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Combining ability for yield attributing traits in wheat (*Triticum aestivum* L.)

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Abstract
Twelve lines were crossed with 4 testers in line x tester fashion to determine the general and specific combining ability for yield and yield contributing traits in wheat. The extent of GCA was higher than SCA for all the characters. Variances due to line x tester showed highly significant differences for all the ten characters in F_1 and F_2 except days to maturity, number of effective tillers per plant and harvest index in F_1. Variances due to line were highly significant for all the characters in both F_1 and F_2 generations, whereas, due to testers were found non-significant except for number of spikelet's per spike and number of grains per spike in F1 only. The significant and positive gca effects for seed yield per plant were exhibited by six lines and one tester which in order of merit among lines were HD 2733, NW 5054, K 9006 and HD 2824 in both F_1 and F_2, respectively and among the testers NW 1014 in F_1 generation only. On the basis of gca effects and mean performance, parent HPW 355 was found good combiner for grain yield per plant along with days to 50 per cent flowering, days to maturity, plant height, number of effective tillers per plant, number of grains per spike and 1000 grain weight in both F_1 and F_2 and Parent NW 5054 for days to 50 per cent flowering, days to maturity, plant height, grain yield per plant and biological yield per plant in both the generations. Out of 48 crosses studied, the most promising crosses were *viz.***,** NW 5054 X K 911, NW 1012 X KRL 210 and K 9006 X NW 1014 in F_1 and HPW 355 X NW 1014, NW 4108 X KRL 210 and K 9107 X NW 1067 in F_2 showed significant & positive sca effects for seed yield per plant as well as some other yield components.

Keywords: General combining ability, Specific combing ability, ANOVA, hybrids, Triticum aestivum L.

Introduction
Wheat is an important cereal of the world and a staple food in India. It plays a remarkable role in meeting the food requirements of the country. A feasible strategy to achieve quantum jump in the yield of wheat (*Triticum aestivum* L.) is the commercial production of hybrid varieties. The exploitation of heterosis in wheat can be accomplished through the vigorous parental line and their subsequent evaluation for combining ability in cross combination to identify hybrid with high heterotic effect. For this purpose, basic knowledge of genetic architecture of yield and yield components and nature of gene action is required. Among various genetic techniques, combining ability analysis developed by Kempthorne [1] provides important information for selection of parents in terms of the performance of their hybrids. Further it elucidates the nature and magnitude of various types of gene actions involved in the expression of quantitative characters. Combining ability has been defined and categorized originally by Spargue and Tatum [2] who described that high general combining ability (GCA) effects were due to additive type of gene action, whereas high specific combining ability (SCA) indicated non-additive gene effects.
Therefore the present studies conducted to assess the relative magnitude of GCA and SCA for yield and yield contributing traits and to select the best combiner for successful wheat hybridization.

Materials and Methods
The experiment was conducted at Main Experiment Station of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) during *rabi,* 2014-15 on 112 treatments (48 F_1's + 48 F_2's + 16 parents) in Randomized Block Design with three replications in a single row (F_1's), 2 rows (parents) and 4 rows (F_2's) in plot of 3 m length with inter and intra-row spacing of 23 cm and 10 cm, respectively. On the basis of 15 randomly selected plants, data were recorded on days to 50 % flowering, days to maturity, plant height (cm), number of effective tillers per plant, number of spikelet's per spike, number of grains per spike, 1000-grain weight (Test Weight) (g), biological yield per plant (g), harvest index (%)

and grain yield per plant (g). 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 [1].

