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Research Article

Combining ability analysis for yield contributing characters in chickpea

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Abstract
In the present investigation, six genotypes of chickpea *viz*., PG0127, PG0126, CSG8962, ICCL87322, HC-1 and BG362 were used as parents for 6 × 6 diallel analysisexcluding reciprocals to estimate general and specific combining ability variances and effects. Genetic analysis revealed that both additive and non-additive genetic components of variation are important for inheritance of all the characters. However, the magnitude of non-additive (sca) variance was considerably higher than additive (gca) variance for all the characters except 100 seed weight representing the predominance of non additive gene action. The parents HC-1 and BG362 were found to be good general combiners for grain yield and most of its component characters and were one of the parents in most of the best specific cross combinations. The crosses HC-1 × BG362 and CSG8962 × HC-1 were the best cross combinations for yield and most of its components. In view of parallel role of both additive and non-additive genetic effects determining the inheritance of different characters, their simultaneous exploitation through adoption of biparental approach is suggested.

Keyword:
Chickpea, diallel, gene action, combining ability

Introduction
The chickpea (*Cicer arietinum* L., 2n=2x=16) also known as garbanzo bean, Indian pea, Bengal gram is an edible self fertilizing annual diploid grain legume of the family Fabaceae and sub family Faboideae. It is the third most important pulse crop of the world after dry bean and dry pea. It is cultivated on large areas in the world, yet with relatively low productivity. India ranks first in chickpea production and area with 7.70 million tonnes production from 8.32 million hectare area but with a low productivity of 841 kg/ha (FAO Statistics, 2012). Since the productivity is quite low and to augment the production, concerted efforts are needed to improve the productivity. Before embarking on the breeding programme, it is necessary to choose the parents carefully for hybridization programme. Combining ability analysis enables the breeder in his task of selecting the parents. It also provides the vital and necessary information on the nature of gene action governing the expression of the character in question and thus helps in deciding upon the future breeding strategy. Hence it is necessary to evaluate the combining ability, which is useful to assess the nicking ability of parents, at the same time elucidates the nature and magnitude of different types of gene action involved. This can be of immense help to plant breeders in choosing desirable genotypes for a breeding programme to provide valuable information regarding cross combinations to be exploited commercially (Salimath and Bahl, 1985). Therefore, the present investigation was undertaken to study the nature and magnitude of additive and non-additive components of genetic variance in chickpea through analysis of general and specific combining abilities for seed yield and its components in a 6 x 6 diallel cross set.

Material and Methods
The material for the present study comprised of 15 F_1s (excluding reciprocals) generated by involving 6 diverse parents in a 6 x 6 diallel cross set. The genotypes involved in study include three lines *viz*., PG0127, PG0126 and ICCL87322 and three varieties *viz.*, CSG8962, BG362 and HC-1. All the six parents were sown in the crop season 2011-12 at Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar and crossed in a diallel fashion. The resulting 15 F_1 hybrids and parents were evaluated in a Randomized Block Design (RBD) with three replications in the crop season 2012-13. The observations were recorded from five plants visually showing good health selected randomly from each plot in all the replications on days to 50% flowering, days to maturity, plant height, number of primary branches per plant, pods per plant, seeds per pod, seeds per plant, 100 seed weight and grain yield per plant.

The data were subjected to combining ability analysis (Griffing, 1956). The significance of gca and sca effects were tested by t-tests utilizing the respective standard errors. The parents with positive and significant gca effects were designated as good combiners, whereas those with negative and non-significant gca effects were designated as poor combiners.

Results and discussion

A general analysis of variance was carried out for all the nine characters *viz*., days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, 100 seed weight and grain yield. The differences were significant to highly significant between genotypes for all the characters except for number of seeds per pod for which non significant differences were observed thus, justifying the use of material in present investigation (Table 1). The ANOVA for combining ability of nine characters given in Table 2 indicated that mean sum of squares due to general combining ability were significant for all the characters except for number of seeds per pod. The variances for specific combining ability were significant for all the characters except for number of primary branches per plant and number of seeds per pod.

