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

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Abstract
The experimental materials comprised of ten diverse lines of chickpea with five 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 in E_1 and E_2 except for number of seeds per pod, whereas variance due to lines was also highly significant for most of the characters studied. Variances due to testers were found highly significant for only 100 seeds weight in both the environments**.** The parental lines JGK 1 and ICCV 05107 with high GCA effects were identified as superior donors for seed yield per plant, biological yield per plant, harvest index and 100 seed weight in both the environments. The crosses ICCV 05107 x Subhra, JGK 1 x Subhra, JGK 1 x ICCV 10, HK 94-134 x BG 5058 in timely sown and ICCV 05107 x Subhra, JGK 1 x ICCV 10, HC 3 x Subhra, HC 3 x Phule G 5 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
An experiment was laid out with 10 lines and 5 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* 2013-14 in line x tester fashion and were evaluated in Randomized Block Design with three replications along with parental lines in *Rabi* 2014-15. 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 in E_1 and E_2 except for number of seeds per pod. Variance due to lines was also highly significant for days to 50 per cent flowering, 100 seeds weight and seed yield per plant in both the environments; whereas for plant height, biological yield per plant in E_1 and days to maturity, secondary branches per plant, seeds per pod and harvest index in E_2. Secondary branches per plant, harvest index in E_1 and plant height, pods per plant, and biological yield per plant in E_2 were found significant. Variances due to testers were also highly significant for 100 seeds weight 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. The significant and positive GCA effects for seed yield per plant were exhibited by four lines and one tester which in order of merit were JGK 1, ICCV 05107, HK 94-134 and HC 3 among lines in both E_1 and E_2, respectively and Subhra among the testers in E_2 only. On the basis of GCA effects and mean performance among lines, parent JGK 1 and ICCV 05107 were found good combiner for Seed yield per plant, biological yield per plant, 100 seed weight and harvest index in both the environments and parent HC 3 for days to maturity, plant height, pods per plant, 100 seed weight biological yield per plant, grain yield per plant and harvest index in both environments. Among testers Subhra was found good general combiner for 100 seed weight and biological yield per plant in both the environments, whereas for seed yield per plant in late sown environment only**.** Similar finding were reported by Chauhan *et al* [6], Sarode *et al.* [7].

Specific combining ability: The estimates of SCA effects of 50 crosses in E_1 and E_2 for 11 characters are given in (Table-3). Out of 50 crosses studied, the most promising crosses were *viz.,* ICCV 05107 x Subhra, JGK 1 x Subhra, JGK 1 x ICCV 10, HK 94-134 x BG 5058 in timely sown and ICCV 05107 x Subhra, JGK 1 x ICCV 10, HC 3 x Subhra, HC 3 x Phule G 5 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 ICCV 05107 X Subhra was the most promising as it had high significant SCA effects for days to maturity, number of pods per plant, seed yield per plant and biological yield per plant; HK 94-134X BG 5058 for number of pods per plant, seed yield per plant, biological yield per plant and harvest index; IPC 2004-52 X Phule G 5 for number of pods per plant, seed yield per plant, biological yield per plant, secondary branches per plant and days to maturity; KAK 2 X BG 5058 for days to maturity, plant height, primary branches per plant, secondary branches per plant and seeds per pod; HC 3 X BG 372 for days to 50% flowering, days to maturity, secondary branches per plant and seed yield per plant in timely sown environment (E_1) and BGM 547 X BG 372 for primary branches per plant, number of pods per plant, seed yield per plant, 100 seed weight and harvest index; HK 94-134X BG 5058 for number of pods per plant, seed yield per plant and biological yield per plant; ICCV 05107 X Subhra for biological yield per plant, number of pods per plant and grain yield per plant; JGK 1 X ICCV 10 for secondary branches per plant, biological yield per plant and 100 seed weight in late sown environment (E_2). Similar finding were reported by Hemati *et al.* [11], Chauhan *et al.* [6], Sarode *et al.* [7], Gadekar *et al.* [12].

