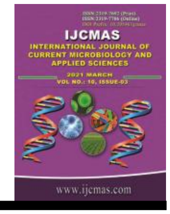
Int.J.Curr.Microbiol.App.Sci (2021) *10*(03): 2135-2145

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 03 (2021)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2021.1003.269

Genetic Architecture through Diallel Analysis in Chickpea for Yield and Related Traits

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A B S T R A C T

Yield in chickpea is influenced by many different components including number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, seed yield per plant and many other traits. All of these traits can potentially be improved through selection as long as there is sufficient genetic variation. To assess the variation for these traits, a diallel mating design was used. In the present investigation two Pantnagar released varieties *viz*. PG 5 and PG 170 and five ICRISAT chickpea collections *viz*. ICC13124, ICC14778, ICC14815, ICC16348 and ICC16349 were crossed in half diallel design and 21 crosses were generated. Observations were collected on eleven yield related traits including yield. Significant variability was observed among all the parents and crosses for all the traits except for the number of primary branches per plant. Variance components of combining ability revealed that both additive and non additive gene actions were important for yield and yield related traits. The parent ICC 13124 was the best general combiner for yield and related traits. It was also one of the parent in best specific combinations for seed yield. The cross *viz.* PG 170 × ICC1 6349, ICC13124 × ICC14815 and ICC 13124 × ICC 16348 were the best specific cross combinations for seed yield per plant and harvest index. This study was also useful to understand the role of additive and non additive genetic effects in determining the inheritance of different characters, for identifying good combiners, evaluating the breeding potential of population and also exploitation through adaptation of biparental approach.

Keywords

Genetic Architecture. Diallel Analysis, Chickpea

Article Info

Accepted:
24 February 2021
Available Online:
10 March 2021

Introduction

Chickpea (*Cicer arietinum* L.) is one of the pulse crop domesticated in the Old World ca 7000 years ago and only domesticated species under the genus *Cicer*, which was originally classified in the tribe *vicieae* of the family Leguminosae and sub family, papilionoideae. It has 2n = 2x = 16 chromosomes with a relatively small genome size of 738.09 Mbp (Varshney *et al.,* 2013). It is an edible self fertilizing annual diploid grain legume, also known as garbanzo bean, Indian pea and bengal gram (Amadabade *et al.,* 2014) that evolved from its wild progenitor *Cicer reticulatum* by selection. Most probably, it has originated in an area of south-eastern Turkey and Syria. Three wild annual *Cicer* species, *C.*

bijugum, *C. echinospermum*, and *C. reticulatum* closely related to chickpea, cohabit with the cultivar in this area. Chickpea is grown all over the world in about 57 countries under varied environmental conditions. South and South-East Asia dominates in chickpea production with 80% of regional contribution (Merga *et al.,* 2019**)**. The crop is widely grown in the Indian subcontinent, the Middle East, eastern Africa, North America and the Mediterranean region (Cho *et al.*, 2002). India is the largest producer of chickpea, accounting for 65% of the total world production (FAO, 2019). On the basis of seed colour and geographical distribution domesticated chickpea has been divided into two major distinct types namely microsperma or 'desi' and macrosperma or 'kabuli' (van der Maesen, 1972; Moreno and Cubero, 1978). The seeds of desi chickpeas are usually small and dark colored with reticulated surface and the aerial plant parts usually anthocyanin pigment bearing pink or purple flowers. In contrast, the kabulis are usually large seeded with beige color seed coat. The plant aerial parts are green that lack anthocyanin pigmentation with white flowers (Upadhyaya *et al.,* 2011). Chickpea seeds contain 20–30% protein, approximately 40% carbohydrates and only 3–6% oil (Gil *et al.*, 1996) and moreover, they are a good source of calcium, magnesium, potassium, phosphorus, iron, zinc and manganese (Ibrikci *et al.*, 2003). It is a cheap source of protein and energy in the developing world, it is also an important food to the affluent populations to alleviate major food-related health problems. (Millan *et al.,* 2006). Furthermore, it plays an important role in maintaining soil fertility by fixing atmospheric nitrogen up to 140 kg/ha through its symbiotic association with rhizobium and meets its 80 % requirement (Saraf *et al.*, 1998) . It also helps in enhancing the soil quality for subsequent cereal crop cultivation by adding organic matter for the maintenance of soil health and ecosystem. (Singh *et al.,* 2014).