Results and Discussion

Analysis of variances for combining ability in F_1 and F_2 is presented in (Table: 1) respectively. Analysis of variances for combining ability revealed that variances due to lines x testers showed highly significant differences for all the ten characters in F_1 and F_2 except days to maturity, number of effective tillers per plant and harvest index in F_1. Variances due to line were highly significant for all the characters in both F_1 and F_2 generations, whereas, variances due to testers were found non-significant for all the characters except for number of spikelets per spike and number of grains per spike in F1 only. Similar finding were reported by Srivastava *et al.* [2], Lohithaswa *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 six lines and one tester which in order of merit were HD 2733, NW 5054, K 9006 and HD 2824 among lines in both F_1 and F_2, respectively and NW 1014 among the testers in F_1 generation. On the basis of gca effects and mean performance, parent HPW 355 was found good combiner for grain yield per plant along with days to 50 per cent flowering, days to maturity, plant height, number of effective tillers per plant, number of grains per spike and 1000 grain weight in both generations whereas, biological yield per plant and number of spikelets per spike in F_2.only.. Parent NW 5054 for days to 50 per cent flowering, days to maturity, plant height, grain yield per plant and biological yield per plant in both the generations *viz.*, F_1 and F_2. Among testers NW 1014 was found good general combiner for number of spikelets per spike and number of grains per spike in both F_1 and F_2 and for grain yield per plant in F_1 only. Similar finding were reported by Zalewski [6], Hassani *et al.* [7], Adel *et al.* [8], Vanpariya *et al.* [9]

Specific combining ability: The estimates of sca effects of 48 crosses in F_1 and F2 for 10 characters are given in (Table: 3). Out of 48 crosses studied, the most promising crosses were *viz.*, NW 5054 X K 911 (1.84), NW 1012 X KRL 210 (1.45), K 9006 X NW 1014 (1.43), PBW 443 X NW 1067 (1.30), K 9107 X NW 1067 (1.17) in F_1 and HPW 355 X NW 1014 (1.31), NW 4108 X KRL 210 (0.84), K 9107 X NW 1067 (0.76), NW 1012 X KRL 210 (0.65) and K 307 X K 911 (0.63) in F_2 showed significant & positive sca effects for seed yield per plant as well as some other yield components. According to Kenga *et al.* (2004), 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 Pancholi *et al.* [10], Lohithaswa *et al.* (2013) Jain and Sastry [11], Seelam *et al.* [12].

In the present study the cross PBW 443 X KRL 210 was the most promising as it had high significant sca effects for with days to 50% flowering, plant height, number of spikelets per spike, number of grains per spike, K 9107 X KRL 210 for number of plant height, number of effective tillers per plant, number of spikelets per spike and number of grains per spike, NW 5054 X K 911 for plant height, biological yield per plant, grain yield per plant and harvest index, HPW 355 X KRL 210 for days to 50 per cent flowering and days to maturity, NW 1012 X KRL 210 for days to maturity, biological yield per plant and grain yield per plant, K 9107 X KRL 210 for plant height, number of spikelets per spike and number of grains per spike, in F_1 and HPW 355 X KRL 210 for days to maturity and plant height, NW 4108 X KRL 210 for plant height, grain yield per plant, number of spikelets per spike, HPW 355 X NW 1014 for grain yield per plant, biological yield per plant and days to 50 per cent flowering in F_2. Similar finding was reported by Awasthi *et al.* [13], Dhadhal *et al.*[15], Vanpariya *et al.* [9] Seelam *et al.* [12].

Table 1: Analysis of variance for combining ability for 10 characters in L x T mating design in wheat (F_1&F_2).

Characters D.F.	Sources of variation											
	Replications		Crosses		Lines		Testers		Lines x testers		Error	
	2		47		11		3		33		94	
Generation	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Days to 50% flowering	1.00	1.92	21.54**	20.76**	74.53**	80.60**	6.62	0.78	5.23**	2.63*	1.11	1.15
Days to maturity	0.81	0.53	84.00**	74.99**	339.74**	315.26**	6.41	1.88	5.80	1.56	1.11	1.14
Plant height (cm)	2.83	0-.67	231.66**	261.76**	954.29**	1080.71**	9.61	3.31	10.97**	12.27**	1.58	2.13
Effective tillers per plant	0.61	0.00	2.13**	0.69**	5.14**	1.77**	3.39	0.07	1.01	0.38*	0.27	0.17
Spikelets per spike	0.32	0.15	8.06**	3.61**	21.77**	9.17**	18.03**	3.17	2.59**	1.80**	0.46	0.24
Grains per spike	0.53	0.09	44.16**	15.98**	113.26**	35.05*	93.68*	10.94	16.62**	10.08**	3.60	2.05
1000 seed weight (g)	0.30	0.30	29.74**	23.41**	118.52**	96.67**	1.42	1.69	2.72**	0.96**	0.29	0.26
Biological yield per plant (g)	18.79	0.84	49.56**	23.60**	146.56**	77.53**	12.20	7.10	20.62**	7.13*	7.46	3.38
Seed yield per plant (g)	1.00	0.31	7.13**	3.76**	22.00**	12.48**	2.12	1.41	2.64**	1.07**	0.63	0.29
Harvest index (%)	1.38	1.50	2.21	3.04**	2.10	3.31	0.47	2.51	2.40	3.00**	1.44	1.13

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

Table 2: Estimates of GCA effects of parents (females and males) for 10 characters in wheat (F_1&F_2).

