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GENETIC ANALYSIS FOR POD YIELD IN COWPEA [*VIGNA UNGUICULATA* (L.) WALP]

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ABSTRACT

The present investigations were carried out to know the extent of standard heterosis in cowpeas [*Vigna unguiculata* (L.) Walp.]. Thirty hybrids were developed by using six parents, namely, NCK-15-9, NCK-15-10, NC-15-41, NC-15-42, NC-15-44, and NC-15-45 adopting full diallel mating design. A set of thirty eight cowpea entries including six parents, thirty crosses and two check varieties, GC-3 and GDVC-2 were evaluated at three locations *viz.* Navsari, Mangrol and Achhalia used a randomized block design with three replications during *Kharif*-2017. The observations were recorded on parents and F_1's for twelve quantitative traits and one quality trait *viz.*, days to 50 per cent flowering, plant height (cm), primary branches per plant, pods per plant, pod length (cm), days to maturity, seeds per pod, green seed wt. (g), green pod yield per plant(g) and protein content (per cent). The cross NC-15-45 × NCK-15-10, NC-15-45 × NC-15-41 and NCK-15-10 × NC-15-45 recorded high heterotic values for green pod yield per plant along with high *per se* performance.

Key words : Cowpea, *Vigna unguiculata* (L.), Standard heterosis, Hybrid variety.

Introduction

Cowpea, *Vigna unguiculata* (L.) Walp. is diploid crop with chromosome number of (2n=22), belongs to family *Fabaceae*, one of the oldest source of human food, in form of green pods as well as grains has most likely been used as a crop. It is native of West Africa (Vavilov, 1951), but Steele (1976) suggested Ethiopia as the primary and Africa as the secondary centre of diversity. Among all the pulses, cowpea locally known as lobiya, chowla (chowli), southern pea or black eye pea, is an annual legume that is adopted to warm condition and cultivated in the tropics and sub-tropics for dry grains, green edible pods for vegetable as well as fodder. Development of cultivars with early maturity, acceptable grain as well as vegetable quality, resistance to some important diseases and pests have significantly increased the yield and cultivated area. The overall effect of plant breeding on genetic diversity has been a long standing concern in the evolutionary biology of crop plants (Simmonds, 1962). Self-pollinating crop like cowpea, variability is often created through hybridization between carefully chosen parents. The scope of exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological feasibilities and the type of gene action involved. The information of such estimates is essential to plan efficient breeding programme for the improvement of crop. Although, the hybrid vigour cannot be exploited commercially in highly self-pollinated crop like cowpea, the heterotic F_1,s can be used to isolate a higher frequency of productive derivatives in their later generations.

Materials and Methods

Thirty hybrids were developed by adopting full diallel mating design. The experimental material for the present investigation consisted of 38 entries including six parents (NCK-15-9, NCK-15-10, NC-15-41, NC-15-42, NC-15-44 and NC-15-45**)** and resultant 30 crosses (full diallel) along with GC-3 and GDVC-2 as checks. The seeds of these entries were obtained from Pulse Research Station, Navsari Agricultural University, Navsari. These parents were selected carefully based on earlier reports as well as the observations recorded at the centre. To obtain hybrid seeds, these six parents were sown at Main Pulse Research Station, NAU, Navsari during *summer* 2017. All possible single crosses (including reciprocals) were made to complete the 6 × 6 full diallel set. Hand emasculation and pollination methods were adopted. All the hybrids and self-seeds of parents were stored properly in seed packets for sowing in the *kharif* season 2017-18. The observations were recorded on parents and F_1's for nine quantitative traits and one quality traits *viz.*days to 50 per cent flowering, plant height (cm), primary branches per plant, pods per plant, pod length (cm), days to maturity, green seed per pod, pod yield per plant (g), and protein content (per cent). Heterosis expressed as per cent increase or decrease in the mean value of F_1 hybrid over standard check (standard heterosis) was calculated for various characters over environments following the procedure given by Fonseca and Patterson (1968).

