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Estimation of Heterosis for Yield and Yield Contributing Characters in Cowpea (*Vigna ungiculata* L.)

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ABSTRACT: The present study was conducted by crossing nine divergent parents in Line × Tester mating design constituting of five lines and four testers to generate twenty F_1 hybrids of cowpea. These hybrids were evaluated in randomised block design with three replications along with parents and two standard checks to estimate the extent of heterosis. The potency of heterosis breeding is enormous in terms of increasing the productivity of crops and could be used as indicative of crosses which are likely to generate productive cultivars. Heterosis was observed for all the traits *viz.*, days to 50% flowering, days to maturity, plant height, number of branches per plant, No. of pods per plant, pod length, No. of seeds per pod, test weight and grain yield per plant were studied during the course of investigation. Appreciable magnitude of heterosis was expressed in hybrids for yield and yield related traits. The cross combinations *viz.*,WCP-1 × PMCP-1016; WCP-1 × VCP-18-032, CPD-311 × PMCP-1016, CPD-311 × KBC-12, CPD-311 × PMCP-1131, CPD-311 × VCP-18-032, CPD-313 × PMCP-1131, CPD-313 × VCP-18-032, PCP-1124 × PMCP-1016, PCP-1124 × KBC-12 for grain yield recorded significant positive standard heterosis. Thus these crosses can be exploited to obtain desirable transgressive segregants for yield and yield contributing traits which will pave the way for selection of individual progenies with optimal traits in further generations and ultimately for identification of high yielding genotypes in cowpea. Heterosis in yield attributes had a significant additive influence on seed yield per plant. It is mainly due to complementary combination of component traits *viz.*, branches per plant, seeds per pod and 100 seed weight and seed yield per plant.

Keywords: Cowpea, Heterosis, Line × Tester mating design, economic heterosis.

INTRODUCTION

Cowpea (*Vigna ungiculata* L.) is a highly self pollinated multipurpose grain legume belonging to the family *Papilionaceae* with a chromosome number of 2n=22 and is native of central Africa. Its role as a crucial component of cropping systems in the world's tropical and subtropical areas and its importance in being a nourishment legume can never be overemphasized (Fatokun *et al*., 2002; Sanchez-Navarro *et al*., 2019). Cowpea contains 20 to 25% protein content, which makes it attractive as a source of quality nourishment for both the rural and urban poor people (Fatokun *et al*., 2002; Uarrota, 2010; Ajayi *et al*., 2014). Because of its high protein content cowpea is referred to as "vegetable meat" and contains high grain and biological value on a dry weight basis. Cowpea is economically grown throughout India and is used for a variety of purposes such as pulse crop and for long green pods, fodder for the cattle, green manure and as a cover crop. Cowpea grows fast, curbs erosion, fixes atmospheric nitrogen (Ajayi & Adesoye 2013) and fertilizes the soil with its decaying residues after harvest (Singh *et al*., 2002). The nutrient rich Cowpea grains comprises of 23.4 per cent protein, 60.3 per cent carbohydrates, 1.8 per cent fat and is a good source of vitamins and phosphorus(Venkatesan *et al.*, 2003). Cowpea is also valued for its low-fat content and high fibre content.

Heterosis or hybrid vigour may be defined as the superiority of a F_1 hybrid over both the parents in terms of yield and some other character (Shull, 1914). It is firstly reported in plants by Koelreuter (1766) in *Nicotiana* spp. Heterotic response for seed yield per plant was mainly due to high heterotic desirable effects for the yield attributing traits like plant height, branches per plant, pods per cluster, pods per plant, pod length and seed yield. The, information on heterosis estimates can be utilized to identify crosses that can result in superior transgressive segregants in the segregating generation. Heterosis for yield and other characters in grain legumes were first reported by Pal (1945).

