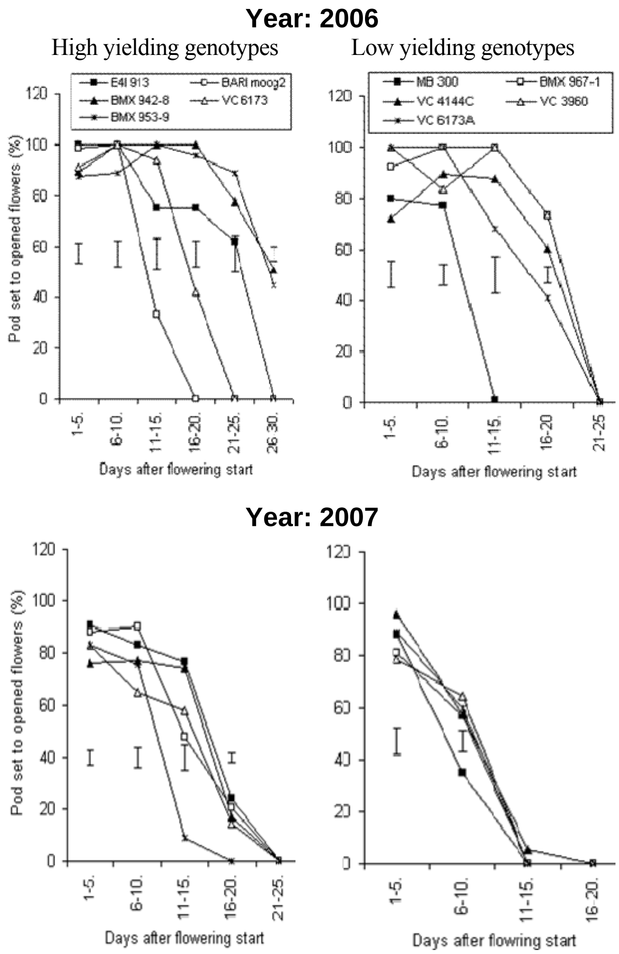
n = 60; ** and * indicate significant at 1% and 5% level of probability, respectively

Correlation co-efficient: Seed yield had shown highly significant positive correlation with flowering duration (r = 0.70**), flower number (r = 0.86**) and pod number (r = 0.74**), but significant negatively associated with RE (r = -0.42**) (Table V). These results indicated that yield could be improved by increasing sink (flower & pod). On the other hand, flower and pod number depend on flowering duration (r = 0.82**, 0.84**, respectively). It means to increase sink production, flowering duration should be increased in mungbean. However, flower production and RE had negative association with each other (r = -0.36**).

DISCUSSION

The flowering duration was longer in 2006 and in 2007 (Tables II & III) and this could be due to increased air temperature (average 27.8°C) with less rainfall (average 22.2 mm) in the latter compared to earlier (average temperature 25.9°C, average rainfall 39.6 mm) (Table I). This result is supported by Begum *et al.* (1998), who observed decreased flowering duration with increased temperature. Islam *et al.* (2005) reported that under water stress condition flowering duration decreased compared to control (under field capacity). It means under water stress condition flowering duration decrease in mungbean. In the present experiments rainfall was almost half in 2007 than in 2006 thereby may be water stress occurred in 2007 and resulting shorter flowering duration in 2007 than in 2006. Genotypes produced increased number of flowers within 10 and 15 DAF in 2007 and 2006, respectively, also produced higher seed yield. This is in conformity with Mondal and Hamid (1998) and Mondal *et al.* (2011a), who studied flowering pattern in groundnut and mungbean and observed increased number of flower production within 15–20 DAF in groundnut and 10–15 DAF in mungbean, also produced

Fig. 1: Variation in pod retention pattern at 5 days interval in ten mungbean genotypes grown under two seasons, 2006 and 2007. Vertical bars represent LSD (0.05)



higher yield in groundnut and mungbean, respectively. Similar results were also reported by Young Keun *et al.* (2002) in groundnut and Fakir *et al.* (2009) in Lignosus bean. This suggests that higher yielding cultivars could be achieved if increased rate of flower production is ensured within 10–15 DAF in mungbean. However, it is well conceived that the genotypes, which produced increased number of flowers within shorter period of time particularly at early growth stages will allow them more time for assimilate accumulation and this attain more sink strength than the later-formed flowers (Mondal & Hamid, 1998; Saitoh *et al.*, 2004; Biswas *et al.*, 2005). Again, Mondal *et al.* (2011c) observed that leaf chlorophyll and nitrogen of mungbean increased with increasing plant age till just before pod development start and thereafter leaf chlorophyll and nitrogen decreased with pod age till physiological maturity indicating early setting pods get available assimilates than later setting ones for its growth and development. This helps in producing high rate of pod set thereby high yield. That is why, the higher rates of flower production within 10–15 DAF in this study possibly had shown higher pod and seed yields. Further, earlier formed flowers had a higher podset than the latter (Fig. 1) might be due to most of the carbohydrate produced by leaf is used in filling the pods that occurs at proximal position of raceme (Spollen *et al*., 1986a).

Spollen *et al.* (1986b) studied assimilate translocation pattern in soybean and reported that early setting and later pods accounted for 70 and 30% of the translocated ^{14}C, respectively. These data indicated that most of the carbohydrate produced by leaf is used in filling the pods that set early at reproductive stage. Similar phenomenon may have occurred in the present experiment. Source limitation during seed filling seem to be relatively common as indicated by starch and nitrogen levels in soybean leaves during seed filling (Egli, 1999). Moreover, several workers (Shibles *et al*., 1987; Egli & Crafts-Brandner, 1996; Saitoh *et al*., 1998) opinioned that soybean yield under most field conditions is thought to be source restricted during the late reproductive period. Further, rachis diameter and radial length of xylem and phloem and vascular tissues decreased at the distal end compared to proximal one (Mondal, 2011c). These results suggested that phloem was poorly developed in the distal part of the raceme and thus providing possibly inadequate amount of photosynthate to the later-formed flowers/pods, which may have caused more flower shedding at the distal end of the raceme. This further indicates that irrespective of yield capacity, the mungbean genotype possibly confer a vascular tissue limitation in the distal part of the rachis. Similar results were also found in soybean (Wiebold & Panciera, 1990), in lignosus bean (Bari & Prodhan, 2001) and in pigeonpea (Begum *et al*., 2007). That is why, earlier formed flowers had a higher pod set than the latter.

Low yielding genotypes had higher RE with fewer open flowers resulting lower yield (Table IV). This could be explained in a way that less competition for assimilates amongst the flowers/pods in the low yielding genotypes by being their fewer flowers and this has certainly facilitated to produce maximum number of pods to flowers and vice versa (Mondal *et al*., 2011b). Positive and significant correlation of yield with opened flowers, but number of opened flowers was negatively and significantly correlated with RE 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 Sharma *et al.* (1990) and Saitoh *et al.* (2004) in soybean 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 also support the present result. Saitoh *et al.* (1999) further observed that with increasing number of flowers per raceme, the rate of podset per raceme decreased, but the total number of pods per raceme increased, which indicated that the increasing number of flowers per raceme contributes to a higher seed yield through the increase number of pods per raceme.

CONCLUSION

High yielding genotypes have higher number of flowers and pods with lower RE whilst reverse trends hold for the low yielder. Earlier opened flowers had greater chance of setting pods and retaining them till maturity. However, it is still un-clear whether source or sink capacity is responsible for such differentiations between high and low yielding genotypes. This presumption is, thus, would be assessed in future research.

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