Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP2: 1042-1047

Combining ability analysis for grain yield and its contributing traits in chickpea (*Cicer arietinum* L.)

Mukesh Kumar, Majahir Rana, Vipin Kumar, Arvind Kumar and PK Singh

Mukesh Kumar
Department of Genetics & Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

Majahir Rana
Department of Genetics & Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

Vipin Kumar
Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

Arvind Kumar
Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

PK Singh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

Correspondence
Mukesh Kumar
Department of Genetics & Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.), India

Abstract
The present studies was conducted at Sardar Vallabhbhai Patel University of Agriculture & Technology during the crop season 2014-15.It was concluded from nine diverse lines of chickpea (*Cicer arietinum* L.) with four broad genetic base testers were crossed in line x tester fashion and evaluated for ten quantitative characters. Analysis of variances for combining ability revealed that variances due to lines x testers showed highly significant differences for all the characters indicating wide spectrum of variation among the genotypes. Based on general combining ability performance for yield and majority of yield components, the RSG 963, Vallabh Hara, C 235, GNG 1581, WCG 9550 and ICC 4958 lines and WCG 3 and Pusa 256 testers were identified as most promising ones to be incorporated in hybridization programme as donor parent for improvement of these characters. For most of the major traits including seed yield both additive and non additive gene action were of prime importance. The present finding revealed that KGD-1161×Pusa-256 was promising cross combination for days to 50% flowering. Similarly, GNG-1581×WCG-3 was good cross combination for early maturity. Although up to certain extent dwarf plant height is a desirable trait for which breeder may select the specific combinations. The crosses namely ICC-4958×WCG-3 and C-235×Pusa-1103 showed significant negative SCA effects which might be utilized for selecting dwarf plants. However, on the basis of *per se* performance and SCA effect, the results indicated that ICC-4958×WCG-3, C-235×Pusa-1103 and C-235× Pusa-256 were the good specific crosses combinations to have a genotype of optimum plant height. Moreover, specific combining ability effects were significant for fifteen crosses. Out of which eight crosses exhibited positive estimates. On the basis of per se performance and SCA effects, three crosses ICC-4958×Pusa-1103, HK-4×Pusa-256 and KGD-1161×WCG-3were most desirable for grain yield per plant as well as some other yield components.

Keywords: Chickpea, gene action, combining ability, genotypes.

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. Food legumes, commonly known as pulses, form an integral part of the predominately vegetarian diet in the Indian sub-continent and play a significant role in Indian farming because of their value in providing quality food to teaming million and restoring soil fertility through biological nitrogen fixation. Pulses contain around 20-30 per cent protein, which is nearly 2.0 to 2.5 times higher than that in the cereals. The green seeds of some pulses are used as green vegetables and provide nutritious green fodders for cattle. Besides being a rich source of protein, pulses maintain soil fertility through biological nitrogen fixation by bacteria prevalent in their root nodules. They also help in conserving and improving physical properties of soil by virtue of their deep tap root system, while heavy leaf drop increases the soil organic matter. According to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) chickpea seeds contain on average- 23% protein, 64% total carbohydrates (47% starch, 6% soluble sugar), 5% fat, 6% crude fiber and 3% ash. High minerals content has been reported for phosphorus (340mg/100g), calcium (190mg/100g), magnesium (140mg/100g), iron (7mg/100g), zinc (3mg/100g (Duke, 1981) [8].
Chickpea is the third most important pulse crop, after dry bean and peas, produced in the world. In India, chickpea was grown on 11.27 m ha area with 12.44 m tonnes production and 889 kg-ha productivity during 2014-15 (Anonymous, 2016) [3]. In U.P, chickpea production was 0.37 m tonnes with average yield of 659 kg-ha from an area of 0.56 m hectares (Anonymous, 2016) [3]. Among major chickpea growing states are Madhya Pradesh, Rajasthan, Uttar Pradesh, Maharashtra, Karnataka and Andhra Pradesh together accounting for 80 per cent of the production of country. Six countries including India, Australia, Turkey, Myanmar, Pakistan and Ethiopia account for about 90% of world chickpea production. 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.
The research efforts made have mostly been directed towards individual plant selection in naturally varying races and progeny selection followed by hybridization. However, varieties good in *per se* performance may not necessarily produce desirable progenies when used in hybridization. To form a sound basis for any breeding programme aimed to achieve higher yields. The study of combining ability helps in identifying the useful parental lines and the desirable specific cross combination which could be further exploited in development of improved varieties. 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. Such studies are essential in choosing the appropriate breeding and selection methodologies for further improvement of crop. Combining ability analysis is frequently employed to identify the desirable parents and crosses. Therefore, the present investigation was undertaken to study the nature and magnitude on the combining ability for yield and yield components of nine lines and four testers of chickpea (*Cicer arietinum* L.) cultivars by line x tester analysis. The studies thus clearly envisage augmenting the relatively scarce information available on these characters which may be profitably exploited in future programmes of chickpea improvement.

