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Genetic Variation Studies for Flower Production, Abscission and Pollen Load in Advanced Lines of Pigeonpea [*Cajanus cajan* (L.) Millsp.]

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ABSTRACT

Background: Flower bud/s, flower/s and fruit/pod/s abscission is one of the momentous bottlenecks in pulses in general and pigeonpea in particular, resulting in poor reproductive efficiency. Abscission occurs both before and after fertilization. Knowledge on nature and extent of genetic variation available in the genotypes help breeders for planning breeding programmes to identify genotypes that retain maximum flowers hence increase pod set.

Methods: A total of 19 advanced stabilized breeding lines including 2 local checks (GRG-811 and TS-3R) were evaluated in randomized block design (RBD) with two replications in rain fed and irrigated condition at Zonal Agricultural Research Station (ZARS), Kalaburagi, during *kharif* 2018. Genetic variation for flower production, abscission and pollen load were studied and interpreted.

Result: The genotypes *viz.,* RIL-63, RIL-59, GRG-152 and KRG-224 showed good number of pods set per plant in rainfed condition and 3 Genotypes WRP-R-29-4, KRG-224 and ICPL-15017 in irrigated condition. The genotype KRG-224 Sets more pods under both conditions. Pollen grains load was more in undropped flower compared to dropped flower.

Key words: Floral abscission, Pollen load.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.], one of the major pulse crops of the tropics and subtropics. Globally it is cultivated in about 7.02 million ha area with an annual production of 6.81 million tonnes and a mean productivity of 970 kg/ha (FAOSTAT, 2019). India is the largest producer and consumer of pigeonpea with an area of 4.23 m ha, annual production of 3.89 m t and productivity of 919 kg/ha. In Karnataka an area of about 1.3 million hectares with production of 0.91 million tonne and productivity 700 kg/ha (Annual Report AICRP on Pulses, 2020-21).

Pigeonpea flowers profusely during September-October, a higher per cent of them abscise (70-96%) without setting into pods. Grain yield depends upon percentage of flowers transforming into pods. Mineral nutrients are known to develop economic source-sink relationship in plants that ultimately increase the flower, fruit set and seed filling, there by increasing the yield. Pre-mature abscission of buds, flowers and fruits lead to reduced realization of sink potential. Thus, flower or fruit dropping is considered as a bottleneck in productivity.

Hence, it is very necessary to have a reliable data on the extent of abscission, its impact on yield and the ways to compensate the high degree of floral abscission by decrease in floral abscission or increase in pod set. In the present study, investigation was carried out to analyse genotypic differences for floral abscission under rainfed and irrigated condition.

MATERIALS AND METHODS

Investigation was carried out during *Kharif* 2018 at Zonal Agriculture Research Station, Kalaburagi which belongs to the Agro-climatic zone-2 (North Eastern Dry Zone) of Karnataka state, India. The experimental material consists of 19 pigeonpea genotypes including two check varieties (TS-3R, GRG-811) which were obtained from ZARS, Kalaburagi. The full set of 19 genotypes including two checks were used to study flower production, buds, flowers, pods abscission and pod set in rainfed and irrigated condition.

The experimental block was divided into two separate plots, one plot as a rainfed condition without the supplementary irrigation and other plot with supplementary irrigation at different crop growth stages. 1 irrigation was given at vegetative stage to rainfed genotypes, where as 3 irrigations were given at vegetative, flowering and pod filling stage to irrigated genotypes. The experiment for floral abscission study was laid out in randomized block design (RBD) with 2 replications. Each genotype was sown in single

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row with spacing of 120 cm between the rows and 60 cm between the plants. Wide spacing would make the collection of dropped flower/s and /or pod/s convenient. Three plants were randomly selected in each treatment to study the flower production and buds, flowers and pods abscission.

