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Studies on Heterosis for Yield and its Component Traits on CGMS Based Pigeonpea *Cajanus cajan* (L.) Millsp. Hybrids

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ABSTRACT

Heterosis is the most important phenomenon for breaking the yield barrier level of crops. Hence, an experiment was undertaken to identify the best heterotic combinations for exploitation of heterosis or hybrid vigour. In this context, three cytoplasmic male sterile lines were crossed with twenty genotypes of pigeonpea in a line×tester mating design during Kharif 2011-12. Thus, the resultant 60 hybrids along with their parents and standard check variety (NDA 2) were evaluated in a randomized block design with three replications during Kharif 2012-13. The results indicated that the manifestation of heterobeltiosis for seed yield per plant was significantly superior of fourteen hybrids ranging from -85.06-33.74% and fifteen hybrids over standard variety ranging from -82.57-26.28%. Most of the crosses which exhibited superiority over better parent or standard variety for seed yield also showed significant heterosis for primary branches per plant, secondary branches per plant, pods per plant, seeds per pod, biological yield per plant and harvest index. Besides seed yield, substantial heterosis was also observed in negative as well as positive direction for remaining characters but number of crosses showing significant estimates of heterosis and its degree varied from one character to another. The best cross combinations in order of merit seed yield and other yield components were NDACMS 1-6A×NDA 98-6, NDACMS 1-6A×NDA 5-14, NDACMS 1-4A×IPA 208, NDACMS 1-6A×ICP 870, NDACMS 1-6A×NDA 96-1, NDACMS 1-6A×NDA 8-6, NDACMS 1-6A×ICP 2309 and NDACMS 1-4A×Bahar. Commencing the experimental findings it could be accomplished that the crosses, NDACMS 1-6A×NDA 98-6, NDACMS 1-6A×NDA 5-14, NDACMS 1-4A×IPA 208, NDACMS 1-6A×ICP 870 were found to be more than 20% standard heterosis for seed yield recommended for commercial utilization.

Key words: Pigeonpea, *Cajanus cajan* (L.) millsp., hybrid vigour, heterobeltiosis, standard heterosis, yield and yield attributes

INTRODUCTION

Pigeonpea *Cajanus cajan* (L.) Millsp., (2n = 22) member of family Leguminosae (Fabaceae) is an important legume (pulse) crop of tropical and subtropical regions of Asia and Africa. Globally, it is grown on about 5.54 million hectares area with production of 3.22 million tonnes and average yield of 708 kg ha^{-1}. It contributes about 5.6% share in global pulse production (Gowda *et al*., 2009). Pigeonpea is generally referred as 'Orphan Crop Legume' because less significant research efforts have been intended for crop improvement due to its highly sensitive nature to environmental changes (Varshney *et al*., 2010).

Now days, per capita per day consumption of pulses have declined to about 30 g as against 80 g recommended by WHO and FAO (Anonymous, 2009). The annual demand for pulses is increasing by 3%. Since the demand for pigeonpea is ever increasing and area available for expansion is limited, research now needs to focus on the genetic enhancement of yield through novel genetic approaches like hybrid technology was felt necessary for achieving a breakthrough in production and productivity of pigeonpea.

Hybrid gives an opportunity to break the yield barrier of conventional varieties and have already been successfully used in rice, maize, pearl millet and sorghum. In pigeonpea, significant heterosis was reported by a number of earlier workers Kumar and Srivastva (1998), 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), Chandirakala *et al.* (2010), Vaghela *et al.* (2011), Gupta *et al.* (2011) and Kumar *et al.* (2012). The success of heterosis breeding in any crop primarily depends on the availability of stable and viable Cytoplasmic Genetic Male Sterility (CGMS) system and the information on various genetic aspects are essential. Pigeonpea being often cross pollinated crop (20-70% out-crossing) in nature provides an opportunity to breed commercial hybrids (Saxena *et al.*, 1990).

The ultimate goal of any plant breeding programme is to develop improved genotypes which are better than the existing ones in producing the economic yield. This requires genetic amelioration through maximum utilization of allelic resources to develop ideal genotype. In pigeonpea comparatively to other important field crops, fewer attempts have been made to know the genetics of important traits. Saxena and Sharma (1990) reported that both additive and non-additive effects governs the expression of characters in pigeonpea. Physiological changes, pleiotropic effects of genes and highly sensitive nature towards major abiotic stresses make it complicated to infer the inheritance of yield and its component traits (Byth *et al.*, 1981). Further, fertility restoration in cytoplasmic genetic male sterility based hybrids is also crucial as it governs the viability of hybrid system.

Pigeonpea has been considered technically suitable for heterosis breeding due to predominance of non-additive genetic variance for the traits like seed yield and other important yield attributes. As compared to conventional varieties Genetic Male Sterility (GMS) based hybrids were found to be gives about 30% yield advantage (Reddy *et al.*, 1978; Saxena *et al.*, 1983). However, this technology could not be commercialized due to seed purity problems during hybrid seed production. Breaking the yield barrier level recorded in the GMS based hybrids inspired scientists to development of alternative and more efficient cytoplasmic genetic male sterility system (Tikka *et al.*, 1997; Saxena and Kumar, 2003; Wanjari and Patel, 2003). 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 (Saxena, 2008).

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.

MATERIALS AND METHODS

Experimental detail: The parental material comprised with 3 CMS lines used as females were crossed with 20 genotypes used as males in a line×tester mating design in Kharif 2011-12 and sufficient number of hand pollinated seeds were produced. The resultant 60 hybrids along with their parents and standard check variety (NDA 2) were evaluated in a randomized block design with three replications at Research Farm of Genetics and Plant Breeding, N.D. University of Agriculture and Technology during next season Kharif 2012-13. Geographically this experimental site is situated between 26.47°N latitude, 82.12°E longitudes and at an altitude of 113 m above the mean sea level. The soil type of experimental site was sandy loam, rich in potash and low in organic carbon, nitrogen and phosphorus. The seeds of each entry were sown on 27th July, 2012 in single row plots of 4 m length with intra-row and inter-row spacing of 25 and 75 cm, respectively. Recommended cultural practices were followed to raise a good crop stand.

Data collection: The observations were recorded on five randomly selected competitive plants of a genotype in a plot in each replication. The characters studied were, days to 50% flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, plant height (cm), pods per plant, seeds per pod, 100-seed weight (g), seed yield per plant (g), biological yield per plant (g) and harvest index (%).

