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Combining ability for yield and its components under normal and sodic soil in barley (*Hordeum vulgare* L.)

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Abstract
Selection of parents based on their combining ability is an effective approach in hybrid breeding. In this study, The 13 parents were involved in a crossing programme line × tester set (10 lines + 3 testers) were used to obtain 30 crosses for analyzing the general combining ability (GCA) and specific combining ability (SCA) for days to 50% flowering, plant height, number of effective tillers /plant, number of spikelets /spike, number of grains/ spike, days to maturity, 1000- grain weight, biological yield / plant, grain yield / plant and harvest index. The results showed that GCA was significantly different among parents and SCA was also significantly different among crosses. The performance of hybrid was significantly correlated with the sum of female and male GCA, SCA. The significant and positive gca effects for seed yield per plant were exhibited by three lines and two tester which in order of merit were NDB 1245, DWRUB 64 and Karan 741 among lines and NDB 943 and BHS 352 among the testers in normal soil (E_1) while, two lines and two tester in saline sodic soil (E_2) which in order of merit were HUB 113 and NDB 1173 among lines and NDB 943 and BHS 352 among testers. significant desirable sca effects to yield in normal soil condition (E_1), were NDB 1465 X DWR 28 and NDB 1465 X NDB 943 for sodic soil (E_2).

Keywords: barley, SCA, GCA, grain yield, *Hordeum vulgare*

Introduction
Barley (*Hordeum vulgare* L. 2n=14, sub family Poaceae) an important winter *rabi* cereal rank fourth after wheat, rice and maize. Since time immemorial, Barley is considered as crop of rainfed and problematic soil conditions i.e. saline alkaline, drought and diara, marginal/coastal area of river. Barley florish well under less resource of irrigation and fertilizers. Thus, this crop has great elasticity of adaptation under various stress situations. Barley being essentially a temperate crop is grown mainly in Russia, China, United States, Africa, France, Canada, USA, Spain, Australia, Germany, Syria, Netherland and Ireland. In India, it is grown to a limited area particularly in States of Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, Bihar, Himanchal Pradesh, Uttarakhand and Jammu & Kashmir. Barley production has been estimated at 1.73 million tonnes from 0.66 million hectares with an average national productivity of 2617 kg/ha.
India has about 6.6 lacs ha area with production of 17.3 lacs metric tonnes and productivity of 26.17 q/ha (2018-19) Annonymous (2019) [1]. In Uttar Pradesh, barley occupied an area of 1.67 lacs ha with a total production of 4.81 lacs mt with productivity of 28.80 q/ha (2014). Uttar Pradesh alone contributes more than one fourth of India's total production of barley. The heterosis breeding has been extensively utilized in improving yield particularly in allogamous crops. The combining ability concept is the most important and efficient tool for choosing the desirable parents capable of providing crosses of high genetic worth. The extent of hybrid vigour depends upon the combining ability of genotypes/varieties used in crosses. The varieties which are capable for transmitting desirable characters or hybrid vigour in their offspring or cross are said to be having good combining ability.

Materials and methods
The present study was carried out during *Rabi* seasons of 2014-15 & 2015-2016 at Genetics and Plant Breeding Research Farm of Narendra Deva University of Agriculture & Technology

Narendra Nagar (Kumarganj), Faizabad. The experimental materials comprised of thirteen genetically diverse varieties/strains and their 30 crosses. The 13 parents were involved in a crossing programme to develop a line × tester set (10 lines + 3 testers) during *Rabi* season of 201-2015. The experimental material was evaluated in Randomized Block design (RBD) with three replications in two environments i.e. under normal fertile soil and saline sodic soil condition. The observations were recorded on ten characters, namely, days to 50% flowering, plant height, number of effective tillers /plant, number of spikelets /spike, number of grains/ spike, days to maturity, 1000- grain weight, biological yield / plant, grain yield / plant and harvest index. The data from 30 crosses obtained by crossing 10 lines with three testers (NDB-943, BHS-352 and DWR 28) along with parents formed the line × testers set which was utilized for estimation of heterosis over better parent and standard variety.

Statistical analysis

The model of Kempthorne (1957) [3] was used for estimating the GCA and SCA effects in combining ability in which is as follows:

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

Where,

μ = general mean

g_i = GCA effect of the i^{th} male (tester); i = 1,2…….m ;

g_j = GCA effect of the j^{th} female (line); j = 1,2…….f ;

S_{ij} = SCA effect of the ij^{th} combination; and

e_{ijk} = Error associated with the observation X_{ijk}; k = 1, 2…..r.

Result and discussion

Positive and significant GCA effects in the desirable direction for grain yield per plant were showed by NDB 1245 (0.74), DWRUB 64 (0.55) and Karan 741 (0.45) among lines. Among males, NDB 943 (0.57) and BHS 352 (0.20) showed significant and positive GCA effect under normal soil condition (E_1). Positive and significant GCA effects in the desirable direction for grain yield per plant were showed by HUB 113 (0.60) and NDB 1173 (0.30) among lines. Among males, NDB 943 (0.25) and BHS 352 (0.15) showed significant and positive GCA effect under saline sodic soil condition (E_2).

Out of thirty crosses, eight crosses combinations showed significant and positive sca effect. The best five crosses were NDB 1465 X DWR 28 (2.07), HUB 113 X BHS 352 (1.70), Karan 741 X DWR 28 (1.35), NDB 1245 X NDB 943 (1.15), and DWRUB 64 X NDB 943 (1.10). Eight crosses exhibited significant and negative sca effect in normal soil condition (E_1).

