

Original Research Article

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Study of CGMS based Short Duration Hybrids of Pigeonpea (*Cajanus cajan* (L.) Millsp.) in Terms of Heterosis

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ABSTRACT

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Twenty seven pigeonpea [*Cajanus cajan* (L.) Millsp.] hybrids were developed by hand pollination using three CMS lines (A lines) and nine testers (R lines). These hybrids along with their parents and two standard checks (VL Arhar1 and ICPL 161) were evaluated in a randomized block design with three replications during *kharif* 2016-17 for the heterosis studies. Results indicated that the crosses ICPA 2039 x ICPL161 and ICPA 2039 x ICPL 90048 had manifested significant heterobeltiosis and standard heterosis over two checks *viz.*, VL Arhar1 and ICPL 161 for grain yield per plant and yield contributing characters. The stability of these promising crosses can be studied across the different environments and feasibility for their commercial utilisation could be tested in further generations.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] (2n=22), member of family Leguminosae (Fabaceae) is an important grain legume crop for resource poor farmers of tropics and subtropics. In India, pigeonpea is grown in an area of 5.21 million hectares with a production of 4.23 million tonnes (D.E.S, 2017). Although India leads the world both in area and production of pigeonpea, its productivity is lower (673 kg/ha) than the world average (762.4 kg/ha) (FAOSTAT, 2015). To promote the pigeonpea production, genetic improvement of pigeonpea was

emphasized by researchers for more than five decades and a number of cultivars were developed from hybridization programmes and selection of landraces. However, the progress in the genetic improvement of yield potential has been limited and the improved cultivars failed to enhance the productivity of the crop. Therefore, an alternative breeding approach such as hybrid technology, which has been profitably used in a number of cereals, fruits, and vegetable crops was attempted in pigeonpea to enhance the yield. In 1974, a source of genetic male-sterility

(GMS) was identified. As a consequence, a GMS based pigeonpea hybrid ICPH 8 was released in 1991 in India (Saxena *et al.*, 1992). Due to the limitation of large-scale hybrid seed production in GMS-based hybrids, the development of cytoplasmic male-sterility (CMS) became imperative.

So far, seven CMS systems have been bred in pigeonpea with varying degrees of success (Saxena and Nadarajan, 2010). Some of the factors responsible for the poor productivity of pigeonpea are the lack of improved cultivars and poor fertility restoration of hybrids.

Research for genetic improvement of this crop, to raise yield levels effectively has to be strengthened countering biotic stresses, through widening genetic base. In view of above consideration, the present study was planned on heterosis and pollen fertility in CGMS-based short duration pigeonpea hybrids.

Materials and Methods

Three CMS genotypes ICPA 2039, ICPA 2089, ICPA 2156 as lines and nine testers *viz.*, ICPL 88034, ICPL 88039, ICPL 149, ICPL 161, ICPL 81-3, ICPL 89, ICPL 90048, ICPL 86022, ICPL 92047 formed the materials of the present study. They were crossed by hand pollination in a line x tester design in *kharif* 2015-16 at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru (17^o53¹N, 78^o27¹E, 545.5MSL), India. The resultant twenty seven hybrids along with their parents and standard check varieties (VL Arhar 1 and ICPL 161) were evaluated in a randomized block design with three replications during *kharif* 2016-17. Each entry was sown in four rows of four metres length with a spacing of 75 x 30 cms from row to row and plant to plant respectively on 4th of July, 2016.

Data collection

Five competitive plants of each entry were selected randomly in each replication for recording the observations of eleven characters *viz.*, plant height (cm), days to 50% flowering, pollen fertility, days to maturity, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight (g), grain yield per plant (g), harvest index (%). To record the pollen fertility observation 2% acetocaramine solution was used. Five well developed flower buds were collected at the time of anthesis from each plant. From each bud, the anthers were collected on a glass slide and crushed with a drop of 2% acetocaramine stain and examined under a light microscope. The mean value of pollen fertility/sterility of five plants was considered as pollen fertility (%) for that genotype. The heterosis was calculated as per the procedure suggested by Fonesca and Patterson (1961). The per cent increase or decrease of F₁ hybrids over better parent as well as standard variety was calculated to estimate possible heterotic effects for above mentioned parameters.

Results and Discussion

Analysis of variance for line x tester analysis

In the table 1 the mean sum of squares in the analysis of variance due to lines were significant for all the characters except pollen fertility, number of primary branches per plant, number of seeds per pod, 100 seed weight and harvest index presenting the importance of general combining ability and additive gene effects. The mean sum of squares due to testers were significant for the characters plant height and 100 seed weight showing the importance of general combining ability and additive gene effects. The mean

sum of squares due to line x tester were significant for all the characters except number of primary branches per plant, number of secondary branches per plant and number of seeds per pod indicating the impact of specific combining ability and non-additive gene effects.

