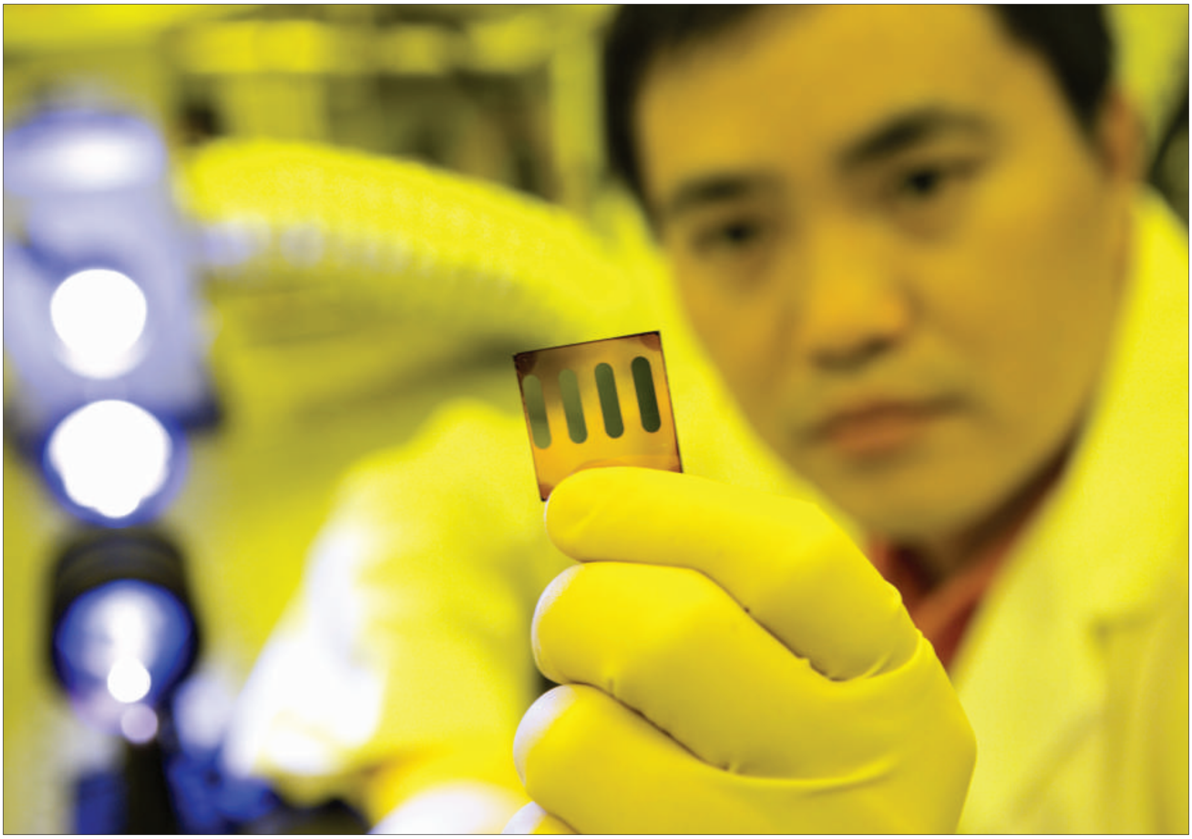

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Variation of Floral Abscission and Reproductive Efficiency in Different Cultivated Genotypes of Pigeonpea (*Cajanus cajan*)