Statistical analysis: The percent increase or decrease of F_1 hybrids over better parent as well as standard variety was calculated to estimate possible heterotic effects for above mentioned parameters (Fonseca and Patterson, 1968):

$$\text{Heterobeltiosis} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\overline{F}_1 - \overline{SV}}{\overline{SV}} \times 100$$

Where:
$\overline{F}_1$ = Mean of F_1
$\overline{BP}$ = Mean of better-parent
$\overline{SV}$ = Mean of standard variety or checj variety

To estimate significant differences among hybrids and parents, the mean data of each character were subjected to Analysis of Variance (ANOVA) as suggested by Steel and Torrie (1980). The characters showing significant differences were subjected to heterosis calculation. Deviation of F_1 from it's either of the parental values was interpreted by Mather and Jink (1977) depicting type of gene action operating for controlling the trait. The't' test was applied to determine significant difference of F_1 hybrid means from respective mid parent and better parent values using formulae as reported by Wynne *et al.* (1970).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed that significant differences among the testers for all the characters under study except days to 50% flowering, seed yield per plant and biological yield per plant, indicating importance of general combining ability and additive gene effects in expression of 8 out of 11 characters. Variances due to lines were significant for days to 50%

Table 1: Analysis of variance for line×tester mating design in pigeonpea

	Replication	Line effect	Tester effect	Line×tester effect	Error
Characters	2	2	19	38	118
Days to 50% flowering	4.11*	1643.54*	207.47	324.70**	1.19
Days to maturity	2.67	921.34**	128.56**	151.39**	1.23
Plant height (cm)	1.29	16568.32**	731.14**	499.76**	7.99
Primary branches/plant	0.23	6.90	5.07**	4.97**	0.49
Secondary branches/plant	20.10	252.34	161.13**	143.91**	14.54
Pods/plant	56.55	57103.75**	9018.62**	9162.62**	22.56
Seeds/pod	0.04	0.16	0.30**	0.21**	0.03
100-seed weight (g)	0.01	4.39	4.63**	4.70**	0.07
Seed yield/plant (g)	9.51	9303.02**	1173.37	1622.53**	3.71
Biological yield/plant (g)	51.15	47801.68	2474.43	6898.23**	48.05
Harvest index (%)	1.50	783.61*	206.61**	192.72**	0.87

*,**Significant at 5 and 1% probability levels, respectively

flowering, seed yield per plant and biological yield per plant, indicating importance of general combining ability and additive gene effects in expression of 8 out of 11 characters. Variances due to lines were significant for days to 50% flowering. The mean squires due to lines×tester interactions, indicating importance of specific combining ability and non-additive gene effects, were found to be highly significant for all the eleven characters under study. The above discussion suggests importance of both additive and non-additive gene effects represented by general and specific combining ability variances, respectively for all the characters except biological yield per plant for which only non additive gene effects were important. 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 (Jahagirdar, 2003; Kumar *et al.*, 2003, 2009; Banu *et al.*, 2007; Vaghela *et al.*, 2009; Shoba and Balan, 2010).

The importance of additive gene effects of fixable nature for seed yield and most of other yield components in the present study suggested that these traits are amenable to improvement through selection even in early generations. This indicated that considerable improvement in status of seed yield and important yield attributes in pigeonpea can still be achieved by following conventional breeding procedures normally used in often cross pollinated crops. The predominance of non-additive gene effects representing non-fixable dominance and epistatic components of genetic variance indicated that maintenance of heterozygosity would be highly fruitful for improving the characters. Hence, the suitable breeding strategy for attaining high yield would be the full or partial exploitation of heterosis through development of hybrid, synthetic or composite cultivars.

Heterosis was computed as percent increase or decrease in F_1 value over better parent (heterobeltiosis) and over best commercial variety (standard heterosis) for 60 F_1's to assess their genetic potential as breeding material were presented in Table 2. The nature and magnitude of hybrid vigour differed for different traits in various hybrid combinations. The most desirable crosses for seed yield and other components were given in Table 3. The salient results obtained on different aspects and conclusions drawn from the experiment are summarized below.

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

Table 2: Extent of percent heterosis over Better Parent (BP) and Standard Varieties (SV) for 11 characters in pigeonpea

