Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 2453-2458
Received: 01-05-2018
Accepted: 05-06-2018

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Genetic analysis for yield and contributing characters in cowpea (*Vigna unguiculata* (L.) Walp)

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Abstract
The present investigations were carried out with a view to know the extent of heterobeltiosis, standard heterosis, general and specific combining ability in cowpea (*Vigna unguiculata* (L.) Walp.). Thirty hybrids were developed by adopting full diallel mating design. A set of thirty eight cowpea entries including six parents (NCK-15-9, NCK-15-10, NC-15-41, NC-15-42, NC-15-44 and NC-15-45), thirty crosses and two check varieties, GC-3 and GDVC-2 evaluated at three locations *viz.* Navsari, Mangrol and Achhalia using randomized block design with three replications during *Kharif*-2017. The observations were recorded on parents and F_1's for traits *viz.* Days to 50 per cent flowering, plant height (cm), primary branches per plant, days to maturity, pods per plant, pod length (cm), pod length (cm), seeds per pod, test weight (g), grain yield per plant (g), straw yield per plant (g), harvest index (per cent) and protein content (per cent). Combining ability analysis revealed significant general and specific combining ability for all the characters across the environment. Reciprocal variances were found to be significant for number of characters. The specific combining ability variances were found more important compared to general combining ability variances for all the traits indicated preponderance of non-additive gene effects. A fairly close association between *per se* performance of parents and their GCA effects were observed for grain yield per plant and its related traits. Similarly, strong relationship between *per se* performance of hybrids and their SCA effects were also observed for all the traits. Parents, NCK-15-10, NC-15-41 and NC-15-45 were found to be most promising due to their high yielding potential and significant general combining ability effects for yield and attributes. The cross combination NC-15-45 X NCK-15-10, NC-15-45 X NC-15-41 and NCK-15-10 X NC-15-45 recorded high *per se* performance for grain yield per plant, resulted from good x good general combiners. Cross NC-15-45 X NCK-15-10 advocated non-significant SCA effect for grain yield per plant.

Keywords: cowpea, heterobeltiosis, combining ability

Introduction
Cowpea (*Vigna unguiculata* (L.) Walp.) Is diploid with a chromosome number of 2n=22 belonging to the tribe Phaseolae of family *Fabaceae*. It is an important *kharif* food legume and forms an integral part of traditional cropping systems for the semiarid regions of the tropics where other food legumes may not perform well. Legumes provide the much needed proteins to our predominantly vegetarian population. It represents the second largest family of higher plants, second only to grasses in agricultural importance (Doyle and Luckow, 2003) [4]. Resource-poor farmers across the developing world depend on grain legumes to sustain the health of their families and livestock, and to enhance their economic well-being. 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) [15]. 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. Although, the hybrid vigour cannot be exploited commercially in highly self-pollinated crop like cowpea, the heterotic F_1S can be used to isolate a higher frequency of productive derivatives in their later generations, a breeder should know the genetic potential of the parents by estimating their combining ability. Besides, the use of combining ability analysis in the selection of parents elucidates the nature and magnitude of various types of gene action involved in the expression of quantitative characters. Such information is of potential use in formulation and executing an efficient breeding programme for achieving maximum genetic gain with minimum resources and time.

Matterials 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 on the basis of earlier reports as well as the observations recorded at the centre. For obtaining 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 x 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 traits *viz.* Days to 50 per cent flowering, plant height (cm), primary branches per plant, days to maturity, pods per plant, pod length (cm), pod length (cm), seeds per pod, test weight (g), grain yield per plant (g), straw yield per plant (g), harvest index (per cent) and protein content (per cent). Heterosis expressed as per cent increase or decrease in the mean value of F_1 hybrid over mid parent (heterosis), better parent (heterobeltiosis) and over standard check (standard heterosis) was calculated for various characters over environments following procedure given by Fonseca and Patterson (1968) [15]. Method of analysis for combining ability was based on method-I, model I as outlined by Griffings (1956) for individual environment. Means of five random plants obtained from each replications were utilized in the analysis.

