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HETEROSIS ANALYSIS FOR SEED YIELD AND BIOCHEMICAL ATTRIBUTES IN PIGEONPEA (*CAJANUS CAJAN* L. MILLSP.)

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ABSTRACT

The present experiment was conducted to estimate heterosis by adopting line x tester matting design among parents and crosses to find out promising cross combinations for seed yield and biochemical attributes in pigeonpea. The experimental material comprised of twelve parents (8 lines & 4 testers) and their 32 F_1 hybrids along with a commercial hybrid check 'ICPL-87119' were testedat College farm, College of Agriculture, Kota, during *kharif*–2022-23. The hybrids *viz.*, RKPV-702-16 x ICPL-88039, RKPV-705 x ICPL-88039, RKPV-807 x PA-291, RKPV-808 x UPAS-120 and RKPV-821-01 x ICPL-88039 showed higher positive heterosis in all three directions for seed yield per plant. Significant to significant positive standard heterosis for seed yield per plant and biochemical attributes in the hybrids involving elite lines as the parents suggested that there is a good scope of exploiting heterosis commercially and also possibility of isolating desirable segregants.

Key words : Heterosis, Biochemical attributes, Segregants.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millspaugh], also known as red gram, tur, or arhar is a major *kharif* pulse crop cultivated in over fifty countries, including regions in Southeast Asia, Eastern Africa, the Caribbean and South and Central America. In India, two distinct varieties of pigeonpea are cultivated: *Cajanus cajan* var. *bicolor* (arhar) and *Cajanus cajan* var. *flavus* (tur). Karyotypic and genomic studies have revealed that pigeonpea often cross-pollinated crop (20– 70%) with diploid chromosome number of 2n = 2x = 22 and a genome size of 833.1 Mbp (Greilhuber and Obermayer, 1998). As a significant pulse crop, pigeonpea plays a vital role in ensuring food and nutritional security for a large segment of the Indian population (Saxena *et al*., 2015).

Pigeonpea holds a pivotal role in India's agricultural landscape, accounting for nearly 71.5% of the world's production. It is grown across an estimated 4.50 million hectares, with an annual production of 3.66 million tones (Anonymous, 2021). Pigeonpea is a versatile legume crop with multiple uses. Its grains are consumed as human food, green pods serve as a vegetable, leaves are used as animal fodder, and its wood is utilized for hut construction and as fuel (Verma *et al*., 2018). This crop is particularly beneficial for resource-poor farmers, as it thrives with minimal inputs and commands a high market price.

The term 'heterosis' was coined by Shull (1914) to replace the phrase '*special stimulus of heterozygosis*'. The exploitation of heterosis has been identified as the most promising strategy to achieve a significant breakthrough in yield (Sekhar *et al*., 2004). A hybridization-based breeding strategy is a promising approach to overcome yield limitations in pigeonpea. Heterosis provides a clear indication of the genetic diversity present in the germplasm, facilitating the selection of ideal parents for producing superior F_1 hybrids. These hybrids not only exploit hybrid vigor but also help establish gene pools for future breeding efforts.

The scope of hybrid vigor exploitation relies on the magnitude and direction of relative heterosis (compared to mid-parents), heterobeltiosis (compared to better parents) and standard heterosis (compared to the check variety) in the gene pool. Of these, standard heterosis is the most significant, as it targets the development of F_1 hybrids superior to current high-yielding commercial varieties. In view of above consideration, study of magnitude and direction of heterosis are very important to know the potential of hybrids.

Materials and Methods

In the present experiment, twelve genotypes (8 advanced breeding lines + 4 varieties as tester) were crossed in line x tester mating design. Parents were sown at Agricultural Research Station, AU, Kota to make direct 32 crosses in *kharif* 2021-22 and the F_1 hybrids were obtained which were evaluated at Agricultural Research Station, AU, Kota in *kharif* 2022-23, with three replications using pigeonpea hybrid ICPL-87119 as standard check. Observations recorded for seed yield and yield attributes *viz.*, days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of pods per plant, number of seeds per pod, pod length, 100 seed weight, seed yield per plant, biological yield per plant, harvest index, protein content and total carbohydrate content. Mid-parent heterosis was calculated following the procedure described by Matzinger (1968). Similarly, better-parent heterosis and standard heterosis were computed using the methods proposed by Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively.