Flowers drop (%) =

$$\frac{\text{No. of flowers dropped per plant}}{\text{Total no. of flowers produced per plant}} \times 100$$

$$\text{Pod set (\%)} = \frac{\text{No. of mature pod per plant}}{\text{Total no. of flowers produced per plant}} \times 100$$

Total no. of flowers produced = Summation of buds dropped, flowers dropped, pods dropped and pods set on the plant. Total no. of flowers dropped = Total number of flowers dropped in each genotype manually collected, counted and averaged. Total no. of pods dropped = Total number of premature pods dropped in each genotyp were manually collected, counted and average.

Collected normal and abscised or dropped flowers from pigeonpea plant. The floral parts were dissected with the help of needles and forceps and anthers of normal and dropped flowers were separately collected on fresh slide, added 2-3 drops of 2% acetocarmine solution to each slide containing anthers. The collected anthers were crushed thoroughly using blunt end of needle, so that pollen grains are released. The debris were removed from the slide with help of forcep and immediately cover slip was kept to prevent the entry of air bubble, after few second, the pollen grain load was observed in normal and abscised flowers per cm^2 with the help of light microscope having high resolution 100x, for clear visibility.

RESULTS AND DISCUSSION

The analysis of variation shown highly significant differences in their mean performance among the genotypes studied under rainfed and irrigated condition (Table 1).

Total number of flowers produced

Wide range of flowers produced from 816.08 (RIL-63) to 2194.21 (GRG-177) with mean value of 1510.54. under rainfed condition, moderate GCV (19.19%) and high PCV (26.24%) were observed with moderate heritability of (57.57%), high GA of (470.10%) and high GAM of (31.12%). The results were in agreement with Kulkarni *et al*. (2019) (Table 2, 3 and 4).

Under irrigated condition ranged from 748.67 (RIL-63) to 3080.00 (GPT-1) with mean value of 1685.57. There was moderate GCV (28.66) and high PCV (30.64) were observed with high heritability of 87.49%, high GA of 930.74% and high GAM of 55.22%. High heritability (57.57%) with high GAM (31.12%) is suggestive of high response to appropriate selection procedures and thus selection for this trait will result in high genetic gain.

Total number of buds dropped

The buds dropped under rainfed condition showed wide variations ranging from 46.00 (RIL-63) to 206.67 (GRG-177)

Table 1: ANOVA for yield and yield attributing traits in 19 pigeonpea genotypes under rainfed and irrigated condition.

Source of variation	D. F		DFF	DM	PH	NPB	NSB	PBL	HSW	TBD	TFD	TPD	TFP	TPPP	YPP
Replications	1	Rainfed	1.68	0.66	1.42	3.79	6.46	7.61	0.24	100.07	579.02	20.14	24189.18	4050.67	120.58*
		Irrigated	0.42	0.42	8.53	5.16	0.49	3.79	2.38	0.66	37510.5	3.79	81855.7	1494.81	182.06
Treatments	18	Rainfed	63.46**	75.45**	232.56**	5.56**	14.53*	74.78*	2.43	3354.94	20823.70	2785.50	24759.0*	33570.72	1450.05*
		Irrigated	60.78**	77.14**	609.74**	8.40**	53.36**	322.50**	2.21	4008.52	36233.86	3284.55	49997.2*	58346.77	1768.49*
Error	18	Rainfed	0.30	0.21	53.85	1.68	5.79	24.88	0.10	908.05	46214.13	321.37	66675.6	9213.95	142.41
		Irrigated	0.25	0.25	36.73	1.71	7.97	67.11	0.13	1504.0	25168.6	348.34	33346.9	5116.09	156.28

**Significant at 5% level; *Significant at 1% level.

TBD= Total number of buds dropped; TFD= Total number of flowers dropped; TPD= Total number of pods dropped; TFP= Total number of flowers produced; TPPP= Total number of pods per plant; YPP= Yield per plant.

Table 2: Genetic variability studies for floral production and abscission in rainfed and irrigated condition.