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.	Sources of variation											
	Replications		Crosses		Lines		Testers		Lines x testers		Error	
	2		49		9		4		36		98	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Days to 50% flowering	0.93	1.41	43.44**	36.94**	170.12**	190.42**	12.03	3.91	15.26**	2.24**	1.05	0.93
Days to maturity	0.18	0.25	30.13**	6.94**	40.53	19.54**	37.76	4.94	26.68**	4.01**	1.07	0.92
Plant height	2.65	7.12	57.63**	45.63**	217.26**	110.24*	43.56	13.82	19.29**	33.01**	2.44	2.96
Primary branches per plant	0.01	0.03	0.57**	0.26**	1.03	0.23	0.59	0.17	0.46**	0.28**	0.17	0.07
Secondary branches per plant	0.69	0.72	18.88**	22.76**	46.16*	85.17**	5.82	10.26	13.52**	8.54**	1.61	2.15
Pods per plant	28.72	14.16	393.73**	154.87**	876.15	352.11*	165.52	150.21	298.47**	106.08**	25.51	18.15
Seeds per pod	0.06	0.01	0.03**	0.04**	0.06	0.13**	0.05	0.01	0.02	0.02	0.02	0.02
100 seed weight (g)	0.48	0.58	168.43**	95.78**	889.43**	483.26**	38.84**	46.21**	2.58**	4.42**	0.55	0.53
Biological yield per plant (g)	15.86	20.56	523.33**	182.59**	1855.65**	384.41*	194.71	369.51	226.76**	111.36**	24.82	9.24
Seed yield per plant (g)	1.57	4.61*	109.39**	29.93**	441.00**	108.45**	11.06	14.81	37.41**	11.98**	3.17	0.83
Harvest index (%)	0.95	3.85	42.44**	56.68**	100.43*	172.21**	19.44	63.64	30.51**	27.03**	3.99	2.22

*, ** 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	6.62**	0.69*	0.13	1.55**	-0.26	2.02**	0.19	0.10	1.65**	5.17**	5.54**	0.67
2	IPC 2004-52	5.22**	-0.31	1.79**	1.15**	-0.82	-0.88	0.15	0.04	0.27	2.39**	8.65**	5.24**
3	PDG 84-16	-1.65**	-6.57**	0.79*	1.15**	0.72	0.49	-0.01	0.05	0.86*	1.54**	-0.80	2.13
4	HC 3	0.69	5.76**	-0.87*	-0.99**	3.40**	4.21**	0.26	0.07	-1.04*	-0.47	1.98	5.08**
5	BGM 547	-0.98**	1.63**	-2.41**	0.21	3.15**	0.23	-0.08	0.06	3.03**	-0.81	1.84	-4.06**
6	KWR 108	-0.98**	2.69**	-1.21**	-1.85**	-2.16**	-1.20*	-0.19	0.00	-0.68	-1.34**	-1.31	-2.99*
7	HK 94-134	-2.31**	-2.57**	0.13	-1.05**	-0.94	-1.38*	-0.27	-0.18	-2.58**	-0.72	6.64**	3.15*
8	ICCV 05107	-0.31	3.23**	2.93**	0.35	7.06**	3.30**	-0.30*	-0.24**	-2.44**	-0.75	-8.76**	-3.68*
9	JGK 1	-2.58**	-2.17**	0.59	-0.92**	-5.62**	-1.68**	0.49**	0.14	0.00	-2.60**	2.96	3.88**
10	KAK 2	-3.71**	-2.37**	-1.87**	0.41	-4.53**	-5.12**	0.11	-0.06	0.93*	-2.41**	-16.76**	-9.44**
	SE(gi) lines	0.26	0.26	0.27	0.24	0.40	0.44	0.11	0.07	0.33	0.37	1.26	1.09
	Testers												
