

Deflowering effect on vasculature and yield attributes in raceme of mungbean [*Vigna radiata* (L.) Wilczek]

M. Monjurul Alam Mondal¹, Md. Solaiman Ali Fakir², A.K.M.Azad-ud-doula Prodhana²,
Mohd. Razi Ismail³ and M. Ashrafuzzaman^{3*}

¹Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

²Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh

³Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

*Corresponding author: drashraf2007@yahoo.com

Abstract

A raceme of mungbean plant generally bears 32-60 flowers but only 3-8 matured pods are borne with the majority of flowers abscise. The experiments were conducted to investigate deflowering effect on podset probability and vasculature in the proximal and distal positions of raceme in mungbean plant. Four deflowering treatments were applied: control (No flower removal), all opened flowers were continuously removed from proximal 1-10, 1-20 and 1-30 nodes of the racemes. The anatomical investigation was made at two positions, basal and distal parts of the rachis of each treatment. Results indicated that mungbean plant compensated for yield loss up to 10-nodes flower removal following a significant yield reduction on further deflowering in the raceme. Results revealed that rachis of the control raceme tapers from proximal to distal end. In contrast, the rachis becomes thicker at distal end of the deflowered rachis than in the distal end of control rachis. It indicates that tissues particularly vascular bundles were poorly developed in the distal end of control raceme but it was well developed at the corresponding position under deflowered condition as indicated by anatomical study. Removal of proximal flowers from 10-30 nodes, however, allowed pod development in the distal end of the raceme, which would otherwise have abscised. Such podset capacity in the distal end of the rachis was possibly due to development of adequate xylem and phloem tissues in the distal part of the deflowered rachis, like a control rachis in the proximal position. The presence of pods in the proximal end on racemes interfere the development of distal pods and increased the abscission probability of reproductive structures borne at distal position in mungbean.

Keywords: intraraceme deflowering effect, xylem and phloem, mungbean yield.

Abbreviation: DAS-days after sowing.

Introduction

In legumes, within raceme, podset probability varied with nodal position and generally decreased with increasing nodal position (Spollen et al., 1986a; Wiebold and Panciera, 1990; Saitoh et al., 1998; Kokubun et al., 2001). Podset probability in raceme was 71, 70, 54, 23 and 8% at node-1, 2, 3, 4 and 5, respectively in mungbean (Fakir et al., 2011). After node-5, no pod was set until 2nd flush started and after physiological maturity of pods in 1st flush, pod setting begins at the distal end (11-15 nodes) of the same raceme which is termed as second flush. Brun and Betts (1984) have shown that podset is determined at anthesis as detected by a decrease in relative accumulation capacity for photosynthates of flowers destined to abscise. Proximal flowers and fruits thus influence distal podset as early as anthesis. It is noted that removal of earlier-formed flowers and pods from proximal 4-5 nodes allow podset at the distal 5-6 nodes which otherwise could have abscised in soybean (Dybing et al., 1986). Further, rachis of the normal raceme in grain legumes tapers from proximal to distal end but when deflowered in proximal part of the raceme, the rachis becomes thicker at distal end than normal one (Bari and Prodhana, 2001; Begum et al., 2007; Mondal et al., 2011). It indicates that tissues particularly vascular bundles are poorly developed in the distal end of normal raceme but it is well developed at the corresponding position under deflowered condition (Bari and Prodhana, 2001). However, 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 (Begum et al., 2007; Fakir et al., 2009; Hoque et al., 2006; Wiebold and Panciera, 1990). The removal of earlier formed flowers/pods (proximal) result in compensatory pod setting from later formed (distal) flowers that would have otherwise abscised in soybean (Wiebold, 1990; Kokubun and Honda, 2000) and in pigeonpea (Begum et al., 2007; Fakir and Islam, 2007; Khattak et al, 2002; Tayo, 1980). These studies suggest that a mechanism of auto regulation of sink development may exist and that flower abscission may likely be a candidate. No such detailed investigation has been carried out in mungbean. The objectives of this research were to measure phloem and xylem areas within the rachis of developing mungbean raceme, to determine if the size of the vascular tissues areas were associated with flower abscission and pod development, and to determine the effect of removal of proximal pods on vascular tissue areas in distal regions of the racemes.