Estimation of Heterosis

The success of hybrid breeding depends on the amount of heterosis and the availability of cost-effective hybrid seed production system. In the present investigation, percent heterosis was calculated over better parent (heterobeltiosis) and standard checks *viz.*, VL Arhar1, ICPL 161 (standard heterosis) in twenty seven crosses developed by crossing three lines with nine testers. The magnitude of heterosis varied from trait to trait and cross to cross is presented in the tables 2 and 3.

To achieve high yield, plant height is one of the desirable yield contributing character. For plant height, the heterobeltiosis ranged from -8.33 to 33.50 percent. Eleven crosses exhibited significant positive heterobeltiosis. Out of 27 crosses maximum significant heterobeltiosis is manifested by ICPA 2039 x ICPL 149 (33.50%) followed by ICPA 2039 x ICPL 86022 (21.71%). The range of standard heterosis is -5.44 to 32.72 and -9.53 to 26.98 percent for VL Arhar1 and ICPL 161 respectively. Ten crosses exhibited significant positive heterosis over the check VL Arhar1, of which the cross ICPA 2039 x ICPL 149 (32.72%) recorded maximum significant positive heterosis. Five crosses exhibited significant positive heterosis over ICPL 161, of which ICPA 2039 x ICPL 149 (26.98%) recorded maximum significant positive heterosis. Similar results were also reported earlier by Wankhade *et al.*, (2005), Baskaran and Muthiah(2006), Patel and Tikka, (2008), Sarode *et al.*, (2009), Chandrikala *et al.*, (2010), Vaghela *et al.*, (2011), Pandey *et al.*, (2013), Sudhir *et al.*, (2015).

In context of breeding for short duration hybrids, early flowering and early maturity is generally preferred. So negative heterosis is desirable for flowering and maturity. For days to 50% flowering, the heterobeltiosis ranges from -12.50 to 14.93 percent. Ten crosses exhibited significant negative heterobeltiosis. Maximum significant negative heterobeltiosis is recorded by ICPA 2089 x ICPL 88034 (-12.50%). The standard heterosis range is 10 to 33.16 and -17.39 to 0 percent for VL Arhar1 and ICPL 161 respectively. No significant negative heterosis is exhibited over the check VL Arhar1. Out of 27 crosses, 23 crosses manifested significant negative heterosis over the check ICPL 161. Maximum significant negative heterosis is recorded by ICPA 2089 x ICPL 88039 (-17.39%) and ICPA 2156 x ICPL 86022 (-17.39%) over the check ICPL 161.

Heterosis in both negative and positive directions for days to 50% flowering have also been reported by Wankhade *et al.*, (2005), Baskaran and Muthiah (2006), Wanjari *et al.*, (2007), Patel and Tikka (2008), Sarode *et al.*, (2009), Chandrikala *et al.*, (2010), Vaghela *et al.*, (2011), Pandey *et al.*, (2013). For days to maturity, the range of negative heterobeltiosis is -8.10 to 18.71 percent. Two crosses recorded significant negative heterobeltiosis *viz.*, ICPA 2039 x ICPL 88034 (-8.10%) and ICPA 2089 x ICPL 88034 (-7.85%). The range of standard heterosis ranged from 12.70 to 28.57 and -11.47 to 1percent for VL Arhar1 and ICPL 161 respectively. None of the crosses exhibited significant negative heterosis over VL Arhar1 for this trait. Out of the twenty seven crosses, the maximum significant negative heterosis was manifested by ICPA 2089 x ICPL 86022 (-11.47%) followed by ICPA 2039 x ICPL 88039 (-9.73%) over the check ICPL 161. These results are in agreement with earlier results reported by Solanki *et al.*, (2008) and Pandey *et al.*, (2013).

For the full exploitation of heterosis, hybrids with good amount of fertile pollen are needed. The range of heterobeltiosis for the trait pollen fertility is -13.43 to 0.92 percent. None of the crosses exhibited positive significant heterobeltiosis. The range of standard heterosis is -12.70 to 0.90 and -13.46 to 0.02 for VL Arhar1 and ICPL 161 respectively.

None of the crosses showed significant positive heterosis over all the checks. Results were in agreement with those reported by Wanjari *et al.*, (2007) and Sudhir *et al.*, (2015).