MATERIAL AND METHODS

The present experimental study was carried out in two seasons in which *kharif*, 2021 for crossing and *Rabi*, 2021-2022 for evaluation at the Regional Agricultural Research Station, Warangal. The experimental materials comprised of twenty hybrids generated from five high yielding lines *viz.*, WCP-6, WCP-1, CDP-311, CDP-313, PCP-1124 and four broad based testers PMCP-1016, KBA-12, PMCP-1131 and VCP-18-032 which were crossed in Line x Tester mating design (5 lines x 4 testers) by conventional method of hybridization. The experimental design used was randomised block design design as suggested by (Nadarajan and Gunasekaran 2005) with three replications, while, L×T analysis of heterosis was performed as per Kempthorne (1957). Two standard check varieties (TPTC-29 & DC-15) were included in the experimental material to estimate standard heterosis. Heterosis was estimated by using the following formulae.

$$\text{Heterosis (\%)}\ (h_1) = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} x100$$

$$\text{Heterobeltiosis (\%)}\ (h_2) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} x100$$

$$\text{Standard heterosis (\%)}\ (h_3) = \frac{\overline{F_1} - \text{Mean of check}}{\text{Mean of check}} x100$$

Where, F_1 = Mean performance of the F_1 hybrid

$\overline{MP}$ = Mean value of the parents (P1 and P2) of a hybrid

$\overline{BP}$ = Mean value of better parent.

RESULTS AND DISCUSSION

The analysis of variance (Table 3) deciphered substantial variations among the genotypes for all the characters studied, demonstrating the presence of variability in the material under study. All the characters studied exhibited considerable mid parent and better parent heterosis, either alone or in combination (Table 4).

In the present study, the heterosis for days to 50 % flowering ranged from -32.20% to 8.93% and -34.07% to 5.59% over mid parent and better parent, respectively, while for standard heterosis it ranged from -23.08% to 21.15% and -29.41% to 11.18% over both the checks. The cross PCP-1124 × PMCP-1131 exhibited superior negative significant heterosis over mid parent (-32.20%) and PCP-1124 × PMCP-1131 for better parent (-34.07%), while the cross PCP-1124 × PMCP-1131 exhibited negative significant standard heterosis over both the checks (-23.08% to -29.41%) respectively. Similar results were obtained by Ushakumari *et al.* (2010); Kadam *et al.* (2013); Anitha *et al.* (2016); Mukati *et al.* (2016).

The heterosis for days to maturity ranged from -21.60 to 4.81% over mid parent, whereas over better parent, it ranged from to 3.30% and standard heterosis from -16.92% to 10.00% and -20.59% to 5.15% over both checks respectively. Significant negative heterosis in desired direction over mid parent was observed in 15 crosses. The hybrid PCP-1124 × PMCP-1131 (-21.60 %) exhibited the highest significant negative heterosis over mid parent. Sixteen crosses exhibited significant negative heterosis over better parent. Negative heterosis for days to maturity were in agreement with Sharma *et al.* (2010); Ajayi *et al.* (2014); Mukati *et al.* (2016) for early maturity.

The heterosis for plant height ranged from – 19.44 to 45.83 per cent and -20.56 to 28.05 per cent over mid and better parents, respectively. Three crosses showed significant negative heterosis over mid parent, while five crosses over better parent. The cross, PCP-1124 × VCP-18-032 (-19.44) exhibited the lowest significant heterosis over mid parent. Standard heterosis ranged from -17.58% to 27.27% and -20.00 to 23.53% over both the checks. Standard heterosis was significant and positive in the cross combinations CPD-313 ×PMCP-1016 , CPD-313 × PMCP-1131, PCP-1124 × KBC-12&PCP-1124 × VCP-18-032 over the check TPTC-29 andWCP-6 × KBC-12 CPD-313 × PMCP-1016, CPD-313 × PMCP-1131, PCP-1124 × KBC-12 and PCP-1124 × VCP-18-032 over the check DC-15 Similar results were reported by Sharma *et al.*(2010); Katariya *et al.* 2016; Sanchez-Navarro *et al.*(2019).

The range of heterosis for branches per plant was from -30.71 to 69.97 per cent and -46.99 to 54.65 per cent over mid and better parents, respectively. Eleven and four crosses manifested significant positive heterosis over both mid and better parents. The cross WCP-1 × PMCP-1131(69.977 %) and (54.65 %) manifested the maximum significant positive relative heterosis and heterobeltiosis, respectively. Standard heterosis ranged from -30.88% to 33.33% (CPD-311 × PMCP-1016) Over both the checks (TPTC-29 & DC-15)Similar results were reported by Bhusana *et al.*(2000); Mehta (2000); Hira Lal *et al.* (2007); Patel *et al.* (2009); Sharma *et al.*(2010).