Results and Discussion

The estimates of heterosis measured as per cent increase or decrease over standard check (standard heterosis) GC-3 (Check-1) and GDVC-2 (Check- 2) estimated for twelve characters on pooled basis are presented in Tables 1 to 3. While interpreting magnitude of heterosis, negative effects were considered favourable for the characters *viz*; days to 50 per cent flowering and days to maturity in order to identify good hybrids for desirable character like earliness, parent with smaller mean value considered as better parent.

For days to 50 per cent flowering out of fifteen direct crosses one and six crosses were significant in desirable direction over check GC-3 and GDVC-2. Among reciprocal crosses six crosses exhibited significant heterosis over check GC-3 and GDVC-2 on pooled basis. Six hybrids shown significant positive heterosis over check GC-3, while ten direct crosses have shown negative standard heterosis over check GDVC-2 for plant height and two crosses registered positive and significant heterosis for check-GC-3. These results are in conformity with those obtained by Mehta *et al.* (2000), Viswanatha *et al.* (2006), Lal *et al.* (2007), Patel *et al.* (2009), Rashwan (2010), Adeyanju *et al.* (2012), Patel *et al.* (2013) and Nautiyal *et al.* (2015).

For pods per plant out of fifteen direct crosses seven, six and four crosses have shown positive and significant standard heterosis over check GC-3 and GDVC-2 respectively, while cross (NCK-15-10 × NC-15-45) recorded positive and significant standard heterosis over check GC-3 and GDVC-2 on pooled basis. Among reciprocal crosses cross NC-15-45 × NCK-15-10 registered maximum standard heterosis over check GC-3 (31.47 per cent) and standard heterosis over check GDVC-2 (27.63 per cent).

The heterosis for number of seed per pod and pod length was high for direct cross NCK-15-9 × NC-15-42 and among reciprocal crosses NC-15-45 × NCK-15-10 recorded highest standard heterosis over both the check. Positive standard heterosis for test weight was significant in ten direct crosses andnine crosses manifested significant positive standard heterosis over check GC-3. For green seed weight cross NC-15-44 × NC-15-42 exhibited highest standard heterosis over GC-3 and GDVC-2 on pooled basis. Thus, the trait seems to be the control of dominance effect. Three crosses *viz.* NC-15-41 × NCK-15-10, NC-15-44 × NC-15-41 and NC-15-45 × NCK-15-10 have registered highly significant and positive standard heterosis over both the checks on pooled basis. Out of fifteen crosses six and eight crosses have shown positive significant standard heterosis over check GC-3 and GDVC-2, respectively for protein content and six and seven reciprocal crosses registered significant standard heterosis over both the check respectively in pooled data. Joseph and Santhosh kumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al.* (2009), Patel *et al.* (2013), Nautiyal *et al.* (2015) and Pathak (2016) were observed similar results.

For grain yield per plant standard heterosis varied from -27.44 (NCK-15-9 × NC-15-45) to 24.73 per cent (NCK-15-10 × NC-15-45) over check GC-3 and -24.02 (NCK-15-9 × NC-15-45) to 30.62 per cent (NCK-15-10 × NC-15-45) over check GDVC-2. Out of fifteen direct crosses two and three crosses have shown significant standard heterosis over check GC-3 and GDVC-2 respectively on pooled basis. Three direct crosses *viz*. NC-15-41 × NC-15-42 and NCK-15-10 × NC-15-45 standard heterosis on pooled basis.

Incase of reciprocal crosses standard heterosis ranged from -20.09 (NC-15-42 × NCK-15-9) to 31.90 per cent (NC-15-45 × NCK-15-10) over GC-3 and -16.32 (NC-15-42 × NCK-15-9) to 38.12 per cent (NC-15-45 × NCK-15-10) over GDVC-2 in pooled analysis. Cross NC-15-45 × NCK-15-10 standard heterosis in pooled analysis. Range of mid parent for reciprocal crosses was 20.74 (NC-15-42 × NC-15-41) to 58.10 per cent (NC-15-45 × NCK-15-10) on pooled basis.