In case of saline soil condition (E_2) six crosses combinations, showed positive and significant sca effect where as ten cross combination, registered negative and significant sca effect, The desirable cross combinations, which could be sorted out, were NDB 1465 X NDB 943 (1.19), RD 2794 X BHS 352 (0.97), NDB 1245 X NDB 943 (0.78), BH 902 X BHS 352 (0.75) and Azad X DWR 28 (0.66).

A perusal of Table 1 and 2 on the basis of gca effects and mean performance, parent Karan 741 was found good combiner for grain yield per plant along with days to 50% flowering, number of spikelets per spike, number of grains per spike and harvest index for normal soil (E_1) and number of grains per spike and biological yield per plant for saline sodic soil (E_2) and DWRUB 64 for grain yield per plant in addition to days to maturity, 1000 grains weight and harvest index in normal soil (E_1) and reduce to plant height in saline sodic soil (E_2) and NDB 1245 for grain yield per plant in addition to days to maturity, plant height and harvest index in normal soil (E_1) and reduce to plant height, days to 50% flowering and days to maturity and in addition to1000 grains weight in saline sodic soil (E_2). Parent NDB 1173 for days to 50% flowering, number of spikelets per spike, number of grains per spike, days to maturity and harvest index in normal soil (E_1) and for grain yield per plant with biological yield per plant in saline sodic soil (E_2) and HUB 113 for grain yield per plant with days to 50% flowering, plant height, number of spikelets per spike, number of grains per spike, biological yield per plant and harvest index in saline sodic soil (E_2).

NDB 943 was found good general combiner for grain yield per plant in addition to number of effective tillers per plant, number of spikelets per spike, number of grains per spike and harvest index in normal soil (E_1) and grain yield per plant in addition to days to 50% flowering, number of spikelets per spike, number of grains per spike, harvest index and reduce plant height for saline sodic soil (E_2) while, BHS 352 was found good general combiner for grain yield per plant in addition to plant height and biological yield per plant in normal soil (E_1) and grain yield per plant in addition to days to maturity, number of effective tillers per plant, harvest index and reduce days to 50% flowering for saline sodic soil (E_2).

The available literature also indicates significant and positive gca effects for seed yield and yield components in barley (Sayed *et al*. 2008, Bornare *et al*. 2013**,** Zhang *et al.* 2015 and Patial *et al.* 2016) [6, 2, 11, 4]. The above maintained lines and testers may be recommended for exploitation in hybridization programme aimed at improving the yield components for which they emerged as good general combiners.

A perusal of Table 3 and 4 the cross combinations which exhibited significant desirable sca effects in normal soil condition (E_1), were NDB 1245 X BHS 352 (-9.26), NDB 1465 X DWR 28 (-5.69), RD 2794 X BHS 352 (-5.01), Azad X BHS 352 (-4.63) and Karan 741 X NDB 943 (-4.27) for days to 50 per cent flowering; NDB 1245 X BHS 352 (-6.31), DWRUB 64 X DWR 28 (-5.64), NDB 1465 X DWR 28 (-4.72) and RD 2794 X BHS 352 (-4.63) for days to maturity, NDB 1173 X DWR 28 (10.89), BH 902 X NDB 943 (8.37), RD 2794 X DWR 28 (5.75), Karan 741 X BHS 352 (5.75), and NDB 1592 X BHS 352 (4.59) for plant height, Karan 741 X BHS 352 (0.92), Azad X BHS 352 (0.83), BH 902 X DWR 28 (0.80), NDB 1465 X NDB 943 (0.69) and RD 2794 X NDB 943 (0.67) for number of effective tillers/plant, HUB 113 X DWR 28 (4.19), NDB 1592 X BHS 352 (2.28), NDB 1245 X NDB 943 (2.07), DWRUB 64 X BHS 352 (2.03), and Azad X NDB 943 (1.92) for number of spikelets/ spike, HUB 113 X DWR 28 (8.42), NDB 1592 X BHS 352 (5.76), DWRUB 64 X BHS 352 (5.21), NDB 1245 X NDB 943 (4.89) and Azad X NDB 943 (4.57) for number of grains/ spike, NDB 1592 X NDB 943 (4.86), NDB 1245 X NDB 943 (3.28), DWRUB 64 X BHS 352 (2.86), Karan 741 X DWR 28 (2.52) and NDB 1173 X BHS 352 (2.47) for 1000-grain weight, HUB 113 X BHS 352 (5.55), NDB 1173 X NDB 943 (3.19), Karan 741 X DWR 28 (2.93), Azad X BHS 352 (2.69) and DWRUB 64 X NDB 943 (1.94) for biological yield, NDB 1465 X DWR 28 (2.07), HUB 113 X BHS 352 (1.70), Karan 741 X DWR 28 (1.35), NDB 1245 X NDB 943 (1.15), and DWRUB 64 X NDB 943 (1.10) for grain yield/plant, NDB 1465 X DWR 28 (4.87), BH 902 X DWR 28 (3.18), NDB 1173 X BHS 352 (2.80), NDB 1592 X BHS 352 (2.63) and NDB 1245 X NDB 943 (2.62) for harvest index.