The pods per plant is an important yield contributing character for which the heterosis ranged from -15.50 to 96.60 per cent and -32.35 to 88.14 per cent over mid and better parents, respectively. Significant positive heterosis over midparent was recorded for 12 crosses and over better parents was recorded for nine crosses. The crosses, CPD-311 × PMCP-1016 (96.60 %) and CPD-313 × KBC-12 (88.14 %) showed maximum significant positive relative heterosis and heterobeltiosis, respectively. Standard heterosis ranged from -20.59% (WCP-6 × KBC-12) to 126.47% and -25.00% (WCP-6 × KBC-12) to 113.89% over both the checks. Bhushana *et al.* (2000); Yadav *et al.* (2010); Chaudhari *et al.* (2013; Katariya *et al.* (2016); Sarath *et al.* (2017) also reported similar results.

The crosses WCP-1 × KBC-12 (24.87 %) and PCP-1124 × VCP-18-032 (18.99 %) manifested significant positive relative heterosis and heterobeltiosis, respectively for pod length and range for this trait was -28.71 to 24.87 per cent and -40.49 to 18.99 per cent over mid and better parents, respectively. Heterosis over mid parent was significant and positive in 6 hybrids, heterobeltiosis in only one hybrid WCP-1 × KBC-12 and standard heterosis in 8 and 10 hybrids crosses (TPTC-29 & DC-15). The range of heterosis was from -24.37 to 41.19 per cent and -30.10 to 35.48 per cent over mid and better parents, respectively for number of seeds per pod. Ten crosses manifested significant positive heterosis over mid parent and seven crosses over better parent for number of seeds per pod. Maximum significant positive heterosis was recorded by WCP-1 × PMCP-1016 i.e. 41.19 % and 35.48 % over mid and better parent respectively for this trait and standard heterosis ranged from -13.87% to 64.45% and -28.71 % to 36.12 % over both the checks.

The heterosis for number of pods per cluster ranged from -40.19% to 105.79% over mid parent, While, heterobeltiosis ranged from -53.03% to 93.02% and standard heterosis ranged from -25.60% to 99.20% over TPTC-29 and -21.85% to 109.24% over DC-15 . The cross CPD-311 × PMCP-1016manifested the maximum significant positive relative heterosis and heterobeltiosis of 105.79% and 93.02 % respectively. Similar results were reported by Yadav *et al.* (2010); Sharma *et al.* (2013); Kadam *et al.* (2013).

For 100 seed weight relative heterosis ranged from -13.92% to 100.96%, heterobeltiosis from -26.20 to 77.92% and standard heterosis from 0.55% to 61.43% and -9.17 to 45.83% for this trait. Twelve crosses exhibited significant positive heterosis over mid parent and 8 over better parent. Among which cross WCP-1 × PMCP-1016 (100.96% and 77.92%) recorded maximum positive heterosis and heterobeltiosis. Similar observations were made by Bhushana *et al.* (2000); Patel *et al.* (2009); Kadam *et al.* (2013); Sanchez-Navarro *et al.* (2019).

For grain yield per plant twelve crosses expressed significant positive heterobeltiosis and eleven hybrids were found promising on both the standard checks with significant positive standard heterosis. The cross combinations are WCP-1 × PMCP-1016; WCP-1 × VCP-18-032, CPD-311 × PMCP-1016, CPD-311 × KBC-12, CPD-311 × PMCP-1131, CPD-311 × VCP-18-032, CPD-313 × PMCP-1131, CPD-313 × VCP-18-032, PCP-1124 × PMCP-1016, PCP-1124 × KBC-12.Thus from the present study it can be concluded that most of the hybrids exhibited significant heterosis for different traits along with grain yield over better parent / standard checks. The genotypes *viz.*, WCP-1, CPD-311, CPD-313, PCP-1124 among lines and PMCP-1016, VCP 18-032, PMCP-1016 and KBC-12 among the testers as one of the parents will provide the basic material for breeding programme for further improvement in yield and yield contributing traits in cowpea. Thus these crosses may offer higher frequency of productive derivatives in their later generations.

Table 1: Analysis of variance (mean squres) for experimental design for different characters in cowpea genotypes.

