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Effects of flowering behavior and pod maturity synchrony on yield of mungbean [*Vigna radiata* (L.) Wilczek]

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Abstract

A number of experiments were set up to assess the flower production and flowering pattern in synchrony with pod maturity and seed yield in twelve mungbean genotypes. Synchrony of pod maturity was measured based on percentage of mature pods at first harvest, where; synchrony (>90% mature pods), partial synchrony (80-90% mature pods) and asynchrony (<80% mature pods). Results revealed that genotypes that produced maximal opened flowers within 10-15 days, and ceased flowering within 15-20 days after first flowering (DAF), have synchrony in pod maturity. Additionally, seed yield was strongly correlated with the number of opened flowers and number of produced mature pods. Four genotypes showed synchrony in pod maturity which accompanied with cessation of flower production at 10-15 DAF, but produced lower yields due to fewer opened flowers. In contrast, the remaining genotypes showed partial synchrony or asynchrony in pod maturity due to longer flowering durations, with higher number of opened flowers and seed yield. These results indicate that synchrony in pod maturity and seed yield in mungbean is inversely related.

Keywords: Flower production, flowering pattern, synchrony in pod maturity, *Vigna radiata,* yield.
Abbreviations: DAF-days after first flowering; DAS-days after sowing.

Introduction

In mungbean [*Vigna radiata* (L.) Wilczek], seed yield is determined by number of produced flowers, percentage of pod set, number of seeds per pod and seed size (Mondal, 2007). In legume crops, many flowers are produced but only a few set pods are formed and result the low yield (Pigeaire et al., 1992; Fakir et al., 1998; Saitoh et al., 2004; Mondal, 2007; Islam et al., 2010). The main reason for such low yields is abscission of flowers and immature pods. If abscission could be prevented or decreased, yields of leguminous crops would be increased. The high percentage of flower abscission in legumes is due to the abscise of most later-formed flowers (Isobe et al., 1995; Kuroda et al, 1998; Mondal, 2007; Yasari et al., 2009; Islam et al., 2010). There has been much debate whether the yield of legumes is sink or source limiting, and much of the argument is in favor of the latter, as earlier-formed pods are heavier than the later-formed ones (Fakir, 1997; Kuroda et al., 1998; Begum et al., 2007). This suggests inadequate assimilate supply to later formed pods. Moreover, genotypes, which produced more flowers within a shorter time, had a greater likelihood of setting pods and retaining until maturity (Fakir, 1997; Biswas et al., 2005; Mondal, 2007). Apart from the magnitude, duration of flowering is equally important since more than seventy percent of pods plant^{-1} originate from the first 10-15 days of flowering in soybean (Yoshida et al., 1983; Nahar and Ikeda, 2002; Islam et al., 2010), *Vicia faba* (Clifford et al., 1990), pigeonpea (Fakir, 1997), and mungbean (Mondal et al., 2009). Plants that produce maximum flowers within two to three weeks after flowering also show higher pod yields in mungbean and groundnut (Mondal and Hamid, 1998; Mondal, 2007). This suggests that understanding of flowering pattern is useful in the selection of high yielding genotypes. There is however little information on flowering behaviour in mungbean. Therefore, morpho-physiological responses in flower production and flowering pattern that ultimately leads to more mature pods and final yield needs to be properly assessed. Not only lower yield but also asynchrony in pod maturity is a major problem in mungbean cultivation that is time consuming and costly practice of hand picking pods. It has been observed that only about 65% of pods can be harvested in the first picking at 70-75 days after sowing (DAS), 18% in the second at 75-80 DAS and 17% in the third at 90-95 DAS (Rahman, 1991). If we can harvest all or more than 90% of total pods in a single harvest, we will be able to lower the total harvesting cost. Thus, genotypes with synchronized maturity are desirable. The present study was conducted to study flowering pattern and its relationship with synchrony in pod maturity and seed yield in six promising mungbean genotypes along with six common cultivars.