Under saline sodic condition(E_2), the cross combinations which exhibited significant desirable sca effects were, HUB 113 X BHS 352 (-4.43), NDB 1465 X NDB 943 (-4.19), NDB 1173 X NDB 943 (-2.88), DWRUB 64 X DWR 28 (-2.74), and NDB 1173 X BHS 352 (-2.49) for days to 50 per cent flowering; NDB 1465 X NDB 943 (-2.94), Azad X NDB 943 (-2.57), RD 2794 X DWR 28 (-2.30), NDB 1592 X BHS 352 (-1.84) and Karan 741 X BHS 352 (-1.53) for days to maturity, NDB 1465 X BHS 352 (5.52), NDB 1245 X DWR 28 (4.80), NDB 1173 X NDB 943 (3.58), HUB 113 X BHS 352 (3.25) and DWRUB 64 X DWR 28 (2.81) for plant height, NDB 1245 X NDB 943 (0.67) for number of effective tillers/plant, NDB 1245 X NDB 943 (2.80), HUB 113 X DWR 28 (1.64), RD 2794 X BHS 352 (1.44), Azad X DWR 28 (1.33) and Karan 741 X BHS 352 (1.07) for number of spikelets/spike, NDB 1245 X NDB 943 (6.05), RD 2794 X BHS 352 (4.87), Azad X DWR 28 (3.66), HUB 113 X DWR 28 (3.71) and Karan 741 X BHS 352 (3.52) for number of grains/ spike, HUB 113 X BHS 352 (5.72), NDB 1173 X NDB 943 (5.25), NDB 1592 X NDB 943 (2.15), NDB 1245 X NDB 943 (1.76) and NDB 1465 X DWR 28 (1.63) for 1000-grain weight, Karan 741 X BHS 352 (3.49), DWRUB 64 X NDB 943 (2.72), NDB 1465 X BHS 352 (2.17), NDB 1245 X NDB 943 (1.68) and HUB 113 X DWR 28 (1.40) for biological yield, NDB 1465 X NDB 943 (1.19), RD 2794 X BHS 352 (0.97), NDB 1245 X NDB 943 (0.78), BH 902 X BHS 352 (0.75) and Azad X DWR 28 (0.66) for grain yield/plant, NDB 1465 X NDB 943 (7.18), BH 902 X BHS 352 (5.55), DWRUB 64 X BHS 352 (4.26), RD 2794 X BHS 352 (4.13) and Karan 741 X NDB 943 (3.31) for harvest index.

The sca effect of the crosses is an estimate for making selection of best cross combinations. High specific combining ability denotes, undoubtedly a high heterotic response, however this, does not mean high performance of the hybrids as well.

In general, maximum number of crosses which showed significant sca effects were invariably associated with better *per se* performance for respective traits. The results are in agreement with the findings of Singh *et al.* (1996) [9], Sharma *et al.* (2003) [7], Singh *et al.* (2005) [8], Saad *et al.* (2005) [5] Sayed *et al.* (2008) [6], Verma *et al.* (2009) [10], Zhang *et al.* (2015) [11] and Patial *et al.* (2016) [4].

Table 1: Estimates of GCA effects of parents (females and males) for 10 characters in Barley (E_1)

S.No.	Lines	Days to 50% flowering		Days to maturity		Plant height		Effective Tillers/ Plant		Spikelets/ Spike	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
1	NDB 1245	86.73	-0.14	121.43	2.24**	77.23	5.87**	6.33	0.11	18.83	0.16
2	NDB 1592	88.43	-1.68**	122.03	-2.26**	75.30	-1.52*	5.53	0.00	25.30	0.95**
3	NDB 1465	85.87	-1.68**	121.43	0.19	76.70	-3.50**	5.40	0.10	19.03	0.31
4	NDB 1173	83.50	-1.94**	127.17	-4.19**	95.70	-0.77	5.97	-0.37**	15.63	1.14**
5	Karan 741	91.40	-4.77**	118.50	-0.76	84.07	-1.01	6.53	0.08	14.83	2.03**
6	DWRUB 64	84.97	4.91**	125.80	2.97**	82.50	0.17	5.77	0.01	17.37	-1.19**
7	RD 2794	91.73	-0.13	126.27	-0.30	84.13	1.70**	5.90	0.09	18.57	0.16
8	HUB 113	85.53	2.41**	123.33	0.97	86.97	-0.92	5.40	-0.42**	18.83	-0.90**
9	BH 902	87.57	2.37**	121.20	1.06	85.73	1.75**	6.60	0.11	23.83	-1.94**
10	Azad	93.23	0.66	124.70	0.07	83.53	-1.78**	6.10	0.27**	25.00	-0.73*
	Mean	87.90	---	123.19	---	83.19	---	5.95	---	19.72	---
	SE(gi) lines	---	0.61	---	0.78	---	0.63	---	0.11	---	0.28
	SE(gi – gj)	---	0.86	---	1.10	---	0.89	---	0.15	---	0.39
Testers											
1	NDB 943	94.07	-0.37	124.43	0.28	87.40	0.51	5.70	0.17**	18.70	1.02**
2	BHS 352	89.33	-0.15	124.73	-0.82	94.17	0.86*	5.47	-0.09	17.53	-0.65**
3	DWR 28	84.93	0.52	125.73	0.54	85.87	-1.38**	4.67	-0.08	11.70	-0.37*
	Mean	89.44	---	124.96	---	89.15	---	5.28	---	15.98	---
	SE(gi) tester	---	0.33	---	0.43	---	0.34	---	0.06	---	0.15
	SE(gi – gj)	---	0.47	---	0.60	---	0.49	---	0.08	---	0.22