Materials and Methods

Thematerial for the present studycrosses were made between 9 lines and 4 testers during Rabi, 2014-15 and sufficient F_1 seed was obtained for all the 36 crosses. All the 13 parents and their 36 F_1 were grown during Rabi 2015-16 at Crop Research Centre, Sardar Vallabh- bhai Patel University of Agriculture & Technology, Meerut research farm ($29^0$4', N latitude and$77^0$42' E longitude a height of 237m above mean sea level) U.P., India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8^0C. The highest mean monthly temperature (38.9^0C) is recorded in May, and the lowest mean monthly temperature (4.5^0C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The predominant soil at the experimental site is classified as *Typicustochrept*. The experiment was laid down in a Randomized Block Design (RBD) and replicated thrice. Each 36 F_1s were planted in two meter long 2 row the parents were sown in three row. The rows were spaced 30cm apart and plant to plant was retained 10cm.The observations were recorded from five plants selected randomly for plant height, number of primary branches per plant, number of pod per plant, number of seed per pod, biological yield per plant, grain yield per plant, harvest index and 100-grain weight in both the parental and F_1 generation except days to 50% flowering and days to maturity which were recorded on plot basis. Analysis of variance for all characters were carried out using analysis of variance technique at 5%significance level was used to compare the treatments means Panse and Sukhatme (1969) [15]. The combining ability analysis was worked out as per method suggested by Kampthorne (1957).

Results and Discussion

A line × tester crosses analysis were involving nine lines and four testers. All the thirteen parents along with their thirty six F_1s were grown. Variation due to treatment was partitioned into various components, i.e., parent, cross and parent vs. cross, which showed significant differences for all the traits except harvest index for parent vs. cross only. Variance due to parent was portioned into line, tester and line × tester; line and tester showed significant differences for all the traits whereas variance due to line × tester was significant differences for all traits except days to 50 per cent flowering, plant height, number of seed per pod and 100-grain weight (Table-1).

Table 1: Analysis of variance for L × T analysis for ten characters of chickpea

Source of variation	D. F.	Days of 50% flowering	Days of maturity	Plant height (cm)	No of primary branches/ plant	No of pod/plant	No of seed/pod	Bio. yield / plant	Harvest index	100 grain weight (g)	Grain yield / plant
Blocks	2	3.86	1.76	0.51	0.08	1.00	0.01	2.68	34.74	4.74	2.27
Parent	12	9.60**	46.14**	34.63**	1.89**	137.47**	0.10**	36.99**	137.13**	91.98**	13.97**
Parent vs. Crosses	1	36.89**	603.97**	76.12**	20.67**	1001.31**	1.29**	1583.55**	7.40	815.69**	379.73**
Crosses	35	6.29**	23.24**	17.92**	1.03**	56.99**	0.11**	28.07**	84.78**	140.72**	15.08**
Line	8	11.12**	54.29**	30.15**	2.00**	163.56**	0.06**	11.10**	162.08**	74.43**	13.67**
Tester	3	8.75**	32.44**	58.12**	1.42**	89.01**	0.25**	20.84**	65.29**	169.42**	18.06**
Line × Tester	1	0.02	22.06**	0.00	2.46**	74.15**	0.01	292.51**	153.08**	0.10	4.03**
Error	96	1.27	2.01	0.07	0.05	0.60	0.01	2.43	10.87	1.64	1.81