(a)	Days to 50% flowering		Days to maturity		Plant height (cm)		Primary branches/plant		Secondary branches/plant		Pods/plant	
Crosses	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDACMS1-3A×NDA 2	-1.68*	1.89**	-1.73**	-1.33**	-8.61**	-3.52*	-30.23**	-0.81	4.90	2.97	20.70**	23.39**
NDACMS1-3A×NDA 3	2.28**	5.91**	0.27	0.67	-5.07**	0.22	2.27	15.72	79.03**	16.06	1.38	5.14*
NDACMS1-3A×NDA 3-3	1.14	4.73**	0.66	1.07**	-5.92**	-0.67	64.47**	92.14**	64.40**	-6.54	-24.23**	-22.54**
NDACMS1-3A×NDA 5-14	-2.51**	0.95	-0.66	-0.27	-11.63**	-6.70**	8.05	32.18*	-2.33	-20.00	-78.14**	-75.19**
NDACMS1-3A×NDA 8-6	-3.88**	-0.47	-1.06	-0.67	-14.66**	-8.52**	-31.94**	-12.93	24.33*	-23.37*	-69.84**	-59.02**
NDACMS1-3A×NDA 96-1	-6.56**	-2.36**	-3.83**	-2.93**	0.26	5.85**	17.18**	37.84**	22.51*	-28.47**	-42.07**	-37.60**
NDACMS1-3A×NDA 96-6	-4.79**	-1.42**	-3.19**	-2.80**	-6.67**	-1.47	-42.30**	-17.12	18.84	-12.14	-44.82**	-20.88**
NDACMS1-3A×NDA 98-6	-16.89**	-13.95**	-5.71**	-5.33**	-10.51**	-5.52**	77.99**	101.4**	102.5**	27.97**	22.86**	25.60**
NDACMS1-3A×NDA 98-7	-6.62**	-3.31**	-3.44**	-2.67**	-12.08**	-7.18**	-33.29**	-15.80	104.3**	15.44	-6.28*	-0.19
NDACMS1-3A×NDA 7-11	-4.79**	-1.42**	-1.33**	-0.93*	-6.23**	-1.00	-9.42	2.50	1.73	-42.51**	-37.67**	-36.28**
NDACMS1-3A×NDA 7-15	-3.63**	0.47	-0.79*	1.07**	-9.93**	-4.91**	-22.41*	-7.64	19.73	-32.34**	-42.68**	-41.40**
NDACMS1-3A×NDAGC 31	-3.41**	0.47	-0.66	0.93*	-11.71**	-6.78**	-6.30	6.02	-23.16*	-46.15**	-41.00**	-24.75**
NDACMS1-3A×NDAGC 1010	0.46	4.02	-0.39	1.33**	-6.93**	1.11	-39.03**	-29.9*	-20.71*	-13.52	-83.68**	-75.23**
NDACMS1-3A×ICP 2309	-7.26**	-3.31**	-4.25**	-3.87**	-9.76**	-4.73**	-25.97**	-16.24	4.26	-19.37	-31.41**	-16.61**
NDACMS1-3A×ICP 2155	9.11**	13.24**	2.79**	3.20**	-9.76**	-4.73**	-44.48**	-37.18**	-60.99**	-64.33**	-40.51**	-11.00**
NDACMS1-3A×ICP 870	9.13**	13.00**	1.99**	2.40**	-11.21**	0.97	-42.51**	-16.24	-61.30**	-51.34**	-24.26**	-15.04**
NDACMS1-3A×ICP 7353	10.96**	14.89**	0.26	2.93**	-0.94	4.58**	-13.12	-1.69	-24.60*	-47.00**	-5.36*	-0.14
NDACMS1-3A×IPA 208	5.48**	9.22**	-0.78*	1.60**	-16.89**	-12.2**	-23.12*	-13.01	-36.37**	-42.56**	-64.90**	-60.65**
NDACMS1-3A×BAHAR	-14.51**	-10.87**	-7.75**	-4.80**	-1.72	3.75**	-21.04	-10.65	-33.67**	-33.82**	-85.12**	-84.39**
NDACMS1-3A×AMAR	-12.33**	-9.22**	-3.83**	-2.80**	-5.10**	0.19	-12.79	-1.32	17.19	-28.40**	-72.21**	-71.16**
NDACMS1-4A×NDA 2	-2.69**	2.60**	-0.79*	1.07**	-18.78**	-8.21**	-38.76**	-12.93	-38.59**	-39.72**	-9.48**	1.57
NDACMS1-4A×NDA 3	-2.02**	3.31**	-1.18**	0.67	-18.96**	-8.42**	6.68	20.87*	-7.57	-11.03	-7.06**	4.28*
NDACMS1-4A×NDA 3-3	-1.35*	4.02**	-0.39	1.47**	-16.27**	-5.38**	-9.75	5.44	-9.69	-13.07	-72.90**	-69.60**
NDACMS1-4A×NDA 5-14	4.71**	10.40**	1.31**	3.20**	-7.33**	4.73**	-5.89	15.14	-12.74	-16.00	-74.81**	-71.41**
NDACMS1-4A×NDA 8-6	12.11**	18.20**	2.75**	4.67**	-11.55**	-0.05	-8.67	16.83	-10.22	-13.58	-84.27**	-78.63**
NDACMS1-4A×NDA 96-1	9.42**	15.37**	1.96**	3.87**	-21.95**	-11.8**	-26.80**	-13.89	-36.26**	-38.65**	-61.25**	-56.52**
NDACMS1-4A×NDA 96-6	6.05**	11.82**	1.70**	3.60**	-7.32**	4.74**	-17.39	18.66	-23.46*	-26.33*	-37.80**	-10.81**
NDACMS1-4A×NDA 98-6	4.48**	10.17**	1.05**	2.93**	-11.52**	-0.01	-15.05	-3.75	-16.95	-20.06	-70.67**	-67.09**
NDACMS1-4A×NDA 98-7	0.22	5.67**	-2.49**	-0.67	-18.12**	-7.47**	-24.16*	-4.26	-29.61*	-32.24**	-34.68**	-26.71**
NDACMS1-4A×NDA 7-11	9.42**	15.37**	3.01**	4.93**	-15.68**	-4.72**	-18.48	-7.64	-26.29*	-29.05**	-32.39**	-24.14**
NDACMS1-4A×NDA 7-15	2.02**	7.57**	1.31**	3.20**	-17.67**	-6.96**	-31.17**	-18.07	-51.40**	-53.22**	-24.79**	-15.61**
NDACMS1-4A×NDAGC 31	3.59**	9.22**	0.39	2.27**	-20.04**	-9.64**	-33.59**	-24.76*	-49.99**	-51.86**	-18.45**	4.02*
NDACMS1-4A×NDAGC 1010	2.02**	7.57**	-1.18**	0.67	-8.35**	3.57**	3.20	18.52	5.96	15.57	-40.37**	-9.52**
NDACMS1-4A×ICP 2309	-3.59**	1.65**	-3.27**	-1.47**	-3.33**	9.24**	11.87	26.75*	37.76**	32.61**	21.45**	47.65**
NDACMS1-4A×ICP 2155	-9.87**	-4.96**	-4.58**	-2.80**	4.45**	18.04**	41.12**	59.88**	11.88	7.70	-24.07**	13.59**
NDACMS1-4A×ICP 870	-18.16**	-13.71**	-8.64**	-6.93**	2.09	16.09**	-34.80**	-5.00	-23.57*	-3.90	11.58**	25.20**
NDACMS1-4A×ICP 7353	2.69**	8.27**	0.26	2.93**	0.34	13.39**	29.12**	46.29**	33.22**	28.24**	0.97	13.30**
NDACMS1-4A×IPA 208	-8.30**	-3.31**	-5.34**	-3.07**	-1.26	11.58**	30.42**	47.76**	35.41**	30.34**	11.92**	25.58**
NDACMS1-4A×BAHAR	-13.45**	-8.75**	-8.66**	-5.73**	-9.60**	2.15	4.02	17.85	26.58*	26.30*	12.88**	26.66**
NDACMS1-4A×AMAR	-7.17**	-2.13**	-2.49**	-0.67	1.36	14.54**	73.09**	96.11**	38.58**	33.39**	-4.39*	7.28**
NDACMS1-6A×NDA 2	-5.67**	-1.65*	-1.60**	-1.60**	0.06	13.50**	-30.90**	-1.76	-19.86	-11.40	-9.50**	6.31*
NDACMS1-6A×NDA 3	-5.22**	-1.18*	-0.53	-0.53	7.41**	21.84**	-26.52**	-3.09	-28.64*	-21.11*	-14.46**	0.47
NDACMS1-6A×NDA 3-3	-6.80**	-2.84**	-2.26**	-2.13**	8.22**	22.76**	-2.67	28.36*	0.58	11.20	-10.33**	5.33*
NDACMS1-6A×NDA 5-14	1.81**	6.15**	0.67	0.67	8.76**	23.37**	3.68	36.74**	23.19*	36.19**	9.51**	28.64**
NDACMS1-6A×NDA 8-6	-10.20**	-6.38**	-4.40**	-4.40**	-5.94**	6.70**	-33.20**	-11.90	-35.49**	-28.69**	-6.91**	26.52**
NDACMS1-6A×NDA 96-1	-17.42**	-13.71**	-10.44**	-9.60**	-9.90**	2.21	-30.58*	-8.45	-27.95*	-20.35*	4.66*	22.94**

