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Heterosis for seed yield and associated traits in cowpea [*Vigna unguiculata* (L.) Walp] genotypes under rainfed condition of Rajasthan

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Abstract
Heterosis for seed yield and its attributing traits was studied in 10 x 10 half diallel set of ten diverse cowpea genotypes under rainfed condition. The analysis of variance showed significant mean squares due to genotypes, parents, generations, F_1, F_2, F_1 vs F_2 progenies and parents vs generations for all the studied characters indicating the ample amount of genetic variability present in experimental material. Highly positive and significant heterosis over mid and better parent for seed yield per plant and its component traits suggested that there is ample scope for exploiting heterosis commercially and possibility of isolating desirable segregants. Heterosis ranged between -2.58 (CPD-119 x IC-2918) to 59.83 (RC-19 x RC-101) for seed yield per plant. Out of 45 crosses, eleven crosses exhibited positive significant heterosis and heterobeltiosis for seed yield per plant. Among these crosses, cross RC-19 x RC-101 for both heterosis and heterobeltiosis; RC-101 x CAZC-10 and IC-7832 x Saffron for heterosis; and Ajmer sel. x IC-2918 and IC-8966 x CAZC-10 for heterobeltiosis were found to be the most promising combinations for seed yield per plant. Out of these five crosses, only cross RC-19 x RC-101 also showed desirable heterosis/heterobeltiosis for most of associated traits i.e. pods per cluster, pods per plant, pod length, 100-seed weight and biomass per plant, hence that cross may be exploited in further plant breeding programme or identification of transgressive sergeants from the advanced generation.

Keywords: Cowpea, rainfed, heterosis, heterobeltiosis, diallel

1. Introduction
Cowpea [*Vigna ungviculata* (L.) Walp; 2n = 2x = 22] is an important multipurpose grain legume which is widely grown under low input production systems and in both arid and semi-arid regions of the world. Cowpea is predominantly a self-pollinated crop, belonging to family Fabaceae and sub family Faboideae (Horn and Shimelis, 2020) [13]. Cowpea is a short duration, photo and thermo-insensitive and most drought tolerant crop among the pulses. In general, depending on preference cowpea seeds are the most important product for human consumption. Cowpea as it is grown for seed, green and dry fodder, cover crop and as green manure etc. (Timko *et al*., 2008) [23]. The dried or green seeds used in vegetables, sprouted or germinated seeds as salad, split grains as dal and in kachori; flour in namkeen (bikaneri), idly, dhokla, dahi vada and so many other dishes.

Cowpea also provides fodder for livestock and improves soil fertility by fixing atmospheric nitrogen through root nodule rhizobia symbiosis. Cowpea makes considerable contribution to food and nutrition security in developing countries, especially India, as it is a cheap source of dietary protein and make up for the low protein present in widely consumed cereals and tuber crop-based food (Boukar *et al*., 2011; Fatokun *et al*., 2020) [10]. Globally, cowpea is grown in an area of 14.5 million ha with the production of 6.2 Million tonnes (FAOSTAT, 2016; Boukar *et al*., 2018) [9, 7]. In India, cowpea is grown across the country primarily in Southern zone. Rajasthan covers 50.06 thousand hectares area in cowpea cultivation with an average productivity of 653 kg/ha and has total production of 32.70 thousand tonnes (Anonymous 2019-20) [5]. Cowpea grain contains lysine and tryptophan (essential amino acids) rich protein (Abadassi, 2015) [1]. Cowpea seeds contain, on average, 25% protein, 53.2 mg/kg iron, 38.1 mg/kg zinc, 826 mg/kg calcium, 1915 mg/kg magnesium, 14,890 mg/kg potassium, and 5055 mg/kg phosphorus (Boukar *et al*., 2011). It exerted health beneficial properties, including anti-diabetic, anti-cancer, anti-inflammatory and anti-hypertensive properties.

Yield is the expression of several characters that are considerably influenced by environment (Amorim *et al*., 2008). Yield-related traits are often correlated and selection for one may lead to negative or positive response in the other traits (Ajibade *et al*., 2000). Hybridization between genetically diverse genotypes provides genetic variability that provide opportunities for selecting plants with a combination of desirable traits from the parents. The transfer of valuable traits between genetically divergent genotypes has been explored extensively in the genus *Vigna* (Hazra *et al*., 2007) [12]. The commercial use of heterosis is considered as an excellent implementation of genetics in plant breeding. The extent of hybrid seed in a crop depends on its exploitation, usage and feasibility of hybrid seed production. Cowpea is a self-pollinating crop and commercially applicable hybrid seed production method is not yet available. Consequently, the heterosis per se may not currently have economic importance in this crop. Nevertheless, knowledge of the degree and extent of heterosis is indispensable for selecting promising crosses to achieve better segregants in advance generations to determine the direction of a future breeding programme and to increase the seed yield in cowpea.

