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STUDY OF HETEROSIS AND COMBINING ABILITY FOR YIELD AND YIELD CONTRIBUTING TRAITS IN BARLEY (*HORDEUM VULGARE* L.)

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ABSTRACT
Thirteen diverse barley genotypes were selected and crossed in a line × tester fashion to evaluate combining ability and heterosis to identify promising hybrids for ten quantitative traits including yield and its components. Analysis of variance for line x tester reveals highly significant differences for most of the characters investigated. The combining ability analysis showed significant differences among the parents for GCA, among crosses for SCA for all the quantitative traits respectively. Among the parents, tester namely RD-2508 and lines INBON-65, INBON-18, Beecher, Rihane, Moroc-9-75, 11th HBSN-146 and HUB-174 were good general combiners for grain yield and its component traits. While among crosses, cross IBNON-65 × RD-2508 was recorded highest magnitude of economic heterosis over the best standard check *viz.*, K- 603 for grain yield. As per SCA effects, the crosses *viz.*,11th HBSN-146 x Lakhan for grain yield per plant and Rihane x Lakhan for 1000 grain weight were most promising. It is, therefore, the selective parents and crosses could be utilized for developing desirable genotypes/hybrids/varieties with better yielding towards exploiting the hybrid vigor or other associated traits under crop improvement.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a most paramount cereal crop and considered as the first cereal domesticated for use by man as food and feed. It is well known as world's fourth most important cereal crop after wheat, maize and rice (Bengtsson, 1992; Anonymous, 2010). Till date availability of desirable genotypes with better yielding is not completely satisfactory. Hence, efforts are being made to develop the desirable genotypes which also can be adopted in various ranges of environmental stress; it is the ultimate goal of plant breeders (Sabaghpour *et al.,* 2003). Desirable attributes along with higher yield from two or more genotypes could be brought together through hybridization and ultimately a new line, reflecting the desirable attributes of the parents are developed. To formulate an efficient breeding program for development of superior genotypes, it is also essential to understand the mode of inheritance, the magnitude of gene effects and its interaction (Farshadfar *et al.,* 2001). Allard (1960) reported that the ability of parents to combine well dependent on complex interaction among genes for trait of interest which cannot be adjusted by mere yield and yield adaptation of the parents. The improvement in the productivity of a crop involves multidirectional approaches including thorough understanding of the genetics and related aspect of crop under consideration. Identification of genetically superior parents is an important pre- requisite for developing promising strains. For this, combining ability analysis provides useful information to select the suitable parents for a hybridization programme (Kakani *et al.*, 2007). It is essential to find out the combining ability of the desirable genotypes to involve in breeding programme, for effective transfer of targeted genes controlling both quantitative and qualitative traits in the resultant progenies. The study of heterosis has a direct bearing on the breeding methodology to be employed for varietal improvement and also provides useful genetic information about usefulness of the parents in breeding programs (Singh *et al.,* 2012).

The breeding value of genotypes, including combining ability, is evaluated on the basis of the analysis of hybrids produced in appropriate crossing schemes. At present frequently diallel or line × tester analysis is applied (Marciniak *et al.*, 2003; Ahuja and Dhayal 2007; Krystkowiak *et al.,* 2009). The knowledge on nature and magnitude of gene effects controlling inheritance of characters related to yield and its component traits will be helpful in formulating efficient breeding programme and enhancing the yield of the crops as well as finding out good general and specific combiners and heterotic cross combinations for yield and yield component traits. In view of above, emphasis was given to select to good combiner enhancing the yield of the barley crop in present investigation through generation mean analysis because it provides the opportunity first to detect the presence or absence of epistasis (scaling test) and when present, it measures them appropriately. It also determines the components of heterosis in terms of gene-effects and some other statistics such as a number of effective factors, potence ratio levels of dominance etc. (Farshadfar *et al.,* 2008a). Therefore, the present investigation was undertaken to investigate the combining ability and estimate the extent of heterosis for yield and yield contributing traits.