Thus, the results revealed that non additive genetic variances accomplished an important role in the expression of different characters. Similar were the findings of Dahiya *et al.* (1980) for pods per plant and plant height; Rawat *et al.* (1981) for days to first flowering, plant height, pods per plant, seeds per plant, seed size and yield per plant; Jeena and Arora (2001) for pods per plant, biological yield per plant, plant height, 100 seed weight, seed yield per plant and days to maturity; Gupta *et al*. (2007) for number of branches per plant, pods per plant, biological yield per plant and harvest index; Sarode *et al.* (2000) for all the yield contributing characters studied except 100 seed weight; Singh *et al.* (2008) for seed weight per plant and Bhardwaj *et al.* (2010) for number of branches per plant.

The estimate of general combining ability effects for all the six parents and specific combining ability effects for half diallel crosses for nine characters with their corresponding standard error are presented in Table 3 and 4, respectively. The estimate of gca effects shown that none of the parental line excelled as good general combiner for all the characters, so it was difficult to pick good combiners for all the characters together because the combining ability effects were not consistent for all the yield components, possibly because of negative association among some of the characters (Gowda and Bahl, 1978). This shows that genes for different desirable characters would have to be combined from different sources (Kumari, 1999). However, the gca effects indicated that HC-1 and BG362 were found to be good general combiners for most of the characters. For days to 50% flowering, HC-1 was found to be good negative combiner, while PG0127 was found to be good negative combiner for earliness. For number of primary branches and number of seeds per pod, none of the parents was good combiner. The parents HC-1 and BG362 were good general combiners for number of pods per plant and number of seeds per plant. For 100 seed weight, PG0126 was good general combiner, while HC-1 and BG362 along with PG0126 were good combiners for grain yield per plant. For taller plant type ICCL87322 was good general combiner, while CSG8962 and BG362 were good combiners for dwarf plant type.

Overall results of parents showed that HC-1 showed good general combining ability for early flowering. Additionally, this parent was good combiner for grain yield per plant which was contributed by two component characters *viz*. number of pods per plant and number of seeds per plant. The parent BG362 also showed good general combining ability for grain yield per plant in addition to yield contributing characters like plant height, number of pods per plant and number of seeds per plant. Hence it is suggested that these parents can be used in hybridization programme for developing high yielding hybrids/varieties in chickpea.

The sca effects of hybrids indicated that nine crosses were found to have significant sca effects for grain yield per plant. Five out of nine crosses *viz*., ICCL87322 × BG362 (1.770), PG0127 × BG362 (4.825), PG0126 × CSG8962 (4.022), CSG8962 × HC-1 (6.233) and HC-1 × BG362 (7.009) showed significance in positive direction while remaining four crosses were negatively significant. Two crosses HC-1 × BG362 and CSG8962 × HC-1 were good specific combiners for grain yield per plant in addition to its component characters like number of pods per plant, number of seeds per pod, number of seeds per plant and 100 seed weight. For early maturity, two crosses *viz.*, PG0127 × HC-1 and PG0127 × BG362 were good specific combiners. The cross PG0127 × BG362 was also good combiner for grain yield per plant along with early maturity, number of pods per plant and number of seeds per plant. The above discussion revealed that crosses having high per se performance were good specific combiners for most of the traits. So, per se performance could be considered as an important source for selection of the crosses, with high sca. Preponderance of non additive gene effects for yield and yield components offers a good scope for the exploitation of hybrid vigour and therefore, heterosis breeding may be rewarding for improving chickpea. But the practical exploitation of hybrid vigour is not biologically feasible due to small size and cleistogamous nature of the flowers and strong hybridization barriers. In view of such problems, the possibility of exploitation of transgressive segregants in chickpea has been reported (Singh, 1974). This suggests that a large proportion of non additive effects in self pollinated crops seems to be due to additive x additive effects and that selection be delayed to later generations (Singh *et al*. 1992).