Currently, productivity of chickpea is very low and has stagnated in recent years. Reasons for only marginal improvements are a series of biotic and abiotic stresses that reduce yield and yield stability. Especially ascochyta blight and fusarium wilt, pod borer, drought, heat and cold are major constraints to yield improvement and adoption of the crop by farmers (Millan *et al.,* 2006). Since the productivity is quite low and to augment the production, concerted efforts are needed to improve the productivity (Amadabade *et a.l,* 2014). The development of high yielding genotypes depends on the availability of variability for yield and its component traits in the populations. Evaluation of breeding materials for general combining ability and specific combining ability as well as to study the extent of heterosis for yield and yield contributing characters are prerequisites for any breeding programme for development of hybrids. The breeding methods to be adopted for improvement of a crop depend on the nature of gene action involved in the inheritance of economically important traits. Besides its use in selection of potential parents and superior crosses, combining ability also provides information on the nature and magnitude of gene effects involved in the expression of quantitative traits.

There are several techniques for evaluating the varieties or cultivars or lines in terms of their combining ability and genetic architecture. Of these, diallel, partial diallel and line x tester techniques are in common use. The diallel crossing technique, which was developed by Griffing (1956), is the one which helps to predict the merits of parents in the F_1 generation. The half-diallel cross technique with parents is an efficient method to study heterosis and combining ability, when material consists of a few selected lines. Diallel analysis offers much useful information by making all possible combinations in a group of parents. Such analysis is very useful for rapidly obtaining the overall information on the genetic system. Success of any plant breeding programme depends on the choice of appropriate genotypes as parents in the hybridization programme. In this context, the information on the combining ability of parents and the nature of gene action would help in understanding the inheritance of characters, selection of suitable parents for hybridization and identification of promising early generation crosses so as to design an appropriate and efficient breeding strategy for further genetic improvement of genotypes (Reddy *et al.,* 2017*)*. For gaining knowledge on these aspects the present investigation was planned with the objectives to estimate general combining ability effects of parents and specific combining ability effects of crosses for yield and its components and also estimate the nature and magnitude of gene action involved in the inheritance of different traits.

Materials and Methods

The genotypes involved in the present study included five ICRISAT chickpea collections *viz*. ICC13124, ICC14778, ICC14815, ICC16348 and ICC16349 and two varieties released from pantnagar *viz*. PG 5 and PG 170. All the seven parents were sown in the crop season 2017-18 and crossed in a half diallel fashion. At the same time, the parents were selfed to get their pure seeds. The resulting 21 F_1 hybrids and parents were evaluated in a Randomized Block Design (RBD) with two replications in the crop season at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture & Technology Pantnagar, U. S Nagar, Uttarakhand during rabi 2018-2019. All the recommended agronomic practices were followed to raise a normal and healthy crop. The various morphological observations were recorded on five randomly selected competitive plants for traits *viz.* days to 50% flowering, days to maturity, plant height, number of primary branches per plants, number of secondary branches per plants, number of pods per plant, number of seeds per pod, 100-seed weight (g), biological yield (g), seed yield per plant (g) and harvest index (percent) and their mean values were subjected to statistical analysis. The standard procedures developed by Griffing, 1956b were followed to estimate the mean sum of squares (MSS) along with variances of SCA and GCA. Standard statistical tools were used to analyse the combining ability effects.

