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Heterosis Studies for Yield and Its Components in CGMS Based Hybrids of Pigeonpea (*Cajanus cajan* (L.) Millsp)

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ABSTRACT

Estimation of the extent of heterosis in diverse cross combinations would always be useful in choosing the best performing crosses for commercial exploitation. In this context, four cytoplasmic male sterile lines were crossed with six genotypes of pigeonpea in a line x tester mating design during Kharif 2016-17. Thus, the resultant 24 hybrids along with their parents and two standard checks ASHA (ICPL 87119) and ICPH 2740 were evaluated in a randomized block design with three replications during Kharif 2017-18.The results indicated that the manifestation of relative heterosis for seed yield per plant was significantly superior of nine hybrids ranging from -35.93% - 49.93%, four hybrids ranging from -44.45% - 36.14%, one hybrid over standard variety ranging from -44.45% - 15.82% and one hybrid over standard hybrid ranging from -52.04% - 21.31% most of the cross combinations the significant positive heterosis was observed for seed yield per plant was mainly due to the manifestation of heterosis for its component characters. The best cross combinations in order of merit seed yield and other yield components were ICPA 2043 x ICPL 20096, ICPA 2047 x ICPL 20098 and ICPA 2078 x ICPL 87119.

Key words: *Pigeonpea (Cajanus cajan (L.) millsp), Hybrid vigour, Relative heterosis, Heterobeltiosis, Standard heterosis, Yield and Yield attributes.*

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp) is an important leguminous short lived perennial cultivated as annual crop in semi-arid tropical and subtropical regions of the world. It is generally cultivated as a sole crop or as a mixed crop with short duration cereals or legumes as well as with other crops like cotton and groundnut. Across the globe, pigeonpea is cultivated on 5.40 m ha, with an annual production of 4.48 m t and productivity of 827 kg ha-1.

India is the leading producer of pigeonpea in the world accounting for 3.88 m ha, 2.84 m t of production and productivity of 733 kg ha-1. Fallen leaves from the plant provide vital nutrient to the plant also enriches soil through symbiotic nitrogen fixation[35]. India is the world largest pigeonpea producer accounting for 90 per cent of the world production.

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Considering the importance of pigeonpea in fulfilling nutritional requirements of ever increasing population with reducing availability of land resources and low productivity level, there is urgent need to develop high yielding conventional and hybrid varieties of pigeonpea adapted to different agro-climatic conditions. Therefore, the present experiment was carried out to identify high yielding hybrids with desired morphology for increasing yield potential of pigeonpea.

Hybrid breeding could revolutionize if the CGMS system is exploited for hybrid breeding. The success of heterosis breeding primarily depends on the availability of a stable and viable cytoplasmic genetic male sterility (CGMS) system. CGMS based hybrids in extra short, short and medium maturity groups have recorded grain yield superiority of 61% over the best control cultivar in different locations across India. The first CGMS line of GT 288A was developed by using *C. scarabaeoides* at Gujarat Agricultural University, S.K. Nagar, India. Consequently, several scientists have identified male-sterile from the interspecific crosses involving *C. volubilis*, *C. acutifolius* and *C. cajanifolius*, while Mallikarjuna and Saxena reported a CMS source from a pigeonpea cultivar itself (*C. cajan*). In 2004, the first CMS based hybrid GTH-1 was released in India after rigorous research. Another CMS based pigeonpea hybrid, ICPH 2671 was developed at ICRISAT.

MATERIAL AND METHODS

The experiment was carried out in Randomized Block Design with three replications during *Kharif*, 2017-18 with four lines viz., ICPA 2043, ICPA 2047, ICPA 2078 and ICPA 2092, six testers viz., ICPL 87119, ICPL 20096, ICPL 20098, ICPL 20103, ICPL 20108 and ICPL 20116 and their 24 F_1's of pigeonpea obtained by L x T mating design along with a standard check ASHA (ICPL 87119) and standard hybrid (ICPH 2740) at ICRISAT, Hyderabad, Telangana. Five plants in each plot in each replications were randomly selected to record the observations for quantitative traits *viz.*, days to 50% flowering, days to maturity, plant height, 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, harvest index, seed protein content, pollen fertility and seed yield per plant. Two characters *viz.*, days to 50% flowering and days to maturity were computed on plot basis. The mean over replication of each character was subjected to statistical analysis. The percent increase or decrease of F_1 hybrids over mid parent, better parent as well as standard variety was calculated to estimate possible heterotic effects for above mentioned parameters by using formulae suggested by Arunachalum[3].

RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed that presence of considerable variability for majority of characters among the lines than in testers and substantial variability for most of characters among hybrids. High and significant variances due to line x tester interaction components indicated differential behaviour of lines with testers across the characters. The above discussion suggests importance of both additive and non-additive gene effects represented by general and specific combining ability variances. The importance of additive as well as non-additive gene effects with predominance of non-additive gene effects in inheritance of seed yield and yield components of pigeonpea has also been reported earlier by Jahagirdar[10] Kumar *et al*,[13,12] Banu *et al*,[4] Vaghela *et al*,[34] Shoba and Balan[30].