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ABSTRACT

The present study has been undertaken to investigate the genotypic variation in flower and raceme production and floral abscission in four cultivated genotypes of pigeonpea (*Cajanus cajan*) plants. Genotypic differences in the number of flower production per plant and also in different parts of the canopy were significant. Significant variation existed in the total number of flower production/plant among the genotypes. The degree of flower production/plant is greater in ICPL-87 (1444.06) than in the SD-35 (925.66), ESD-19 (777.33) and ESD-39 (672.66). Total number of pods per plant significantly varied between the genotypes with the magnitude being again high in ICPL-87 (165.30), intermediate in SD-35 and ESD-19 (average of 111.1) and low in ESD-39 (77.80). Results revealed that the total number of reproductive unit (buds + flowers + pods that existed and abscised) varied between 1721.79 and 2753.98 among the genotypes. Total number of racemes per plant varied between 75.66 and 134.21. Percentage of abscission increased linearly with increasing time after first bud initiation and increases with the progression of nodal position. High degree of abscission in pigeonpea develops fewer pods. The abscission was greater in the secondary branch than in the primary branch. Percentage of floral abscission varied between 90 and 96 among the genotypes. It was observed that ICPL-87 is a high yielding genotype due to highest reproductive unit and lowest floral abscission and ESD-39 is a low yielding genotype. Our results suggest that, genotypic variation exists in sink (raceme and flower) production indicating increased sink production and decreased abscission may be used as selection criteria for improved yield in Short Duration (SD) pigeonpea.

Key words: Floral abscission, genotypic variation, pod yield, pigeonpea (*Cajanus cajan*), reproductive efficiency

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] or redgram is one of the most important grain legume crops in Bangladesh as well as tropics and sub-tropics. Besides Bangladesh, also India, Myanmar, Uganda, Kenya and West Indies are the major pigeonpea producing countries (Sivaramakrishnan *et al.*, 2002; Kalaimangal *et al.*, 2008; Choudhury *et al.*, 2008). It is grown in wide range of soils, from sandy to heavy soils. It is able to tolerate drought conditions during dry seasons. It cannot tolerate even light frost during any stage of its growth. It appears to be better adapted to marginal climatic conditions than any other pulse crops (Kalaimangal *et al.*, 2008; Choudhury *et al.*, 2008). The dry split seeds, which have a protein content of approximately

20-25%. Green pods are used as vegetables and fodder (Soomro *et al.*, 2001; Snapp *et al.*, 2003; Wasike *et al.*, 2005; Janboonme *et al.*, 2007). In addition, pigeonpea is a multipurpose crop, is used for fodder, soil fertility enhancement, soil erosion control and for fuel (Soomro *et al.*, 2001; Snapp *et al.*, 2003; Janboonme *et al.*, 2007) and leaves are excellent fodder as shown by Rao *et al.* (2002) in recent study. Minor uses include indigenous medicinal practices which generally involve a pain relieving effect (Snapp *et al.*, 2003). Therefore, pigeonpea is gaining popularity to the farmers of Bangladesh day by day.

Past studies in Bangladesh indicate the possibility of using pigeonpea to produce pulp for paper industry (Akhtaruzzaman *et al.*, 1986; Choudhury *et al.*, 2008). Pigeonpea is more feasible than any other possible pulses due to its special characteristics. It has high ability to tolerate drought condition, can be used as mixed crop and can be grown in unconventional lands like homesteads, roadsides, public places and borders of the crop fields (Kalaimangal *et al.*, 2008; Saxena *et al.*, 2005, 2006). However, there are barriers to wider production of pigeonpea (Mallikarjuna and Saxena, 2002; Snapp *et al.*, 2003; Mallikarjuna and Saxena, 2005; Wasike *et al.*, 2005; Choudhury *et al.*, 2008).

Yield of pigeon pea remains low due to high level of floral abscission (70-96%). It has a problem of pre-mature abscission of flowers and fruits leading to a much-reduced realization of sink potential (Sheldrake *et al.*, 1979; Sivaramakrishnan *et al.,* 2002; Mallikarjuna and Saxena, 2002; Saxena *et al.*, 2006). Therefore, the low yield in pigeonpea is due to poor pod set resulting from high flower and pod drops. Therefore, it is very necessary to compensate the high degree of floral abscission in pigeonpea and increase the pod yield to minimize the protein requirement for urban people of Bangladesh.