Results and Discussion

Analysis of variance for randomized block design (RBD) and Combining Ability

The analysis of variance for all the eleven characters studied *viz.* days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight (g), biological yield (g), seed yield per plant (g) and harvest index (percent) was carried out before proceeding for detailed statistical analysis and the results were presented in Table 1. It was cleared from the table that genotypes differ significantly for all characters except the number of primary branches per plant indicating the presence of sufficient genetic variability among experimental material. Genetic variability is prerequisite for any crop improvement programme, as it provides wider scope for selection. Thus, before planning and initiating any breeding programme, the most important step is to confirm the presence of sufficient genetic variability for various traits. Significant differences among the parents and their crosses indicated inherent genetic differences for all the characters studied, which proved suitability of the experimental materials chosen for the present investigation. Analysis of variance for combining ability of eleven characters was given in the Table 2. The results indicated that mean sum of squares due to general combining ability were highly significant for all the traits except for number of primary branches per plant and number of seeds per pod. The variances for specific combining ability were highly significant for all the traits under study except for primary branches per plant. This highlighted the importance of both additive gene action and non additive (dominance and epistasis) gene action for expression of the traits.

Estimation of genetic component and variances

The average performance of a genotype in series of hybrid combinations is termed as general combining ability (GCA), whereas, deviation in performance of a particular cross from the performance expected from the general combining abilities of their parents is known as specific combining ability (SCA). The GCA variance is mainly a function of the additive genetic variance, but if epistasis is present, GCA will also include additive × additive type of non allelic interaction. Thus GCA helps in the selection of suitable parents for hybridization. On the other hand, SCA variance is mainly a function of dominance variance. If epistasis is present, it would also include additive × dominance and dominance × dominance type of non allelic interaction. The SCA helps in the identification of superior cross combinations for commercial exploitation of heterosis. The estimates of general combining ability and specific combining ability variances and their ratios for various characters under study were computed and furnished in Table 3 The results on variance component showed that, characters like plant height, number of primary branches per plant and 100 seed weight, showed higher GCA value than days to 50% flowering, days to maturity, number of secondary branches per plant, number of pods per plant, number of seeds per pod, biological yield, seed yield per plant and harvest index for which SCA variance are higher. The results on variance ratio showed that, ratio was less than one for most of the characters except for the characters plant height and 100 seed weight indicating the predominance of non additive gene action for these nine characters. Whereas, plant height and 100 seed weight were governed by additive gene action. Thus, the results revealed that non additive genetic variance accomplished an important role in expression of most of the characters related to yield. Similar findings for GCA and SCA for different traits were also reported by Hemati *et al.,* (2010) for days to flowering, number of primary and secondary branches, number of pods in plant, number of seeds in pod, seed yield and plant width; Amadabade *et al.,* (2013) for all the characters except 100 seed weight; Nagargoje *et al.,* (2016) for number of pods per plant and seed yield per plant; Gupta (2007) for the number of branches per plant, pods per plant, biological yield per plant and harvest index; Sarode *et al.,* (2017) for number of pods per plant and seed yield per plant; Singh *et al.,* (2008) for seed weight per plant and Bhardwaj *et al.,* (2010) for number of branches per plant.

The estimates of general combining ability effects for all the seven parents and specific combining ability effects for all the twenty one crosses for different traits related to yield is helpful in identification of parents for specific traits. At the same time estimates of specific combining ability effects help in the selection of superior cross combinations in developing commercial hybrids. These estimates of GCA and SCA effects were presented in the Table 4 and Table 5.