Results

Deflowering and yield components in raceme

In the raceme, flowering begins from the basal nodes and proceeds acropetally and each raceme takes about a week for flowering is called first flush (1-5 nodes)(Fig. 1). Following

Table 1. Effect of number of deflowering nodes on yield attributes in a raceme[†] of two mungbean genotypes during Kharif-I season of 2009 and 2010

Treatment	Pods raceme ⁻¹ (no.)	Seeds pod ⁻¹ (no.)	Single pod weight (mg)	100-seed weight (g)	Seed yield raceme ⁻¹ (g)
Year					
2009	2.93 b	10.1 a	631.6 a	4.52 a	1.34 a
2010	3.37 a	9.37 b	443.7 b	3.82 b	1.21 b
Genotype (G)					
BMX 942-8 (G ₁)	3.95 a	9.76 ns	456.7 b	3.19 b	1.27 ns
MB 300 (G ₂)	2.35 b	9.73	618.5 a	5.15 a	1.22
Deflowered (D) node (no.)					
0 (control)	3.55 a	10.6 a	611.7 a	4.40 a	1.56 a
10	3.48 a	10.5 a	605.5 a	4.44 a	1.53 a
20	3.19 b	10.2 a	527.3 b	4.24 b	1.27 b
30	2.38 c	7.65 b	406.0 c	3.70 c	0.63 c
G × D node					
G ₁ × 0	4.50 a	10.7 a	510.3 c	3.41 c	1.64 a
G ₁ × 10	4.30 ab	10.5 a	522.0 c	3.42 c	1.54 ab
G ₁ × 20	3.98 b	10.2 a	446.7 d	3.08 d	1.25 c
G ₁ × 30	3.00 c	7.65 b	347.8 e	2.85 d	0.65 d
G ₂ × 0	2.60 d	10.5 a	713.0 a	5.39 a	1.47 b
G ₂ × 10	2.65 cd	10.5 a	709.0 a	5.47 a	1.52 ab
G ₂ × 20	2.40 d	10.3 a	608.0 b	5.20 a	1.29 c
G ₂ × 30	1.75 e	7.65 b	464.2 cd	4.55 b	0.61 d
CV (%)	9.87	5.08	4.70	7.03	7.33

In a column, within a particular treatment, the figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; †: 50 racemes/replication sampled; ns: Not significant.

first flush, further flowering does not occur until completion of pod growth of first flush within 14-16 days after flowering start. After physiological maturity of pods in first flush, flower opening begins again at the distal end (13-15 nodes) of the same raceme, which is termed as second flush and the duration of flowering in the second flush is about 2-4 days. In control and 10-nodes deflowered raceme, second flush was observed but it was absent in 20 and 30-nodes deflowered raceme (Fig. 1). However, removal of flowers from the raceme had significant effect on number of pods raceme⁻¹, seeds pod⁻¹, single pod and 100-seed weight, and seed yield raceme⁻¹ (Table 1). Number of pods raceme⁻¹ was higher in 2010 than in 2009. In contrast, seeds pod⁻¹, single pod and 100-seed weight and seed yield were greater in 2009 than in 2010. High yielding genotype (BMX 942-8) had greater number of pods raceme⁻¹ than in low yielding one (MB 300) while the higher single pod and 100-seed weight was observed in the latter than in the former genotype. Results further revealed that increasing deflowered nodes of the raceme reduced the yield attributes like pods raceme⁻¹, seeds pod⁻¹ and 100-seed weight resulting decreased seed yield (Table 1). The yield attributes were greater in intact raceme and 10-node deflowered raceme than in the others. Further, number of pods raceme⁻¹, single pod weight, 100-seed weight and seed yield were not significantly affected up to 10 nodes deflowering and beyond 10 nodes deflowering, the yield components and yield was decreased significantly compared to control raceme. On the other hand, removal of proximal flowers did not affect the number of seeds pod⁻¹ up to 20 nodes followed by significant reduction. Interaction effects between genotype and deflowered node on pods raceme⁻¹, seeds pod⁻¹, single pod weight, 100-seed weight and seed yield raceme⁻¹ were also significant (Table 1). Number of pods raceme⁻¹ was decreased markedly beyond 10-nodes deflowering in high yielding genotype (BMX 942-8) and beyond 20-nodes flowering in low yielding genotype (MB 300). This result indicates that compensatory capacity

of flower loss was higher in low yielding genotype than in the high yielding one.