Variability parameters	Level	Range		Mean	Variance		Co-efficient of variation (%)		h^2bs (%)	GA (%)	GAM (%)
		Minimum	Maximum		Genotypic variance	Phenotypic variation	Gen.	Phen.			
Total number of buds dropped	Rainfed	46.00	206.67	127.80	1223.45	2131.5	27.37	36.13	57.4	54.59	42.72
	Irrigated	42.67	265.83	149.82	2252.25	3756.26	31.68	40.91	59.96	75.70	50.53
Total number of flowers dropped	Rainfed	474.0	1565.33	1004.71	61007.79	107221.9	24.58	32.59	56.9	383.81	38.2
	Irrigated	494.67	2433.50	1164.84	168582.61	193751.25	35.25	37.79	87.01	788.97	67.73
Total number of pods dropped	Rainfed	39.00	115.33	85.57	232.07	553.43	17.8	27.49	67.93	20.32	23.75
	Irrigated	27.67	211.00	99.98	1468.10	1816.44	38.32	42.63	80.82	70.96	70.97
Total number of flowers produced	Rainfed	816.0	2194.21	1510.54	90460.03	157135.99	19.91	26.24	57.57	470.1	31.12
	Irrigated	748.67	3080.00	1685.57	233312.13	266659.08	28.66	30.64	87.49	930.74	55.22
Total number of pods per plant	Rainfed	108.0	548.67	364.48	7178.38	16392.33	27.73	41.91	63.79	115.5	37.81
	Irrigated	159.50	853.33	506.04	26615.34	31731.43	49.76	54.34	83.88	307.79	93.89

h^2 (bs)= Heritability in broad sense; GA= Genetic advance; GAM= Genetic advance as per cent mean.

with mean of 127.80. High GCV (27.37%) and PCV (36.13%) with moderate heritability of 57.40%, high GA of 54.59% and high GAM of 42.72%.

In irrigated situation it was ranged from 42.67 (RIL-63) to 265.83 (GRG-177) with mean of 149.82. High GCV (31.68%) and PCV (40.91%) with moderate heritability of 59.96%, high GA of 75.70 and high GAM of 50.53%. Genotype RIL-63, reported a less number of buds drop in both situations. Hence, it can be further tested and can be utilized in the breeding programme.

Total number of buds, flowers and pods dropped in the entries investigated ranged from 308.25 (RAJA) to 12195.0 (GRG-177) with mean value of 4121.82. The GCV and PCV were as high as 59.32 and 62.30% respectively with high heritability of 90.67%, higher GA of 4796.81% and GAM of 116.38%, reported by Kulkarni *et al*. (2019).

Total number of flowers dropped

Rainfed condition flower dropped ranged from 474.00 (RIL-63) to 1565.33 (GRG-177) with mean value of 1004.71. The high GCV 24.58% and PCV 32.59% with moderate heritability of 56.90%, high GA of 383.81% and high GAM of 38.20%.

Irrigated condition ranged from 494.67 (RIL-63) to 2433.50 (GPT-1) with mean value of 1164.84. The GCV (35.25%) and PCV (37.79%) high. with high heritability of 87.01%, higher GA of 788.97 and high GAM of 67.73%. PCV slightly higher then the GCV Which shows that the presence of environment effect on this trait.

In rainfed genotype RIL-59 showed the lowest flower drop (52.20%) and in irrigated condition KRG-224 showed the lowest flower drop (56.42%). Large genotypic variations were found with respect to flower drop in all the genotype under both the situations.

The highest flower drop could be due to internal hormonal changes like ABA (Abscissic acid), Ethylene, Proline, *etc.* and external factors like moisture content, availability of nutrients at flowering and pod filling stages (Gagandeep, 2014) pest and diseases, source to sink relationship, photosynthetic rate, sometimes pollen viability *etc.*

The genotypes *viz.,* KRG-155, RIL-59, KRG-224, GRG-222 showed less flower drop irrespective of situation, can be considered as stable genotype for the pod set. However, large differences have been noticed in the genotypes like GPT-1, GRG-177, GRG-222, GRG-224, KRG-244, KRG-251, JSA-59-2, GRG-811 and RIL-59 under both condition.