S. No.	Lines	Days to 50% flowering		Days to maturity		Plant hight (cm)		Effective Tillers per plant	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1	HD-2733	-0.10	0.67	-2.98**	-0.62	2.97**	3.20**	-0.43*	-0.42**
2	NW 5054	2.98**	3.17**	7.44**	4.13**	3.78**	6.29**	0.53**	0.17
3	HPW 355	1.48**	3.76**	3.94**	5.97**	21.56**	22.09**	0.85**	0.52**
4	PBW 443	0.23	-0.66	-2.31**	-1.78**	-8.07**	-7.85**	0.03	0.00
5	NW 1012	1.98**	-1.91**	-3.56**	-6.28**	-1.94**	-2.72**	-0.35	-0.07
6	K 307	0.73	-0.74	-3.40**	-1.45**	-8.00**	-8.11**	-0.18	-0.50**

7	K 9107	-2.44**	-3.49**	-2.81**	-2.95**	0.93	-1.61**	-0.16	-0.35*
8	K 9006	1.40**	2.17**	10.85**	10.47**	-0.51	-0.22	0.15	0.48**
9	DBW 17	0.65	-1.33**	-3.90**	-3.62**	-14.11**	-15.66**	1.33**	0.67**
10	K 8027	-0.77	-2.16**	-3.23**	-3.62**	6.86**	7.84**	-0.97**	-0.18
11	HD 2824	-6.60**	-2.99**	-5.06**	-4.95**	-1.05	-0.39	-0.02	-0.05
12	NW 4108	0.48	3.51**	5.02**	4.72**	-2.43**	-2.86**	-0.78**	-0.26
	SE(gi) lines	0.44	0.43	0.44	0.44	0.57	0.59	0.20	0.17
	Testers								
1	K 911	-0.55*	-0.19	-0.62**	-0.26	-0.52	-0.07	-0.41**	-0.01
2	NW 1067	0.37	0.01	0.27	0.30	0.44	0.29	-0.01	-0.01
3	NW 1014	-0.13	0.17	0.08	-0.03	0.45	-0.40	0.32	0.06
4	KRL 210	0.31	0.01	0.27	-0.01	-0.37	0.17	0.10	-0.05
	SE(gj) tester	0.25	0.25	0.25	0.25	0.33	0.34	0.11	0.09

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S.No.	**Lines**	**Spikelets per spike**		**Grains per spike**		**1000 seed weight**		**Biological yield per plant**	
		F_1	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
1	HD-2733	-0.08	0.16	0.21	0.50	-1.22**	-0.96**	2.64**	1.41*
2	NW 5054	0.12	-0.13	0.55	-0.50	-6.04**	-5.19**	2.72**	2.91**
3	HPW 355	0.49	1.61**	1.99**	2.71**	1.32**	1.37**	2.87**	0.61
4	PBW 443	-0.64*	-0.34	-1.45	-1.35*	-3.18**	-3.23**	0.90	1.15
5	NW 1012	1.44**	1.12**	3.55**	2.33**	-0.16	-0.68**	0.06	1.44*
6	K 307	1.27**	-0.10	2.84**	-0.35	-1.02**	-0.79**	-2.06*	-1.36
7	K 9107	-1.84**	-1.91**	-3.85**	-3.60**	6.49**	6.06**	-4.37**	-2.37**
8	K 9006	1.72**	0.41	3.68**	1.17*	2.08**	2.22**	2.01*	2.30**
9	DBW 17	0.31	-0.48*	-0.95	-0.98	0.39	0.77**	-4.74**	-4.31**
10	K 8027	-2.11**	0.06	-5.13**	0.21	1.51**	-0.04	-6.35**	-4.61**
11	HD 2824	-1.83**	-0.56**	-3.88**	-0.95	-2.19**	-1.34**	3.82**	1.76*
12	NW 4108	1.16**	0.17	2.45**	0.82	2.01**	1.82**	2.50**	1.09
	SE(gi) lines	0.27	0.22	0.79	0.59	0.22	0.20	1.01	0.74
	Testers								
1	K 911	-0.89**	-0.36**	-1.97**	-0.64**	-0.16	-0.30**	-0.38	-0.63
2	NW 1067	-0.24	0.09	-0.63	0.12	0.28*	0.21	0.08	0.03
3	NW 1014	0.49**	0.35**	1.04*	0.68**	0.01	0.00	0.79	0.24
4	KRL 210	0.64**	-0.08	1.56**	-0.15	-0.13	0.09	-0.49	0.36
	SE (gj) tester	0.16	0.13	0.45	0.34	0.13	0.12	0.58	0.43