1	BG 372	-0.41	-0.31	0.09	-0.12	-1.28**	0.00	-0.14	0.07	-0.35	-0.37	2.37*	-0.99
2	Phule G 5	-0.75**	-0.24	1.53**	-0.35	0.73	-0.71	-0.02	-0.05	0.65*	0.96**	1.17	0.18
3	ICCV 10	-0.15	-0.24	0.46	-0.39	-1.31**	-0.05	0.22**	0.09	-0.46	-0.21	1.17	2.53*
4	Subhra	0.65**	0.43	-1.44**	0.45	1.21**	1.10**	-0.10	-0.06	0.03	-0.50	-1.19	1.49
5	BG 5058	0.65**	0.36	-0.64**	0.41	0.66	-0.34	0.04	-0.05	0.13	0.11	-3.51**	-3.22**
	SE(gi) tester	0.19	0.18	0.19	0.17	0.28	0.31	0.08	0.05	0.23	0.26	0.89	0.77

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	-0.04	0.09	-4.07**	-1.47**	-4.40**	0.73	-2.39**	0.34	-1.02	0.25
2	IPC 2004-52	-0.05	0.13**	-6.65**	-6.30**	-6.05**	-1.89	-3.92**	-1.06**	-2.54**	-1.03
3	PDG 84-16	0.03	0.03	-3.56**	-6.10**	0.56	-0.17	-2.49**	-2.65**	-3.67**	-5.75**
4	HC 3	-0.06	-0.05	2.80**	4.04**	0.76	4.69**	1.62**	3.28**	1.97**	3.46**
5	BGM 547	-0.04	-0.03	-4.03**	-1.82**	-9.07**	0.24	-3.43**	-2.29**	0.12	-5.44**
6	KWR 108	0.10*	0.11*	-6.67**	-5.47**	-5.38**	-7.18**	-4.15**	-2.38**	-3.25**	0.55
7	HK 94-134	0.07	0.06	-1.71**	-0.80**	4.39**	1.59	3.01**	1.38**	1.99**	2.32**
8	ICCV 05107	-0.06	-0.09	16.59**	10.92**	17.85**	5.87**	8.35**	3.53**	2.66**	3.23**
9	JGK 1	-0.04	-0.11**	10.24**	6.42**	18.09**	5.42**	9.48**	3.15**	3.71**	3.27**
10	KAK 2	0.08*	-0.13**	-2.95**	0.59*	-16.74**	-9.30**	-6.08**	-3.30**	0.03	-0.86
	SE(gi) lines	0.03	0.03	0.19	0.20	1.24	0.77	0.43	0.24	0.49	0.41
	Testers										
1	BG 372	0.02	0.04	-1.19**	-1.47**	-2.53*	-5.39**	-0.04	-0.88**	1.34**	2.31**
2	Phule G 5	-0.02	0.00	0.50**	0.61**	2.18	1.83*	0.49	0.41	-0.47	-0.68
3	ICCV 10	0.06	-0.01	-1.21**	-1.20**	-0.47	-1.08	-0.14	-0.15	0.18	0.52
4	Subhra	-0.03	-0.01	1.31**	0.84**	3.08**	3.89**	0.61	0.95**	-0.53	-0.83*
5	BG 5058	-0.03	-0.01	0.59**	1.22**	-2.26	0.76	-0.92*	-0.33	-0.52	-1.32**
	SE(gi) tester	0.02	0.02	0.14	0.14	0.88	0.55	0.31	0.17	0.35	0.29

*, ** 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 (cm)		Primary branches per plant		Secondary branches per plant		Pods per plant	
		SCA		SCA		SCA		SCA		SCA	SCA	SCA	SCA
		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 X BG 372	1.35	0.31	2.44**	0.72	1.88	-3.21*	-0.28	-0.13	-0.67	-3.50**	-2.80	3.94
2	SAKI 9516 X Phule G 5	-1.32	-0.43	-2.99**	-0.38	-0.93	-2.93*	0.00	0.30	-1.31	3.76**	2.77	-5.66
3	SAKI 9516 X ICCV 10	-3.92**	0.91	-3.59**	0.99	-2.39*	-3.99**	0.06	-0.21	-1.30	-3.17**	-1.37	2.05