Table.1 Analysis of variance for eleven characters studied for seven parents and twenty one F_1's in chickpea

		Mean sum squares of different characters										
Source of variation	**d.f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height**	**Number of primary branches per plant**	**Number of secondary branches per plant**	**Number of pods per plant**	**Number of seeds per pod**	**100 seed weight**	**Biological yield**	**Seed yield per plant**	**Harvest index (%)**
Replication	1	0.09	2.57	8.91	0.18	1.80	0.45	0.80	0.15	0.60	0.46	4.77
Treatment	27	6.45*	9.44**	166.49**	0.43	23.41**	19.60**	0.22**	36.58**	33.91**	13.81**	157.51**
Error	27	2.58	1.42	7.80	0.46	0.89	1.54	0.29	0.58	1.82	0.38	1.62
SE		1.14	0.84	1.97	0.48	0.67	0.88	0.12	0.54	0.96	0.44	0.90
CD (1%)		4.45	3.31	7.74	1.87	2.61	3.44	0.47	2.10	3.74	1.71	3.52
CD (5%)		3.30	2.45	5.73	1.39	1.93	2.54	0.35	1.56	2.77	1.27	2.61
CV (%)		2.41	0.88	5.89	16.75	3.22	2.96	9.51	4.10	5.24	6.29	3.29

Table.2 Analysis of variance of general combining ability (GCA) and specific combining ability (SCA) for eleven characters in chickpea

		Mean sum squares of different characters										
Source of variation	**d.f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height**	**Number of primary branches per plant**	**Number of secondary branches per plant**	**Number of pods per plant**	**Number of seeds per pod**	**100 seed weight**	**Biological yield**	**Seed yield per plant**	**Harvest index (%)**
GCA	6	10.49**	23.57**	679.16**	0.451	29.22**	40.29**	0.056	147.60**	56.85**	29.09**	169.73**
SCA	21	5.28*	5.40**	20.02*	0.42	21.75**	13.68**	0.269**	4.86**	31.15**	13.3**	124.0**
Error	27	2.579	1.423	7.798	0.456	0.886	1.538	0.029	0.576	1.70	0.25	7.62

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

Table.3 Variance components of combining ability for eleven characters in chickpea

Characters	GCA	SCA	GCA/SCA
Days to 50% flowering	0.579	2.71	0.214
Days to maturity	2.019	3.984	0.507
Plant height	73.238	12.222	5.992
Number of primary branches	0.003	-0.037	-0.081
Number of secondary branches	0.803	20.867	0.038
Number of pods per plant	2.956	12.15	0.243
Number of seeds per pod	-0.024	0.24	-0.100
100 seed weight	15.86	4.285	3.701
Biological yield	14.44	92.65	0.15
Seed yield per plant	3.69	17.09	0.22
Harvest index (%)	5.08	116.38	0.044

Table.4 Estimates of general combining ability (GCA) effects of parents for eleven characters of seven parents in chickpea

Parent	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches per plant	Number of secondary branches per plant	Number of pods per plant	Number of seeds per pod	100 seed weight	Biological yield (g)	Seed yield per plant (g)	Harvest index (%)
PG 5	0.58 (A)	1.11**(P)	10.34** (G)	0.02 (A)	-1.11** (P)	-0.80** (P)	-0.05 (A)	-0.86** (P)	-0.01 (A)	-0.81** (P)	-2.90** (P)
PG 170	0.80* (P)	0.83** (P)	4.12** (G)	-0.34* (P)	-1.22** (P)	-1.59** (P)	-0.05 (A)	0.04 (A)	0.35 (A)	1.62** (G)	4.88** (G)
ICC 13124	0.41 (A)	-0.78** (G)	-5.43** (P)	0.16 (A)	1.05** (G)	2.76** (G)	0.12**(G)	6.27**(G)	2.61** (G)	1.96**(G)	3.69** (G)
ICC 14778	-0.20 (A)	0.89** (P)	-5.02** (P)	0.08 (A)	2.27** (G)	1.29** (G)	-0.01 (A)	-2.37** (P)	-1.86**(P)	-0.99** (P)	-1.13 (A)
ICC 14815	-0.31 (A)	-1.11** (G)	-6.48** (P)	0.01 (A)	0.18 (A)	-0.35 (A)	0.01 (A)	-1.47** (P)	-1.99** (P)	-1.17** (P)	-1.49** (P)
ICC 16348	0.19 (A)	0.72** (P)	2.44** (G)	-0.01 (A)	-0.43* (P)	-0.49 (A)	0.00 (A)	-0.69** (P)	-1.00**(P)	-0.47** (P)	-0.38 (A)
ICC 16349	-1.48** (G)	-1.67** (G)	0.03 (A)	0.08 (A)	-0.74**(P)	-0.81**(P)	-0.01 (A)	-0.92** (P)	1.90** (G)	-0.16 (A)	-2.67** (P)