Table 2: Countinue

(a)	Days to 50% flowering		Days to maturity		Plant height (cm)		Primary branches/plant		Secondary branches/plant		Pods/plant	
Crosses	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDACMS1-6A×NDA 96-6	-8.84**	-4.96**	-3.20**	-3.20**	0.03	13.47**	-44.65**	-20.50*	9.59	21.16*	-8.63**	31.01**
NDACMS1-6A×NDA 98-6	-6.58**	-2.60**	-1.33**	-1.33**	-0.69	12.65**	-15.99	10.80	-16.35	-7.52	25.74**	47.70**
NDACMS1-6A×NDA 98-7	-8.62**	-4.73**	-3.31**	-2.53**	-7.42**	5.02**	-17.38	8.96	-31.09**	-23.82*	-4.89*	11.72**
NDACMS1-6A×NDA 7-11	-6.80**	-2.84**	-2.80**	-2.80**	8.10**	22.62**	-33.87	-12.78	-45.24**	-39.46**	-0.78	16.55**
NDACMS1-6A×NDA 7-15	-8.39**	-4.49**	-5.10**	-3.33**	9.55**	24.27**	-39.50**	-20.21*	-22.26*	-14.05	-78.70**	-74.98**
NDACMS1-6A×NDAGC 31	-0.45	3.78**	-0.66	0.93*	-9.99**	2.11	-21.06*	4.11	-40.54**	-34.27**	-65.85**	-56.44**
NDACMS1-6A×NDAGC 1010	-4.08**	0.00	-3.67**	-2.00**	10.44**	25.28**	-23.57*	0.81	4.72	15.77	-14.00**	30.48**
NDACMS1-6A×ICP 2309	-5.22**	-1.18*	-3.85**	-3.47**	10.16**	24.95**	-13.48	14.11	15.26	27.43*	25.21**	52.21**
NDACMS1-6A×ICP 2155	-6.35**	-2.36**	-5.71**	-5.33**	1.98	15.68**	-40.28**	-21.23*	-45.25**	-39.47**	-34.06**	-1.36
NDACMS1-6A×ICP 870	-7.03**	-3.07**	-2.93**	-2.93**	8.84**	23.77**	-35.10**	-5.44	-13.89	8.27	20.09**	41.06**
NDACMS1-6A×ICP 7353	-6.12**	-2.13**	-4.16**	-1.60**	9.06**	23.71**	-25.01**	-1.10	-36.92**	-30.26**	-15.54**	-0.78
NDACMS1-6A×IPA 208	-5.67**	-1.65*	-2.99**	-0.67	5.36**	19.52**	-28.69**	-5.95	-34.42**	-27.50*	-17.86**	-3.52
NDACMS1-6A×BAHAR	-5.44**	-1.42*	-4.01**	-0.93*	-10.80**	1.19	-23.29*	1.18	-39.41**	-33.02**	-17.96**	-3.63
NDACMS1-6A×AMAR	-6.80**	-2.84**	-2.64**	-1.60**	-4.93**	7.84**	-14.54	12.71	-11.02	-1.63	-28.43**	-15.93**
No. of crosses with significant +ve heterosis	16	25	9	19	11	29	6	11	1	9	11	23
No. of crosses with significant -ve heterosis	40	31	40	34	38	21	29	2	25	28	46	28
Range of heterosis												
Lowest	-18.16	-13.95	-10.44	-9.60	-21.95	-12.25	-44.65	-37.18	-61.30	-64.33	-85.12	-84.39
Highest	12.11	18.20	3.01	4.93	10.44	25.28	77.99	101.40	104.28	36.19	25.74	52.21

(b)	Seeds/pod		100-Seed wt. (g)		Seed yield/plant (g)		Biological yield/ plant (g)		Harvest index (%)	
Crosses	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDACMS1-3A×NDA 2	10.19**	8.18*	-28.85**	-26.95**	4.85	7.89**	3.14	3.10	1.86	4.94
NDACMS1-3A×NDA 3	-2.19	1.36	-10.72**	-8.33**	29.15**	4.98	20.07**	-2.33	7.56**	7.49**
NDACMS1-3A×NDA 3-3	41.67**	8.18*	-22.96**	-20.91**	-7.72*	-26.35**	4.90	-19.51**	-12.25**	-8.42**
NDACMS1-3A×NDA 5-14	-4.79	-18.64**	-25.85**	-15.99**	-84.63**	-81.24**	-18.43**	1.04	-81.15**	-81.42**
NDACMS1-3A×NDA 8-6	-14.56**	-20.00**	-14.99**	-12.72**	-81.76**	-78.72**	-37.72**	-30.39**	-70.72**	-69.43**
NDACMS1-3A×NDA 96-1	-6.83	-13.18**	-37.86**	-36.20**	-68.42**	-73.61**	37.46**	19.84**	-77.05**	-78.01**
NDACMS1-3A×NDA 96-6	23.16**	6.36	-9.74**	-7.34**	-21.77**	-10.67**	-14.72**	-9.57**	-8.32**	-1.23
NDACMS1-3A×NDA 98-6	18.46**	5.00	-22.89**	-20.83**	31.12**	13.13**	30.42**	7.71**	0.62	5.08*
NDACMS1-3A×NDA 98-7	24.44**	1.82	-24.13**	-22.11**	19.50**	-15.11**	8.30**	-16.90**	10.32**	2.17
NDACMS1-3A×NDA 7-11	-5.73	-2.73	-38.32**	-36.68**	-35.71**	-45.01**	-18.14**	-30.57**	-21.45**	-20.74**
NDACMS1-3A×NDA 7-15	-3.30	-6.82	-24.13**	-22.11**	-24.63**	-46.46**	-13.43**	-33.57**	-22.59**	-19.40**
NDACMS1-3A×NDAGC 31	-5.97	-14.09**	-11.52**	-9.16**	-80.15**	-79.15**	-12.49**	-9.10**	-77.34**	-77.08**
NDACMS1-3A×NDAGC 1010	-0.54	-15.91**	-16.96**	-14.75**	-79.32**	-80.22**	22.28**	5.83*	-83.10**	-81.31**
NDACMS1-3A×ICP 2309	23.89**	1.36	-23.55**	-21.51**	-5.05	-26.56**	10.56**	-15.16**	-17.72**	-13.38**
NDACMS1-3A×ICP 2155	31.11**	7.27*	-16.89**	-14.67**	-20.69**	-12.31**	-7.20**	-5.48*	-14.66**	-7.28**
NDACMS1-3A×ICP 870	14.51**	0.45	-30.18**	-28.32**	-14.25**	-39.09**	-9.75**	-23.80**	-13.76**	-20.12**
NDACMS1-3A×ICP 7353	3.24	1.36	-23.01**	-20.96**	15.63**	-17.86**	12.64**	-12.76**	1.70	-5.80**
NDACMS1-3A×IPA 208	24.44**	1.82	-22.84**	-20.78**	-63.90**	-66.43**	-41.87**	-48.29**	-38.02**	-35.21**
NDACMS1-3A×BAHAR	6.04	-12.27**	-15.09**	-12.82**	-76.57**	-81.12**	-6.90*	-28.56**	-76.18**	-73.58**
NDACMS1-3A×AMAR	8.38*	-11.82**	-14.43**	-12.15**	-72.31**	-78.98**	-7.45**	-28.98**	-72.96**	-70.42**
NDACMS1-4A×NDA 2	4.63	2.73	-20.85**	-22.03**	-19.96**	-17.64**	-20.79**	-20.82**	0.91	3.96