Morphology and anatomy of rachis in raceme

Results showed that rachis diameter of mungbean genotypes gradually and markedly decreased towards the distal end of the raceme in control plant irrespective of season and genotype (Table 2). On the other hand, rachis diameter was also decreased but less markedly from proximal to the distal end in deflowered raceme. For example, the rachis diameter of distal position in the intact raceme was 0.17 cm whereas it was 0.19, 0.26 and 0.24 cm for 10, 20 and 30-nodes deflowered raceme, respectively compared to corresponding distance of intact raceme of BMX 942-8 in 2010. The radial length of xylem, phloem and vascular tissue at proximal and distal end in the control and deflowered raceme is presented in the Table 3. There was a significant effect of nodal position on phloem and xylem radial length. In either case, the radial length of phloem and xylem was decreased from proximal end to distal end of the control raceme. Similarly, the vascular tissues in the upper part of rachis were fewer and poorly developed compared to that of the basal part in the control raceme (Fig. 2). The removal of proximal flowers affected the radial dimension of xylem and phloem tissues in the distal part of the deflowered rachis (Table 3). The radial dimension of xylem, phloem and vascular tissues at distal parts of the deflowered rachis was increased compared to the corresponding part to the normal rachis in both the genotypes (Table 3). For example, in BMX 942-8, in distal portion, radial lengths of xylem and phloem in control raceme were 0.024 and 0.056 mm, respectively whereas they were 0.116 and 0.090 mm, respectively in 20-nodes deflowered raceme indicating the vascular tissue becomes more developed under deflowered condition. From the Fig. 2, it was observed that the vascular tissue of distal part of the control raceme was poorly developed whereas in the corresponding distance of the deflowered raceme, the vascular tissue was well

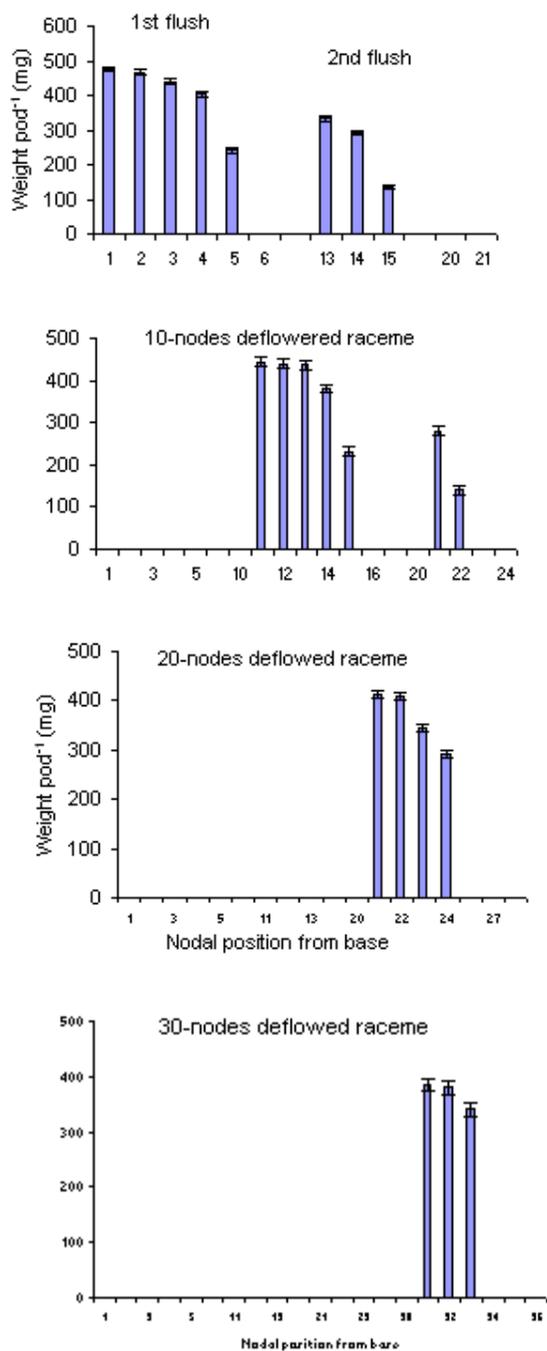


Fig 1. Effect of deflowering on podset and single pod weight at different nodal position within raceme of BMX 942-8*. Small bars on the top of the valus indicate standard deviation (*, Similar results were also observed incase of MB 300).

developed possibly for the support, growth and development of the later-formed flowers and pods in the high yielding genotype, BMX 942-8. Similar phenomenon was also observed in case of a low yielding genotype, MB 300, under deflowered condition (Data not shown).