*, ** Significant at 5% and 1% levels, respectively

Combining ability and component of genetic variance for yield and its traits

A wide range of variation was observed in the estimates of components of genetic variance (σ^2 g) which was partitioned into σ^2gf (due to female) and σ^2gm (due to male) (Table-2). The estimates of component of genetic variance due to line were found to be higher as compared to tester for all the traits (Table-2). Analysis of variances for combining ability revealed that variances due to σ^2sca (specific combining ability) was found to be more than σ^2gca (general combining ability) for all character except plant height, number of primary branches plant^{-1}, number of pod plant^{-1}and 100-grain weight, suggested that the presence of non-additive gene effects i.e. dominance to over-dominance for each of the traits. Similar finding were reported Bicer and Sakar (2008) [7]; Karmi (2011); Kumar *et al.* (2013) [13]; Parameshwarappa *et al.* (2012) [16]; Amadabade *et al.* (2014) [2]; Saxena *et al.* (2014) [17]; Labdi *et al.* (2015) [14].

Table 2: Estimates of components of genetic variance and degree of dominance for ten characters of chickpea

Component	Days of 50% flowering	Days of maturity	Plant height (cm)	No of primary branches/ plant	No of pod/plant	No of seed/ pod	Biological yield / plant	Harvest index	100 grain weight (g)	Grain yield / plant
COV(HS)	0.72	2.72	2.91	0.16	8.67	0.01	1.66	5.01	19.18	0.36
COV(FS)	2.18	8.31	6.83	0.39	18.10	0.04	7.05	23.57	47.17	3.99
COV(HS)/COV(FS)	0.330	0.327	0.425	0.399	0.479	0.295	0.235	0.213	0.406	0.090
σ^2 gca	0.72	2.72	2.91	0.16	8.67	0.01	1.66	5.01	19.18	0.36
σ^2 sca	0.74	2.88	1.02	0.08	0.77	0.02	3.74	13.54	8.82	3.27
σ^2 A	1.44	5.44	5.82	0.31	17.33	0.03	3.31	10.03	38.35	0.72
σ^2 D	0.74	2.88	1.02	0.08	0.77	0.02	3.74	13.54	8.82	3.27
$\sqrt{\frac{\sigma^2 D}{\sigma^2 A}}$	1.942	1.892	5.712	3.949	22.627	1.389	0.884	0.740	4.347	0.220

General combining ability effect

The GCA effects of the parents (Females + males) parented in the (Table- 3) indicating that the estimates of GCA effect showed that it was difficult to choose a good combiner for all the traits, as the combining ability effects were not consistent for the entire yield and its traits simultaneously (Table-3). It might be possible due to low negative association of different traits. The data fairly showed that none of the parent was good general combiner for all the characters. However, Sadbhavana, RSG-963 and Vallabh Hara proved as best general combiner for days to 50% flowering, plant height (dwarf stature) and days to maturity. Vallabh Hara, WCG-3 and KGD-1161 for number of primary branches per plant, WCG-3, RSG-963 and C-235 for number of pod per plant, HK-4, RSG-963and Pusa-256 for 100-grain weight, GNG-1581, WCG-9550 and ICC-4958 for grain yield per plant, respectively.