Number of primary branches per plant is one such character which influences productivity. Therefore, the hybrids with more primary branches per plant have to be identified. The range of heterobeltiosis for the trait number of primary branches per plant is -18.26 to 22.50 percent. Two crosses exhibited significant positive heterobeltiosis for this trait *viz.*, ICPA 2039 x ICPL 90048 (22.50%) and ICPA 2039 x ICPL 81-3 (19.67%). The range of standard heterosis is -7.96 to 12.89 and -0.78 to 21.69 percent for VL Arhar1 and ICPL 161 respectively.

None of the crosses registered significant negative heterosis over VL Arhar1 for this trait. Over ICPL 161, the cross ICPA 2039 x ICPL 81-3 (21.69%) showed significant positive heterosis. Similar results were earlier reported by Shoba and Balan (2010), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

For the trait number of secondary branches per plant, heterobeltiosis ranged from -13.22 to 20.04 percent. Maximum significant positive heterobeltiosis is exhibited by ICPA 2156 x ICPL 88034 (20.04%) followed by ICPA 2039 x ICPL 90048 (13.81%). The range of standard heterosis is -14.31 to 13.64 and -12.63 to 16.55 percent for VL Arhar1 and ICPL 161 respectively. The cross ICPA

2156 x ICPL 88034 (13.64%) recorded significant positive heterosis over the check VL Arhar1. Three crosses exhibited significant positive heterosis over the check ICPL 161. Maximum significant positive heterosis was shown by ICPA 2156 x ICPL 88034 (16.55%) followed by ICPA 2039 x ICPL 90048 (14.59%) over the check ICPL 161. Results were in conformity with those obtained by Wankhade *et al.*, (2005), Baskaran and Muthiah (2006), Patel and Tikka (2008), Sarode *et al.*, (2009), Chandrikala *et al.*, (2010), Vaghela *et al.*, (2011), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

More number of pods per plant are believed to be closely related to achieve high yield. The range of heterobeltiosis for the trait number of pods per plant is -51.09 to 64.68 percent. Out of twenty seven crosses, nine crosses manifested significant positive heterobeltiosis.

Maximum significant positive heterobeltiosis is exhibited by ICPA 2039 x ICPL 90048 (64.68%) followed by ICPA 2039 x ICPL 88034 (45.37%). The range of standard heterosis was -38.49 to 126.33 and -62.83 to 36.76 percent for VL Arhar1 and ICPL 161 respectively. Maximum significant positive heterosis was recorded by ICPA 2039 x ICPL 161 over both the checks VL Arhar1 and ICPL 161. These results are in agreement with the finding of Baskaran and Muthiah (2006), Patel and Tikka (2008), Sarode *et al.*, (2009), Chandrikala *et al.*, (2010), Vaghela *et al.*, (2011), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

Positive heterosis for number of seeds per pod is found to be desirable to increase the yield. For the trait number of seeds per pod, heterobeltiosis ranged from -19.23 to 7.14 percent. None of the crosses exhibited significant positive heterobeltiosis.

Table.1 ANOVA for L x T analysis

Sources of variation	d. f.	Mean sum of squares										
		Plant height (cm)	Days to 50 % flowering	Pollen fertility (%)	Days to maturity	Number of primary branches per plant	No. of secondary branches per plant	Number of pods per plant	No. of seeds per pod	100 seed weight (g)	Grain yield per plant (g)	Harvest Index (%)
Replications	2	72.99	15.46	2.41	24.98	0.60	4.82	301.46	0.06	0.16	11.08	1.56
Crosses	26	525.90**	57.12**	65.41**	60.61**	0.79	7.25**	17538.31**	0.07	0.81**	1518.42**	117.19**
Parents (Line)	2	2552.01**	394.16**	168.10	202.31*	1.27	25.76*	100271.93**	0.02	0.88	7695.10**	189.37
Parents (Tester)	8	703.07*	45.15	40.18	45.85	1.07	7.91	13939.54	0.09	1.36*	975.95	82.22
Line x Tester	16	184.05**	20.98**	65.19**	50.28**	0.58	4.61	8996.00**	0.06	0.52*	1017.57**	125.65**
Error	52	45.03	6.53	6.04	18.19	0.83	2.69	142.91	0.05	0.24	29.74	15.97

*- Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Note: A lines and B lines are isogenic except for pollen fertility. The observations of yield and yield contributing characters except pollen fertility were recorded on B-lines (ICPB 2039, ICPB 2089 and ICPB 2156).