Results

Flowering pattern and flower production

The pattern of flowering and flower production in the twelve mungbean genotypes during both growing seasons of 2006 and 2007 was almost similar (Tables 1-4). Variations in flowering pattern and duration, total flower production and

Table 1. Flowering behavior and seed yield of mungbean genotypes (Expt 1; season-I, 2006; Mymensingh)

Genotypes/ cultivars	Opened flowers produced at 5 days interval							Opened flowers/ plant (no.)	Flowering duration (days)	Seed yield/ plant (g)	Seed yield at first harvest (g/plant)	Degree of synchrony in pod ripening
	1-5 DAF	6-10 DAF	Cumulative flowers till 10 DAF (no.)	Flowers of the total till 10 DAF (%)	11-15 DAF	16-20 DAF	21-25 DAF					
E_4I 901 ††	13.0 a	21.0 a	34.0 a	79.8 cd	5.0 c	3.3 b	0.3 c	42.6 a	23 a	5.34 a	4.64 a	Partial synchrony
E_4I 913 ††	12.8 ab	15.2 c	28.0 b	72.5 e	2.3 de	5.8 a	2.4 a	38.6 b	22 a	4.96 ab	3.98 b	Asynchrony
MB 290 †	6.20 e	6.00 f	12.2 e	82.4 bc	2.6 d	0	0	14.8 g	12 d	2.07 h	2.07 h	Partial synchrony
MB 300 †	8.20 d	7.00 f	15.2 d	100 a	0	0	0	15.2 g	10 d	2.51 g	2.51 g	Synchrony
BMX 942-8 ††	14.0 a	11.8 de	25.8 bc	72.3 e	7.5 b	0.7 d	0	35.7 c	15 c	5.21 ab	4.20 b	Asynchrony
VC 3960 †	9.00 cd	5.00 f	14.0 de	100 a	0	0	0	14.0 g	10 d	2.61 g	2.61 e	Synchrony
BINAmung2 ††	9.00 cd	18.0 b	27.0 b	68.9 f	10.0 a	2.3 b	0	39.2 b	15 c	3.38 f	3.81 bc	Asynchrony
BINAmung5 †	10.5 c	5.00 f	15.5 d	81.2 bc	3.3 c	0	0	19.1 f	17 b	3.59 d	3.41 cd	Partial synchrony
BARI mung2 ††	12.8 ab	13.0 d	25.8 bc	73.3 e	4.2 c	3.5 b	1.7	35.2 c	12 d	3.76 c	3.32 d	Asynchrony
BARImung3 ††	13.0 a	13.0 d	26.0 bc	85.5 b	1.7 e	0	0	30.4 d	15 c	3.82 c	3.82 bc	Partial synchrony
BARImung4 ††	12.8 a	12.8 d	25.6 bc	77.6 d	5.8 c	1.6 c	0	33.0 cd	18 b	3.91 c	3.30 d	Asynchrony
BARImung5 †	10.8 b	11.5 e	22.3 c	100 a	0	0	0	22.3 e	10 d	3.33 e	3.33 d	Synchrony
Range	6.2-14.0	5.0-21.0	12.2-34.0	68.9-100	0-10	0-5.8	0-2.4	14.8-42.6	10-24	2.07-5.21	2.51-4.64	
CV (%)	6.67	10.22	8.90	5.66	6.80	10.30		13.30	16.20	12.60	7.52	
r (n = 36)	---	---	0.84**	---	---	---	---	0.64**	0.45**	---	---	

Means within columns with the same letters are not significantly different (DMRT; p<0.05), DAF = Days after flowering start; †: Low yielding genotypes; ††: High yielding genotypes; r = Phenotypic correlation coefficient with seed yield; Synchrony: > 90% pod matured; Partial synchrony: 80-90% pod matured and Asynchrony: < 80% pod matured at 1st harvest.

Table 2. Flowering behavior and seed yield of mungbean genotypes (Expt 2; season-II, 2006; Mymensingh)