Results and Discussion

The analysis of variance for combining ability indicated that general and specific combining ability variances were highly significant for all the traits, suggesting that both additive and non-additive gene effects were involved in the expression of character. Combining ability variances revealed that the SCA variances were higher than their respective GCA variances for all the traits. This suggested that non-additive gene action play important role in the expression of these traits. The GCA and SCA ratio (σ2GCA/ σ2SCA) was less than unity for all the traits except for pod length at Navsari location, and seeds per pod at Mangrol location this indicated that non-additive components play relatively greater role in the inheritance of most of the traits. Predominant role of non-additive gene action in inheritance of yield and most of characters as observed in this study was also observed by many workers, Zaveri, *et al.,* (1983) [20], Aravindhan and Das, (1996) [1], Jayarani and Manju, (1996) [8], Singh, *et al.,* (2006) [16], Valarmathi, *et al.,* (2007) [19], Kwaye, *et al.,* (2008) [10], Patel, *et al.,* (2008) [3]; Meena, *et al.,* (2010) [11], Uma and Kalibowilla, (2010) and Chaudhari, *et al.,* (2013).

The mean square due to GCA X environment and SCA X environment interaction and RCA X environment were highly significant for all the characters indicating sensitivity of all kinds of gene effects to environmental variation. The sensivity of both GCA and SCA variances for environmental variations indicated that adequate sampling of environment is essential for reaching reliable conclusion.

In the light of present investigation, parents *viz.* NCK-15-10, NC-15-41 and NC-15-45 were found to be promising due to their high yield potential, significant general combining ability for grain yield per plant. These parents were also found to be good and average general combiner for many yield attributing traits *viz.* Days to 50 per cent flowering, Pods per plant, pod length, harvest index. NC-15-41 and NC-15-45 were good general combiner for protein content also, among these NC-15-45 was average stable for days to 50% flowering, and pods per plant, pod length, grain yield per plant, harvest index and also for protein content. Therefore these parents can be exploited in systematic varietal development programme for cowpea. The estimates of GCA effects further revealed that the parental line showing high GCA effects for seed yield also exhibited high to average GCA effect for one or other yield components. These findings are in accordance with Thiyagarajan, *et.al.* (1990a) [17], Sawant, *et al.* (1995) [14], Kumar *et al.*, (2000) [9] and Kwaye *et al*. (2008) [10].

Top ranking three hybrids *viz.* NC-15-45 X NC-15-41 (GXG) and NCK-15-10 X NC-15-45 (G X G) found to posses high mean performance, high heterosis over better parent and over standard check GC-3 and GDVC-2 and desirable SCA effect for grain yield per plant. Therefore hybrid *viz.* NC-15-45 X NC-15-41 (GXG) and NCK-15-10 X NC-15-45 (G X G) having high SCA effect which indicated additive x additive type gene interaction may produce desirable transgressive seggregants in subsequent generation or could be considered as valuable for future breeding programme, in such case as such repeated backcross method may be allocated to have good recombinant.

Reciprocal differences were also observed and crosses *viz.* NC-15-45 X NCK-15-10, NC-15-45 X NC-15-41, NC-15-44 X NC-15-41, NC-15-45 X NC-15-44 performed best in terms have significant SCA effect and also high *per se* performance for grain yield per plant indicating that small group of cytoplasmic genes also playing key role and affecting hybrid vigour. So, it is better to attempt even reciprocal crosses when direct crosses are not showing desirable results. Apart from conventional approaches, identification of candidate genes associated with hybrid vigour using epigenous and mitochondrial genome sequencing may be fruitful for further improvement programme. These findings are in agreement with the earlier findings of Singh, *et al.,* (2006) [16], Patil and Nawale, (2006), Valarmathi, *et al.,* (2007), Kwaye, *et al.,* (2008) [10], Patel, *et al.,* (2008) [12], Bhawna Pandey and Singh, (2010) [16], Meena, *et al.,* (2010) [11].

