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Studies on CGMS Based Short Duration Hybrids of Pigeonpea (*Cajanus cajan* (L.) Millsp.) in Terms of Combining Ability

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A B S T R A C T

To estimate combining ability, twenty seven hybrids were made from 12 parents in a line × tester mating design during *Kharif* 2015-16 and tested in a Randomized block design with three replications during *Kharif* 2016-17. Among these parents ICPL 161 and ICPL 149 had desirable GCA effect for grain yield per plant and its contributing characters. Ten crosses exhibited significant positive SCA effect for grain yield. Out of them most promising crosses in terms of grain yield were ICPA 2039 × ICPL 161, ICPA 2156 × ICPL 86022 and ICPA 2039 × ICPL 90048. On the basis of *per se* performance and combining ability, the parents ICPA 2039, ICPL 88039, ICPL 161 and ICPL 149 can be used for future hybridization programmes.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is an important multipurpose grain legume crop primarily grown in tropical and subtropical areas of Asia, Africa and Latin America. The crop has multiple uses as food, fodder, fuel wood as well as for soil conservation and soil fertility enhancement. In particular, pigeonpea is both a crop and a food of the poor and plays an important role in food security and nutrition for some of the world's most disadvantaged people (Van der Maesen 1990). It also restores soil fertility by fixing atmospheric nitrogen and has the ability to solubilize fixed phosphorus (Ae *et al.*,1990). 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).

Cytoplasmic-genic male sterility has been used since long time to improve the yield level of pigeonpea. This new hybrid pigeonpea technology is capable of substantially increasing the pigeonpea productivity (Saxena and Nadarajan, 2010).

Identifying the parents with good combining ability can boost up the hybrid pigeonpea technology. Therefore, the present investigation was conducted to study the combining ability of three cytoplasmic male sterile lines with nine restorers to identify good general and specific combiners for grain yield and its components.

Materials and Methods

The materials under study comprise of three CMS lines (ICPA 2039, ICPA 2089 and ICPA 2156) and nine testers (ICPL 88034, ICPL 88039, ICPL 149, ICPL 161, ICPL 81-3, ICPL 89, ICPL 90048, ICPL 86022, ICPL 92047). These were crossed in an L × T fashion during the *kharif* 2015-16. The resultant 27 F_1's along with 12 parents were planted in Randomized Block Design with three replications during *kharif* 2016-17. Each of the material under investigation was sown in four rows of four meters length with a spacing of 75 × 25 cm between row to row and plant to plant respectively. Recommended and timely agronomic practices were taken up. Observations were recorded on five randomly selected plants for the traits *viz.*,Plant height, 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, grain yield per plant, harvest index. The general combining ability (GCA) and specific combining ability (SCA) variances were worked out as per the method given by Kempthorne (1957).

Results and Discussion

In the Table 1, the analysis of variances of the study is presented. The genotypes were found highly significant for all the traits which indicated that the treatments used in this study were significantly different from each other. The mean sum of squares (MSS) of the treatments was further partitioned into parent, cross and parents vs crosses. The results showed that all the parameters for parent, cross and parents vs crosses were found significant for plant height, days to 50% flowering, pollen fertility, days to maturity, number of secondary branches per plant, number of pods per plant, 100 seed weight, grain yield per plant and harvest index. 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 and 100 seed weight indicating 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 indicating the importance of general combining ability and additive gene effects. The mean sum of squares due to line × 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.

The proportional contribution of lines, testers, and line × testers for various characters are presented in Table 2. The data revealed that contribution of line × tester was higher than both lines and testers for characters pollen fertility (61.33%), days to maturity (51.05%), number of primary branches per plant (45.64%), number of secondary branches per plant (45.64%), number of seeds per pod (55.62%), grain yield per plant (41.23%) and harvest index (65.98%) indicating the preponderance of non-additive gene action for these characters. The contribution of tester was highest for plant height (41.13%) and 100 seed weight (51.94%) than line and line × tester. The contribution of lines was more than testers and line × tester for the character days to 50% flowering (53.07%) and number of pods per plant (43.97%) indicated that the concerned characters were influenced by additive gene action.