Significant and negative heterosis for days to 50 per cent flowering and days to maturity were also documented by Chaudhary (1993), Thiyagarajan (1993), Patel *et al.*

Table 1 : The extent of standard heterosis over GC-3 and GDVC-2 in per cent for days to 50 per cent flowering, plant height (cm), primary branches per plant and days to maturity on the pooled basis in cowpea.

Direct Crosses		Days to 50 per cent flowering		Plant height (cm)		Primary branches per plant		Days to maturity	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
1	NCK-15-9 x NCK-15-10	8.22**	2.48	-6.66*	-18.06**	5.97	9.60	0.24	0.74
2	NCK-15-9 x NC-15-41	2.89	-2.56	-14.54**	-24.98**	-7.44	-4.26	1.02	1.51
3	NCK-15-9 x NC-15-42	-2.56	-7.72**	-8.19**	-19.40**	0.80	4.26	-6.35*	-5.89*
4	NCK-15-9 x NC-15-44	-1.61	-6.82**	-6.91*	-18.28**	-5.75	-2.52	-3.70	-3.22
5	NCK-15-9 x NC-15-45	2.97	-2.49	-10.06**	-21.04**	7.16	10.84**	1.09	1.59
6	NCK-15-10 x NC-15-41	-1.32	-6.55**	5.66*	-7.25**	12.72**	16.59**	-0.23	0.26
7	NCK-15-10 x NC-15-42	1.79	-3.61	3.66	-9.00**	8.06*	11.77**	-2.73	-2.26
8	NCK-15-10 x NC-15-44	3.85	-1.66	-7.75**	-19.02**	8.52*	12.24**	2.01	2.51
9	NCK-15-10 x NC-15-45	6.60**	1.00	3.54	-9.11**	32.55**	37.10**	2.36	2.86
10	NC-15-41 x NC-15-42	0.77	-4.57	13.74**	-0.15	-7.55	-4.38	-3.8	-3.33
11	NC-15-41 x NC-15-44	-4.15	-9.23**	5.10	-7.74**	4.77	8.36	-7.51**	-7.05**
12	NC-15-41 x NC-15-45	-1.43	-6.65**	8.95**	-4.36	14.22**	18.14**	-0.35	0.14
13	NC-15-42 x NC-15-44	10.80**	4.93	15.90**	1.74	-1.73	1.64	9.29**	9.83**
14	NC-15-42 x NC-15-45	2.35	-3.08	9.34**	-4.02	7.25	10.93**	0.45	0.94
15	NC-15-44 x NC-15-45	-5.36*	-10.38**	-1.57	-13.60**	4.27	7.85	-1.58	-1.1
Range from		**-5.36**	**-10.38**	**-14.54**	**-24.98**	**-7.44**	**-4.38**	**-7,51**	**-7.05**
To		**10.80**	**4.93**	**15.90**	**1.74**	**32.55**	**37.10**	**9.29**	**9.83**
Number of desirable crosses		**1**	**6**	**5**	**0**	**5**	**7**	**2**	**2**