GRG-177 showed the highest flower drop (93.06%) and genotype RAJA showed the lowest flower drop (27.11%), Genotypes RAJA, GRG-2013, ICP-11320 and BAHAR showed lesser flower produced to pod set ratio indicating a greater number of pods set for total flowers produced and effective utilization of photosynthates. Observed by Kulkarni *et al*. (2019).

Total number pods dropped

Pods dropped in rainfed condition ranged from 39.00 (RIL-63) to 115.33 (KRG-244) with mean value of 85.57. There was

Table 3: Genotypic variation for flower production and abscission in pigeonpea genotypes under rainfed condition.

Genotypes	Total number of flowers produced	Total number of buds dropped	Total number of flowers dropped	Total number of pods dropped	Total number of pods produced	% flower dropped	% pod set	Flower produced to pod set ratio
GRG-152	1847.50	100.34	1104.50	94.00	548.67	60.11	29.14	3.4:1
GRG-177	2194.21	174.54	1565.33	102.83	351.50	70.02	17.47	6.3:1
GRG-222	1703.88	110.71	1100.83	70.83	421.50	64.21	24.73	4.0:1
GRG-617	1222.81	109.81	793.00	68.83	251.17	64.54	20.76	4.9:1
KRG-224	888.51	73.84	493.83	74.17	246.67	56.69	26.63	4.5:1
KRG-33	1580.84	162.85	1105.50	101.17	211.33	69.79	13.42	7.5:1
KRG-221	1423.94	80.61	1053.00	109.83	180.50	73.95	12.65	7.9:1
KRG-244	1313.06	99.23	789.50	115.33	309.00	60.16	23.54	4.2:1
KRG-155	1648.11	142.11	1010.17	80.50	415.33	61.36	25.11	4.0:1
KRG-251	1534.16	102.99	1141.67	91.00	198.50	74.16	13.13	7.7:1
AGL-1603-2	1690.40	147.24	1200.33	93.50	249.34	71.03	14.78	6.9:1
WRP-R-29-4	1753.16	121.33	1152.00	95.83	384.00	65.78	21.95	4.6:1
JSA-59-2	1352.97	133.47	957.00	75.17	187.34	71.03	13.47	7.2:1
GPT-1	1764.50	113.67	1299.50	87.00	264.33	74.32	13.89	6.7:1
ICPL-15017	1392.47	61.31	914.00	70.17	347.00	65.59	24.96	4.0:1
TS-3R	1955.22	140.05	1397.67	113.67	303.84	71.68	15.08	6.4:1
GRG-811	1547.89	151.73	983.83	86.17	326.17	63.54	21.09	4.7:1
RIL-59	1070.64	122.80	553.83	56.83	337.17	52.20	31.28	3.2:1
RIL-63	816.08	45.75	474.00	39.00	257.33	58.05	31.53	3.2:1
Overall mean	1510.54	115.49	1004.71	85.57	304.77	65.70	20.77	
SD	351.85	34.35	290.03	19.82	94.15			

Table 4: Genotypic variation for flower production and abscission in pigeonpea genotypes under irrigated condition.