Combining ability analysis

Investigation of GCA effects (Table 3) revealed that the parents ICPA 2039 among lines, ICPL 161, ICPL 149, and ICPL 90048 among testers were the good general combiners for yield and most of the yield contributing characters. Hence these good general combiners of males and females may be extensively used in future for pigeonpea breeding programmes. The negative GCA effect was desirable in days to 50 % flowering, days to maturity, which was observed in ICPA 2089, ICPA 2156 among lines and among testers it was observed in ICPL 88039. Among these parents, ICPL 161 and ICPL 149 had desirable GCA effect for grain yield per plant, plant height, number of secondary branches per plant, number of pods per plant, number of seeds per pod and harvest index. In general, good general combiners for grain yield also had good or average combining ability for one or more yield components. The GCA effects of lines and testers have been depicted in the graph 1 and 2. In most of the parents high GCA effects were associated with high *per se* mean for yield and yield components. It is important to mention here that the parents which showed good GCA effects for grain yield per plant also indicated significantly positive GCA effects for number of pods per plant. The results are in corroborance with the findings of Banu *et al.*, (2006), Kumar *et al.*, (2009), Vaghela *et al.,* (2009), Shoba and Balan (2010) and Sudhir *et al.*, (2017).

Specific combining ability effect is the index to determine usefulness of a particular combination in the exploitation of heterosis. The estimate of SCA effects of the hybrids are presented in Table 4. For the trait plant height, the cross ICPA 2089 × ICPL 149 and ICPA 2039 × ICPL 149 exhibited significant negative SCA effects. For days to 50% flowering and days to maturity negative SCA effects are desirable. Only one cross ICPA 2039 × ICPL 88039 recorded significant negative SCA effect over both the traits. Only one cross recorded significant positive SCA effect for number of primary branches per plant *viz.*, ICPA 2039 × ICPL 81-3. For the trait number of secondary branches per plant, only one cross showed significant positive SCA effect *viz.*, ICPA 2156 × ICPL 88039.

Eight crosses exhibited significant positive SCA effect for pollen fertility. Maximum significant positive SCA effect was shown by ICPA 2156 × ICPL 89 followed by ICPA 2156 × ICPL 161. These results are in agreement with Wanjari *et al.*, (2007).

For the trait number of pods per plant twelve crosses exhibited significant positive SCA effects. Maximum significant positive SCA effect was registered by ICPA 2039 × ICPL 161 followed by ICPA 2156 × ICPL 86022. Only one cross recorded significant positive SCA effect *viz.*, ICPA 2156 × ICPL 90048 for the trait number of seeds per pod. For the trait 100 seed weight, three crosses exhibited significant positive SCA effects. Maximum significant positive SCA effect was registered by the cross ICPA 2089 × ICPL 92047.

Ten crosses exhibited significant positive SCA effect for grain yield. Most promising crosses in the order of their merit are ICPA 2039 × ICPL 161 (35.63), ICPA 2156 × ICPL 86022 (22.53), ICPA 2039 × ICPL 90048 (24.02), ICPA 2089 × ICPL 81-3 (15.01), ICPA 2089 × ICPL 89 (11.56), ICPA 2039 × ICPL 149 (8.85), ICPA 2156 × ICPL 88039 (8.37), ICPA 2156 × ICPL 89 (8.37) and ICPA 2156 × ICPL 92047 (7.86) for grain yield per plant.