Discussion

The yield attributes and yield were decreased with increasing nodal position of the raceme due to rachis tapering from

proximal to distal end. The morphological and anatomical observations showed that the vascular tissues in the upper part of rachis were fewer and poorly developed compared to that of the basal part in the control raceme. These results suggested that due to fewer phloem in the distal part of the raceme, possibly providing inadequate amount of photosynthate to the apex, perhaps resulting greater abscission of flowers in the distal end of the rachis. Similar results were also found in soybean (Wiebold and Panciera, 1990) and in lignosus bean (*Dipogon lignosus* L.) (Bari and Prodhan, 2001). However, the radial dimension of xylem, phloem and vascular tissues at distal parts of the deflowered rachis was increased compared to the corresponding part of the normal rachis indicating the vascular tissue becomes more developed under deflowered condition. It seems that removal of proximal flowers enhances the development of mechanical and conducting tissue in the raceme for the support, growth and development of the later-formed pods in the distal part of the rachis. In the distal position of the raceme, pod needs mechanical support, which is related to the economic yield (Wiebold and Panciera, 1990). Therefore, the mechanical tissue becomes more developed in the upper part of the deflowered rachis. In the intact raceme, if proximal pods are present then vascular bundles are poorly developed in the upper part of the rachis, which hampering the growth of upper flowers in the rachis possibly due to inadequate supply of assimilates to the later-formed flowers/pods. This may have caused more flowers shedding at the distal end of the raceme. Spollen et al. (1986b) suggested that distal pods undergo a period of adjustment after proximal pods were removed. In the present experiment, removal of proximal flowers greatly increased radial length of vascular tissues in the distal part of the raceme and thus possibly may have supplied more assimilates to the distal pods, which otherwise indicating translocation barrier was present for the later-formed pods for growth and development.

In conclusion, the presence or absence of the proximal pods affects development of distal pods and abscission probability. Proximal pods also influence translocation of photosynthates into distal pods which determine whether pod set or not in the distal part of a raceme.

Materials and methods

Site description

Two experiments were carried out at the Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh (24.8° N 90.5° E), Bangladesh, during Kharif-I season (February-May) of 2009 and 2010. The soil of the experimental area of BAU is silty loam having a total nitrogen 0.06%, organic matter 1.15%, available phosphorus 18.5 ppm, exchangeable potassium 0.28 meq%, sulphur 18 ppm and pH 6.8.

Planting materials and experimental design

Two genotypes (One high and one low yielding) were considered in the study. The genotypes were BMX 942-8 (high yielding) and MB 300 (low yielding). Seeds were sown on 22 and 18 February for the year 2009 and 2010, respectively. The row to row distance was 30 cm and plant to plant distance was 10 cm. The experimental design was split plot with three replications i.e. genotype was assigned in the main-plot and four deflowering were in the sub-plot. The sub-plot unit size was 1.5 m × 1.5 m.

Table 2. Effect of deflowering on rachis diameter at two nodal positions in raceme of two mungbean genotypes in Kharif-I seasons of 2009 and 2010

Number of deflowered nodes	Rachis diameter (cm)							
	BMX 942-8 (high yielding)				MB 300 (low yielding)			
	2009		2010		2009		2010	
	Proximal	Distal [†]	Proximal	Distal [†]	Proximal	Distal [†]	Proximal	Distal [†]
0 (control)	0.31	0.21	0.30	0.17	0.34	0.21	0.41	0.29
10	0.30	0.24	0.31	0.19	0.34	0.30	0.40	0.29
20	0.30	0.28	0.30	0.26	0.33	0.31	0.40	0.36
30	0.32	0.26	0.30	0.24	0.34	0.30	0.41	0.38
LSD (0.05)	0.029		0.032		0.025		0.038	