On the basis of overall experimental result, we came to the conclusion that low SCA effects with the high heterotic expression of the hybrids is the indication of additive gene effects that could be exploited by pedigree method, looking towards the duel purpose varietal improvement programme cross NC-15-45 X NCK-15-10, had shown non-significant SCA effect for grain yield per plant with parents having good x good combiner indicating importance of additive gene action. The presence of additive gene action would enhance the chance for making improvement through simple selection of transgressive seggregants in later generation.

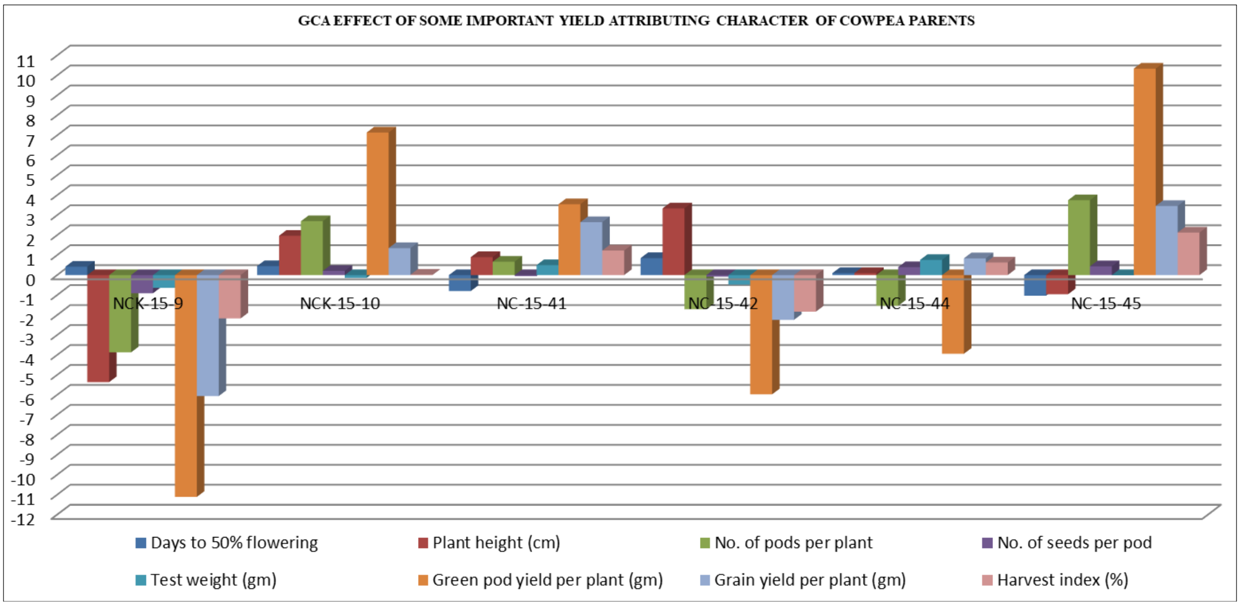

Fig 1: 2 General combining ability of all the six parents (NCK-15-9, NCK-15-10, NC-15-41, NC-15-42, NC-15-44, NC-15-45) for some important yield attributing

Table 1: Mean sum of squares for general and specific combining ability and GCA: SCA ratio for various characters at individual location in cowpea