Seed yield per plant: Yield is a complex trait and end product of a number of components most of which are under polygenic control. All changes in yield must be accompanied by changes in one or more of the components. A wide range of variation in the estimates of relative heterosis, heterobeltiosis and standard heterosis in positive and negative direction was observed for seed yield per plant (Table 2). The relative heterosis ranged from -35.93 to 49.93%, heterobeltiosis from -44.45 to

36.14% and standard heterosis over ASHA from -44.45 to 15.82%. and over ICPH 2740 from -52.04 to 21.31%.

Ten crosses showed positive significant heterosis over their mid parent, eight crosses over better parent and six crosses over standard variety and two crosses over standard hybrid. The crosses ICPA 2043 x ICPL 20096 and ICPA 2047 x ICPL 20098 may throw superior segregants for seed yield in the succeeding generations for selection and isolation of superior genotypes as they also had significant positive heterobeltiosis. These results are in confirmity with the findings of Narladker and Kapre[18], Manivel *et al*.[15], Khorgade *et al*.[11], Pandey and Singh[19], Sekhar *et al*.[29], Aher[1], Patel and Tikka[24], Shoba and Balan[30], Chandirakala *et al.*[5], Vaghela *et al.*[33], Pandey *et al.*[21], Patel *et al.*[25], Kumar *et al.*[14], Reddy *et al.*[27] and Singh and Singh[31].

Days to 50% flowering: Early maturing hybrids are generally preferred therefore, negative heterosis for days to 50% flowering is considered as useful parameter. Out of 24 crosses, 22 and 9 hybrids were exhibited significant negative for standard heterosis over the checks ASHA (ICPL 87119) and ICPH 2740, respectively, when compared to mid parent and better parent, significant earlier flowering plants were observed in 19 crosses and 23 crosses. Heterosis for this trait ranged from -23.28% to 5.93% and -25.89% to -2.63% over mid parent and better parent, respectively, while for standard heterosis it ranged from -23.24% to -1.89% over ASHA and from -8.39% to 19.35% over ICPH 2740 (Table 2). The *per se* performance and heterosis were in same direction. These results are supported by Manivel *et al*.[15] and Dheva *et al*.[7].

Days to maturity: Heterosis over mid parent ranged from -15.58% to 6.74%, whereas over better parent, it ranged from -20.34% to 3.86%, and standard heterosis from -22.56% to -3.03% over ASHA and from -8.00% to 15.20 % over ICPH 2740 (Table 2). Heterosis over mid parent was negative and significant in 18 crosses, heterobeltiosis in 22 crosses and all crosses showed superiority over ASHA and 11crosses over ICPH 2740 (Table 2). The significant negative heterosis for this trait is advantageous in getting early maturing hybrids. Similar results were documented by Aher *et al*.[1], Bhanu *et al*.[4], Dheva *et al*.[7], Shoba and Balan[30], Pandey *et al*.[21], Kumar *et al*.[14], Mahsal *et al*.[17], Reddy *et al*.[27] and Singh and Singh[31].

Plant height: Relative heterosis ranged from -10.84% to 40.36%, heterobeltiosis ranged from -18.21% to 23.39% and standard heterosis ranged from 0.95% to 23.37% and -18.94% to -1.42% over ASHA and ICPH 2740, respectively (Table 2). Heterosis over mid parent was positive and significant in 18 crosses, heterobeltiosis in ten crosses and standard heterosis in 21 crosses over ASHA, but none of them identified over standard hybrid. Present results are in close agreement with earlier reports of several workers like Mehetre *et al*.[16], Hooda *et al*.[9], Khorgade *et al*.[11], Shoba and Balan[30], Gite and Madrap[8], Patel and Tikka[25], Kumar *et al*.[14], Reddy *et al*.[27] and Singh and Singh[31].

Number of primary branches per plant: Heterosis over mid parent ranged from -29.66% to 47.31%, heterobeltiosis ranged from -39.74% to 38.30% and standard heterosis ranged from -4.55% to 89.39% over ASHA and from -19.00% to 60.71% over ICPH 2740 (Table 2). Seven crosses recorded positive significant heterosis over mid parent, heterobeltiosis was observed in four crosses and positive significant standard heterosis was observed in 21 crosses over ASHA and eight crosses over ICPH 2740 (Table 2). Similar results were reported by Chaudhary *et al*.[6], Narladkar and Khapre[18], Hooda *et al*.[9], Khorgade *et al*.[11], Pandey and Singh[19], Sarode *et al*.[28], Singh and Singh[31], Patel and Tikka[25], and Gite and Madrap[8]. Pandey[20], Shoba and Balan[30] and Kumar *et al*.[14] reported significant positive standard heterosis for this trait.