Reciprocal crosses		Days to 50 per cent flowering		Plant height (cm)		Primary branches per plant		Days to maturity	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
16	NCK-15-10 x NCK-15-9	4.18	-1.35	1.02	-11.32**	1.46	4.94	2.36	2.86
17	NC-15-41 x NCK-15-9	2.80	-2.65	-9.77**	-20.79**	-1.68	1.69	1.06	1.56
18	NC-15-41 x NCK-15-10	-7.56**	-12.46**	6.76*	-6.28	11.52**	15.35**	-10.30**	-9.86**
19	NC-15-42 x NCK-15-9	-2.01	-7.20**	-7.01*	-18.36**	-0.59	2.82	-4.11	-3.64
20	NC-15-42 x NCK-15-10	-5.83*	-10.82**	20.73**	5.99	9.04*	12.78**	-8.11**	-7.66**
21	NC-15-42 x NC-15-41	6.71**	1.05	1.83	-10.61**	10.13*	13.91**	-4.29	-3.82
22	NC-15-44 x NCK-15-9	-8.96**	-13.78**	-6.09*	-17.56**	3.09	6.62	-11.39**	-10.96**
23	NC-15-44 x NCK-15-10	-1.37	-6.60**	-1.62	-13.64**	5.14	8.75	-0.86	-0.38
24	NC-15-44 x NC-15-41	-1.62	-6.84**	-1.22	-13.28**	17.40**	21.43**	-2.27	-1.79
25	NC-15-44 x NC-15-42	0.82	-4.52	5.27	-7.59**	1.85	5.34	4.60	5.12*
26	NC-15-45 x NCK-15-9	-8.22**	-13.08**	-3.72	-15.48**	5.47	9.09	-1.35	-0.87
27	NC-15-45 x NCK-15-10	2.35	3.07	5.52	-7.37**	14.34**	18.26**	3.61	4.12
28	NC-15-45 x NC-15-41	-6.46**	-11.42**	-2.37	-14.30**	12.63**	16.50**	-7.05**	-6.59*
29	NC-15-45 x NC-15-42	-2.54	-7.71**	-1.75	-13.75**	3.40	6.94	-0.36	0.13
30	NC-15-45 x NC-15-44	-4.84*	-9.88**	2.46	-10.06**	17.10**	21.12**	-5.35*	-4.89
Range From		**-8.96**	**-13.78**	**-9.77**	**-20.79**	**-1.68**	**1.69**	**-11.39**	**-10.96**
To		**6.71**	**1.05**	**20.73**	**5.99**	**17.40**	**21.43**	**4.60**	**5.12**
Number of desirable crosses		**6**	**10**	**2**	**0**	**7**	**7**	**5**	**4**

(1994), Sawant *et al.* (1994), Bhushana *et al.* (2000), Mehta (2000), Patil *et al.* (2005), Pal *et al*. (2007) and Patel *et al*. (2013).

Moderate to high heterosis observed in present study has been also reported by several workers for pod length (Prajapati 2000; Sangwan *et al*., 2000; Shavithramma *et al*., 2001; Patil *et al*., 2005 and Kajale and Ravindrababu

Table 2 : Extent of standard heterosis over GC-3 and GDVC-2 for Pods per plant, pod length, seeds per pod and test weight on the pooled basis in cowpea.