Source of variation	DF	Days to 50% flowering (Days)	Days to maturity (Days)	Plant height (cm)	Number of Branches per plant (no)	Number of pods per plant (no)	Number of seeds per pod (no)	Pod length (cm)	Pods per cluster (no)	Test weight (g)	Seed yield per plant (gms)
Replication	2	0.32	1.28*	3.87	0.08	4.88*	0.29	0.15	0.70	0.18	0.97
Genotype	28	85.49**	82.06**	158.39**	8.11**	73.85**	17.08**	31.11**	23.54**	12.85**	62.04**
Parents	8	130.70**	122.78**	107.83**	10.08**	36.53**	20.06**	5.96**	24.53**	6.87**	74.30**
Hybrids	19	66.48**	66.16**	175.40**	7.58**	83.91**	15.03**	34.48**	24.31**	15.87**	54.61**
Parents vs Hybrids	1	83.71**	58.36**	239.83**	2.56**	181.36**	32.09**	168.29**	1.07	3.17**	105.24**
Error	56	0.25	0.40	13.59	0.07	1.21	0.36	0.54	0.65	0.11	1.01

*, **significant at 5% and 1% levels of probability, respectively

Table 2: Range of mean and the heterosis % over Mid parent (MP) and Better parent (BP) for Yield and yield contributing characters in cowpea.

Characters	Range of mean		Range of heterosis % over		Range of standard checks in (%)	
	Parent	Crosses	MP	BP	SC_1 (TPTC-29)	SC_2 (DC-15)
Days to 50% flowering	51.33 - 62.33	40.00 – 63.00	-32.20 – 8.93	-34.07 – 5.59	-23.08 – 21.15	-29.41 – 11.18
Days to maturity	84.66 – 91.00	72.00 – 95.33	-21.60 – 4.81	-22.30 – 3.30	-16.92 – 10.00	-20.59 – 5.15
Plant height (cm)	41.33 – 64.33	41.33 – 70.00	-19.44 – 45.83	-20.56 – 28.05	-17.58 – 27.27	-20.00 – 23.53
Number of branches per plant	4.70 – 8.86	4.70 – 9.06	-30.71 – 69.97	-46.99 – 54.65	-30.88 – 33.33	-30.88 – 33.33
Number of pods per plant	9.66 – 18.40	9.66 – 30.80	-15.50 – 96.60	-32.35 – 88.14	-20.59 – 126.47	-25.00 – 113.89
Number of seeds per pod	11.20 – 16.50	9.93 – 18.96	-24.37 – 41.19	-30.10 – 35.48	-13.87 – 64.45	-28.71 – 36.12
Pod length (cm)	11.79 – 21.48	11.70 – 21.50	-28.71 – 24.87	-40.49 – 18.99	-19.24 – 48.46	-6.62 – 71.64
Number of pods per cluster	6.20 – 13.20	6.20 – 16.60	-40.19 – 105.79	-53.03 – 93.02	-25.60 – 99.20	-21.85 – 109.24
Test weight	6.36 – 15.47	15.47 – 11.61	-13.92 – 100.96	-15.24 – 131.85	0.55 – 61.43	-9.17 – 45.83
Seed yield per plant	9.78 – 17.16	12.98 – 28.26	-26.20 – 77.92	-18.95 – 128.82	-17.11 – 89.12	-20.32 – 81.78

Table 3: Estimates of heterosis per cent over mid parent, better parent, and standard check for days to 50% flowering and days to maturity.

