International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 407-413

Received: 25-07-2019
Accepted: 27-08-2019

Dalbeer
Department of Genetics and Plant Breeding, NDUA&T, Kumarganj, Faizabad, Uttar Pradesh, India

Shiva Nath
Department of Genetics and Plant Breeding, NDUA&T, Kumarganj, Faizabad, Uttar Pradesh, India

Kavita
Department of Plant Pathology, NDUA&T, Kumarganj, Faizabad, Uttar Pradesh, India

Correspondence
Dalbeer
Department of Genetics and Plant Breeding, NDUA&T, Kumarganj, Faizabad, Uttar Pradesh, India

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

Dalbeer, Shiva Nath and Kavita

Abstract
The experimental materials comprised of ten diverse lines of chickpea with six broad genetic base testers were crossed in line x tester fashion and evaluated for 11 quantitative characters in timely (E_1) and late sown (E_2) environments. Analysis of variances for combining ability revealed that variances due to lines x testers showed highly significant differences for all the characters except for days to 50% flowering in both the environments, whereas variance due to lines was also highly significant for most of the characters studied for days to 50 per cent flowering. Variances due to testers were found non significant for all the characters in both the environments**.** The parental lines ICCV 10 and Phule G 5 and and among testers KAK 2 with high GCA effects were identified as superior donors for seed yield per plant in both the environments. The crosses BG 362 X ICCV 07112, Phule G 5 X IPC 97-72, BG 1003 X KAK 2, ICCV 10 X ICCV 97 in timely sown and BG 362 X ICCV 07112, ICC 14364 X KAK 2, PANT G 186 X KAK 2, ICCV 10 X ICCV 97 in late sown environment showed significant & positive SCA effects for seed yield per plant as well as some other yield components.

Keywords: Chickpea, GCA, SCA, ANOVA and variance

Introduction
Chickpea (*Cicer arietinum* L.) is an important grain legume in India and plays a dominant role in the agriculture of rainfed areas of the country. It is the world's third most impotent food legume after soybean and pea. Out of total production of pulses, chickpea accounts for 37% and area wise 28.28%. India contributes the major share to the global chickpea area (65%) and production (68%). In India, total pulses were grown on an area of 23.55 m ha. with production of 17.15 million tones and productivity 728 kg/ha in year 2014-15 and total production of chickpea was 7.33 million tonnes from of 8.25 million ha area with average yield of 889 kg/ha in year 2014-15. In area, production and productivity Uttar Pradesh possessed 367.70 thousand ha., 558.00 thousand tonnes, 659 kg ha^{-1} respectively in year 2014-15, Anonymous [1]. Chickpea is the cheapest and most readily available source of protein (19.5%), fat (1.4%), carbohydrates (57-60%), ash (4.8%) and moisture (4.9-15.59%). The average production of chickpea is low in the country; this may be attributed to the lack of high yielding varieties, resistant to diseases and pests, high response to high inputs and other management practices. Keeping in view these problems, 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. 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, it is urgently required to identify the best combiners and desirable crosses. Line x Tester analysis is an extension of top cross method in which several testers are used Kempthorne,[2] which provides information about general and specific combining ability of parents and at the same time it is helpful in identifying best heterotic crosses.

Materials and Methods
The experiment was laid out with 10 lines and 6 testers in timely (E_1) and late sown (E_2) environments, at Student's Instructional Farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad (U.P.). The crosses were made during *Rabi* 2014-15 in line x tester fashion and were evaluated in Randomized Block Design with three replications along with parental lines in *Rabi* 2015-16. Each line was grown in one row of 4 meter length. Row to row and plant-to-plant spacing was 30cm and 10cm, respectively.

Data were recorded on five randomly selected plants for primary branches per plant, secondary branches per plant, plant height (cm), pods per plant, seeds per pod, biological yield per plant (g), seed yield per plant (g), harvest index (%) and 100-seed weight (g) except days to 50% flowering and days to maturity which were recorded on plot basis.
Data in each experiment of all entries was subjected to analysis of variance Panse and Sukhatme, [3] for testing the significance of treatments. Combining ability analysis and the testing of significance of different genotypes was based on the procedure given by Kampthorne [2].

Results and Discussion
Analysis of variances for combining ability in E_1 and E_2 is presented in (Table-1). Analysis of variances for combining ability revealed that variances due to lines x testers showed highly significant differences for all the characters except for days to 50% flowering in both the environment, primary branches per plant in E1 and number of secondary branches per plant in E2. Variance due to lines was also highly significant for all the characters except for days to 50 per cent flowering, number of secondary branches per plant in late sown environment and number of pods per plant in timely sown environment only. Variances due to testers were found non significant for all the characters in both the environments. Similar finding were reported by Yamini *et al.* [4], Biranvand *et al.* [5].
General combining ability: The GCA effects of the parents (Females + males) parented in the (Table-2) indicating GCA effects for almost all the characters. Among the lines, ICCV 10 (7.51), Phule G 5 (7.15), BG 1003 (6.61), BG 362 (3.93) in E1 and ICCV 10 (5.75), Phule G 5 (4.86), BG 362 (4.39) and BG 1003 (3.90) in E2 displayed high positive and significant gca effects. Whereas, among the testers, ICCV 07112 (0.91) in E2 showed significant and positive *gca* effects. On the basis of GCA effects and mean performance among lines, parent ICCV 10 and Phule G 5 were found good combiner for Seed yield per plant, biological yield per plant, days to 50% flowering, primary and secondary branches per plant and seeds per pod in both the environments and parent BG 103 for pods per plant, seeds per pod and harvest index in both environments. Among testers ICCV 07112 was found good general combiner for seed yield per plant, pods per plant and biological yield per plant in both the environments**.** Similar finding were reported by Chauhan *et al* [6], Sarode *et al.* [7].

