



## Heterosis and Combining Ability Studies by Line x Tester Analysis in Pigeonpea (*Cajanus cajan* (L.) Millsp.)

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### ABSTRACT

In a line x tester study significant heterosis over check variety LRG-30 was exhibited by the crosses viz., ICPL-15225 x ICPL-8863, LRG-41 x ICPL-87119 and LRG-41 x PRG-158 for seed yield and its attributing traits i.e., pods per plant, seeds per pod, pod length and 100-seed weight. The total genetic variation was found due to non-additive type of gene action for all characters. GCA effects revealed that among the lines ICPL-15225 and LRG-41, while in testers ICPL-87119 and ICPL-8863 can be considered as good general combiners for most of the traits. The hybrid combinations viz., ICPL-15225 x ICPL-8863, LRG-41 x PRG-158 and ICPL-15225 x ICPL-87119 exhibited significant *sca* effects coupled with high *per se* performance for yield and yield attributes. These cross combinations can be potentially utilized in future breeding programmes.

**Key words :** Combining ability, Heterosis, Pigeonpea.

Combining ability analysis helps to choose suitable parents for hybridization and provides valuable information regarding cross combinations to be exploited commercially. Pigeonpea is an often-cross pollinated crops and also has a substantial amount of non-additive genetic variance and hybrid vigour for seed yield (Shrivastava *et al.*, 1976) which can profitably be exploited through heterosis breeding. This study aims to determine the extent of heterosis and combining ability for yield and yield traits.

### MATERIAL AND METHODS

The present study involved twenty four genotypes (five lines, three testers, their respective crosses via line x tester mating design and one local check LRG-30). The crossing programme was conducted in 2009 *kharif* and the experimental material along with parents were raised in 2010 *kharif* at Dry Land Farm, Regional Agricultural Research Station, Tirupati. Each entry was grown in three rows of 4m length with 150 x 30 cm spacing in each plot. From each plot, fifteen competitive plants were selected randomly for recording the observations in 14 characters. Data were subjected to analysis of combining ability (Kempthorne, 1957) and heterosis estimates .

### RESULTS AND DISCUSSION

The analysis of variance for combining ability in Table 1 revealed the presence of considerable variability for majority of characters among the lines than in testers and substantial variability for most of characters among hybrids. High significant variances due to line x tester interaction component indicated differential behaviour of lines with testers across the characters. Predominance of non-additive gene action for all the characters was noticed from the ratio of *gca* / *sca* variance suggesting good scope for heterotic breeding and the ratio of variance due to additive and dominance components indicated the predominance of dominance gene action in the genetic control of all the characters except plant height and primary branches per plant (Table 2). The above findings are in agreement with the earlier reports of Sunilkumar *et al.* (2003), Sekhar *et al.* (2004) and Sameer Kumar *et al.* (2009). The greater contribution of lines to the performance of crosses was maximum in respect of all the characters except seed protein and phenol content, which were contributed highly by the line x tester interaction (Table 2).

Higher magnitude of standard heterosis in positive direction was expressed for seed yield per plant and major yield attributing traits i.e., pods per

Table 1. Analysis of variance for combining ability in Line x Tester experiment for 14 characters in pigeonpea.