Results and Discussion

The present study aimed to estimate the heterosis of hybrids and their respective parents using twelve diverse pigeonpea genotypes. The variance analysis (Table 1) for various traits revealed that the genotypes exhibited highly significant differences for all the characters studied. The analysis of variance demonstrated that the mean sum of squares for lines was significant for all traits. Similarly, the mean sum of squares for testers was significant for all traits except plant height and seed yield per plant indicating substantial variation among the lines and testers studied. Furthermore, the mean sum of squares for line x tester interactions showed significant effects on days to 50% flowering, days to maturity, pod length, biological yield per plant and total carbohydrate content. Highly significant differences were observed

Table 1 : Analysis of variance (MSS) for various traits in pigeonpea.

Sources	df	Mean sums of squares											
		DFF	DM	PH	PB	PP	SP	PL	HSW	SY	BY	HI	PC	TC
Replication	2	0.96	7.80	37.13	0.14	69.24	0.18	0.04	0.07	5.59	48.99	0.77	0.11	1.36
Genotype	43	211.49**	456.61**	414.24**	6.22**	1895.69**	0.68**	0.77**	2.83**	89.97**	1142.15**	6.92**	5.15**	96.25**
Parent	11	179.36**	255.96**	343.55*	3.59**	643.05**	0.24*	0.52**	1.09**	31.69**	656.17**	5.29*	2.11**	99.62**
Line	7	180.71**	210.57**	430.23**	2.59**	319.87*	0.20	0.46**	1.42**	41.82**	605.81**	4.98	2.39**	140.29**
Tester	3	80.97**	283.56**	72.45	7.09**	1573.83**	0.40**	0.64**	0.58**	11.45	731.06**	7.35*	2.15**	35.66**
L vs T	1	465.13**	490.89**	550.01	0.02	113.00	0.01	0.63*	0.31	21.41	784.08**	1.34	0.02	6.76*
P vs H	1	232.38**	896.22**	0.44	3.85**	6087.02**	0.26	0.38	2.15**	103.57**	2540.22*	0.22	18.16**	0.52
Hybrids	31	222.21**	513.63**	452.68**	7.23**	2204.97**	0.85**	0.88**	3.48**	110.21**	1269.49**	7.72**	5.81**	98.14**
Error	86	2.11	4.83	147.68	0.32	150.96	0.10	0.11	0.10	7.65	118.22	2.55	0.50	1.32

* - Significant at 5 % and **- Significant at 1%

DFF- Days to 50% flowering; **DM** - Days to maturity; **HSW** -100 Seed weight (gm)
PH - Plant height (cm); **PP**- Number of pods per plant; **PB** - Number of primary branches per plant
SP - Number of seeds per pod; **SY** -Seed yield per plant (gm); **PL** - Pod length (cm)
BY -Biological yield per plant (gm); **PC** -Protein content (%); **HI** -Harvest index (%)
TC -Total carbohydrate content (%)

among parents and hybrids for all the characters. Parents *vs.* hybrids comparison indicated that means of hybrids were significantly different from the means of the parents for plant height, number of seed per pod, pod length, harvest index and total carbohydrate content.

The estimates of heterosis (Table 2) of 32 hybrids, for 13 different traits were worked out with respect to mid-parent, better-parent and standard heterosis. While, standard heterosis was worked out by comparing F_1 with standard check hybrid 'RKPV-87119' statistically. In the present investigation, mid-parent, better-parent andstandard heterosis ranged from -40.57 to 31.36, -46.27 to 27.17 and -38.89 to 39.43 per centfor seed yield per plant in pigeonpea. The five best hybrids *viz;* RKPV-702-16 x ICPL-88039 (28.88, 21.11 & 34.25), RKPV-705 x ICPL-88039 (31.36, 15.72 & 28.21), RKPV-807 x PA-291 (29.16, 27.17 & 22.42), RKPV-808 x UPAS-120 (20.77, 16.03 & 39.43) and RKPV-821-01 x ICPL-88039 (17.34, 14.32 & 33.59) were found promising for seed yield per plant and its attribute traits. The hybrids show standard heterosis for seed yield per plant may probably due to dominance nature of genes and due to high heterosis value was in positive direction for yield attributes like, like number of primary branches per plant, number of pods per plant, number of seed per pod and 100 seed weight were found significant standard heterosis in desirable direction. Almost identical result was reported by Patel and Tikka (2008), Shoba and Balan (2010), Chandirakala *et al.* (2010).