S.No.	**Lines**	**Grain yield per plant**		**Harvest index**	
		F_1	**F_2**	**F_1**	**F_2**
1	HD-2733	0.75**	0.55**	-0.65	-0.17
2	NW 5054	1.22**	1.26**	0.35	0.30
3	HPW 355	1.08**	0.38	-0.29	0.49
4	PBW 443	0.46	0.40	0.30	-0.31
5	NW 1012	-0.16	0.42*	-0.50	-0.84*
6	K 307	-0.71**	-0.71**	0.27	-0.77
7	K 9107	-1.61**	-1.03**	0.62	-0.11
8	K 9006	0.90**	0.97**	0.10	0.14
9	DBW 17	-1.97**	-1.65**	-0.33	0.62
10	K 8027	-2.40**	-1.75**	0.53	0.74
11	HD 2824	1.47**	0.80**	-0.26	0.35
12	NW 4108	0.99**	0.36	-0.14	-0.44
	SE(gi) lines	0.29	0.21	0.48	0.43
	Testers				
1	K 911	-0.18	-0.25*	-0.10	-0.05
2	NW 1067	0.07	-0.06	0.16	-0.27
3	NW 1014	0.31*	0.18	-0.05	0.36
4	KRL 210	-0.20	0.13	-0.02	-0.04
	SE (gj) testers	0.17	0.12	0.27	0.25

Table 3: Estimates of SCA effects of crosses for 11 characters in wheat (F_1&F_2)

S. No.	**Crosses**	**Daya to 50% flowering**		**Days to maturity**		**Plant height (cm)**		**Effective tillers per plant**	
		SCA		**SCA**		**SCA**		**SCA**	
		F_1	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
1	HD-2733 x K 911	0.63	1.27*	0.53	-0.08	0.61	-1.80*	-0.06	-0.19
2	HD-2733 x NW 1067	0.38	0.74	1.98**	0.70	3.24**	1.28	0.28	0.08
3	HD-2733 x NW 1014	-1.45*	-0.76	-2.16**	-1.63*	-0.73	1.36	-0.72*	-0.13
4	HD-2733 x KRL 210	0.44	-1.26*	-0.35	1.01	-3.12**	-0.84	0.50	0.25
5	NW 5054 x K 911	0.88	0.44	-1.55*	0.84	3.37**	2.54**	0.11	0.22
6	NW 5054 x NW 1067	-0.70	0.58	-0.77	-0.72	-1.98*	-1.53	0.25	0.16