[†]: Corresponding distance of control raceme in case of deflowered raceme

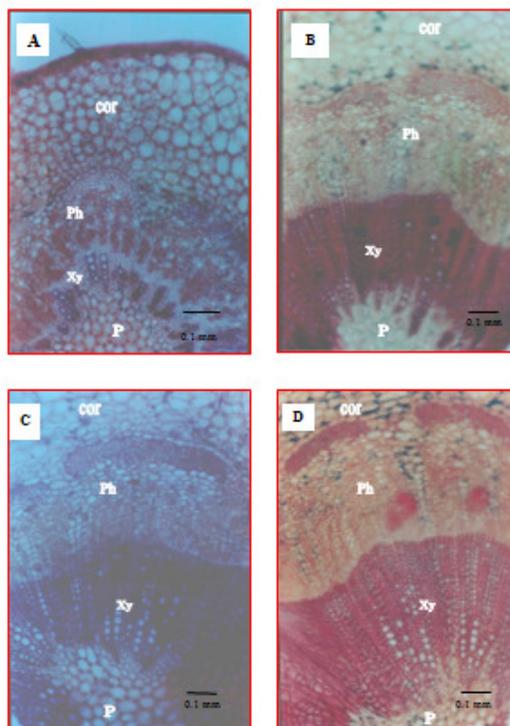


Fig 2. T.S. of distal part of a rachis in BMX 942-8 under (A) normal (control, 1.5 cm distance from base), (B) 10 nodes (1.5 cm distance), (C) 20 nodes (3.4 cm distance) and (D) 30 nodes (5.0 cm distance) deflowered raceme. Legend shows cortex (cor), phloem (Ph), xylem (Xy) and pith (P) × 180

Management practices

Seeds were sown continuously in line and two weeks after germination, the plants were thinned to a density of 30 plants/m². Cultural practices were the same in both the seasons. Uniform plant stands (30 plants m⁻²) were maintained in both the seasons. Urea, triple superphosphate, muriate of potash and gypsum were used as a source of nitrogen, phosphorus, potassium and sulphur at the rate of 40, 120, 80 and 30 kg ha⁻¹, respectively at the time of final land preparation. First weeding was done followed by thinning at about 21 days after sowing (DAS) and second weeding was done at 40 DAS. A single irrigation was given at 25 DAS at both the seasons. Insecticide (Ripcord 50 EC at 0.025%) was sprayed twice (50 and 60 DAS) at flowering and fruiting stage to control shoot and fruit borer.

Treatments

The four deflowering treatments were employed at the beginning of opening of flowering phase (40 and 35 DAS for 2009 and 2010, respectively). For deflowering treatments in the raceme, 50 healthy and unaffected racemes were randomly selected in each replication of each treatment. The four deflowering treatments in the raceme were: control (No flower removal), all opened flowers were removed continuously from proximal 1-10, 1-20 and 1-30 nodes of the racemes. The anatomical investigations i.e. radial length of xylem, phloem and vascular tissues at two positions, proximal and distal ends of the rachis were studied of each of the four treatments. Two different types of rachis were hand sectioned. One was normal (untreated or control) with 4-6 nodes bore 3-5 pods at proximal end and pod developed

Table 3. The radial length of vascular tissue, xylem and phloem both at proximal and distal end of pod bearing rachis in two mungbean genotypes in 2010

Number of deflowered nodes	Genotype: BMX 942-8 (high yielding)					
	Proximal end (mm) [†]			Distal end (mm) [†]		
	Xylem	Phloem	Vascular tissue	Xylem	Phloem	Vascular tissue
0 (Control)	0.111	0.087	0.198	0.024	0.056	0.080
10	0.115	0.089	0.204	0.032	0.060	0.092
20	0.110	0.086	0.196	0.116	0.090	0.206
30	0.112	0.090	0.202	0.100	0.084	0.184
LSD (0.05)	0.045		0.012	0.008		0.014
Number of deflowered nodes	Genotype: MB 300 (low yielding)					
	Proximal (mm) [†]			Distal (mm) [†]		
	Xylem	Phloem	Vascular tissue	Xylem	Phloem	Vascular tissue
0 (Control)	0.113	0.092	0.205	0.040	0.050	0.090
10	0.114	0.090	0.204	0.036	0.055	0.091
20	0.115	0.088	0.203	0.110	0.075	0.185
30	0.115	0.090	0.205	0.109	0.070	0.179
LSD (0.05)	0.0069		0.013	0.0072		0.015

[†]: Corresponding distance of control raceme in case of deflowered raceme

naturally up to maturity. Other type was deflowered (treated) rachis where flower was removed from basal 1-10, 1-20 and 1-30 nodes and then allowed the rachis to flower and to develop pods naturally up to maturity. After ceasement of deflowering in the rachis, pods were found to be set at 11-15, 21-24 and 30-34 nodes, respectively for 1-10, 1-20 and 1-30 nodes deflowered rachis.