Table.1 ANOVA for line × tester analysis

Sources of variation	d. f.	Mean sum of squares										
		Plant height (cm)	**Days to 50 % flowering**	**Pollen fertility (%)**	**Days to maturity**	**No. of primary branches/ plant**	**No. of secondary branches /plant**	**No. of pods / plant**	**No. of seeds / pod**	**100 seed weight (g)**	**Grain yield / plant (g)**	**Harvest Index (%)**
Treatment	38	638.77**	79.87**	2046.23**	126.53**	1.58*	6.84**	17430.13**	0.08**	0.94**	1430.75**	113.93**
Replications	2	123.96	14.80	1.70	40.26	2.05	2.78	384.34	0.04	0.06	11.36	0.89
Parent (P)	11	459.42**	132.94**	6007.32**	217.90**	3.30**	4.24*	18128.51**	0.11**	1.27**	1307.45**	113.83**
Crosses (C)	26	525.90**	57.12**	65.41**	60.61**	0.79	7.25**	17538.31**	0.07	0.81**	1518.42**	117.19**
Parents vs crosses	1	5546.48**	87.48**	9975.72**	835.56**	3.22**	25.03**	6935.13**	0.01	0.61	507.67**	30.23
Line	2	2552.01**	394.16**	168.10	202.31*	1.27	25.76**	100271.93**	0.02	0.88	7695.10**	189.37**
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 xTester	16	184.05**	20.98**	65.19**	50.28**	0.58	4.61	8996.00**	0.06	0.52*	1017.57**	125.65**
Error	76	45.19	5.51	6.04	19.56	0.85	2.18	137.55	0.04	0.20	30.72	14.85

* - 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 Proportional contribution of lines, testers and line × tester

Sr. No.	Characters	Line (%)	Tester (%)	Line × tester (%)
1.	Plant height (cm)	37.32	41.13	21.53
2.	Days to 50% flowering	53.07	24.32	22.06
3.	Pollen fertility (%)	21.14	14.40	64.44
4.	Days to maturity	25.67	23.27	51.05
5.	Number of primary branches / plant	12.38	41.96	45.64
6.	Number of secondary branches / plant	27.33	33.55	39.11
7.	Number of pods/ plant	43.97	24.45	31.56
8	Number of seeds / pod	2.21	42.16	55.62
9.	100 seed weight (g)	8.42	51.94	39.63
10.	Grain yield / plant (g)	38.98	19.77	41.23
11.	Harvest Index (%)	12.42	21.58	65.98

Table.3 General combining ability of parents in pigeonpea

Sr. No	Parents	Plant height (cm)	Days to 50 % flowering	Pollen fertility (%)	Days to maturity	No. of primary branches / plant	No. of secondary branches / plant	No. of pods per plant	No. of seeds / pod	100 seed wt. (g)	Grain yield / plant (g)	Harvest Index (%)
	Female parents											
1.	ICPA 2039	11.02**	4.40**	1.79**	2.95**	0.23	0.83**	69.84**	-0.03	-0.11	19.37**	-2.90**
2.	ICPA 2089	-7.35**	-2.53**	-2.85**	-2.46**	-0.20	0.25	-27.44**	0.02	-0.10	-7.78**	0.61
3.	ICPA 2156	-3.68**	-1.86**	1.06**	-0.49	-0.04	-1.08**	-42.40**	0.01	0.21*	-11.59**	2.29**
	Male parents											
4.	ICPL 88034	0.52	-0.68	0.86	-3.01*	-0.20	1.15*	13.31**	-0.10	-0.01	2.13	-5.70**
5.	ICPL 88039	-10.75**	-2.46**	-1.22	-2.79*	-0.34	0.03	-35.36**	0.19*	0.14	-4.20*	2.85*
6.	ICPL 149	15.63**	2.99**	2.48**	2.21	-0.24	-1.05	50.95**	0.03	-0.31	9.68**	2.37*
7.	ICPL 161	4.97*	2.77**	-1.46*	2.65	0.09	1.11*	57.45**	-0.03	-0.53**	13.91**	2.68*
8.	ICPL 81-3	8.63**	2.43**	-0.48	1.32	0.48	0.53	-0.38	-0.02	0.26	2.34	0.38
9.	ICPL 89	-9.03**	-0.90	-3.34**	-0.57	0.34	0.49	-50.69**	-0.01	0.16	-14.20**	-3.66**
10.	ICPL 90048	-5.75*	-0.35	0.67	2.32	0.45	-0.08	-0.01	0.13*	0.77**	8.85**	-1.56
11.	ICPL 86022	-6.70**	3.12**	3.50**	-2.12	-0.29	-1.58**	-48.26**	-0.09	-0.17	-16.37**	1.60
12.	ICPL 92047	2.48	-0.68	-1.00	-0.01	-0.31	-0.59	12.98**	-0.09	-0.32*	-2.13	1.03
	SE $\pm$ Gi (line)	1.29	0.49	0.009	0.82	0.17	0.31	2.30	0.04	0.09	1.04	0.68
	SE $\pm$ Gj (tester)	2.23	0.85	0.016	1.42	0.30	0.54	3.98	0.07	0.16	1.81	1.18