MATERIALS AND METHODS

There are three testers namely K-603, Lakhan and RD 2508 and ten lines (Moroc-9-75, Rihane, Harmal, Beecher, INBON-18, INBON-65, INBON-67, 24th IBYT-19, 11th HBSN-146 and HUB-174) were selected based on the phenotypic diversity of the plants in respect of yield and yield components. These parental testers and lines were sown in crossing block at two dates of 10 days interval. Line x Tester fashion was followed for making crosses, using tester as female and lines as male parents. Sufficient crosses were made to assure adequate amount of cross seeds. All these hybrids were produced during cropping seasons and, as such, all the thirteen parents along with standard check were grown together during in a Randomized Block Design (RBD) with three replications at Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The row length was 5.0 m and distance between rows was 0.25 m. All the recommended cultural practices were applied to raise good crop. Ten competitively plants were selected randomly for recording the data on yield and its contributing traits *viz*., plant height, number of effective tillers per plant, flag leaf length, flag leaf width, peduncle length, spike length with awn, spike length excluding awn, a number of grain per spikes, grain yield per plant and 1000 grain weight. The mean data of each plot was used for statistical analysis. Analysis of variance for Line x Tester was carried out according to procedure given by Kempthorne (1957). The generalized model to estimate the general and specific combining ability effects of ijkth observations is given below

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

Where,

μ = Population mean

g_i = gca effect of ith male parent

g_j = gca effect of jth female parent

s_{ij} = sca effect of ijth combinations

e_{ijk} = error associated with the observation X_{ijk}

$_i$ = number of male parents

j = numbrer of female parents

k = number of replications

Heterosis expressed as percentage increase or decreases of F_1s' over mid parent and check variety (standard heterosis) was also calculated according to the methods suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) revealed significant differences among the parents, crosses, parent vs. cross for all the characters studied (Table 1). The variation arises due to crosses were partitioned in to male (line), female (tester) and male x female (line × female). The lines (male) showed good response, exhibiting significance differences for six characters excluding flag leaf width, a number of effective tillers per plant, peduncle length, and grain yield per plant. Further, variance due to testers (female) also revealed significance differences for six characters excluding flag leaf length, flag leaf width, a number of grains per spike and grain yield per plant. Variances due to line x tester effects were significant for all the characters studied indicating the presence of adequate amount of variability and there is possibility of selection of desirable plants for trait of interest. Analysis for variance for combining ability analysis indicated that the variance due to General Combining Ability (GCA) and Specific Combing Ability (SCA) were highly significant for all the characters studied (Table 2 and 3). A wide range of variation was observed for σ^2GCA for most of the characters studied (Table 4). The maximum σ^2 GCA was recorded for a number of grains per spike and minimum for flag leaf width. The ratio of additive and non- additive (GCA/SCA) variances revealed that the characters such as plant height, effective tillers per plant, peduncle length, spike length with awn, spike length excluding awn, a number of grains per spike and 1000 grain weight influenced more by additive effect while, remaining traits showed the preponderance of non- additive variance. These results were in consonance with that of Yap and Harvey (1972) for effective tillers per plant, peduncle length and a number of grains per spike, Sharma *et al*. (2003) for peduncle length, spike length and plant height Joshi and Singh (2004) and Saini *et al*. (2006) for plant height and effective tillers per plant. Potentiality of line to be used as parent in hybridization or of cross used for commercial hybrid may be determined by comparing the *per se* performance of the parent, the F_1 value and the combining ability effects. The best three of each parent, F_1s, general and specific combiners for ten quantitative characters presented in table 5, from which

Table 1: Analysis of variance for line x tester analysis for yield and its component traits in barley