Earliness and early maturity most desirable characters for pigeonpea. Heterosis for days to 50% flowering range from -15.48 to 15.86, -20.07 to 12.86, -15.38 to 17.13 per cent over mid, better and standard heterosis respectively.The hybrids RKKPV-702-16 x ICPL-88039, RKPV-705 x ICPL-88039, RKPV-807 x PA-291, RKPV-807 x ICPL-88039 and RKPV-821-01 x ICPL-88039 were exhibited significant heterosis at all three level in desirable direction. For days to 50% flowering heterosis in both negative and positive direction were also evident by Wankhade *et al.* (2005), Baskaran and Muthiah (2006), Wanjari *et al.* (2007), Patel and Tikka (2008), Sarode *et al.* (2009) and Vaghela *et al.* (2011). Heterosis over mid parent ranged from -10.34 to 16.56, whereas over better parent, it ranged from -15.67 to 13.76 and standard heterosis from -15.17 to 17.17 for days to maturity. Out of five best hybrids; RKPV-705 x ICPL-88039, RKPV-808 x UPAS-120, RKPV-821-01 x ICPL-88039 were reported negative and significant heterosis in all three direction. Similar results were reported by Bhanu *et al*. (2007), Dheva *et al*. (2008), Shoba and Balan (2010) and Pandey *et al*. (2013).

Relative heterosis ranged from -11.93% to 21.55%, heterobeltiosis ranged from -16.80% to 21.03% and standard heterosis ranged from -10.14 to 13.03% for plant height. Similar findings were also recorded by Wankhade *et al.* (2005), Gite *et al*. (2014), Patel and Tikka (2014), Reddy *et al*. (2015) and Maida *et al.* (2017). The hybrids RKPV-808 x UPAS-120 and RKPV-821-01 x ICPL-88039 (except in base parent) reflected significant heterosis at mid parent and standard heterosis in desirable direction.

Heterosis over mid parent ranged from -30.04% to 29.61%, heterobeltiosis from -33.08% to 27.97% and standard heterosis from -32.52% to 38.21%. Out of five best hybrids, twohybrids RKPV-807 x PA-291 and RKPV-821-01 x ICPL-88039 exhibited the highest positive significant heterosis at all three levels in desirable direction, while hybrids RKPV-702-16 x ICPL-88039 and RKPV-808 x UPAS-120 exhibited significant heterosis over mid-parent and standard heterosis. Heterosis in positive direction is desirable for number of pods per plant as more pods can lead to higher seed yield per plant. Relative heterosis ranged from -41.35% to 22.50%; heterobeltiosis from -42.81% to 15.36% and standard heterosis over the check ICPL 87119 from -41.88% to 19.58%. Results were found agreement with Sekhar *et al.* (2004), Patel and Tikka (2008), Pagi *et al.* (2016) for number of primary branches per plant and number of pods per plant.

For pod length, results revealed relative heterosis ranged from -28.14% to 31.04%, heterobeltiosis ranged from -28.72% to 21.68% and standard heterosis ranged from -29.75 to 15.17%. This trait exhibited a relatively low level of heterosis compared to other traits. Consistent with these observations, Hiremeth and Talwar (1971), Singh (1972) also reported limited genetic advance for pod length.

In pigeonpea breeding, quantitative parameters like seed per pod and 100-seed weight hold significant importance due to their impact on crop yield and selection efficiency. Hybrids RKPV-807 x PA-291 for number of seed per pod and RKPV-702-16 x ICPL-88039, RKPV-808 x UPAS-120, RKPV-821-01 x ICPL-88039 for 100-seed weight found desirable heterosis in all three level. Almost similar result was recorded by Yadav and Singh (2004), Baskaran and Muthiah (2006), Gaikwad *et al.* (2017) for number of seed per pod and 100-seed weight.

Biological yield per plant desirable trait, while hybrids *viz;* RKPV-702-16 x ICPL-88039, RKPV-807 x PA-291 and RKPV-808 x UPAS-120 were found significant and desirable heterosis in all three level of heterosis. Positive

Table 2 : Magnitude of standard heterosis for different characters in pigeonpea.