However, cowpea is often grown in rainfed areas, which receives about 600 mm of annual rainfall (Agele and Agbi, 2012) [2], but irrigation or assured water supply increases both its production and productivity compared to rainfed agriculture. In cowpea, many researchers have reported significant seed yield reductions in rainfed conditions compared to irrigated conditions (Peksen, 2007) [19]. Therefore, there is a need for genetic improvement and development of cowpea varieties to meet the growing food supply of humans and livestock. The objectives of this study were to determine the magnitude of the heterosis over mid (average heterosis) and better parents (heterobeltiosis) for seed yield and associated traits in crosses obtained from cowpea genotypes.

Material and Methods

The present investigation was conducted at the experimental area of Agricultural Research Farm, Rajasthan Agricultural Research Institute (Sri Karan Narendra Agriculture University, Jobner), Durgapura, Jaipur, Rajasthan during *Kharif* – 2019, *Summer* – 2020 and *Kharif* – 2020. Ten diverse parents namely: RC-19, RC-101, CPD-119, Ajmer sel., IC-2918, IC-8966, CAZC-10, IC-7832, GC-3 and Saffron were selected and crossed in diallel fashion (excluding reciprocals) in all possible combinations during *Kharif* – 2019. In *Summer* – 2020, half of the F_1's seed were raised to advance the generation. In *Kharif* – 2020, ten parents along with their resulting 45 F_1's and 45 F_2's progenies were evaluated under rainfed condition with three replications in randomized block design. Row to row and plant to plant distance was kept 45 cm and 15 cm, respectively. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. All recommended agronomical package of practices were adopted to raise good crop. Observations were recorded on pods per cluster, pods per plant, pod length, seeds per pod, 100-seed weight, seed yield per plant, biomass per plant and harvest index. Heterosis over mid parent was calculated by = $[(F_1\text{-MP})/ \text{MP}] \times 100$ and heterobeltiosis were calculated by formula proposed by Fonseca and Patterson (1968) [11] i.e. $[(F_1\text{-BP})/ \text{BP}] \times 100$. Where F_1= mean values of hybrid, MP = Mean values of mid parents and BP= Mean values of batter parents.

Result and Discussion

The analysis of variance showed significant mean squares due to genotypes, parents and generations for all the studied characters. Similarly F_1 and F_2 generations also showed significant differences for all studied characters. The occurrence of inbreeding depression was supported by the significance of F_1 vs F_2 for all the studied characters. Mean squares due to F_1 vs F_2 were found significant for all the studied characters. Likewise, the difference among the parents vs generations were significant for all the studied traits. This significant difference between generations vs parents showed the presence of heterosis.

The commercial exploitation of heterosis in crop plant is regarded as major breakthrough in the realm of plant breeding. It is a phenomenon of immense practical importance, as its utilization has led to considerable yield improvement in several crop plants. The main aim of heterosis in the present study was to search out the best combination of parents giving high degree of heterosis and its exploitation to get better transgressive segregants.

The degree of heterosis varied from cross to cross for all the studied characters. High heterosis in certain crosses and low in others revealed that nature of gene action varied with the genetic makeup of the individual parents. In the present investigation, the crosses exhibited conspicuous heterotic response over mid-parental values for different characters. However, the measure of relative heterosis is relatively less important than heterobeltiosis and, therefore, it is better to measure the heterosis in terms of superiority over the better parent rather than mid-parent.

In this study, maximum range of heterosis has been estimated for all the studied characters. An overall appraisal of the investigation revealed that heterosis ranged from -9.45 to 42.51 for pods per cluster; -7.68 to 52.46 for pods per plant; -1.54 to 38.12 for pod length; -2.15 to 38.54 for seeds per pod; -23.96 to 19.77 for 100-seed weight; -2.58 to 59.83 for seed yield per plant; -48.70 to 110.89 for biomass per plant; and -41.55 to 118.85 for harvest index. The results for different characters are in conformity with the findings obtained by several researchers such as Anitha *et al*. (2016) [4], Patel *et al.* (2016) [17], Pathak *et al*. (2017) [18], Pethe *et al.* (2017) [20], Pampaniya *et al*. (2017) [15], Raut *et al.* (2017) [21], Sarath and Reshma (2017) [22], Varan *et al.* (2017) [24], Kumari and Chauhan (2018) [14] and Babariya *et al.* (2018) [6].