Table.2 Estimation of heterobeltiosis for yield and yield contributing characters

Sr. No	Crosses	Plant height (cm)	Days to 50 per cent flowering	Pollen fertility (%)	Days to maturity	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per pod	100 seed wt. (g)	Grain yield Per Plant (g)	Harvest Index (%)
1.	ICPA 2039 x ICPL 88034	12.87**	-6.85**	-2.34	-8.10**	-16.80**	6.15	45.37**	1.79	0.41	40.84**	-20.16*
2.	ICPA 2039 x ICPL 88039	9.87*	-5.63*	0.92	-5.07	-2.59	11.91	-5.93	1.79	-18.64**	-9.48	0.05
3.	ICPA 2039 x ICPL 149	33.50**	5.44*	0.10	8.00**	10.14	5.88	12.02**	0.00	4.60	21.10**	3.40
4.	ICPA 2039 x ICPL 161	12.50**	2.47	-5.07**	4.21	5.44	11.59	30.61**	0.89	2.51	32.76**	-15.86*
5.	ICPA 2039 x ICPL 81-3	14.93**	7.20**	-0.47	6.38*	19.67*	8.48	-12.70**	-1.77	5.86	-9.46	-22.93**
6.	ICPA 2039 x ICPL 89	18.86**	3.90	-13.43**	3.73	6.55	11.15	-12.56**	0.00	-2.51	-21.99**	-36.33**
7.	ICPA 2039 x ICPL 90048	12.49**	7.79**	-3.54*	6.93*	22.50**	13.81*	64.68**	-6.67	4.63	83.25**	-7.14
8.	ICPA 2039 x ICPL 86022	21.71**	-1.73	-2.21	1.33	6.68	4.63	-14.15**	0.88	-2.89	-24.87**	16.86
9.	ICPA 2039 x ICPL 92047	18.20**	3.00	-0.53	0.00	-3.53	-7.75	36.07**	0.89	-10.89*	21.47**	-27.93**
10.	ICPA 2089 x ICPL 88034	3.47	-12.50**	-4.02*	-7.85**	-18.26**	10.37	21.50**	-19.23**	2.89	17.18*	-4.42
11.	ICPA 2089 x ICPL 88039	-0.35	2.45	-3.66*	6.47*	-8.18	0.59	-8.07	-4.62	-17.63**	-14.69*	36.99**
12.	ICPA 2089 x ICPL 149	19.80**	-5.44*	-4.43*	-3.47	-5.80	8.38	-21.93**	-7.69*	-1.77	-25.44**	9.35
13.	ICPA 2089 x ICPL 161	-8.33*	-5.76*	-13.13**	1.05	-5.86	13.32*	-40.73**	-13.08**	-8.40	-43.25**	-9.30
14.	ICPA 2089 x ICPL 81-3	-0.68	-6.36*	-12.94**	-1.60	-5.92	10.81	-15.40**	-12.31**	4.27	-9.05	-11.37
15.	ICPA 2089 x ICPL 89	-1.27	2.33	-10.98**	3.98	0.63	7.29	21.48**	-13.08**	6.84	39.66**	8.92
16.	ICPA 2089 x ICPL 90048	6.85	-0.46	-5.28**	4.10	-7.34	5.12	0.62	-11.54**	3.86	-5.97	-4.40
17.	ICPA 2089 x ICPL 86022	3.55	5.88*	-1.27	4.41	-5.77	-6.08	-23.96**	-14.62**	1.65	-6.67	-0.24

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Table.2 Continued.....