Number of secondary branches per plant: Relative heterosis ranged from -36.43% to 55.20%, heterobeltiosis ranged from -39.30% to 39.68% and standard heterosis ranged from -24.84% to 45.16% and from -18.67% to 57.07% over ASHA and ICPH 2740, respectively (Table 2). Nine crosses recorded positive significant heterosis over mid parent, four crosses over better parent, whereas 16 crosses over ASHA and 20 crosses over standard hybrid out of 24 crosses showed positive significant heterosis. These results are in accordance with the results reported by Pandey and Singh[19] and Sarode *et al*.[28], Chandirakala *et al.*[5], Gite and Madrap[8], Patel and Tikka[25], Reddy *et al.*[27] and Singh and Singh[31].

Number of pods per plant: Heterosis over mid parent ranged from -47.53% to 55.54%, heterobeltiosis from -63.40% to 34.25% and standard heterosis from -55.98% to 24.65% over ASHA and from -64.69% to -6.59% over ICPH 2740 (Table 2). Heterosis in positive direction is desirable for this trait as more pods can lead to higher seed yield per plant. Among 24 hybrids studied, 10 hybrids for relative heterosis, seven for heterobeltiosis, three hybrids for standard heterosis over the check ASHA (ICPL 87119) and none of the hybrids for standard heterosis over the check ICPH-2740 recorded positive and significant values (Table 4.9). These results are in agreement with the earlier findings of Chaudhary *et al.*[6], Patel[22], Rana[26], Mehetre *et al.*[16], Hooda *et al*.[9], Khorgade *et al.*[11], Pandey and Singh[19], Sarode *et al.*[28], Ajay *et al.*[2], Patel and Tikka[24], Sekhar *et al*.[29] and Gite and Madrap[8] over better parent, whereas Pandey[20], Sekhar *et al*[29], Patel and Tikka[24], Shoba and Balan[30] and Reddy *et al.*[27] for desirable heterosisover standard check.

Number of seeds per pod: Relative heterosis ranged from -23.25% to 11.74%, heterobeltiosis from -30.67% to 9.52 % and standard heterosis ranged from -14.41% to 16.95% and from -4.72% to 30.19% over the checks ASHA (ICPL 87119) and ICPH-2740, respectively (Table 2). Significant and positive heterosis was recorded in two hybrids for relative heterosis and standard heterosis in two and 12 hybrids over the checks ASHA (ICPL 87119) and ICPH-2740, respectively. None of the hybrid showed positive significant heterobeltiosis (Table 2). High heterosis was also reported earlier by Sarode *et al.*[28] and Shoba and Balan[30].

100-seed weight (g): Nine hybrids exhibited significant positive relative heterosis, while the heterobeltiosis was in four hybrids. Relative heterosis ranged from -25.05% to 30.25%; heterobeltiosis from -28.38% to 30.15% and standard heterosis over the check ASHA (ICPL 87119) ranged from -10.21% to 30.15%. It ranged from -31.01% to -0.75% over the check ICPH 2740. Significant positive standard heterosis was recorded in 10 hybrids over the check ASHA (ICPL 87119) and none of the hybrid exhibited significant positive heterosis over the check ICPH 2740 (Table 2). Desirable relative heterosis for this trait was also reported by Patel *et al*.[23], Khorgade *et al*.[11], Sarode *et al*.[28] and Patel and Tikka[25], while Chaudary *et al*.[6], Manivel *et al*.[15] and Gite and Madrap[8] reported significant positive heterobeltiosis.

Harvest index (%): Relative heterosis ranged from -30.05% to 59.81%; heterobeltiosis from -40.42% to 26.15% and standard heterosis over the check ASHA (ICPL 87119) from -40.42% to 24.79% and from -33.98% to 38.28% over the check ICPH-2740. Significant positive relative heterosis was recorded in two hybrids, heterobeltiosis in four and standard heterosis in one and two hybrids over the checks ASHA (ICPL 87119) and ICPH 2740, respectively (Table 2). These crosses can be exploited in hybrids production. The significant positive heterosis was also reported by Singh *et al*.[32], Patel and Tikka[25] and Singh and Singh[31].

Seed protein content (%): Relative heterosis varied from -42.71% to 22.35% and heterobeltiosis from -43.57% to 22.23%. Standard heterosis over the checks ASHA (ICPL 87119) and ICPH 2740 ranged from -40.35% to 21.73% and from -48.19% to 5.72%, respectively. Significant positive relative heterosis was recorded in nine hybrids, heterobeltiosis in eight and standard heterosis in 14 and two hybrids over the checks ASHA (ICPL 87119) and ICPH 2740, respectively (Table 2). Significant positive heterosis was also observed earlier by Khorgade *et al*.[11], Patel and Tikka[25] and Patil *et al*.[25], while negative heterosis was noticed by Pankaja Reddy *et al*. for seed protein.