A good number of crosses had significant desired heterosis and heterobeltiosis for seed yield and its contributing characters. For pods per cluster, seven crosses namely RC-19 x IC-2918, RC-19 x IC-8966, RC-101 x IC-2918, CPD-119 x IC-8966, IC-2918 x IC-8966, IC-8966 x CAZC-10 and Ajmer sel. x CAZC-10 exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for pods per cluster. For pods per plant, fourteen crosses namely RC-19 x RC-101, RC-19 x IC-2918, RC-19 x IC-8966, RC-101 x IC-8966, CPD-119 x IC-8966, CPD-119 x IC-7832, IC-2918 x IC-8966, IC-2918 x GC-3, IC-2918 x Saffron, IC-8966 x CAZC-10, IC-8966 x GC-3, IC-8966 x Saffron, CAZC-10 x GC-3, GC-3 x Saffron exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for pods per plant.

For pod length, thirteen crosses namely RC-19 x RC-101, RC-19 x Ajmer sel., RC-101 x CPD-119, RC-101 x Ajmer sel., RC-101 x IC-8966, RC-101 x IC-7832, CPD-119 x Ajmer sel., CPD-119 x IC-8966, CPD-119 x IC-7832, CPD-

119 x Saffron, Ajmer sel. x Saffron, IC-2918 x IC-8966, IC-8966 x GC-3 exhibited positive significant heterosis and heterobeltiosis for pod length. Therefore, these crosses were considered the most desirable for pod length. For seeds per pod, thirteen crosses namely RC-19 x CPD-119, CPD-119 x IC-8966, CPD-119 x IC-7832, CPD-119 x Saffron, Ajmer sel. x IC-2918, Ajmer sel. x GC-3, Ajmer sel. x Saffron, IC-2918 x CAZC-10, IC-2918 x GC-3, IC-2918 x Saffron, IC-8966 x GC-3, IC-8966 x Saffron, IC-7832 x Saffron exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for seeds per pod.

For 100-seed weight, seven crosses namely RC-19 x CPD-119, RC-19 x CAZC-10, RC-101 x GC-3, CPD-119 x IC-7832, CPD-119 x GC-3, IC-2918 x IC-8966, CAZC-10 x GC-3 exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for 100-seed weight. For seed yield per plant, eleven crosses namely RC-19 x RC-101, RC-101 x CAZC-10, CPD-119 x IC-8966, Ajmer sel. x IC-2918, IC-2918 x CAZC-10, IC-8966 x CAZC-10, IC-8966 x GC-3, IC-8966 x Saffron, IC-7832 x GC-3, IC-7832 x Saffron and GC-3 x Saffron exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for seed yield per plant.

For biomass per plant, fifteen crosses namely RC-19 x RC-101, RC-19 x IC-2918, RC-19 x IC-8966, RC-19 x CAZC-10, RC-19 x IC-7832, RC-101 x IC-2918, RC-101 x CAZC-10, RC-101 x IC-7832, RC-101 x Saffron, Ajmer sel. x IC-7832, IC-2918 x CAZC-10, IC-2918 x IC-7832, IC-8966 x IC-7832, CAZC-10 x IC-7832, IC-7832 x Saffron exhibited positive significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for seed yield per plant. For harvest index, seven crosses namely CPD-119 x Ajmer sel., CPD-119 x GC-3, IC-8966 x GC-3, IC-8966 x Saffron, GC-3 x Saffron, RC-101 x CPD-119 and CPD-119 x IC-8966 exhibited positive and significant heterosis and heterobeltiosis. Therefore, these crosses were considered the most desirable for harvest index.