Genotypes	Total number of flowers produced	Total number of buds dropped	Total number of flowers dropped	Total number of pods dropped	Total number of pods produced	% flower dropped	% pod set	Flower produced to pod set ratio
GRG-152	1214.50	107.33	826.17	101.17	179.84	68.10	14.77	6.8:1
GRG-177	2448.50	265.83	1835.00	135.50	212.17	74.73	8.84	11.5: 1
GRG-222	1569.34	155.17	986.00	80.83	347.34	62.46	22.38	4.5: 1
GRG-617	1478.00	117.17	944.83	79.00	337.00	63.54	22.92	4.4: 1
KRG-224	1265.84	78.50	714.67	59.50	413.17	56.42	32.70	3.1: 1
KRG-33	1571.50	188.00	1117.50	98.00	344.34	73.02	23.34	4.6: 1
KRG-221	1618.17	189.17	1051.83	117.50	210.34	65.02	12.87	7.8: 1
KRG-244	1765.00	210.67	1211.83	135.67	222.84	68.68	12.56	8.6: 1
KRG-155	1458.83	172.17	915.33	123.67	194.33	62.72	13.31	7.5: 1
KRG-251	1975.83	217.17	1411.83	154.67	199.17	71.38	10.09	9.9: 1
AGL-1603-2	1866.00	154.50	1367.33	97.50	292.33	73.31	15.67	6.4: 1
WRP-R-29-4	1627.66	97.83	1011.33	85.17	535.50	62.24	32.89	3.1: 1
JSA-59-2	1893.17	108.67	1195.17	75.67	501.00	63.11	26.43	3.8: 1
GPT-1	3552.34	203.67	2433.50	211.00	853.34	68.79	23.96	4.2: 1
ICPL-15017	1389.00	119.00	1029.83	84.50	445.67	73.84	31.87	3.4: 1
TS-3R	1947.33	117.17	1281.83	84.83	352.67	65.91	18.11	5.5: 1
GRG-811	1933.83	156.83	1393.83	90.00	241.84	72.16	12.53	8.0: 1
RIL-59	1342.67	145.00	909.50	57.83	206.50	68.07	15.83	6.5: 1
RIL-63	748.67	42.67	494.67	27.67	159.33	66.22	21.38	4.7: 1
Overall mean	1719.27	149.82	1164.84	99.98	328.88	67.35	19.60	
SD	575.04	54.81	425.64	40.53	169.64			

moderate GCV (17.80%) and high PCV (27.49%) was reported. with moderate heritability of 67.93%, high GA of 20.32% and high GAM of 23.75%.

Under irrigated condition ranged from 27.67 (RIL-63) to 211.00 (GPT-1) with mean value of 99.98. The GCV and PCV were recorded to be high 38.32% and 42.63% respectively with high heritability of 80.82%, high GA of 70.96% and high GAM of 70.97%. The results were in agreement with Kulkarni *et al*. (2019).

Total number of pods per plant

Total number of pods per plant under rainfed condition ranged from 180.50 (KRG-221) to 548.67 (GRG-152) with mean of 305.48. The GCV and PCV were high *i.e.,* 27.73% and 41.91% respectively with moderate heritability of 63.79%, high GA and GAM of 115.50% and 37.81% respectively.

Under irrigated condition ranged from 159.50 (RIL-63) to 853.33 (GPT-1) with mean of 327.83. GCV and PCV were high *i.e.,* 49.76% and 54.34% respectively with high heritability of 83.88%, high GA and GAM of 307.79% and 93.89%.

The genotypes expressing higher number of pods set per cent are considered to have high reproductive efficiency. This higher efficiency can be utilized to improve the yield of pigeonpea.

Rainfed condition genotypes RIL-63, RIL-59, GRG-152, KRG-224 and in irrigated condition genotypes like WRP-R-29-4, ICPL-15017, KRG-224 and JSA-59-2 showed higher number of pods per plant. Higher number of pods per plant indicating their high reproductive efficiency. Results are in agreement with previous studies conducted by Kulkarni *et al*. (2019), Sarsamkar *et al.* (2008), Vange and Egbe (2009), Bhadru (2011), Sharma *et al.* (2012) and Rao *et al.* (2013) whereas, Vanisree *et al*. (2013) and Yogendra *et al.* (2013) obtained low heritability. Muniswamy *et al*. (2014) and Singh *et al*. (2018) obtained high GCV, PCV, heritability and GAM.