Thus, the sca effect of a cross was reflected through the gca of its parents which demands inclusion of at least one good combining parent in producing superior hybrids. However, a few of the superior crosses involved both of the parents with poor combining abilities *viz.*, PG0127 × BG362 and PG0127 × HC-1 for early maturity, PG0126 × HC-1 and ICCL87322 × HC-1 for dwarf plant type, PG0126 × CSG8962 for number of pods per plant and CSG8962 × HC-1 for 100 seed weight, while some superior crosses involved one of the parent with poor combining ability *viz.*, PG0127 × BG362 and PG0126 × CSG8962 for grain yield per plant, PG0127 × PG0126 and PG0126 × BG362 for 100 seed weight, CSG8962 × HC-1 and ICCL87322 × BG362 for number of seeds per plant and a very few superior crosses had both the parents with better combining abilities *viz.*, CSG8962 × BG362 for dwarf plant type and HC-1 × BG362 for number of pods per plant, number of seeds per plant and grain yield per plant. This suggests that high sca effect of any cross combination does not necessarily depend on the gca effects of the parental lines involved. This superiority of sca effects may be due to complementary type of gene action or involvement of non allelic interaction of fixable and non fixable genetic variance (Sharma and Mani, 2001).

Thus the present investigation revealed the importance of both additive and non additive genetic effects for different characters. Under such a situation where both additive and non additive genetic variances are important factors of inheritance, maximum grain production may be attainable with a system that can exploit both additive and non additive genetic effects simultaneously. Therefore, in such cases, it is advisable to practice biparental mating in F_2 among selected crosses by way of intermating the most desirable segregants alternately with selection to isolate superior genotypes or use of recurrent selection scheme (diallel selective mating system) to enhance the frequency of desirable recombinants with high yield potential (Nagaraj *et al.* 2002). This will help in building the population from which desirable purelines could be developed simultaneously. Linkage is another factor that complicates the problem in selection. If linkages are predominantly of the repulsion type, a generation of intercrossing to increase the opportunity of recombination may become important (Singh *et al.* 1992). It can also be concluded from the data that genetically diverse and high combining parents should be used in formulating cross combinations. Selection by progeny testing as well as recurrent selection can then be used to evolve lines which may transgress both the combining parents.

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Table 1. Analysis of variance of different characters studied for parents and F_1's

Source of variation	d.f.	Mean sum of squares of different characters								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	100 seed weight (g)	Grain yield (g)
Replication	2	40.08184	7.351191	21.82961	0.4285649	4.438058	0.2139700	2.924851	2.782087	2.886789
Treatment	20	28.38437**	17.1875**	77.11667**	0 .738094*	698.7059**	0.069159	836.4927**	5.1223**	40.7748 **
Error	40	2.345908	2.732440	7.370692	0.3952384	55.29294	0.0596344	54.99883	.4721902	2.296562
SE		0.8842903	0.9543655	1.567449	0.3629685	4.293131	0.1409899	4.281699	.3967326	0.8749403
CD(1%)		3.382306	3.650336	5.995309	1.388312	16.42072	0.5392698	16.37699	1.517455	3.346544
CD(5%)		2.527542	2.727836	4.480196	1.037463	12.27094	0.4029875	12.23826	1.133970	2.500817
CV(%)		1.656533	1.195084	6.164560	24.44866	16.96132	19.47431	14.93895	2.876565	12.72716

*, ** significant at 5% and 1% probability level.

Table 2. Analysis of variance for GCA and SCA for different characters

Source of variation	d.f.	Mean sum of squares of different characters								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	100 seed weight (g)	Grain yield (g)
GCA	5	58.211**	32.311**	36.274**	1.750**	590.419**	0.070	709.778**	230.529**	30.938**
SCA	15	18.440**	12.140**	90.732**	0.401	734.801**	0.069	878.731**	23.320**	44.054**
Error	40	2.347	2.733	7.370	0.395	55.293	0.060	54.999	0.472	2.297

*, ** significant at 5% and 1% probability level.