Sr. No	Crosses	Plant height (cm)	Days to 50 per cent flowering	Pollen fertility (%)	Days to maturity	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per pod	100 seed wt. (g)	Seed yield Per Plant (g)	Harvest Index (%)
18.	ICPA 2089 x ICPL 92047	-5.91	-6.44*	-12.92**	0.00	-7.18	-10.08	-7.40	-13.08**	2.82	-12.57	2.27
19.	ICPA 2156 x ICPL 88034	12.62**	-8.87*	-6.26**	-4.81	-16.61**	20.04**	-12.59*	0.89	2.48	-14.72	-24.10**
20.	ICPA 2156 x ICPL 88039	-0.25	14.93**	-12.44**	18.71**	-4.69	-8.22	-16.34**	7.14	-8.47*	-18.96**	3.31
21.	ICPA 2156 x ICPL 149	4.89	-4.18	-0.03	2.13	-3.08	-9.01	-32.05**	0.00	5.70	-32.54**	14.50
22.	ICPA 2156 x ICPL 161	-3.95	-6.58**	-0.37	-1.58	5.03	5.71	-51.09**	0.00	-3.36	-55.53**	-1.91
23.	ICPA 2156 x ICPL 81-3	2.94	-3.39	-2.88	-1.06	0.33	2.25	-44.03**	0.88	-14.10**	-35.31**	-0.57
24.	ICPA 2156 x ICPL 89	0.75	-1.40	0.05	5.11	5.96	-0.17	9.81	2.68	-16.24**	21.55**	-40.52**
25.	ICPA 2156 x ICPL 90048	3.24	-2.30	-4.75**	0.82	8.01	-13.22*	16.34**	5.00	4.25	0.63	23.36**
26.	ICPA 2156 x ICPL 86022	7.23	3.98	-1.17	13.25**	-1.69	-10.39	25.63**	-4.42	0.83	47.50**	-8.44
27.	ICPA 2156 x ICPL 92047	6.05	-7.30**	-5.44**	-2.63	-5.71	-9.61	-3.48	-4.46	-4.84	0.40	14.85
	SE (d) ±	5.49	1.92	1.67	3.61	0.76	1.21	9.58	0.16	0.37	4.53	3.15
	CD at 5 %	11.01	3.84	3.35	7.25	1.51	2.42	19.22	0.32	0.74	9.08	6.31
	CD at 1 %	14.67	5.12	4.46	9.66	2.02	3.22	25.6	0.43	0.98	12.1	8.41

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Table.3 Estimation of standard heterosis over the checks VL Arhar1 (Standard Check 1) and ICPL 161 (Standard Check 2)

Sr. No	Crosses	Plant height (cm)		Days to 50 per cent flowering		Pollen fertility (%)		Days to maturity		No. of primary branches per plant		No. of secondary branches per plant	
		SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2
1.	ICPA 2039 x ICPL 88034	10.84**	6.05	21.58**	-8.70**	-1.19	-2.05	15.24**	-9.48**	-5.03	2.37	0.50	3.07
2.	ICPA 2039 x ICPL 88039	5.49	0.93	14.74**	-13.83**	0.78	-0.10	13.02**	-11.22**	-5.35	2.03	10.98	13.82*
3.	ICPA 2039 x ICPL 149	32.72**	26.98**	32.63**	-0.40	0.14	-0.74	28.57**	1.00	-4.40	3.05	-1.16	1.37
4.	ICPA 2039 x ICPL 161	24.70**	19.30**	31.05**	-1.58	-4.30*	-5.14**	25.71**	-1.25	-2.52	5.08	7.32	10.07
5.	ICPA 2039 x ICPL 81-3	23.48**	18.14**	33.16**	0.00	0.58	-0.30	26.98**	-0.25	12.89	21.69**	4.33	7.00
6.	ICPA 2039 x ICPL 89	9.38*	4.65	26.32**	-5.14*	-12.70**	-13.46**	23.49**	-2.99	-2.83	4.75	7.82	10.58
7.	ICPA 2039 x ICPL 90048	6.37	1.77	31.05**	-1.58	-2.27	-3.12	27.30**	0.00	6.32	14.61	11.73	14.59*
8.	ICPA 2039 x ICPL 86022	3.55	-0.93	19.47**	-10.28**	-1.05	-1.91	20.63**	-5.24	-7.08	0.17	0.83	3.41
9.	ICPA 2039 x ICPL 92047	21.54**	16.28**	26.32**	-5.14*	0.88	0.00	20.63**	-5.24	-5.35	2.03	-1.00	1.54
10.	ICPA 2089 x ICPL 88034	1.60	-2.79	14.21**	-14.23**	-2.88	-3.73*	15.56**	-9.23**	-6.70	0.58	4.49	7.17
11.	ICPA 2089 x ICPL 88039	-4.33	-8.47*	10.00**	-17.39**	-3.79*	-4.63**	14.92**	-9.73**	-7.89	-0.71	-0.25	2.30
12.	ICPA 2089 x ICPL 149	19.11**	13.95**	18.95**	-10.67**	-4.40*	-5.24**	14.92**	-9.73**	-5.50	1.86	1.16	3.75
13.	ICPA 2089 x ICPL 161	1.60	-2.79	20.53**	-9.49**	-12.43**	-13.19**	21.90**	-4.24	-5.57	1.80	8.99	11.77
14.	ICPA 2089 x ICPL 81-3	6.71	2.09	16.32**	-12.65**	-12.02**	-12.79**	17.46**	-7.73**	-5.63	1.73	6.57	9.30
15.	ICPA 2089 x ICPL 89	-5.44	-9.53*	15.79**	-13.04**	-10.23**	-11.01**	16.19**	-8.73**	0.94	8.81	4.08	6.74
16.	ICPA 2089 x ICPL 90048	2.33	-2.09	13.68**	-14.62**	-4.03*	-4.87**	20.95**	-4.99	-7.04	0.20	3.19	5.84
17.	ICPA 2089 x ICPL 86022	-0.83	-5.12	13.68**	-14.62**	-0.10	-0.97	12.70**	-11.47**	-5.47	1.90	-9.48	-7.17

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Table.3 Continued.....

