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Diallel analysis in Cowpea (*Vigna unguiculata* (L.)Walp.)

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Abstract

Seven diverse cowpea parents were selected and crossed in half diallel fashion in order to determine combining ability to identify promising hybrids for eleven traits including yield and its components.Analysis of variance for general and specific combining ability revealed that gca and sca variances were significant for all the characters. Whereas, comparison of σ^2gca/ σ^2sca indicated the non additive gene effects were predominance for all the characters except days to maturity, number of pod per plant and protein content. Among the parents CP-105 was proved to be a good general combiner for six characters *viz.*, days to 50 % flowering, days to maturity, number of branches per plant, number of pods per plant, seed yield per plant and protein content and GC-3 showed best gca effect for number of branches per plant, number of pods per plant, number of seed per pod, seed yield per plant and harvest index. While, JOB-129 was good general combiner for days to 50 % flowering, days to maturity, 100 seed weight and protein content. Among the crosses GC-3 x HC-08-02 was best specific combination for seed yield per plant as well as number of pods per plant, number of branches per plant, 100 seed weight, harvest index and protein content. It is evident from present investigation that the hybrid combinations GC-3 x HC-08-02, GC-06-01 x JOB-129, HC-08-02 x PGCP-1 and GC-3 x CP-105 exhibited the high *per se* performance and sca effect for seed yield per plant and highly promising even in respect of other characters could be advanced by selecting desirable segregants and recombinants in each generation for funneling the new genotype or for using further advanced breeding programme.

Key words: Cowpea, Half diallel, gca,s ca, Yield component.

Introduction:

Cowpea (*Vigna unguiculata* (L.)Walp.) is called as poor man's food or vegetable meat due to high amount of protein in grain with better biological value on dry weight basis. Cowpea grain contains about 24.8 % protein, 1.9 % fat and 63.6 % carbohydrates and is rich source of calcium and iron (Davis *et al*., 2000). In the cultigens cowpea, four sub species have been identified, in which *unguiculata*, the grain types and *sesquipedal* is the yard long bean type were commonly cultivated. The most encountered problem with cultivation of yard long bean or vegetable type is providing space and support for its vigorous viny growth habit (Valarmathi *et al.,* 2007). In view of low input requirement and short maturity, its cultivation is quite economic. As compared with crops particularly the cereals, cowpea offers better chances of crop production under adverse conditions of moisture stress and low fertility. Though India is leading producers of cowpea, however, its grain productivity is dismally low. In cowpea, research work for its improvement is very limited. Therefore, there is a great scope for its improvement and to increase the production by developing high yielding, disease and pest resistant, moisture stress resistant varieties (Ehlers and Hall, 1997) and improvement in nutritional value by increasing especially protein content.Among the different pulses grown, cowpea is grown in 12.5 million hectares with the productivity of 499 kg per ha in India (Anonymous, 2012).

A breeder is confronted at the onset, by a rather complex problem normally the choice of parents for hybridization, because yield is a complex character, comprising a number of components each of which is a polygenically controlled and therefore, very susceptible to environmental fluctuations. The choice becomes still more difficult when the breeder has to select the parents from large germplasm and become often difficult to predict the parents on *per se* performance whether, any two parents would combine well to produce desirable genotypes. What is more important than characteristics of the individual parents is how well they combine with each other.The information concerning breeding behavior of the parents is of fundamental important in plantbreeding programme. For this application of biometric technique like diallel analysis was appeared to be the best useful tool for screening parents with rapid and reasonable degree of confidence which has practical utility in breeding programme aimed at genetic improvement of yield.