7	NW 5054 x NW 1014	-0.87	-0.26	0.76	-0.05	-3.63**	-3.28**	-0.56	-0.44
8	NW 5054 x KRL 210	0.69	-0.76	1.56*	-0.08	2.24**	2.27**	0.20	0.06
9	HPW 355 x K 911	1.05	-0.48	0.62	-0.33	-2.71**	-3.09**	-0.21	0.41
10	HPW 355 x NW 1067	0.13	0.33	-1.60*	0.45	-1.09	-0.02	-0.20	-0.19
11	HPW 355 x NW 1014	0.63	-0.51	-0.74	1.12	2.25**	-0.70	0.39	0.34
12	HPW 355 x KRL 210	-1.81**	0.66	1.73**	-1.24*	1.55	3.80**	0.02	-0.55*
13	PBW 443 x K 911	-0.70	0.27	-0.47	0.09	-1.74*	-0.27	-0.12	-0.01
14	PBW 443 x NW 1067	1.05	-0.59	-0.02	-1.13	-0.33	-2.30**	-0.32	0.26
15	PBW 443 x NW 1014	2.22**	-0.42	1.84**	0.20	-0.32	1.32	0.68*	-0.01
16	PBW 443 x KRL 210	-2.56**	0.74	-1.35*	0.84	2.40**	1.25	-0.23	-0.24
17	NW 1012 x K 911	1.22	-0.15	1.12	0.26	0.93	0.20	0.59*	0.46
18	NW 1012 x NW 1067	1.63*	0.66	-0.77	-0.30	1.45	1.01	0.33	-0.27
19	NW 1012 x NW 1014	-1.87**	-0.17	1.76**	0.70	-0.45	-1.50	-0.21	-0.08
20	NW 1012 x KRL 210	-0.98	-0.34	-2.10**	-0.66	-1.93*	0.28	-0.72*	-0.10
21	K 307 x K 911	-0.20	-0.98	0.28	0.09	-0.13	2.25**	-0.31	-0.31
22	K 307 x NW 1067	-0.78	-0.17	-1.60*	-0.13	0.87	0.55	0.23	-0.04
23	K 307 x NW 1014	0.72	1.33*	0.26	0.20	1.33	-0.69	0.16	0.22
24	K 307 x KRL 210	0.27	-0.17	1.06	-0.16	-2.07*	-2.12*	-0.08	0.13
25	K 9107 x K 911	-1.70**	-0.56	-0.30	-0.41	-1.69*	1.60	-0.03	0.27
26	K 9107 x NW 1067	-1.28*	0.58	-0.19	-0.30	-1.24	0.58	0.27	0.14
27	K 9107 x NW 1014	1.55*	-0.59	-0.33	0.03	0.20	-2.82**	0.93**	0.01
28	K 9107 x KRL 210	1.44*	0.58	0.81	0.67	2.74**	0.64	-1.17**	-0.42
29	K 9006 x K 911	1.13	-0.56	0.37	-0.16	1.19	-0.87	0.36	-0.56*
30	K 9006 x NW 1067	-0.12	1.91**	0.48	0.95	-0.63	-0.51	0.96**	0.44
31	K 9006 x NW 1014	-1.28*	0.08	-0.33	-0.38	2.04*	1.09	-1.24**	-0.36
32	K 9006 x KRL 210	0.27	-1.42*	-0.52	-0.41	-2.60**	0.29	-0.08	0.48*
33	DBW 17 x K 911	-1.45*	0.60	-0.55	-0.41	0.04	-1.91*	0.31	0.26
34	DBW 17 x NW 1067	-0.37	-1.92**	-0.10	0.70	-0.27	0.86	-0.82**	-0.21
35	DBW 17 x NW 1014	0.47	0.58	0.09	0.03	-0.13	2.64**	0.11	-0.08
36	DBW 17 x KRL 210	1.35*	0.74	0.56	-0.33	0.36	-1.59	0.40	0.03
37	K 8027 x K 911	-0.70	0.10	-0.22	0.92	0.57	-1.25	-0.26	-0.16
38	K 8027 x NW 1067	0.38	-1.42*	0.56	-0.30	-0.46	0.81	-0.32	0.18
39	K 8027 x NW 1014	-0.78	1.08	-1.58*	-0.30	-0.23	2.55**	0.14	-0.23
40	K 8027 x KRL 210	1.10	0.24	1.23	-0.33	0.12	-2.11*	0.43	0.21
41	HD 2824 x K 911	-0.20	0.27	-0.38	-0.08	-0.43	0.33	-0.54	-0.03
42	HD 2824 x NW 1067	-0.78	-0.26	0.40	0.37	0.85	-1.60	0.06	-0.22
43	HD 2824 x NW 1014	1.72**	0.24	2.26**	-0.30	-0.09	0.93	0.46	0.64**
44	HD 2824 x KRL 210	-0.73	-0.26	-2.27**	0.01	-0.34	0.34	0.02	-0.39
45	NW 4108 x K 911	0.05	-0.23	0.53	-0.74	-0.01	2.26**	0.15	-0.35
46	NW 4108 x NW 1067	0.47	-0.42	1.65*	-0.30	-0.42	0.87	-0.71*	-0.32
47	NW 4108 x NW 1014	-1.03	-0.59	-1.83**	0.37	-0.24	-0.91	-0.15	0.11
48	NW 4108 x KRL 210	0.52	1.24*	-0.35		0.66	-2.22**	0.71*	0.55*
	SE (S_i)	0.62	0.61	0.63	0.62	0.80	0.84	0.28	0.23
	SE (Sij - Sik)	1.59	1.55	1.60	1.58	2.05	2.13	0.72	0.60