S.No.	Lines	Grains/ Spike		1000 grains weight		Biological yield /plant		Harvest Index		Grain Yield/ Plant	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
1	NDB 1245	46.93	0.57	36.40	-0.12	31.43	0.40	36.27	1.88**	11.40	0.74**
2	NDB 1592	64.27	2.54**	36.33	0.41	30.37	1.25**	32.70	-1.88**	9.93	-0.17
3	NDB 1465	41.17	1.09	38.23	-0.87*	32.10	1.59**	39.77	-0.99*	12.77	0.27
4	NDB 1173	34.53	2.31**	35.73	-0.26	30.73	-1.16**	39.03	1.29**	12.00	-0.01
5	Karan 741	43.80	5.25**	36.67	0.65	33.10	-1.00**	37.07	2.72**	12.27	0.45*
6	DWRUB 64	47.53	-2.81**	33.47	1.45**	33.93	-0.18	38.97	1.86**	13.23	0.55**
7	RD 2794	44.43	0.60	36.33	0.08	32.73	-2.70**	35.63	0.15	11.67	-0.85**
8	HUB 113	38.23	-3.21**	34.27	-1.89**	29.53	0.20	36.43	-0.46	10.77	-0.14
9	BH 902	56.10	-4.69**	35.03	-1.36**	34.17	-0.68*	35.90	-2.70**	12.27	-1.02**
10	Azad	60.83	-1.65*	36.73	1.92**	31.37	2.27**	33.07	-1.88**	10.37	0.18
	Mean	47.78	---	35.92	---	31.95	---	36.48	---	11.67	---
	SE(gi) lines	---	0.70	---	0.35	---	0.30	---	0.46	---	0.17
	SE(gi – gj)	---	0.98	---	0.49	---	0.43	---	0.65	---	0.24
Testers											
1	NDB 943	47.83	2.80**	32.47	-0.03	27.90	-0.50**	29.57	2.50**	8.23	0.57**
2	BHS 352	44.93	-1.71**	31.53	0.06	28.90	0.50**	31.97	0.18	9.23	0.20*
3	DWR 28	25.87	-1.09**	29.17	-0.03	19.03	-0.01	30.80	-2.68**	5.87	-0.78**
	Mean	39.54	---	31.06	---	25.28	---	30.78	---	7.78	---
	SE(gi) tester	---	0.38	---	0.19	---	0.16	---	0.25	---	0.09
	SE(gi – gj)	---	0.54	---	0.27	---	0.23	---	0.36	---	0.13

Table 2: Estimates of GCA effects of parents (females and males) for 10 characters in Barley (E_2)

S.No.	Lines	Days to 50% flowering		Days to maturity		Plant height		Effective Tillers/ Plant		Spikelets/ Spike	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
1	NDB 1245	78.80	-1.03*	118.13	-1.67**	61.29	-3.61**	4.63	0.11	12.47	-0.63*
2	NDB 1592	81.63	-1.24*	117.77	-0.47	57.03	-0.85**	4.03	-0.20	18.23	-0.78*
3	NDB 1465	76.63	2.86**	116.23	0.03	55.20	-1.10**	4.43	0.05	11.00	0.49*
4	NDB 1173	79.80	0.68	117.17	0.18	75.23	1.55**	5.17	-0.07	15.27	0.31
5	Karan 741	79.27	-0.74	117.00	-0.11	63.43	3.82**	5.37	0.06	13.97	0.48
6	DWRUB 64	79.37	2.63**	117.13	0.31	72.77	-1.29**	5.03	-0.11	11.86	-1.50**
7	RD 2794	82.50	-0.82	118.80	1.64**	64.37	1.33**	5.33	-0.32*	15.81	1.03**
8	HUB 113	79.33	-3.97**	116.57	-0.55	71.37	1.57**	4.57	0.23	16.53	1.01**
9	BH 902	81.90	1.56**	118.13	0.80*	64.83	-4.91**	5.50	0.10	12.37	0.40
10	Azad	80.87	0.06	116.13	-0.17	73.83	3.49**	5.93	0.15	14.87	-0.81**
	Mean	80.01	---	117.31	---	65.94	---	5.00	---	14.24	---
	SE(gi) lines	---	0.49	---	0.30	---	0.25	---	0.15	---	0.29
	SE(gi – gj)	---	0.70	---	0.43	---	0.36	---	0.22	---	0.41
Testers											
1	NDB 943	86.60	2.31**	123.63	-0.13	82.43	-0.33*	4.37	0.16	15.93	1.00**
2	BHS 352	81.80	-1.24**	116.57	0.44*	85.43	0.21	4.93	0.19*	15.70	-0.61**
3	DWR 28	76.43	-1.07**	118.73	-0.31	62.80	0.11	4.57	-0.35**	10.50	-0.39*
	Mean	81.61	---	119.64	---	76.89	---	4.62	---	14.05	---
	SE(gi) tester	---	0.27	---	0.17	---	0.14	---	0.08	---	0.16
	SE(gi – gj)	---	0.38	---	0.24	---	0.20	---	0.12	---	0.23