Crosses	Days to 50 %flowering (Days)				Days to maturity (Days)			
	$MP(H_1)$	$BP(H_2)$	SC (H_3)	SC (H_3)	$MP(H_1)$	$BP(H_2)$	$SC_1(H_3)$	$SC_2(H_3)$
WCP-6 × PMCP-1016	6.51**	-1.10	15.38**	5.88**	6	-4.93**	3.85**	-0.74
WCP-6 × KBC-12	-12.54**	-19.79**	-3.85**	-11.76**	-6.49**	-11.58**	-3.08**	-7.35**
WCP-6 × PMCP-1131	-7.69**	-14.29**	0.00	-8.24**	-3.01**	-7.19**	-0.77	-5.15**
WCP-6 × VCP-18-032	-9.25**	-15.08**	-2.56**	-10.59**	-3.80**	-6.99**	-2.69**	-6.99**
WCP-1 × PMCP-1016	7.43**	3.30**	20.51**	10.59**	3.44**	0.70	10.00**	5.15**
WCP-1 × KBC-12	-1.97**	-6.95**	11.54**	2.35**	-5.42**	-8.07**	0.77	-3.68**
WCP-1 × PMCP-1131	-9.71**	-13.19**	1.28	-7.06**	-6.03**	-7.55**	-1.15	-5.51**
WCP-1 × VCP-18-032	-17.58**	-20.11**	-8.33**	-15.88**	-13.12**	-13.60**	-9.62**	-13.60**
CPD-311 × PMCP-1016	8.93**	0.55	17.31**	7.65**	4.81**	-0.35	8.85**	4.04**
CPD-311 × KBC-12	-8.50**	-16.58**	0.00	-8.24**	-7.95**	-12.63**	-4.23**	-8.46**
CPD-311 × PMCP-1131	-7.74**	-14.84**	-0.64	-8.82**	-4.12**	-7.91**	-1.54*	-5.88**
CPD-311 × VCP-18-032	-4.50**	-11.17**	1.92*	-6.47**	-1.14*	-4.04**	0.38	-4.04**
CPD-313 × PMCP-1016	-13.07**	-15.93**	-1.92*	-10.00**	-8.27**	-10.21**	-1.92**	-6.25**
CPD-313 × KBC-12	-8.12**	-12.30**	5.13**	-3.53**	-4.49**	-6.67**	2.31**	-2.21**
CPD-313 × PMCP-1131	-10.23**	-13.19**	1.28	-7.06**	-6.91**	-7.91**	-1.54*	-5.88**
CPD-313 × VCP-18-032	4.30**	1.68*	16.67**	7.06**	2.21**	2.21**	6.92**	2.21**
PCP-1124 × PMCP-1016	-3.95**	-6.59**	8.97**	0.00	-3.05**	-4.93**	3.85**	-0.74
PCP-1124 × KBC-12	-14.76**	-18.18**	-1.92*	-10.00**	-8.60**	-10.53**	-1.92**	-6.25**
PCP-1124 × PMCP-1131	-32.20**	-34.07**	-23.08**	-29.41**	-21.60**	-22.30**	-16.92**	-20.59**
PCP-1124 × VCP-18-032	7.69**	5.59**	21.15**	11.18**	3.49**	3.30**	8.46**	3.68**
Range (min)	-32.20	-34.07	-23.08	-29.41	-21.60	-22.30	-16.92	-20.59
Range (max)	8.93	5.59	21.15	11.18	4.81	3.30	10.00	5.15

* ,** Significant at 5%, and 1% respectivelyH_1:Averagae heterosis, H_2:Heterobeltiosis, H_3:Stanadard heterosis

Table 4: Estimates of heterosis per cent over mid parent, better parent, and standard check for plant height and branches per plant.

Crosses	Plant height(cm)				Number of branches per plant			
	$MP(H_1)$	$BP(H_2)$	SC (H_3)	SC (H_3)	$MP(H_1)$	$BP(H_2)$	$SC_1(H_3)$	$SC_2(H_3)$
WCP-6 × PMCP-1016	24.22**	20.45**	-3.64	-6.47	-14.29**	-25.00**	-30.88**	-30.88**
WCP-6 × KBC-12	-4.49	-17.22**	-9.70	-12.35*	2.64	-12.50**	-14.22**	-14.22**
WCP-6 × PMCP-1131	26.39**	16.67**	10.30	7.06	0.00	0.00	-30.88**	-30.88**
WCP-6 × VCP-18-032	2.77	-13.47**	1.21	-1.76	11.41**	-11.02**	2.94	2.94
WCP-1 × PMCP-1016	6.99	-5.56	-7.27	-10.00	47.78**	41.49**	30.39**	30.39**
WCP-1 × KBC-12	-2.34	-7.22	1.21	-1.76	8.60**	1.00	-0.98	-0.98
WCP-1 × PMCP-1131	9.43	7.41	5.45	2.35	69.97**	54.65**	30.39**	30.39**
WCP-1 × VCP-18-032	0.85	-7.25	8.48	5.29	19.61**	3.39	19.61**	19.61**
CPD-311 × PMCP-1016	45.83**	28.05**	27.27**	23.53**	33.33**	23.64**	33.33**	33.33**
CPD-311 × KBC-12	19.77**	14.44**	24.85**	21.18**	8.57**	3.64	11.76**	11.76**
CPD-311 × PMCP-1131	28.13**	25.00**	24.24**	20.59**	35.18**	10.91**	19.61**	19.61**
CPD-311 × VCP-18-032	0.28	-7.25	8.48	5.29	-11.40**	-14.41**	-0.98	-0.98
CPD-313 × PMCP-1016	3.97	-5.88	-12.73*	-15.29**	-14.29**	-25.00**	-30.88**	-30.88**
CPD-313 × KBC-12	8.71	0.56	9.70	6.47	-17.30**	-29.50**	-30.88**	-30.88**
CPD-313 × PMCP-1131	-11.97*	-12.82*	-17.58**	-20.00**	0.00	0.00	-30.88**	-30.88**
CPD-313 × VCP-18-032	4.05	-6.74	9.09	5.88	29.44**	3.39	19.61**	19.61**
PCP-1124 × PMCP-1016	5.15	-8.38	-7.27	-10.00	-11.89**	-24.81**	-1.96	-1.96
PCP-1124 × KBC-12	-17.58**	-20.56**	-13.33*	-15.88**	14.16**	0.00	30.39**	30.39**
PCP-1124 × PMCP-1131	1.55	-1.80	-0.61	-3.53	-30.71**	-46.99**	-30.88**	-30.88**
PCP-1124 × VCP-18-032	-19.44**	-24.87**	-12.12*	-14.71**	5.98*	0.00	30.39**	30.39**
Range (min)	-19.44	-20.56	-17.58	-20.00	-30.71	-46.99	-30.88	-30.88
Range (max)	45.83	28.05	27.27	23.53	69.97	54.65	33.33	33.33