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S. No.	Crosses	No. of spikelets per spike		No.of grains per spike		1000 seed weight	
		SCA		SCA		SCA	
		F_1	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
1	HD-2733 x K 911	0.67	0.38	2.20	0.64	1.41**	-0.30
2	HD-2733 x NW 1067	0.29	0.77*	0.00	0.72	-1.13**	0.79**
3	HD-2733 x NW 1014	-0.91*	-0.26	-2.80*	-0.31	-1.64**	-1.10**
4	HD-2733 x KRL 210	-0.06	-0.90**	0.60	-1.05	1.36**	0.60*
5	NW 5054 x K 911	0.81*	0.01	1.13	0.44	-0.74*	-0.90**
6	NW 5054 x NW 1067	-0.51	0.50	-1.17	0.82	0.93**	-0.54
7	NW 5054 x NW 1014	0.29	0.03	0.80	0.69	-0.72*	1.18**
8	NW 5054 x KRL 210	-0.59	-0.54	-0.76	-1.95*	0.53	0.26
9	HPW 355 x K 911	0.91*	2.08**	2.02	6.24**	-0.92**	-0.23
10	HPW 355 x NW 1067	0.19	0.03	1.00	0.31	1.19**	0.04
11	HPW 355 x NW 1014	-0.01	-0.37	-0.11	-2.39**	0.86**	0.58*
12	HPW 355 x KRL 210	-1.09**	-1.74**	-2.91*	-4.16**	-1.13**	-0.40
13	PBW 443 x K 911	1.04**	-0.11	4.18**	-0.41	-0.35	-0.07
14	PBW 443 x NW 1067	0.86*	0.05	0.64	0.00	-0.06	-0.02
15	PBW 443 x NW 1014	-0.01	0.65*	-0.08	1.31	0.68*	-0.01
16	PBW 443 x KRL 210	-1.89**	-0.59	-4.74**	-0.90	-0.28	0.10
17	NW 1012 x K 911	-0.78*	-0.11	-1.00	-0.76	0.37	0.46
18	NW 1012 x NW 1067	0.58	-0.62	1.31	-1.72*	1.00**	0.53
19	NW 1012 x NW 1014	-0.03	0.12	-0.17	0.39	0.21	-0.59*
20	NW 1012 x KRL 210	0.23	0.61	-0.13	2.08*	-1.59**	-0.41