S.No.	Lines	Grains/ Spike		1000 grains weight		Biological yield /plant		Harvest Index		Grain Yield/ Plant	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
1	NDB 1245	30.60	-0.17	25.60	1.61**	22.07	0.21	36.40	-0.34	8.03	0.06
2	NDB 1592	44.70	-3.03**	25.77	2.72**	19.77	-1.08**	31.87	-1.58**	6.30	-0.68**
3	NDB 1465	23.50	0.76*	28.67	1.44**	27.13	-0.49	29.10	2.02**	7.90	0.22
4	NDB 1173	37.50	-0.09	26.07	-0.55	21.37	1.88**	31.63	-1.85**	6.77	0.30*
5	Karan 741	34.30	1.08**	26.70	-0.26	20.47	1.16**	31.60	-1.88**	6.47	-0.08
6	DWRUB 64	29.53	-3.37**	23.93	-1.02**	21.73	-1.29**	34.37	0.87	7.47	-0.30*
7	RD 2794	41.33	3.53**	27.17	-4.79**	25.17	-1.11**	24.40	1.10*	6.13	-0.16
8	HUB 113	40.47	2.03**	22.90	-0.85**	21.10	0.82**	32.40	1.24**	6.83	0.60**
9	BH 902	30.27	0.68	26.53	-0.54	19.73	-1.34**	39.87	2.52**	7.87	0.03
10	Azad	36.37	-1.43**	27.27	2.25**	21.97	1.24**	33.27	-2.08**	7.30	0.01
	Mean	34.86	---	26.06	---	22.05	---	32.49	---	7.11	---
	SE(gi) lines	---	0.35	---	0.29	---	0.30	---	0.44	---	0.13
	SE(gi – gj)	---	0.49	---	0.42	---	0.43	---	0.62	---	0.19
Testers											
1	NDB 943	38.31	1.67**	26.067	1.09**	19.60	-0.24	33.33	1.50**	6.53	0.25**
2	BHS 352	38.17	-1.45**	32.33	-0.65**	22.91	0.14	30.33	0.59*	6.93	0.15*
3	DWR 28	22.47	-0.22	34.27	-0.45**	17.67	0.10	30.43	-2.09**	5.37	-0.40**
	Mean	32.98	---	30.89	---	20.06	---	31.37	---	6.28	---
	SE(gi) tester	---	0.19	---	0.16	---	0.16	---	0.24	---	0.07
	SE(gi – gj)	---	0.27	---	0.23	---	0.23	---	0.34	---	0.10

Table 3: Estimates of SCA effects of crosses for 10 characters in Barley (E_1)

S. No.	Crosses	Days to 50% flowering		Days to maturity		Plant height		Effective Tillers/ Plant		Spikelets/ Spike	
		Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
1	NDB 1245 X NDB 943	94.30	6.70**	126.40	3.99**	90.37	3.32**	6.37	-0.05	25.50	2.07**
2	NDB 1245 X BHS 352	78.57	-9.26**	115.00	-6.31**	86.93	-0.46	6.07	-0.08	19.03	-2.73**
3	NDB 1245 X DWR 28	91.07	2.57*	125.00	2.33	82.30	-2.85*	6.30	0.14	22.70	0.66
4	NDB 1592 X NDB 943	84.03	-2.03	117.40	-0.51	81.07	1.41	6.07	-0.24	25.33	1.11*
5	NDB 1592 X BHS 352	89.07	2.78*	116.93	0.12	84.60	4.59**	6.10	0.06	24.83	2.28**
6	NDB 1592 X DWR 28	86.20	-0.75	118.57	0.39	71.77	-6.00**	6.23	0.18	19.43	-3.40**
7	NDB 1465 X NDB 943	91.3	5.31**	123.07	2.71*	75.93	-1.75	7.10	0.69**	25.27	1.69**
8	NDB 1465 X BHS 352	86.67	0.38	121.27	2.01	81.63	3.60**	5.63	-0.51**	21.70	-0.20
9	NDB 1465 X DWR 28	81.27	-5.69**	115.90	-4.72**	73.93	-1.85	5.97	-0.19	20.70	-1.48**
10	NDB 1173 X NDB 943	84.60	-1.20	114.33	-1.65	75.00	-5.40**	6.33	0.40*	24.17	-0.24
11	NDB 1173 X BHS 352	87.77	1.74	117.37	2.49	75.27	-5.49**	5.50	-0.16	22.23	-0.50
12	NDB 1173 X DWR 28	86.17	-0.53	115.40	-0.84	89.40	10.89**	5.43	-0.24	23.77	0.75
13	Karan 741 X NDB 943	78.70	-4.27**	117.87	-1.55	78.33	-1.84	5.33	-1.05**	23.37	-1.93**
14	Karan 741 X BHS 352	90.80	7.60**	120.03	1.72	86.27	5.75**	7.03	0.92**	24.60	0.97*
15	Karan 741 X DWR 28	80.53	-3.33**	119.50	-0.17	74.37	-3.91**	6.27	0.14	24.87	0.96
16	DWRUB 64 X NDB 943	92.53	-0.12	125.40	2.25	75.63	-5.71**	6.67	0.35	21.00	-1.08*
17	DWRUB 64 X BHS 352	95.37	2.49*	125.43	3.39*	85.00	3.30**	6.27	0.22	22.43	2.03**
18	DWRUB 64 X DWR 28	91.17	-2.38*	117.77	-5.64**	81.87	2.41*	5.50	-0.56**	19.73	-0.95