Based on *per se* performance and GCA effects, an overall observations for traits indicated that the line WCG-9550, GNG-1581 and HK-4 were the good general combiners for harvest index. Similar findings were also reported by Labdi *et al.* (2015) [14], Ali *et al.* (2013) [1], Bhatt *et al.* (2013) [6], Bhardwaj *et al.* (2009) [4], Hegde *et al.* (2007) [10]. The GCA effects together with relative *per se* performance was useful for selecting desirable parent with favourable genes for different components traits of yield and its components. The *per se* performance of the parents and their GCA effects for all the characters were almost in close agreement, which indicated that the *per se* performance of the parent for these traits could possibly be taken as a criterion for selection of parent. Importance of non-additive effects for days to flowering, plant height, number of branches per plant, pods per plant, days to maturity and number of seed per pod have also been reported by Bhardwaj *et al.* (2009) [4], Karmi (2011); Kumar *et al.* (2013) [13]; Parameshwarappa *et al.* (2012) [16]; Labdi *et al.* (2015) [14], Amadabade *et al.* (2014) [2]; Saxena *et al.* (2014) [17]; Labdi *et al.* (2015) [14]. Based on performance for yield and majority of yield components, the RSG 963, Vallabh Hara, C 235, GNG 1581, WCG 9550 and ICC 4958 lines and WCG 3 and Pusa 256 testers were identified as most promising ones to be incorporated in hybridization programme as donor parent for improvement of these characters.

Table 3: Estimates of general combining ability (gca) effects of parent for ten characters of chickpea

S. No.	Parents	Days of 50% flowering	Days of maturity	Plant height in (cm)	No of primary branches per plant	No of pod per plant	No of seed per pod	Biolo. yield / plant	Harvest index	100 grain weight (g)	Grain yield / plant
	lines										
1	ICC-4958	-0.50**	0.88**	0.70**	0.17	1.60**	0.02	1.39**	-1.40	0.42	0.96*
2	GNG-1581	0.83**	1.21**	0.03	-0.68**	-4.70**	-0.02	0.97*	5.06**	0.01	2.35**
3	KGD-1161	0.33*	1.13**	2.03**	0.28**	2.73**	-0.11**	2.81**	-0.31	0.41	0.60
4	C-235	0.58**	0.38	-2.49**	0.07	1.23**	0.08*	3.64**	-3.74**	-3.56**	-0.82*
5	RSG-963	-1.33**	-3.70**	-0.69**	-0.30**	-1.43**	0.10*	0.97*	-3.92**	7.34**	-0.12
6	DCP-92-3	0.25	-0.37	-1.32**	0.00	-3.63**	0.06	-2.03**	-2.00*	-4.12**	-2.07**
7	Vallabh Hara	-0.83**	1.63**	1.90**	0.68**	5.48**	-0.03	-2.44**	-2.59**	-6.67**	-2.35**
8	HK-4	0.42*	0.71	2.06**	-0.28**	-5.13**	-0.02	-2.19**	2.37*	10.08**	0.36
9	WCG-9550	0.25	-1.87**	-2.22**	0.07	3.85**	-0.08*	-3.11**	6.52**	-3.91**	1.10**
	Tester										
1	Sadbhavana	-1.55**	-1.91**	-1.88**	-0.50**	0.18	0.05	-0.54	1.73**	-3.43**	0.28
2	Pusa-256	0.60**	1.83**	0.75**	0.24**	2.64**	-0.16**	-0.80**	-0.20	4.64**	-0.19
3	Pusa-1103	0.45**	-1.20**	2.02**	-0.18**	-3.30**	-0.07*	0.35	-2.94**	2.08**	-0.71**
4	WCG-3	0.49**	1.28**	-0.89**	0.44**	0.47**	0.17**	0.98**	1.40**	-3.29**	0.63*
S.E(g_j) Lines ±		0.31	0.37	0.07	0.06	0.16	0.03	0.45	0.85	0.35	0.38
S.E(g_j) Tester ±		0.19	0.23	0.04	0.04	0.10	0.02	0.27	0.52	0.21	0.23