Pollen fertility (%): Relative heterosis ranged from -57.97% to -4.35%; heterobeltiosis from -58.67% to -4.67% and standard heterosis over the checks ASHA (ICPL 87119) and ICPH 2740 ranged from -58.67% to -4.67% and from -55.07% to 3.62%, respectively. Among 24 hybrids studied, none of the hybrids recorded positive and significant heterosis for relative heterosis, heterobeltiosis and standard heterosis over ASHA (ICPL 87119). One hybrid recorded positive and significant heterosis over the check ICPH 2740 (Table 2).

Table 1. Analysis of variance for combining ability in Line x Tester design for 12 characters in pigeonpea

Source of variation	D.F	Environments	Days to 50% flowering	Days to maturity	Plant height (cm)	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)	Harvest index (%)	Seed protein content (%)	Seed yield per plant (g)	Pollen Fertility (%)
Genotypes	33	E_1	357.67**	493.53**	1738.56**	20.41**	42.52**	36251.77**	0.45**	5.51**	74.64*	17.90**	638.10**	661.57**
Lines	3	E_1	391.38**	774.11**	652.83**	26.29**	81.10**	8333.23**	1.09**	3.07**	58.28*	61.16**	562.28**	283.33**
Testers	5	E_1	96.38**	277.30**	1314.35**	27.96**	18.33**	41560.95**	0.35*	7.11**	28.25**	7.63**	272.13**	838.76**
Line × Tester	15	E_1	296.66**	248.78**	514.15**	16.21**	45.52**	37572.49**	0.16	3.36**	45.42**	22.95**	522.33**	533.56**
Error	66	E_1	1.40	1.34	7.56	0.17	0.36	482.82	0.10	0.09	15.09	0.04	1.37	2.76

** Significant at 1% level, * Significant at 5% level

Table 2. Realized heterosis over mid parent (MP), better parent (BP) and standard checks (SC and SH) for yield and yield components in pigeonpea