Specific combining ability: The estimates of SCA effects of 60 crosses in E_1 and E_2 for 11 characters are given in (Table-3). Out of 60 crosses studied, the most promising crosses were *viz.*, BG 362 X ICCV 07112 (15.35), Phule G 5 X IPC 97-72 (12.35), BG 1003 X KAK 2 (12.30), ICCV 10 X ICCV 97 (11.23) and ICC 14364 X KAK 2 (8.49) in timely and BG 362 X ICCV 07112 (17.40), ICC 14364 X KAK 2 (9.94), PANT G 186 X KAK 2 (9.27), ICCV 10 X ICCV 97 (7.98) and Phule G 5 X IPC 97-72 (7.46) in late sown environment showed significant & positive SCA effects for seed yield per plant as well as some other yield components. According to Yamini *et al.* [4] cross-combinations with high means favourable SCA estimates and involving at least one of the parents with high GCA would likely enhance the concentration of favorable alleles to improve target traits. Similar finding were reported by Bhardwaj *et al.* [8], Ezzat and Talebi *et al.* [9], Kumhar *et al.* [10].
In the present study the cross BG 362 X ICCV 07112 was the most promising as it had high significant SCA effects for seed yield per plant and biological yield per plant; BG 362 X ICCV 07112 seed yield per plant, biological yield per plant and PLANT height; ICC 14364 X KAK 2 for number of seeds per plant and harvest index; ICCV 07104 X PDG 84-16 for 100 seed weight; ICCV 10 X ICCV 97 for number of pods per plant; L 550 x ICCV 05107 for secondary branches per plant in both timely and sown environments. Similar finding were reported by Hemati *et al.* [11], Chauhan *et al.* [6], Sarode *et al.* [7], Gadekar *et al.* [12].

Conclusion
The extent GCA was higher than SCA for all the characters in both the environments indicates towards existence of genetic variability in the parental lines included in the present study and involvement of both additive and non-additive gene effects in the inheritance of these traits. The study on the general combining ability effects of parents showed their ability to transmit additive genes in the desirable direction for all the traits under study. Among the 10 lines ICCV 10, Phule G 5, BG 1003 and JG 14 were the best general combiners exhibited high GCA effects each in desirable direction for most of the characters in both environments. Among the testers (male parents), ICCV 07112, ICCV 05107 and KAK 2 were the best combiner for most of the major characters in both the environments. Out of 60 crosses studied, the most promising crosses were *viz***.,** BG 362 X ICCV 07112 (15.35), Phule G 5 X IPC 97-72 (12.35), BG 1003 X KAK 2 (12.30), ICCV 10 X ICCV 97 (11.23) and ICC 14364 X KAK 2 (8.49) in timely sown and BG 362 X ICCV 07112 (17.40), ICC 14364 X KAK 2 (9.94), PANT G 186 X KAK 2 (9.27), ICCV 10 X ICCV 97 (7.98) and Phule G 5 X IPC 97-72 (7.46) in late sown environment showed significant & positive SCA effects for seed yield per plant as well as some other yield components. In most of the cases significantly higher SCA effects were associated with high heterosis for different characters. This study provided combining ability information on tested inbred lines. The promising lines have to be maintained and used in hybridization program. The promising single crosses could be tested across locations and seasons to fix the desirable characters through advanced selection generations.

Abbreviations
E_1, Timely Sown Environment; E_2, Late Sown Environment; GCA, General Combining Ability; SCA, Specific Combining Ability; m. ha, Million hectare; Kg/ha, Kilogram per hectare.

Table 1: Analysis of variance for combining ability for 11 characters in L x T mating design in chickpea in E_1 and E_2.

Characters	d.f.	Lines	Testers	Line x Tester	Error
		9	5	45	118
Days to 50% flowering	E1	11.96**	5.16	2.96	4.80
	E2	9.28	7.00	6.99	5.93
Days to maturity	E1	99.24**	28.97	30.29**	16.12
	E2	16.56*	6.94	6.14**	2.34
Plant height (cm)	E1	0.78*	0.70	0.36**	0.17
	E2	95.66**	32.88	30.90**	9.28
No. of primary branches per plant	E1	0.37*	0.27	0.17	0.21
	E2	37.54**	10.17	11.58**	0.40
No. of secondary branches per plant	E1	9.60*	4.91	3.59**	1.42
	E2	847.64	374.24	339.00	16.63
No. of pods per pod	E1	402.27	221.75	256.79**	19.59
	E2	1.92**	0.19	0.47**	0.00
No. of seeds per pod	E1	1.88**	0.18	0.48**	0.01
	E2	134.35**	11.10	18.70**	0.62
100 Seed weight (g)	E1	123.18**	3.20	16.83**	1.57
	E2	3449.40**	146.42	621.41**	16.49
Biological yield (g)	E1	474.17*	152.15	207.96**	16.32
	E2	75.12**	19.01	23.87**	9.29
Harvest index (%)	E1	767.86**	50.11	105.07**	5.86
	E2	738.59**	9.57	129.42**	4.19
Seed yield per plant (g)	E1	454.47**	14.4	96.96**	3.57
	E2	11.96**	5.16	2.96	4.80

*,**significant at 5 and 1 per cent probability levels, respectively.

Table 2: Estimates of GCA effects of parents (females and males) for 11 characters in Chickpea in E_1 and E_2.