Sprague and Tatum (1942) suggested that the breeding value of genotypes, including combining ability helps in the identification of parents with high gca and parental combinations with high sca. Based on combining ability analysis of different characters, higher sca values refers to dominance gene effects and higher gca effects indicate a greater role of additive gene effects controlling these characters. But both the gca and sca values are not significant then epistatic gene effects may play an important role in determining these characters. At present frequently diallel or line x tester analysis is applied (Marciniak *et al.*, 2003; Ahuja and Dhayal 2007). The knowledge on nature and magnitude of gene effects controlling inheritance of characters related to yield and its component traits will be helpful in formulating efficient breeding programme and enhancing the yield of the crops as well as finding out good general and specific combiners for yield and yield component traits. Therefore, the present investigation was planned to investigate the combining ability for yield and yield contributing traits.

Materials and Methods:

There are seven genotypes namely GC-3, CPD-91, JOB-129, HC-08-02, CPD-91, PGCP-1, and GC-06-01 were selected based on the phenotypic diversity of the plants in respect of yield and yield components. Crosses were made between the seven parents following the scheme of 7 x 7 half diallel and 21 hybrids were obtained. All these crosses along with parents were grown together during *Kharif* 2013 in a Randomized Block Design (RBD) with two replications at Agricultural Botany Section, College of Agriculture, Dhule, Maharashtra, India. The row of 4.5 m. length and spacing of 0.45 m was adopted. Border rows were planted at the extreme of each replication. All the recommended cultural practices were carried out to raise a good crop. Five competitive plants were selected randomly for recording the data on yield and its contributing traits viz., days to 50 % flowering, days to maturity, plant height at maturity, number of branches per plant, number of pods per plant, pod length (cm), number of seeds per plant, 100 seed weight (g), seed yield per plant (g), harvest index (%) and protein content (%). The mean data of each plot was used for statistical analysis. The variation among the hybrids was partitioned into genetic components attributed to general combining ability (gca) variances and specific combining ability (sca) variances and effects were analyzed by adopting Model-I, Method-II of Griffing's (1956), assumes the following mathematical model.

$X_{ij} = \mu + gi + gj + sij + 1 / bc\ \Sigma\ \Sigma eijkl$

Where,

i, j = 1,2,……….., n

k = 1, 2,……….., b

l = 1, 2,……….., c

μ = Population mean

g_i = General combining ability (gca) effect of i th parent

g_j= General combining ability (gca) effect of j th parent

S_{ij}= Specific combining ability (sca) effect of (i × j) th cross

e_{ijkl} = Environmental effect associated with the ijklthindividualobservation

n = Number of parents

b = Number of replications

c = Number of individual in each replication

The model assumes that

a = $\Sigma_{gij} = 0$ and $\Sigma S_{ij} = 0$ (for each i)

b = the error (eijkl) is normally and independently distributed with mean equal to zero and variance equals σ^2c.

Results and discussion:

Analysis of variance revealed significant differences among the genotypes, parents and hybrids for all characters except pod length in parents (Table 1). This may obviously be attributed to the existence of sufficient variation among the parents and hybrids. Average performance of hybrids was different from that of the parent for all characters except pod length, as evident from the significant parent's vs crosses source of variation for the characters studied. These results were in consonance with that of Meena *et al.* (2009)for seed yield per plant and other related traits.Analysis for combining ability of variances due to general and specific combining ability was significant for all the characters studied (Table 2 and 3) indicating the presence of adequate amount of variability and there is possibility of selection of desirable plants for trait of interest. A wide range of variation was observed σ^2gca for most of the characters studied (Table 4). Variances due to general combining ability were higher as compared to specific combining ability for all the characters except pod length. The maximum GCA was recorded for plant height at maturity and protein content while minimum for pod length. The ratios of general combining ability variances were high for the characters days to maturity, number of pods per plant and protein content (Table 4). Further, it revealed that both the additive and non-additive gene effects are important in inheritance all characters. The comparison of magnitude of general combining ability and specific combining ability variance indicated that the non- additive genetic effects were predominant in the characters, days to 50 % flowering, plant height, number of branches per plant, pod length, number of seeds per pod, 100 seed weight, seed yield per plant and harvest index which suggested prime role of non-additive gene action. These results are in accordance with Ushakumari *et al*. (2010), Kadam *et al*. (2013)and Chaudhari *et al*. (2013) revealed that magnitude of general combining ability (gca) variances were smaller than the specific combining ability (sca) variances for pods per plant, seeds per pod and 100 seed weight. The additive genetic effects were predominant for control of the characters, days to maturity, number of pods per plant and protein content suggesting influenced by additive gene action, also confirmed by σ^2gca / σ^2scaratio which was more than unity. The present results are in corroboration with the findings ofPatel *et al.* (2013). The predominant role of additive gene action in the inheritance of protein content was also reported byMannivannan and Sekar (2005) and Chaudhari *et al.* (2013).Under the circumstances, where both additive and non-additive gene actions were in operation, the most appropriate and effective breeding approach would be to mop up the additive genes and simultaneously maintaining degree of heterozygosity for exploiting dominance component by adopting biparental mating and *inter se* crossing between suitable lines followed by recurrent selection.Potentiality of parent to be used in hybridization or of cross used for commercial hybrid may be determined by comparing the *per se* performance of the parent, the F_1 value and the combining ability effects. The parents showed significant high general combining ability for eleven characters presented in Table 5. From which it can concluded that none of the parent reported uniformity in high general combining ability for all the characters. The parent CP-105 exhibited highly significant gca for characters,seed yield per plant,days to 50% flowering, days to maturity, number of branches per plant, number of pods per plant, and protein content and GC-3 for seed yield per plant,number of branches per plant, number of pods per plant, number of seeds per plant, and harvest index. JOB-129 for four characters, days to 50% flowering, days to maturity, 100 seed weight and protein content.While, CPD-91for days to 50% flowering, days to maturity and plant height at maturityand GC-06-01 for three characters days to 50% flowering, pod length and protein content.The parents HC-08-02 andPGCP-1 recorded highly significant gca for each two characters viz., Plant height at maturity, number of branches per plant andpod length, 100 seed weight, respectively.Considering the gca performance (Table 5) it could be concluded that the parent showing significant high or average gca effects were also having higher or average mean value for respective characters. For instance parent GC-3 exhibited positive and significant gca effect and have high mean value for seed yield per plant, number of branches per plant, number of pods per plant, number of seeds per pod and harvest index. Similarly, superior parent CP-105 was good general combiner for seed yield per plant have higher *per se* performance for days to 50 % flowering, days to maturity, number of branches per plant, number of pods per plant and protein content.Similar results were also reported by Patil and Bhapkar (1986) and Ayo-vaughan*et al.*(2013). GC-3 was best general combiner for seed yield per plant, seeds per pod and pods per plantconfirmed earlier in the report of Kumar and Sangawan (2005). The present investigation also confirmed that some of the parents having significant positive gca effects for seed yield per plant also showed positive gca effects for one or more of yield contributing traits and can also be concluded that parents, who exhibited high *per se* performance, also displayed good general combining ability effects. Hence, *per se* performance may be used effectively for the selection of parents. Similar results of positive association of *per se* performance and general combining ability and it's usefulness in selection of the parents were also reported by Mannivannan and Sekar (2005).The parents showing high general combining ability with gca effects and the hybrids showing best specific combinations with sca effects for different characters were presented in Table 6.The hybrids, GC-3 x HC-08-02,GC-06-01 x JOB-129 and HC-08-02 x PGCP-1showed the significant positive sca effect for seed yield per plant. The hybrids, GC-3 x JOB-129 and GC-3 x PGCP-1 exhibited highest significant positive sca effect for number of seeds per pod. While hybrids GC-3 x CPD-91 and PGCP-1 x JOB-129revealed significant positive sca effectfor 100 seed weight and hybrids PGCP-1 x CP-105,CPD-91 x CP-105 and PGCP-1 x JOB-129 recorded maximum significant positive sca effect for the character protein content. These results were in accordance with Mannivannan and Sekar (2005),HiraLal*et al.* (2009) and Ayo-Vaughan (2013)for number of pods per plant and 100 seed weight.The best combinationsfor seed yield per plant viz., GC-3 x HC-08-02, GC-06-01 x JOB-129, HC-08-02 x PGCP-1, JOB-129 x CP-105 and GC-3 x CP-105 involved one or both the parents having either good or average or poor general combiner for seed yield, and possessed high gca effects(parent) and also exhibited significant sca effects(crosses) in desirable directions for one or more yield contributing attributes. To cite an example, the hybrids viz., GC-3 x HC-08-02, GC-06-01 x JOB-129 and HC-08-02 x PGCP-1 displayed significant sca effects for six, three and six characters, respectively in desirable direction including seed yield per plant (Table 6).The relationship between gca and sca effects confirmed that significant and desirable sca effects can occur in any group of gca of parents indicating the presence of higher order interactions in the expression of these traits and in addition to this, sca effects occurred because it all depends upon how well genes from two parents interact. The occurrence of high sca effects in good x good group might be due to cumulative effect of high combining loci and no mutual cancelation of gene effects between high general combining loci. On the other hand high sca effects in good x average or average x good, average x poor or poor x average group might be due to complementation of low, good and poor or average combining loci. Therefore, based on outstanding performance of selective parents and crosses in present study, can be concluded that desirable parents could be used as donors to get high yield and the selective crosses were identified as outstanding for seed yield and its components traits due to possessing high sca effect for seed yield may further be utilized in future under breeding programme.