19	RD 2794 X NDB 943	87.13	-0.48	118.03	-1.84	82.43	-0.45	7.07	0.67**	23.30	-0.13
20	RD 2794 X BHS 352	82.83	-5.01**	114.13	-4.63**	77.93	-5.30**	6.10	-0.03	22.53	0.77
21	RD 2794 X DWR 28	94.00	5.49**	126.60	6.47**	86.73	5.75**	5.50	-0.64**	21.40	-0.64
22	HUB 113 X NDB 943	89.93	-0.22	121.97	0.82	83.33	3.07**	5.80	-0.08	18.90	-3.47**
23	HUB 113 X BHS 352	89.90	-0.48	119.53	-0.51	82.77	2.16	5.17	-0.45*	19.97	-0.73
24	HUB 113 X DWR 28	91.73	0.69	121.10	-0.31	73.13	-5.23**	6.17	0.54**	25.17	4.19**
25	BH 902 X NDB 943	87.97	-2.15*	118.67	-2.57	91.30	8.37**	6.40	-0.02	21.40	0.07
26	BH 902 X BHS 352	94.73	4.39**	124.50	4.37**	77.60	-5.68**	5.37	-0.78**	20.23	0.57
27	BH 902 X DWR 28	88.77	-2.24*	119.70	-1.80	78.33	-2.70*	6.97	0.80**	19.30	-0.64
28	Azad X NDB 943	86.87	-1.54	118.60	-1.65	78.37	-1.03	5.90	-0.67**	24.47	1.92**
29	Azad X BHS 352	84.00	-4.63**	116.50	-2.64	77.27	-2.48*	7.13	0.83**	18.40	-2.47**
30	Azad X DWR 28	95.47	6.17**	124.80	4.29**	81.00	3.50**	6.17	-0.15	21.70	0.55
Mean		88.12	---	119.89	---	80.66	---	6.13	---	22.25	---
$SE(S_{ij})$		---	1.05	---	1.35	---	1.09	---	0.18	---	0.48
$SE(S_{ij} - S_{kl})$		---	1.49	---	1.91	---	1.54	---	0.26	---	0.68

S. No.	Crosses	Grains/ Spike		1000 grains weight		Biological yield /plant		Harvest Index		Grain Yield/ Plant	
		Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
1	NDB 1245 X NDB 943	63.83	4.89**	40.27	3.28**	30.80	0.92	41.00	2.62**	12.63	1.15**
2	NDB 1245 X BHS 352	47.67	-6.77**	34.50	-2.57**	30.03	-0.85	33.73	-2.33**	10.13	-0.98**
3	NDB 1245 X DWR 28	56.93	1.88	36.27	-0.71	30.30	-0.07	32.90	-0.30	9.97	-0.17
4	NDB 1592 X NDB 943	63.47	2.54*	42.37	4.86**	31.93	1.21*	34.57	-0.05	11.03	0.46
5	NDB 1592 X BHS 352	62.17	5.76**	36.30	-1.30*	29.37	-2.36**	34.93	2.63**	10.27	0.06
6	NDB 1592 X DWR 28	48.73	-8.30**	33.93	-3.57**	32.37	1.15*	26.87	-2.57**	8.70	-0.52
7	NDB 1465 X NDB 943	63.70	4.23**	35.97	-0.26	30.93	-0.14	31.63	-3.88**	9.80	-1.22**
8	NDB 1465 X BHS 352	54.37	-0.59	36.27	-0.05	30.43	-1.64**	32.20	-0.99	9.80	-0.85**
9	NDB 1465 X DWR 28	51.93	-3.64**	36.53	0.31	33.33	1.77**	35.20	4.87**	11.73	2.07**
10	NDB 1173 X NDB 943	60.93	0.24	35.27	-1.57*	31.50	3.19**	37.03	-0.75	11.67	0.93**
11	NDB 1173 X BHS 352	53.23	-2.94*	39.40	2.47**	26.47	-2.85**	38.27	2.80**	10.13	-0.24
12	NDB 1173 X DWR 28	59.50	2.70*	35.93	-0.90	28.47	-0.34	30.57	-2.04*	8.70	-0.69*
13	Karan 741 X NDB 943	58.60	-5.03**	37.40	-0.35	26.63	-1.85**	37.03	-2.19**	9.87	-1.33**
14	Karan 741 X BHS 352	61.63	2.51*	35.67	-2.17**	28.40	-1.08*	38.03	1.13	10.80	-0.03
15	Karan 741 X DWR 28	62.27	2.52*	40.27	2.52**	31.90	2.93**	35.10	1.06	11.20	1.35**
16	DWRUB 64 X NDB 943	52.63	-2.93*	36.67	-1.88**	31.23	1.94**	39.73	1.38	12.40	1.10**
17	DWRUB 64 X BHS 352	56.27	5.21**	41.50	2.86**	30.50	0.21	35.50	-0.54	10.83	-0.09
18	DWRUB 64 X DWR 28	49.40	-2.28	37.57	-0.98	27.63	-2.15**	32.33	-0.84	8.93	-1.01**
19	RD 2794 X NDB 943	58.40	-0.58	36.03	-1.15	27.77	0.99	38.77	2.12*	10.77	0.87**
20	RD 2794 X BHS 352	56.47	2.00	36.33	-0.94	26.50	-1.28*	33.93	-0.39	9.00	-0.53
21	RD 2794 X DWR 28	53.67	-1.42	39.27	2.09**	27.57	0.30	29.73	-1.73*	8.20	-0.35
22	HUB 113 X NDB 943	47.37	-7.80**	33.83	-1.37*	24.73	-4.95**	38.53	2.50**	9.53	-1.07**
23	HUB 113 X BHS 352	50.03	-0.62	35.73	0.44	36.23	5.55**	32.90	-0.82	11.93	1.70**
24	HUB 113 X DWR 28	59.70	8.42**	36.13	0.93	29.57	-0.60	29.17	-1.69*	8.63	-0.62*
25	BH 902 X NDB 943	53.57	-0.12	34.77	-0.97	29.13	0.34	32.67	-1.13	9.53	-0.20
26	BH 902 X BHS 352	50.73	1.56	35.80	-0.03	31.40	1.61**	29.43	-2.05*	9.23	-0.13
27	BH 902 X DWR 28	48.37	-1.43	36.73	1.00	27.33	-1.95**	31.80	3.18**	8.70	0.32
28	Azad X NDB 943	61.30	4.57**	38.43	-0.58	30.10	-1.65**	34.00	-0.62	10.23	-0.70*
29	Azad X BHS 352	46.10	-6.12**	40.40	1.29*	35.43	2.69**	32.87	0.56	11.63	1.07**
30	Azad X DWR 28	54.40	1.56	38.30	-0.71	31.20	-1.04	29.50	0.06	9.20	-0.38
Mean		55.58	---	37.13	---	29.97	---	34.00	---	10.17	---
$SE(S_{ij})$		---	1.20	---	0.60	---	0.52	---	0.80	---	0.30
$SE(S_{ij} - S_{kl})$		---	1.70	---	0.85	---	0.74	---	1.13	---	0.42