4	SAKI 9516 X Subhra	2.61**	0.91	1.64*	0.49	0.62	11.32**	0.01	0.01	2.17*	2.79**	8.86*	0.99
5	SAKI 9516 X BG 5058	1.28	-1.69*	2.51**	-1.81*	0.81	-1.20	0.21	0.03	1.11	0.12	-7.45*	-1.33
6	IPC 2004-52 X BG 372	-5.59**	0.97	-1.23	0.12	4.34**	4.29**	-0.45	0.07	-0.29	1.55	2.33	4.50
7	IPC 2004-52 X Phule G 5	1.75*	0.24	-2.33**	-0.65	0.69	3.20*	0.03	-0.08	2.41*	-2.26*	13.86**	6.97*
8	IPC 2004-52 X ICCV 10	2.15**	-0.43	1.07	2.05**	0.33	-2.05	0.36	0.08	0.12	1.81*	-5.04	-4.72

9	IPC 2004-52 X Subhra	-0.32	-0.43	2.31**	-0.11	0.17	-2.04	-0.09	0.27	-2.11*	0.10	-6.72	-7.41*
10	IPC 2004-52 X BG 5058	2.01*	-0.36	0.17	-1.41*	-5.54**	-3.40**	0.14	-0.34	-0.11	-1.20	-4.43	0.67
11	PDG 84-16 X BG 372	1.61*	-0.76	-0.89	1.45*	-1.37	-3.21*	0.15	-0.01	-0.45	0.19	6.14	9.38**
12	PDG 84-16 X Phule G 5	-0.05	0.84	7.34**	-0.31	-1.08	0.30	0.20	0.15	-2.69**	-0.54	-11.19**	0.28
13	PDG 84-16 X ICCV 10	1.01	-0.83	-0.59	0.39	1.09	1.05	-0.31	-0.36	5.96**	1.03	7.61*	1.63
14	PDG 84-16 X Subhra	-1.79*	0.84	-2.69**	-1.78*	2.40*	2.76*	0.15	0.16	-0.31	0.15	-7.84*	-11.50**
15	PDG 84-16 X BG 5058	-0.79	-0.09	-3.16**	0.25	-1.04	-0.90	-0.19	0.05	-2.50**	-0.82	5.29	0.21
16	HC 3 X BG 372	-3.05**	-0.76	-3.56**	-0.75	-2.58*	-1.86	0.24	-0.03	3.35**	-1.09	7.03	1.94
17	HC 3 X Phule G 5	0.28	1.17	-2.66**	0.49	-0.43	-0.08	0.49*	0.40*	1.61	0.97	-0.81	1.84
18	HC 3 X ICCV 10	-0.65	0.51	0.41	-0.81	3.85**	0.63	0.15	0.06	-1.81	2.14*	-0.74	3.15
19	HC 3 X Subhra	2.21**	-0.83	5.97**	0.35	-0.65	-0.36	-0.49	-0.56**	-0.47	-1.17	-8.05*	3.62
20	HC 3 X BG 5058	1.21	-0.09	-0.16	0.72	-0.19	1.68	-0.40	0.13	-2.67**	-0.84	2.57	-10.53**
21	BGM 547 X BG 372	0.28	0.71	-0.69	2.72**	-0.93	0.48	0.48*	0.81**	1.01	1.97*	4.27	7.00*
22	BGM 547 X Phule G 5	2.28**	-0.36	-0.79	-0.71	0.09	1.03	0.00	-0.40	1.08	-1.03	-9.60**	-0.16
23	BGM 547 X ICCV 10	-2.32**	-1.36	1.61*	-2.01**	2.07	-0.06	-0.44	-0.07	-1.78	0.41	3.37	-1.45
24	BGM 547 X Subhra	-0.79	0.64	-0.49	0.49	-0.63	-0.75	-0.02	-0.25	-0.81	-1.57	6.89	-2.45
25	BGM 547 X BG 5058	0.55	0.37	0.37	-0.48	-0.60	-0.70	-0.02	-0.09	0.50	0.23	-4.92	-2.93
26	KWR 108 X BG 372	1.28	-0.36	1.11	-0.88	-0.85	-0.42	-0.17	0.07	0.32	0.77	0.35	-3.26
27	KWR 108 X Phule G 5	0.28	-0.76	0.67	1.69*	1.80	2.63*	0.21	-0.24	0.49	0.20	20.79**	2.17
28	KWR 108 X ICCV 10	1.68*	0.24	1.74*	-0.61	1.28	-1.76	0.64*	0.36*	-0.74	-1.29	-3.51	-0.55
29	KWR 108 X Subhra	-1.79*	0.57	0.31	0.22	-3.05**	-0.95	0.06	-0.09	0.10	0.63	-5.99	1.55