*Significant at 5% probability level. ** Significant at 1% probability level. G- Good general combiner, A- Average general combiner, P- Poor general combiner

Table.5 Mean (*per se*), estimates of SCA and GCA effects of parents for different traits in chickpea

Crosses	Days to 50% flowering			Days to maturity			Plant height			Number of primary branches			Number of secondary branches per plant			Number of pods per plant		
	Mean	SCA	GCA	Mean	SCA	GCA	Mean	SCA	GCA	Mean	SCA	GCA	Mean	SCA	GCA	Mean	SCA	GCA
P 1 × P2	67.50	-0.54	AP	136.50	-0.44	PP	62.67	0.82	GG	3.84	0.12	AP	23.30	-3.62**	PP	44.5	4.96**	PP
P 1 × P3	68.00	0.35	AA	135.00	-0.33	PG	55.75	3.45	GP	4.75	0.54	AA	23.65	-5.54**	PG	42.5	-1.38	PG
P 1 × P4	67.50	0.46	AA	136.50	-0.50	PP	49.50	-3.21	GP	4.75	0.62	AA	34.30	3.89**	PG	42.35	-0.06	PG
P 1 × P5	67.00	0.07	AA	138.50	3.50**	PG	48.50	-2.75	GP	3.50	-0.56	AA	30.00	1.69**	PA	39.05	-1.72*	PA
P 1 × P6	64.50	-2.93**	AA	134.00	-2.83**	PP	59.25	-0.91	GG	3.75	-0.29	AA	24.75	-2.96**	PP	40.35	-0.28	PA
P 1 × P7	66.00	0.24	AG	134.50	0.06	PG	49.50	-8.26**	GA	3.84	-0.30	AA	29.90	2.50**	PP	41.15	0.84	PP
P 2 × P3	67.00	-0.88	PA	139.00	3.94**	PG	44.34	-1.74	GP	3.84	-0.02	PA	29.80	0.72	PG	39.65	-3.44**	PG
P 2 × P4	66.00	-1.26	AA	135.50	-1.22	PP	49.00	2.52	GP	4.25	0.47	PA	31.85	1.55*	PG	38.35	-3.27**	PG
P 2 × P5	70.00	2.85**	AA	135.00	0.28	PG	43.25	-1.78	GP	3.75	0.04	PA	29.90	1.70**	PA	41.30	1.32	PA
P 2 × P6	70.50	2.85**	AA	136.00	-0.56	PP	52.00	-1.94	GG	3.50	-0.19	PA	25.55	-2.05**	PP	41.65	1.81*	PA
P 2 × P7	65.50	-0.49	AG	133.50	-0.67	PG	51.25	-0.28	GA	3.75	-0.03	PA	26.70	-0.59	PP	35.05	-4.48**	PP
P 3 × P4	66.00	-0.88	AA	136.50	1.39	GP	35.75	-1.19	PP	4.50	0.23	AA	34.60	2.03**	GG	44.30	-1.67*	GG
P 3 × P5	68.00	1.24	AA	133.50	0.39	GG	33.50	-1.99	PP	4.75	0.55	AA	31.35	0.88	GA	43.90	-0.43	GA
P 3 × P6	66.50	-0.76	AA	134.00	-0.94	GP	44.25	-0.15	PG	3.75	-0.43	AA	31.45	1.58*	GP	44.65	0.46	GA
P 3 × P7	66.50	0.90	AG	132.00	-0.56	GG	42.75	0.76	PA	3.75	-0.52	AA	26.20	-3.36**	GP	43.80	-0.07	GP
P 4 × P5	67.50	1.35	AA	134.00	-0.78	PG	37.00	1.11	PP	3.50	-0.62	AA	22.50	-9.19**	GA	42.70	-0.15	GA
P 4 × P6	68.00	1.35	AA	138.50	1.89*	PP	44.25	-0.55	PG	3.50	-0.60	AA	30.50	-0.59	GP	39.05	-3.67**	GA
P 4 × P7	65.50	0.51	AG	134.00	-0.22	PG	45.00	2.60	PA	3.50	-0.70	AA	30.75	-0.03	GP	41.80	-0.60	GP
P 5 × P6	64.00	-2.54*	AA	134.00	-0.61	GP	41.95	-1.40	PG	4.25	0.22	AA	27.85	-1.14	AP	39.60	-1.48	AA
P 5 × P7	62.00	-2.88**	AG	132.00	-0.22	GG	38.75	-2.19	PA	4.25	0.13	AA	29.75	1.07	AP	41.85	1.09	AP
P 6 × P7	66.50	1.13	AG	136.00	1.94*	PG	54.25	4.40*	GA	4.75	0.65	AA	32.00	3.93**	PP	39.85	-0.77	AP