Parameters measured

Pods bearing raceme (both control and deflowered) at mature stage (20-30 days old) were collected. The raceme samples were collected from the upper part of the mainstem. Sample of rachis was divided into two positions, proximal (basal 1-5 nodes) and distal (top 10-30 nodes, depending on deflowering) for morphological and anatomical investigation. Normally individual raceme consisted of 16-25 nodes and flowered acropetally. In the present investigation, free hand sectioning of rachis in the two positions (proximal 1-5 nodes and distal 10-30 nodes, depending on deflowering treatments) of the raceme was followed according to Johansen (1940). Before sectioning, the length and diameter of pod bearing rachis both at proximal and distal positions was recorded using a ruler and slide calipers, respectively. Hand sectioning of fresh material was done by sharp stainless razor blades within four hours after sample collection. The sections were stained with Safranin dye and were examined under the compound microscope immediately after preparation. The radial length of vascular tissue, xylem and phloem at both proximal and distal positions of the normal and deflowered rachis was measured separately using a micrometer set at the eyepiece.

Statistical analysis

All data were analyzed statistically as per the used design following the analysis of variance (ANOVA) technique and the mean differences were adjusted with Duncan's Multiple Range Test (DMRT) using the statistical computer package

program, MSTAT-C (Russell, 1986). Microsoft Excel was used for graphical presentation.

References

- Bari SMA, Prodhan AKMA (2001) Anatomy of lignosus bean (*Dipogon lignosus* L.) IV. Rachis of inflorescence. Pakistan J Biol Sci, 4(9): 1070-1074
- Begum S, Islam MA, Prodhan AKMA (2007) Anatomy of rachis of the inflorescence in pigeon pea. Int J Bot, 3: 85-90
- Brun WA, Betts KJ (1984) Source-sink relations of abscising and non-abscising soybean flowers. Plant Physiol, 75: 187-191
- Dybing CD, Ghiasi H, Paech C (1986) Biochemical characterization of soybean ovary growth from anthesis to abscission of aborting ovaries. Plant Physiol 81:1069-1074
- Fakir MSA, Islam MN (2007) Pigeonpea production in the 'ail' of rice field: II. Effect of date of planting on flower shedding and yield. J Agrofor Environ, 1(2): 1-5.
- Fakir MSA, Bari MA, Prodhan AKMA (2009) Flower production and reproductive abscission in Lignosus bean. Bangladesh J Crop Sci, 20(1): 49-54.
- Fakir MSA, Mondal MMA, Ismail MR, Ashrafuzzaman M (2011) Flowering pattern and reproductive efficiency in mungbean. Int J Agric Biol, 13: 966-970
- Hoque MM, Hossain MA, Fakir MSA (2006). Study of flower and pod production in mungbean genotypes. Bangladesh J Crop Sci 17(2):317-323.
- Johansen DA (1940) Plant Micro technique. McGraw-Hill, New York.
- Khattak GSS, Haq MA, Ashraf M, Said Hassan (2002) Yield and yield components at various flowers flushes in mungbean (*Vigna radiata* (L.) Wilczek). Breed Sci, 52: 61-63.
- Kokubun M, Honda I (2000) Intra raceme variation in pod set probability is associated with cytokinin content in soybeans. Plant Prod Sci, 3: 354-359

- Kokubun M, Shimada S, Takahashi M (2001) Flower abortion caused by preanthesis water deficit is not attributed to impairment of pollen in soybean. *Crop Sci*, 41:1517-1521
- Mondal MMA, Fakir MSA, Ismail MR, Ashrafuzzaman M (2011) Effect of defoliation on growth, reproductive characters and yield in mungbean [*Vigna radiata* (L.) Wilczek]. *Australian J Crop Sci*, 5 (8):987-992
- Russell DF (1986) MSTAT-C computer package programme, Crop and Soil Sci Dept, Michigan State Univ, USA
- Saitoh K, Isobe S, Kuroda T (1998) Pod elongation and seed growth as influenced by nodal position on stem and raceme order in a determinate type of soybean cultivar. *Japanese J Agric Sci*, 67 (4): 325-328
- Spollen WG, Wiebold WJ, Glenn S (1986a) Intraceme competition in field grown soybean. *Agron J*, 78: 280-283
- Spollen WG, Wiebold WJ, Glenn S (1986b) Effect of altered intra raceme competition on carbon-14-labeled assimilate and abscisic acid in soybean. *Crop Sci*, 26: 1216-1219
- Tayo TO (1980) Compensatory growth and yield of pigeon pea following pod removal at different stages of reproductive growth. *J Agric Sci (Camb)*, 95: 487-491
- Wiebold JW, Panciera MT (1990) Vasculature of soybean racemes with altered intra raceme competition. *Crop Sci* 30: 1089-193
- Wiebold WJ (1990) Rescue of soybean flowers destined to abscise. *Agron J*, 82: 85-88