Source of variation	Df	Days to flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Pods per plant	Seeds per pod	Pod length (cm)	100-seed weight (g)	Harvest index(%)	SCMR at vegetative phase	Seed protein(%)	Phenol content(%)	Seed yield per plant (g)
Replications	2	2.17	24.28	913.23	3.88	127.17	38551.04*	0.02	0.26	6.78**	0.44	0.29	0.08*	0.06	3498.80*
Treatments	22	246.37*	385.53**	2052.90**	53.13**	297.99**	368227.71**	0.66**	1.59**	17.27**	45.87**	15.79**	3.02**	4.63**	23150.45**
Parents	7	376.00**	530.55**	3146.29**	53.88**	436.76**	81436.74**	1.50**	2.63**	35.43**	100.58**	16.15**	3.89**	5.33**	5128.09**
Parents vs crosses	1	12.68	633.39**	1098.67	19.91	154.49	933948.50**	0.0031	0.30	5.076*	11.91	49.96**	3.52**	36.97**	50596.44**
Crosses	14	198.25**	295.32**	1574.38**	55.14**	238.87**	471214.66**	0.29**	1.18**	9.08**	20.94**	13.17**	1.14**	1.98**	30201.21**
Lines	4	341.59*	855.55**	3827.09*	104.70*	622.42**	1024174.69	0.68*	2.58*	23.83*	65.49**	25.88	0.68	1.26	64029.73
Testers	2	436.21*	144.81	589.56	107.02*	88.87	161709.33	0.01	1.03	1.49	0.30	0.29	2.35	1.94	12175.26
Line x Tester	8	67.09**	52.83**	694.22	17.38	84.59	272111.00**	0.17*	0.51**	3.60**	3.83	10.04**	1.07**	2.35**	17793.44**
Error	44	3.64	7.70	449.20	10.55	50.36	11859.10	0.07	0.11	0.99	4.45	1.23	0.02	0.04	983.07

\* Significant at 5% level

\*\* Significant at 1% level

plant, seeds per pod, pod length and 100-seed weight by the cross combinations viz., ICPL-15225 X ICPL-8863, LRG-41 x ICPL-87119 and LRG-41 x PRG-158 (Table 3). High heterotic performance was exhibited by the cross combinations viz., ICPL-15225 x ICPL-87119, ICPL-15225 x ICPL-8863 and LRG-41 x PRG-158 over better parent for seed yield. The magnitude of standard heterosis for pods per plant was very high in cross combinations involving the lines ICPL-15225, ICPL-6974 and LRG-41 as parents, which showed high positive heterosis values for seed yield and most of the yield attributing traits, indicating that it is the most important trait. The desirable negative significant heterosis values were expressed for days to maturity and days to flowering for almost all crosses.

The general combining ability (*gca*) effects of parents revealed that, among the lines, the genotype LRG-41 was found to be a good general combiner for plant height, primary and secondary branches per plant, pods per plant, pod length and seed yield per plant. ICPL-15225 was a good combiner for pods per plant, seeds per pod, harvest index, protein content and seed yield. ICPL-7035 was a good combiner for seeds per pod, pod length, 100-seed weight and SCMR at vegetative phase. ICPL-6974 was the best combiner for earliness, while ICPL-2376 was found to be a good combiner not only for earliness but also for protein content and phenol content. Among the testers, ICPL-8863 was a good general combiner for earliness, pod length, seed protein and phenol content. ICPL-87119 was a good combiner for primary branches per plant, pods per plant, phenol content and seed yield per plant (Table 4). Among the lines, ICPL-15225 and LRG-41, while among the testers ICPL-87119 and ICPL-8863 can be considered as good general combiners for seed yield and most of its component traits and can be used extensively in hybridization programme.

The specific combining ability (*sca*) effects were considered to be the best criteria for selection of superior hybrids (Table 5). In the present study, the parents involving in crosses, ICPL-15225 x ICPL-8863 and ICPL-15225 x ICPL-87119 (pods per plant and seed yield per plant), ICPL-7035 x ICPL-8863 (pod length and SCMR at vegetative phase), ICPL-7035 x ICPL-87119 (100-seed weight), ICPL-15225 x ICPL-87119 (seed protein) and ICPL-2376 x ICPL-8863 and LRG-41 x ICPL-87119 (phenol content) had high *gca* effects and produced high *sca* effects. These crosses involved high x high or high x moderate parental *gca* combinations indicating the

Table 2. Magnitude of genetic variance due to general and specific combining ability and proportionate contribution of lines, testers and line x tester interaction towards total variance in hybrids (in per cent) for 14 characters of pigeonpea