Surprisingly, research attention to pigeonpea remains limited (Snapp *et al.*, 2003). Recently, some attention has been given for improvement of pigeonpea in Bangladesh. For a successful improvement program it is the pre-requisite to know about the status of the plant in respect of its morphological and physiological features. Physiological bases of yield improvement in pigeonpea depend on the canopy structure, flower production and yield attributes and their interrelationships. There are few reports are available on flower and pod production, canopy structure and flowering pattern in pigeonpea (Sheldrake and Narayanan, 1979; Remanandan *et al.*, 1988; Togun and Tayo, 1990; Soomro *et al.*, 2001). Literature on the flower production, flowering pattern and levels of floral abscission is available in *Lablab purpureus* genotypes, but reports on those characters of pigeonpea grown under Bangladesh climatic conditions is very scanty (Fakir *et al.*, 1992, 2000). Moreover, physiological mechanisms of floral abscission in pigeonpea are still not yet fully understood. Therefore, this study was made to observe the raceme, bud, flower and pod production, degree and pattern of floral abscission and their interrelationships in pigeonpea genotypes under Bangladesh climatic condition.

The main purpose of this study is to select one high yielding genotype under Bangladesh climatic conditions on the basis of degree and pattern of floral abscission in pigeonpea genotypes.

MATERIALS AND METHODS

Plant materials: The experiment was carried out at the experimental field of Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh, during the period from November 2009 to May 2010. Four determinate types of cultivated pigeonpea genotypes were grown for this present investigation. The genotypes were named as SD-35, ESD-19, ESD-39 and ICPL-87 collected from the International Crop Research Institute for the Semi Arid Tropics

(ICRISAT). The field experiment was laid out in a randomized completely block design (RCBD) with three replications. Seeds of these selected pigeonpea genotypes were sown at the first week of November 2009. Five plants were randomly selected from each plot and data collected during flowering stage.

Collection of samples: Five plants were tagged for raceme and flower production from each plot. Counting of raceme in each tagged plant was registered when it produced first opened flower. It means that as soon as opened flower was observed in a raceme it was treated and counted as a raceme. Thus, counting of raceme production was continued on every alternate date for 60 days after first flowering (DAFF). Flower production was estimated by multiplying number of nodes by 2 in a raceme (Fakir *et al.*, 1998).

Estimation of floral abscission: Percentage abscission in five tagged plants/plot was estimated following the method of Fakir *et al.* (1998) as follows:

$$\%\text{Abscission} = 100 - \frac{\text{TNP}}{\text{TRU} - \text{X} - \text{Y}} \times 100$$

Where:

TNP	=	Total No. of pods set
TRU	=	Total No. of Reproductive Unit (TRU) per plant and was estimated as follows
TRU/plant	=	No. of racemes per plant×number nodes per raceme×2

The variables X and Y represent the number of flowers and buds, respectively, present at the time of abscission measurement. The number of flowers (X) and buds (Y) was subtracted from TRU since the latter form flowers and buds often abscise.

Statistical analysis: The collected data on various characteristics were compiled and analyzed statistically to find out the statistical significance of the experimental results. The means for all the harvest were calculated and the analysis of variances for all the characters were performed. The mean differences were evaluated by Duncan's New Multiple Range Test and also by significance difference test. The data of four pigeonpea genotypes were recorded, analyzed and presented in the tables.

RESULTS

Inflorescence production: The total number of inflorescence per plant was greater in short duration genotype ICPL-87 (134.21) than in ESD-19 and ESD-39 (average of 108.08) and SD-35 (75.66) (Table 1). The percent of fertile inflorescence per plant was also greater in ICPL-87 (74.21) than in SD-35 and ESD-19 (average of 66.61) and in ESD-39 (55.04) (Table 1). In ICPL-87 and ESD-19, primary branch (1^0) bore the greater number of fertile inflorescence (average of 52.71) than in SD-35 (49.03) and ESD-39 (43.04). In main stem, per cent fertile inflorescence was also significantly ($p \leq 0.01$) greater in ICPL-87 (20.78) than in SD-35 (17.39), ESD-19 (15.60) and ESD-39 (12.0) (Table 1).

