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Heterosis in relation to molecular diversity in pigeonpea [*Cajanus cajan* (L.) Millsp.]

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ABSTRACT

Pigeonpea is the only grain legume crop where hybrid vigour has been exploited commercially. For sustaining this technology, it is imperative that information about the genetic nature of hybrid vigour is generated and new high-yielding hybrids are bred at regular intervals. In this context, a set of genetic materials, consisting 19 hybrids, their parents and F_2 bulks was studied. Only four hybrids expressed significant heterosis over mid-parent; and of these, two were found to be significantly superior to their respective better parent also. The hybrid between ICPA 2209 and ICPL 20108 was the best with respect to heterobeltiosis (55.9%) and relative heterosis (60.5%**). The studies also showed that both additive as well as non-additive genetic variation played a key role in the manifestation of hybrid vigour. Based on the molecular diversity of the parents, two heterotic groups were formed in A-lines, while three heterotic groups were formed in the R-lines. The results showed that in this material high heterosis was not necessarily related to their molecular diversity.**

Key words: Gene action, Hybrid vigour, Inbreeding depression, Molecular diversity, Pigeonpea

In self-pollinated crops, breeding of inbred cultivars is the most popular approach to develop new cultivars, which primarily involves accumulation of useful alleles from the two parents in a single genotype. This approach, however, has a limitation of the availability of different favorable alleles and therefore, may lead to plateauing of productivity. To overcome this constraint, Shull (1908) proposed the concept of exploiting hybrid vigour. This technology could only be applied to the crops where large-scale production of F_1 hybrid seed was easy and economically viable; and for this reason, legumes could not be benefited from this genetic phenomenon due to their highly self-pollinated nature. In some legumes such as faba bean, soybean, and pigeonpea, however, some degree of natural out-crossing exists and attempts were made in the past to breed hybrids; but the success was achieved only in pigeonpea. In this pulse crop three commercial hybrids with 25-40% yield advantages, were released in India (Saxena 2015, Saxena *et al.* 2017). For the success of this technology, it is important that genetic information related to the manifestation of hybrid vigour is generated and new hybrids are bred at regular intervals. In this context, the present study was conducted to get some insight into gene action involved in the expression of hybrid vigour for seed yield and other important traits. Besides this, the levels of hybrid vigour and their relationship with molecular diversity were also studied.

MATERIALS AND METHODS

In the present investigation, 19 pigeonpea hybrids, their parents, and F_2s were studied for estimating the extents of hybrid vigour over both mid-parent (relative heterosis) as well as the better parent (heterobeltiosis). Besides this, depression in performance of the hybrids due to their inbreeding was also estimated. Six CMS lines and 11 known fertility restorers were identified from ICRISAT's Pigeonpea Breeding Programme. These included five CMS lines (ICPA 2043, ICPA 2047, ICPA 2048, ICPA 2078, and ICPA 2092] with A_4 (*Cajanus cajanifolius*) cytoplasm; while ICPA 2209 carried the cytoplasm of *Cajanus lineatus*, designated as A_6. The fertility restoring (R-) lines were ICPLs 87119, 20093, 20096, 20106, 20108, 20129, 20177, 20343, 20346, 20347, and 20349. A total of 19 hybrid (A- x R-) combinations were developed by hand pollinating the male sterile plants in 2010 rainy season. The hybrid seeds were grown in 2011 and to advance the generation, the plants were self-pollinated using muslin cloth bags of 100 x 60 cm size.

The evaluation of the test materials was carried out in two separate trials; one for studying hybrid vigour and another for estimating inbreeding depression during 2012 rainy season in Vertisols at ICRISAT Campus, Patancheru. Since one of the parents used for the production of hybrids was male-sterile, their respective maintainer (B-) lines were used in the trails to collect information on various traits. Both the trials were sown in randomized complete block design with three replications at the on-set of rainy season. Each entry was sown in four meter long rows, spaced 75 cm apart. The intra row spacing was kept at 30 cm. In the hybrid trial, the test entries were sown in four row plots. In the inbreeding trial, the F_1 hybrids and their parents were sown in four-row plots, whereas the F_2 populations were evaluated in eight-row plots. The crop received four irrigations in the post rainy season. The weeds were controlled by hand weeding at early seedling and pre-flowering stages. To control the pod borers, three sprays of insecticide 'Spinosad' were applied during flowering and podding stages. In the hybrid trial, five competitive plants were selected randomly in each plot for recording observations.