Hybrids	Days to 50% flowering				Days to maturity				Plant height (cm)				Number of primary branches per plant			
	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH
ICPA 2043 × ICPL 87119	-16.59**	-23.24**	-23.24**	-8.39**	-12.98**	-19.87**	-19.87**	-4.80**	6.16**	0.00	0.00	-18.94**	47.31**	38.30**	57.58**	33.71**
ICPA 2043 × ICPL 20096	-1.34	-8.29**	-10.27**	7.10**	-5.63**	-8.30**	-18.18**	-2.80**	2.06	-11.39**	6.36**	-13.79**	-5.33*	-13.11**	18.48**	0.54
ICPA 2043 × ICPL 20098	-6.95**	-16.75**	-11.35**	5.81**	-11.96**	-18.99**	-18.86**	-3.60**	30.10**	23.39**	21.62**	-1.42	-25.25**	-39.74**	12.12**	-4.86
ICPA 2043 × ICPL 20103	-11.44**	-18.60**	-18.38**	-2.58*	-10.82**	-15.16**	-20.88**	-6.00**	-5.06**	-18.21**	0.00	-18.94**	-22.79**	-28.41**	-4.55	-19.00**
ICPA 2043 × ICPL 20108	3.93**	-5.05**	-3.51**	15.16**	-3.01**	-8.36**	-13.30**	3.00**	6.30**	-10.37**	15.42**	-6.44**	-11.24**	-20.04**	13.64**	-3.57
ICPA 2043 × ICPL 20116	-12.44**	-17.98**	-21.08**	-5.81**	-10.16**	-12.21**	-22.56**	-8.00**	16.87**	5.18**	16.22**	-5.80**	1.23	-1.60	12.12**	-4.86
ICPA 2047 × ICPL 87119	-14.84**	-16.22**	-16.22**	0.00	-10.87**	-15.82**	-15.82**	0.00	15.39**	8.38**	23.37**	0.00	1.28	-11.21**	17.85**	0.00
ICPA 2047 × ICPL 20096	-6.11**	-6.63**	-8.65**	9.03**	-2.84**	-3.02**	-13.47**	2.80**	1.97*	-0.66	19.24**	-3.35**	3.83	2.44	39.70**	18.54**
ICPA 2047 × ICPL 20098	-22.34**	-25.89**	-21.08**	-5.81**	-15.58**	-20.34**	-20.20**	-5.20**	10.63**	3.21**	17.49**	-4.77**	-29.66**	-39.74**	12.12**	-4.86
ICPA 2047 × ICPL 20103	-18.24**	-19.68**	-19.46**	-3.87**	-11.09**	-13.18**	-19.02**	-3.80**	-10.84**	-13.91**	5.25**	-14.69**	-27.11**	-27.27**	-3.03	-17.72**
ICPA 2047 × ICPL 20108	-16.08**	-18.09**	-16.76**	-0.65	-13.94**	-16.55**	-21.04**	-6.20**	-5.37**	-10.86**	14.79**	-6.96**	-11.58**	-14.50**	21.52**	3.11
ICPA 2047 × ICPL 20116	0.28	0.00	-3.24**	15.48**	0.19	-0.19	-11.28**	5.40**	5.32**	3.77**	18.12**	-4.25**	3.40	-6.39*	24.24**	5.43
ICPA 2078 × ICPL 87119	5.93**	-3.51**	-3.51**	15.16**	6.74**	-6.73**	-6.73**	10.80**	32.28**	12.72**	12.72**	-8.63**	29.57**	27.11**	32.12**	12.11**
ICPA 2078 × ICPL 20096	-9.31**	-16.57**	-18.38**	-2.58*	3.08**	-5.28**	-15.49**	0.40	11.69**	-11.39**	6.36**	-13.79**	-5.09*	-16.38**	14.03**	-3.24
ICPA 2078 × ICPL 20098	-10.03**	-20.30**	-15.14**	1.29	-1.44**	-13.95**	-13.80**	2.40**	40.36**	20.32**	18.60**	-3.87**	21.84**	-5.05**	76.67**	49.91**
ICPA 2078 × ICPL 20103	-5.48**	-14.02**	-13.78**	2.90*	-4.61**	-14.08**	-19.87**	-4.80**	8.58**	-14.43**	4.61**	-15.21**	-17.50**	-26.59**	-2.12	-16.95**
ICPA 2078 × ICPL 20108	-15.29**	-23.40**	-22.16**	-7.10**	-2.58**	-12.81**	-17.51**	-2.00**	18.44**	-8.40**	17.97**	-4.38**	-6.65**	-19.19**	14.85**	-2.55
ICPA 2078 × ICPL 20116	-13.94**	-20.22**	-23.24**	-8.39**	4.55**	-3.44**	-14.81**	1.20*	15.64**	-5.32**	4.61**	-15.21**	10.03**	8.17*	16.36**	-1.26
ICPA 2092 × ICPL 87119	-8.27**	-9.47**	-7.03**	10.97**	-8.26**	-12.12**	-12.12**	4.40**	18.70**	18.33**	19.08**	-3.48**	-2.54	-16.01**	16.06**	-1.52
ICPA 2092 × ICPL 20096	-0.27	-2.63**	0.00	19.35**	5.21**	3.86**	-4.88**	13.00**	8.07**	-0.66	19.24**	-3.35**	4.86*	4.17	43.94**	22.14**
ICPA 2092 × ICPL 20098	-6.20**	-7.87**	-1.89	17.10**	1.14*	-3.19**	-3.03**	15.20**	8.22**	7.11**	7.79**	-12.63**	16.82**	1.79	89.39**	60.71**
ICPA 2092 × ICPL 20103	-5.99**	-7.11**	-4.59**	13.87**	-8.38**	-9.21**	-15.32**	0.60	-9.42**	-17.43**	0.95	-18.17**	0.22	-1.54	36.06**	15.45**
ICPA 2092 × ICPL 20108	-23.28**	-23.68**	-21.62**	-6.45**	-14.47**	-15.84**	-20.37**	-5.40**	-0.49	-11.36**	14.15**	-7.47**	-16.76**	-17.91**	16.67**	-1.00
ICPA 2092 × ICPL 20116	-9.78**	-12.63**	-10.27**	7.10**	-1.31**	-3.13**	-11.28**	5.40**	10.99**	6.04**	17.17**	-5.03**	20.84**	7.46**	48.48**	26.00**
S.E.(Heterosis)	0.90	0.96	1.02	0.98	0.83	0.87	1.08	0.96	2.01	2.15	2.32	2.41	0.21	0.24	0.24	0.20
Lowest	-23.28	-25.89	-23.24	-8.39	-15.58	-20.34	-22.56	-8.00	-10.84	-18.21	0.95	-18.94	-29.66	-39.74	-4.55	-19.00
Highest	5.93	-2.63	-1.89	19.35	6.74	3.86	-3.03	15.20	40.36	23.39	23.37	-1.42	47.31	38.30	89.39	60.71