S.No.	Character	s <sup>2</sup> gca	s <sup>2</sup> sca	s <sup>2</sup> gca/ s <sup>2</sup> sca	Lines	Testers	Line x Tester interaction
1	Days to flowering	4.64	21.15	0.22	49.23	31.43	19.34
2	Days to maturity	8.57	15.04	0.57	82.77	7.01	10.22
3	Plant height	31.12	81.67	0.38	69.45	5.35	25.20
4	Primary branches per plant	1.33	2.28	0.59	54.26	27.73	18.02
5	Secondary branches per plant	5.45	11.41	0.48	74.45	5.31	20.24
6	Pods per plant	7039.02	86750.63	0.08	62.10	4.90	33.00
7	Seeds per pod	0.00	0.03	0.13	66.53	0.47	33.00
8	Pod length (cm)	0.02	0.14	0.17	62.68	12.46	24.86
9	100-seed weight (g)	0.19	0.87	0.22	75.00	2.34	22.66
10	Harvest index (%)	0.61	-0.21	-2.90	89.35	0.21	10.44
11	SCMR at vegetative phase	0.11	2.94	0.04	56.14	0.32	43.54
12	Seed protein (%)	0.00	0.35	0.00	16.99	29.44	53.57
13	Phenol content (%)	-0.01	0.77	-0.01	18.19	14.02	67.79
14	Seed yield per plant (g)	438.66	5603.46	0.08	60.57	5.76	33.67

major role of additive x additive gene action in the expression of these traits.

The cross combinations involving parents with high x low and low x high *gca* effects also produced significant *sca* effects. It was observed in the crosses *viz.*, ICPL-6974 x PRG-158, ICPL-7035 x PRG-158, ICPL-2376 x ICPL-87119 and LRG-41 x ICPL8863 (days to 50 per cent flowering), ICPL-6974 x ICPL-87119 and ICPL-15225 x ICPL-8863 (days to maturity), LRG-41 x ICPL8863 (primary branches per plant), LRG-41 x PRG-158 (pods per plant), ICPL-15225 x ICPL-8863 (pod length), ICPL-6974 x ICPL-87119 (SCMR at vegetative phase), five crosses for seed protein, six crosses for phenol content and LRG-41 x PRG-158 (seed yield per plant). The high *sca* effects of high x low combinations indicating the operation of additive x dominance gene effects and could be used in heterosis breeding. In some of the crosses, high significant *sca* effects were observed in the crosses of poor x poor general combiners indicating the operation of non-additive gene effects in them. They were ICPL-15225 x PRG-158 (days to 50 per cent

flowering), ICPL-6974 x PRG-158 (pod length and 100-seed weight), ICPL-15225 x PRG-158 (SCMR at vegetative phase) and ICPL-6974 x PRG-158 and ICPL-7035 x ICPL-87119 (seed protein).

In the present study, critical evaluation of standard heterosis and *sca* effects of crosses, indicated ICPL-6974 x ICPL-87119, ICPL-6974 x ICPL-87119, ICPL-2376 x ICPL-8863 and ICPL-2376 x ICPL-87119 were the promising crosses for days to flowering, days to maturity, primary branches per plant and phenol content, while LRG-41 x ICPL-8863 and ICPL-15225 x ICPL-87119 for plant height, primary branches per plant and pod length. Whereas ICPL-7035 x ICPL-8863 and ICPL-15225 x ICPL-8863 for pod length, seeds per pod, 100-seed weight and SCMR at vegetative phase. Similarly, the crosses *viz.*, ICPL-15225 x ICPL-8863, ICPL-15225 x ICPL-87119, LRG-41 x PRG-158 were found to be most rewarding for the traits, pods per plant, harvest index, seed protein and seed yield. Finally it was suggested that inter-mating of superior segregants in future generation followed by recurrent selection or multiple crossing in a judicious approach to

Table 3. Heterosis over better parent (BP) and standard check (SC) for yield and yield components in a 5x3 line x tester analysis of pigeonpea.