Flower production: Genotypic differences in the number of flower production per plant and also in different parts of the canopy were significant ($p \leq 0.01$) (Table 2). Significant ($p \leq 0.01$) variation existed in the total number of flower production/plant among the genotypes. The degree of flower

Table 1: Inflorescence production and its distribution in different parts of canopy in four cultivated pigeonpea genotypes

			Fertile inflorescence (%)	
Genotypes	Inflorescence/plant (No.)	Total fertile inflorescence (%)	Main stem (MS)	Primary branch
ICPL-87	134.21a	74.21a	20.78a	53.43a
SD-35	75.66c	66.42b	17.39b	49.03b
ESD-19	115.24b	66.81b	15.60c	51.21a
ESD-39	100.92b	55.04 c	12.00d	43.04 c

Values with common letter(s) in a column do not differ significantly at ($p \leq 0.01$)

Table 2: Production and distribution of flowers in the main stem and branches in four cultivated pigeonpea genotypes

		No. of flowers per plant		
Genotypes	Flowers/plant (No.)	Main stem	Primary branch	Secondary branch
ICPL-87	1444.06a	264.66a	1094.04a	86.00a
		(18.32)	(75.78)	(5.88)
SD-35	925.66b	139.66b	704.00b	82.00a
		(15.08)	(76.05)	(8.85)
ESD-19	777.33c	129.33b	586.67c	61.33c
		(16.63)	(75.47)	(7.89)
ESD-39	672.66d	128.67b	477.67d	66.33b
		(19.12)	(71.01)	(9.86)

Values within parenthesis indicate the percentage of total number of flowers per plant. Values with common letter(s) in a column do not differ significantly at ($p \leq 0.01$)

production/plant is greater in ICPL-87 (1444.06) than in the SD-35 (925.66), ESD-19 (777.33) and ESD-39 (672.66) (Table 2). Flower production on main stem was significantly greater in ICPL-87 (264.66) than in the SD-35, ESD-19 and ESD-39 (average of 132.55). Flower production on secondary branch was also significantly greater in ICPL-87 than in the SD-35, ESD-39 and ESD 19 (Table 2). The pattern of flower production on primary branch was similar to that of total number of flowers/plant. About 71-76 and 5-10% of total flower production occurred on primary (1^0) and secondary (2^0) branches (Table 2).

Pod production: Number of pod in primary (1^0) branch was much greater (60-70% of the total) than that on the main stem (21-27% of the total) and secondary branch (8-14% of the total) (Table 3). Number of pod in the main stem was greater in ICPL-87 (43.25) than SD-35 (22.83) and two ESD genotypes (average of 20.98). Number of pods in primary branch was greater in ICPL-87 (99.67), moderate in SD-35 and ESD-19 (average of 76.5) and lower in ESD-39 (54.00). Number of pods in secondary branch was also greater in ICPL-87 (22.38) than in SD-35 (9.1), ESD-19 (12.47) and ESD-39 (6.63) (Table 3). Total number of pods per plant significantly ($p \leq 0.01$) varied between the genotypes with the magnitude being again high in ICPL-87 (165.30), intermediate in SD-35 and ESD-19 (average of 111.1) and low in ESD-39 (77.80).