Direct Crosses		**Pods per plant**		**Pod length (cm)**		**Seeds per pod**		**Test weight (g)**	
		SC1	**SC2**	**SC1**	**SC2**	**SC1**	**SC2**	**SC1**	**SC2**
1	NCK-15-9 x NCK-15-10	-9.90**	-12.53**	-13.28**	-12.87**	-16.51**	-11.61**	-2.36	-16.08**
2	NCK-15-9 x NC-15-41	-17.11**	-19.54**	-17.15**	-16.76**	-17.87**	-13.05**	3.07	-11.42**
3	NCK-15-9 x NC-15-42	-15.41**	-17.88**	-14.54**	-14.13**	-17.88**	-13.06**	-3.54	-17.10**
4	NCK-15-9 x NC-15-44	-8.78*	-11.44**	-13.46**	-13.05**	-8.08**	-2.69	6.22*	-8.71**
5	NCK-15-9 x NC-15-45	0.02	-2.91	-10.98**	-10.56**	-9.20**	-3.87	-4.55	-17.96**
6	NCK-15-10 x NC-15-41	18.83**	15.35**	-3.67**	-3.22*	2.64	8.66**	14.49**	-1.60
7	NCK-15-10 x NC-15-42	8.25*	5.08	-12.07**	-11.65**	-12.30**	-7.16**	3.01	-11.47**
8	NCK-15-10 x NC-15-44	-2.04	-4.90	-9.84**	-9.41**	-10.82**	-5.59	5.64*	-9.21**
9	NCK-15-10 x NC-15-45	30.57**	26.76**	8.91**	9.43**	3.98	10.07**	9.97**	-5.48*
10	NC-15-41 x NC-15-42	9.44**	6.24	0.21	0.69	-0.33	5.52	18.50**	1.84
11	NC-15-41 x NC-15-44	-17.77**	-20.18**	-5.91**	-5.47**	-8.43**	-3.06	12.89**	-2.98
12	NC-15-41 x NC-15-45	13.00**	9.70**	-7.36**	-6.92**	-14.13**	-9.10**	20.48**	3.55
13	NC-15-42 x NC-15-44	-15.74**	-18.20**	-1.83	-1.36	2.70	8.72**	12.82**	-3.04
14	NC-15-42 x NC-15-45	15.28**	11.91**	-9.03**	-8.59**	-7.62**	-2.20	8.23**	-6.99**
15	NC-15-44 x NC-15-45	4.43	1.37	13.11**	13.65**	-0.41	5.43	16.68**	0.28
Range from		**-5.36**	**-17.77**	**-20.18**	**-17.15**	**-16.76**	**-17.88**	**-4.55**	**-17.96**
To		**10.80**	**30.57**	**26.76**	**13.11**	**13.65**	**3.98**	**20.48**	**3.55**
Number of desirable crosses		**1**	**6**	**4**	**2**	**2**	**0**	**10**	**0**

Reciprocal crosses		**Pods per plant**		**Pod length (cm)**		**Seeds per pod**		**Test weight (g)**	
		SC1	**SC2**	**SC1**	**SC2**	**SC1**	**SC2**	**SC1**	**SC2**
16	NCK-15-10 x NCK-15-9	-0.73	-3.64	-6.88**	-6.44**	-6.62**	-1.15	7.42**	-7.68**
17	NC-15-41 x NCK-15-9	-12.93**	-15.47**	-13.12**	-12.71**	-13.45**	-8.38**	4.92	-9.82**
18	NC-15-41 x NCK-15-10	24.50**	20.86**	-0.36	0.11	4.26	10.38**	18.02**	1.43
19	NC-15-42 x NCK-15-9	-12.69**	-15.24**	-16.65**	-16.26**	-9.66**	-4.36	2.73	-11.71**
20	NC-15-42 x NCK-15-10	3.01	0.01	-4.19**	-3.73**	-2.71	2.99	-7.08**	-20.14**
21	NC-15-42 x NC-15-41	-4.68	-7.47	-14.19**	-13.79**	-7.92**	-2.53	0.19	-13.89**
22	NC-15-44 x NCK-15-9	-8.04*	-10.73**	-4.89**	-4.44**	-1.61	4.16	12.65**	-3.18
23	NC-15-44 x NCK-15-10	14.28**	10.94**	-7.54**	-7.10**	-1.91	3.84	18.12**	1.52
24	NC-15-44 x NC-15-41	10.45**	7.22	4.36**	4.86**	2.72	8.74**	20.85**	3.86
25	NC-15-44 x NC-15-42	-1.94	-4.81	5.25**	5.75**	-0.17	5.68	15.34**	-0.88
26	NC-15-45 x NCK-15-9	12.82**	9.52**	-8.95**	-8.52**	-10.99**	-5.78	3.62	-10.94**
27	NC-15-45 x NCK-15-10	31.47**	27.63**	12.41**	12.94**	16.59**	23.43**	10.03**	-5.44*
28	NC-15-45 x NC-15-41	25.37**	21.71**	4.17**	4.67**	8.36**	14.72**	2.75	-11.70**
29	NC-15-45 x NC-15-42	10.61**	7.37	-2.29	-1.83	1.01	6.93**	7.32**	-7.76**
30	NC-15-45 x NC-15-44	14.01**	10.68**	10.53**	11.05**	9.80**	16.24**	8.29**	-6.93**
Range from		**-8.96**	**-13.78**	**-9.77**	**-17.15**	**-16.76**	**-17.88**	**0.19**	**-20.14**
To		**6.71**	**1.05**	**20.73**	**13.11**	**13.65**	**3.98**	**20.85**	**3.86**
Number of desirable crosses		**6**	**10**	**2**	**2**	**2**	**0**	**9**	**0**