S. No.	Lines	Days to 50% flowering		Days to maturity		Plant height (cm)		Primary branches per plant		Secondary branches per plant		Pods per plant	
		GCA		GCA		GCA		GCA		GCA		GCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	SAKI 9516	1.23*	2.42**	1.38*	2.27**	-2.76**	-2.00**	-0.36**	-0.32**	-2.09**	-1.29**	1.21	0.30
2	IPC 2004-52	-0.44	-1.03**	0.04	-1.18**	2.07*	4.16**	0.23*	0.10	1.97**	1.06**	7.08**	6.22**
3	PDG 84-16	-0.72	-0.81*	-0.62	-0.12	-0.07	-0.63	0.06	0.01	-1.06**	-0.79**	5.08**	5.67**
4	HC 3	1.23*	-0.19	-0.18	-0.01	0.62	1.66*	-0.10	-0.16	-1.53**	-0.59*	-8.24**	-3.45**
5	BGM 547	0.01	0.36	0.49	0.04	-0.06	-1.88*	0.19*	-0.04	-0.01	0.74**	-3.22**	-4.43**
6	KWR 108	-0.49	0.36	-0.84	0.66*	0.63	0.72	-0.23*	0.14	-0.83**	0.64*	-13.83**	-8.68**
7	HK 94-134	0.73	-0.19	0.93	0.38	-0.35	-2.10**	0.04	0.04	0.39**	-0.15	-2.40*	-2.17*
8	ICCV 05107	-0.61	-0.58	-0.34	-0.96**	3.32**	2.44**	-0.18	0.12	0.25	0.07	6.03**	3.86**
9	JGK 1	-1.05	-0.14	-0.51	-0.84**	1.47	0.59	0.25**	0.08	2.44**	0.05	3.77**	1.64
10	KAK 2	0.12*	-0.19	-0.34	-0.23	-4.86**	-2.94**	0.11	0.03	0.47**	0.26	4.52**	1.03
	SE(gi) lines	0.52	0.40	0.583	0.30	0.93	0.72	0.094	0.11	0.15	0.28	0.94	1.06
	Testers												
1	BG 372	-0.78	-0.14	-0.32	-0.21	0.51	-0.80	-0.07	-0.04	-0.47**	-0.73**	-3.90**	-2.24**
2	Phule G 5	0.45	0.79**	0.41	0.62**	0.52	0.20	-0.17**	-0.05	-0.35**	0.27	4.28**	3.15**
3	ICCV 10	0.15	0.19	-0.59	1.06**	-0.43	-0.79	0.00	-0.12	-0.17	0.32	-1.45*	-2.54**
4	Subhra	0.12	-0.07	0.44	0.12	1.16	1.92**	0.05	-0.02	0.61**	0.02	4.55**	3.67**
5	BG 5058	-0.02	-0.11	-0.39	-0.88**	-1.66*	0.15	-0.08	0.09	-0.47**	-0.15	-1.66*	-0.87
	SE(gi) tester	0.08	-0.67*	0.44	-0.71**	-0.11	-0.67	0.27**	0.14	0.85**	0.29	-1.81*	-1.15

S. No.	Lines	Seeds per pod		100 seed weight (g)		Biological yield per plant (g)		Seed yield per plant (g)		Harvest index (%)	
		GCA		GCA		GCA		GCA		GCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	SAKI 9516	-0.45**	-0.45**	-4.23**	-4.93**	-19.83**	-6.47**	-9.43**	-9.11**	-2.95**	-13.87**
2	IPC 2004-52	0.48**	0.46**	-2.07**	-2.22**	11.28**	2.03*	6.61**	3.90**	3.72**	6.69**
3	PDG 84-16	-0.21**	-0.20**	4.34**	3.19**	2.88**	1.12	0.76	1.10*	-0.41	2.24**
4	HC 3	0.21**	0.22**	3.72**	3.28**	9.06**	6.72**	3.93**	4.39**	1.14	3.49**
5	BGM 547	-0.38**	-0.38**	-0.01	0.86**	-14.08**	-5.36**	-6.06**	-4.50**	-0.30	-4.49**
6	KWR 108	-0.28**	-0.28**	-2.11**	-1.56**	-18.12**	-5.42**	-8.54**	-5.48**	-3.13**	-6.98**
7	HK 94-134	0.12**	0.12**	-1.89**	-1.80**	-3.11**	-3.52**	-1.88**	-1.22**	-0.51	0.58
8	ICCV 05107	0.22**	0.22**	2.08**	2.10**	15.37**	6.95**	7.15**	4.86**	0.49	4.78**
9	JGK 1	0.39**	0.39**	0.14	0.42	18.39**	4.99**	7.51**	5.75**	0.17	5.90**
10	KAK 2	-0.09**	-0.09**	0.03	0.66*	-1.83	-1.04	-0.06	0.30	1.78*	1.65**
	SE(gi) lines	0.02	0.02	0.25	0.31	0.94	0.95	0.72	0.56	0.50	0.47
	Testers										
1	BG 372	0.09**	0.09**	-0.49*	-0.09	-1.85*	-0.86	-0.19	0.22	1.19*	1.01*
2	Phule G 5	-0.09**	-0.10**	0.04	0.21	1.17	0.96	0.42	-0.05	-1.01	-0.60

3	ICCV 10	-0.05**	-0.05**	1.10**	0.53*	0.06	-1.80*	0.01	-0.95**	0.29	-1.34**
4	Subhra	-0.01	0.004	-0.60**	-0.41	3.43**	4.06**	0.64	0.91*	-0.77	-1.32**
5	BG 5058	0.10**	0.09**	-0.12	-0.05	-0.01	-0.42	0.09	0.49	0.11	1.79**
	SE(gi) tester	-0.04**	-0.02*	0.07	-0.18	-2.80**	-1.94**	-0.98*	-0.61	0.19	0.46

*,** significant at 5 and 1 per cent probability levels, respectively.