Sr. No	Crosses	Plant height (cm)		Days to 50 per cent flowering		Pollen fertility (%)		Days to maturity		No. of primary branches per plant		No. of secondary branches per plant	
		SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2
18.	ICPA 2089 x ICPL 92047	-3.26	-7.44	14.74**	-13.83**	-11.68**	-12.45**	20.63**	-5.24	-6.89	0.37	-3.49	-1.02
19.	ICPA 2156 x ICPL 88034	10.60*	5.81	18.95**	-10.67**	-5.15**	-5.98**	19.37**	-6.23*	-4.81	2.61	13.64*	16.55**
20.	ICPA 2156 x ICPL 88039	-2.77	-6.98	21.58**	-8.70**	-12.56**	-13.33**	22.86**	-3.49	-7.39	-0.17	-8.99	-6.66
21.	ICPA 2156 x ICPL 149	4.28	-0.23	20.53**	-9.49**	0.00	-0.87	21.59**	-4.49	-7.96	-0.78	-14.31*	-12.12
22.	ICPA 2156 x ICPL 161	6.47	1.86	19.47**	-10.28**	0.44	-0.44	18.73**	-6.73*	-0.25	7.53	1.66	4.27
23.	ICPA 2156 x ICPL 81-3	10.60*	5.81	20.00**	-9.88**	-1.86	-2.72	18.10**	-7.23**	-4.72	2.71	-1.66	0.85
24.	ICPA 2156 x ICPL 89	-1.80	-6.05	11.58**	-16.21**	0.90	0.02	17.46**	-7.73**	0.63	8.47	-3.16	-0.68
25.	ICPA 2156 x ICPL 90048	0.63	-3.72	11.58**	-16.21**	-3.49*	-4.33*	17.14**	-7.98**	2.58	10.58	-14.81*	-12.63*
26.	ICPA 2156 x ICPL 86022	4.52	0.00	10.00**	-17.39**	0.00	-0.87	19.37**	-6.23*	-6.64	0.64	-13.64*	-11.43
27.	ICPA 2156 x ICPL 92047	9.04*	4.33	13.68**	-14.62**	-4.10*	-4.93**	17.46**	-7.73**	-7.48	-0.27	-3.00	-0.51
	SE (d) ±	5.48	5.48	1.91	1.91	1.67	1.67	3.61	3.61	0.75	0.75	1.21	1.21
	CD at 5 %	11.01	11.01	3.84	3.84	3.35	3.35	7.25	7.25	1.51	1.51	2.41	2.41
	CD at 1 %	14.68	14.68	5.12	5.12	4.45	4.45	9.65	9.65	2.02	2.02	3.22	3.22