* ,** Significant at 5%, and 1% respectivelyH_1:Averagae heterosis, H_2:Heterobeltiosis, H_3:Stanadard heterosis

Table 5: Estimates of heterosis percentage over mid parent, better parent, and standard check for pods per plant, seeds per pod.

Crosses	Number of pods per plant				Number of seeds per pod			
	MP(H_1)	BP(H_2)	SC_1(H_3)	SC_2(H_3)	MP(H_1)	BP(H_2)	SC_1(H_3)	SC_2(H_3)
WCP-6 × PMCP-1016	26.29**	4.47	25.98**	18.98**	15.79**	4.76	27.17**	5.26
WCP-6 × KBC-12	2.21	0.62	-20.59**	-25.00**	7.29*	-3.74	19.08**	-1.44
WCP-6 × PMCP-1131	7.62	-14.34**	14.22*	7.87	19.01**	11.92**	24.86**	3.35
WCP-6 × VCP-18-032	19.45**	-5.43	27.94**	20.83**	14.97**	-3.03	38.73**	14.83**
WCP-1 × PMCP-1016	84.65**	46.75**	76.96**	67.13**	41.19**	35.48**	64.45**	36.12**
WCP-1 × KBC-12	36.21**	31.41**	0.49	-5.09	-12.04**	-16.36**	3.47	-14.35**
WCP-1 × PMCP-1131	-11.75*	-32.35**	-9.80	-14.81*	28.24**	28.24**	43.06**	18.42**
WCP-1 × VCP-18-032	11.64*	-14.86**	15.20*	8.80	19.64**	6.46*	52.31**	26.08**
CPD-311 × PMCP-1016	96.60**	87.80**	126.47**	113.89**	35.48**	35.48**	64.45**	36.12**
CPD-311 × KBC-12	45.26**	23.21**	35.29**	27.78**	3.77	2.80	27.17**	5.26
WCP-1 × PMCP-1016	44.56**	31.80**	75.74**	65.97**	19.11**	14.29**	38.73**	14.83**
CPD-311 × VCP-18-032	-1.60	-10.87*	20.59**	13.89*	-24.37**	-30.10**	0.00	-17.22**
CPD-313 × PMCP-1016	52.25**	30.89**	57.84**	49.07**	-0.53	-10.48**	8.67*	-10.05**
CPD-313 × KBC-12	100.00**	88.14**	63.24**	54.17**	3.66	-7.48*	14.45**	-5.26
CPD-313 × PMCP-1131	11.36*	-8.09	22.55**	15.74*	-17.45**	-22.80**	-13.87**	-28.71**
CPD-313 × VCP-18-032	66.89**	36.96**	85.29**	75.00**	36.94**	14.95**	64.45**	36.12**
PCP-1124 × PMCP-1016	-15.50**	-19.26**	6.86	0.93	-18.92**	-23.08**	4.05	-13.88**
PCP-1124 × KBC-12	57.75**	24.44**	64.71**	55.56**	-9.37**	-13.25**	17.34**	-2.87
PCP-1124 × PMCP-1131	-1.48	-1.84	30.88**	23.61**	2.58	-6.41*	26.59**	4.78
PCP-1124 × VCP-18-032	4.76	3.62	40.20**	32.41**	-5.92*	-8.48**	30.92**	8.37*
Range (min)	-15.50	-32.35	-20.59	-25.00	-24.37	-30.10	-13.87	-28.71
Range (max)	96.60	88.14	126.47	113.89	41.19	35.48	64.45	36.12