Table 3: Estimates of SCA effects of crosses for 11 characters in Chickpea in E_1 and E_2 environments

S. No.	Crosses	Days to 50% flowering		Days to maturity		Plant height		No. of primary branches per plant (cm)	
		SCA		SCA		SCA		SCA	
		E1	E2	E1	E2	E1	E2	E1	E2
1	L 550 X KAK 2	-0.99	-2.58**	-2.01	-1.90*	2.29	1.06	-0.80***	-0.10
2	L 550 X IPC 97-72	2.44	4.15***	5.59***	3.60***	5.55*	4.02*	0.17	-0.16
3	L 550 X PDG 84-16	0.07	3.08***	0.59	3.50***	-0.90	-1.09	0.07	0.01
4	L 550 X ICCV 07112	0.44	-2.32**	-1.78	-2.57***	-2.29	-2.97	-0.12	-0.08
5	L 550 X ICCV 05107	-1.09	-1.28	-1.28	-0.90	-0.04	-1.16	0.28	-0.09
6	L 550 X ICCV 97	-0.86	-1.05	-1.11	-1.73*	-4.59*	0.15	0.39	0.42
7	BG 1003 X KAK 2	0.67	0.53	1.99	-0.12	-3.15	-2.66	-0.62**	0.08
8	BG 1003 X IPC 97-72	0.77	-0.07	-0.74	0.71	-5.62*	-6.93***	-0.25	-0.15
9	BG 1003 X PDG 84-16	0.74	-2.14*	-0.41	-1.39	5.33*	3.79*	0.29	-0.14
10	BG 1003 X ICCV 07112	-1.23	1.46	-0.78	-1.46	0.37	-0.46	0.40	-0.47
11	BG 1003 X ICCV 05107	-0.09	2.49**	0.72	1.21	1.09	1.69	0.23	0.58*
12	BG 1003 X ICCV 97	-0.86	-2.27*	-0.78	1.04	1.97	4.57*	-0.06	0.10
13	JG 14 X KAK 2	0.28	-1.03	0.66	-1.51*	-4.01	-1.91	-0.15	-0.30
14	JG 14 X IPC 97-72	-0.95	-0.63	-0.74	-2.68***	-4.28	-1.51	0.42	0.21
15	JG 14 X PDG 84-16	0.68	-2.03*	1.92	0.56	-2.40	-1.62	-0.25	-0.29
16	JG 14 X ICCV 07112	0.38	1.24	-1.44	2.16**	5.18*	4.90**	-0.30	0.05
17	JG 14 X ICCV 05107	-0.48	0.27	0.06	1.49*	1.03	-1.29	0.33	0.37
18	JG 14 X ICCV 97	0.08	2.17*	-0.44	-0.01	4.48	1.43	-0.06	-0.04
19	BG 362 X KAK 2	-1.33	1.03	-2.12	0.71	-4.96*	-1.56	-0.05	-0.03
20	BG 362 X IPC 97-72	-1.23	-0.24	-0.52	-0.12	2.47	2.53	0.02	-0.16
21	BG 362 X PDG 84-16	0.41	0.69	-0.52	1.11	-1.02	1.29	-0.32	-0.15
22	BG 362 X ICCV 07112	0.44	-1.04	0.78	-1.62*	5.56*	3.81*	0.33	0.28
23	BG 362 X ICCV 05107	0.24	-0.67	-0.06	-1.62*	-0.96	-4.28*	-0.11	-0.06
24	BG 362 X ICCV 97	1.47	0.23	2.44	1.54*	-1.08	-1.79	0.14	0.12
25	HC 3 X KAK 2	-0.44	-0.86	0.88	0.66	2.05	-0.19	0.02	0.18
26	HC 3 X IPC 97-72	-0.67	0.21	-1.19	-1.18	-2.02	-2.83	0.02	-0.28
27	HC 3 X PDG 84-16	0.63	0.47	0.14	-0.28	-3.34	1.46	0.09	0.20
28	HC 3 X ICCV 07112	-0.67	0.07	-1.56	0.99	-1.13	-2.28	0.23	0.03
29	HC 3 X ICCV 05107	0.13	-0.23	-0.39	-0.68	-0.67	2.39	-0.14	-0.14
30	HC 3 X ICCV 97	1.03	0.34	2.11	0.49	5.11*	1.44	-0.22	0.01
31	ICC 14364 X KAK 2	0.06	0.81	0.54	-0.29	3.32	3.04	0.01	-0.09
32	ICC 14364 X IPC 97-72	-1.17	0.21	-0.52	0.21	-0.45	0.81	-0.02	0.11
33	ICC 14364 X PDG 84-16	-0.21	-0.53	-0.86	0.78	1.83	-0.74	0.38	0.25
34	ICC 14364 X ICCV 07112	0.83	-0.26	1.44	0.38	-1.36	3.78*	0.13	0.19
35	ICC 14364 X ICCV 05107	-0.04	-0.23	-0.39	-0.29	-2.84	-3.74*	-0.24	-0.25
36	ICC 14364 X ICCV 97	0.53	0.01	-0.22	-0.79	-0.52	-3.16	-0.26	-0.20
37	ICCV 07104 X KAK 2	0.51	2.03*	-1.23	0.32	0.54	0.66	0.27	-0.03
38	ICCV 07104 X IPC 97-72	0.27	-0.91	-0.30	1.16	2.60	3.06	0.51*	0.17
39	ICCV 07104 X PDG 84-16	-0.43	-1.31	-1.63	-1.94*	0.15	0.28	-0.06	-0.12
40	ICCV 07104 X ICCV 07112	1.94	-0.37	3.33*	-0.34	-1.84	-1.63	-0.58*	0.02
41	ICCV 07104 X ICCV 05107	-0.59	-0.01	0.17	-1.01	1.05	-1.16	-0.05	-0.13
42	ICCV 07104 X ICCV 97	-1.69	0.56	-0.33	1.82*	-2.51	-1.21	-0.10	0.09
43	Phule G 5 X KAK 2	1.17	0.75	-0.29	1.66*	0.51	3.36	0.72**	-0.08
44	Phule G 5 X IPC 97-72	-0.73	-1.52	-1.02	-1.18	1.84	4.32*	-0.74**	-0.04
45	Phule G 5 X PDG 84-16	-1.43	1.08	-0.02	-0.61	0.75	0.04	-0.24	0.07
46	Phule G 5 X ICCV 07112	-0.73	0.68	1.28	0.66	-0.31	-7.14***	-0.06	0.01
47	Phule G 5 X ICCV 05107	0.74	-0.28	0.78	0.99	0.91	4.27*	-0.13	-0.17
48	Phule G 5 X ICCV 97	0.97	-0.72	-0.72	-1.51*	-3.71	-4.84**	0.45	0.21
49	ICCV 10 X KAK 2	-0.38	0.31	1.21	1.54*	-1.04	-1.73	0.39	-0.07
50	ICCV 10 X IPC 97-72	0.72	-0.63	-0.86	-0.29	1.29	-3.54*	-0.23	0.17
51	ICCV 10 X PDG 84-16	-0.65	-0.03	-0.19	-2.39**	-1.73	-2.51	0.16	0.11
52	ICCV 10 X ICCV 07112	0.05	0.24	-0.89	0.21	0.58	3.17	0.21	-0.06
53	ICCV 10 X ICCV 05107	0.18	-0.06	0.61	0.21	1.03	2.95	-0.32	-0.03
54	ICCV 10 X ICCV 97	0.08	0.17	0.11	0.71	-0.12	1.67	-0.21	-0.12
55	PANT G 186 X KAK 2	0.45	-0.97	0.38	-1.07	4.45	-0.06	0.20	0.45
56	PANT G 186 X IPC 97-72	0.55	-0.57	0.31	-0.23	-1.38	0.07	0.10	0.12
57	PANT G 186 X PDG 84-16	0.18	0.69	0.98	0.67	1.33	-0.91	-0.13	0.06
58	PANT G 186 X ICCV 07112	-1.45	0.29	-0.39	1.60*	-4.76*	-1.19	-0.25	0.03