Source	D.F.	Days to 50per cent flowering			Plant height (cm)		
		Navsari	Mangrol	Achhalia	Navsari	Mangrol	Achhalia
GCA	5	4.83**	4.89**	19.13**	123.04**	160.98**	119.96**
SCA	15	11.61**	10.62**	11.39**	24.55**	22.90**	41.36**
Reciprocal	15	2.58**	3.45**	8.55**	30.24**	8.32**	43.85**
Error	70	1.24	1.31	1.74	4.38	4.02	3.42
σ^2GCA	-	0.30	0.30	1.45	9.89	13.08	9.71
σ^2SCA	-	10.37	9.32	9.65	20.18	18.89	37.9
σ^2RCA	-	1.34	2.14	6.81	25.87	4.31	40.43
σ^2GCA:σ^2SCA	-	0.029	0.032	0.150	0.490	0.690	0.260
Source	D.F.	Primary branches per plant			Days to maturity		
		Navsari	Navsari	Mangrol	Achhalia	Mangrol	Achhalia
GCA	5	2.69**	17.81**	15.77**	17.81**	15.77**	115.38**
SCA	15	0.49**	49.06**	39.32**	49.06**	39.32**	40.28**
Reciprocal	15	0.28**	17.59**	9.41	17.59**	9.41	24.76**
Error	70	0.07	5.17	5.53	5.17	5.53	7.12
σ^2GCA	-	0.22	1.05	0.85	1.05	0.85	9.02
σ^2SCA	-	0.42	43.89	33.79	43.89	33.79	33.15
σ^2RCA	-	0.22	12.41	0.001	12.41	0.001	17.63
σ^2GCA:σ^2SCA	-	0.516	0.024	0.025	0.024	0.025	0.272
Source	D.F.	Pods per plant			Pod length (cm)		
		Navsari	Mangrol	Achhalia	Navsari	Mangrol	Achhalia
GCA	5	109.09**	99.48**	121.98**	5.49**	4.49**	6.12**
SCA	15	21.20**	10.67**	14.94**	0.51**	1.94**	1.62**
Reciprocal	15	5.88**	15.89**	5.96**	1.11**	0.68**	0.91**
Error	70	1.63	1.38	2.24	0.11	0.13	0.16
σ^2GCA	-	8.95	8.18	9.98	0.45	0.36	0.50
σ^2SCA	-	19.57	9.29	12.70	0.40	1.81	1.45
σ^2RCA	-	4.25	14.52	3.73	1.00	0.56	0.75
σ^2GCA:σ^2SCA	-	0.458	0.880	0.785	1.13	0.20	0.34

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

Table 1: Contd...…

Source	D.F.	Seeds per pod			Test weight (g)		
		Navsari	Mangrol	Achhalia	Navsari	Mangrol	Achhalia
GCA	5	3.41**	3.06**	3.65**	2.77**	180.31**	74.00**
SCA	15	1.26**	0.25**	0.87**	0.43**	54.02**	53.72**
Reciprocal	15	0.74**	0.90**	1.24**	0.75**	38.01**	20.31**
Error	70	0.15	0.13	0.09	0.12	4.88	5.30
σ^2GCA	-	0.27	0.24	0.30	0.22	14.62	5.72
σ^2SCA	-	1.12	0.12	0.78	0.30	49.15	48.42

σ^2RCA	-	0.60	0.76	1.15	0.62	33.13	15.00
σ^2GCA:σ^2SCA	-	0.24	2.11	0.38	0.724	0.30	0.12
Source	**D.F.**	**Grain yield per plant (g)**			**Straw yield per plant (g)**		
		Navsari	**Navsari**	**Mangrol**	**Navsari**	**Mangrol**	**Achhalia**
GCA	5	180.31**	74.00**	256.56**	77.89**	198.01**	123.17**
SCA	15	54.02**	53.72**	54.77**	67.85**	11.64**	68.17**
Reciprocal	15	38.01**	20.31**	42.57**	19.84	20.33**	44.90**
Error	70	4.88	5.30	5.48	13.84	6.19	11.98
σ^2GCA	-	14.62	5.72	20.92	5.34	15.985	9.266
σ^2SCA	-	49.15	48.42	49.29	54.01	5.454	56.197
σ^2RCA	-	33.13	15.00	37.09	0.002	14.14	32.92
σ^2GCA:σ^2SCA	-	0.30	0.12	0.42	0.099	2.931	0.165
Source	**D.F.**	**Harvest index (per cent)**			**Protein content (per cent)**		
		Navsari	**Mangrol**	**Achhalia**	**Navsari**	**Mangrol**	**Achhalia**
GCA	5	50.61**	12.51**	61.66**	5.79**	5.84**	7.23**
SCA	15	16.13**	17.86**	12.28**	4.27**	2.37**	4.26**
Reciprocal	15	12.89**	8.88**	12.94**	1.30**	1.39**	1.33**
Error	70	2.55	2.47	2.62	0.08	0.13	0.06
σ^2GCA	-	4.01	0.84	4.92	0.476	0.476	0.597
σ^2SCA	-	13.58	15.39	9.66	4.190	2.231	4.195
σ^2RCA	-	10.34	6.41	10.32	1.23	1.25	1.27
σ^2GCA:σ^2SCA	-	0.29	0.05	0.51	0.114	0.213	0.142