* ,** Significant at 5%, and 1% respectivelyH_1:Averagae heterosis, H_2:Heterobeltiosis, H_3:Stanadard heterosis

Table 6: Estimates of heterosis percentage over mid parent, better parent, and standard check for pod length, per pods per cluster.

Crosses	Pod length (cm)				Number of pods per cluster			
	MP(H_1)	BP(H_2)	SC (H_3)	SC (H_3)	MP(H_1)	BP(H_2)	SC_1(H_3)	SC_2(H_3)
WCP-6 × PMCP-1016	1.80	-21.16**	16.94**	35.20**	42.48**	42.48**	28.80**	35.29**
WCP-6 × KBC-12	-28.71**	-40.49**	-11.73**	2.05	-4.15	-7.96	-16.80*	-12.61
WCP-6 × PMCP-1131	-1.17	-21.14**	16.96**	35.22**	4.62	-7.48	8.80	14.29
WCP-6 × VCP-18-032	14.76**	-6.05*	39.35**	61.11**	-40.19**	-53.03**	-25.60**	-21.85*
WCP-1 × PMCP-1016	19.51**	-5.12	31.39**	51.90**	73.79**	58.41**	43.20**	50.42**
WCP-1 × KBC-12	24.87**	7.21*	48.46**	71.64**	32.99**	25.96**	4.80	10.08
WCP-1 × PMCP-1131	4.89	-14.09**	18.96**	37.54**	54.58**	26.19**	48.40**	55.88**
WCP-1 × VCP-18-032	22.22**	2.82	42.38**	64.62**	17.87**	-13.38*	37.20**	44.12**
CPD-311 × PMCP-1016	-7.27	-18.26**	-12.77**	0.85	105.79**	93.02**	99.20**	109.24**
CPD-311 × KBC-12	-5.29	-8.58*	-2.44	12.80*	51.93**	37.21**	41.60**	48.74**
CPD-311 × PMCP-1131	-14.51**	-21.86**	-16.61**	-3.59	34.78**	26.53**	48.80**	56.30**
CPD-311 × VCP-18-032	-11.82**	-16.86**	-11.27*	2.58	-36.39**	-47.47**	-16.80*	-12.61
CPD-313 × PMCP-1016	-5.24	-12.79**	-15.55**	-2.37	-12.06	-17.70	-25.60**	-21.85*
CPD-313 × KBC-12	-12.39**	-13.48**	-14.08**	-0.67	27.41**	24.04*	3.20	8.40
CPD-313 × PMCP-1131	-10.59**	-14.50**	-17.21**	-4.28	-12.83	-27.21**	-14.40	-10.08
CPD-313 × VCP-18-032	-5.34	-6.46	-9.43*	4.71	15.35*	-13.64**	36.80**	43.70**
PCP-1124 × PMCP-1016	1.43	-2.94	-13.53**	-0.03	-21.92**	-36.31**	-8.80	-4.20
PCP-1124 × KBC-12	-14.26**	-18.67**	-19.24**	-6.62	41.34**	11.73*	60.00**	68.07**
PCP-1124 × PMCP-1131	9.70*	9.25	-2.67	12.53*	7.98	-1.68	40.80**	47.90**
PCP-1124 × VCP-18-032	22.51**	18.99**	12.47**	30.03**	6.10	1.01	60.00**	68.07**
Range (min)	-28.71	-40.49	-19.24	71.64	-40.19	-53.03	-25.60	-21.85
Range (max)	24.87	18.99	48.46	-6.62	105.79	93.02	99.20	109.24

* ,** Significant at 5%, and 1% respectivelyH$_1$:Averagae heterosis, H_2:Heterobeltiosis, H_3:Stanadard heterosis

Table 7: Estimates of heterosis percentage over mid parent, better parent, and standard check for test weight, seed yield per plant.