2012.) and seeds per pod (Sangwan *et al*., 2000; Patil *et al*., 2005; Patel *et al*., 2009; Sharma *et al*., 2010; Kajale and Ravindrababu, 2012 and Patel *et al*., 2013) harvest index (Patel *et al*., 2013), protein content (Shavithramma *et al*., 2001 and Patel *et al*., 2009).

Low amount of standard heterosis in positive direction for test weight recorded in this study is in accordance with findings of Bhushana *et al.* (2000), Shashibhushan and Chaudhari (2000a), Patel *et al.* (2009), Meena *et al.* (2009) and Patel *et al.* (2013). However, the heterosis in

Table 3 : Extent of standard heterosis over GC-3 and GDVC-2 for green seed weight, green pod yield per plant, grain yield per plant seeds and protein percentage on the pooled basis in cowpea.

Direct Crosses		Green seed weight (g)		Green pod yield per plant (g)		Grain yield per plant (g)		Protein content (per cent)	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
1	NCK-15-9 x NCK-15-10	-6.58**	-10.79**	-13.28**	-12.87**	-23.01**	-19.39**	2.09	4.16**
2	NCK-15-9 x NC-15-41	-0.78	-5.25	-17.15**	-16.76**	-19.88**	-16.10**	6.44**	8.60**
3	NCK-15-9 x NC-15-42	-4.40	-8.71**	-14.54**	-14.13**	-24.80**	-21.26**	6.53**	8.69**
4	NCK-15-9 x NC-15-44	1.78	-2.81	-13.46**	-13.05**	-10.59*	-6.38	-6.17**	-4.27**
5	NCK-15-9 x NC-15-45	-0.96	-5.42	-10.98**	-10.56**	-27.44**	-24.02**	5.82**	7.97**
6	NCK-15-10 x NC-15-41	2.66	-1.97	-3.67**	-3.22*	4.88	9.82	-14.82**	-13.10**
7	NCK-15-10 x NC-15-42	6.13*	1.35	-12.07**	-11.65**	-1.97	2.64	-12.66**	-10.90**
8	NCK-15-10 x NC-15-44	6.86**	2.04	-9.84**	-9.41**	-3.59	0.95	-13.80**	-12.06**
9	NCK-15-10 x NC-15-45	7.73**	2.87	8.91**	9.43**	24.73**	30.61**	1.96	4.02**
10	NC-15-41 x NC-15-42	-1.70	-6.13	0.21	0.69	21.22**	26.93**	4.40**	6.51**
11	NC-15-41 x NC-15-44	1.30	-3.26	-5.91**	-5.47**	-13.70**	-9.64	1.72	3.78**
12	NC-15-41 x NC-15-45	11.74**	6.71**	-7.36**	-6.92**	9.28	14.43**	12.19**	14.46**
13	NC-15-42 x NC-15-44	12.78**	7.70**	-1.83	-1.36	-9.00	-4.72	15.02**	17.35**
14	NC-15-42 x NC-15-45	-0.24	-4.73	-9.03**	-8.59**	0.29	5.02	-11.89**	-10.10**
15	NC-15-44 x NC-15-45	9.99**	5.03	13.11**	13.65**	-5.67	-1.23	-11.91**	-10.12**
Range from		**-5.36**	**-6.58**	**-10.79**	**-17.15**	**-16.76**	**-24.80**	**-14.82**	**-13.10**
To		**10.80**	**12.78**	**7.70**	**13.11**	**13.65**	**24.73**	**15.02**	**17.35**
Number of desirable crosses		**1**	**6**	**2**	**2**	**2**	**2**	**6**	**9**