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

Table 2: Mean sum of squares due to combining ability analysis over environments for different characters in cowpea

Sources	**DF**	**Days to 50 per cent flowering**	**Plant height**	**Pods per plant**	**Pod length (cm)**
GCA	5	20.27**	327.31**	303.02**	14.20**
SCA	15	22.90**	33.74**	33.73**	2.02**
Reciprocal	15	8.65**	33.35**	18.79**	1.26**
Location (L)	2	33.00**	3174.20**	244.14**	16.49**
GCA X L	10	4.29**	38.34**	13.76**	0.95**
SCA X L	30	5.36**	27.54**	6.54**	1.02**
Reciprocal X L	30	2.97**	24.54**	4.47**	0.72**
Error	210	1.43	3.94	1.75	0.13
σ^2GCA	-	0.55	9.01	8.397	0.39
σ^2SCA	-	22.43	30.66	32.986	1.92
σ^2SCA	-	8.18	30.26	18.05	1.16
σ^2GCA:σ^2SCA	-	0.025	0.29	0.255	0.20

Sources	**DF**	**Seeds per pod**	**Test weight (g)**	**Grain yield per plant (g)**	**Straw yield per plant (g)**
GCA	5	8.90**	10.76**	455.30**	336.76**
SCA	15	1.49**	0.86**	119.21**	68.64**
Reciprocal	15	1.93**	1.40**	74.51**	37.37**
Location (L)	2	3.46**	1.86**	114.92**	2316.17**
GCA X L	10	0.61**	0.66**	27.78**	31.16**
SCA X L	30	0.44**	0.27**	21.65**	39.51**
Reciprocal X L	30	0.47**	0.42**	13.19**	23.85**
Error	210	0.12	0.12	5.22	10.67
σ^2GCA	-	0.25	0.298	12.50	9.257
σ^2SCA	-	1.44	0.821	113.99	65.128
σ^2SCA	-	1.88	1.36	69.29	33.86
σ^2GCA:σ^2SCA	-	0.17	0.36	0.11	0.142

Table 2: Contd...…

Sources	**DF**	**Harvest index (per cent)**	**Protein content (per cent)**
GCA	5	106.31**	18.30**
SCA	15	24.71**	10.37**
Reciprocal	15	22.84**	3.67**
Location (L)	2	79.68**	5.20**
GCA X L	10	9.24**	0.28**
SCA X L	30	10.78**	0.26**
Reciprocal X L	30	5.93**	0.17**
Error	210	2.55	0.01
σ^2GCA	-	2.88	0.508
σ^2SCA	-	22.17	10.344
σ^2RCA	-	20.29	3.65
σ^2GCA:σ^2SCA	-	0.13	0.049

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

Table 3: General combining ability effects of parents and Specific combining ability of crosses for grain yield and related characters along with crude protein in cowpea on the pooled basis.