Crosses	Days to flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Pods per plant	Seeds per pod	Podlength (cm)	100-seed weight (g)	Harvest index(%)	SCMR at vegetative phase	Seed protein(%)	Phenol content(%)	Seed yield per plant (g)
ICPL-6974 x BP	16.15**	-16.11**	-8.00	-7.35	-31.63	16.76	-3.57	-5.47	24.00*	-22.94**	0.78	-4.25**	26.18**	-1.01
ICPL-87119 SC	-8.89**	-23.48**	-1.04	75.00**	28.85	179.61**	2.08	-6.65	-14.29*	23.70*	-0.47	4.16**	33.65**	110.73**
ICPL-6974 x BP	3.78*	-9.28**	-11.63	0.00	-43.48*	-12.98	-3.57	1.10	20.00*	-0.96	-6.96**	0.09	1.21	-26.22
ICPL-8863 SC	-18.60**	-21.15**	3.71	38.89	0.00	103.68**	2.08	-3.09	12.50	26.96*	-8.12**	8.88**	7.20*	42.49
ICPL-6974 x BP	7.22**	-17.21**	7.97	-12.24	14.81	31.19	3.57	5.49	44.00**	32.03**	-4.85*	-2.53**	-4.43	48.08
PRG-158 SC	-15.90**	-23.30**	-1.48	19.44	19.23	138.55**	9.64	3.75	-7.69	42.39**	-6.04**	6.03**	1.23	82.40*
ICPL-15225 x BP	3.43*	0.77	1.38	-1.47	-14.29	132.64**	-8.45	-13.69**	44.00**	-18.91**	2.51	6.57**	23.14**	123.39**
ICPL-87119 SC	-2.43	-6.63**	9.05	86.11**	61.54	457.11**	22.87**	2.96	0.00	65.10**	-5.42*	7.91**	20.32**	375.54**
ICPL-15225 x BP	11.97**	-8.32**	-7.33	6.00	8.70	163.63**	-4.23	5.08	56.00**	-19.35**	0.49	8.39**	34.51**	160.00**
ICPL-8863 SC	-6.74**	-15.05**	8.75	47.22*	92.31**	517.11**	28.54**	25.35**	-12.82*	64.21**	-5.03*	10.29**	21.60**	402.15**
ICPL-15225 x BP	-1.43	-5.61**	15.57	0.00	14.81	5.35	-21.13**	-17.99**	36.00**	-24.97**	7.13**	0.50	-4.37	5.28
PRG-158 SC	-7.01**	-12.54**	-6.38	36.11	19.23	91.58*	5.86	-2.17	-20.97**	52.75**	-0.09	3.04**	-1.97	36.91
ICPL-7035 x BP	-5.22**	-2.36	-24.00**	-29.41*	-28.57	-44.51**	-19.75**	-17.77**	96.00**	-14.92*	11.47**	4.97**	9.39**	-43.75**
ICPL-87119 SC	-7.01**	-10.93**	-18.25*	33.33	34.62	32.89	22.87**	17.58**	-29.03**	36.58**	2.85	6.28**	6.88*	19.74
ICPL-7035 x BP	1.94	-7.13**	-28.45**	-42.00*	-55.43**	-38.67*	-20.99**	-4.79	76.00**	-1.31	17.91**	4.48**	74.74**	-37.11*
ICPL-8863 SC	-15.09**	-15.95**	-16.02*	-19.44	-21.15	43.55	20.98**	36.14**	-38.71**	38.54**	11.43**	6.31**	26.19**	21.46
ICPL-7035 x BP	2.22	-5.61**	10.98	-36.73*	-12.96	-43.42*	-19.75**	-20.07**	52.00**	-5.02	9.03**	-1.41**	-6.09*	-29.97
PRG-158 SC	-0.54	-12.54**	-13.06	-13.89	-9.62	2.89	22.87**	14.29**	-11.43	33.34**	1.69	1.09*	-3.73	-13.73
ICPL-2376 x BP	5.39**	-9.63**	-3.03	-7.35	-5.10	-33.02*	0.93	6.20	24.00*	-26.51**	-2.21	6.39**	10.97**	-42.34**
ICPL-87119 SC	-15.63**	-17.56**	4.30	75.00**	78.85*	60.39	3.02	4.87	-8.57	17.97	2.47	7.73**	8.43**	22.75
ICPL-2376 x BP	0.34	-6.80**	-29.71**	-3.92	-50.00**	-37.66*	4.76	3.43	28.00**	-14.42	-8.70**	3.14**	49.17**	-43.56*
ICPL-8863 SC	-19.68**	-19.00**	-17.51*	36.11	-7.69	45.92	3.97	-0.86	-3.13	9.70	-4.34*	4.94**	33.81**	9.01
ICPL-2376 x BP	12.12**	-10.06**	-8.00	-11.76	-34.38	-16.79	9.26	-1.34	24.00*	14.93	-3.47	5.23**	31.27**	-6.62
PRG-158 SC	-10.24**	-16.67**	-11.28	25.00	21.15	51.32	11.53	-2.96	0.00	12.79	1.15	7.89**	34.56**	15.02
LRG-41 x BP	-1.37	-6.25**	-1.10	-10.29	-0.93	47.42**	2.56	-0.28	40.00**	-16.20*	-0.16	1.03*	2.38	16.53
ICPL-87119 SC	-2.96*	-8.60**	6.38	69.44**	103.85**	253.03**	13.42*	16.13**	0.00	34.52**	-2.25	3.09**	23.68**	148.07**
LRG-41 x BP	5.18**	-10.29**	-7.71	35.09*	17.76	-13.60	4.27	2.15	40.00**	13.36	4.10	5.74**	-8.21**	-2.44
ICPL-8863 SC	-12.40**	-12.54**	8.31	113.89**	142.31**	102.24**	15.31*	18.96**	0.00	45.31**	1.92	7.89**	10.88**	88.41*
LRG-41 x BP	3.60**	-5.70**	5.37	-5.26	8.41	109.68**	4.27	-0.17	36.00**	25.52**	-0.71	1.40**	-3.36	102.04**
PRG-158 SC	0.81	-8.06**	4.75	50.00*	123.08**	290.66**	15.31*	16.26**		45.07**	-2.79	3.97**	16.75**	197.42**