Pod abscission: Pod abscission percentage was also greater in 2^0 branches than in the 1^0 branches and main stem (Table 3). Percentage of pod abscission in main stem was significantly ($p \leq 0.01$) greater in ESD-19 and ESD-39 (average of 93.73) than ICPL-87 and SD-35 (average of 87.34) (Table 3). In contrast, pod abscission in 1^0 branches was significantly ($p \leq 0.01$) lower in SD-35 (90.67) than ICPL-87, ESD-39 (average of 92.38) and ESD-19 (93.90). Again pod abscission in secondary branch was significantly ($p \leq 0.01$) greater in ESD-39 (96.23) than in the ICPL-87 and

Table 3: Pod distribution and abscission percentage in different parts of canopy in four cultivated genotypes of pigeonpea

	Number of pod/plant				Pod abscission (%)			
Genotypes	Main stem	Primary branch	Secondary branch	Total	Main stem	Primary branch	Secondary branch	Total
ICPL-87	43.25a	99.67a	22.38a	165.30a	86.36c	92.40c	94.37b	91.04b
	(26.16)	(60.25)	(13.53)					
SD-35	22.83b	74.00b	9.1c	105.93b	88.33b	90.67c	91.53c	90.17b
	(21.67)	(69.85)	(8.59)					
ESD-19	24.80b	79.00b	12.47b	116.25b	93.97a	93.90a	94.03b	93.96a
	(21.32)	(67.94)	(10.72)					
ESD-39	17.17c	54.00c	6.63d	77.80c	93.50a	92.37b	96.23a	94.03a
	(22.06)	(69.40)	(8.52)					

Values within parenthesis indicate the percentage of total no. of pod/plant. Values with common letter(s) in a column do not differ significantly at ($p \leq 0.01$)

ESD-19 (average of 94.20) and SD-35 (91.53) (Table 3). Average percentage of pod abscission was significantly ($p \leq 0.01$) greater in ESD-19 and ESD-39 (average of 93.99) than in ICPL-87 and SD-35 (average of 90.6) (Table 3).

Reproductive efficiency: Number of raceme born in the primary branch (1^0) was greater than that of Main Stem (MS). Total number of racemes per plant was significantly ($p \leq 0.01$) greater in ICPL-87 (134.21) than in the others (Table 4). The trend in raceme production borne on 1° branches was similar to that of the total raceme production. In contrast, raceme number on MS was significantly ($p \leq 0.01$) greater in ICPL-87 (37.35) than in ESD-19 (30.84) and SD-35, ESD-39 (average of 22.36) (Table 4). Higher number of Reproductive Unit (RU) per raceme in MS and 1° branches also produced greater number of total RU per plant in ICPL-87. Total RU per plant was fewer in ESD-39 and SD-35 (average of 1756.8) than in the ICPL-87 (2753.98) and ESD-19 (2042.04) (Table 4).

Number of pods per plant is the function of number of racemes per plant, nodes per raceme and pods per raceme. Thus, in ICPL-87, increased number of raceme (134.21) and moderate number of node per raceme (10.26) and highest number of pod per node (0.120) produced the highest number of pod per plant (165.30). Although SD-35, number of pod per node was significantly greater (average of 0.123) but highest number of pod per plant produced in ICPL-87 (165.30) and moderate number of pods produced in SD-35 (105.93). Number of nodes per raceme was fewer in ESD-19 and ESD-39 (average of 8.87) than in SD-35 (11.38) and ICPL-87 (10.26) (Table 4). Number of pod per node was fewer in ESD-39 (0.086) and greater in ICPL-87 and SD-35 (average of 0.121). In contrast, number of node per plant was greater in ICPL-87 (1376.99) than in ESD-19 (1021.02) and ESD-39, SD-35 (average of 878.39) (Table 4). Number of pod per raceme was fewer in Esd-39 (0.77) than in ICPL-87, ESD-39 (average of 1.10) and SD-35 (1.40) (Table 4). The number of pod per plant was greater in ICPL-87 (165.30), moderate in ESD 19 (116.27) and SD-35 (105.93) and significantly lower in ESD-39 (77.80) (Table 4).