Genotypes/ cultivars	Opened flowers produced at 5 days interval								Opened flowers/ plant (no.)	Flowering duration (days)	Seed yield/ plant (g)	Seed yield at first harvest (g/plant)	Degree of synchrony in pod ripening
	1-5 DAF	6-10 DAF	11-15 DAF	Cumulative flowers till 15 DAF (no.)	Flowers of the total till 15 DAF (%)	16-20 DAF	21-25 DAF	26-30 DAF					
E_4I 901 ††	5.0 e	11.2 c	12.0 b	28.2 b	85.5 d	3.00 c	1.80 c	0	33.0 d	22 c	4.93 b	4.21 b	Partial synchrony
E_4I 913 ††	3.50 f	11.3 c	13.3 ab	28.1 b	71.7 f	4.00 c	4.50 b	2.5 ab	39.1 c	27 b	4.85 b	3.68 c	Asynchrony
MB 290 †	12.0 ab	6.80 e	2.30 e	21.1 e	91.3 bc	2.00 d	0	0	23.1 ef	17 d	3.54 d	3.37 d	Synchrony
MB 300 †	5.50 de	10.0 c	3.00 de	18.3 f	100 a	0	0	0	18.5 g	13 e	3.40 d	3.40 d	Synchrony
BMX 942-8 ††	3.00 f	10.0 c	15.0 a	28.0 b	59.8 g	12.5 b	4.30 b	2.0 b	46.8 b	30 a	5.36 b	3.43 d	Asynchrony
VC 3960 †	6.50 d	6.80 e	4.80 d	18.1 f	88.7 cd	2.30 d	0	0	20.4 fg	17 d	3.56 d	3.42 d	Synchrony
BINAmung2 ††	6.80 d	8.00 d	15.0 a	29.8 b	47.1 h	20.5 a	10.0 a	3.0 a	63.3 a	30 a	6.50 a	3.88 bc	Asynchrony
BINAmung5 †	10.5 a	13.0 d	2.00 e	25.5 cd	100 a	0	0	0	25.5 e	11 e	4.13 c	4.13 b	Synchrony
BARI mung2 ††	13.0 a	17.5 a	4.00 d	34.5 a	96.3 a	1.30 d	0	0	35.8 cd	16 d	5.48 b	5.30 a	Synchrony
BARImung3 ††	11.3 b	10.0 c	5.20 d	26.5 c	73.6 ef	3.20 c	3.50 b	2.8 a	36.0 cd	30 a	4.63 c	3.40 d	Asynchrony
BARImung4 ††	9.30 c	6.80 e	8.50 c	24.6 d	76.9 e	4.30 c	2.00 c	1.5 b	32.0 d	29 ab	4.32 c	3.51 cd	Partial synchrony
BARImung5 †	4.30 ef	16.3 b	3.30 de	23.9 d	92.3 bc	2.00 d	0	0	25.9 e	13 e	3.52 d	3.40 d	Synchrony
Range	3.0-13.0	6.0-17.0	2.0-15.0	18.1-34.5	47.1-100	0.0-20.5	0.0-10.0	0.0-3.0	18.5-63.3	11-30	3.40-6.50	3.37-5.30	
CV (%)	8.88	9.44	13.1	8.65	5.70	25.3	21.8	12.63	6.34	6.31	5.27	7.11	
r (n = 36)	---	---	---	0.87**	---	---	---	---	0.95**	0.60**	---	---	

Means within columns with the same letters are not significantly different (DMRT; $p<0.05$)

DAF = Days after flowering start; †: Low yielding genotypes; ††: High yielding genotypes; r = Phenotypic correlation coefficient with seed yield;

Synchrony: > 90% pod matured; Partial synchrony: 80-90% pod matured and Asynchrony: < 80% pod matured at 1st harvest.

seed yield in twelve mungbean genotypes were significant (Tables 1-4). Results indicated that the duration of flowering was dependent to growing seasons and genotypes. The duration of flowering was 5-10 days earlier in the first growing season (season-I) compared to the second season (season-II). In both the seasons, the duration of flowering was longer in the high yielding genotypes (range 20-30 days) than in the low yielding ones (range 10-20 days).

The duration of flowering varied between 20 and 25 days in season-I, while the duration was between 25 and 30 days in season-II, in high yielding genotypes. On the other hand, in low yielding genotypes, the flowering duration was 10-15 days in season-I, and 15-20 days in season-II. These results indicate that yield was dependent on flowering duration. The correlation coefficients between flowering duration and seed yield were 0.45** and 0.62** for the year 2006 and 2007 during the season-I, and 0.60** and 0.82** for the year 2006 and 2007 during the season-II, respectively (Tables 1-4).