Crosses	Days to 50% flowering			Days to maturity			Plant height (cm)			Number of primary branches per plant		
	MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
RKPV-702-16 X UPAS- 120	8.95**	8.73**	-4.20**	1.55	1.32	-8.18**	-6.57	-13.64*	-4.98	-3.77	-6.50	-6.50
RKPV-702-16 X PA-291	12.52**	8.96**	2.10	8.95**	7.54**	-0.40	-4.99	-9.63	-0.57	-12.03*	-13.82*	-13.82*
RKPV-702-16 X PAU-881	-0.92	-7.59**	-6.29**	-1.87	-7.45**	-5.79**	-9.41*	-13.92 **	-5.28	-16.13 **	-26.02 **	-26.02 **
RKPV-702-16 X ICPL-88039	-7.28**	-10.70 **	-15.38 **	3.57**	2.65*	-7.39**	7.51	1.86	12.08*	19.41**	8.67	32.52**
RKPV-705 X UPAS- 120	3.61**	-0.73	-4.55**	11.30**	9.87**	2.20*	8.80	3.73	6.84	-13.01 **	-17.69 **	-13.01*
RKPV-705 X PA-291	2.03	0.73	-3.15*	1.29	1.07	-5.99**	4.32	2.43	5.51	-16.13 **	-20.00 **	-15.45 **
RKPV-705 X PAU-881	4.07**	1.38	2.80*	1.23	-3.14**	-1.40	1.60	-0.33	2.66	-22.32 **	-33.08 **	-29.27 **
RKPV-705 X ICPL-88039	-8.06**	-8.73**	-12.24 **	-5.27**	-7.51**	-13.97 **	4.85	2.55	5.62	1.43	-5.33	15.45**
RKPV-807 X UPAS- 120	13.97**	6.16**	8.39**	8.12**	4.98**	1.00	5.91	5.09	-0.30	-22.94 **	-23.28 **	-27.64 **
RKPV-807 X PA-291	-5.71**	-9.59**	-7.69**	-1.06	-2.90*	-6.59**	8.44	6.04	5.27	29.61**	27.97**	22.76**
RKPV-807 X PAU-881	0.34	0.00	2.10	-1.61	-4.31**	-2.59*	8.01	5.71	4.75	-2.39	-11.30	-17.07 **
RKPV-807 X ICPL-88039	-6.93**	-10.27 **	-8.39**	-0.65	-4.56**	-8.18**	13.85**	11.77*	10.07	3.40	-8.67	11.38*
RKPV-808 X UPAS- 120	-2.26	-7.14**	-9.09**	-9.89**	-13.71 **	-14.57 **	21.55**	21.03**	13.03*	19.22**	9.35	23.58**
RKPV-808 X PA-291	11.31**	8.93**	6.64**	8.75**	5.24**	4.19**	-4.40	-7.62	-8.28	-15.18 **	-21.58 **	-11.38*
RKPV-808 X PAU-881	2.46*	0.69	2.10	-0.20	-1.57	0.20	3.35	-0.04	-0.95	-15.02 **	-28.78 **	-19.51 **
RKPV-808 X ICPL-88039	14.70**	12.86**	10.49**	14.68**	8.67**	7.58**	16.76**	13.27*	11.55*	1.04	-2.67	18.70**
RKPV-810-01 X UPAS-120	15.86**	5.18**	13.64**	16.56**	12.50**	9.58**	3.84	1.08	-0.30	5.56	-1.72	-7.32
RKPV-810-01 X PA-291	1.91	-4.85**	2.80*	2.52*	0.00	-2.59*	-0.71	-1.03	-1.75	-23.85 **	-29.66 **	-32.52 **
RKPV-810-01 X PAU-881	10.18**	6.80**	15.38**	14.63**	12.16**	14.17**	3.88	3.64	2.70	11.34	8.00	-12.20*
RKPV-810-01 X ICPL-88039	6.90**	0.32	8.39**	10.73**	5.74**	2.99**	-4.70	-4.78	-6.08	-12.80 **	-27.33 **	-11.38*
RKPV-816-01 X UPAS- 120	8.23**	-3.13**	8.04**	1.03	-5.04**	-2.20*	1.74	-4.82	2.05	-21.99 **	-24.80 **	-23.58 **
RKPV-816-01 X PA-291	14.14**	5.02**	17.13**	19.80**	13.76**	17.17**	-9.70*	-13.04*	-6.76	-30.04 **	-32.00 **	-30.89 **
RKPV-816-01 X PAU-881	2.79**	-1.88	9.44**	2.73**	2.13*	5.19**	-9.61*	-13.04*	-6.76	3.20	-9.60	-8.13
RKPV-816-01 X ICPL-88039	3.05**	-4.70**	6.29**	5.63**	-1.74	1.20	-11.93*	-15.52 **	-9.42	-19.27 **	-26.00 **	-9.76
RKPV-817-01 X UPAS- 120	4.06**	-6.35**	3.15*	-0.20	-7.20**	-2.20*	-9.61*	-16.80 **	-7.60	-12.44*	-18.10 **	-22.76 **
RKPV-817-01 X PA-291	9.09**	0.95	11.19**	10.28**	3.60**	9.18**	-6.83	-11.77*	-2.01	8.68	0.85	-3.25
RKPV-817-01 X PAU-881	2.81**	-1.27	8.74**	1.54	-0.19	5.19**	-8.59	-13.51*	-3.95	9.74	5.94	-13.01*
RKPV-817-01 X ICPL-88039	8.53**	0.95	11.19**	4.32**	-3.98**	1.20	-10.93*	-15.98 **	-6.69	3.59	-13.33 **	5.69
RKPV-821-01 X UPAS- 120	13.67**	3.95**	10.49**	7.52**	2.18*	2.79*	6.43	2.49	3.38	0.41	-4.65	0.00
RKPV-821-01 X PA-291	7.34**	0.99	7.34**	9.71**	5.36**	5.99**	-10.21*	-10.92	-10.14	-17.41 **	-20.93 **	-17.07 **
RKPV-821-01 X PAU-881	8.42**	5.92**	12.59**	7.50**	6.86**	8.78**	9.60	8.63	9.57	-16.59 **	-27.91 **	-24.39 **
RKPV-821-01 X ICPL-88039	-15.48 **	-20.07 **	-15.03 **	-10.34 **	-15.67 **	-15.17 **	12.18*	10.85	11.82*	21.86**	13.33**	38.21**