Similarly, in the inbreeding trial also, five plants were sampled within the each plot of hybrid and its parents; while in the F_2 plot, 200 competitive plants were sampled randomly. In both the trials, observations were recorded on individual plants for plant height (cm), number of primary branches, number of pods, 100-seed weight (g), seeds/ pod, and seed yield (g). Data on days to flower and bulk yield (kg/ha) were recorded on plot basis.Hybrid vigour was estimated as percent advantage of the hybrid over mid-parent or better parent. Similarly, the inbreeding depression was estimated as percent increase or decrease of F_2 over F_1 generation.

RESULTS

Hybrid Vigour: For bulk seed yield, four hybrids exhibited significant mid-parent heterosis (Table 1). These included ICPA 2043 × ICPL 20347 (71.28 %**), ICPA 2092 x ICPL 20108 (60.52 %**), ICPA 2048 × ICPL 20106 (50.64 %*) and ICPA 2043 x ICPL 20129 (39.82 %* heterosis). Significant better-parent heterosis for bulk plot yield was recorded inhybrids ICPA 2043 x ICPL 20347 (43.08 %*) and ICPA 2209 x ICPL 20108 (55.92%**). Both these hybrids were rated as promising, as they exhibited significant heterosis over their respective mid-parent values also. For individual plant yield only one hybrid ICPA 2209 x ICPL 20108 (55.57 %**) exhibited significant mid-parent heterosis; while four hybrids namely ICPA 2078 × ICPL 87119 (3.86 %**), ICPA 2078 × ICPL 20346 (4.25 %**), ICPA 2078 × ICPL 20347 (12.44 %**) and ICPA 2209 × ICPL 20108 (46.38 %**) exhibited significant positive heterosis over their respective better parent and of these, three hybrids had common female parent ICPA 2078.

In pigeonpea, number of primary branches on a plant plays an important role in the manifestation of yield. For this trait, 18 out of 19 hybrids exhibited significant better parent heterosis. The mid-parent heterosis for this trait was significant and positive in all the hybrids, with highest heterosis being recorded for ICPA 2078 × ICPL 20346. Among these, four hybrids [ICPA 2209 × ICPL 20108, ICPA 2078 × ICPL 20347, ICPA 2078 x ICPL 20346 and ICPA 2078 x ICPL 87119] also exhibited significant better parent heterosis for seed yield/plant. For number of secondary branches/plant, 12 hybrids exhibited positive significant mid-parent heterosis and it ranged from 6.07 %** to 42.64 %**. Among these, eight hybrids showed significant positive better parent heterosis for this trait. Considering both primary and secondary branches together; it was observed that respectively, 7 and 12 hybrids exhibited significant heterosis over both better as well as mid-parent values.

For plant height, three hybrids ICPA 2078 × ICPL 87119 (16.0 %*), ICPA 2078 × ICPL 20346 (12.12 %*) and ICPA 2078 × ICPL 20343 (11.38 %*) recorded significant positive mid-parent heterosis, but none with respect to heterobeltiosis. For seeds/pod only two hybrids ICPA 2048 × ICPL 20347 (5.70 %*) and ICPA 2092 × ICPL 20093 (5.38 %*) exhibited significant positive heterosis over mid-parent, but none of them had significant better parent heterosis (Table 1). For seed size, hybrids ICPA 2047 × ICPL 87119 (16.15 %**), ICPA 2078 × ICPL 20346 (15.11 %**), ICPA 2209 × ICPL 20108 (13.82 %*), ICPA 2047 × ICPL 20347 (13.73 %*) and ICPA 2043 × ICPL 20096 (12.06 %*) recorded significant positive heterosis over mid-parent. Interestingly, for days to 50% flowering none of the hybrids showed significant better parent heterosis.