Source of variation	d. f.	Mean sum of square Plant height	Flag leaf length	Flag leaf width	Effective tillers per plant	Peduncle length	Spike length with awn	Spike length excluding awn	Grains per spike	1000 grain weight	Grain yield per plant
Replication	2	1.04	0.35	0.002	0.59	3.71	2.76	0.15	0.57	0.12	0.93
Treatment	42	133.86**	10.61**	0.02**	7.46**	39.40**	60.18**	3.68**	368.61**	109.93**	12.19**
Parent	12	142.23**	11.53**	0.01*	4.42**	31.07**	24.20**	1.61**	333.49**	116.04**	3.03**
Cross	29	128.20**	8.29**	0.02**	3.62**	370.70**	59.56**	2.34**	389.42**	90.16**	9.49**
Parent vs. Cross	1	197.69**	66.66**	0.13**	155.17**	59.02**	510.43**	67.53**	186.39**	609.99**	200.57**
Line (male)	9	197.90**	17.34**	0.01	3.07	35.69**	182.41**	3.58**	1238.28**	98.60**	14.32**
Tester (Female)	2	533.78**	0.63	0.01	14.90**	112.89**	12.32*	9.06**	2.50	597.77**	11.31**
L × T	18	48.28**	4.62**	0.03*	2.64**	20.24**	3.34**	0.97**	7.62**	29.54**	6.87**
Error	84	1.27	0.45	0.004	0.16	6.28	1.60	0.09	1.24	0.78	1.01

* Significant at p= 0.05, ** Significant at p= 0.01

Table 2: Estimates of general combining ability effects for yield and its component traits in barley

Parents	Plant height	Flag leaf length	Flag leaf width	Effective tiller per plant	Peduncle length	Spike length with awn	Spike length excluding awn	Grains per spike	1000 grain weight	Grain yield per plant
Moroc -9-75	-6.72**	0.88**	0.01	0.19	-1.75*	-2.97**	-0.18	3.37**	-2.75**	0.64
Rihane	-5.52**	-1.02**	-0.05*	0.56**	-3.10**	-2.88**	-0.42**	3.65**	1.40**	-0.001
Harmal	4.35**	-1.90**	0.02	0.45**	1.95	-2.77**	-0.43**	-3.23**	-4.73**	-0.89**
Beecher	-6.02**	-2.08**	-0.002	-0.19	-2.63**	4.57**	-0.84**	6.31**	-1.62**	-0.13
INBON-18	0.09	0.47*	-0.005	-0.67**	1.53	4.38**	0.22*	3.09**	2.85**	-2.04**
INBON-67	-0.34	-0.03	-0.02	0.10	1.48	5.52**	-0.30**	3.39**	-0.91**	-0.07
INBON-65	4.58**	0.07	0.06**	-0.02	2.40**	6.05**	074**	2.64**	0.80**	2.60**
24th IBYT-19	5.25**	-0.22	0.03	-1.25**	1.11	-2.97**	0.82**	3.71**	-2.50**	-1.11**
11th HBSN-146	4.24**	2.03**	0.03	0.21	-0.87	-3.38**	0.91**	1.09	0.37	0.93**
HUB-174	0.12	1.79**	-0.07**	0.64**	-0.12	-5.51**	-0.54**	-1.60**	6.91**	0.16
K-603	1.28**	-0.03	-0.02	-0.52**	0.85	-0.30	0.62**	-0.33**	5.10**	-0.40*
RD-2508	-4.71**	-0.13	0.02	-0.29**	-2.22**	-0.44	-0.43**	0.20**	-3.20**	0.71**
Lakhan	3.43**	0.16	-0.002	0.80	1.37**	0.74**	-0.19**	0.13**	-1.90**	-0.30

* Significant at p= 0.05, ** Significant at p= 0.01

Table 3: Estimates of specific combining ability effects for yield and its component traits in barley