Table.5 continue....

Crosses	Number of seeds per pod			100 seed weight			Biological yield per plant			Seed yield per plant			Harvest index		
	Mean	**SCA**	**GCA**	**Mean**	**SCA**	**GCA**	**Mean**	**SCA**	**GCA**	**Mean**	**SCA**	**GCA**	**Mean**	**SCA**	**GCA**
P 1 × P2	1.50	-0.19	AA	17.02	0.66	PA	20.15	-6.69**	AA	7.80	-3.10**	PG	38.71	-1.27	PG
P 1 × P3	1.17	-0.69**	AG	24.15	0.26	PG	26.15	-2.96**	AG	11.80	0.56	PG	45.12	6.20**	PG
P 1 × P4	1.84	0.11	AA	15.10	-0.15	PP	22.8	-1.84*	AP	7.20	-1.09**	PP	31.58	-2.59	PA
P 1 × P5	1.50	-0.24*	AA	16.45	0.30	PP	29.6	5.09**	AP	7.88	-0.23	PP	26.62	-7.06**	PP
P 1 × P6	2.00	0.26*	AA	17.05	0.12	PP	26.85	1.36	AP	8.715	-0.10	PP	32.46	-2.41	PA
P 1 × P7	1.84	0.11	AA	16.45	-0.25	PP	27.8	-0.59	AG	9.76	0.64	PA	35.11	2.54	PP
P 2 × P3	1.84	-0.02	AG	23.70	-1.09*	AG	25.65	-3.82**	AG	8.45	-5.21**	GG	32.94	-13.72**	GG
P 2 × P4	1.50	-0.22*	AA	17.25	1.10*	AP	25.3	0.30	AP	8.85	-1.87**	GP	34.98	-6.87**	GA
P 2 × P5	2.00	0.26*	AA	15.80	-1.25*	AP	24.8	-0.07	AP	10.20	-0.34	GP	41.13	-0.11	GP
P 2 × P6	1.50	-0.24*	AA	17.20	-0.63	AP	25.95	0.09	AP	12.85	1.61**	GP	49.52	7.02**	GA
P 2 × P7	1.50	-0.22*	AA	23.45	5.85**	AP	35.25	6.49**	AG	18.70	7.15**	GA	53.05	12.83**	GP
P 3 × P4	1.33	-0.56**	GA	22.25	-0.13	GP	25.5	-1.76*	GP	14.05	3.00**	GP	55.10	14.58**	GA
P 3 × P5	2.00	0.09	GA	24.60	1.32*	GP	30.05	2.92**	GP	14.10	3.22**	GP	46.92	6.74**	GP
P 3 × P6	2.50	0.60**	GA	24.35	0.29	GP	29.7	1.58	GP	14.00	2.42**	GP	47.14	5.89**	GA
P 3 × P7	1.84	-0.05	GA	23.86	0.01	GP	27.9	-3.12**	GG	11.00	-0.89*	GA	39.43	0.45	GP
P 4 × P5	1.84	0.06	AA	15.10	0.46	PP	28.05	5.39**	PP	8.15	0.22	PP	29.06	-6.39**	AP
P 4 × P6	2.33	0.55**	AA	16.00	0.59	PP	21.7	-1.95*	PP	9.10	0.47	PP	41.94	5.30**	AA
P 4 × P7	2.00	0.24*	AA	15.00	-0.19	PP	24.1	-2.45**	PG	9.42	0.48	PA	39.09	5.01**	AP
P 5 × P6	1.33	-0.47**	AA	16.55	0.24	PP	23.05	-0.47	PP	8.06	-0.39	PP	34.97	-1.10	PA
P 5 × P7	2.00	0.22*	AA	15.60	-0.49	PP	21	-5.42**	PG	7.17	-1.59**	PA	34.14	0.35	PP
P 6 × P7	2.00	0.22*	AA	16.55	-0.32	PP	22.5	-4.90**	PG	8.35	-1.11**	PA	37.11	-1.27	PP