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Table 3. Estimate of general combining ability (*gca*) effects of parents for various characters in Chickpea

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	100 seed weight (g)	Grain yield (g)
PG0127	-0.028	-2.028**	-0.085	-0.250	-2.194	-0.039	-2.129	-0.629**	-0.983**
PG0126	1.972**	-0.194	0.329	-0.083	-5.498**	-0.072	-5.721**	6.024**	1.418**
CSG8962	-1.153**	0.139	-1.381**	-0.250	-2.079	0.086	-2.404	0.142	-0.216
ICCL87322	-1.236**	0.222	2.015**	-0.083	-2.615	-0.001	-3.402*	-2.186**	-1.578**
HC-1	-1.403**	0.306	0.300	0.292	5.963**	0.011	6.894**	-2.358**	0.626*
BG362	1.847**	1.556**	-1.177*	0.375	6.423**	0.015	6.763**	-0.992**	0.735**
SE (gi)	0.285	0.308	0.506	0.117	1.386	0.046	1.382	0.128	0.282

*, ** significant at 5% and 1% probability level.

Table 4. Estimate of specific combining ability (sca) effects of crosses for various characters in chickpea

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	100 seed weight (g)	Grain yield (g)
PG0127 × PG0126	1.595*	-4.095**	2.816*	0.095	-7.415	-0.010	-6.793	4.651**	-0.175
PG0127 × CSG8962	0.720	-0.429	-3.074*	0.262	-1.568	-0.168	0.390	1.099**	0.379
PG0127 × ICCL87322	-0.863	0.488	3.897**	-0.238	8.701*	-0.047	9.088*	-3.673**	0.788
PG0127 × HC-1	-3.363**	-0.262	1.245	-0.613	-0.076	0.040	-1.074	1.050**	-0.043
PG0127 × BG362	-3.946**	2.821**	-4.945**	0.637*	23.664**	0.003	24.957**	-1.467**	4.825**
PG0126 × CSG8962	-1.280	0.405	2.412	-0.238	14.970**	-0.001	14.682**	1.586**	4.022**
PG0126 × ICCL87322	1.137	2.655**	-1.051	-0.071	-1.495	0.020	-2.020	1.975**	0.960
PG0126 × HC-1	-0.363	1.238	-9.086**	-0.113	5.095	-0.060	3.818	-4.020**	-1.577*
PG0126 × BG362	-1.613*	-0.345	0.307	-0.196	-12.065**	-0.130	-13.585**	3.880**	-1.966*
CSG8962 × ICCL87322	1.929*	-2.012*	0.760	0.095	-6.613	-0.139	-7.837*	-1.794**	-2.226**
CSG8962 × HC-1	0.095	0.905	-2.259	0.054	20.426**	0.315*	21.601**	2.328**	6.233**
CSG8962 × BG362	-3.821**	-3.012**	-4.349**	-0.030	3.149	-0.089	1.832	-2.339	-1.559*
ICCL87322 × HC-1	0.179	-2.179*	-9.422**	-0.113	-7.588*	-0.064	-7.985*	1.723**	-1.278
ICCL87322 × BG362	-0.405	-0.095	-5.778**	0.470	10.951**	0.332**	10.430**	0.873	1.770*
HC-1 × BG362	0.095	1.488	3.337*	0.429	23.274**	0.053	29.501**	1.262**	7.009**
SE (Sij)	0.784	0.846	1.389	0.322	3.805	0.125	3.795	0.352	0.776
SE (Sij-Skl)	1.083	1.169	1.920	0.445	5.258	0.173	5.244	0.486	1.072

*, ** significant at 5% and 1% probability level.