\* Significant at 5% level

\*\* Significant at 1% level

Table 4. Estimates of general combining ability (*gca*) effects in parents for seed yield and yield components of pigeonpea.

Parents	Days to flowering maturity (cm)	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Pods per plant	Seeds per pod	Pod length (cm)	100-seed weight (g)	Harvest index (%)	SCMR at vegetative phase (%)	Seed Protein content (%)	Phenol content (%)	Seed yield per plant (g)
<b>LINES</b>													
ICPL-6974	-6.16**	6.84	-0.04	-5.16*	-44.13	-0.31**	-0.58**	-1.11**	-0.88	-1.73**	0.09	-0.12	-19.69
ICPL-15225	5.07**	14.51*	1.4	2.07	499.64**	0.20*	-0.03	0.22	3.80**	-1.14**	0.27**	-0.17*	130.20**
ICPL-7035	2.40**	-29.49**	-5.38**	-7.71**	-333.36**	0.31**	0.67**	2.67**	-0.07	2.67**	-0.34**	-0.39**	-73.58**
ICPL-2376	-7.04**	-12.38	0.07	-2.60	-267.24**	-0.25**	-0.46**	-1.44**	-3.64**	0.27	0.21**	0.60**	-68.58**
LRG-41	5.73**	20.51**	3.96**	13.40**	145.09**	0.05	0.39**	-0.33	0.79	-0.07	-0.24**	0.07	31.64**
SE (g <sub>j</sub> )	0.64	7.06	1.08	2.37	36.30	0.09	0.11	0.33	0.70	0.37	0.05	0.07	10.45
<b>TESTERS</b>													
ICPL-87119	2.60**	6.16	2.76**	2.73	97.71**	-0.02	-0.12	0.24	-0.16	0.13	-0.03	0.16**	24.44**
ICPL-8863	-6.20**	0.22	-0.18	-0.80	11.31	0.03	0.30**	0.11	0.05	0.02	0.41**	0.25**	6.84
PRG-158	3.60**	-6.38	-2.58**	-1.93	-109.02**	-0.01	-0.18*	-0.36	0.11	-0.15	-0.38**	-0.41**	-31.29**
SE (g <sub>j</sub> )	0.49	5.47	0.84	1.83	28.12	0.07	0.08	0.26	0.54	0.29	0.04	0.05	8.10

\* Significant at 5% level

\*\* Significant at 1% level

Table 5. Estimates of specific combining ability (*sca*) effects in crosses for seed yield and yield components of pigeonpea.