59	PANT G 186 X ICCV 05107	1.02	-0.01	-0.22	0.60	-0.61	0.35	0.15	-0.08
60	PANT G 186 X ICCV 97	-0.75	0.56	-1.06	-1.57*	0.97	1.74	-0.07	-0.59*
	SE (Si)	1.28	0.87	1.43	0.75	2.30	1.80	0.23	0.30
	SE (Sij - Sik)	2.42	1.70	2.73	1.42	4.40	3.40	0.44	0.51

S. No.	**Crosses**	**No. of secondary branches per plant**		**No. of pods per plant**		**No. of seeds per pod**		**100 seed weight**	
		SCA		**SCA**		**SCA**		**SCA**	
		E1	**E2**	**E1**	**E2**	**E1**	**E2**	**E1**	**E2**
1	L 550 X KAK 2	-4.91**	-3.73**	-3.68	-3.38	-0.09*	-0.09*	-0.69	-0.60
2	L 550 X IPC 97-72	1.31**	0.27	-5.02*	-2.81	0.09*	0.10**	0.01	-0.37
3	L 550 X PDG 84-16	-0.07	1.76*	-2.59	-2.15	0.05	0.05	-0.75	-1.56
4	L 550 X ICCV 07112	-2.39**	-1.81**	-5.00*	-3.06	0.01	0.00	0.69	1.95
5	L 550 X ICCV 05107	3.26**	1.63*	9.72**	8.94***	-0.10**	-0.09*	0.67	0.72
6	L 550 X ICCV 97	2.81**	1.88**	6.57**	2.46	0.04	0.02	0.08	-0.15
7	BG 1003 X KAK 2	-1.30**	-0.67	6.15**	4.96	-0.02	0.00	6.76***	5.56
8	BG 1003 X IPC 97-72	-0.31	-0.20	-6.06**	-3.77	-0.30**	-0.37**	1.02	1.96
9	BG 1003 X PDG 84-16	0.41	0.31	3.80	4.59	0.13***	0.14**	-1.58*	-0.77
10	BG 1003 X ICCV 07112	0.65	0.08	-10.87**	-6.26*	0.08*	0.10*	-1.24*	-1.53
11	BG 1003 X ICCV 05107	2.54**	1.35*	5.78*	0.15	-0.02	0.01	-2.05**	-2.02
12	BG 1003 X ICCV 97	-1.98**	-0.86	1.20	0.33	0.11**	0.12**	-2.91**	-3.19
13	JG 14 X KAK 2	-0.17	-0.02	9.58**	2.24	-0.33**	-0.34***	0.18	0.15
14	JG 14 X IPC 97-72	-0.25	0.11	8.51**	7.62**	-0.14**	-0.14**	-1.26*	-1.38
15	JG 14 X PDG 84-16	0.50	0.73	12.87***	12.18**	-0.18**	-0.20**	-2.65**	-2.07
16	JG 14 X ICCV 07112	0.68	-0.07	1.43	3.53	-0.23**	-0.24**	-0.58	-0.67
17	JG 14 X ICCV 05107	-0.34	0.23	-19.45**	-16.33**	0.67**	0.67**	2.07**	1.54
18	JG 14 X ICCV 97	-0.42	-0.98	-12.94**	-9.25**	0.20**	0.25**	2.24**	2.44
19	BG 362 X KAK 2	-0.34	-0.46	5.94*	3.07	-0.75**	-0.76**	-1.20	-1.44
20	BG 362 X IPC 97-72	1.11**	0.57	12.43**	8.24**	-0.56**	-0.56**	-2.37**	-2.74
21	BG 362 X PDG 84-16	0.37	-0.41	0.83	-3.13	0.33**	0.38**	2.17**	2.67
22	BG 362 X ICCV 07112	1.31**	-0.14	5.29*	15.89**	0.35**	0.34**	5.34**	5.30
23	BG 362 X ICCV 05107	-2.44**	-0.17	-10.50**	-10.74**	0.25**	0.24**	-1.57*	-1.59
24	BG 362 X ICCV 97	-0.02	0.61	-13.98**	-13.32**	0.38**	0.36**	-2.37**	-2.19
25	HC 3 X KAK 2	-0.32	1.11	-13.15**	-5.99*	0.24**	0.24**	-1.11	0.88
26	HC 3 X IPC 97-72	-0.07	-0.62	-17.33**	-18.08**	0.03	0.04	-0.58	-1.35
27	HC 3 X PDG 84-16	0.38	-0.74	5.37*	2.81	-0.01	-0.02	1.06	0.26
28	HC 3 X ICCV 07112	1.82**	1.56*	3.53	-0.94	-0.06	-0.06	-1.00	-0.64