Crosses	Test weight(g)				Seed yield per plant (g)			
	MP(H_1)	BP(H_2)	SC_1(H_3)	SC_2(H_3)	MP(H_1)	BP(H_2)	SC_1(H_3)	SC_2(H_3)
WCP-6 × PMCP-1016	41.89**	18.87**	59.67**	44.24**	24.65**	12.79*	12.11*	7.76
WCP-6 × KBC-12	30.40**	11.24**	49.41**	34.98**	10.35	-1.08	-1.67	-5.49
WCP-6 × PMCP-1131	4.41*	2.29	37.40**	24.12**	7.66	6.08	8.63	4.42
WCP-6 × VCP-18-032	-2.72	-12.93**	48.02**	33.72**	3.92	-3.07	11.33*	7.01
WCP-1 × PMCP-1016	100.96**	77.92**	61.43**	45.83**	88.85**	71.24**	37.82**	32.48**
WCP-1 × KBC-12	63.18**	41.75**	34.43**	21.44**	41.76**	29.77**	2.27	-1.69
WCP-1 × PMCP-1131	16.97**	-9.78**	16.26**	5.03	20.54**	-1.20	1.18	-2.74
WCP-1 × VCP-18-032	4.58*	-26.20**	25.46**	13.34**	79.79**	41.15**	62.11**	55.82**
CPD-311 × PMCP-1016	48.91**	34.61**	51.17**	36.57**	131.85**	128.82**	89.12**	81.78**
CPD-311 × KBC-12	22.79**	13.24**	27.18**	14.89**	49.45**	45.98**	20.65**	15.97**
CPD-311 × PMCP-1131	25.49**	17.42**	51.32**	36.70**	41.96**	28.27**	31.36**	26.26**
CPD-311 × VCP-18-032	-9.54**	-24.89**	27.69**	15.35**	17.57**	1.09	16.10**	11.60*
CPD-313 × PMCP-1016	26.08**	9.56**	34.69**	21.67**	-9.29	-18.95**	-17.11**	-20.32**
CPD-313 × KBC-12	-7.65**	-18.21**	0.55	-9.17**	18.28**	4.71	7.09	2.94
CPD-313 × PMCP-1131	-6.84**	-8.98**	17.29**	5.96*	23.16**	23.08**	26.05**	21.16**
CPD-313 × VCP-18-032	1.61	-12.45**	48.83**	34.45**	65.14**	56.10**	79.28**	72.33**
PCP-1124 × PMCP-1016	-3.92	-17.44**	4.25	-5.82*	40.89**	25.72**	28.95**	23.94**
PCP-1124 × KBC-12	32.41**	15.93**	46.37**	32.23**	89.16**	67.25**	71.54**	64.89**
PCP-1124 × PMCP-1131	-0.16	-1.17	27.36**	15.06**	-15.24**	-15.31**	-13.14*	-16.51**
PCP-1124 × VCP-18-032	-13.92**	-24.99**	27.51**	15.19**	25.20**	18.50**	36.11**	30.83**
Range (min)	-13.92	-26.20	0.55	-9.17	-15.24	-18.95	-17.11	-20.32
Range (max)	100.96	77.92	61.43	45.83	131.85	128.82	89.12	81.78

*,** Significant at 5%, and 1% respectively H_1:Averagae heterosis, H_2:Heterobeltiosis, H_3:Stanadard heterosis

CONCLUSION

Thus from the present study it can be concluded that most of the hybrids exhibited significant heterosis for different traits along with grain yield over better parent / standard checks. The characters branches per plant, plant height, pod length, pods per plant, seeds per pod, pods per cluster and 100 seed weight largely define the seed yield of cowpea and hence should be prioritized in selection programmes in order to develop high yielding varieties and hybrids.

FUTURE SCOPE

Through the studies on heterosis the traits that were desirable for improvement in yield were identified. Thus these crosses may offer higher frequency of productive derivatives in their future generations. The genotypes *viz.*, WCP-1, CPD-311, CPD-313, PCP-1124 among lines and PMCP-1016, VCP 18-032, PMCP-1016 and KBC-12 among the testers as one of the parents will provide the basic material for breeding programme for further improvement in yield and yield contributing traits in cowpea. The data can also be useful for selecting selecting superior lines for the development of varieties and hybrids.

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