Table 2: Countinue

(b)	Seeds/pod		100-Seed wt. (g)		Seed yield/plant (g)		Biological yield/plant (g)		Harvest index (%)	
Crosses	BP	SV	BP	SV	BP	SV	BP	SV	BP	SV
NDACMS1-4A×NDA 3	-4.39	-0.91	4.86*	-24.08**	-9.27**	-17.72**	-15.34**	-18.16**	0.60	0.53
NDACMS1-4A×NDA 3-3	-20.56**	-22.73**	-19.95**	-20.13**	-79.44**	-81.36**	-45.75**	-47.55**	-65.92**	-64.44**
NDACMS1-4A×NDA 5-14	-0.93	-3.64	-24.09**	-14.00**	-83.72**	-80.13**	-61.53**	-52.35**	-57.84**	-58.43**
NDACMS1-4A×NDA 8-6	-3.27	-5.91	-7.87**	-20.88**	-85.06**	-82.57**	-63.30**	-58.98**	-59.29**	-57.51**
NDACMS1-4A×NDA 96-1	4.21	1.36	-0.73	-21.51**	-59.13**	-62.93**	-51.64**	-53.25**	-17.31**	-20.77**
NDACMS1-4A×NDA 96-6	6.07	3.18	9.29**	-6.66**	-21.70**	-10.59**	-16.62**	-11.58**	-6.14*	1.12
NDACMS1-4A×NDA 98-6	-9.35*	-11.82**	-30.97**	-34.98**	-75.49**	-77.77**	-48.75**	-50.46**	-57.07**	-55.16**
NDACMS1-4A×NDA 98-7	-5.61	-8.18**	39.44**	0.20	-17.72**	-25.38**	-19.12**	-21.82**	1.78	-4.54
NDACMS1-4A×NDA 7-11	-1.76	1.36	5.89*	-9.81**	-20.16**	-27.60**	-25.34**	-27.83**	-0.52	0.37
NDACMS1-4A×NDA 7-15	-14.02**	-16.36**	22.05**	-12.30**	-28.95**	-35.57**	-24.86**	-27.36**	-14.90**	-11.39**
NDACMS1-4A×NDAGC 31	0.47	-2.27	18.87**	-6.01**	3.45	8.63**	-3.29	0.46	6.97**	8.20**
NDACMS1-4A×NDAGC 1010	-15.42**	-17.73**	18.92**	-14.55**	-28.97**	-32.04**	-26.10**	-28.57**	-13.88**	-4.80
NDACMS1-4A×ICP 2309	0.47	-2.27	4.93*	-24.60**	26.15**	14.41**	9.23**	5.59*	2.94	8.36**
NDACMS1-4A×ICP 2155	4.86	2.00	-7.40**	-21.66**	-11.91**	-2.60	-2.56	-0.75	-9.67**	-1.86
NDACMS1-4A×ICP 870	8.88	5.91	0.38	-27.87**	8.91**	-1.22	4.21	0.74	4.56	-1.94
NDACMS1-4A×ICP 7353	-2.78	-4.55	7.92**	-22.46**	-0.35	-9.62**	-2.44	-5.69*	2.15	-4.19
NDACMS1-4A×IPA 208	0.93	-1.82	6.12**	-1.37	33.74**	24.38**	12.67**	8.91**	9.24**	14.19**
NDACMS1-4A×BAHAR	-4.21	-6.82	19.75**	-8.01**	26.87**	15.06**	19.29**	15.32**	-10.03**	-0.21
NDACMS1-4A×AMAR	-8.41*	-10.91**	16.08**	1.42	21.66**	10.33**	14.06**	10.26**	-8.53**	0.07
NDACMS1-6A×NDA 2	-4.37	-0.45	-10.74**	-12.08**	-6.71*	-0.58	-0.46	5.26*	-8.31**	-5.54*
NDACMS1-6A×NDA 3	-10.04**	-6.36	24.65**	-7.91**	-8.26**	-2.23	-2.21	3.41	-6.23*	-5.48*
NDACMS1-6A×NDA 3-3	-14.85**	-11.36**	1.50	1.27	-5.81*	0.39	-2.95	2.62	-6.29*	-2.20
NDACMS1-6A×NDA 5-14	-7.42	-3.64	-12.55**	-0.92	2.08	24.60**	-2.37	20.93**	2.26	3.08
NDACMS1-6A×NDA 8-6	-11.35**	-7.73*	10.78**	-4.87**	1.02	17.89**	0.30	12.11**	0.75	5.16*
NDACMS1-6A×NDA 96-1	-3.49	0.45	10.79**	-12.40**	11.28**	18.60**	11.59**	18.00**	-0.28	0.53
NDACMS1-6A×NDA 96-6	-1.31	2.73	-22.67**	-33.96**	-17.09**	-5.33	-5.65*	0.06	-12.19**	-5.40*
NDACMS1-6A×NDA 98-6	-2.18	1.82	-9.77**	-15.02**	22.24**	26.28**	1.06	6.86	16.74**	21.92**
NDACMS1-6A×NDA 98-7	-0.87	3.18	-0.44	-26.45**	-13.37**	-7.67**	-6.92**	-1.58	-6.95**	-6.20**
NDACMS1-6A×NDA 7-11	-11.35**	-7.73*	9.29**	-6.91**	4.68	11.56**	-1.53	4.13	6.18*	7.14**
NDACMS1-6A×NDA 7-15	-2.62	1.36	5.61*	-21.98**	-79.10**	-77.73**	7.94**	14.13**	-81.21**	-80.44**
NDACMS1-6A×NDAGC 31	-20.52**	-17.27**	-2.18	-22.65**	-78.05**	-76.61**	-14.90**	-10.01**	-74.25**	-73.95**
NDACMS1-6A×NDAGC 1010	-2.62	1.36	4.83*	-22.55**	5.98*	12.94**	5.11*	11.15**	-8.08**	1.61
NDACMS1-6A×ICP 2309	-5.24	-1.36	-2.23	-27.77**	10.29**	17.54**	5.95*	12.03**	-0.29	4.96
NDACMS1-6A×ICP 2155	-6.11	-2.27	-7.20**	-21.48**	-28.16**	-20.57**	-19.60**	-14.98**	-13.97**	-6.53**
NDACMS1-6A×ICP 870	-0.87	3.18	6.42**	-21.38**	14.03**	21.52**	11.16**	17.54**	2.63	3.46
NDACMS1-6A×ICP 7353	-3.49	0.45	4.46*	-22.83**	-22.90**	-17.83**	-14.91**	-10.02**	-9.40**	-8.67**
NDACMS1-6A×IPA 208	-6.55	-2.73	-14.39**	-20.43**	-27.13**	-22.35**	-21.29**	-16.77**	-10.66**	-6.61**
NDACMS1-6A×BAHAR	-4.37	-0.45	12.37**	-13.67**	-17.98**	-12.59**	-9.99**	-4.82*	-17.31**	-8.28**
NDACMS1-6A×AMAR	-0.87	3.18	7.88**	-5.74**	-13.20**	-7.49**	-3.30	2.25	-17.29**	-9.52**
No. of crosses with significant +ve heterosis	10	3	22	0	14	15	16	15	6	8
No. of crosses with significant -ve heterosis	11	17	31	55	39	38	29	14	39	32
Range of heterosis										
Lowest	-20.52	-22.73	-38.32	-36.68	-85.06	-82.57	-63.30	-58.98	-83.10	-81.42
Highest	41.67	8.18	39.44	1.42	33.74	26.28	37.46	20.93	16.74	21.92