* - 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.4 Specific combining ability of crosses in pigeonpea

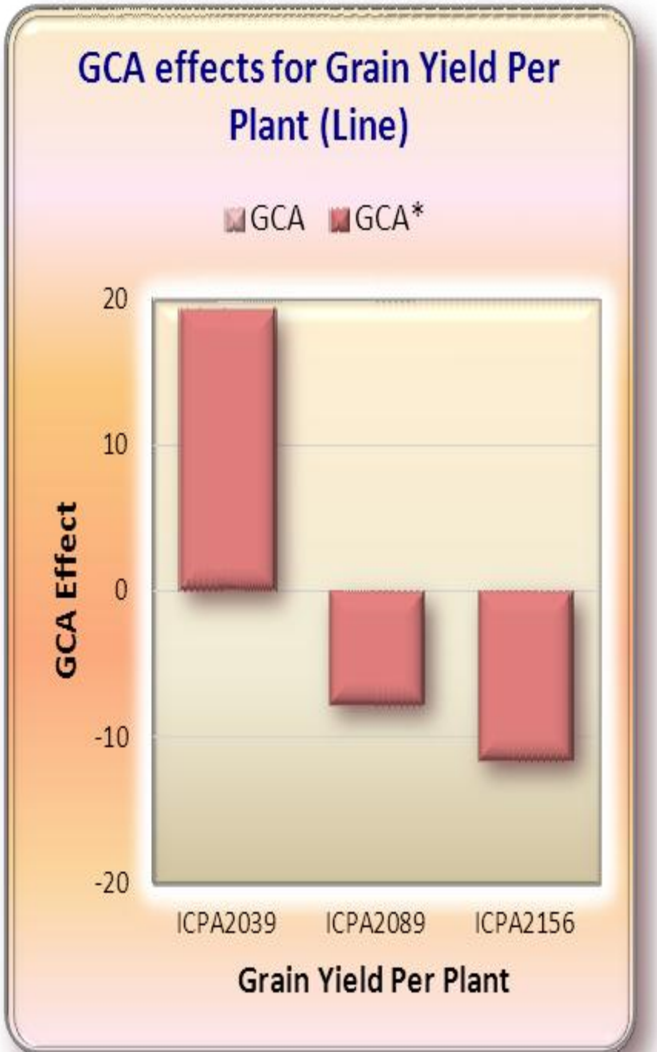
Sr. No	Crosses	Plant height (cm)	Days to 50 % flowering	Pollen fertility (%)	Days to maturity	No. of primary branches / plant	No. of secondary branches / plant	No. of pods / plant	No. of seeds / pod	100 seed wt. (g)	Grain yield / Plant (g)	Harvest Index (%)
1.	ICPA2039 × ICPL88034	-6.69	-2.28	0.06	-4.51	-0.18	-1.97*	12.25	0.14	-0.01	3.74	1.10
2.	ICPA2039 × ICPL88039	-2.76	-4.84**	4.09**	-7.06**	-0.07	1.25	50.15**	-0.15	-0.25	-15.92**	-0.55
3.	ICPA2039 × ICPL149	8.20*	1.05	-0.26	4.27	-0.07	-0.11	11.87	-0.06	0.53*	8.85**	1.07
4.	ICPA2039 × ICPL161	7.86*	0.27	-0.68	0.83	-0.20	-0.56	107.55**	0.04	0.58*	35.63**	0.09
5.	ICPA2039 × ICPL81-3	2.53	1.94	3.14*	3.49	1.04*	-0.58	-37.13**	-0.04	0.06	-12.47**	-1.60
6.	ICPA2039 × ICPL89	0.86	0.94	-7.06**	1.72	-0.49	0.15	-49.18**	-0.01	-0.51	-19.92**	-2.60
7.	ICPA2039 × ICPL90048	-6.56	3.38*	-0.81	2.83	0.37	1.51	67.37**	-0.16	0.15	24.02**	1.40
8.	ICPA2039 × ICPL86022	-9.47*	-1.17	-2.45*	0.27	-0.30	0.83	-55.05**	0.13	-0.11	-19.59**	7.22**
9.	ICPA2039 × ICPL92047	6.02	0.72	3.96**	-1.84	-0.10	-0.53	-7.55	0.10	-0.43	-4.34	-6.13**
10.	ICPA2089 × ICPL88034	-0.99	-0.02	3.04*	1.23	0.07	-0.59	17.66*	-0.21	0.17	4.89	2.33
11.	ICPA2089 × ICPL88039	2.15	-0.91	4.23**	0.35	0.09	-0.41	25.80**	0.14	-0.17	7.56*	2.47
12.	ICPA2089 × ICPL149	7.90*	-0.69	-0.08	-4.65	0.24	0.94	2.48	0.16	-0.43	-3.33	-3.74
13.	ICPA2089 × ICPL161	-5.43	0.53	-4.04**	2.23	-0.10	0.35	-43.23**	-0.01	-0.34	-13.55**	-0.72
14.	ICPA2089 × ICPL81-3	-2.10	-1.80	-4.62**	-1.10	-0.49	0.45	52.35**	0.02	-0.26	15.01**	-0.51
15.	ICPA2089 × ICPL89	-1.10	1.20	0.01	-0.54	0.34	-0.01	25.10**	-0.03	0.04	11.56**	12.08**
16.	ICPA2089 × ICPL90048	6.28	-0.69	2.09	1.57	-0.62	0.38	52.08**	-0.11	0.06	-15.67**	-11.26**
17.	ICPA2089 × ICPL86022	2.90	2.09	3.13*	-2.65	0.29	-0.66	-20.20**	-0.02	0.24	-2.94	-2.23