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References:

huja, S. L. and Dhayal, L. S. 2007. Combining ability estimates for yield and fiber quality traits in4 x 13 line x tester crosses of *Gossypium hirsutum*. Euphytica. 153: 87-98.

Anonymous. 2012. FAO, FAOSTAT. http//www.faostat.fao.org.

Ayo-Vaughan, MonininuolaAdefolake, Ariyo, Omolayo Johnson and Alake, ChristopherOlusanya.2013. Combiningabilityand genetic components for pod and seed traits incowpea lines.Italian Journal of Agronomy. 8: 73-78.

Chaudhari, S. B., Naik, M. R., Patil, S. S. and Patel, J. D. 2013. Combinig ability for podYield an seed protein in cowpea (*Vignaunguiculata* (L.) Walp) over environments. Biosciences.6: 395-398.

Davis, D. W., Oelke, E. A., Oplinger, J., Doll J. D., Hansan, C. V. and Putnam, D. H. 2000.Alternative field crops manual. pp. 1-9.

Ehlers, J. D. and Hall, A. E. 1997.Cowpea (*Vigna unguiculata* (L.) Walp.) Field Crop Res. 53:
187-204

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallelCrossing system. *Aust. J. Biol. Sci*., 9: 463-493.

HiraLal, Singh, A. P., Matura, Rai, Bhardwaj, D. R., Rai, N. and VishwaNath. 2009. Combining ability of quantitative characters in cowpea (*Vignaunguiculata* (L.) Walp). Veg. Sci. 36: 265-267.

Kadam, Y. R., Patel, A. I., Patel, J. M.,Chaudhari, P. P. andMore, S. J. 2013. CombiningAbility study in vegetable cowpea (*Vignaunguiculata*(L.) Walp). Crop Res., Hissar. 45:196-201.

Kumar, D. andSangwan V. P. 2005. Combining ability studies for yield and architectural traits in cowpea (*Vignaunguiculata*(L.)Walp).Ann. of Bio. 21: 47-49.

Manivannan, R. and Sekar, K.. 2005.Combining ability for yield and different quality traits invegetable cowpea (*Vignaunguiculata* (L.)Walp.) Indian J. Hort. 62: 196-199.