Sr. no.	Parents	Days to 50 per cent flowering	plant height (cm)	pods per plant	pod length (cm)	seeds per pod	test weight (g)	grain yield per plant (g)	straw yield per plant (g)	harvest index (per cent)	protein content (per cent)
1	NCK-15-9	0.42	-5.36**	-3.87**	-1.06**	-0.91**	-0.64**	-6.06**	-5.59**	-2.19**	0.73**
2	NCK-15-10	0.45	1.97**	2.70**	0.16**	0.21**	-0.14**	1.35**	2.76**	0.06	-1.09**
3	NC-15-41	-0.80**	0.90**	0.67**	-0.04	-0.05	0.50**	2.65**	1.38**	1.21**	0.57**
4	NC-15-42	0.85**	3.34**	-1.71**	-0.27**	-0.08	-0.48**	-2.24**	2.28**	-1.85**	0.15**
5	NC-15-44	0.10	0.10	-1.54**	0.52**	0.40**	0.76**	0.84*	0.06	0.60*	-0.63**
6	NC-15-45	-1.03**	-0.96**	3.75**	0.69**	0.44**	-0.01	3.46**	-0.90	2.17**	0.27**
	S.E.Gi	0.18	0.30	0.20	0.06	0.05	0.05	0.35	0.50	0.24	0.02
	Direct Crosses										
7	NCK-15-9 x NCK-15-10	1.35**	1.70*	-0.87	0.23	-0.12	0.25*	0.31	2.03	-0.05	0.45**
8	NCK-15-9 x NC-15-41	1.25**	-2.57**	-1.78**	-0.22	-0.33**	-0.24*	0.97	-2.26*	1.28*	-0.07
9	NCK-15-9 x NC-15-42	-2.48**	-2.40**	0.90	-0.04	-0.08	0.29*	0.90	0.94	0.37	0.98**
10	NCK-15-9 x NC-15-44	-2.94**	1.47*	2.44**	-0.02	0.47**	0.07	4.11**	2.30*	2.07**	-0.89**
11	NCK-15-9 x NC-15-45	-0.74	2.30**	1.63**	-0.29*	-0.19	-0.19	-1.86*	2.59*	-1.31*	0.94**
12	NCK-15-10 x NC-15-41	-1.72**	0.61	2.75**	0.24	0.77**	0.52**	1.37	1.67	0.38	-1.29**
13	NCK-15-10 x NC-15-42	-2.40**	1.59*	0.28	-0.31*	-0.47**	-0.39**	0.90	2.41*	0.05	-0.91**
14	NCK-15-10 x NC-15-44	-0.34	-4.82**	0.26	-1.17**	-0.82**	-0.19	-0.10	-3.46**	0.84	-1.21**
15	NCK-15-10 x NC-15-45	2.11**	1.51*	2.50**	1.12**	1.06**	0.38**	7.86**	2.88*	3.24**	1.79**
16	NC-15-41 x NC-15-42	1.18**	0.13	1.33**	0.03	0.18	0.15	3.62**	1.27	1.76**	0.11*
17	NC-15-41 x NC-15-44	-0.75	0.03	-0.67	0.02	-0.15	-0.31**	0.15	1.00	-0.38	1.25**
18	NC-15-41 x NC-15-45	-0.05	1.86**	0.95	-0.24	-0.21	-0.09	2.49**	3.77**	0.35	1.41**
19	NC-15-42 x NC-15-44	1.11**	2.54**	0.15	0.57**	0.35*	0.39**	0.56	-0.75	0.76	1.52**
20	NC-15-42 x NC-15-45	-0.15	-0.29	1.45**	-0.53**	-0.22	0.50**	2.29**	-1.23	1.66**	-2.35**
21	NC-15-44 x NC-15-45	-1.42**	1.04	0.15	0.90**	0.22	-0.26*	-1.36	1.86	-1.42**	-1.15**
	S.E. Sij	0.41	0.69	0.46	0.13	0.12	0.12	0.79	1.13	0.55	0.05

CONTD.......