Reciprocal crosses		Green seed weight (g)		Green pod yield per plant (g)		Grain yield per plant (g)		Protein content (per cent)	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
16	NCK-15-10 x NCK-15-9	1.83	-2.76	-2.37	-7.41	-6.67	-2.27	-1.51	0.48
17	NC-15-41 x NCK-15-9	10.42**	5.44	-13.87**	-18.32**	0.06	4.77	5.48**	7.62**
18	NC-15-41 x NCK-15-10	5.89*	1.12	24.78**	18.33**	14.85**	20.26**	-3.23**	-1.28
19	NC-15-42 x NCK-15-9	7.00**	2.18	-11.45*	-16.03**	-20.09**	-16.32**	11.61**	13.87**
20	NC-15-42 x NCK-15-10	6.28*	1.50	1.16	-4.07	-5.44	-0.98	-5.80**	-3.90**
21	NC-15-42 x NC-15-41	8.99**	4.08	-6.09	-10.95*	-8.27	-3.95	3.59**	5.68**
22	NC-15-44 x NCK-15-9	15.04**	9.86**	-9.26*	-13.95**	-2.50	2.09	-1.84	0.15
23	NC-15-44 x NCK-15-10	16.15**	10.91**	12.03*	6.24	6.70	11.73	-15.31**	-13.60**
24	NC-15-44 x NC-15-41	17.35**	12.06**	21.47**	15.19**	24.66**	30.53**	9.85**	12.07**
25	NC-15-44 x NC-15-42	18.08**	12.76**	-12.12*	-16.66**	-2.76	1.82	-4.92**	-3.00*
26	NC-15-45 x NCK-15-9	4.19	-0.50	6.49	0.99	-2.59	2.00	13.01**	15.30**
27	NC-15-45 x NCK-15-10	7.75**	2.90	26.05**	19.54**	31.90**	38.12**	7.36**	9.53**
28	NC-15-45 x NC-15-41	15.09**	9.91**	31.27**	24.48**	26.73**	32.70**	9.69**	11.92**
29	NC-15-45 x NC-15-42	3.10	-1.55	5.61	0.15	9.96*	15.15**	-7.31**	-5.44**
30	NC-15-45 x NC-15-44	9.66**	4.72	11.54*	5.78	13.03**	18.36**	-3.12*	-1.16
Range from		**-8.96**	**-13.78**	**-9.77**	**-15.51**	**-20.09**	**-16.32**	**-15.31**	**-13.60**
To		**6.71**	**1.05**	**20.73**	**28.67**	**31.90**	**38.12**	**13.01**	**15.30**
Number of desirable crosses		**6**	**10**	**2**	**4**	**6**	**6**	**7**	**7**

negative direction was also reported by of Patel *et al.* (1994) and Sawant *et al.* (1994) for this trait.

The presence of appreciable amount of heterotic effects in most of the crosses for different traits studied in this investigation may be attributed to non-allelic interaction, which can either increase or decrease the expression of heterosis. A few modifier genes with negative effects might also be involved. Similar

Table 4 : Top ten crosses on the basis of *per se* performance with standard for green pod yield per plant with yield attributing traits, which registered significant and desirable standard heterosis in cowpea.