Hybrids	Number of secondary branches per plant				Number of pods per plant				Number of seeds per pod				100-seed weight			
	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH
ICPA 2043 × ICPL 87119	25.37**	15.49**	37.10**	48.34**	-41.38**	-47.11**	-34.26**	-47.26**	-1.64	-4.76	1.69	13.21	8.49**	5.10*	5.10*	-19.24**
ICPA 2043 × ICPL 20096	-8.07**	-11.82**	4.68	13.26**	-6.01	-35.42**	-19.74**	-35.61**	4.13	0.00	6.78	18.87**	4.80*	-0.87	4.22	-19.92**
ICPA 2043 × ICPL 20098	-3.23	-6.25**	11.29**	20.42**	-45.40**	-63.40**	-54.51**	-63.51**	-12.41**	-18.92**	1.69	13.21	-13.95**	-28.03**	0.32	-22.92**
ICPA 2043 × ICPL 20103	-36.43**	-36.68**	-24.84**	-18.67**	14.93**	-14.82**	5.87	-15.07**	-1.21	-3.17	3.39	15.09*	-10.46**	-19.55**	-5.36*	-27.28**
ICPA 2043 × ICPL 20108	-3.54	-8.52**	8.60**	17.50**	4.09	-18.06**	1.83	-18.30**	-6.15	-8.96	3.39	15.09*	3.18	-4.90*	5.73*	-18.76**
ICPA 2043 × ICPL 20116	-30.67**	-33.97**	-21.61**	-15.18**	0.72	-17.12**	3.01	-17.36**	-0.40	-2.38	4.24	16.04*	5.80*	2.42	-3.97	-26.22**
ICPA 2047 × ICPL 87119	-26.73**	-39.30**	-7.58**	0.00	19.94**	15.58**	24.65**	0.00	-20.90**	-29.33**	-10.17	0.00	30.25**	30.15**	30.15**	0.00
ICPA 2047 × ICPL 20096	-7.41**	-20.55**	20.97**	30.89**	3.42	-25.99**	-20.18**	-35.96**	-18.80**	-28.00**	-8.47	1.89	10.30**	7.52**	13.04**	-13.14**
ICPA 2047 × ICPL 20098	-19.22**	-30.08**	6.45*	15.18**	-26.23**	-48.64**	-44.61**	-55.56**	-19.46**	-20.00**	1.69	13.21	1.01	-13.31**	20.83**	-7.17**
ICPA 2047 × ICPL 20103	-17.56**	-26.91**	11.29**	20.42**	-47.53**	-59.18**	-55.98**	-64.69**	-9.23	-18.00**	4.24	16.04*	-4.13*	-11.38**	4.25	-19.90**
ICPA 2047 × ICPL 20108	-17.71**	-30.08**	6.45*	15.18**	21.82**	1.22	9.17*	-12.42**	-18.31**	-22.67**	-1.69	9.43	-7.46**	-12.18**	-2.36	-24.98**
ICPA 2047 × ICPL 20116	0.99	-13.88**	31.13**	41.88**	-7.33*	-19.18**	-12.84**	-30.08**	-23.25**	-30.67**	-11.86	-1.89	-4.28	-10.07**	-10.21**	-31.01**
ICPA 2078 × ICPL 87119	55.20**	39.68**	39.68**	51.13**	24.23**	16.43**	16.43**	-6.59*	11.48*	7.94	15.25*	28.30**	12.76**	0.05	29.17**	-0.75
ICPA 2078 × ICPL 20096	14.33**	-0.89	8.06**	16.93**	-4.49	-26.85**	-36.02**	-48.68**	0.83	-3.17	3.39	15.09*	-15.67**	-23.50**	-1.23	-24.11**
ICPA 2078 × ICPL 20098	-1.35	-15.22**	-5.65*	2.09	10.57*	-17.95**	-28.25**	-42.44**	-9.49*	-16.22**	5.08	16.98*	-22.13**	-25.00**	4.54	-19.68**
ICPA 2078 × ICPL 20103	0.65	-15.48**	-0.48	7.68**	31.61**	10.91*	-3.01	-22.19**	11.74*	9.52	16.95**	30.19**	-25.05**	-28.38**	-7.53**	-28.95**
ICPA 2078 × ICPL 20108	4.84*	-8.18**	-2.26	5.76*	3.65	-5.87	-17.68**	-33.96**	0.77	-2.24	11.02	23.58**	-1.93	-8.74**	17.83**	-9.47**
ICPA 2078 × ICPL 20116	8.61**	-5.26*	1.77	10.12**	-43.66**	-45.97**	-52.75**	-62.10**	-4.45	-6.35	0.00	11.32	1.02	-15.15**	9.55**	-15.83**
ICPA 2092 × ICPL 87119	10.95**	1.33	22.58**	32.64**	-41.50**	-52.02**	-52.02**	-61.51**	-8.18	-14.41*	-14.41*	-4.72	3.97	-0.63	-0.63	-23.65**
ICPA 2092 × ICPL 20096	-6.59**	-11.20**	7.42**	16.23**	55.54**	34.25**	-14.01**	-31.02**	3.67	-2.59	-4.24	6.60	10.37**	3.03	8.32**	-16.78**
ICPA 2092 × ICPL 20098	23.06**	18.13**	42.90**	54.62**	2.48	-14.89*	-45.49**	-56.27**	-1.60	-16.89**	4.24	16.04*	4.80*	-13.34**	20.79**	-7.19**
ICPA 2092 × ICPL 20103	21.62**	20.00**	45.16**	57.07**	18.82**	15.01*	-26.34**	-40.91**	2.24	-5.79	-3.39	7.55	-10.16**	-20.27**	-6.21*	-27.94**
ICPA 2092 × ICPL 20108	7.52**	1.07	22.26**	32.29**	24.92**	18.50**	-15.41**	-32.14**	8.47	-4.48	8.47	20.75**	-0.75	-9.69**	0.41	-22.85**
ICPA 2092 × ICPL 20116	2.12	-3.60	16.61**	26.18**	30.66**	17.46**	-5.72	-24.37**	-9.42	-16.53**	-14.41*	-4.72	15.62**	13.48**	3.43	-20.53**
S.E.(Heterosis)	0.55	0.45	0.60	0.54	12.14	11.42	12.00	12.43	0.10	0.15	0.12	0.13	0.31	0.37	0.36	0.34
Lowest	-36.43	-39.30	-24.84	-18.67	-47.53	-63.40	-55.98	-64.69	-23.25	-30.67	-14.41	-4.72	-25.05	-28.38	-10.21	-31.01
Highest	55.20	39.68	45.16	57.07	55.54	34.25	24.65	-6.59	11.74	9.52	16.95	30.19	30.25	30.15	30.15	-0.75