Table 2 contd....

Table 2 contd....

Crosses	Number of pods per plant			Number of seeds per pod			Pod length (cm)			100-seed weight (gm)		
	MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
RKPV-702-16 X UPAS- 120	-15.99 **	-16.16*	-19.03 **	-2.48	-6.35	-4.84	0	-10.01	-8.67	5.19*	1.08	-0.63
RKPV-702-16 X PA-291	2.93	2.82	-0.91	-5.00	-9.52	-8.06	23.34**	21.68**	1.49	-11.80 **	-12.05 **	-13.54 **
RKPV-702-16 X PAU-881	-16.20 **	-25.32 **	-28.17 **	-25.40 **	-25.40 **	-24.19 **	-6.91	-10.26	-21.52 **	-17.54 **	-20.59 **	-21.93 **
RKPV-702-16 X ICPL-88039	10.42*	4.54	12.53*	15.15**	10.14	22.58**	21.26**	7.73	12.56*	12.25**	11.46**	11.14**
RKPV-705 X UPAS- 120	-12.20*	-14.52*	-17.45 **	2.52	0.00	-1.61	-4.92	-11.78	-10.46	18.28**	11.05**	0.63
RKPV-705 X PA-291	-13.87*	-16.07*	-19.11 **	5.08	1.64	0.00	-3.07	-4.99	-17.49 **	-12.57 **	-20.71 **	-22.50 **
RKPV-705 X PAU-881	-24.94 **	-31.58 **	-37.43 **	-25.81 **	-26.98 **	-25.81 **	-11.84	-12.14	-23.17 **	-7.90**	-13.71 **	-21.44 **
RKPV-705 X ICPL-88039	7.03	-1.02	6.54	9.23	2.90	14.52*	10.16	0.86	5.38	13.38**	1.91	1.62
RKPV-807 X UPAS- 120	-41.35 **	-42.81 **	-41.88 **	-12.07*	-12.07	-17.74 **	-28.14 **	-28.72 **	-27.65 **	-14.48 **	-14.94 **	-22.92 **
RKPV-807 X PA-291	12.04*	9.15	10.91	33.91**	32.76**	24.19**	21.37**	11.38	11.21	10.43**	5.84*	3.46
RKPV-807 X PAU-881	-1.76	-14.50*	-13.12*	2.48	-1.59	0.00	-11.89*	-17.37 **	-17.49 **	-2.11	-2.87	-11.57 **
RKPV-807 X ICPL-88039	-2.65	-5.37	1.86	-8.66	-15.94 **	-6.45	-10.17	-12.16*	-8.22	-2.57	-7.50**	-7.76**
RKPV-808 X UPAS- 120	14.03**	9.46	14.93*	15.87**	7.35	17.74**	13.88*	6.92	8.52	24.69**	18.40**	19.32**
RKPV-808 X PA-291	-26.71 **	-29.72 **	-26.20 **	-0.80	-8.82	0.00	0.52	-2.68	-13.30*	-19.57 **	-20.78 **	-20.17 **
RKPV-808 X PAU-881	-15.32 **	-27.32 **	-23.68 **	-11.45*	-14.71*	-6.45	11.09	10.07	-1.94	4.85	-0.21	0.56