Inbreeding Depression: For seed yield/plot, hybrid ICPA 2043 × ICPL 87119 exhibited significant inbreeding depression with a large yield (19.83 %*) decline in F_2 generation (Table 2). On the contrary, hybrid ICPA 2078 ×

Table 1. Heterosis over mid parent and better parent in F_1 hybrids

Genotype	Days to 50% flower		Plant height		Primary branches		Secondary branches		Pods/ plant	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
1. ICPA 2043 × ICPL 20129	-1.53	-3.01	2.43	-4.36	40.00 **	26.00*	18.27 **	8.22*	-28.82	-40.26
2. ICPA 2043 × ICPL 20096	0	-0.83	4.46	-2.99	46.81 **	38.00 **	6.07 **	-8.02	1.05	-1.35
3. ICPA 2078 × ICPL 20343	-0.97	-1.65	11.38 *	0.79	64.38 **	57.89 **	27.55 **	24.05 **	11.91	5.97
4. ICPA 2078 × ICPL 20346	-3.85	-3.85	12.12 *	-0.75	83.61 **	47.37 **	27.95 **	19.31 **	13.45	-3.29
5. ICPA 2043 × ICPL 20343	-0.7	-1.39	5.37	4.45	38.82 **	18	42.64 **	29.01 **	15.19	-17.79
6. ICPA 2043 × ICPL 20349	-0.7	-1.39	3.52	2.51	58.57 **	30.00 *	36.71 **	24.57 **	15.39	-16.53
7. ICPA 2048 × ICPL 20347	-0.56	-0.56	6.98	2.14	76.62 **	65.85 **	9.62 **	4.74 **	15.76	12.72
8. ICPA 2078 × ICPL 87119	0.41	0.27	16.00 **	-1.69	58.14 **	41.66 **	7.94 **	-15.27	7.31	-21.41
9. ICPA 2047 × ICPL 20177	0.55	0.28	-2.55	-12.18	74.65 **	51.22 **	-13.59	-23.19	3.65	-6.08
10.ICPA 2048 × ICPL 20106	1.25	1.11	3.51	0.46	62.5 **	58.54 **	-10.58	-11.69	-14.72	-23.02
11.ICPA 2092 × ICPL 20093	1.11	0.55	3.29	2.61	71.05 **	51.16 **	-7.97	-20.53	-5.06	-15.46
12.ICPA 2078 × ICPL 20347	0.55	0	7.63	-6.15	70.27 **	65.79 **	-2	-17.43	16.68	-3.97
13.ICPA 2078 × ICPL 20349	0.41	-0.27	8.67	-1.58	48.57 **	36.84 *	11.39 **	7.47 **	14.67	10.92
14. ICPA 2043 × ICPL 20347	0.84	0	2.24	-1.09	46.51 **	26.00 *	5.48 **	0	8.75	-5.38
15. ICPA 2047 × ICPL 20347	0	-0.28	-2.7	-9.31	48.05 **	39.02 *	-18.76	-27.29	4.55	-4.67
16.ICPA 2092 × ICPL 20347	1.26	0.83	-0.09	-4.3	76.81 **	69.44 **	17.47 **	12.99 **	-16.96	-30.9
17.ICPA 2209 × ICPL 20108	0.55	0	4.93	-0.31	61.90 **	58.14 **	-19.68	-24.94	-17.65	-25.89
18.ICPA 2043 × ICPL 87119	0.7	-0.82	-1.89	-8.11	38.77 **	36.00 **	7.87 **	-5.85	8.49	6.99
19.ICPA 2047 × ICPL 87119	-0.69	-1.1	1.46	-2.34	39.32 **	29.17 *	-14.49	-16.67	-19.38	-24.48

where *,** indicates significance at 5% and 1% respectively; MPH-Mid Parent Heterosis, BPH- Better Parent Heterosis

Table 1. (contd): Mid parent and better parent heterosis of F_1 pigeonpea hybrids