Marciniak, K., Kaczmarek, Z., Adamski, T. and surma, M. 2003.The anther-cultureresponse of Triticale line x tester proginies. Cell Mol. Biol. Lett. 8: 343-351.

Meena Ramesh, Pithia, M. S, Savaliya, J. J. and Pansuriya, A. G. 2009.Heterosis invegetable cowpea (*Vignaunguiculata* (L) Walp.), Crop Improv. 36: 47-50.

Patel, M. D., Ravindrababu, Y.,Sharma, S. C. and Patel, A. M. 2013.Combining abilitystudies in cowpea (*Vignaunguiculata* (L.)Walp).Environment and Ecology. 31: 1054-1056.

Patil, R. B. and Bhapkar, B. G.. 1986. Combining ability in cowpea. J. Maharashtra Agric.Univ. 11: 303-306.

Sprague, G. P. and Tatum, L. A. 1942. General vs. specific combining ability in single crosses of corn. J. Amer. Soc. Agron. 34: 923-932.

Ushakumari, R., Vairam, N., Anandakumar, R. and Malini, N. 2010.Studies on hybridVigour and combining ability for seed yield and contributing characters in cowpea (*Vignaunguiculata*).Electronic J. of Plant Breeding. 1: 940-947.

Valarmathi, G., Surendran, C. and Muthiah, A. R. 2007. Studies on combining ability foryield and yield traits in inter subspecies of cowpea (*Vignaunguiculata* SSP. *Unguiculata* and*Vignaunguiculata* SSP. *Sesquipedalis*)LegumeRes. 30: 173 - 179.

Table 1: Analysis of variance for diallel analysis for seed yield and its components traits in cowpea.

Source of Variation	d.f.	Mean sum of squares										
		Days to 50% Flowering	**Days to Maturity**	**Plant Height at Maturity**	**No. of Branches /Plant**	**No. of Pods/ Plant**	**Pod Length**	**No. of Seeds/ Pod**	**100 Seed Weight**	**Seed Yield /Plant**	**Harvest Index**	**Protein Contain**
Replications	1	1.446	1.786	12.635	0.483	0.206	1.612	0.339	0.031	5.375	6.365	0.845
Treatments	27	60.632**	121.587**	344.025**	0.991**	21.493**	2.643**	3.914**	2.938**	13.851**	5.771**	118.897**
Parents	6	62.333**	190.643**	581.913**	1.190**	26.025**	1.073	1.617*	4.693**	4.947*	4.298**	230.834**
Crosses	20	59.745**	100.431**	287.018**	0.889**	18.997**	3.149**	4.553**	2.459**	13.124**	4.831**	89.631**
Parent vs Crosses	1	68.149**	130.381**	56.840**	1.844**	44.229**	1.929	4.923**	1.972*	81.831**	33.411**	32.595**
Error	27	2.483	2.008	4.299	0.112	4.067	0.619	0.600	0.424	1.474	1.101	0.591

* Significant at 5 % level. ** Significant at 1 % level.

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Table 2: Estimates of General Combining effects for seed yield and its components traits in cowpea.

Parents	Days to 50% Flowering	Days to Maturity	Plant Height at Maturity	No. of Branches /Plant	No. of Pods/ Plant	Pod Length	No. of Seeds/ Pod	100 Seed Weight	Seed Yield /Plant	Harvest Index	Protein Contain
GC-3	2.579**	3.651**	0.658	0.263**	3.317**	0.070	0.568**	0.177	2.206**	1.601**	-2.638**
CPD-91	-2.032**	-4.849**	1.755**	-0.137	-1.394**	-0.170	-0.287	0.250	-0.063	-0.152	-4.511**
HC-08-02	1.357**	5.762**	13.882**	0.586**	-1.016*	-0.045	0.164	-0.718**	-0.990**	-0.747**	-5.719**
PGCP-1	2.635**	3.429**	-7.806**	-0.359**	-1.371**	0.390*	0.249	0.849**	-0.710*	-0.159	-2.139**
GC-06-01	-1.143**	2.040**	-1.522**	-0.492**	-1.116*	0.472*	0.271	-0.062	-0.800**	-0.279	3.075**
JOB-129	-1.698**	-5.016**	-7.292**	-0.192*	-0.627	-0.407*	-0.855**	0.535**	-0.446	-0.092	5.810**
CP-105	-1.698**	-5.016**	0.324	0.330**	2.206**	-0.311	-0.110	-1.030**	0.801**	-0.173	6.121**

* Significant at 5 % level. ** Significant at 1 % level.