S. no.	Crosses	Green pod yield per plant (g)	Heterosis over check GC-3	Heterosis over check GDVC-2	Other characters which registered significant and desirable standard heterosis
1.	NC-15-45 x NC-15-41	126.30	31.27**	24.48**	DF, PB,DM,PPP,PL,SPP,GSW, GY,HI,PRT
2.	NCK-15-10 x NC-15-45	123.79	28.67**	22.02**	PB,PPP,PL,TSW,GSW, HI
3	NC-15-45 x NCK-15-10	121.28	26.05**	19.54**	PB,PPP,PL,SPP,TSW,GSW,GY,HI
4	NC-15-41 x NCK-15-10	120.06	24.78**	18.33**	DF, PB,PPP,SPP,TSW,GSW, GY,HI
5	NC-15-44 x NC-15-41	116.86	21.47**	15.19**	DF, PB,DM,PPP,PL,SPP,TSW,GSW,HI
6	NCK-15-10 x NC-15-41	109.02	13.32**	7.46**	DF, PB,DM,PPP.TSW,GSW,HI
7	NC-15-41 x NC-15-42	107.83	12.08**	6.29**	DF,DM,PPP,PL,TSW,HI
8	NC-15-44 x NCK-15-10	107.78	12.03**	6.24**	DF, DM,PPP,HI
9	NC-15-45 x NC-15-44	107.32	11.54**	5.78**	DF, PB,DM,PPP,PL,SPP,HI
10	NCK-15-10 x NC-15-42	106.03	10.21**	4.51**	DF, PB,DM,PPP,TSW,GSW

*Significant at 5per cent level and **Significant at 1 per cent level

Where, DF-Days to 50per cent flowering; PH-Plant height; PB-Primary branches per plant; DM- Days to 50% maturity ;PPP-pods per plant, PL-Pod length; SPP- seeds per pod; TSW-Test weight; GSW-Green seed weight; GPY-Green pod yield per plant; GY-Grain yield per plant.

observations were also recorded earlier by Sangwan *et al*. (2000), Shashibhushan and Chaudhari (2000a), Sangwan and Lodhi (2002), Patil *et al.* (2005), Meena *et al*. (2009), Sharma *et al.* (2010), Yadav *et al.* (2010), Kajale and Ravindrababu (2012), Chaudhari *et al.* (2013), Patel *et al.* (2013) and Ratnakumari *et al*. (2023) in crosses involving intra and inter sub-specific crosses.

The utility of hybrid breeding approach lies in the identification of most heterotic and useful crosses for yield and yield contributing character. Out of thirty hybrids evaluated, ten promising hybrid based on mean performance for green pod yield per plant along with heterosis (heterobeltiosis and standard heterosis) and combining ability effect are given in Table 4 for green pod yield per plant.

A perusal of Table 4 revealed that crosses NC-15-45 × NCK-15-10, NC-15-45 × NC-15-41 and NCK-15-10 × NC-15-45 are top three hybrids for dual purpose having high performance for grain yield as well as green pod yield per plant. Cross NC-15-45 × NCK-15-10 registered highest standard heterosis for grain yield per plant over check GC-3 and GDVC-2, followed by NC-15-45 × NC-15-41 and NCK-15-10 × NC-15-45, while cross NC-15-45 × NC-15-41 documented highest standard heterosis for green pod yield per plant followed by NCK-15-10 × NC-15-45 and NC-15-45 × NC-15-10.

It will be of considerable interest to know the cause of heterosis for grain yield. Whitehouse *et al.* (1958) and Grafius (1959) have suggested that there cannot be any gene system for yield *per se* and yield is an end product of the multiplicative interaction between the yield components. This would indicate that the heterosis for seed yield should be through the heterosis for individual yield components or alternatively due to multiplicative effects of partial dominance of component characters. Williams and Gilbert (1960) have reported that even simple dominance in respect of yield components may lead to expression of heterosis in respect of yield. In order to see whether similar situation exists in cowpea or not, a comparison of ten crosses for seed yield was made for other yield related characters along with average seed yield per plant (Table 4). The data revealed that heterotic hybrids for seed yield did not show significant heterosis for all the yield components. In fact, appreciable heterosis for one or two components was sufficient to manifest heterosis for seed yield.

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