Genotype	Yield/ plant		Yield/plot		Seeds/ pod		100-Seed weight	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
ICPA 2043 × ICPL 20129	-37.71	-55.99	39.82 *	33.1	3.33	3.33	-1.66	-7.19
ICPA 2043 × ICPL 20096	-2.87	-17.15	20.5	8.36	0.55	-0.36	12.06 *	11.27
ICPA 2078 × ICPL 20343	5.35	-5.69	10.94	2.94	1.21	-1.98	7.32	-5.04
ICPA 2078 × ICPL 20346	20.24	4.25 **	-26.78	-42.12	-1.9	-2.83	15.11 **	-0.31
ICPA 2043 × ICPL 20343	-2.58	-27.05	23.17	10.32	-3.56	-4.86	1	-15.11
ICPA 2043 × ICPL 20349	4.24	-22.88	-7.55	-9.7	-0.83	-0.83	1.98	-9.97
ICPA 2048 × ICPL 20347	10.08	-12.58	15.37	-4.93	5.70 *	-1.02	5.86	5.5
ICPA 2078 × ICPL 87119	35.26	3.86 **	18.74	-10.88	2.48	1.51	3.7	-4.05
ICPA 2047 × ICPL 20177	8.05	-3.24	28.94	5.9	2.21	-0.8	2.67	1.41
ICPA 2048 × ICPL 20106	-6.84	-31.05	50.64 *	26.11	0.71	-3.56	4.49	0.64
ICPA 2092 × ICPL 20093	2.75	-3.38	21.37	-12.39	5.38 *	0.55	1.2	-7.26
ICPA 2078 × ICPL 20347	22.66	12.44 *	-3.6	-4.07	3.57	3.08	7.52	2.49
ICPA 2078 × ICPL 20349	-2.21	-11.01	3.31	-14.99	-1.27	-3.1	-16.76	-22.37
ICPA 2043 × ICPL 20347	11.14	-18.21	71.28 **	43.08 *	0.66	-1.67	7.83	6.53
ICPA 2047 × ICPL 20347	7.93	-11.69	-5.5	-26.75	1.4	-2.68	13.73 *	11
ICPA 2092 × ICPL 20347	-24.48	-38.88	21	-11.31	0	-1.94	-13.49	-17.03
ICPA 2209 × ICPL 20108	55.57 **	46.38 **	60.52 **	55.92 **	1.72	1.26	13.82 *	12.59
ICPA 2043 × ICPL 87119	-11.31	-23.1 **	-9.58	-21.34	-5.42	-6.29	6.5	4.44
ICPA 2047 × ICPL 87119	-17.43	-17.83	-17.15	-21.2	-2.34	-4.96	16.15 **	15.31 *

where *, ** indicates significance at 5% and 1% respectively; MPH-Mid Parent Heterosis, BPH- Better Parent Heterosis

ICPL 20347 manifested significant negative (-23.59 %**) inbreeding depression due to selfing. This could be attributed to the presence of some superior recombinants in F_2 generation. The estimates of inbreeding depression for seed yield/plant were non-significant; but ranged from -68.33% (ICPA 2047 × ICPL 20347) to 20.23% (ICPA 2043 × ICPL 20347).

All the 19 hybrids showed significant positive inbreeding depression for number of primary branches/plant (Table 2).The highest inbreeding depression for this trait was recorded in cross ICPA 2078 × ICPL 87119 (60.07 %**), followed by ICPA 2092 × ICPL 20093 (55.51 %**), and ICPA 2043 × ICPL 20096 (55.22 %**). These results suggested that the genetic systems operating for the expression of primary branches were under the control of non-additive genetic variance; while additivity appeared to have controlled the expression of the secondary branches (Table 2).

DISCUSSION

Hybrid vigour has been globally recognized as the most potential plant breeding force for enhancing productivity. It is a complex genetic phenomenon and a number of theories have been put forward to explain it; but

Table 2. Inbreeding depression in CMS based pigeonpea hybrids derived from diverse inbred lines