*, ** significant at 5% and 1% probability level, respectively. GCA= General combining ability of the parent, G- Good combiner, A- Average combiner, P- Poor combiner, P1 = PG 5, P2 = PG 170, P3 = ICC13124, P4 = ICC 14788, P5 = ICC14185, P6 = ICC 16348, P7 = ICC 16349

Parents with significant GCA effect towards desirable direction were considered as good general combiners and those towards undesirable direction were considered as poor combiners. Similarly different crosses were also categorized as good specific combiners, average specific combiners and poor specific combiners.

Based on the results, it was clear that none of the parental line excelled as a good general combiner for all the characters under study. For characters like days to 50% flowering and days to maturity, parents have an ability to mature early or starts flowering early were considered as desirable. Hence, parents showing significant GCA and SCA in a negative direction were considered as desirable for early flowering and maturity. Overall results of parents showed that ICC 13124 showed good general combining ability seed yield per plant. Additionally, this was contributed by component characters *viz*., of secondary branches per plant, number of pods per plant, number of seeds per pod and 100-seed weight (g). The parent ICC 16349 showed superiority both in days to maturity and days to 50% flowering hence, considered as good general combiner for earliness, including parents *viz*. ICC 13124 and ICC 14815 for days to maturity. For plant height, parents PG 5, PG 170 and ICC 16348 were found to be good general combiners for tall plant height and can be considered as desirable for mechanical harvesting, while ICC 13124, ICC 14778 and ICC 14815 were good combiners for dwarf plant type. For number of primary branches none of the parent was good combiner. Parent ICC 14788 was found to be a good general combiner for the number of secondary branches per plant and number of pods per plant. PG 170 was found to be a good general combiner for seed yield per plant as well as Harvest index. Hence it is suggested that these parents can be used in hybridization programmes for developing high yielding hybrids/varieties in chickpea.