30	KWR 108 X BG 5058	-1.45	0.31	-3.83**	-0.41	0.81	0.50	-0.74*	-0.10	-0.16	-0.31	-11.63**	0.10
31	HK 94-134 X BG 372	0.28	-0.09	-1.23	-1.68*	0.92	1.43	-0.09	-0.48*	0.09	0.05	3.70	-5.54
32	HK 94-134 X Phule G 5	-0.72	1.17	0.01	0.22	0.68	-1.72	0.06	-0.06	0.42	-0.52	-2.13	0.00
33	HK 94-134 X ICCV 10	1.68*	-0.16	0.74	0.59	-3.28**	2.79*	-0.38	0.14	-0.47	0.22	-0.80	0.87
34	HK 94-134 X Subhra	-2.45**	-1.49	-3.03**	1.09	-0.21	-2.40	0.27	0.22	1.43	-1.32	-10.94**	-4.22
35	HK 94-134 X BG 5058	1.21	0.57	3.51**	-0.21	1.88	-0.09	0.14	0.18	-1.46	1.57	10.18**	8.89**
36	ICCV 05107 X BG 372	-1.39	-0.89	1.97*	-0.75	3.82**	2.78*	0.40	0.15	0.08	0.25	-12.86**	-6.00
37	ICCV 05107 X Phule G 5	-1.39	-0.96	-1.13	-0.18	-1.29	0.56	-0.62	-0.12	-0.82	1.98*	4.71	-4.34
38	ICCV 05107 X ICCV 10	3.01**	1.71*	2.27**	-0.48	2.15	3.77**	-0.02	0.14	-0.94	-1.31	-18.93**	-7.39*
39	ICCV 05107 X Subhra	2.21**	-0.29	-4.83**	0.02	-3.57**	-5.32**	0.30	-0.01	0.96	-0.79	11.13**	9.81**
40	ICCV 05107 X BG 5058	-2.45**	0.44	1.71*	1.39	-1.12	-1.78	-0.07	-0.15	0.73	-0.13	15.95**	7.93*
41	JGK 1 X BG 372	3.21**	0.51	0.31	-0.81	-3.09**	0.52	-0.68*	-0.10	-0.06	0.83	-8.88*	-10.54**
42	JGK 1 X Phule G 5	-2.45**	-0.56	-2.46**	0.42	0.26	-5.56**	-0.17	0.06	-0.13	-1.57	-16.11**	3.03
43	JGK 1 X ICCV 10	-0.72	-0.23	-2.39**	0.45	-1.09	1.15	0.39	0.28	0.28	1.37	13.45**	5.84
44	JGK 1 X Subhra	1.48	0.44	2.84**	-1.05	3.35**	-1.11	0.18	-0.07	1.12	-0.24	12.24**	3.98
45	JGK 1 X BG 5058	-1.52	-0.16	1.71*	0.99	0.57	5.00**	0.28	-0.17	-1.21	-0.38	-0.70	-2.31
46	KAK 2 X BG 372	2.01*	0.37	1.77*	-0.15	-2.15	-0.80	0.39	-0.37	-3.35**	-1.02	0.73	-1.42
47	KAK 2 X Phule G 5	1.35	-0.36	4.34**	-0.58	0.20	2.58	-0.20	-0.01	-1.05	-0.99	-2.27	-4.12

48	KAK 2 X ICCV 10	-1.92*	-0.36	-1.26	-0.55	-4.02**	-1.51	-0.47	-0.42*	0.69	-1.19	5.97	0.59
49	KAK 2 X Subhra	-1.39	-0.36	-2.03**	0.29	1.55	-1.14	-0.38	0.33*	-2.07*	1.44	0.42	5.63
50	KAK 2 X BG 5058	-0.05	0.71	-2.83**	0.99	4.41**	0.88	0.65*	0.46*	5.80**	1.77*	-4.85	-0.69
	SE (S_i)	0.59	0.57	0.6d0	0.54	0.90	0.99	0.24	0.15	0.73	0.82	2.82	2.43
	SEd (Sij - Sik)	1.24	1.20	1.25	1.14	1.88	2.08	0.51	0.32	1.53	1.72	5.91	5.10

S. No.	Crosses	Seeds per pod		100 seed weight (g)		Biological yield per plant (g)		Seed yield per plant (g)		Harvest index (%)	
		SCA		SCA		SCA		SCA		SCA	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	SAKI 9516 X BG 372	0.07	-0.08	0.86	0.94	2.36	7.91**	1.49	1.12	0.89	-3.66**