The results also showed shorter flowering duration in season-I as compared to season-II, and that peak flower production was reached within 10 days from the beginning of flowering in the former, while it was 15 days in the latter. In general, high yielding genotypes produced higher number of flowers plant^{-1} (average 31.9 plant^{-1}) than in low yielding ones (average 16.2 plant^{-1}) in both seasons. Genotypes which produced higher number of flowers, within 10 days after commencement of flowering (DAF) in the season-I, and within 15 DAF in the season-II produced higher seed yields. Seed yield was strongly correlated with early higher flower production (r = 0.84**, 0.88** and 0.87**, 0.89** for 10 and 15 DAF in season-I and -II, respectively) (Tables 1-4). Genotypes E_4I 901, E_4I 913, BMX 942-8, BINAmung2 and BARImung2 that produced increased number of flowers plant^{-1} within 10 DAF in season-I (range 17.0-34.0) and within 15 DAF in season-II (range 23.8-40.9) showed higher seed yields (range 3.76-6.50 g plant^{-1}). In contrast, the genotypes MB 290, MB 300, VC 3960, BINAmung5 and BARImung5 produced fewer flowers within the above mentioned time period (range 11.2-26.0 flowers plant^{-1} in season-I and 17.5-26.8 flowers plant^{-1} in season-II) and also produced lower seed yield (range 2.07-4.25 g plant^{-1}). Likewise, genotypes with higher total number of flowers during its lifetime (range 30.4-63.3 flowers plant^{-1}); produced higher seed yields (Tables 1-4).

Flowering pattern and synchrony in pod maturity

Genotypes which produced maximum flowers (>80% of the total) within 10 days from commencement of flowering in season-I and within 15 days in season-II, and ceased flowering within 15 DAF in season-I and within 20 DAF in season-II showed synchrony in pod ripening (Tables 1-4). The environment significantly influenced flowering pattern as well as degree of synchrony in pod maturity. In general, mungbean genotypes produced more synchronous flowering in season-I rather than season-II. In both seasons, the genotypes MB 300, MB 290, VC 3960, BINAmung5 and BARImung5 produced maximum number of flowers (range 82.4-100% of the total) within 10 and 15 days after commencement of flowering in season-I and II, respectively. These five genotypes ceased flowering within 10 days in season-I and within 15 days in season-II and showed synchrony in pod maturity, but produced lower yield due to production of fewer opened flowers. Furthermore, BARImung2 showed synchrony in pod maturity in season-II, due to production of maximum flowers within 15 DAF. In contrast, E_4I 901, E_4I 913, BARImung2 (in season-I), BINAmung2, BARImung4 and MBX 942-8 showed asynchrony in pod maturity although they produced higher seed yield in first harvest (average 3.97 g plant^{-1}). This was due to production of higher number of opened flowers within 10-15 DAF compared to synchronous low yielding ones (average 3.34 g plant^{-1}). These results indicate that in general, low yielding genotypes of mungbean have shorter flowering duration (range 10-20 days) with synchrony in pod maturity than those of high yielding ones (range 20-30 days). The trials over locations also demonstrated similar results for high/low yields versus asynchrony/synchrony in pod maturity with few exceptions (Table 5).

Pod maturity behavior

The results from experiment six showed that branches started flowering 7 days after main stem flowering in high yielding genotypes, while in low yielding genotype, branches began flowering 5-6 days after main stem flowering (Table 6). Additionally, in high yielding genotype, branches contributed higher number of total flowers ($\geq$ 50%) than in low yielding genotype (22-30%). Branches of high yielding genotype reached the peak flowering at 10-15 days after main stem flowering started. This indicates flowering and pod growth and development occurs simultaneously in high yielding genotypes and may explain the asynchrony in pod maturity. In contrast, peak flowering in low yielding genotype occurred at the same time in both main stem and branches. This might have facilitated synchronous flowering and pod maturity in low yielding genotypes.