*,**Significant at 5 and 1% probability levels, respectively

or more of the components have been pointed out by Grafius (1959). A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction was

Table 3: Heterosis for other traits of crosses showing significant positive heterobeltiosis and standard heterosis for seed yield per plant

Hybrids (Crosses)	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Pods/ plant	Seeds/ pod	100 seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Seed yield/ plant (g)
Heterobeltiosis											
NDACMS1-4A×IPA 208	-	-	-	+	+	+	+	+	+	+	33.74**
NDACMS1-3A×NDA 98-6	-	-	-	+	+	+	+	-	+	+	31.12**
NDACMS1-3A×NDA 3	+	+	-	+	+	+	-	-	+	+	29.15**
NDACMS1-4A×BAHAR	-	-	-	+	+	+	+	+	+	-	26.87**
NDACMS1-4A×ICP 2309	-	-	-	+	+	+	+	+	+	+	26.15**
NDACMS1-6A×NDA 98-6	-	-	-	-	-	+	-	-	+	+	22.24**
NDACMS1-4A×AMAR	-	-	+	+	+	-	-	+	+	-	21.66**
NDACMS1-3A×NDA 98-7	-	-	-	-	+	-	+	-	+	+	19.50**
NDACMS1-3A×ICP 7353	+	+	-	-	-	-	+	-	+	+	15.63**
NDACMS1-6A×ICP 870	-	-	+	-	-	+	-	+	+	+	14.03**
NDACMS1-6A×NDA 96-1	-	-	-	-	-	+	-	+	+	-	11.28**
NDACMS1-6A×ICP 2309	-	-	+	+	+	+	-	-	+	-	10.29**
NDACMS1-4A×ICP 870	-	-	+	-	-	+	+	+	+	+	8.91**
NDACMS1-6A ×NDAGC 1010	-	-	+	-	+	-	-	+	+	-	5.98**
Standard heterosis											
NDACMS1-6A×NDA 98-6	-	-	+	+	-	+	+	-	+	+	26.28**
NDACMS1-6A×NDA 5-14	+	+	+	+	+	+	-	-	+	+	24.60**
NDACMS1-4A×IPA 208	-	-	+	+	+	+	-	-	+	+	24.38**
NDACMS1-6A×ICP 870	-	-	+	-	+	+	+	-	+	+	21.52**
NDACMS1-6A×NDA 96-1	-	-	+	-	-	+	+	-	+	+	18.60**
NDACMS1-6A×NDA 8-6	-	-	+	-	-	+	-	-	+	+	17.89**
NDACMS1-6A×ICP 2309	-	-	+	+	+	+	-	-	+	+	17.54**
NDACMS1-4A× BAHAR	-	-	+	+	+	+	-	-	+	-	15.06**
NDACMS1-4A×ICP 2309	-	-	+	+	+	+	-	-	+	+	14.41**
NDACMS1-3A×NDA 98-6	-	-	-	+	+	+	+	-	+	+	13.13**
NDACMS1-6A ×NDAGC 1010	+	-	+	+	+	+	+	-	+	+	12.94**
NDACMS1-6A×NDA 7-11	-	-	+	-	-	+	-	-	+	+	11.56**
NDACMS1-4A×AMAR	-	-	+	+	+	+	-	+	+	+	10.33**
NDACMS1-4A×NDAGC 31	+	+	-	-	-	+	-	-	+	+	8.63**
NDACMS1-3A×NDA 2	+	-	-	-	+	+	+	-	+	+	7.89**

*,**Significant at 5 and 1% probability levels, respectively, +: Significant and positive estimates of heterobeltiosis and standard heterosis, -: Significant and negative estimates of heterobeltiosis and standard heterosis

observed for seed yield per plant (Table 2). The heterobeltiosis ranged from -85.06 to 33.74% and standard heterosis varied from -82.57 to 26.28%. Out of 60 crosses 15 crosses viz., NDACMS 1-6A×NDA 98-6, NDACMS 1-6A×NDA 5-14, NDACMS 1-4A×IPA 208, NDACMS 1-6A×ICP 870, NDACMS 1-6A×NDA 96-1, NDACMS 1-6A×NDA 8-6, NDACMS 1-6A×ICP 2309, NDACMS 1-4A×Bahar, NDACMS 1-4A×ICP 2309, NDACMS 1-3A×NDA 98-6, NDACMS 1-6A×NDAGC 1010, NDACMS 1-6A×NDA 7-11, NDACMS 1-4A×Amar, NDACMS 1-4A×NDAGC 31 and NDACMS 1-3A ×NDA 2 showed significant positive heterosis over standard variety (NDA 2). For commercial exploitation of heterosis, yield advantage of 20-30% over best available standard variety is necessary to encourage farmers to take-up hybrid pigeonpea cultivation. In the present investigation four combinations exhibited standard heterosis more than 20% increased seed yield were NDACMS 1-6A×NDA 98-6, NDACMS 1-6A×NDA 5-14,

NDACMS 1-4A×IPA 208, NDACMS 1-6A×ICP 870. These findings were in close agreement with the findings of earlier workers (Kumar and Srivastva, 1998; 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; Chandirakala *et al.*, 2010; Vaghela *et al.*, 2011; Gupta *et al.*, 2011; Kumar *et al.*, 2012).