Crosses	Plant height	Flag leaf length	Flag leaf width	Effective tiller per plant	Peduncle length	Spike length with awn	Spike length excluding awn	Grains per spike	1000 grain weight	Grain yield per plant
Moroc-9-75 × K-603	2.52**	-0.27	0.08*	0.64**	-0.82	-0.43	0.005	0.50	1.01	1.72**
Moroc-9-75 × RD-2508	-1.63*	0.44	0.04	-0.93**	2.49	-0.60	0.10	-0.60	-0.21	-1.67**
Moroc-9-75 × Lakhan	-0.89	-0.17	-0.12**	0.29	-1.67	1.03	-0.10	0.11	-0.80	0.05
Rihane × K-603	-1.63*	1.04**	-0.03	-0.19	2.78	0.84	-0.55**	0.95	-2.10**	0.56
Rihane × RD-2508	-4.50**	-1.07**	-0.10**	1.02**	-5.80**	0.12	0.47**	-1.12	-5.69**	0.05
Rihane × Lakhan	6.13**	0.03	0.13**	-0.82**	3.05*	-0.63	0.08	0.162	7.79**	-0.61
Harmal × K-603	-2.32**	0.20	-0.13	-0.54*	-0.86	0.56	-0.33	-0.57	-1.61**	-1.46*
Harmal × RD-2508	-0.87	-0.14	0.15**	1.26**	0.72	-0.77	0.12	0.17	0.74	0.85
Harmal × Lakhan	3.19**	0.12	-0.02	-0.72**	0.13	0.19	0.21	0.41	0.87	0.61
Beecher × K-603	1.92**	0.86*	0.14**	-0.18	0.68	-1.71*	0.24	1.54*	2.70*	1.83*
Beecher × RD-2508	-1.11	-0.85*	-0.13**	0.43	2.38	2.16**	0.01	-1.23	-1.48**	1.30*
Beecher × Lakhan	-0.81	-0.01	-0.00	-0.25	-3.05*	-0.45	-0.25	-0.32	-1.22*	-3.13**
IBNON-18 × K-603	-0.72	-0.27	0.01	-0.96**	-2.75	-0.42	0.84**	-0.69	-1.19*	0.36
IBNON-18 × RD-2508	3.50**	0.0.3	0.07	0.24	3.23*	0.31	-1.55**	-0.003	-1.67**	-1.16
IBNON-18 × Lakhan	-2.77**	0.24	-0.08*	-0.18**	-0.48	0.12	0.72**	0.72	2.86**	0.80
IBNON-67 × K-603	4.97**	-0.27	-0.005	-0.16	0.27	-1.05	-0.37*	0.21	2.23**	-1.19
IBNON-67 × RD-2508	-6.47**	0.03	0.03	0.48*	-0.14	1.53*	0.39*	0.08	0.95	0.37
IBNON-67 × Lakhan	1.50*	0.24	-0.03	-0.14	-0.13	-0.48	-0.03	-0.29	-3.17**	0.82
IBNON-65 × K-603	-1.11	-2.60**	-0.02	-0.40	-0.72	0.48	0.06	0.62	0.22	-0.89
IBNON-65 × RD-2508	2.64**	2.37**	-0.02	-0.11	2.20	-0.05	0.47*	0.09	0.78	1.03
IBNON-65 × Lakhan	-1.53**	0.24	0.04	0.50*	-1.48	-0.42	-0.53**	-0.72	-1.00	-1.14
24th IBYT-19 × K-603	-3.35**	0.20	-0.87*	0.28	0.10	0.51	0.04	0.37	1.27*	0.02
24th IBYT-19×RD-2508	2.16**	-0.27	-0.011	-1.61*	-2.40	-0.52	-0.20	-1.48*	1.18**	-0.68
24th IBYT-19 × Lakhan	1.19	0.08	0.09*	1.32**	1.51	0.01	0.16	1.10	-2.89**	0.66
11th HBSN-146 × K-603	-1.58*	-0.06	0.02	0.09	-0.76	0.33	0.12	-0.95	-0.65	-0.47
11th HBSN-146 × RD-2508	6.88**	0.20	-0.01	-0.36	-1.09	-1.30	-0.26	-0.48	2.67**	-0.52
11th HBSN-146 × Lakhan	-5.30**	-0.15	-0.001	0.27	1.85	0.96	0.13	1.43*	-2.02**	1.99**
HUB-174 × K-603	1.31*	-0.45	0.05	1.43**	1.30	0.10	-0.07	-2.00**	-1.87**	0.47
HUB-174 × RD-2508	-0.60	-1.22**	-0.02	-0.43	-1.57	-0.56	0.46*	4.60**	2.29**	1.42*
HUB-174 × Lakhan	-0.71	1.66	0.001	-0.99**	0.27	-0.34	-0.39*	-2.59**	-0.42	-0.95

* Significant at p= 0.05, ** Significant at p= 0.01

Table 4: Estimates of genetic component of variance and degree of dominance for yield and its component traits in barley