Table 3: Estimates of specific combining ability effects for seed yield and its components traits in cowpea.

Parents	Days to 50% Flowering	Days to Maturity	Plant Height at Maturity	No. of Branches /Plant	No. of Pods/ Plant	Pod Length	No. of Seeds/ Pod	100 Seed Weight	Seed Yield /Plant	Harvest Index	Protein Contain
GC-3 X CPD-91	6.542**	9.056**	3.057*	0.844**	1.208	0.442	0.686	1.569**	1.882*	0.067	2.103**
GC-3 X HC-08-02	5.153**	0.444	-8.049**	0.722**	3.331*	-3.448**	-3.365**	1.047*	4.714**	2.732**	2.136**
GC-3 X PGCP-1	3.375**	-4.722**	-3.082*	-0.533**	-3.514*	0.717	1.820**	-0.061	-1.281	1.449*	-3.289**
GC-3 X GC-06-01	5.153**	-5.333**	2.034	0.100	1.431	0.956	-0.802	-0.724	-1.166	-0.956	0.142
GC-3 X JOB-129	-0.792	-1.778	5.424**	-0.300	0.442	1.819**	2.024**	-0.316	1.825*	0.162	2.637**
GC-3 X CP-105	-1.292	-0.778	2.308	0.078	0.308	0.679	1.044*	0.653	2.198**	1.298	-0.159
CPD-91 X HC-08-02	-5.236**	-6.556**	-14.036**	-0.478*	2.042	-1.213*	0.525	0.494	1.078	1.144	0.589
CPD-91 X PGCP-1	3.486**	-2.722**	5.672**	0.167	1.197	-0.123	-1.125*	-0.098	1.568	1.661*	0.289
CPD-91 X GC-06-01	-5.236**	-5.333**	-12.793**	0.300	-0.658	1.041*	0.183	0.218	0.613	1.816*	-3.600**
CPD-91 X JOB-129	1.319	1.722	7.647**	0.300	0.253	-0.686	-1.221*	-1.183*	-0.806	-1.726*	-3.026**
CPD-91 X CP-105	-6.181**	0.722	4.972**	-0.622**	-1.081	0.654	0.999	0.546	-1.678*	0.070	5.244**
HC-08-02 X PGCP-1	-7.903**	5.667**	11.875**	0.644**	0.819	1.392**	1.354*	-0.030	2.535**	1.191	-2.748**
HC-08-02 X GC-06-01	6.875**	4.056**	11.111**	-0.322	-0.836	0.271	0.432	0.076	-1.600*	-0.504	2.338**
HC-08-02 X JOB-129	-2.569*	-4.889**	5.461**	-0.022	-2.425	0.859	0.623	-0.426	-1.814*	-0.221	2.723**
HC-08-02 X CP-105	6.931**	-5.389**	-1.955	0.056	-0.458	0.644	1.813**	-0.246	-0.181	0.050	-1.673**
PGCP-1 X GC-06-01	0.097	1.889*	5.028**	0.422	-1.381	0.246	-0.753	-0.796	-1.435	-1.507*	2.668**
PGCP-1 X JOB-129	-3.347**	-1.556	-9.132**	-0.078	2.131	0.779	0.503	1.477**	0.261	-0.683	5.053**
PGCP-1 X CP-105	-2.347*	-4.556**	-16.187**	0.200	0.597	-0.786	-0.937	1.082*	0.784	-0.008	7.722**
GC-06-01 X JOB-129	2.431*	-0.667	6.584**	-0.144	1.975	-0.642	1.286*	-0.112	3.321**	0.982	-6.391**
GC-06-01 X CP-105	3.931**	-1.167	-7.852**	-0.067	2.342	-0.808	0.606	-0.722	1.599*	1.042	-2.347**
JOB-129 X CP-105	2.986**	3.389**	14.128**	0.933**	3.053*	-0.544	-2.102**	-0.174	2.240**	1.306	-1.162*