In the present study crosses showed significant and negative SCA effects for days to 50 % flowering and days to maturity, where as significant and positive SCA effects for plant height, number of primary branches per plants, number of secondary branches per plants, number of pods per plant, number of seeds per pod, 100-seed weight, biological yield, seed yield per plant and harvest index, which indicated that parents involved in the crosses were good specific combiners for desirable characters. The early maturity had been considered as important desirable trait in order to escape harmful effects of terminal drought and heat stress. Hence, for days to 50% flowering crosses, *viz*. PG 5 × ICC 16348, ICC 14815 × ICC 16348 and ICC 14815 × ICC 16349 and for days to maturity cross, PG 5 × ICC 16348 was considered as an desirable because, exhibited significant SCA in desirable direction. For seed yield per plant twelve crosses showed significant SCA effects. Out of twelve, five crosses *viz*. PG 170 × ICC 16349 (7.15) followed by ICC 13124 × ICC 14815 (3.22), ICC13124 × ICC 14778 (3.00), ICC 13124 × ICC 16348 (2.42) and PG 170 × ICC 16348 (1.61) showed significant SCA effect in positive direction and seven crosses showed significant SCA effects in negative direction. Plant height was desired for mechanical harvesting, Hence, cross ICC16348 × ICC 16349 considered as good combiners for plant height as it showed highly significant positive SCA effects. Crosses having more number of secondary branches per plant are considered as desirable as pods are born on these. Eight crosses namely, ICC 16348 × ICC 16349 (3.93), PG5 × ICC 14778 (3.89), PG5 × ICC 16349 (2.50), ICC 13124 × ICC 14778 (2.03), PG 170 × ICC 14815 (1.70), PG 5 × ICC 14815 (1.69), ICC 13124 × ICC 16348 (1.58) and PG 170 × ICC 14778 (1.55) were the most promising as showed significant positive SCA effects. However six crosses showed negative significant SCA effects. For 100 seed weight, crosses PG 170 × ICC 16349, ICC 13124 × ICC 14815 and PG 170 × ICC 14778 showed the highest significant SCA effect in positive direction, so these crosses were identified as good specific combiner. More number of pods per plant has been considered as desirable. Hence, in present investigation two crosses (PG 5 × PG 170 and PG 170 × ICC 16348) showed significant SCA in desirable direction and were considered as best combiners for this trait. Overall results on SCA effects of eleven yield contributing traits showed that, the crosses PG 170 × ICC 16349 and ICC 13124 × ICC 14815 were found to be good specific combiners as they exhibited highly significant SCA effects in desirable direction mainly for yield contributing traits including seed yield per plant. The cross ICC 13124 × ICC 16348 showed superiority for characters like number of secondary branches per plant, number of seeds per pod, seed yield per plant and harvest index. The characters like secondary branches per plant, number of pods per plant and number of seeds per plant were required to achieve final destination *i.e.* yield improvement. For these traits, most of the crosses showed significant SCA in a desirable direction.

In conclusion the present study, most of the crosses with high SCA effects involved the parents with good x poor, average x poor or average x average general combining abilities and few were poor x poor general combiners. The crosses with high *per se* performance possessed high SCA effects. Thus, even the parents with poor or average general combining abilities can lead to high SCA effects in the crosses indicating, thereby the influence of non additive gene action in these crosses. Generally, the significant desirable SCA effects do not contribute much towards the improvement of self pollinated crops like chickpea where commercial exploitation of heterosis is not feasible. Thus, in self pollinated crops, SCA effect is not so much important as it is mostly related with non-additive gene effects, which could not be fixed in a pure line. However, if a cross combination exhibits high SCA effect as well as *per se* performance having at least one parent as a good general combiner for a particular trait, it is expected that such cross combinations would throw some desirable transgressive segregants in later generations subjected to sufficient population growth.

Acknowledgement

The authors are grateful to International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India for providing the chickpea entries of ICC number to GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

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How to cite this article:

Priyanka Halladakeri, Anju Arora, R. K. Panwar and Verma, S. K. 2021. Genetic Architecture through Diallel Analysis in Chickpea for Yield and Related Traits. *Int.J.Curr.Microbiol.App.Sci.* 10(03): 2135-2145.
doi: https://doi.org/10.20546/ijcmas.2021.1003.269