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Table.3 Continued

Sr. No	Crosses	No. of pods per plant		No. of seeds per pod		100 seed wt. (g)		Grain yield Per Plant (g)		Harvest Index (%)	
		SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2
1.	ICPA 2039 x ICPL 88034	56.84**	-5.23	-5.00	3.64	-17.06**	2.10	27.29**	-6.43	-3.20	-33.61**
2.	ICPA 2039 x ICPL 88039	1.50	-38.67**	-5.00	3.64	-18.09**	0.84	-9.62	-33.57**	21.30	-16.81*
3.	ICPA 2039 x ICPL 149	75.42**	5.99*	-6.67	1.82	-14.68**	5.04	45.27**	6.78	25.36*	-14.02
4.	ICPA 2039 x ICPL 161	126.33**	36.76**	-5.83	2.73	-16.38**	2.94	89.28**	39.13**	22.97*	-15.67*
5.	ICPA 2039 x ICPL 81-3	25.42**	-24.22**	-7.50	0.91	-13.65**	6.30	4.58	-23.13**	8.83	-25.36**
6.	ICPA 2039 x ICPL 89	-5.66	-43.00**	-6.67	1.82	-20.48**	-2.10	-29.49**	-48.17**	-9.11	-37.66**
7.	ICPA 2039 x ICPL 90048	77.67**	7.36*	-6.67	1.82	-7.51	13.87**	65.62**	21.74**	12.59	-22.79**
8.	ICPA 2039 x ICPL 86022	-7.38	-44.03**	-5.00	3.64	-19.80**	-1.26	-32.10**	-50.09**	44.49**	-0.91
9.	ICPA 2039 x ICPL 92047	46.81**	-11.29**	-5.83	2.73	-24.57**	-7.14	9.78	-19.30**	-4.96	-34.82**
10.	ICPA 2089 x ICPL 88034	11.06*	-32.89**	-12.50**	-4.55	-15.02**	4.62	-9.62	-33.57**	13.63	-22.07**
11.	ICPA 2089 x ICPL 88039	-9.14	-45.10**	3.33	12.73**	-17.06**	2.10	-14.83*	-37.39**	44.51**	-0.89
12.	ICPA 2089 x ICPL 149	22.26**	-26.13**	0.00	9.09*	-24.23**	-6.72	-10.57	-34.26**	20.72	-17.21*
13.	ICPA 2089 x ICPL 161	2.72	-37.94**	-5.83	2.73	-25.60**	-8.40	-19.08**	-40.52**	32.55**	-9.10
14.	ICPA 2089 x ICPL 81-3	21.53**	-26.57**	-5.00	3.64	-16.72**	2.52	5.05	-22.78**	25.16*	-14.16
15.	ICPA 2089 x ICPL 89	-17.13**	-49.92**	-5.83	2.73	-14.68**	5.04	-23.34**	-43.65**	55.48**	6.63
16.	ICPA 2089 x ICPL 90048	-30.33**	-57.90**	-4.17	4.55	-8.19*	13.03**	-29.26**	-48.00**	-19.92	-45.08**
17.	ICPA 2089 x ICPL 86022	-38.49**	-62.83**	-7.50	0.91	-16.04**	3.36	-47.00**	-61.04**	23.35*	-15.41*

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

Table.3 Continued.....

Sr. No	Crosses	No. of pods per plant		No. of seeds per pod		100 seed wt. (g)		Grain yield Per Plant (g)		Harvest Index (%)	
		SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2	SC 1	SC 2
18.	ICPA 2089 x ICPL 92047	-1.83	-40.68**	-5.83	2.73	-12.97**	7.14	-27.60**	-46.78**	34.86**	-7.51
19.	ICPA 2156 x ICPL 88034	-20.10**	-51.72**	-5.83	2.73	-15.36**	4.20	-34.23**	-51.65**	-0.89	-32.03**
20.	ICPA 2156 x ICPL 88039	-17.31**	-50.04**	0.00	9.09*	-7.85*	13.45**	-19.08**	-40.52**	34.90**	-7.49
21.	ICPA 2156 x ICPL 149	6.41	-35.70**	-6.67	1.82	-17.75**	1.26	-19.08**	-40.52**	49.51**	2.53
22.	ICPA 2156 x ICPL 161	-15.25**	-48.79**	-6.67	1.82	-21.50**	-3.36	-36.59**	-53.39**	43.35**	-1.69
23.	ICPA 2156 x ICPL 81-3	-19.60**	-51.42**	-5.00	3.64	-8.87*	12.18*	-25.28**	-45.08**	40.41**	-3.70
24.	ICPA 2156 x ICPL 89	-25.08**	-54.73**	-4.17	4.55	-7.17	14.29**	-33.28**	-50.96**	-15.1	-41.77**
25.	ICPA 2156 x ICPL 90048	-19.45**	-51.33**	5.00	14.55**	-7.85*	13.45**	-24.29**	-44.35**	61.08**	10.47
26.	ICPA 2156 x ICPL 86022	1.63	-38.59**	-10.00*	-1.82	-16.72**	2.52	-16.24*	-38.43**	19.55	-18.01*
27.	ICPA 2156 x ICPL 92047	2.33	-38.17**	-10.83**	-2.73	-19.45**	-0.84	-16.86*	-38.89**	51.45**	3.87
	SE (d) ±	9.57	9.57	0.16	0.16	0.37	0.37	4.52	4.52	3.14	3.14
	CD at 5 %	19.21	19.21	0.32	0.32	0.73	0.73	9.08	9.08	6.31	6.31
	CD at 1 %	25.60	25.60	0.43	0.43	0.98	0.98	12.1	12.1	8.41	8.41

* - Significant at 5 % level of significance, ** - Significant at 1 % level of significance

The range of standard heterosis was -12.50 to 5 and -4.55 to 14.55 percent over the check VL Arhar1 and ICPL 161 respectively. None of the crosses recorded significant positive heterosis over the check VL Arhar1. Over ICPL 161 maximum significant positive heterosis was registered by ICPA 2156 x ICPL 90048 (14.55%) followed by ICPA 2089 x ICPL 88039 (12.73%). These findings were in agreement with the findings of Patel and Tikka (2008), Sarode *et al.*, (2009), Kumar *et al.*, (2012), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