Hybrids	Harvest index (%)				Seed protein content (%)				Pollen fertility (%)				Seed yield per plant (g)			
	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH	MP	BP	SC	SH
ICPA 2043 × ICPL 87119	-30.05**	-35.46**	-23.64	-15.38	0.88	-0.37	2.17*	-11.26**	-4.35**	-4.67**	-4.67**	3.62**	-28.21**	-35.47**	-19.11*	-30.16**
ICPA 2043 × ICPL 20096	23.04	-18.27	-3.30	7.16**	-42.71**	-43.57**	-40.35**	-48.19**	-30.27**	-31.21**	-31.67**	-25.72**	14.94*	-18.87**	1.70*	12.19**
ICPA 2043 × ICPL 20098	-13.46	-35.73**	-23.96	-15.74	-30.77**	-31.23**	-28.53**	-37.93**	-42.47**	-43.62**	-44.00**	-39.13**	-18.32*	-41.33**	-26.46**	-36.50**
ICPA 2043 × ICPL 20103	19.67	-16.32	-0.99	9.72	-36.45**	-38.05**	-36.46**	-44.82**	-29.95**	-30.54**	-31.00**	-25.00**	10.00**	-18.91**	1.65**	-12.24
ICPA 2043 × ICPL 20108	-11.88	-21.88	-7.57	2.43	8.86**	5.36**	8.05**	-6.16**	-10.84**	-13.09**	-13.67**	-6.16**	3.98	-19.25**	1.22	-12.61
ICPA 2043 × ICPL 20116	-5.13	-19.80	-5.11	5.15	6.08**	4.74**	7.42**	-6.71**	-9.64**	-10.40**	-11.00**	-3.26*	-11.19	-24.11**	-4.87	-17.86**
ICPA 2047 × ICPL 87119	-9.34	-9.76	-9.76	0.00	11.96**	8.94**	15.14**	0.00	-8.00**	-8.00**	-8.00**	0.00	16.89*	15.82*	15.82*	0.00
ICPA 2047 × ICPL 20096	22.44	-14.76	-15.55	-6.42	-3.61**	-3.62**	1.88	-11.51**	-15.25**	-16.67**	-16.67**	-9.42**	9.70	-16.32*	-17.85*	-29.07**
ICPA 2047 × ICPL 20098	1.19	-20.09	-20.83	-12.27	-19.12**	-19.80**	-15.24**	-26.38**	-11.60**	-13.67**	-13.67**	-6.16**	19.22*	-7.16	-8.86	21.31**
ICPA 2047 × ICPL 20103	-4.24	-29.32*	-29.98*	-22.41	7.35**	3.14**	9.01**	-5.32**	-39.97**	-40.67**	-40.67**	-35.51**	-3.47	-22.50**	-23.92**	-34.31**
ICPA 2047 × ICPL 20108	-13.10	-16.43	-17.21	-8.25	-12.50**	-16.52**	-11.78**	-23.38**	-10.81**	-13.33**	-13.33**	-5.80**	23.99**	5.78*	3.85**	-10.34
ICPA 2047 × ICPL 20116	-19.04	-26.12	-26.81*	-18.90	0.37	-2.35*	3.21**	-10.36**	-14.00**	-15.00**	-15.00**	-7.61**	10.28	5.06**	3.14**	-10.95
ICPA 2078 × ICPL 87119	24.85*	24.79**	24.79**	38.28*	17.19**	15.56**	15.56**	0.37	-11.38**	-13.00**	-13.00**	-5.43**	32.65**	14.48**	14.48**	-1.16
ICPA 2078 × ICPL 20096	10.09	-23.54	-23.62	-15.36	19.98**	15.16**	21.73**	5.72**	-17.10**	-17.24**	-20.00**	-13.04**	-0.95	-15.28	-38.48**	-46.89**