Parents	Plant height	Flag leaf length	Flag leaf width	Effective tiller per plant	Peduncle length	Spike length with awn	Spike length excluding awn	Grains per spike	1000 grain weight	Grain yield per plant
σ^2 female	17.75**	0.01	0.002	0.49*	3.55*	0.36*	0.30**	0.04	19.90**	0.30
σ^2 male	21.85**	1.87**	0.001	0.32	3.27	20.09**	0.39**	137.45**	10.87**	1.48
σ^2 GCA	18.70**	0.44	0.0004	0.45**	3.49**	4.91**	0.32**	31.75**	17.82**	0.61**
σ^2SCA	15.67**	1.30**	0.0073**	0.83	4.65**	0.59*	0.29**	2.25**	9.56**	1.95**
σ^2A	74.78	0.88	0.0016	0.90	6.98	9.8	0.64	63.50	35.63	1.21
σ^2D	62.69	1.39	0.029	0.83	4.65	0.59	0.29	2.25	9.56	1.95
$\sqrt{\sigma^2 D/ ó^2 A}$	0.92	1.26	4.26	0.96	0.82	0.24	0.67	0.19	0.52	1.27

* Significant at p= 0.05, ** Significant at p= 0.01

Table 5: Best three parents, F_1s and best general and specific combiners for yield and its component traits in barley

Characters	Best parents (*per se* performance)	Best general combiner	Best F_1 (with respect to *per se* performance)	Best F_1 (with respect to SCA)	Best F_1 (with respect to Standard heterosis)
Plant height	Rihane	Moroc-9-75	Rihane × RD-2508	INBON-67 × RD-2508	Rihane × RD-2508
	11th HBSN-146	Beecher	Moroc-9-75 × RD-2508	11th HBSN-146 × Lakhan	Moroc-9-75 × RD-2508
	Moroc-9-75	Rihane	Beecher × RD-2508	Rihane × RD-2508	Beecher × RD-2508
Flag leaf length	INBON-18	11th HBSN-146	INBON-65 × RD-2508	INBON-65 × RD-2508	HUB-174 × Lakhan
	11th HBSN-146	HUB-174	11th HBSN-146 × RD-2508	HUB-174 × Lakhan	INBON-65 × RD-2508
	Lakhan	Moroc-9-75	11th HBSN-146 × Lakhan	Rihane × K-603	11th HBSN-146 × RD-2508
Flag leaf width	Beecher	INBON-65	Harmal × RD-2508	Harmal × RD-2508	Harmal × RD-2508
	RD-2508	24th IBYT-19	Beecher × K-603	Beecher × K-603	Beecher × K-603
	Lakhan	11th HBSN-146	24thIBYT-19 × Lakhan	Rihane × Lakhan	24th IBYT-19 × Lakhan
Effective tillers per plant	Lakhan	Lakhan	HUB-174 × K-603	HUB-174 × K-603	HUB-174 × K-603
	RD-2508	HUB-174	Harmal × RD-2508	24th IBYT-19 × Lakhan	Harmal × RD-2508
	K-603	Rihane	Rihane × RD-2508	Harmal × RD-2508	Rihane × RD-2508
Peduncle length	Lakhan	INBON-65	11th HBSN-146 × Lakhan	INBON-18 × RD-2508	24thIBYT-19 × Lakhan
	K-603	Harmal	Harmal × Lakhan	Rihane x Lakhan	Harmal × Lakhan
	HUB-174	Lakhan	24thIBYT-19 × K-603	Rihane × RD-2508	24thIBYT-19 × K-603
Spike length with awn	INBON-18	INBON-67	INBON-67 × RD-2508	Beecher × RD-2508	INBON-67 × RD-2508
	Lakhan	Beecher	INBON-65 × Lakhan	INBON-67 × RD-2508	INBON-65 × Lakhan
	K-603	INBON-18	Beecher x RD-2508	Moroc-9-75 × Lakhan	Harmal × RD-2508
Spike length excluding awn	K-603	11th HBSN-14624th	INBON-18 × K-603	INBON-18 × K-603	INBON-18 × K-603
	Lakhan	IBYT-19	11th HBSN-146 × K-603	INBON-18 × Lakhan	11th HBSN-146 × K-603
	Moroc-9-75	INBON-65	24thIBYT-19 × K-603	Rihane × RD-2508	24thIBYT-19 × K-603
Number of grains per spike	11th HBSN-146	Beecher24th	11th HBSN-146 × Lakhan	HUB-174 × RD-2508	11th HBSN-146 × Lakhan
	Moroc-9-75	IBYT-19	11th HBSN-146 × RD-2508	Beecher × K-603	11th HBSN-146 × RD-2508
	Beecher	Rihane	11th HBSN-146 × K-603	11th HBSN-146 × Lakhan	24thIBYT-19 × K-603
1000 grain weight	HUB-174	HUB-174	HUB-174 × K-603	Rihane × Lakhan	HUB-174 × K-603
	K-603	K-603	Rihane × Lakhan	INBON-18 × K-603	Rihane × Lakhan
	INBON-18	INBON-18	INBON-18 × K-603	Beecher × K-603	INBON-18 × K-603
Grain yield per plant	RD-2508	INBON-65	INBON-65 × RD-2508	11th HBSN-146 × Lakhan	INBON-65 × RD-2508
	Lakhan	11th HBSN-146	11th HBSN-146 × Lakhan	Beecher × K-603	11th HBSN-146 × Lakhan
	K-603	RD-2508	INBON-65 × Lakhan	Moroc-9-75 × K-603	HUB-174 × RD-2508