RKPV-808 X ICPL-88039	-7.70	-8.84	-1.87	-10.95*	-11.59*	-1.61	5.64	-2.15	2.24	-6.09*	-6.58*	-5.85*
RKPV-810-01 X UPAS-120	-18.31 **	-18.36 **	-21.16 **	11.50	8.62	1.61	8.39	0.88	2.39	-15.32 **	-18.74 **	-19.89 **
RKPV-810-01 X PA-291	-32.53 **	-32.56 **	-34.95 **	-14.29*	-15.79*	-22.58 **	-17.76 **	-19.66 **	-29.75 **	-20.83 **	-21.17 **	-22.28 **
RKPV-810-01 X PAU-881	-11.43	-21.16 **	-23.96 **	-5.08	-11.11	-9.68	17.69**	17.69*	2.91	-6.47*	-10.05 **	-11.32 **
RKPV-810-01 X ICPL-88039	-6.14	-11.02*	-4.22	-4.84	-14.49*	-4.84	-13.24*	-20.31 **	-16.74 **	1.99	1.41	1.13
RKPV-816-01 X UPAS- 120	-15.15 **	-15.99*	-18.87 **	4.13	0.00	1.61	2.05	-1.18	0.3	-3.78	-7.23*	-9.45**
RKPV-816-01 X PA-291	-29.46 **	-30.09 **	-32.62 **	-23.33 **	-26.98 **	-25.81 **	-13.23*	-18.55 **	-22.57 **	-22.09 **	-22.15 **	-23.91 **
RKPV-816-01 X PAU-881	-10.99	-20.11 **	-24.39 **	-9.52	-9.52	-8.06	-4.34	-8.18	-12.71*	-8.93**	-11.99 **	-14.10 **
RKPV-816-01 X ICPL-88039	-26.61 **	-31.04 **	-25.77 **	-7.58	-11.59*	-1.61	-16.70 **	-20.46 **	-16.89 **	-19.30 **	-20.16 **	-20.38 **
RKPV-817-01 X UPAS- 120	-14.42*	-19.46 **	-22.22 **	-0.85	-1.69	-6.45	-1.31	-5.74	-4.33	-2.95	-3.97	-12.98 **
RKPV-817-01 X PA-291	-1.69	-7.40	-10.76	-1.72	-3.39	-8.06	13.61*	8.09	-0.15	-2.50	-7.00*	-9.10**
RKPV-817-01 X PAU-881	22.50**	15.36*	-1.73	-4.92	-7.94	-6.45	-1.91	-4.53	-11.81	-10.47 **	-11.62 **	-19.53 **
RKPV-817-01 X ICPL-88039	-17.29 **	-25.92 **	-20.25 **	-1.56	-8.70	1.61	3.42	-2.58	1.79	-0.22	-5.73*	-5.99*
RKPV-821-01 X UPAS- 120	0.93	-0.28	-1.34	-11.67*	-14.52*	-14.52*	14.53*	-2.5	-1.05	-2.28	-3.42	-12.48 **
RKPV-821-01 X PA-291	-4.82	-6.05	-7.05	2.52	-1.61	-1.61	14.20*	5.91	-11.66	-11.55 **	-15.73 **	-17.63 **
RKPV-821-01 X PAU-881	-10.93	-21.59 **	-22.42 **	-8.80	-9.52	-8.06	1.32	-8.03	-19.58 **	-0.47	-1.86	-10.65 **
RKPV-821-01 X ICPL-88039	15.77**	11.09*	19.58**	12.98*	7.25	19.35**	31.04**	10.23	15.17*	18.85**	12.16**	11.85**