Discussion

Temperature is a major environmental factor that determines growth and reproductive behavior in mungbean. The vegetative, flowering and grain filling durations in mungbean shortened in higher air temperatures (Begum et al., 1998; Roknuzzaman et al., 2007). Mondal (2007) also observed that flowering duration of mungbean was shorter in summer than in winter. In the present study, air temperature was higher in season-I (range 19.4-33.3 ^{0}C, average 27.4 ^{0}C) compared to season-II (range 15.0-31.4 ^{0}C, average 22.9 ^{0}C), which explains the shorter flowering duration in season-I (Table 7). The genotypes, which produced higher number of flowers at early flowering, produced higher number of pods as well as seed yields. These results are in agreement with the findings of Mondal et al. (2009). It was reported that mungbean genotypes with higher number of flowers within 10-15 DAF produced higher yields. Thus, higher yields in cultivars could be achieved if an increase in the rate of flower production is obtained within 10-15 DAF. This observation was also supported by the results of Young-Keun et al. (2002) and Mondal et al. (2009). Furthermore, it is well conceived that genotypes which produce more flowers within a shorter period of time, particularly at early reproductive stages, will allow for development of more sink strength (Munier-Jolain et al., 1993; Fakir, 1997; Biswas et al., 2005). The assimilate sink strength of the earlier-formed pods will be greater than the later-formed ones (Kuroda et al., 1998; Kokubun et al., 2001; Begum et al., 2007; Mondal, 2007), which helps in producing a high rate of pod set, thereby giving higher yields. This would explain the higher pod numbers and seed yields associated with the higher rates of flower production within 10-15 DAF. In general, high yielding genotypes show asynchrony in pod maturity due to longer flowering durations of 20-30 days. Flowering and pod growth development occur

Table 3. Flowering behavior and seed yield of mungbean genotypes (Expt 3; season-I, 2007; Mymensingh)

Genotypes/ cultivars	Opened flowers produced at 5 days interval							Opened flowers/ plant (no.)	Flowering duration (days)	Seed yield/ plant (g)	Seed yield at first harvest (g/plant)	Degree of synchrony in pod ripening
	1-5 DAF	6-10 DAF	Cumulative flowers till 10 DAF (no.)	Flowers of the total till 10 DAF (%)	11-15 DAF	16-20 DAF	21-25 DAF					
E_4I 901 ††	4.66 de	17.8 a	24.5 a	82.7 c	2.50 de	2.2 b	0	27.2 b	16 b	5.42 b	4.83 a	Partial synchrony
E_4I 913 ††	5.80 cd	15.2 b	21.0 b	71.9 e	5.80 c	2.4 b	0	29.2 b	18 a	5.52 ab	4.17 b	Asynchrony
MB 290 †	3.16 ef	8.50 d	12.7 e	77.0 d	3.50 d	0	0	15.2 de	13 c	3.40 de	2.91 e	Partial synchrony
MB 300 †	2.66 f	7.83 de	12.5 e	78.0 d	3.00 de	0	0	13.5 e	11 cd	3.50 de	3.14 de	Partial synchrony
BMX 942-8 ††	9.70 ab	14.0 b	23.7 a	66.2 f	6.70 b	4.0 a	0	35.8 a	18 a	6.01 a	4.36 ab	Asynchrony
VC 3960 †	11.2 a	5.40 e	16.6 c	100 a	0	0	0	16.6 d	10 d	3.05 e	3.05 e	Synchrony
BINAmung2 ††	4.50 d	13.8 b	18.3 c	55.0 g	10.0 a	5.0 a	0	33.3 a	19 a	5.92 a	3.70 c	Asynchrony
BINAmung5 †	4.83 d	9.33 cd	14.2 d	78.0 d	4.00 c	0	0	18.2 d	13 c	4.40 c	3.87 bc	Partial synchrony
BARI mung2 ††	2.66 f	14.3 b	17.0 c	63.0 f	7.00 b	3.0 b	0	27.0 b	19 a	5.11 b	3.61 cd	Asynchrony
BARImung3 ††	6.20 c	6.80 e	13.0 de	72.2 e	3.00 d	2.0 b	0	18.0 d	16 b	3.80 d	3.17 de	Asynchrony
BARImung4 ††	11.2 a	11.2 c	22.2 b	89.6 b	1.00 e	1.2 c	0	25.0 c	17 ab	4.70 b	4.42 ab	Synchrony
BARImung5 †	3.50 e	7.66 de	11.2 e	83.0 c	2.33 e	0	0	13.5 e	11 cd	3.45 de	3.22 de	Synchrony
Range	2.66-11.2	7.66-17.8	11.2-24.5	55.0-100	0.0-10.0	0.0-5.0	---	13.5-35.8	11-19	3.45-6.01	2.91-4.83	
CV (%)	11.2	8.99	10.0	7.23	11.7	12.3	---	14.1	15.6	11.4	7.52	
r (n = 36)	---	---	0.88**	---	---	---	---	0.76**	0.62**	---	---	