*, ** Significant at 0.05 and 0.01 levels, respectively

Specific combining ability effects

Specific combining ability was associated with interaction effects, which may be due to dominance and epistemic component of variation that were non-fixable in nature. Hence, it can be utilized in F_1 generation only for development of hybrid varieties. The study revealed that none of the cross combination showed high SCA effects for all the characters (Table-4). Hegde *et al.* (2007) [10] and Bhatnagar *et al.* (2005) [5] also found that none of the cross exhibited significant SCA effect for all the traits. Data depicted in (Table-4) reported that KGD-1161×Pusa-256 was promising cross combination for days to 50% flowering. Similarly, GNG-1581×WCG-3 would likely good cross combination for early maturity. In the present study the dwarf plant height was a most promising trait as it had breeder may select the specific combinations. Table-4 elicited that crosses ICC-4958×WCG-3 and C-235×Pusa-1103 showed significantly negative SCA effects which might be utilized for selecting the dwarf plants. On the basis of *per se* performance and SCA estimates that ICC-4958×WCG-3, C-235×Pusa-1103 and C-235×Pusa-256 would likely enhance the concentration of favourable specific crosses combinations to have a genotype of optimum plant height.

Desirable positive and significant SCA effects were observed in a number of cross combinations for number of primary branches per plant, number of pod per plant, number of seed per pod, days of maturity, biological yield per plant, grain yield per plant, harvest index and100-grain weight. Similar pattern of association between SCA effects for grain yield per plant with other yield attributing traits were reported by Kumar *et al.* (2001), Amadabade *et al.* (2014) [2], Girase and Deshmukh (2000) [9]. Labdi *et al.* (2015) [14], Saxena *et al.* (2014) [17]. Ali *et al.* (2013) [1] suggested that non-additive gene effects were predominant for yield and its components. This superiority was that cross combinations, which expressed high SCA effects for grain yield, may be due to complementary type positive SCA effects for one or more yield related traits also. Thus the present investigation revealed the importance of selecting the best specific combination for yield. Therefore, in such cases, it is advisable to practice due weightage to yield related traits by way of intermitting the most desirable to enhance the frequency of desirable gene with high yield potential, but yield was an end product of multiplicative interaction among various yield components.This will help in building the population from which desirable pure lines 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 inter-crossing to increase the opportunity of recombination may become important.

Table 4: Estimates of specific combining ability (sca) effects of 36 hybrids for ten characters of chickpea