Table 2 contd....

Table 2 contd....

Crosses	Seed yield per plant (gm)			Biological yield per plant (gm)			Harvest index (%)			Protein content(%)		
	MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
RKPV-702-16 X UPAS- 120	-31.08 **	-35.20 **	-28.25**	-21.43 **	-27.29 **	-15.85**	-12.60*	-13.96*	-14.86**	-3.72	-6.18*	-6.58*
RKPV-702-16 X PA-291	-1.86	-2.47	-4.88	-7.66	-12.80	-14.14**	6.12	0.77	10.91**	-9.24**	-9.42**	-9.45**
RKPV-702-16 X PAU-881	9.48	6.15	10.17*	3.34	-0.97	6.39	5.57	4.37	3.28	-4.47	-5.80*	-6.20*
RKPV-702-16 X ICPL-88039	28.88**	21.11**	34.25**	13.15*	5.57	20.04**	14.11**	13.25*	12.05**	0.57	-1.49	2.28
RKPV-705 X UPAS- 120	-22.31 **	-31.52 **	-24.16**	-21.13 **	-29.20 **	-18.05**	-1.62	-3.81	-7.74	-0.98	-2.44	-5.02
RKPV-705 X PA-291	11.15	4.33	0.25	10.76	8.01	-0.55	0.13	-8.26	0.99	2.97	1.63	1.59
RKPV-705 X PAU-881	-35.08 **	-41.13 **	-38.89**	-34.15 **	-38.86 **	-34.31**	-1.40	-3.98	-7.14	2.31	2.01	-0.69
RKPV-705 X ICPL-88039	31.36**	15.72*	28.21**	14.52*	3.63	17.83**	15.18**	11.73*	8.88*	-3.19	-6.20*	-2.61
RKPV-807 X UPAS- 120	-1.65	-9.38	0.34	1.78	-7.47	7.10	-3.53	-4.76	-6.28	-12.51 **	-16.33 **	-13.39 **
RKPV-807 X PA-291	29.16**	27.17**	22.42**	25.46**	20.69**	14.31**	2.82	-2.63	7.18**	4.29	2.51	6.11*
RKPV-807 X PAU-881	-8.89	-13.50	-10.20*	-15.38*	-20.39 **	-14.47**	7.55	6.62	4.92	-9.91**	-12.83 **	-9.77**
RKPV-807 X ICPL-88039	-3.06	-10.74	-1.03	-7.37	-15.10*	-3.46	4.52	4.01	2.35	-11.58 **	-11.72 **	-8.34**
RKPV-808 X UPAS- 120	20.77**	16.03*	39.43**	10.48	9.51	26.75**	9.13	4.02	10.07**	-0.37	-5.60*	-0.33
RKPV-808 X PA-291	-40.57 **	-46.47 **	-35.67**	-31.89 **	-39.74 **	-31.48**	-13.20 **	-14.88 **	-6.30	-11.82 **	-14.16 **	-9.37**
RKPV-808 X PAU-881	-5.60	-12.02	5.71	-12.10*	-14.52*	-2.80	7.39	2.76	8.73**	-7.16**	-11.02 **	-6.06*
RKPV-808 X ICPL-88039	-22.77 **	-25.76 **	-10.79*	-24.15 **	-24.15 **	-13.76**	1.62	-2.39	3.29	-10.70 **	-11.44 **	-6.50*
RKPV-810-01 X UPAS-120	8.10	-4.11	6.16	6.57	-9.70	4.52	0.06	-5.06	0.94	6.19*	5.72	-0.11
RKPV-810-01 X PA-291	-16.56*	-21.14*	-24.09**	-7.51	-11.26	-22.34**	-10.14*	-11.46*	-1.69	-0.31	-3.46	-3.49
RKPV-810-01 X PAU-881	23.00**	12.27	16.53**	18.25**	3.38	11.07*	3.04	-1.85	4.86	-8.80**	-10.28 **	-13.15 **
RKPV-810-01 X ICPL-88039	-29.75 **	-37.72 **	-30.97**	-26.88 **	-37.58 **	-29.03**	-4.90	-9.07	-2.85	-9.91**	-14.33 **	-11.05 **
RKPV-816-01 X UPAS- 120	2.01	-5.22	4.93	0.68	-11.60	2.31	0.26	-5.53	2.42	**	-9.53**	-14.52 **
RKPV-816-01 X PA-291	-32.48 **	-32.91 **	-35.41**	-21.45 **	-21.45*	-31.26**	-14.35 **	-14.99 **	-6.43	-10.19 **	-13.16 **	-13.18 **
RKPV-816-01 X PAU-881	-23.48 **	-26.72 **	-23.93**	-11.97	-20.13 **	-14.20**	-13.15 **	-17.85 **	-10.93**	11.59**	9.62**	6.11*
RKPV-816-01 X ICPL-88039	-10.40	-16.79*	-7.76	-10.83	-21.10 **	-10.29*	-0.29	-5.33	2.65	3.15	-2.04	1.71
RKPV-817-01 X UPAS- 120	-26.92 **	-29.17 **	-21.56**	-29.39 **	-33.05 **	-22.51**	5.08	2.71	3.15	5.00*	2.36	1.83
RKPV-817-01 X PA-291	-13.86*	-17.02*	-13.81**	-14.13*	-20.85 **	-17.88**	-0.22	-4.59	5.00	-6.76**	-6.98*	-7.01*
RKPV-817-01 X PAU-881	-10.45	-10.49	-7.01	-17.02 **	-18.44 **	-12.38**	8.01	6.00	6.46	-11.28 **	-12.48 **	-12.93 **
RKPV-817-01 X ICPL-88039	-22.16 **	-24.61 **	-16.44**	-23.21 **	-26.57 **	-16.51**	0.93	-0.57	-0.14	-2.68	-4.71	-1.07
RKPV-821-01 X UPAS- 120	-25.88 **	-27.84 **	-15.61**	-29.00 **	-29.91 **	-18.88**	6.03	2.00	5.86	-1.26	-3.87	-4.11
RKPV-821-01 X PA-291	-9.81	-17.77*	-3.89	1.57	-9.81	1.71	-11.81*	-14.33 **	-5.71	-14.51 **	-14.61 **	-14.63 **
RKPV-821-01 X PAU-881	-31.14 **	-34.99 **	-24.00**	-34.97 **	-36.51 **	-28.40**	7.02	3.37	7.28	-10.05 **	-11.38 **	-11.61 **
RKPV-821-01 X ICPL-88039	17.34**	14.32*	33.59**	6.93	6.49	21.08**	9.54	6.21	10.23**	8.43**	6.30*	10.36**

Table 2 contd....