Flower produced to pod set ratio

Genotype KRG-221 showed the highest flower produced to pod set ratio (7.9: 1) in rainfed and in irrigated condition genotype GRG-177 showed highest flower produced to pod ratio of (11.5:1) which indicated that out of 7.9 flowers in rainfed and 11.5 in irrigation condition are required to produce one pod. But the genotypes KRG-224 and WRP-R-29-2 showed lowest flower produced to pod set ratio (3.1:1) in irrigated condition and genotype RIL-59 and RIL-63 reported lowest flower produced to pod set ratio (3.2:1) in rainfed condition which indicates reproductive efficiency of the genotypes. Similar results were obtained by Kulkarni *et al*. (2019).

This genetic variation is due to differential response of genotypes to source and sink relationship. The character flower production and abscission showed high heritability indicating genetic governance of the trait. The genotypes which are contrasting for this trait can be further used to study the number of genes governing the floral abscission. The genotypes with more floral abscission and fewer pod set shows their reproductive inefficiency in terms of improper use of photosynthates. In contrast, the genotypes with less floral abscission and more pod set are preferred as they exhibit high reproductive efficiency without wasting photosynthates of plant. The genotypes KRG-224, WRP-R-29-2, RIL-59 and RIL-63 were found to be good reproductive efficiency. Details given in Table 3 and 4.

Pollen load study reveals that number of pollen grains in each six microscopic field with 1 cm^2 area, in normal flower was 27, 19, 21, 14, 18 and 19. Hence, the average pollen load per microscopic field is 19.7. Where as in abscised flowers the pollen load was 10, 7, 9, 12, 7 and 8 and average pollen load for each microscopic field was 8.9. The observation revealed that more load of pollens in normal flower compared to pollen grain in abscised flower. Reviews were not available for this study indicating its novelty. Given in Plate I and II.

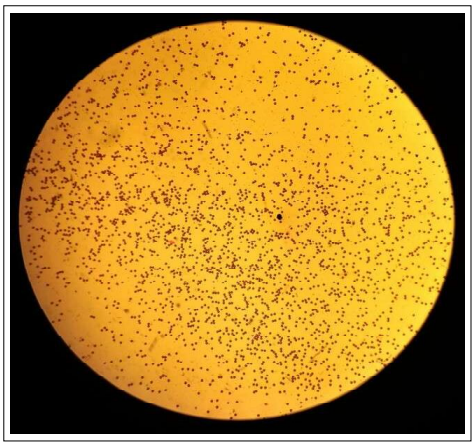


Plate I: Pollen load in undropped flower.

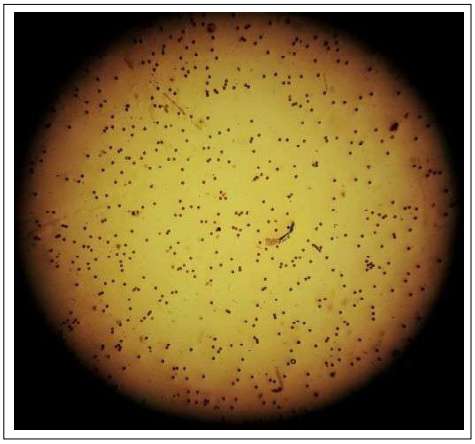


Plate II: Pollen load in dropped flower.

CONCLUSION

The genotypes contrasting to the trait flower abscission like KRG-224, WRP-R-29-2, RIL-59 and RIL-63 can be used in crossing to identify number of genes governing the trait and developing mapping population.

The genotypes RIL-59, KRG-224, RIL-63, GRG-152, GRG-222, KRG-155, ICPL-15017 and KRG-244 showed highest pod set as indicated by flower produced to pod set ratio in rainfed condition and the genotype KRG-224, RIL-59, KRG-244, KRG222, KRG-617, KRG-155 and WRP-R-29-4 showed highest pod set as indicated by flower produce to pod set ratio in irrigated condition. These genotypes can be further tested and can be included in yield improvement programmes. The pollen grains load was more in undropped flower compared to dropped flower, indicating role of pollen grains load on fertilization which may be directly influenced on pod set.

Conflict of interest

All authors declared that there is no conflict of interest.

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