29	HC 3 X ICCV 05107	0.08	-0.10	11.58**	10.60**	-0.16**	-0.16**	0.25	-0.16
30	HC 3 X ICCV 97	-1.88**	-1.21	10.00**	11.62**	-0.03	-0.04	1.39*	1.00
31	ICC 14364 X KAK 2	-1.86**	-0.35	-0.47	1.22	0.74**	0.74**	1.89**	2.33
32	ICC 14364 X IPC 97-72	0.22	-0.15	5.68*	3.20	-0.07*	-0.06	-1.35*	-1.20
33	ICC 14364 X PDG 84-16	1.31**	0.23	14.55**	9.06**	-0.11**	-0.12**	-1.84**	-1.46
34	ICC 14364 X ICCV 07112	2.05**	1.10	1.81	0.98	-0.16**	-0.16**	0.70	0.15
35	ICC 14364 X ICCV 05107	-0.60	-1.20	-8.64**	-7.85**	-0.26**	-0.26**	0.38	-0.11
36	ICC 14364 X ICCV 97	-1.12**	0.36	-12.93**	-6.60*	-0.13**	-0.14**	0.22	0.29
37	ICCV 07104 X KAK 2	2.71**	1.14	-6.57**	-7.55**	0.34**	0.34**	-0.13	-0.59
38	ICCV 07104 X IPC 97-72	2.70**	0.54	5.82*	3.16	0.53**	0.54**	-1.70**	-1.62
39	ICCV 07104 X PDG 84-16	-2.08**	-0.88	-0.35	2.18	-0.51**	-0.52**	6.91**	5.69
40	ICCV 07104 X ICCV 07112	-1.60**	0.42	-1.06	1.00	-0.56**	-0.56**	-0.52	-1.51
41	ICCV 07104 X ICCV 05107	-1.72**	-0.37	7.59**	8.68**	0.34**	0.34**	-1.57*	-0.57
42	ICCV 07104 X ICCV 97	-0.01	-0.85	-5.43*	-7.47**	-0.13**	-0.14**	-3.00**	-1.40
43	Phule G 5 X KAK 2	2.09**	1.38*	6.23**	3.32	0.24**	0.24**	-3.99**	-4.56
44	Phule G 5 X IPC 97-72	-1.43**	-0.95	-3.71	-3.77	0.43**	0.44**	3.13**	3.47
45	Phule G 5 X PDG 84-16	-1.34**	-0.17	-6.78**	-4.78	0.39**	0.38**	-2.60**	-1.98
46	Phule G 5 X ICCV 07112	-1.42**	-0.37	-11.92**	-12.30**	0.34**	0.34**	-2.09**	-2.05
47	Phule G 5 X ICCV 05107	-1.14**	-0.43	6.13**	2.91	-0.76**	-0.76**	2.39**	2.73
48	Phule G 5 X ICCV 97	3.24**	0.55	10.05**	14.63**	-0.63**	-0.64**	3.16**	2.39
49	ICCV 10 X KAK 2	2.13**	0.93	-3.75	-4.39	-0.93**	-0.93**	-2.26**	-2.88
50	ICCV 10 X IPC 97-72	-1.95**	-0.63	-1.92	4.75	0.26**	0.27**	1.10	1.92
51	ICCV 10 X PDG 84-16	1.90**	0.15	-2.99	-1.29	0.22**	0.21**	-0.86	-0.20
52	ICCV 10 X ICCV 07112	1.11**	0.12	1.37	1.09	0.17**	0.17**	0.88	0.37
53	ICCV 10 X ICCV 05107	-1.77**	-0.41	-11.48**	-11.60**	0.07	0.08*	0.17	0.41
54	ICCV 10 X ICCV 97	-1.42**	-0.16	18.77**	11.45**	0.20**	0.19**	0.97	0.38
55	PANT G 186 X KAK 2	1.96**	0.66	-0.26	6.52*	0.55**	0.55**	0.56	1.15
56	PANT G 186 X IPC 97-72	-1.32**	1.06	1.60	1.46	-0.26**	-0.26**	1.99**	1.32
57	PANT G 186 X PDG 84-16	-1.37**	-0.99	-24.71***	-19.45**	-0.30**	-0.31**	0.16	-0.57
58	PANT G 186 X ICCV 07112	-2.22**	-0.89	15.42**	0.07	0.05	0.08*	-2.17**	-1.37
59	PANT G 186 X ICCV 05107	2.13**	-0.52	9.27**	15.24**	-0.02	-0.08*	-0.75	-0.96
60	PANT G 186 X ICCV 97	0.81*	0.67	-1.31	-3.84	-0.02	0.03	0.22	0.44
	SE (Si)	0.34	0.68	0.30	2.60	0.04	0.04	0.60	0.76