Table 4: Estimates of SCA effects of crosses for 10 characters in Barley (E_2)

S. No.	Crosses	Days to 50% flowering		Days to maturity		Plant height		Effective Tillers/ Plant		Spikelets/ Spike	
		Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
1	NDB 1245 X NDB 943	86.10	3.07**	115.80	0.16	71.33	-0.96*	6.17	0.67*	18.80	2.80**
2	NDB 1245 X BHS 352	78.27	-1.21	115.33	-0.87	69.00	-3.84**	4.93	-0.59*	14.57	0.18
3	NDB 1245 X DWR 28	77.80	-1.86*	116.17	0.71	77.53	4.80**	4.90	-0.08	11.63	-2.98**
4	NDB 1592 X NDB 943	80.37	-2.45**	119.40	2.56**	75.97	0.91*	5.20	0.02	15.73	-0.12
5	NDB 1592 X BHS 352	82.87	3.60**	115.57	-1.84**	72.43	-3.16**	5.33	0.12	14.47	0.22
6	NDB 1592 X DWR 28	78.30	-1.14	115.93	-0.73	77.73	2.25**	4.53	-0.14	14.37	-0.10
7	NDB 1465 X NDB 943	82.73	-4.19**	114.40	-2.94**	73.10	-1.71**	5.87	0.43	16.83	-0.29
8	NDB 1465 X BHS 352	85.97	2.60**	118.63	0.73	80.87	5.52**	5.13	-0.34	14.97	-0.55
9	NDB 1465 X DWR 28	85.13	1.59	119.37	2.21	71.43	-3.81**	4.83	-0.09	16.57	0.83
10	NDB 1173 X NDB 943	81.87	-2.88**	117.27	-0.21	81.03	3.58**	5.07	-0.25	17.30	0.36
11	NDB 1173 X BHS 352	78.70	-2.49**	119.07	1.02	76.80	-1.19**	5.73	0.39	15.97	0.63
12	NDB 1173 X DWR 28	86.73	5.37**	116.50	-0.80	75.50	-2.39**	4.67	-0.14	14.57	-0.99
13	Karan 741 X NDB 943	81.67	-1.65	117.47	0.28	81.80	2.07**	5.07	-0.38	17.37	0.26

14	Karan 741 X BHS 352	82.70	2.93**	116.23	-1.53**	77.73	-2.54**	5.63	0.15	16.57	1.07*
15	Karan 741 X DWR 28	78.67	-1.28	118.27	1.25*	80.63	0.47	5.17	0.23	14.40	-1.32*
16	DWRUB 64 X NDB 943	86.90	0.21	119.50	1.89**	74.73	0.11	5.73	0.46	14.83	-0.30
17	DWRUB 64 X BHS 352	85.67	2.53**	117.40	-0.78	72.23	-2.93**	5.13	-0.17	14.13	0.61
18	DWRUB 64 X DWR 28	80.57	-2.74**	116.33	-1.10*	77.87	2.81**	4.47	-0.29	13.43	-0.31
19	RD 2794 X NDB 943	84.07	0.82	120.37	1.42**	75.57	-1.67**	5.07	0.01	15.23	-2.43**
20	RD 2794 X BHS 352	78.43	-1.26	120.40	0.88	80.50	2.72**	5.40	0.31	17.50	1.44**
21	RD 2794 X DWR 28	80.30	0.43	116.47	-2.30**	76.63	-1.04*	4.23	-0.32	17.27	0.99
22	HUB 113 X NDB 943	85.77	5.68**	117.30	0.54	75.33	-2.14**	5.67	0.05	17.07	-0.57
23	HUB 113 X BHS 352	72.10	-4.43**	116.10	-1.23**	81.27	3.25**	5.70	0.05	14.97	-1.07*
24	HUB 113 X DWR 28	75.47	-1.24	117.27	0.69	76.80	-1.11*	5.00	-0.10	17.90	1.64**
25	BH 902 X NDB 943	86.63	1.01	116.97	-1.14*	69.93	-1.06*	4.70	-0.78*	17.97	0.94
26	BH 902 X BHS 352	80.83	-1.23	119.90	1.23*	72.50	0.96*	5.80	0.29	13.57	-1.86**
27	BH 902 X DWR 28	82.47	0.22	117.83	-0.09	71.53	0.10	5.47	0.50	16.57	0.92
28	Azad X NDB 943	84.50	0.38	114.57	-2.57**	80.27	0.87	5.30	-0.24	15.17	-0.65
29	Azad X BHS 352	79.53	-1.03	120.10	2.39**	81.13	1.20**	5.37	-0.20	13.53	-0.68
30	Azad X DWR 28	81.40	0.66	117.13	0.17	77.76	-2.07**	5.47	0.44	15.77	1.33*
Mean		81.75	---	117.43	---	76.23	---	5.22	---	15.63	---
$SE(S_{ij})$		---	0.85	---	0.53	---	0.44	---	0.26	---	0.51
$SE(S_{ij} - S_{kl})$		---	1.21	---	0.75	---	0.62	---	0.37	---	0.72