S. No.	Genotypes	Days of 50% flowering	Days of maturity	Plant height in (cm)	No of primary branches per plant	No of pod per plant	No of seed per pod	Biolo. yield / plant	Harvest index	100 grain weight (g)	Grain yield / plant
1	ICC-4958×Sadbhavana	-0.20	-1.51**	0.43**	-0.30**	-0.73*	0.00	-2.46**	0.68	-2.11**	-1.81**
2	GNG-1581×Sadbhavana	1.46**	-1.18*	-0.50**	-0.05	0.83**	0.08	-0.71	0.37	1.53*	0.14
3	KGD-1161×Sadbhavana	0.63	-1.09	-0.17	0.58**	-0.20	-0.18*	1.79*	0.32	-0.74	1.22
4	C-235×Sadbhavana	-0.62	0.32	-0.52**	0.20	0.03	0.06	1.29	-3.81**	-1.10	-1.03
5	DCP-92-3×Sadbhavana	0.71	-0.26	0.98**	-0.33**	0.30	-0.08	1.62*	0.66	1.67**	1.22
6	RSG-963×Sadbhavana	-0.37	1.41**	0.55**	-0.03	0.77*	0.01	-0.38	-3.41**	-2.27**	-1.10
7	VallabhHara×Sadbhavana	-0.54	-0.93	0.03	0.18	0.12	0.17*	1.70*	-2.12	1.51*	-0.16
8	HK-4×Sadbhavana	-0.12	2.32**	-1.00**	-0.25*	-0.13	-0.01	-0.21	0.57	2.27**	-0.20
9	WCG-9550×Sadbhavana	-0.95	0.91	0.21	0.00	-0.98**	-0.05	-2.63**	6.72**	-0.75	1.72*
10	VallabhHara×Pusa -256	-0.69	1.67**	0.20	0.04	1.06**	-0.17*	-2.37**	7.83**	-3.93**	2.84**
11	GNG-1581×Pusa -256	-0.35	0.08	0.60**	-0.39**	0.11	-0.27**	0.55	-0.89	-4.81**	-0.39
12	KGD-1161×Pusa -256	-2.19**	-0.50	0.07	-0.29*	0.01	0.07	0.38	-1.11	2.86**	-0.64
13	C-235×Pusa -256	0.57	0.92	-1.22**	-0.14	-0.23	0.16*	1.88**	-3.40**	-2.11**	-1.23
14	RSG-963×Pusa -256	-0.52	-1.33**	-0.42*	0.23*	0.11	0.07	1.21	-2.46	4.46**	0.25
15	DCP-92-3×Pusa -256	-0.10	-0.33	0.02	0.33**	0.04	0.14*	-1.12	0.72	-0.61	-0.31
16	HK-4×Pusa -256	0.73	1.25*	0.03	0.01	-0.66*	-0.15*	-2.29**	4.95**	3.99**	2.96**
17	WCG-9550×Pusa -256	0.90	-0.83	0.32*	0.06	-1.04**	0.12*	1.96**	-5.79**	-0.16	-1.81**
18	ICC-4958× Pusa-256	1.65**	-0.92	0.40**	0.16	0.61*	0.04	-0.20	0.15	0.32	-1.67**
19	GNG-1581×Pusa -1103	-1.54**	3.45**	0.79**	0.63**	0.12	0.17*	3.73**	1.41	-2.31**	1.80**
20	KGD-1161×Pusa -1103	-0.04	-0.13	0.33	-0.14	-0.05	-0.06	-1.44	-4.91**	-1.31*	-3.45**
21	C-235×Pusa -1103	-0.62	0.62	-1.36**	-0.12	-0.89**	-0.08	-1.94**	3.29**	2.25**	0.30
22	RSG-963×Pusa -1103	0.63	-0.63	0.04	0.25*	0.45	-0.09	-0.27	4.21**	1.55*	1.84**
23	VallabhHara×Pusa -1103	0.13	1.37**	0.13	-0.07	-0.74*	-0.11*	-0.52	0.59	2.50**	-0.50
24	HK-4×Pusa -1103	0.55	-1.38**	1.36**	-0.17	0.82**	-0.01	2.57**	-5.37**	-6.05**	-2.54**
25	WCG-9550×Pusa -1103	0.38	-0.80	-1.16**	-0.12	2.23**	-0.08	-0.19	1.74	0.74	0.38
26	DCP-92-3×Pusa -1103	0.38	-0.96	-0.66**	-0.25*	-1.35**	0.12*	-0.27	-0.46	0.15	-0.79
27	ICC-4958×Pusa -1103	0.13	-1.55**	0.53**	-0.02	-0.59*	0.14*	-1.69*	-0.50	2.48**	2.97**
28	ICC-4958× WCG-3	-1.57**	3.97**	-1.36**	0.16	0.71*	-0.18*	4.35**	-0.34	-0.68	0.51
29	GNG-1581×WCG-3	0.43	-2.36**	-0.89**	-0.19	-1.06**	0.02	-3.57**	-0.89	5.59**	-1.54*
30	KGD-1161×WCG-3	1.59**	1.72**	-0.22	-0.16	0.24	0.16*	-0.73	5.70**	-0.81	2.88**
31	C-235×WCG-3	0.68	-1.86**	3.09**	0.06	1.08**	-0.13*	-1.23	3.92**	0.96	1.96**
32	RSG-963×WCG-3	0.26	0.56	-0.17	-0.44**	-1.32**	0.02	-0.57	1.66*	-3.74**	-0.99
33	DCP-92-3×WCG-3	-0.99	1.56**	-0.34	0.26*	1.01**	-0.18*	-0.23	-0.93	-1.21	-0.13
34	Vallabh Hara×WCG-3	1.09	-2.11**	-0.36*	-0.16	-0.44	0.11*	1.19	-6.30**	-0.07	-2.17**
35	HK-4×WCG-3	-1.16*	-2.19**	-0.39*	0.41**	-0.02	0.17*	-0.07	-0.15	-0.21	-0.22
36	WCG-9550 ×CG-3	-0.32	0.72	0.63**	0.06	-0.21	0.01	0.85	-2.67**	0.17	-0.29
S.E.(S_{ij}) ±		0.531	0.64	0.118	0.102	0.281	0.048	0.772	1.474	0.603	