Crosses	Days to flowering maturity	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Pods per plant	Seeds per pod	Pod length (cm)	100-seed weight (g)	Harvest index (%)	SCMR at vegetative phase (%)	Seed Protein content (%)	Phenol content (%)	Seed yield per plant (g)
ICPL-6974 x ICPL-87119	4.29**	-4.33**	-9.38	0.91	-0.51	1.07	-0.07	-0.11	-0.69	-0.99	1.77**	-0.50**	1.06**	0.56
ICPL-6974 x ICPL-8863	1.09	-3.13*	7.22	-0.49	-1.98	-104.87	-0.12	-0.36	-0.89	-0.69	-1.42*	0.20*	-0.67**	-34.84
ICPL-6974 x PRG-158	-5.38**	-1.80	2.16	-0.42	2.49	103.80	0.19	0.47*	1.58**	1.69	-0.35	0.30**	-0.39**	34.29
ICPL-15225 x ICPL-87119	1.07	6.11**	5.62	0.80	-2.07	160.29*	0.15	-0.17	-0.36	0.86	-0.95	0.23**	0.27*	56.33**
ICPL-15225 x ICPL-8863	4.53**	-3.42*	10.89	-0.93	6.80	398.69**	0.30	0.54**	0.78	0.50	-0.67	0.37**	0.27*	94.60**
ICPL-15225 x PRG-158	-5.60**	-2.69	-16.51	0.13	-4.73	-558.98**	-0.46**	-0.37	-0.42	-1.36	1.63*	-0.60**	-0.54**	-150.93**
ICPL-7035 x ICPL-87119	-1.93	1.33	-11.71	1.24	3.04	-81.38	0.04	-0.14	1.53*	0.23	-1.20	0.45**	-0.35**	-16.22
ICPL-7035 x ICPL-8863	-3.13**	-1.87	-0.78	-2.16	-3.09	32.02	-0.07	0.38*	0.00	0.32	2.62**	0.01	0.78**	2.71
ICPL-7035 x PRG-158	5.07**	0.53	12.49	0.91	0.04	49.36	0.03	-0.25	-1.53*	-0.55	-1.42*	-0.46**	-0.43**	13.51
ICPL-2376 x ICPL-87119	-3.16**	-2.44	21.84	0.80	5.60	-77.82	-0.09	0.35	-0.36	0.87	1.04	0.24**	-1.24**	-18.89
ICPL-2376 x ICPL-8863	0.64	1.02	-21.22	-0.93	-5.87	-28.09	-0.11	-0.36	0.11	-0.65	-1.78**	-0.87**	0.27*	-11.96
ICPL-2376 x PRG-158	2.51*	1.42	-0.62	0.13	0.27	105.91	0.20	0.01	0.24	-0.22	0.75	0.63**	0.97**	30.84
LRG-41 x ICPL-87119	-0.27	-0.67	-6.38	-3.76	-6.07	-2.16	-0.03	0.07	-0.13	-0.96	-0.65	-0.43**	0.25*	-21.78
LRG-41 x ICPL-8863	-3.13**	-1.87	3.89	4.51*	4.13	-297.76**	-0.01	-0.21	0.00	0.52	1.26	0.29**	-0.64**	-50.51**
LRG-41 x PRG-158	3.40**	2.53	2.49	-0.76	1.93	299.91**	0.03	0.14	0.13	0.44	-0.61	0.13	0.39**	72.29**
SE (S <sub>ij</sub> )	1.10	1.60	12.24	1.88	4.10	62.87	0.16	0.19	0.58	1.22	0.64	0.08	0.12	18.10

\* Significant at 5% level

\*\* Significant at 1% level

harness both additive and non-additive kinds of gene effects in the present set of biological material. The transgressive segregants produced as a result of this will lead to the development of desirable high yielding genotypes of pigeonpea.

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(Received on 21.10.2011 and revised on 16.01.2012)