S.No.	Genotype	Days to 50% flower	Plant height	Number of primary branches	Number of secondary branches	Pods/ plant	Seeds/ pod	100-seed weight	Yield/ plant	Yield (kg/ ha)
1	ICPA 2043 × ICPL 20129	0	8.1	51.43 **	0.5	-13.15	1.61	-0.44	-9.26	1.44
2	ICPA 2043 × ICPL 20096	0.84	7.71	55.22 **	4.28	19.06	4.01	8.92	28.01	6.03
3	ICPA 2078 × ICPL 20343	1.12	-3.09	43.75 **	-9.64	-13.11	1.85	7.7	15.16	-23.99
4	ICPA 2078 × ICPL 20346	-2.86	-2.9	55.07 **	9.96	29.63	1.24	6.92	31.28	-11.4
5	ICPA 2043 × ICPL 20343	0	4.21	49.69 **	-1.91	3.99	3.01	5.03	8.36	-26.94
6	ICPA 2043 × ICPL 20349	-2.54	3.6	48.94 **	-16.55	-14.45	2.41	28.08 **	20.49	-24.19
7	ICPA 2048 × ICPL 20347	-1.4	-6.93	47.92 **	-13.59	-14.62	14.05 *	-3.05	-1.94	-32.61
8	ICPA 2078 × ICPL 87119	2.46	10.57	60.07 **	2.66	9.75	9.52	2.8	19.25	2.38
9	ICPA 2047 × ICPL 20177	0.41	6	51.61 **	-24.07	10.58	9.45	-29.46	-0.18	-2.4
10	ICPA 2048 × ICPL 20106	-1.51	17.61	54.08 **	-25.13	-44.83	-1.45	-8.09	-24.61	-13.23
11	ICPA 2092 × ICPL 20093	-1.24	17.14 *	55.51 **	4.14	27.92	4.69	1.96	41.12	5.72
12	ICPA 2078 × ICPL 20347	-1.37	-7.84	50.38 **	0.29	27.39	7.09	5.53	30.08	-23.59 **
13	ICPA 2078 × ICPL 20349	-0.83	-25.17 *	39.57 **	-43.32	-28.51	-0.05	14.52	-17.1	-12.56
14	ICPA 2043 × ICPL 20347	1.67	-7	48.7 **	-5.74	7.1	7.15	-0.01	23.15	20.23
15	ICPA 2047 × ICPL 20347	-2.22	2.9	42.76 *	-24.33	7.67	2.27	6.23	56.72	-68.33
16	ICPA 2092 × ICPL 20347	0.83	12.1	41.38 *	3.22	-6.8	-0.41	-19.13 *	-61.33	-29.48
17	ICPA 2209 × ICPL 20108	-0.83	28.88 **	53.88 **	1.89	12.39	7.57	2.17	35.5	-8.72
18	ICPA 2043 × ICPL 87119	2.21	3.58	53.18 **	-25.63	18.24	-3.34	-0.2	0.34	19.83 *
19	ICPA 2047 × ICPL 87119	1.94	14.77 *	47.19 **	-14.45	-11.67	2.5	0.73	-15.86	-35.73

Where * indicates significance at 5% and 1% respectively its reality is still under natural wraps. The evolution of hybrid technology in pigeonpea (Saxena 2015) has created a sort of revolution in breeding of this pulse crop with 25-40% on-farm yield advantage.

In the present investigation, hybrid ICPA 2209 x ICPL 20108 exhibited the highest (55.92 %**) better parent heterosis for plot yield. Kandalkar (2007), Saxena and Nadarajan (2010), Wanjari and Rathod (2012) and Pandey *et al.* (2013) also reported significant positive heterosis for grain yield in some CMS-based hybrids of pigeonpea. The absence of inbreeding depression in this cross gave an indication for the additive genetic control of yield. Further, it can be assumed that the genes controlling yield with additive effects came together from both the parents and expressed in the hybrid to produce heterotic effect. This hybrid can also be subjected to pedigree selection to derive high yielding inbred lines. In contrast, hybrid ICPA 2043 x ICPL 87119 exhibited non-significant heterosis but the inbreeding depression was highly significant. This situation may arise due to the presence of genes, predominantly with non-additive affects, which upon selfing, produced unproductive F_2 segregants and poor yield.

For yield/plant, four hybrids expressed significant heterosis over their respective better parent and all of them also had highly significant inbreeding depression for yield and number of primary branches. It appears that the number of primary branches that is controlled by non-additive gene action at most loci, directly contributed to hybrid vigour for seed yield. A perusal of overall data further indicated that inbreeding depression for seed yield was the consequence of significant inbreeding depression for yield contributing trait such as number of primary branches. Studies on component analysis in pigeonpea also revealed that number of primary branches played the most important role in determining yield (Saxena and Sharma 1990, Phad 2003, Yadav and Singh 2004, Phad *et al.* 2009 and Chandirakala *et al*. 2010).

The differences observed between per plant yield and bulk plot yield data with respect to heterosis and inbreeding depression, observed in some hybrid combinations, could be attributed to the influence of unequal competition between the individual plant and environment on the expression of these traits. Green *et al.* (1981) and Saxena and Sharma (1983) reported highly significant intra-population variability for individual plant yield even within highly inbred lines in pigeonpea. They postulated that such situation can arise under the field-grown trials because the pigeonpea plants are highly sensitive to changes in the micro-environment. They also concluded that the individual pigeonpea plants are highly competitive with respect to space, sunlight, moisture etc.