*, ** Significant at 0.05 and 0.01 levels, respectively

Table 5: Best three parents, F_1s, best general combiners and best specific combiner for yield and its components of chickpea in Line×Tester analysis

Components	Best parents (*per se* performance)	Best general combiners (gca)	Best F_1s with respect to *per se* performance	Best F_1s with respect to sca effects
Days of 50% flowering	RSG-963 Sadbhavana Vallabh Hara	Sadbhavana RSG-963 Vallabh Hara	RSG-963×Sadbhavana VallabhHara×Sadbhavana ICC-4958×Sadbhavana	KGD-1161×Pusa-256 ICC-4958×WCG-3 GNG-1581×Pusa-1103
Days of maturity	RSG-963 Sadbhavana Pusa-1103	Sadbhavana RSG-963 WCG-9550	RSG-963×Pusa-1103 RSG-963×Sadbhavana WCG-9550×Pusa-1103	GNG-1581×WCG-3 HK-4×WCG-3 Vallabh Hara×WCG-3
Plant height (cm)	C-235 WCG-3 Sadbhavana	C-235 WCG-9550 Sadbhavana	C-235×Sadbhavana WCG-9550×Sadbhavana C-235×Pusa-256	ICC-4958×WCG-3 C-235×Pusa-1103 C-235×Pusa-256
No of primary branches/plant	Vallabh Hara WCG-3 Pusa-259	Vallabh Hara WCG-3 KGD-1161	Vallabh Hara×Pusa-256 Vallabh×Hara WCG-3 ICC-4958×WCG-3	GNG-1581×Pusa-1103 HK-4×WCG-3 KGD-1161×Sadbhavana
No of pod/plant	Vallabh Hara Pusa-256 KGD-1161	Vallabh Hara WCG-9550 KGD-1161	Vallabh Hara×Pusa-256 VallabhHara×Sadbhavana Vallabh Hara×WCG-3	WCG-9550×Pusa-1103 C-235×WCG-3 VallabhHara×Pusa-256
No of seed/pod	WCG-3 Sadbhavana Vallabh Hara	WCG-3 RSG-963 C-235	HK-4×WCG-3 RSG-963×WCG-3 Vallabh Hara×WCG-3	VallabhHara×SadbhavanaGNG-1581×Pusa-1103 KGD-1161×WCG-3
Biolo. yield/plant	WCG-3 Sadbhavana Pusa-1103	C-235 KGD-1161 ICC-4958	ICC-4958×WCG-3 GNG-1581×Pusa-1103 ICC-4958×Pusa-1103	ICC-4958×WCG-3 GNG-1581×Pusa-1103 HK-4×Pusa-1103
Harvest index	RSG-963 GNG-1581 WCG-9550	WCG-9550 GNG-1581 HK-4	WCG-9550×Sadbhavana GNG-1581×Sadbhavana HK-4×Pusa-256	Vallabh Hara×Pusa-256 WCG-9550×Sadbhavana HGD-1161×WCG-3
100 grain weight (g)	Pusa-256 HK-4 RSG-963	HK-4 RSG-963 Pusa-256	HK-4×Pusa-256 RSG-963×Pusa-256 RSG-963×Pusa-1103	GNG-1581×WCG-3 RSG-963×Pusa-256 HK-4×Pusa-256
Grain yield / plant	RSG-963 WCG-3 GNG-1581	GNG-1581 WCG-9550 ICC-4958	KGD-1161×WCG-3 GNG-1581×Pusa-1103 ICC-4958×Pusa-1103	ICC-4958×Pusa-1103 HK-4×Pusa-256 KGD-1161×WCG-3

Conclusion

On the basis of *per se* performance, Sadbhavana, Vallabh hara and RSG-963 were one of the best parents for all the traits, whereas Sadbhavana was one of the best general combiner (Tester) for days to 50% flowering, days to maturity and plant height, respectively. Among the lines WSG-963, Vallabh Hara, GNG 1581, WCG 9550, ICC 4958 and HK 4 were good general combiner for grain yield per plant and its components. These lines may be exploited for development of desirable hybrids. The cross combination HK-4 x Pusa-256 was the best F_1s for harvest index, 100-grain weight and grain yield per plant, whereas GNG-1581 x Pusa-1103 was the best cross combination for number of primary branches per plant and biological yield per plant. These crosses may be use further for chickpea improvement programme.