2	SAKI 9516 X Phule G 5	-0.08	0.16*	-0.42	-0.67	1.41	-1.51	-2.00	-0.24	-3.52*	0.81
3	SAKI 9516 X ICCV 10	0.04	-0.03	0.11	0.80	-0.61	0.36	1.71	0.80	2.84	1.47
4	SAKI 9516 X Subhra	-0.01	-0.09	-1.70**	-1.58**	0.42	-3.53	0.31	-2.21**	0.06	-2.36
5	SAKI 9516 X BG 5058	-0.01	0.04	1.15*	0.50	-3.58	-3.24	-1.51	0.53	-0.27	3.73**
6	IPC 2004-52 X BG 372	-0.05	-0.12	0.11	0.19	0.14	-1.37	0.26	-0.09	0.29	0.92
7	IPC 2004-52 X Phule G 5	0.00	-0.08	0.26	0.31	10.39**	2.88	3.25*	0.71	0.01	-0.21
8	IPC 2004-52 X ICCV 10	0.05	0.06	0.06	0.01	-1.43	-1.95	-0.44	-0.55	-0.04	-0.09
9	IPC 2004-52 X Subhra	0.07	0.00	0.08	-1.52**	-5.87	-5.58*	-0.88	-2.41**	1.54	-1.64
10	IPC 2004-52 X BG 5058	-0.06	0.13	-0.51	1.01	-3.24	6.01**	-2.20	2.33**	-1.80	1.02
11	PDG 84-16 X BG 372	0.00	0.04	1.02*	-1.64**	-1.13	0.15	2.89*	1.22	4.81**	1.95
12	PDG 84-16 X Phule G 5	-0.08	0.01	0.20	-1.05	-4.75	-2.64	-4.55**	-0.62	-4.40**	0.25
13	PDG 84-16 X ICCV 10	0.10	0.09	0.18	-1.83**	12.00**	-1.60	4.65**	0.12	0.82	0.93
14	PDG 84-16 X Subhra	0.06	0.03	-0.61	1.77**	-3.34	-5.33*	-2.16	-1.17	-1.44	0.73
15	PDG 84-16 X BG 5058	-0.08	-0.17*	-0.78	2.74**	-2.78	9.43**	-0.83	0.44	0.22	-3.87**
16	HC 3 X BG 372	0.10	-0.01	-1.76**	-0.89	5.59	4.52	3.93**	0.31	2.64	-2.64*
17	HC 3 X Phule G 5	0.08	0.03	1.54**	0.58	7.71*	0.73	2.79*	1.76*	-0.02	3.29**
18	HC 3 X ICCV 10	-0.14	-0.03	-1.07	0.57	-0.84	0.14	-3.24*	0.78	-4.27**	1.74
19	HC 3 X Subhra	0.02	-0.03	2.58**	1.75**	-10.05**	2.21	-1.04	1.39	4.17**	1.28
20	HC 3 X BG 5058	-0.05	0.04	-1.30*	-2.01**	-2.42	-7.60**	-2.44	-4.24**	-2.52	-3.68**
21	BGM 547 X BG 372	-0.06	-0.03	0.55	1.53**	5.63	2.53	0.37	2.78**	-2.73	4.11**
22	BGM 547 X Phule G 5	-0.02	0.01	-0.17	0.36	-10.62**	2.01	-2.82*	0.06	1.36	-0.63
23	BGM 547 X ICCV 10	0.04	-0.05	-0.30	-0.64	8.19*	-0.32	1.59	-0.79	-2.35	-2.00
24	BGM 547 X Subhra	-0.01	0.03	-0.92	-0.60	2.98	-4.68*	0.50	-1.21	-1.32	0.59
25	BGM 547 X BG 5058	0.06	0.03	0.84	-0.65	-6.18	0.45	0.37	-0.83	5.05**	-2.07
26	KWR 108 X BG 372	0.07	0.23*	-0.45	-0.57	2.21	0.29	0.52	0.57	-0.47	1.18
27	KWR 108 X Phule G 5	-0.02	-0.07	-0.39	0.79	5.86	2.57	4.40**	1.01	3.60*	-0.11
28	KWR 108 X ICCV 10	0.10	-0.13	0.30	-0.91	-6.76	-9.53**	1.00	-1.85*	5.40**	4.30**
29	KWR 108 X Subhra	-0.08	0.01	-0.12	1.15	-1.94	9.51**	-2.60*	0.98	-3.10*	-4.76**
30	KWR 108 X BG 5058	-0.08	-0.05	0.66	-0.46	0.63	-2.83	-3.32**	-0.71	-5.42**	-0.62