S. No.	Crosses	Grains/ Spike		1000 grains weight		Biological yield /plant		Harvest Index		Grain Yield/ Plant	
		Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
1	NDB 1245 X NDB 943	49.73	6.05**	35.57	1.76**	23.53	1.68**	38.50	0.74	9.07	0.78**
2	NDB 1245 X BHS 352	41.47	0.90	31.40	-0.67	21.30	-0.93	35.63	-1.23	7.60	-0.58*
3	NDB 1245 X DWR 28	34.83	-6.96**	31.17	-1.10*	21.43	-0.75	34.67	0.49	7.43	-0.20
4	NDB 1592 X NDB 943	42.33	1.51*	37.07	2.15**	21.70	1.14*	35.87	-0.65	7.77	0.22
5	NDB 1592 X BHS 352	37.87	0.16	31.97	-1.21*	19.93	-1.01	34.23	-1.38	6.83	-0.60*
6	NDB 1592 X DWR 28	37.27	-1.67**	32.43	-0.94	20.77	-0.13	34.97	2.03*	7.27	0.38
7	NDB 1465 X NDB 943	45.57	0.95	34.37	0.73	20.37	-0.78	47.30	7.18**	9.63	1.19**
8	NDB 1465 X BHS 352	37.30	-4.20**	29.53	-2.37**	23.70	2.17**	32.37	-6.85**	7.67	-0.67**
9	NDB 1465 X DWR 28	45.97	3.24**	33.73	1.63**	20.10	-1.38*	36.20	-0.33	7.27	-0.52*
10	NDB 1173 X NDB 943	44.20	0.44	36.90	5.25**	24.00	0.48	37.50	1.25	9.00	0.48*
11	NDB 1173 X BHS 352	41.93	1.29*	29.10	-0.81	24.97	1.07*	34.07	-1.28	8.50	0.09
12	NDB 1173 X DWR 28	40.13	-1.74**	25.67	-4.44**	22.30	-1.55**	32.70	0.03	7.30	-0.56*
13	Karan 741 X NDB 943	44.77	-0.17	30.03	-1.90**	18.47	-4.33**	39.53	3.31**	7.30	-0.84**
14	Karan 741 X BHS 352	45.33	3.52**	31.13	0.93	26.67	3.49**	32.13	-3.18**	8.57	0.53
15	Karan 741 X DWR 28	39.70	-3.35**	31.37	0.97	23.97	0.84	32.50	-0.13	7.80	0.31
16	DWRUB 64 X NDB 943	39.30	-1.18	31.33	0.15	23.07	2.72**	34.23	-4.74**	7.90	-0.02
17	DWRUB 64 X BHS 352	39.60	2.24**	28.57	-0.88	18.90	-1.83**	42.33	4.26**	8.00	0.19
18	DWRUB 64 X DWR 28	37.53	-1.06	30.37	0.72	19.80	-0.88	35.87	0.48	7.10	-0.16
19	RD 2794 X NDB 943	40.57	-6.81**	28.57	1.16*	19.30	-1.23*	38.03	-1.17	7.33	-0.73**
20	RD 2794 X BHS 352	49.13	4.87**	23.37	-2.30**	21.07	0.16	42.43	4.13**	8.93	0.97**
21	RD 2794 X DWR 28	47.43	1.94**	27.00	1.13*	21.93	1.07*	32.67	-2.95**	7.17	-0.24
22	HUB 113 X NDB 943	45.00	-0.88	24.63	-6.71**	22.40	-0.06	41.40	2.06**	9.27	0.45
23	HUB 113 X BHS 352	39.93	-2.83**	35.33	5.72**	21.50	-1.34*	38.27	-0.17	8.23	-0.48*
24	HUB 113 X DWR 28	47.70	3.71**	30.80	0.99	24.20	1.40**	33.87	-1.89*	8.20	0.04
25	BH 902 X NDB 943	46.50	1.97**	31.07	-0.59	21.10	0.80	34.10	-6.52**	7.20	-1.05**
26	BH 902 X BHS 352	37.23	-4.18**	30.37	0.45	19.67	-1.01	45.27	5.55**	8.90	0.75**
27	BH 902 X DWR 28	44.87	2.22**	30.27	0.15	20.83	0.20	38.00	0.97	7.90	0.30
28	Azad X NDB 943	40.53	-1.89**	32.43	-2.01**	22.47	-0.42	34.57	-1.45	7.77	-0.47*
29	Azad X BHS 352	37.53	-1.77**	33.83	1.12*	22.50	-0.76	35.27	0.15	7.93	-0.19
30	Azad X DWR 28	44.20	3.66**	33.80	0.89	24.40	1.18*	33.73	1.30	8.23	0.66**
Mean		42.18	---	31.11	---	21.88	---	36.61	---	7.97	---
$SE(S_{ij})$		---	0.61	---	0.51	---	0.52	---	0.77	---	0.23
$SE(S_{ij} - S_{kl})$		---	0.86	---	0.72	---	0.74	---	1.08	---	0.33

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