21	K 307 x K 911	-0.74	-0.32	-2.44*	-1.07	-0.42	-0.11
22	K 307 x NW 1067	0.28	0.21	1.49	0.74	-0.29	0.28
23	K 307 x NW 1014	0.61	0.74*	1.53	1.48	-0.03	0.01
24	K 307 x KRL 210	-0.14	-0.63*	-0.58	-1.15	0.75*	-0.18
25	K 9107 x K 911	-0.29	0.59	-1.52	0.21	-0.80*	-0.40
26	K 9107 x NW 1067	-0.21	-0.99**	-0.43	-1.85*	0.24	0.10
27	K 9107 x NW 1014	-1.01*	-0.25	-3.14**	0.22	-0.26	0.31
28	K 9107 x KRL 210	1.51**	0.64*	5.09**	1.42	0.82*	-0.02
29	K 9006 x K 911	-0.26	-0.32	-1.11	-0.32	0.13	0.33
30	K 9006 x NW 1067	-0.04	0.10	0.27	0.45	0.11	0.30
31	K 9006 x NW 1014	-0.78*	0.43	-1.13	0.56	-0.65*	-0.93**
32	K 9006 x KRL 210	1.08**	-0.21	1.97	-0.68	0.41	0.31
33	DBW 17 x K 911	-1.91**	-0.84**	-3.26**	-1.24	0.41	0.42
34	DBW 17 x NW 1067	-0.42	-0.42	-0.29	-0.43	-1.29**	-1.09**
35	DBW 17 x NW 1014	0.64	0.18	0.27	-0.36	0.25	0.60*
36	DBW 17 x KRL 210	1.69**	1.08**	3.29**	2.03*	0.64*	0.07
37	K 8027 x K 911	0.91*	-0.51	2.14	-1.70*	-0.49	0.24
38	K 8027 x NW 1067	-0.67	0.11	-1.96	0.41	0.20	-0.23
39	K 8027 x NW 1014	-0.28	-0.42	0.00	0.05	1.45**	-0.07
40	K 8027 x KRL 210	0.04	0.81*	-0.19	1.24	-1.15**	0.06
41	HD 2824 x K 911	0.02	-0.56	-0.58	-1.01	0.79*	0.63*
42	HD 2824 x NW 1067	0.31	0.06	0.64	0.10	-0.68*	-0.18
43	HD 2824 x NW 1014	0.44	-0.07	2.26*	-0.53	-0.44	-0.30
44	HD 2824 x KRL 210	-0.77*	0.56	-2.32*	1.43	0.33	-0.15
45	NW 4108 x K 911	-0.36	-0.29	-1.76	-1.04	0.63	-0.09
46	NW 4108 x NW 1067	-0.67	0.20	-1.50	0.47	-0.22	0.02
47	NW 4108 x NW 1014	1.06**	-0.80*	2.57*	-1.09	0.27	0.32
48	NW 4108 x KRL 210	-0.02	0.89**	0.69	1.67*	-0.68*	-0.25
	SE (S_i)	0.38	0.31	1.16	0.84	0.32	0.29
	SE (Sij - Sik)	0.92	0.80	2.85	2.14	0.81	0.74

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S. No.	Crosses	Biological yield per plant		Grain yield per plant		Harvest index	
		SCA		SCA		SCA	
		F_1	F_2	F_1	F_2	F_1	F_2
1	HD-2733 x K 911	-1.88	-0.57	-0.68	-0.26	-0.19	-0.35
2	HD-2733 x NW 1067	0.74	0.96	0.42	0.17	0.68	-0.91
3	HD-2733 x NW 1014	-1.62	-0.61	-0.76	-0.01	-0.38	1.08
4	HD-2733 x KRL 210	2.76	0.22	1.01*	0.09	-0.11	0.17
5	NW 5054 x K 911	6.43**	-0.15	1.84**	0.08	-2.04**	0.58
6	NW 5054 x NW 1067	-4.68**	-1.27	-1.51**	-0.44	1.04	0.22
7	NW 5054 x NW 1014	-0.87	0.53	-0.14	0.26	0.69	0.26
8	NW 5054 x KRL 210	-0.88	0.89	-0.19	0.10	0.31	-1.06
9	HPW 355 x K 911	-0.09	0.20	0.09	0.10	0.28	0.27
10	HPW 355 x NW 1067	1.44	-0.99	0.03	-0.56	-1.70*	-0.94
11	HPW 355 x NW 1014	-1.40	2.52*	-0.28	1.31**	1.07	1.39*
12	HPW 355 x KRL 210	0.04	-1.74	0.17	-0.85**	0.35	-0.72
13	PBW 443 x K 911	-2.85*	-0.24	-1.02*	-0.11	0.46	0.05
14	PBW 443 x NW 1067	3.96**	-0.15	1.30**	0.08	-1.04	0.57
15	PBW 443 x NW 1014	0.90	1.77	0.46	0.35	0.26	-1.64**
16	PBW 443 x KRL 210	-2.01	-1.38	-0.74	-0.32	0.32	1.03
17	NW 1012 x K 911	-0.04	-0.80	0.42	-0.13	1.87**	1.01
18	NW 1012 x NW 1067	-1.73	-2.04	-0.93*	-0.97**	-1.03	-0.97
19	NW 1012 x NW 1014	-2.08	1.72	-0.94*	0.45	-0.36	-0.99
20	NW 1012 x KRL 210	3.85**	1.12	1.45**	0.65*	-0.49	0.95
21	K 307 x K 911	1.31	1.73	0.43	0.63*	-0.37	-0.38
22	K 307 x NW 1067	-2.77	-0.61	-0.81	0.12	1.08	1.73**
23	K 307 x NW 1014	1.41	-1.58	0.41	-0.64*	-0.48	0.31
24	K 307 x KRL 210	0.06	0.45	-0.02	-0.11	-0.22	-1.67**
25	K 9107 x K 911	-0.94	-0.30	-0.20	-0.02	0.59	0.36
26	K 9107 x NW 1067	3.36*	2.55*	1.17**	0.76*	-0.93	-0.46
27	K 9107 x NW 1014	-2.61	-2.59*	-0.90*	-0.93**	0.40	-0.32
28	K 9107 x KRL 210	0.20	0.34	-0.07	0.18	-0.05	0.41
29	K 9006 x K 911	0.74	0.57	0.47	0.25	0.44	0.19
30	K 9006 x NW 1067	-2.32	-0.94	-0.95*	-0.35	-0.10	0.20
31	K 9006 x NW 1014	3.87**	0.62	1.43**	0.10	-0.34	-0.77
32	K 9006 x KRL 210	-2.29	-0.25	-0.94*	0.00	0.00	0.39
33	DBW 17 x K 911	-1.01	-0.78	-0.19	-0.43	0.75	-0.59
34	DBW 17 x NW 1067	-0.41	-0.50	-0.03	-0.30	0.44	-0.79