Table 1: Analysis of variance showing mean sum of squares for parents, F_1's and F_2's for seed yield and associated traits

Characters	Source of variation															
		Genotypes		Parents		Generations		F_1		F_2		F_1 vs F_2		Parents vs Generations		Error
df	(2)	(99)		(9)		(89)		(44)		(44)		(1)		(1)		(198)
Pods per cluster	0.01	0.14	**	0.20	**	0.11	**	0.11	**	0.12	**	0.16	**	1.96	**	0.02
Pods per plant	0.75	16.39	**	34.11	**	13.15	**	13.70	**	12.75	**	6.33	*	145.37	**	1.13
Pod length	1.35	4.96	**	5.77	**	3.81	**	3.40	**	4.10	**	9.41	**	100.15	**	0.64
Seeds per pod	0.06	6.21	**	7.50	**	5.42	**	6.61	**	4.16	**	8.23	**	64.94	**	0.47
100-seed weight	0.13	4.07	**	5.35	**	3.33	**	3.15	**	3.54	**	2.17	**	58.78	**	0.30
Seed yield per plant	0.73	21.63	**	29.99	**	17.63	**	18.35	**	16.88	**	18.90	**	302.83	**	2.20
Biomass per plant	33.44	347.42	**	876.33	**	271.66	**	129.84	**	317.36	**	4501.00	**	2329.61	**	22.88
Harvest index	9.62	184.62	**	318.84	**	172.39	**	197.77	**	120.77	**	1327.16	**	64.98	*	14.25

Table 2: Crosses showing significant heterosis and heterobeltiosis for seed yield and associated traits

S. No.	Crosses	Seed yield per plant		Pods per cluster		Pods per plant		Pod length	
		H	HB	H	HB	H	HB	H	HB
1	RC-19 X RC-101	59.83**	58.95**	18.15*	7.33	39.83**	16.22*	28.87**	20.79**
2	RC-101 X CAZC-10	50.36**	20.96*	35.45**	30.64**	14.30*	-0.70	7.30	-3.29
3	CPD-119 X IC-8966	40.06**	29.99**	32.28**	29.55**	33.23**	12.65*	28.86**	16.89*
4	Ajmer sel. X IC-2918	40.70**	38.35**	7.05	4.19	20.31**	-0.51	21.92**	8.24
5	IC-2918 X CAZC-10	28.43**	20.76*	21.24*	18.14	18.75*	13.40	16.16**	8.24
6	IC-8966 X CAZC-10	45.23**	36.94**	33.03**	25.00**	38.47**	25.64**	22.00**	20.39**
7	IC-8966 x GC-3	31.14**	25.46**	14.80*	-1.69	25.01**	18.44*	14.62*	12.75
8	IC-8966 x Saffron	37.10**	19.69*	3.51	-0.79	52.46**	42.97**	25.57**	21.96**
9	IC-7832 x GC-3	28.46**	27.25**	-9.45	-18.28**	10.11	-12.33*	18.50**	-1.63
10	IC-7832 x Saffron	48.16**	33.45**	4.85	3.05	11.06*	-12.30*	19.33**	2.87
11	GC-3 x Saffron	39.00**	26.27**	-4.58	-15.21*	45.34**	43.76**	22.39**	16.99*

Table 2: Continue…..

S. No.	Crosses	Seeds per pod		100-seed weight		Biomass per plant		Harvest index	
		H	HB	H	HB	H	HB	H	HB
1	RC-19 X RC-101	11.94	-4.93	13.17**	7.36	100.14**	70.51**	-24.46**	-34.85**
2	RC-101 X CAZC-10	18.23**	-11.07*	11.4*	4.74	69.39**	53.97**	-12.03	-22.8**
3	CPD-119 X IC-8966	26.92**	23.23**	22.01**	5.3	-2.33	-26.59**	32.49**	5.07
4	Ajmer sel. X IC-2918	17.75**	17.62**	14.15**	1.1	-2.47	-21.74**	33.78**	5.54
5	IC-2918 X CAZC-10	27.06**	16.38**	19.65**	3.48	30.08**	26.14*	-2.79	-10.9
6	IC-8966 X CAZC-10	26.22**	5.25	20.11**	6.76	22.49*	18.73	17.67*	15.22
7	IC-8966 x GC-3	35.98**	21.4**	11.86**	4.85	-24.75**	-40.96**	60.29**	21.81**
8	IC-8966 x Saffron	30.45**	29.91**	9.49*	7.42	-7.41	-7.55	48.43**	29.02**
9	IC-7832 x GC-3	32.77**	25.22**	19.7**	8.85	28.69**	-7.21	-17.42*	-41.28**
10	IC-7832 x Saffron	26.07**	19.39**	22.93**	3.81	49.27**	32.44**	-5.49	-24.42**
11	GC-3 x Saffron	11.03*	-0.5	16.35**	7.14	-18.94**	-36.33**	63.98**	39.71**