Bud, flower and pod abscission: Bud abscission was significantly ($p \leq 0.01$) greater in ESD-19 and in ESD-39 (average of 19.29), than ICPL-87 (15.89) and SD-35 (18.66) (Table 5). In contrast, flower abscission was also significantly ($p \leq 0.01$) greater in ESD-19 (65.38) than in the ICPL-87 (60.04) and SD-35 (62.51) and ESD-19 (65.38). Again, pod abscission was significantly ($p \leq 0.01$) low in SD-35 (10.57), than ICPL-87 (15.23), moderate in and ESD-19 (16.34) and high in ESD-39 (18.90) (Table 5).

Table 4: Reproductive efficiency in four cultivated genotypes of pigeonpea

	No. of Raceme/plant			No. of RU/plant								
Genotypes	Main stem	Primary branch	Total	Main stem	Primary branch	Total	RU /Raceme	Node /Raceme	Pod /Node	Node /Plant	Pod /Raceme	Pod /Plant
ICPL-87	37.35a	96.86a	134.21a	766.42a	1987.56a	2753.98a	20.52a	10.26b	0.120a	1376.99a	1.21b	165.30a
	(-27.82)	(-72.17)		(-27.82)	(-72.17)							
SD-35	22.90c	52.75c	75.66c	521.20b	1192.59c	1721.79c	22.76a	11.38a	0.121a	860.89c	1.40a	105.93b
	(-30.27)	(-69.72)		(-30.27)	(-69.72)							
ESD-19	30.84b	84.40b	115.24b	546.48b	1495.56b	2042.04b	17.72b	8.86c	0.113b	1021.02b	1.00b	116.27b
	(-26.76)	(-73.23)		(-26.76)	(-73.23)							
ESD-39	21.82c	79.10b	100.92b	386.21c	1405.60b	1791.81c	17.77b	8.88c	0.086c	895.90c	0.77c	77.80c
	(-21.6)	(-78.39)		(-21.55)	(-78.44)							

Values within parenthesis indicate the percentage of each respective item. Values with common letter(s) in a column do not differ significantly at ($p \le 0.01$)

Table 5: Average percentage of floral abscission and its components-bud, flower and pod in four cultivated pigeonpea genotypes

Genotypes	% Floral abscission (Average)	% Bud abscission	% Flower abscission	% Pod abscission
ICPL-87	91.1 4b	15.89c	60.04c	15.23b
SD-35	91.17b	18.66b	62.51b	10.57c
ESD-19	95.60a	19.18a	65.38a	16.34b
ESD-39	96.70a	19.40a	61.40b	18.90a

Values with common letter(s) in a column do not differ significantly at ($p \leq 0.01$)

DISCUSSION

Genotypic variation in flower and raceme production and floral abscission were observed in the present investigation. Number of pods per plant is a function of number of raceme per plant, number of flowers per plant and percentage of floral abscission. Thus, a variety with increased number of racemes and flowers may produce higher pod yield if the percentage abscission is moderate or low. In ICPL-87, for example, the increased number of raceme (134.21) and flowers (1444.06) produced greater pod yield (165.30) when the percentage abscission was moderate (91.04). The reverse was true for ESD-39.

Greater proportion of the total number of pods was produced on primary branch (1°). Increased number of sink production (flowers and racemes) perhaps produced greater pod yield on primary branches. About 71-76% of the total flowers, 69-78% of the total racemes and 60-72% of the total number of pods produced in 1^0branches. Percentage abscission was greater in 1^0branches than that in main stem. Increased floral abscission in 1^0branches still produced greater pod yield on primary branches. Increased abscission on primary branches was possibly compensated or balanced by greater degree of sink production (flower) on primary branches and thus, produced higher yield on 1° branches indicating that not only magnitude of sink production but also the propensity of sink determines pod yield in pigeonpea. In addition, this result is in agreement with the pod yield in some other legumes. This result further reveals that increased number of primary branch may be used as an index of selection criteria for greater pod yield. This was supported by Togun and Tayo (1990) and Sivaramakrishnan *et al.* (2002), who noted that primary branch contributed 70-80% of the total flower production and 73-75% of the total pod production of pigeonpea.