31	HK 94-134 X BG 372	-0.04	-0.05	-0.23	0.23	0.13	-5.71*	-0.66	-2.07**	-0.91	-0.13
32	HK 94-134 X Phule G 5	0.01	0.05	0.06	0.04	-5.85	4.80*	-0.44	0.88	2.66	-1.71
33	HK 94-134 X ICCV 10	-0.07	-0.01	-0.08	0.32	-2.43	8.10**	-1.78	-0.02	-1.18	-5.93**
34	HK 94-134 X Subhra	-0.05	0.00	-0.49	-0.52	-7.31*	-9.89**	-5.62**	-1.38	-4.27**	4.67**
35	HK 94-134 X BG 5058	0.15*	0.00	0.73	-0.07	15.46**	2.70	8.50**	2.59**	3.69*	3.11*
36	ICCV 05107 X BG 372	0.03	0.03	-0.16	0.30	-6.33	-1.06	-4.73**	-1.07	-3.34*	-1.48
37	ICCV 05107 X Phule G 5	0.01	-0.07	-0.39	-0.91	-3.71	-5.61*	1.68	-3.16**	3.41*	-2.37
38	ICCV 05107 X ICCV 10	0.06	0.01	-0.09	0.33	-22.23**	-6.74**	-7.03**	-2.46**	1.80	-0.01
39	ICCV 05107 X Subhra	0.02	0.08	0.67	-0.93	24.90**	11.46**	7.21**	4.79**	-2.17	1.33
40	ICCV 05107 X BG 5058	-0.12	-0.05	-0.03	1.22*	7.36*	1.95	2.87*	1.90**	0.30	2.52*
41	JGK 1 X BG 372	0.00	0.05	0.24	-0.95	-6.53	-7.38**	-2.79*	-2.53**	-0.52	0.23
42	JGK 1 X Phule G 5	0.18*	-0.04	0.21	0.55	2.88	-2.20	-0.49	0.72	-1.73	2.87*
43	JGK 1 X ICCV 10	-0.16*	0.03	0.18	1.51**	6.83	10.24**	2.33	3.27**	-0.54	-1.18
44	JGK 1 X Subhra	-0.01	-0.03	-0.67	-0.29	4.19	7.34**	2.64*	0.04	0.90	-4.58**
45	JGK 1 X BG 5058	-0.01	-0.03	0.05	-0.82	-7.38*	-8.00**	-1.69	-1.50*	1.90	2.65*
46	KAK 2 X BG 372	-0.12	-0.07	-0.18	0.86	-2.07	0.11	-1.27	-0.24	-0.66	-0.50
47	KAK 2 X Phule G 5	-0.07	-0.03	-0.91	0.00	-3.32	-1.04	-1.82	-1.12	-1.36	-2.20
48	KAK 2 X ICCV 10	-0.02	0.05	0.71	-0.15	7.26	1.30	1.20	0.69	-2.47	0.76
49	KAK 2 X Subhra	0.00	-0.01	1.19*	0.75	-3.98	-1.50	1.65	1.19	5.63**	4.73**
50	KAK 2 X BG 5058	0.20*	0.05	-0.81	-1.46*	2.12	1.13	0.24	-0.53	-1.13	-2.79*
	SE (S_i)	0.07	0.07	0.44	0.44	2.78	1.73	0.97	0.54	1.10	0.92
	SEd (Sij - Sik)	0.14	0.16	0.92	0.93	5.83	3.63	2.03	1.14	2.31	1.93

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

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 JGK 1, ICCV 05107 and HC 3 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), Subhra was the best combiner for 100 seed weight, biological yield per plant, grain yield per plant and some other characters. Out of 50 crosses studied, the most promising crosses were *viz.***,** ICCV 05107 x Subhra, JGK 1 x Subhra, JGK 1 x ICCV 10, HK 94-134 x BG 5058 in timely sown and ICCV 05107 x Subhra, JGK 1 x ICCV 10, HC 3 x Subhra, HC 3 x Phule G 5 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.

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