The range of heterobeltiosis for the trait 100 seed weight is -18.64 to 16.24 percent. Maximum significant positive heterobeltiosis is exhibited by ICPA 2156 x ICPL 89 (-16.24%) followed by ICPA 2156 x ICPL 81-3 (-14.10%). The range of standard heterosis for the trait 100 seed weight was -25.60 to -7.17 and -8.40 to 14.29 percent over the check VL Arhar1 and ICPL 161 respectively. None of the crosses showed significant positive heterosis over the check VL Arhar1. Six crosses recorded significant positive heterosis over the check ICPL161. Maximum significant positive heterosis is manifested by ICPA 2156 x ICPL 89 (14.29%) followed by ICPA 2039 x ICPL 90048 (13.87%) over the check ICPL 161. Heterosis with respect to 100 seed weight in positive and negative direction have also been reported by Wankhade *et al.*, (2005), Baskaran and Muthiah (2006), Patel and Tikka (2008), Sarode *et al.*, (2009), Kumar *et al.*, (2012), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

The ultimate goal of any breeding programme is to develop a high yielding hybrid. The high degree of heterosis for yield need not be due to the high heterosis in all yield contributing characters but may be of heterosis in one or two yield contributing characters even. A wide range of variation in the estimates of

heterobeltiosis and standard heterosis in positive and negative direction was observed for grain yield per plant. For the trait, heterobeltiosis ranged from -55.53 to 83.25%. Nine crosses manifested significant positive heterobeltiosis for this trait. Maximum significant positive heterobeltiosis is manifested by ICPA 2039 x ICPL 90048 (83.25%) followed by ICPA 2156 x ICPL 86022 (47.50%). The range of standard heterosis was -47.00 to 89.28 and -61.04 to 39.13 percent over the checks VL Arhar1 and ICPL 161 respectively. The cross ICPA 2039 x ICPL 161 (89.28%) exhibited significant positive heterosis over the check VL Arhar1 followed by ICPA 2039 x ICPL 90048 (65.62%). Maximum significant positive heterosis is recorded by ICPA 2039 x ICPL 161 (39.13%) over the check ICPL 161 followed by ICPA 2039 x ICPL 90048 (21.74%). These findings were in close agreement with the results of earlier workers Pandey and Singh (2002), Wankhade *et al.*, (2005), Baskaran and Muthiah, (2006), Wanjari *et al.*, (2007), Solanki *et al.*, (2008), Patel and Tikka, (2008), Sarode *et al.*, (2009), Singh and Singh, (2009), Dheva *et al.*, (2009), Bharate *et al.*, (2010), Chandrikala *et al.*, (2010), Vaghela *et al.*, (2011), Gupta *et al.*, (2011), Kumar *et al.*, (2012), Pandey *et al.*, (2013) and Sudhir *et al.*, (2015).

Harvest Index is one of the trait which indirectly influences the grain yield. The range of heterobeltiosis ranged from -40.52 to 36.99 percent for the trait harvest index. Maximum significant positive heterobeltiosis is recorded by ICPA 2089 x ICPL 88039 (36.99%) followed by ICPA 2156 x ICPL 90048 (23.36%). The range of standard heterosis was -19.92 to 61.08 and -45.08 to 10.47 percent over the checks VL Arhar1 and ICPL 161 respectively. Out of 27 crosses, 15 crosses exhibited significant positive heterosis over the check VL Arhar1. Maximum significant positive heterosis manifested by

ICPA 2156 x ICPL 90048 (61.08%) followed by ICPA 2089 x ICPL 89 (55.48%) over the check VL Arhar1. None of the crosses showed significant positive heterosis over the check ICPL 161. The significant positive and negative heterosis for harvest index was also reported by Singh and Singh (2009), Dheva *et al.*, (2009), Bharate *et al.*, (2010), Gupta *et al.*, (2011) and Pandey *et al.*, (2013).

Ultimate aim of breeding is to gain the heterotic yield associated with the other heterotic characters. The estimates of heterosis showed that the crosses ICPA 2039 x ICPL161 and ICPA 2039 x ICPL 90048 had significant standard heterosis for grain yield per plant and some of its components. Exploitation of heterosis in short duration hybrids could pave a way to face the challenge of stagnant productivity in pigeonpea. These short duration hybrids also serve the purpose of getting fit into different agro-ecological niches.

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