35	DBW 17 x NW 1014	2.22	0.48	0.64	0.31	-0.84	0.87
36	DBW 17 x KRL 210	-0.80	0.80	-0.42	0.41	-0.35	0.51
37	K 8027 x K 911	0.33	0.93	0.01	0.35	-0.56	-0.13
38	K 8027 x NW 1067	-0.23	0.62	0.28	0.46	1.49*	1.15
39	K 8027 x NW 1014	-0.94	-1.43	-0.58	-0.70*	-0.72	-0.50
40	K 8027 x KRL 210	0.84	-0.13	0.29	-0.11	-0.22	-0.52
41	HD 2824 x K 911	1.23	1.34	0.30	0.21	-0.63	-1.55*
42	HD 2824 x NW 1067	2.00	1.82	0.86*	0.63*	0.26	-0.56
43	HD 2824 x NW 1014	-0.51	-0.44	-0.15	0.04	0.10	1.00
44	HD 2824 x KRL 210	-2.72	-2.71*	-1.01*	-0.88**	0.26	1.12
45	NW 4108 x K 911	-3.24*	-1.94	-1.48**	-0.69*	-0.60	0.54
46	NW 4108 x NW 1067	0.66	0.55	0.17	0.40	-0.20	0.76
47	NW 4108 x NW 1014	1.62	-0.99	0.82*	-0.55	0.59	-0.70
48	NW 4108 x KRL 210	0.97	2.38*	0.48	0.84**	0.20	-0.61
	SE (S_i)	1.43	1.05	0.41	0.30	0.67	0.61
	SE (Sij - Sik)	3.65	2.68	1.04	0.77	1.72	1.56

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

Conclusion:

The extent GCA was higher than SCA for all the characters 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 that 6 out of 12 lines and one out of four testers had high (H) overall general combining ability status suggesting their ability to transmit additive genes in the desirable direction for all the traits under study. Among the 12 lines HPW 355, NW 5054 and K 9006 were the best general combiners exhibited high gca effects each in desirable direction for most of the characters in both generations. Among the testers (male parents), NW 1014 was the best combiner for grain yield per plant and some other characters. Out of 48 crosses studied, the most promising crosses were ***viz*.,** NW 5054 X K 911, NW 1012 X KRL 210 and K 9006 X NW 1014 in F_1 and HPW 355 X NW 1014, NW 4108 X KRL 210 and K 9107 X NW 1067 in F_2 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.

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