* Significant at 5 % level. ** Significant at 1 % level.

Table 4: Analysis of variance for combining ability for seed yield and its components traits in cowpea.

Source of Variation	d.f.	Mean sum of squares										
		Days to 50% Flowering	Days to Maturity	Plant Height at Maturity	No. of Branches /Plant	No. of Pods/ Plant	Pod Length	No. of Seeds/ Pod	100 Seed Weight	Seed Yield /Plant	Harvest Index	Protein Contain
G.C.A.	6	39.962**	204.414**	469.107**	1.422**	33.550**	1.010*	1.967**	4.021**	11.749**	4.926**	217.905**
S.C.A.	21	27.560**	19.759**	87.128**	0.231**	4.231*	1.410**	1.954**	0.740**	5.548**	2.303**	14.175**
Error	27	1.242	1.004	2.149	0.056	2.034	0.309	0.300	0.212	0.737	0.550	0.295

Components of variance

Source of Variation	Days to 50% Flowering	Days to Maturity	Plant Height at Maturity	No. of Branches /Plant	No. of Pods/ Plant	Pod Length	No. of Seeds/ Pod	100 Seed Weight	Seed Yield /Plant	Harvest Index	Protein Contain
σ^2gca	4.302	22.601	51.884	0.152	3.502	0.078	0.185	0.423	1.224	0.486	24.179
σ^2sca	26.318	18.755	84.979	0.175	2.198	1.101	1.654	0.527	4.811	1.752	13.880
σ^2error	1.242	1.004	2.149	0.056	2.034	0.309	0.300	0.212	0.737	0.550	0.295
σ^2gca / σ^2sca	0.163	1.205	0.611	0.869	1.593	0.071	0.112	0.802	0.254	0.277	1.742

* Significant at 5 % level. ** Significant at 1 % level.

σ^2gca-General combining ability variance, σ^2 sca -Specific combining ability variance, σ^2 error -Environmental variance.

Table 5: Parents showing significantand highgeneral combining ability for seed yield and its components traits in cowpea.

Parent	No. of characters	Per se performance	Name of the characters
GC-3	5	10.00	Seed yield per plant
		4.00	Number of branches per plant
		16.90	Number of pods per plant
		11.59	Number of seeds per plant
		11.02	Harvest index
CPD-91	3	48.00	Days to 50% flowering
		66.00	Days to maturity
		74.26	Plant height at maturity
HC-08-02	2	93.57	Plant height at maturity
		4.80	Number of branches per plant
PGCP-1	2	12.14	Pod length
		10.83	100 seed weight
GC-06-01	3	40.0	Days to 50% flowering
		12.88	Pod length
		40.02	Protein content
JOB-129	4	46.00	Days to 50% flowering
		66.00	Days to maturity
		11.35	100 seed weight
		41.98	Protein content
CP-105	6	8.79	Seed yield per plant
		44.00	Days to 50% flowering
		68.00	Days to maturity
		4.30	Number of branches per plant
		13.90	Number of pods per plant
		38.71	Protein content

Table 6: Best significant general combiners and specificcombinationsfor seed yield and itscomponents traits in cowpea.