Table 6: Estimates of standard heterosis for yield and its component traits in barley

Crosses	Plant height	Flag leaf length	Flag leaf width	Effective tiller per plant	Peduncle length	Spike length with awn	Spike length excluding awn	Grains per spike	1000 grain weight	Grain yield per plant
Moroc-9-75 × K-603	-6.30**	9.36*	7.49*	14.14**	-7.5	5.93	8.82	3.76*	-0.85	20.81**
Moroc-9-75 × RD-2508	-15.11**	13.56**	7.25	2.84	-6.81	4.45	-0.29	2.87*	-22.51**	9.33**
Moroc-9-75 × Lakhan	-7.39**	11.36**	-5.80	22.29**	-8.52	17.95**	0.10	3.86**	-20.64**	12.42**
Rihane × K-603	-8.89**	5.32	-4.35	10.21**	-0.80	12.49**	1.14	4.91**	1.50	11.74**
Rihane × RD-2508	-16.58**	-9.77	-7.00	22.29**	-35.87**	6.73	0.89	2.51	-25.22**	14.77**
Rihane × Lakhan	-0.28	-0.32	7.73*	15.97**	1.60	10.40*	-0.54	4.38**	7.98**	6.38
Harmal × K-603	-0.88	-6.53	-7.00	6.35**	3.47	11.68*	3.11	-53.72**	-11.19**	-2.94
Harmal × RD-2508	-4.82**	-10.68**	15.94**	23.42**	-1.00	4.66	-2.60	-51.72**	-24.55**	14.31**
Harmal × Lakhan	5.78**	-5.75	2.42	15.97**	8.02	14.90**	0.57	-51.46**	-21.34**	8.02
Beecher × K-603	-6.21**	-3.15	11.11**	4.02	-5.71	36.11**	4.70	5.01*	5.50**	17.03**
Beecher × RD-2508	-04.05**	-15.56**	-5.80	11.05**	-9.82	54.11**	-7.52**	1.51	-22.54**	19.97**
Beecher × Lakhan	-6.71**	-7.83*	1.93	14.53**	-15.33**	47.20**	-7.74**	2.82	-19.06**	-7.38
IBNON-18 × K-603	-3.20**	17.53**	1.93	-6.66*	-3.51	41.41**	20.46**	1.46	6.79**	0.42
IBNON-18 × RD-2508	-4.74**	12.51**	8.70*	5.43	5.27	44.27**	-12.48**	3.34*	-12.94**	-1.59
IBNON-18 × Lakhan	-3.11**	-4.34	-4.11	18.64**	4.96	49.01**	11.64**	4.38**	0.14	3.19
IBNON-67 × K-603	1.38	3.15	-0.24	6.61**	5.41	43.82**	4.00	3.34*	6.01**	2.60
IBNON-67 × RD-2508	-13.77**	4.52	5.07	13.68**	-5.01	55.5**	1.21	3.97**	-15.50**	16.06**
IBNON-67 × Lakhan	0.23	7.90*	-0.97	16.36**	5.81	51.53**	-0.48	3.27*	-21.86**	13.26**
IBNON-65 × K-603	0.36	-12.14**	4.59	3.60	5.21	53.78**	17.99**	2.82	5.75**	17.53**
IBNON-65 × RD-2508	-1.58	21.13**	6.76	7.96**	4.79	50.57**	11.83**	2.82	-11.61**	32.80**
IBNON-65 × Lakhan	1.87*	8.63*	9.90**	22.29**	4.51	54.43**	4.70	1.44	-12.72**	21.81**
24th IBYT-19 × K-603	-1.00	4.97	-2.17	-1.10	6.21	10.40**	18.59**	4.12**	0.29	3.44
24th IBYT-19×RD-2508	-1.41	1.10	5.07	-15.01**	-12.93**	4.77	6.28*	2.04	-17.56**	5.54
24th IBYT-19 × Lakhan	4.82**	5.43	10.63**	18.81**	9.62	12.97**	11.99**	5.95**	-24.77**	7.21
11th HBSN-146 × K-603	-0.33	18.67**	4.83	9.59**	-4.71	7.67	20.24**	13.26**	2.43	11.24**
11th HBSN-146 × RD-2508	1.81*	19.81**	5.07	7.76**	-14.93*	-0.85	6.60**	14.82**	-8.74**	11.58**
11th HBSN-146 × Lakhan	-1.69*	19.35**	4.59	22.29**	4.71	15.70**	13.63**	17.69**	-16.36**	24.16**
HUB-174 × K-603	-1.40	14.33**	-2.66	24.54**	3.71	0.11	4.57	-7.93**	14.39**	7.38
HUB-174 × RD-2508	-8.27**	8.40*	-2.42	10.77**	-14.13*	-7.60	-0.38	3.24*	5.11**	22.48**
HUB-174 × Lakhan	-1.29	30.08**	-2.66	15.27**	2.20	-0.85	-6.19**	-8.14**	1.92	5.45