Sr. no.	Parents	Days to 50 per cent flowering	plant height (cm)	pods per plant	pod length (cm)	seeds per pod	test weight (g)	grain yield per plant (g)	straw yield per plant (g)	harvest index (per cent)	protein content (per cent)
	Reciprocal Crosses										
22	NCK-15-10 x NCK-15-9	-0.82	2.19**	1.39*	0.41**	0.57**	0.51**	3.23**	2.53	1.40*	-0.37**
23	NC-15-41 x NCK-15-9	-0.02	1.36	0.63	0.26	0.26	0.10	3.94**	1.36	1.81**	-0.10
24	NC-15-41 x NCK-15-10	-1.26*	0.32	0.86	0.21	0.09	0.18	1.97*	-1.46	1.23	1.18**
25	NC-15-42 x NCK-15-9	0.11	0.34	0.41	-0.13	0.48**	0.33*	0.93	1.84	0.15	0.52**
26	NC-15-42 x NCK-15-10	-1.54**	4.88**	-0.79	0.50**	0.56**	-0.52**	-0.69	4.88**	-1.40*	0.70**
27	NC-15-42 x NC-15-41	1.20*	-3.41**	-2.14**	-0.92**	-0.44**	-0.95**	-5.83**	-3.41*	-2.18**	-0.08
28	NC-15-44 x NCK-15-9	-1.49**	0.23	0.11	0.54**	0.38**	0.33*	1.60	0.23	0.90	0.44**
29	NC-15-44 x NCK-15-10	-1.06*	1.75*	2.47**	0.15	0.52**	0.65**	2.03*	2.86*	0.47	-0.15*
30	NC-15-44 x NC-15-41	0.51	-1.81*	4.27**	0.65**	0.65**	0.41**	7.58**	-0.96	4.20**	0.82**
31	NC-15-44 x NC-15-42	-2.02**	-3.04**	2.09**	0.45**	-0.17	0.13	1.23	-4.54**	1.80**	-2.02**
32	NC-15-45 x NCK-15-9	-2.26**	1.81*	1.94**	0.13	-0.10	0.42**	4.91**	-0.41	3.41**	0.73**
33	NC-15-45 x NCK-15-10	-0.87	0.57	0.14	0.22	0.73**	0.001	1.42	2.23	0.11	0.55**
34	NC-15-45 x NC-15-41	-1.02*	-3.24**	1.87**	0.73**	1.30**	-0.92**	3.45**	-1.35	2.18**	-0.25**
35	NC-15-45 x NC-15-42	-0.99*	-3.17**	-0.71	0.43**	0.50**	-0.05	1.91*	-2.34	1.67*	0.46**
36	NC-15-45 x NC-15-44	0.11	1.15	1.45**	-0.16	0.59**	-0.43**	3.70**	1.43	1.59*	0.89**
S.E.Rij		0.49	0.81	0.54	0.15	0.14	0.14	0.93	1.33	0.65	0.06

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

Sr. No.	Crosses	Grain yield per plant (g)	SCA effect	Better parent heterosis (per cent)	Standard heterosis over GC-3	Standard heterosis over GDVC-2	Other characters which registered significant and desirable standard heterosis
1.	NC-15-45 X NCK-15-10	52.15	1.42	46.67**	31.90**	38.12**	PPP,PL,SPP,TSW, GY,HI.PRT
2.	NC-15-45 X NC-15-41	50.11	3.45**	40.92**	26.73**	32.70**	DF, DM,PPP,PL,SPP,GY,HIPRT
3	NCK-15-10 X NC-15-45	49.32	7.86**	38.70**	24.73**	30.61**	PPP,PL, TSW,SP, HI
4	NC-15-44 X NC-15-41	49.28	7.58**	35.53**	24.66**	30.53**	DF, PPP,TSW,HI
5	NC-15-41 X NC-15-42	47.92	3.62**	37.87**	21.22**	26.93**	DF, PPP,PL,SPP,TSW, HI
6	NC-15-41 X NCK-15-10	45.41	1.97*	30.63**	14.85**	20.26**	DF,PPP.TSW,HI
7	NC-15-45 X NC-15-44	44.69	3.70**	22.89**	13.03**	18.36**	DF, PPP,PL,TSW,HI
8	NC-15-45 X NC-15-42	43.48	1.91*	22.28**	9.96*	15.15**	PPP,HI

9	NC-15-41 X NC-15-45	43.21	2.49**	21.52**	9.28	14.43**	DF, PB,PPP,PL,SPP, HI
10	NC-15-44 X NCK-15-10	42.19	2.03*	16.00**	6.70	11.73*	DF,PPP,TSW,GSW,HI

*Significant at 5per cent level and **Significant at 1per cent level
Where,
DF-Days to 50per centfloweing; PH-Plant height; PPP- pods per plant, PL-Pod length; SPP- seeds per pod; TSW-Test weight; GY-Grain yield per plant;SY- Straw yield per plant; HI-Harvest index; PRT-Protein content.

Acknowledgement
The work on cowpea in this paper has been supported financially by DST– INSPIRE, Dept. of Science and Technology, Ministry of Science and Technology, Govt. of India.

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