The number of flowers produced and degree of their survivability determine number of pods per plant. Primarily it depends on the number of raceme per plant and number of nodes per raceme and the latter depends on the number of pod set per node. Therefore, number of pod production per plant is a function of number of raceme per plant, number of nods per raceme and number of pods per node. In our present research, increased number of raceme per plant and moderate number of nodes per raceme and greater number of pods per node in ICPL-87 produced higher pod yield in this genotype. In contrast, moderate number of racemes per plant and fewest nodes per raceme did not produce higher yield in ESD-19 and ESD-39. This was perhaps due to fewer pods per node that was negative effect on higher pod yield. Such compensations or interactions of pod yield components were more pronounced in low yielding genotypes. Burn and Betts (1984) and Choudhury *et al.* (2008) stated that flower abscission occurred in the distal position that makes a negative effect on higher pod yield. Our present observation also showed that flower abscission was higher in distal position and lower in the proximal position, which supports previous study. Thus, in ESD-39 fewest pods per node might be a negative effect on higher pod yield in spite of greater racemes per plant.

High degree of flower shedding is very common feature in grain legume (Hamid, 1989; Fakir *et al.*, 2000; Choudhury *et al.*, 2008; Wasike *et al.*, 2005). Flower shedding or abscission is regulated by different environmental (Osumi *et al.*, 1998; Mallikarjuna and Saxena, 2002) and physiological factors (Saxena *et al.*, 2006). These previous research results were fully agreed with our present investigation. Controlling or reducing of flower shedding is very difficult. The easiest opportunity is, perhaps, to select a genotype with increased RU production and decreased abscission. The former represents the magnitude of sink production (RU) and the latter represent the propensity or survivability of sink (pod set or abscission). These results suggest that a genotype with increased sink production and decreased abscission might be used to breed a high yielding variety and in agreement with report of Fakir *et al.* (2000), Wasike *et al.* (2005) and Choudhury *et al.* (2008) in pigeonpea.

Some previous reports showed that average percentage abscission varied between 90-100% in pigeonpea. They found that abscission ranged 94-99% in primary branch, 92-99% in secondary branch and 90-100% in the terminal axillary main stem in indeterminate genotypes of pigeonpea. Our result showed that, abscission ranged from 90-93% in primary branches, in secondary branch 90-94% and in the main stem it varied between 86-94% in case of four determinate genotypes of pigeonpea. Wasike *et al.* (2005) and Choudhury *et al.* (2008) reported that pigeonpea produces larger number of flowers of which as much as 90% are shaded. Our result clearly showed that the total floral abscission ranged from 90-93% among the selected genotypes of pigeonpea. Among the total floral abscission bud contributed about 35-66%, flower contributed 84-92% and pod contributed 15-19%. As many as 10% immature young pod drops off in pigeonpea (Sheldrake *et al.*, 1979), which is almost similar with the present research work.

Floral abscission increases with the progression of nodal position. At the base of the raceme floral abscission is low, at the terminal portion of the raceme all most all of the flowers were shaded. According to Weis and Webster (1990), Burn and Betts (1984), Wasike *et al.* (2005) and Choudhury *et al.* (2008), the probability of abscission of bud or any flowering organ increased with distance from the base of the raceme.

Number of pods per plant is also a function of number of raceme per plant, number of reproductive unit per raceme and number of pods per node. Thus, in higher yielding genotypes like ICPL-87, three components are higher that provides greater pods per plant. In contrast, one or more of those yield components reduced the final yield for example, number of pods per plant also reduced in ESD-39.

CONCLUSION

Improved pod yield might be achieved by selecting genotypes with increased number of sink production (raceme per plant) and greater survivability of those sink at each raceme and higher pod set per node. Therefore, it can be suggest that ICPL-87 might be a high yielding genotype among the studied genotypes of pigeonpea in this investigation. It is still unclear that which factors are responsible for pod abscission, therefore, factors affecting pod abscission needs to be investigated in future research.

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