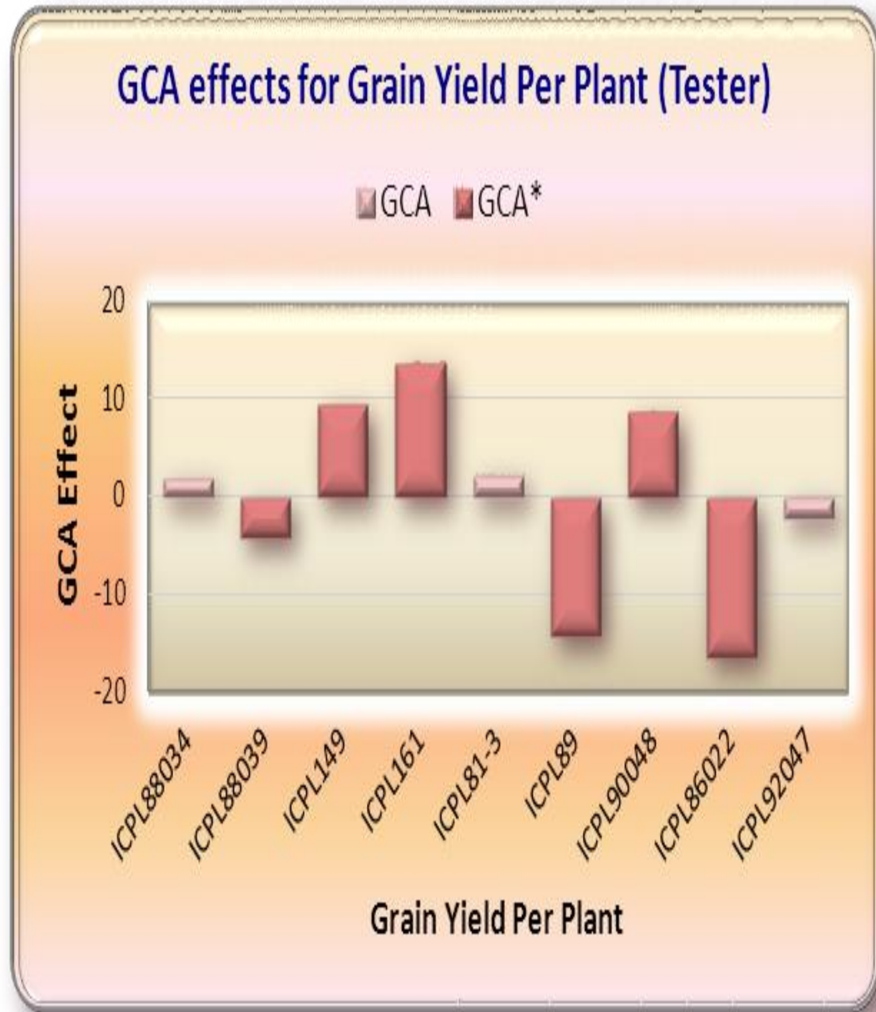
Table.4 Continued……

Sr. No	Crosses	Plant height (cm)	Days to 50 % flowering	Pollen fertility (%)	Days to maturity	No. of primary branches / plant	No. of secondary branches / plant	No. of pods / plant	No. of seeds / pod	100 seed wt. (g)	Grain yield / Plant (g)	Harvest Index (%)
18.	ICPA2089 × ICPL92047	-9.61*	0.31	-3.76**	3.57	0.16	-0.45	-7.87	0.05	0.68*	-3.52	1.57
19.	ICPA2156 × ICPL88034	7.68*	2.31	-3.10*	3.27	0.11	2.57**	-29.91**	0.06	-0.16	-8.63**	-3.44
20.	ICPA2156 × ICPL88039	0.61	5.75**	-8.32**	6.72**	-0.02	-0.84	24.35**	0.01	0.42	8.37**	-1.92
21.	ICPA2156 × ICPL149	-16.10**	-0.36	0.34	0.38	-0.18	-0.83	-14.36*	-0.10	-0.10	-5.52	2.67
22.	ICPA2156 × ICPL161	-2.43	-0.80	4.72**	-3.06	0.30	0.21	-64.32**	-0.04	-0.24	-22.08**	0.63
23.	ICPA2156 × ICPL81-3	-0.43	-0.14	1.47	-2.40	-0.55	0.13	-15.23*	0.02	0.20	-2.54	2.10
24.	ICPA2156 × ICPL89	0.23	-2.14	7.05**	-1.17	0.15	-0.14	24.09*	0.04	0.47	8.37**	-9.48**
25.	ICPA2156 × ICPL90048	0.28	-2.69	-1.28	-4.40	0.24	-1.90*	-15.29*	0.26*	-0.21	-8.35**	9.86**
26.	ICPA2156 × ICPL86022	6.57	-0.91	-0.68	2.38	0.01	-0.17	75.25**	-0.11	-0.13	22.53**	-4.99**
27.	ICPA2156 × ICPL92047	3.59	-1.02	-0.20	-1.73	-0.06	0.98	15.42*	-0.15	-0.25	7.86*	4.56*
	SEij	3.87	1.47	0.12	2.46	0.53	0.95	6.90	0.13	0.27	3.14	2.05
	C.D. 5%	7.78	2.72	2.37	5.12	1.07	1.71	13.59	0.23	0.52	6.42	4.46

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

Graph.1 and 2 Graphs showing the GCA effects of lines and testers for the trait grain yield / plant





For the trait harvest index four crosses recorded significant positive SCA effects. Maximum significant positive SCA effect was exhibited by ICPA 2089 × ICPL 89 followed by ICPA 2156 × ICPL 90048. These results are in agreement with the findings of Shoba and Balan (2010) and Gupta *et al.*, (2011).

This study clearly indicated that there was no particular relationship between positive and significant SCA effects of crosses with GCA effects of their parents for all the characters under study. This was in agreement with the findings of Pandey *et al.*, (2014) and Sudhir *et al.*, (2017).

In crop improvement programme specific combining ability is important to pinpoint specific cross combination for commercial exploitation or varietal development. On the basis of *per* se performance and combining ability, the parents ICPA 2039, ICPL 88039, ICPL 161 and ICPL 149 can be used for future hybridization programmes. Promising crosses exhibiting significant positive SCA effect *viz.*, ICPA 2039 × ICPL 161, ICPA 2156 × ICPL 86022 and ICPA 2039 × ICPL 90048 for grain yield/plant may be considered for the hybrid breeding programme.

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