Table 2 contd....

Crosses	Total carbohydrate content (%)		
	MP	BP	SH
RKPV-702-16 X UPAS- 120	22.21**	6.96**	16.52**
RKPV-702-16 X PA-291	-1.75	-7.08**	-14.79 **
RKPV-702-16 X PAU-881	7.97**	-1.77	-2.02
RKPV-702-16 X ICPL-88039	18.85**	9.55**	6.17**
RKPV-705 X UPAS- 120	0.82	-3.3	14.70**
RKPV-705 X PA-291	-6.99**	-17.54 **	-2.19
RKPV-705 X PAU-881	2.31	-5.83**	11.70**
RKPV-705 X ICPL-88039	11.01**	0.86	19.63**
RKPV-807 X UPAS- 120	-8.98**	-18.14 **	-10.82 **
RKPV-807 X PA-291	1.72	-0.88	-9.10**
RKPV-807 X PAU-881	-13.91 **	-19.40 **	-19.61 **
RKPV-807 X ICPL-88039	34.55**	27.68**	23.74**
RKPV-808 X UPAS- 120	-18.57 **	-19.07 **	-11.84 **
RKPV-808 X PA-291	12.42**	4.13*	12.02**
RKPV-808 X PAU-881	0.02	-3.62	3.69
RKPV-808 X ICPL-88039	-3.56*	-8.35**	-1.4
RKPV-810-01 X UPAS-120	-14.65 **	-21.56 **	-14.55 **
RKPV-810-01 X PA-291	18.93**	18.67**	8.83**
RKPV-810-01 X PAU-881	-15.59 **	-19.17 **	-19.37 **
RKPV-810-01 X ICPL-88039	-3.38	-6.18**	-9.08**
RKPV-816-01 X UPAS- 120	4.45*	-8.50**	-0.32
RKPV-816-01 X PA-291	13.64**	7.58**	-1.34
RKPV-816-01 X PAU-881	18.43**	7.85**	7.58**
RKPV-816-01 X ICPL-88039	-4.60*	-11.97 **	-14.69 **
RKPV-817-01 X UPAS- 120	-5.40**	-7.22**	5.12*
RKPV-817-01 X PA-291	-19.30 **	-26.99 **	-17.27 **
RKPV-817-01 X PAU-881	-18.48 **	-23.35 **	-13.15 **
RKPV-817-01 X ICPL-88039	-17.28 **	-23.27 **	-13.06 **
RKPV-821-01 X UPAS- 120	-9.60**	-14.25 **	-6.59**
RKPV-821-01 X PA-291	-4.22*	-7.16**	-9.29**
RKPV-821-01 X PAU-881	-5.49**	-6.45**	-6.69**
RKPV-821-01 X ICPL-88039	-2.02	-2.42	-4.65*

* - Significant at 5 % and **- Significant at 1%

heterosis earlier observed for this trait by Srivarsha *et al.* (2017) and Mallikarjuna *et al.* (2018).

Seed yield is indirectly influenced by the harvest index, which determines the allocation of photosynthates between source and sink. For this trait, out of top five hybrids four cross combination RKPV-702-16 x IPLC-88039 and RKPV-705 x ICPL-88039 found desirable heterosis in all three level of heterosis. The significant positive heterosis was also reported by Patel and Tikka (2014), Singh and Singh (2015).

Among the biochemical trait, for protein contain the cross RKPV-821-01 x ICPL-88039 depicted significant heterosis at all three levels. Similar result earlier finding by Khorgade *et al.* (2000) and Patil *et al.* (2014), while negative heterosis was noticed by Pawar *et al.* (2017) for seed protein. Heterosis for total carbohydrate content revealed that hybrids RKPV-702-16 x UPAS-120 and RKPV-810-01 x PA-291 showed significant heterosis at all the three levels in desirable direction. Joshi *et al.* (2016) similarly observed significant heterosis in the desired direction for total carbohydrate content in pigeonpea.

Conclusion

The crosses RKPV-702-16 x ICPL-88039, RKPV-705 x ICPL-88039, RKPV-807 x PA-291, RKPV-808 x UPAS-120 and RKPV-821-01 x ICPL-88039 emerged as good heterotic crosses in all three directions for seed yield per plant and some other more characters. Hence, these crosses found as promising type for tangible advancement of pigeonpea yield.

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