	SE (Sij - Sik)	0.70	1.30	4.40	4.95	0.07	0.07	0.17	1.50

S. No.	Crosses	Biological yield(g)		Seed yield per plant (g)		Harvest index (%)	
		SCA		SCA		SCA	
		E1	E2	E1	E2	E1	E2
1	L 550 X KAK 2	-4.17	-2.87	-1.03	-1.04	2.44	-1.15
2	L 550 X IPC 97-72	3.34	1.45	-0.20	-0.42	-3.53*	-1.06
3	L 550 X PDG 84-16	-4.32	-0.24	-0.59	-0.37	2.95	-0.80
4	L 550 X ICCV 07112	-3.78	-4.50	-0.82	0.41	0.27	4.38**
5	L 550 X ICCV 05107	6.38**	3.32	1.00	0.90	-3.94*	-0.24
6	L 550 X ICCV 97	2.55	2.83	1.64	0.54	1.81	-1.13
7	BG 1003 X KAK 2	27.62**	13.76**	12.30**	7.06**	-0.39	1.90
8	BG 1003 X IPC 97-72	-10.43**	-5.40*	-4.24**	-4.43**	1.69	-4.49**
9	BG 1003 X PDG 84-16	1.28	1.05	0.88	0.22	0.19	0.63
10	BG 1003 X ICCV 07112	-13.89**	-7.69**	-4.99**	-2.11	1.45	2.18
11	BG 1003 X ICCV 05107	-1.52	-1.42	-1.27	-0.87	-0.92	-0.79
12	BG 1003 X ICCV 97	-3.06	-0.31	-2.67*	0.13	-2.01	0.58
13	JG 14 X KAK 2	-1.61	-2.93	-1.68	-2.17	-1.98	-2.01
14	JG 14 X IPC 97-72	-6.46**	-0.54	-1.85	0.42	2.73	1.03
15	JG 14 X PDG 84-16	-1.66	1.38	-2.27	-2.24	-3.19	-4.40**
16	JG 14 X ICCV 07112	-5.59*	-2.28	-2.87*	-4.73**	-1.75	-6.82**
17	JG 14 X ICCV 05107	9.48**	5.13*	6.22**	5.74**	3.93*	5.94**
18	JG 14 X ICCV 97	5.84*	-0.76	2.45*	2.98**	0.27	6.25**
19	BG 362 X KAK 2	-22.46**	-10.96**	-10.65**	-9.20**	-3.30	-9.41**
20	BG 362 X IPC 97-72	-18.51**	-7.25**	-8.66**	-7.27**	-1.51	-7.19**
21	BG 362 X PDG 84-16	13.46**	4.22	8.02**	4.35**	2.81	6.08**
22	BG 362 X ICCV 07112	42.80**	29.99**	15.35**	17.40**	-2.30	7.40**
23	BG 362 X ICCV 05107	-8.30**	-5.51*	-1.49	-1.90	3.60*	0.76
24	BG 362 X ICCV 97	-7.00**	-10.49**	-2.56*	-3.38**	0.70	2.35
25	HC 3 X KAK 2	-2.08	-1.77	-1.13	1.80	-0.12	5.50**
26	HC 3 X IPC 97-72	-8.44**	-7.54**	-3.81**	-3.61**	-0.16	-3.51*
27	HC 3 X PDG 84-16	6.57**	2.15	2.51*	1.02	-0.50	1.22
28	HC 3 X ICCV 07112	-4.59*	-3.21	-1.59	-1.49	1.53	-0.50
29	HC 3 X ICCV 05107	3.17	4.23	1.16	0.59	-2.25	-1.93
30	HC 3 X ICCV 97	5.37*	6.14**	2.86*	1.69	1.50	-0.78
31	ICC 14364 X KAK 2	17.12**	8.55**	8.49**	9.94**	4.15*	14.02**
32	ICC 14364 X IPC 97-72	-0.80	-0.17	-1.29	-1.60	-1.60	-2.96*
33	ICC 14364 X PDG 84-16	3.71	1.99	1.03	-0.82	-0.17	-2.13
34	ICC 14364 X ICCV 07112	-5.72*	-1.66	-1.54	-2.98**	1.25	-3.92**
35	ICC 14364 X ICCV 05107	-8.15**	-5.63*	-3.39**	-2.83*	-0.16	-2.89*
36	ICC 14364 X ICCV 97	-6.16**	-3.08	-3.29**	-1.70	-3.47	-2.13
37	ICCV 07104 X KAK 2	4.17	-1.34	1.86	0.77	1.05	2.52
38	ICCV 07104 X IPC 97-72	11.99**	1.08	6.09**	5.87***	2.88	11.22**
39	ICCV 07104 X PDG 84-16	-6.14**	0.89	-1.36	-0.88	2.20	-1.37
40	ICCV 07104 X ICCV 07112	-21.41**	-5.34*	-8.40**	-7.14***	-0.42	-10.41**
41	ICCV 07104 X ICCV 05107	18.93**	9.20	6.06**	5.63***	-2.39	3.80**
42	ICCV 07104 X ICCV 97	-7.54**	-4.49	-4.24**	-4.25***	-3.32	-5.76**
43	Phule G 5 X KAK 2	1.30	-6.95**	0.53	-2.88*	1.02	0.09
44	Phule G 5 X IPC 97-72	15.68**	13.67**	12.35**	7.46**	3.91*	2.85*
45	Phule G 5 X PDG 84-16	0.49	1.02	1.00	2.88*	2.21	5.35**
46	Phule G 5 X ICCV 07112	1.76	-0.76	-0.97	0.84	-1.48	2.21
47	Phule G 5 X ICCV 05107	-13.04**	-4.73*	-7.44**	-5.71**	-2.22	-7.47**
48	Phule G 5 X ICCV 97	-6.18**	-2.25	-5.48**	-2.59*	-3.44	-3.02*
49	ICCV 10 X KAK 2	-36.46**	-11.11**	-16.76**	-13.54**	-4.39*	-17.18**
50	ICCV 10 X IPC 97-72	14.76**	6.23**	4.43**	5.00**	-0.62	5.43**
51	ICCV 10 X PDG 84-16	6.40**	-2.93	0.24	2.75*	-3.12	2.55
52	ICCV 10 X ICCV 07112	5.84*	1.94	4.31**	1.19	2.54	2.55
53	ICCV 10 X ICCV 05107	-9.87**	-8.70**	-3.44**	-3.39**	1.44	2.37
54	ICCV 10 X ICCV 97	19.33**	14.57**	11.23**	7.98**	4.15*	4.27**
55	PANT G 186 X KAK 2	16.56**	15.61**	8.07**	9.27**	1.51	5.72**
56	PANT G 186 X IPC 97-72	-1.13	-1.54	-2.81*	-1.42	-3.78*	-1.31
57	PANT G 186 X PDG 84-16	-19.79**	-9.53**	-9.46**	-6.92**	-3.38	-7.13**
58	PANT G 186 X ICCV 07112	4.58*	-6.48**	1.54	-1.38	-1.08	2.92*
59	PANT G 186 X ICCV 05107	2.92	4.10	2.60*	1.84	2.92	0.44
60	PANT G 186 X ICCV 97	-3.15	-2.17	0.06	-1.40	3.81*	-0.64
	SE (S_i)	2.30	2.32	1.80	1.40	1.23	1.13
	SE (Sij - Sik)	4.40	4.50	3.40	2.60	2.40	2.18