ICPA 2078 × ICPL 20098	-15.55	-33.51*	-33.58*	-26.40	16.42**	12.66**	17.08**	1.69	-17.22**	-17.65**	-20.67**	-13.77**	17.35	2.90	-25.29**	-35.49**
ICPA 2078 × ICPL 20103	25.82	-7.38	-7.48	2.52	22.35**	22.23**	19.06**	3.40**	-36.08**	-36.52**	-38.00**	-32.61**	49.68**	36.14**	-1.15	-14.65*
ICPA 2078 × ICPL 20108	-13.69	-17.33	-17.42	-8.49	-2.36*	-2.98**	-5.69**	-18.09**	-30.07**	-30.80**	-33.33**	-27.54**	15.27	12.67	-18.19*	-29.37**
ICPA 2078 × ICPL 20116	-20.90	-28.09*	-28.17*	-20.40	-2.19*	-3.54**	-3.57**	-16.25**	-38.49**	-38.91**	-40.33**	-35.14**	-15.49	-23.22**	-31.76**	-41.08**
ICPA 2092 × ICPL 87119	-28.71*	-40.42**	-40.42**	-33.98*	-4.12**	-9.65**	2.13*	-11.30**	-14.33**	-14.33**	-14.33**	-6.88**	-35.93**	-44.45**	-44.45**	-52.04**
ICPA 2092 × ICPL 20096	59.81**	26.15*	-15.28	-6.11	-5.62**	-8.68**	3.23**	-10.35**	-57.97**	-58.67**	-58.67**	-55.07**	49.93**	27.67**	-6.28	-19.08**
ICPA 2092 × ICPL 20098	12.72	4.54**	-29.79*	-22.20	4.40**	0.19	13.26**	-1.64	-12.29**	-14.33**	-14.33**	-6.88**	10.15	-3.87	-29.43**	-39.07**
ICPA 2092 × ICPL 20103	26.54	7.70**	-27.67*	-19.85	1.30	-5.71**	6.59**	-7.43**	-16.02**	-17.00**	-17.00**	-9.78**	27.91**	15.76**	-15.01*	-26.62**
ICPA 2092 × ICPL 20108	6.78	-7.41	-15.31	-6.15	-4.77**	-11.96**	-0.48	-13.57**	-10.46**	-13.00**	-13.00**	-5.43**	27.60**	24.05*	-8.93	-21.37**
ICPA 2092 × ICPL 20116	2.48	-6.65	-23.71	-15.46	-11.09**	-16.23**	-5.30**	-17.75**	-12.98**	-14.00**	-14.00**	-6.52**	7.88	-1.50	-12.46	-24.42**
S.E.(Heterosis)	1.02	1.05	1.17	1.21	0.10	0.13	0.12	0.14	0.95	1.00	1.08	1.06	2.95	2.47	3.40	3.45
Lowest	-30.05	-40.42	-40.42	-33.98	-42.71	-43.57	-40.35	-48.19	-57.97	-58.67	-58.67	-55.07	-35.93	-44.45	-44.45	-52.04
Highest	59.81	26.15	24.79	38.28	22.35	22.23	21.73	5.72	-4.35	-4.67	-4.67	3.62	49.93	36.14	15.82	21.31

**Significant at 1% level, *Significant at 5% level
MP = Mid-Parent heterosis/Relative heterosis
BP = Better parent heterosis/Heterobeltiosis
SC = Standard heterosis over ASHA
SH = Standard heterosis over ICPH-2740

CONCLUSION

The magnitude of heterosis expressed by the hybrids for 12 characters varied among themselves, the magnitude of standard heterosis was high for secondary branches per plant, pods per plant, harvest index and seed yield per plant, whereas for seeds per pod and days to 75% maturity it was very low. Out of 24 crosses, the crosses viz., ICPA 2043 x ICPL 20096, ICPA 2043 x ICPL 20103, ICPA 2047 x ICPL 87119, ICPA 2047 x ICPL 20098, ICPA 2047 x ICPL 20108, ICPA 2047 x ICPL 20116 and ICPA 2078 x ICPL 87119 had recorded significant and maximum heterosis for most of the characters over the both checks.

Studies on heterosis suggested that higher and significant heterosis was contributed through characters studied except number of primary branches per plant, number of pods per plant, 100-seed weight, seed protein content and pollen fertility in ICPA 2043 x ICPL 20096 and ICPA 2047 x ICPL 20098 and through the traits except pollen fertility and seed protein in ICPA 2043 x ICPL 20103, ICPA 2047 x ICPL 87119, ICPA 2047 x ICPL 20108, ICPA 2047 x ICPL 20116 and ICPA 2078 x ICPL 87119. Hence, significant positive heterosis observed for seed yield per plant was mainly due to the manifestation of heterosis for its component characters viz., days 50% flowering, days to maturity, plant height, number primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight and harvest index. This would clearly indicate that heterosis for seed yield was through heterosis for individual component characters.

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