Means within columns with the same letters are not significantly different (DMRT; p<0.05), DAF = Days after flowering start; †: Low yielding genotypes; ††: High yielding genotypes; r = Phenotypic correlation coefficient with seed yield; Synchrony: > 90% pod matured; Partial synchrony: 80-90% pod matured and Asynchrony: < 80% pod matured at 1st harvest.

Table 4. Flowering behavior and seed yield of mungbean genotypes (Expt 4; season-II, 2007; Mymensingh)

Genotypes/ cultivars	Opened flowers produced at 5 days interval								Opened flowers/ plant (no.)	Flowering duration (days)	Seed yield/ plant (g)	Seed yield at first harvest (g/ plant)	Degree of synchrony in pod ripening
	1-5 DAF	6-10 DAF	11-15 DAF	Cumulative flowers till 15 DAF (no.)	Flowers of the total till 15 DAF (%)	16-20 DAF	21-25 DAF	26-30 DAF					
E_4I 901 ††	3.30 d	10.3 bc	15.0 b	28.6 bc	76.1 d	4.0 cd	3.5 b	1.3 b	37.6 b	30 a	5.60 ab	4.47 b	Asynchrony
E_4I 913 ††	3.50 d	7.50 d	12.8 c	23.8 d	66.3 e	6.3 ab	3.5 b	2.3 ab	35.9 b	30 a	5.43 ab	3.77 cd	Asynchrony
MB 290 †	7.80 b	12.0 b	7.00 d	26.8 cd	91.5 b	2.5 e	0	0	29.3 c	16 d	4.25 c	3.92 c	Synchrony
MB 300 †	5.50 c	10.0 bc	5.00 e	20.5 ef	100 a	0	0	0	20.5 e	12 e	3.89 cd	3.89 c	Synchrony
BMX 942-8 ††	6.30 c	10.3 bc	15.3 b	31.9 b	85.5 c	3.7 d	1.7 c	0	37.3 b	27 b	5.65 ab	5.00 a	Synchrony
VC 3960 †	6.30 c	6.70 d	4.50 e	17.5 f	86.2 c	2.5 e	0	0	20.3 e	17 d	3.27 d	2.90 e	Synchrony
BINAmung2 ††	4.70 d	16.7 a	19.5 a	40.9 a	77.2 d	7.5 a	2.0 c	3.0 a	53.4 a	30 a	6.10 a	5.10 a	Asynchrony
BINAmung5 †	8.00 b	15.0 a	7.20 d	30.3 b	83.0 c	5.2 bc	1.0 d	0	36.4 b	20 c	5.48 ab	4.82 ab	Partial synchrony
BARI mung2 ††	6.50 c	7.00 d	6.20 d	19.7 f	83.1 c	4.0 cd	0	0	23.7 d	18 d	3.55 d	3.00 e	Synchrony
BARImung3 ††	10.3 a	10.0 bc	7.90 d	28.2 bc	79.7 d	6.2 ab	1.0 d	0	35.4 b	21 c	5.33 b	4.52 b	Partial synchrony
BARImung4 ††	6.00 c	10.5 bc	6.50 d	23.8 de	59.9 f	7.2 a	5.2 a	3.0 a	38.4 b	30 a	5.17 b	3.46 d	Asynchrony
BARImung5 †	7.00 bc	9.50 c	5.80 de	22.3 e	100 a	0	0	0	22.3 de	12 e	3.71 cd	3.71 cd	Synchrony
Range	3.3-10.3	6.7-16.7	4.5-19.5	17.5-40.9	59.9-100	0.0-7.5	0.0-5.2	0.0-3.0	20.3-53.4	12-30	3.27-6.10	2.90-5.10	
CV (%)	13.1	11.1	12.9	10.5	8.82	18.0	16.5	14.5	9.94	12.9	9.62	9.20	
r (n = 36)	---	---	---	0.89**	---	---	---	---	0.93**	0.82**	---	---	

Means within columns with the same letters are not significantly different (DMRT; p<0.05), DAF = Days after flowering start; †: Low yielding genotypes; ††: High yielding genotypes; r = Phenotypic correlation coefficient with seed yield; Synchrony: > 90% pod matured; Partial synchrony: 80-90% pod matured and Asynchrony: < 80% pod matured at 1st harvest.