Table 3: Top three promising hybrids for their heterosis and heterobeltiosis for seed yield and associated traits

Characters	Pods per cluster	Pods per plant	Pod length	Seeds per pod
Heterotic crosses	RC-19 x IC-2918	IC-8966 x Saffron	RC-101 x IC-7832	RC-101 x CPD-119
	IC-8966 x CAZC-10	IC-2918 x GC-3	CPD-119 x IC-7832	Ajmer sel. X IC-2918
	IC-7832 x Saffron	GC-3 x Saffron	CPD-119 x Ajmer sel.	RC-19 x Ajmer sel.
Heterobeltiotic crosses	RC-19 x IC-2918	IC-2918 x GC-3	RC-101 x CPD-119	RC-19 X CPD-119
	RC-101 x IC-2918	GC-3 x Saffron	RC-101 x IC-7832	IC-8966 X IC-7832
	RC-19 x Ajmer sel.	IC-8966 x Saffron	CPD-119 x IC-7832	RC-19 X Saffron

Table 3: Continue….

Characters	100-seed weight	Seed yield per plant	Biomass per plant	Harvest index
Heterotic crosses	RC-19 x CPD-119	RC-19 x RC-101	RC-19 x IC-7832	CPD-119 x GC-3
	CPD-119 x Saffron	RC-101 x CAZC-10	RC-19 x RC-101	GC-3 x Saffron
	CPD-119 X IC-7832	IC-7832 x Saffron	RC-19 x IC-2918	CPD-119 x Ajmer sel.
Heterobeltiotic crosses	RC-19 x CPD-119	RC-19 x RC-101	RC-19 x IC-7832	CPD-119 x GC-3
	CPD-119 x IC-7832	Ajmer sel. x IC-2918	RC-19 x RC-101	CPD-119 x Ajmer sel.
	RC-19 x CAZC-10	IC-8966 x CAZC-10	IC-2918 x IC-7832	GC-3 x Saffron

An overall appraisal of table 2 revealed that the eleven crosses found heterotic and heterobeltiotic for seed yield per plant, also exhibited desirable heterosis or heterobeltiosis for other yield related characters.

The table 3 shows a significant relation between heterosis and heterobeltiosis for seed yield and its component characters i.e. crosses which exhibited desirable heterosis and heterobeltiosis for seed yield have shown desirable heterosis and heterobeltiosis for at least three or more yield contributing characters. For instance, pods per cluster, pods per plant, seeds per pod, 100-seed weight and biomass per plant mainly contributed to heterosis and heterobeltiosis for seed yield per plant. Though, the crosses exhibiting heterotic expressions for seed yield per plant were not heterotic for all the characters. It was also observed that the expression of heterosis and heterobeltiosis was influenced by the environment for most of the traits due to significant G x E interactions. These results are in partial agreements with the findings of earlier researchers such as Yadav *et al*. (2010) [25], Kadam *et al.* (2013), El-Ameen *et al*. (2014) [8], Alle *et al*. (2014) [3], Pandey and Singh (2015) [16], Anitha *et al*. (2016) [4], Pampaniya *et al*. (2017) [15], Raut *et al.* (2017) [21], Kumari and Chauhan (2018) [14] and Babariya *et al.* (2018) [6].

The cross RC-19 x RC-101, RC-101 x CAZC-10 and IC-7832 x Saffron for heterosis; and Ajmer sel. x IC-2918 and IC-8966 x CAZC-10 for heterobeltiosis were found to be the most promising combinations for seed yield and also exhibited desirable heterosis and/or heterobeltiosis for most of the yield related traits, hence these five crosses can be further used in further plant breeding programme.

Conclusion

The cross RC-19 x RC-101 for both heterosis and heterobeltiosis; RC-101 x CAZC-10 and IC-7832 x Saffron for heterosis; and Ajmer sel. x IC-2918 and IC-8966 x CAZC-10 for heterobeltiosis were found to be the most promising combinations for seed yield and some of the yield contributing traits. Among these five crosses, cross RC-19 x RC-101 also showed desirable heterosis/heterobeltiosis for associated traits like pods per cluster, pods per plant, pod length, 100-seed weight and biomass per plant, hence that cross may be exploited in further plant breeding programme or identification of transgressive sergeants from the advanced generation.

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