*, ** significant at 5 and 1 per cent probability levels, respectively

Acknowledgement
The work on chickpea reported in this paper has been supported by research and teaching faculties of Department of Genetics and Plant Breeding, N.D.U.A.T. Kumarganj Faizabad (U.P.) and we would also like to thank Mr. M. M. Khetan for statistical analysis.

References
1. Anonymous. All India Coordinated Research Project on Chickpea, 2015.
2. BL Kumhar, 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):1-13.
3. Bhardwaj R, Sandhu JS, Gupta SK. Gene action and combining ability estimates for yield and other quantitative traits in chickpea (*Cicer arietinum* L.). Indian Journal of Agricultural Sciences. 2009; 79:11.
4. Biranvand HP, Farshadfar E, Sabakhpour H. Gene action of some agronomic characters in chickpea under stress and non-stress conditions. Asian Journal of Experimental Biological Sciences. 2013; 4(2):266-272.
5. Chauhan VS, Dodiya NS, Parihar AK. Heterosis, combining ability and inbreeding depression in chickpea (*Cicer arietinum* L.). Journal of Food Legumes. 2013; 26(1-2):34-38.
6. Ezzat Karami, Reza Talebi. Nature of gene action and genetic parameters for yield and its components in chickpea. African Journal of Biotechnology. 2013; 12(51):7038-7042.
7. Hemati I, Sabaghpour SH, Taeb M, Choukan R. Study on genetic parameters for different agronomic traits in Chickpea (*Cicer arietinum* L.) genotypes using diallel analysis. Seed and Plant Improvement Journal. 2010; 26(1):205-218.
8. Kempthorne O. An introduction to genetic statistics. John Wiley and Sons, Inc., New York, 1957, 468- 471p.
9. Gadekar MS, Dodiya NS. Heterosis and combining ability analysis for yield and yield contributing traits in chickpea (*Cicer arietinum* L.). Legume Res. 2013; 36(5):373-379.
10. Panse VG, Shukhatme PV. Statistical methods for agricultural workers, IInd Ed., ICAR, New Delhi, 1967, 381p.
11. Sarode SB, Nagargoje GP, Patil DK. Heterosis and combining ability analysis in chickpea (*Cicer arietinum* L.). Adv. Res. J. Crop Improv. 2016; 7(1):151-154.
12. Yamini BR, Jayalakshmi V, Narendra B, Umamaheshwar i P. Gene action and combining ability studies in chickpea (*Cicer arietinum* L.). Journal of Research ANGRAU. 2013; 41(1):74-78.