References

1. Ali Q, Iqbal M, Ahmad A, Tahir NHM, Ahsan M, Javed N *et al*. Screening of chickpea (*Cicer arietinum* L.) germpalsm against *ascochyta* blight [*Ascochyta rabiei* (Pass.) Lab.] Correlation and combining ability analysis for various quantitative traits, Journal of Plant Breeding and Crop Science. 2013; 5(6):103-110.
2. Amadabade J, Arora A, Sahu H. Combining ability analysis for yield contributing characters in chickpea (*Cicer arietinum* L.) Electronic Journal of Plant Breeding. 2014; 5(4):664-670
3. Anonymous. Area, production and productivity. Government of India, ministry of agriculture & farmers welfare, department of agriculture, cooperation & farmers welfare, directorate of economics & statistics, Pocket book of agriculture statistics, New Delhi, 2016.
4. Bhardwaj R, Sandhu JS, Gupta SK. Nature of Gene Action of Some Quantitative Traits in Chickpea (*Cicer arietinum* L.), Indian Journal of Agricultural Sciences. 2009; 79(11):897-900.
5. Bhatnagar, Santosh, Singh PK. Combining ability for seed yield and yield contributing traits in chickpea over generations. Farm Science Journal. 2005; 14(1):57-60.
6. Bhatt H, Arora A, Panwar RK. Genetic studies for yield and yield contributing characters in chickpea (*Cicer arietinum* L.) genotypes. Pantnagar Journal of Research. 2013; 11(2):214-218.
7. Bicer BT, Sakar D. Heritability and gene effects for yield and yield components in chickpea. *Hereditas.* 2008; 145:220-224.
8. Duke JA. Handbook of legumes of world economic importance. Plenum, New York, 1981, 52-57.
9. Girase VS, Deshmukh RB. Gene action for yield and its components in Chickpea (*Cicer arietinum*) Indian journal of Genetics & plant breeding. 2000; 60(2):185-189.
10. Hegde SV, Yadav SS, Kumar J. Heterosis and combining ability for biomass and harvest index in chickpea under a drought-prone, short-duration environment. Euphytica, 2007; 157:223-230.
11. Karami E. Genetic analysis of some agronomic characters in chickpea (*Cicer aretinum* L.) African Journal of Agricultural Research. 2011; 6(6):1349-1358.
12. Kempthorne O. An introduction to Genetic Statistics. John Wiley and Sons Inc. New York, 1957.
13. Kumar BL, Singh D, Bhanushally TB, Koli NR. Gene Effects for Yield and Yield Components in Chickpea

(*Cicer arietinum* L.) under Irrigated and Rainfed Conditions. Journal of Agricultural Science. 2013; 5(3):1-12.
14. Labdi Mohamed, Samia Ghomari, Samia Hamdi. Combining Ability and Gene Action Estimates of Eight Parent Diallel Crosses of Chickpea for Ascochyta Blight. Advances in Agriculture, 2015, 1-7.
15. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi. 1969, 282-301.
16. Parameshwarappa SG, Salimath PM, Upadhyaya HD, Kajjidoni ST, Patil SS. Validation of Biometrical Principles for Genetic Enhancement of Chickpea (*Cicer arietinum* L.) Indian J. Plant Genet. Resour. 2012; 26(3):207-214.
17. Saxena K, Ravindrababu Y, Ram K. Nature of Gene Action for Grain Yield and Yield Component Traits in Chickpea (*Cicer arietinum* L.), Trends in Biosciences. 2014; 7(24):4068-4071.