In the present study, some fertility restoring lines were derived from inter-specific crosses and these had very low productivity and it may be the consequence of undesirable linkage drag in the progenies. In pigeonpea, significant negative heterosis for flowering (earliness) was reported by Shoba and Balan (2010) and Sameerkumar *et al.* (2012), but none of the hybrids showed significant inbreeding depression. This suggested that the flowering time was predominantly controlled by additive genes. Similar conclusions were also made by Kandalkar (2007) and Sarode *et al*. (2009).

Heterosis in Relation to Molecular Diversity of Parents: Mudaraddi and Saxena (2015) assessed the molecular diversity of among hybrid parents including 20 A-lines and 135 R-lines using 24 simple sequence repeat (SSR) markers. In this study the number of alleles amplified ranged from 3 to 41 at an average of 14.5 alleles per marker with mean polymorphic information content (PIC) value of 0.64. Based on this information, they constructed two heterotic groups (HG) for A-lines and three HGs for R-lines. The information generated in this study was used to study the relationship of hybrid vigour with molecular diversity of the hybrid parents (Table 3).

Out of three crosses involving the parents representing HG I and HG II, only one (33.3%) hybrid ICPA 2209 x ICPL 20108 exhibited significant heterosis for seed yield. Similarly, among the crosses involving parents representing HG I and HG III, out of nine hybrids, only three (33.3%) had significant positive heterosis for yield. All the three hybrids involved ICPA 2078 as female parent. In one hybrid combination ICPA 2043 x ICPL 87119 the yields were significantly lower than the better parent. All the seven hybrids with HG II and HG III parentage failed to produce any hybrid with significant yield advantage. Application of this information in the present data set related to the realized heterosis for plot yield showed that both the hybrids exhibiting high and positive heterosis for plot yield had the parents from different heterotic groups.

Table 3. Relationship of hybrid performance and molecular diversity of the parents, as indicated by heterotic groupings, for seed yield in 19 hybrids

S. No.	Hybrid	Het. group female parent	Het. group male parent	Heterosis yield/ plot
1	ICPA 2043 × ICPL 20129	I	II	NS
2	ICPA 2043 × ICPL 20096	I	II	NS
3	ICPA 2209 × ICPL 20108	I	II	*
1	ICPA 2078 × ICPL 20343	I	III	NS
2	ICPA 2078 × ICPL 20346	I	III	*
3	ICPA 2043 × ICPL 20343	I	III	NS
4	ICPA 2043 × ICPL 20349	I	III	NS
5	ICPA 2078 × ICPL 87119	I	III	*
6	ICPA 2078 × ICPL 20347	I	III	*
7	ICPA 2078 × ICPL 20349	I	III	NS
8	ICPA 2043 × ICPL 20347	I	III	NS
9	ICPA 2043 × ICPL 87119	I	III	*-ve
1	ICPA 2047 × ICPL 87119	II	III	NS
2	ICPA 2048 × ICPL 20347	II	III	NS
3	ICPA 2047 × ICPL 20177	II	II	NS
4	ICPA 2048 × ICPL 20106	II	II	NS
5	ICPA 2092 × ICPL 20093	II	II	NS
6	ICPA 2047 × ICPL 20347	II	III	NS
7	ICPA 2092 × ICPL 20347	II	III	NS

For example, in hybrid ICPA 2043 x ICPL 20347 the female and male parents, respectively, represented heterotic groups I and III. Similarly, the other hybrid ICPA 2092 x ICPL 20108 had the parents belonging to the heterotic group II and III. But, all the parents from diverse heterotic groups did not produce heterotic hybrids. The present studies showed that even though the hybrids were produced using diverse parents, the frequency of heterotic hybrids was low; this may be due to their poor per se performance and combining ability.

CONCLUSIONS

Considering the observations on heterosis and inbreeding depression together, it was concluded that in pigeonpea both additive and non-additive genetic variation played a significant role in the manifestation of seed yield. However, their relative importance varied from cross to cross. Among the 19 hybrids tested, ICPA 2209 x ICPL 20108 was adjudged the best for productivity, because it exhibited significant positive hybrid vigour for both per plant and per plot yields. Besides this, the inbreeding depression in this cross was also non-significant; suggesting that in this heterotic combination the expression of high yield was the consequence of combining the genes with additive effects. Hence besides exploiting its hybridity, this cross can also be used to breed inbred cultivars with more number of additive genes. Such inbreds can also be used as parental lines to breed second generation of high yielding hybrids.The results also showed that molecular diversityin this set of hybrid parents was limited and it was found related to high hybrid vigour only in a few hybrid combinations.

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