Table 5. Seed yield and degree of synchrony of pod ripening among genotypes (Expt 5; conducted at three locations; season-I, 2008)

Genotypes/ cultivars	Average seed yield (kg/ha)	Degree of synchrony in pod maturity over three locations at 1st harvest		
		Rangpur	Magura	Ishurdi
E_4I 901 ††	913	Partial synchrony	Synchrony	Partial synchrony
E_4I 913 ††	988	Asynchrony	Asynchrony	Partial synchrony
MB 290 †	611	Partial synchrony	Synchrony	Partial synchrony
MB 300 †	560	Synchrony	Synchrony	Synchrony
BMX 942-8 ††	920	Asynchrony	Partial synchrony	Partial synchrony
VC 3960 †	638	Partial synchrony	Synchrony	Synchrony
BINAmung2 ††	848	Asynchrony	Asynchrony	Asynchrony
BINAmung5 †	684	Asynchrony	Partial synchrony	Synchrony
BARI mung2 ††	863	Asynchrony	Asynchrony	Asynchrony
BARImung3 ††	800	Partial synchrony	Partial synchrony	Synchrony
BARImung4 ††	858	Asynchrony	Partial synchrony	Asynchrony
BARImung5 †	660	Partial synchrony	Synchrony	Synchrony

Synchrony: > 90% pod mature; Partial synchrony: 80-90% pod matured; Asynchrony: < 80% pod matured at 1st harvest;
†: Low yielding genotypes; ††: High yielding genotypes.

simultaneously in high yielding genotypes. Early set pods matured at 14-18 days after anthesis (Mondal, 2007), while later setting pods (>10 days after commencement of flowering) were still in the growth and developmental stage. This behavior might have led to asynchrony in pod maturity in high yielding genotypes in this study. On the other hand, in low yielding genotypes, most of the pods set within 10-15 days of flowering started, resulting in synchronous pod growth and development as well as synchrony in pod maturity.

Materials and methods

Planting materials and experimental design

The first two experiments were conducted at Mymensingh, Bangladesh (24.75^0 N latitude and 90.50^0 E longitude) with six advanced lines of mungbean and six common mungbean cultivars during the season-I (February-May) and season-II (September-December) in 2006. The experiments were repeated in 2007 at the same location and were designated as third and fourth experiments. The name of the genotypes is presented in Table 1. The treatments were arranged in a randomized complete block design in three replicates. The unit plot size was 2 × 2 m with a plant spacing of 30 cm between rows and 10 cm within rows. For confirmation of four previous experimental results of pod maturity synchronization, a fifth experiment was conducted over three locations [Rangpur (25.7^0 E 89.3^0 N), Ishurdi (24.1^0 E 89.0^0 N) and Magura (25.5^0 E 89.5^0 N)] during the season-I in 2008. A sixth experiment was conducted during the season-I of 2008 and 2009 to assess the possible reasons of asynchrony/synchrony in pod maturity by study of flowering pattern on the main stem and branches of high and low yielding genotypes. The sixth experiment was conducted in pots, containing 10 kg soil with one plant per pot, and arranged in a completely randomized design with five replications.

Crop establishment and cultural practices

Seeds were sown between 20-22nd February in 2006, 2007 and 2008 for the season-I, and between 14-22nd September in 2006 and 2007 for the season-II. The same cultural practices were used in both seasons and years. Fertilizers were applied in the form of urea, triple superphosphate, muriate of potash and gypsum at 20, 25, 30 and 5 kg ha^{-1} of nitrogen, phosphorus, potassium and sulphur, respectively (BARC, 2005). All fertilizers were applied as a basal dose during final land preparation. Watering, weeding and other cultural operations were carried out when necessary to ensure normal growth.