Characters	Best general combiner	gca effects	No. of crosses with significant sca effects	Best specific combination with high sca effects	sca effect
Days to 50% flowering	CPD-91	-2.032	7	HC-08-02 x PGCP-1	-7.903
	CP-105	-1.698		CPD-91 x CP-105	-6.181
	JOB-129	-1.698		CPD-91 x HC-08-02	-5.236
	GC-06-01	-1.143		CPD-91 x GC-06-01	-5.236
				PGCP-1 x JOB-129	-3.347
				HC-08-02 x JOB-129	-2.569
				PGCP-1 x CP-105	-2.347
Days to maturity	CP-105	-5.016	8	CPD-91 x HC-08-02	-6.556
	JOB-129	-5.016		HC-08-02 x CP-105	-5.389
	CPD-91	-4.849		GC-3 x GC-06-01	-5.333
				CPD-91 x GC-06-01	-5.333
				HC-08-02 x JOB-129	-4.889
				GC-3 x PGCP-1	-4.722
				PGCP-1 x CP-105	-4.556
				CPD-91 x PGCP-1	-2.722
Plant height at maturity	HC-08-02	13.882	11	JOB-129 x CP-105	14.028
	CPD-91	1.755		HC-08-02 x PGCP-1	11.875
				HC-08-02 x GC-06-01	11.111
				CPD-91 x JOB-129	7.647
				GC-06-01 x JOB-129	6.584
				CPD-91 x PGCP-1	5.672
				HC-08-02 x JOB-129	5.461
				GC- x JOB-129	5.428
				PGCP-1 x GC-06-01	5.028
				CPD-91 x CP-105	4.972
				GC-3 x CPD-91	3.057
No. of branches per plant	HC-08-02	0.586	4	JOB-129 x CP-105	0.933
	CP-105	0.330		GC-3 x CPD-91	0.844
	GC-3	0.263		GC-3 x HC-08-02	0.722
				HC-08-02 x PGCP-1	0.644
No. of pods per plant	GC-3	3.317	2	GC-3 x HC-08-02	3.331
	CP-105	2.206		JOB-129 x CP-105	3.053
Pod length	GC-06-01	0.472	3	GC-3 x JOB-129	1.819
	PGCP-1	0.390		HC-08-02 x PGCP-1	1.392
				CPD-91 x GC-06-01	1.041

No. of seeds per pod	GC-3	0.568	6	GC-3 x JOB-129	2.024
				GC-3 x PGCP-1	1.820
				HC-08-02 x CP-105	1.813
				HC-08-02 x PGCP-1	1.354
				GC-06-01 x JOB-129	1.286
				GC-3 x CP-105	1.044
100 Seed weight	PGCP-1	0.849	4	GC-3 x CPD-91	1.569
	JOB-129	0.535		PGCP-1 x JOB-129	1.477
				PGCP-1 x CP-105	1.082
				GC-3 x HC-08-02	1.047
Seed yield per plant	GC-3	2.206	8	GC-3 x HC-08-02	4.714
	CP-105	0.801		GC-06-01 x JOB-129	3.321
				HC-08-02 x PGCP-1	2.535
				JOB-129 x CP-105	2.240
				GC-3 x CP-105	2.198
				GC-3 x CPD-91	1.882
				GC-3 x JOB-129	1.825
				GC-06-01 x CP-105	1.599
Harvest index	GC-3	1.601	4	GC-3 x HC-08-02	2.732
				CPD-91 x PGCP-1	1.661
				GC-3 x PGCP-1	1.449
				CPD-91 x HC-08-02	1.144
Protein content	CP-105	6.121	9	PGCP-1 x CP-105	7.722
	JOB-129	5.810		CPD-91 x CP-105	5.244
	GC-06-01	3.075		PGCP-1 x JOB-129	5.033
				HC-08-02 x JOB-129	2.723
				PGCP-1 x GC-06-01	2.668
				GC-3 x JOB-129	2.637
				HC-08-02 x GC-06-01	2.338
				GC-3 x HC-08-02	2.136
				GC-3 x CPD-91	2.103