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 60 crosses 31 crosses had early flowering than the standard variety (NDA 2). When compared to better parent, significant earlier flowering plants were observed in 40 crosses while; 16 crosses were identified for late flowering. The magnitude of heterosis observed over better parent ranged from -18.16% (NDACMS 1-4A×ICP 870) to 12.11% (NDACMS 1-4A×NDA 8-6), the magnitude of standard heterosis ranged from -13.95% (NDACMS 1-3A×NDA 98-6) to 18.20% (NDACMS 1-4A×NDA 8-6). The 5 superior crosses having heterobeltiosis for early flowering were NDACMS 1-4A×ICP 870, NDACMS 1-6A×NDA 96-1, NDACMS 1-3A×NDA 98-6, NDACMS 1-3A×Bahar and NDACMS 1-4A ×Bahar. In respect of standard heterosis the most promising cross combinations for early flowering were NDACMS 1-3A×NDA 98-6, NDACMS 1-4A×ICP 870, NDACMS 1-6×NDA 96-1, NDACMS 1-3A×Bahar and NDACMS 1-3A×Amar. Heterosis in both negative and positive directions for days to 50% flowering have also been reported by Kumar and Srivastva (1998), Wankhade *et al.* (2005), Baskaran and Muthiah (2006), Wanjari *et al.* (2007), Patel and Tikka (2008), Sarode *et al.* (2009) Chandirakala *et al.* (2010) and Vaghela *et al.* (2011).

Days to maturity: Out of 60 crosses 34 crosses had early maturity than the standard variety (NDA 2). When compared to better parent, significantly earlier maturity were observed in 40 crosses while; 9 crosses were identified for late maturity. The magnitude of heterosis observed over better parent ranged from -10.44% (NDACMS 1-6A×NDA 96-1) to 3.01% (NDACMS 1-4A× NDA 7-11), the magnitude of standard heterosis ranged from -9.60% (NDACMS 1-6A×NDA 96-1) to 4.93% (NDACMS 1-4A×NDA 8-6). The 5 superior cross combinations having heterobeltiosis for early maturity were NDACMS 1-6A×NDA 96-1, NDACMS 1-4A×Bahar, NDACMS 1-4A×ICP 870, NDACMS 1-3A×Bahar and NDACMS 1-3A×NDA 98-6. However, in respect of standard heterosis the most promising cross combinations were NDACMS 1-6A×NDA 96-1, NDACMS 1-4A ×ICP 870, NDACMS 1-4A×Bahar, NDACMS 1-6A×ICP 2155 and NDACMS 1-3A×NDA 98-6. The desirable combinations were common for both the heterosis for days to maturity are not cross specific. Solanki *et al.* (2008) reported that most of the promising hybrids depicted significant negative heterosis for days to 50% flowering and days to maturity, thereby suggesting that high yield in hybrids can be achieved along with early flowering and maturity.

Plant height: In pigeonpea plant height is desirable character for achieving high yield as vigour in plant height may lead to increase biomass as well as source-sink capacity for obtaining optimum yield. The maximum significant positive heterosis observed over the better parent was 10.44% (NDACMS 1-6A×NDAGC 1010), while in case of standard heterosis, it was 25.28% in same cross. Five crosses namely, NDACMS 1-6A×NDAGC 1010, NDACMS 1-6A×NDAGC 31, NDACMS 1-6A×NDA 7-15, NDACMS 1-6A×ICP 7353 and NDACMS 1-6A×NDA 5-14 exhibited significant positive heterobeltiosis. Whereas, eleven and twenty nine crosses expressed taller stature in comparison to both better parent and standard variety, respectively. The most promising crosses with significant positive heterosis over standard variety were NDACMS 1-6A×NDAGC 1010, NDACMS 1-6A×ICP 2309, NDACMS 1-6A×NDA 7-15, NDACMS 1-6A×ICP 870 and NDACMS 1-6A×ICP 7353. Present observations are in close agreement with earlier report of several workers (Kumar and Srivastva, 1998; Wankhade *et al.*, 2005; Baskaran and Muthiah, 2006; Patel and Tikka, 2008; Sarode *et al.*, 2009; Chandirakala *et al.*, 2010; Vaghela *et al.*, 2011).

Primary branches per plant: More primary branches per plant are believed to be closely associated with high seed yield per plant resulting high productivity. Therefore, the cross combinations with more primary branches per plant were to be identified. The significant positive heterosis for this trait was exhibited by 6 and 11 hybrids over better parent and standard variety, respectively. Further the heterobeltiosis varied from -44.65% NDACMS 1-6A×NDA 96-6) to 77.99% (NDACMS 1-3A×NDA 98-6) and standard heterosis from -37.18% (NDACMS 1-3A ICP 2155) to 101.40% (NDACMS 1-3A×NDA 98-6). As regards, the expression of heterobeltiosis, the most promising crosses were NDACMS 1-3A×NDA 98-6, NDACMS 1-4A×Amar, NDACMS 1-3A×NDA 3-3, NDACMS 1-4A×ICP 2155 and NDACMS 1-4A×IPA 208. Considering standard heterosis, the 5 superior cross combinations were NDACMS 1-3A×NDA 98-6, NDACMS 1-4A×Amar, NDACMS 1-3A×NDA 3-3, NDACMS 1-4A×ICP 2155 and NDACMS 1-4A×IPA 208.

Secondary branches per plant: The significant positive heterosis for this trait was exhibited by 10 and 9 hybrids over better parent and standard variety, respectively. The range of heterobeltiosis varied from -61.30% (NDACMS 1-3A×ICP 870) to 104.28% (NDACMS 1-3A×NDA 98-7) and standard heterosis from -64.33% (NDACMS 1-3A×ICP 2155) to 36.19% (NDACMS 1-6A×NDA 5-14). As regards the expression of heterobeltiosis, the most promising crosses were NDACMS 1-3A×NDA 98-7, NDACMS 1-3A×NDA 98-6, NDACMS 1-3A×NDA 3-3, NDACMS 1-3A×NDA 3 and NDACMS 1-4A×Amar. Considering standard heterosis, the 5 superior cross combinations were NDACMS 1-6A×NDA 5-14, NDACMS 1-4A×Amar, NDACMS 1-4A×ICP 2309, NDACMS 1-4A×IPA 208 and NDACMS 1-3A×NDA 98-6. Results for significantly high number of primary branches and secondary branches per plant are in conformity with those obtained by Wankhade *et al.* (2005), Baskaran and Muthiah (2006), Patel and Tikka (2008), Sarode *et al.* (2009), Chandirakala *et al.* (2010) and Vaghela *et al.* (2011).