Parameters measured

Five plants from each replication were randomly tagged for daily count of opened flowers. Flower counts began from the date of opening of the first flower and were continued daily until flowering ceased. Total flower production at 5-day intervals and duration were calculated from the data. The yield and yield attributes were recorded from the tagged plants. In the fifth experiment, only yields and percentage of mature pods to total pods were recorded. At first harvest, three scales of pod ripening based on percentage of mature pods were developed: (i) synchrony: with >90% mature pods; (ii) partial synchrony: with 80-90% mature pods and (iii) asynchrony: with <80% mature pods. In the sixth experiment, flowers were daily counted from the date of opening of first flower, separately on the main stem and branches, then continued until flowering ceased. Flowering pattern or flower production at 3-day durations were calculated from the data.

Statistical analysis

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

Conclusion

To achieve synchronous pod maturity with high yield in mungbean, plants should be uniculm or have fewer branches and the capacity to produce high number of flowers within 10-15 days after commencement flowering.

Table 6. Flowering behavior on main stem and branches of two mungbean genotypes (Expt 6; conducted in pots; season-I, 2008 and 2009)

Genotypes	Commencement of flowering (days after sowing)	Opened flowers produced at 3 days interval (no.)						Opened flowers/ plant (no.)	% of total flowers
		Days after flowering start							
		1-3	4-6	7-9	10-12	13-15	16-18		
Season-I, 2008									
BMX 942-8									
Mainstem	32	4.17	9.66	13.2	8.2	1.17	0	36.4	50.1
Branches †	39	0	0	9.0	12.8	10.0	3.4	36.2	49.9
LSD $_{(0.05)}$	3.34			1.84	2.01	1.50		3.22	3.29
VC 3960									
Mainstem	30	9.0	13.4	3.80	0.40	0	0	26.6	70.4
Branches ††	35	0	3.8	6.40	1.00	0	0	11.2	29.6
LSD $_{(0.05)}$	2.74		1.44	1.02	0.56			3.67	5.21
Season-I, 2009									
BMX 942-8									
Mainstem	33	9.50	10.83	9.33	7.66	2.17	0	39.5	47.1
Branches †	39	0	0	9.50	11.3	20.2	3.3	44.3	52.9
LSD $_{(0.05)}$	2.10			1.18	1.90	2.11		3.33	2.54
VC 3960									
Mainstem	31	7.50	14.2	8.40	2.40	0	0	32.5	77.9
Branches ††	36	0	5.0	3.22	1.00	0	0	9.22	22.1
LSD $_{(0.05)}$	1.42		1.47	1.12	0.80			2.50	3.88

† : No. of branches plant^{-1} ranged was 3-4; †† : No. of branch plant^{-1} ranged was 0-1

Table 7. Mean monthly air temperatures at BAU farm, Mymensingh, Bangladesh (Seasons-I & II; 2006, 2007)

Months	Season-I, 2006 and 2007			Months	Season-II, 2006 and 2007		
	Maximum	Minimum	Average		Maximum	Minimum	Average
March				September			
01-07	31.1	19.4	25.3	01-07	31.4	25.8	28.6
08-15	30.4	20.9	25.6	08-15	30.0	26.2	28.1
16-23	30.4	22.7	26.6	16-22	31.0	25.9	28.4
24-31	30.6	22.9	26.7	23-30	30.5	25.1	27.8
April				October			
01-07	31.3	23.1	27.2	01-07	29.8	22.7	26.2
08-15	31.1	22.4	26.7	08-15	29.4	20.8	25.1
16-22	32.1	23.6	27.8	16-23	30.6	20.5	25.5
23-30	32.3	23.9	28.1	24-31	29.9	19.5	24.7
May				November			
01-07	33.3	23.4	28.3	01-07	29.4	18.3	23.9
08-15	33.2	24.8	29.0	08-15	28.9	16.7	22.8
16-23	31.7	24.5	28.1	16-22	28.2	15.4	21.8
24-31	31.8	24.4	28.1	23-30	28.2	15.0	21.6

Source: Bangladesh Meteorological Department, Mymensingh, Bangladesh

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