Pods per plants: The hybrids with positive heterosis for number of pods per plants are desirable to increase the yield. The lowest estimates of heterosis (-85.12%) over better parent and (-84.39%) standard variety was recorded in the cross NDACMS 1-3A×Bahar, while maximum heterosis over better parent and standard variety was observe d in case of cross NDACMS 1-6A×NDA 98-6 (25.74%) and NDACMS 1-6A×ICP 2309 (52.21%). Out of 60 crosses, 11 crosses over better parent and 23 crosses over standard variety exhibited significant higher number of pods per plant. Significantly less number of pods per plant over the better parent and standard variety was observed in 46 and 28 crosses, respectively. The 5 superior crosses considering standard heterosis were NDACMS 1-6A×ICP 2309, NDACMS 1-6A×NDA 98-6, NDACMS 1-4A×ICP 2309, NDACMS 1-6A×NDA 96-6 and NDACMS 1-6A×NDA 5-14. Similar findings were also reported by Baskaran and Muthiah (2006), Banu *et al.* (2007), Patel and Tikka (2008), Sarode *et al.* (2009), Chandirakala *et al.* (2010) and Vaghela *et al.* (2011). They concluded that heterosis in yield was primarily due to increased number of pods per plant in pigeonpea.

Seeds per pods: The hybrids with positive heterosis for number of seeds per pod are desirable to increase the yield. The lowest estimates of heterosis (-20.52%) over better parent and (-22.73%) standard variety were recorded in the cross NDACMS 1-6A×NDAGC 31 and NDACMS 1-4A×NDA 3-3, respectively, while maximum heterosis over better parent (41.67%) and standard variety (8.18%) was observed in case of cross NDACMS 1-3A×NDA 3-3. Out of 60 crosses, 10 crosses over better parent and 3 crosses over standard variety exhibited significant higher number of seeds per pod. Significantly less number of seeds per pod over the better parent and standard variety was observed in 11 and 17 crosses, respectively. Considering standard heterosis, the best crosses were NDACMS 1-3A×NDA 3-3, NDACMS 1-3A×NDA 2 and NDACMS 1-3A×ICP 2155. These findings were closely agreement with (Banu *et al.*, 2007; Patel and Tikka, 2008; Sarode *et al.*, 2009; Kumar *et al.*, 2012).

Hundred-seed weight: The 100 seed weight is one of the important common traits which influence the yield. The extent of heterobeltiosis varied from -38.32% (NDACMS 1-3A×NDA 7-11) to 39.44% (NDACMS 1-4A×NDA 98-7) and standard heterosis from -36.68% (NDACMS 1-3A×NDA 7-11) to 1.42% (NDACMS 1-4A×Amar). Significantly higher 100-seed weight was observed in case of 22 crosses when tested against their better parents and none of the crosses against the standard variety. The five best heterotic crosses in respect of heterobeltiosis were NDACMS 1-4A×NDA 98-7, NDACMS 1-6A×NDA 3, NDACMS 1-4A×NDA 7-15, NDACMS 1-4A×Bahar and NDACMS 1-4A×NDAGC 1010. Among 60 crosses, 22 and 31 hybrids showed significant heterobeltiosis over better parent in positive and negative direction, respectively whereas 3 non significant positive heterosis and 55 significant negative heterosis over standard variety. Heterosis with respect to 100-seed weight in positive and negative direction have also been reported by Kumar and Srivastva (1998), Wankhade *et al.* (2005), Baskaran and Muthiah (2006), Patel and Tikka (2008), Sarode *et al.* (2009), Chandirakala *et al.* (2010), Vaghela *et al.* (2011) and Kumar *et al.* (2012).

Biological yield per plant: The extent of heterobeltiosis for this trait varied from -63.30% (NDACMS 1-4A×NDA 8-6) to 37.46% (NDACMS 1-3A×NDA 96-1) and standard heterosis from-58.98% (NDACMS 1-4A×NDA 8-6) to 20.93% (NDACMS 1-6A×NDA 5-14). Out of 60 hybrids, 16 crosses recorded significantly higher heterobeltiosis while, 15 crosses exhibited in the case of standard heterosis. The top five crosses in relation to standard heterosis for biological yield were NDACMS 1-6A×NDA 5-14, NDACMS 1-3A×NDA 96-1, NDACMS 1-6A×NDA 96-1, NDACMS 1-4A×Bahar and NDACMS 1-6A×NDA 7-15. Significant but negative heterosis was exhibited by 29 and 14 hybrids over better parent and standard variety, respectively. These results are in close agreement with (Baskaran and Muthiah, 2006; Patel and Tikka, 2008; Sarode *et al.*, 2009; Chandirakala *et al.*, 2010).

Harvest-index: Harvest-index indirectly influences the seed yield through partitioning photosynthates in source and sink. The minimum heterosis for harvest-index varied from -83.10 and -81.42% over better parent and standard variety, respectively in cross NDACMS 1-3A×NDAGC 1010 and NDACMS 1-3A×NDA 5-14. However, the maximum heterosis was 16.74% over better parent and 21.92% over standard variety in cross NDACMS 1-6A×NDA 98-6. Among 60 crosses studied only 6 crosses showed significant positive and 39 showed significant negative heterobeltiosis while 8 crosses showed significant positive and 32 crosses exhibit significant negative standard heterosis. The most promising crosses having maximum positive heterobeltiosis as well as standard heterosis for harvest-index were NDACMS 1-6A×NDA 98-6, NDACMS 1-4A×IPA 208, NDACMS 1-6A×NDA 7-11 and NDACMS 1-3A×NDA 98-7. 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) and Gupta *et al.* (2011).

CONCLUSION

The heterosis breeding has been used extensively in improving yield potential through development of hybrid cultivars in most of the crops including pigeonpea. The exploitation of heterosis for developing high yielding commercial hybrids in pigeonpea has been found highly fruitful in spite of its often cross-pollinated nature because significant heterosis is encountered in F_1 hybrids for successful and economical technology for commercial hybrid seed production is available. The estimates of heterosis showed that fifteen crosses had significant standard heterosis for seed yield per plant and some of its components. Among them 4 crosses viz., NDACMS1-6A×NDA 98-6, NDACMS1-6A×NDA 5-14, NDACMS1-4A×IPA 208 and NDACMS1-6A×ICP 870 were found to be more than 20% standard heterosis recommended for commercial utilization.

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