* Significant at $p = 0.05$, ** Significant at $p = 0.01$

it was proved that the estimates of GCA effects were correlated with the *per se* performance of the parent for some of the traits studied. Thus *per se* performance of the parents may provide a reasonable indication of their GCA effects to a certain extent. It was confirmed earlier in the report of Gulati *et al*. (1969), Sharma *et al*. (2002) and Saini *et al*. (2006).

The parents (Moroc-9-75, Beecher, and Rihane) were superior general combiner for plant height (Table 5) and 11th HBSN-

146, HUB-174 and Moroc-9-75 for flag leaf length. Considering the GCA performance it could be concluded that RD-2508 was the best tester for breeding in connection with high yield, a number of grains per spike and dwarfness of the plant. Other superior lines were INBON-65, INBON-18 and Rihane. The present investigation also revealed that some of the parents having significant positive GCA effects for grain yield per plant also showed positive GCA effects for one or more of yield contributing traits. The parent RD- 2508 exhibited positive and significant GCA effects for grain yield per plant, a number of grains per spike and plant height. Similarly, INBON-18 was good for grain yield per plant, a number of grains per spike, peduncle length, spike length with awn, spike length excluding awn and 1000 grain weight. The crosses, Moroc-9-75 × K-603, Beecher × K-603, Beecher × RD-2508 and HUB-174 × RD-2508 showed significant SCA effects for grain yield per plant. The crosses HUB-174 × K-603, Rihane x Lakhan, INBON-18 x K-603, 11th HBSN-146 × RD-2508, HUB-174 × RD-2508, 24th IBYT-19 × K-603, 24th IBYT-19 × RD-2508 revealed significant positive SCA effects for 1000 grain weight. These results were in accordance with Singh *et al*. (1980) and Varma *et al*. (1981). The extent of heterosis for different characters in relation to standard check (Table 6) appeared that the overall good heterotic crosses were Moroc-9-75 × RD-2508 for plant height, HUB-174 × K-603 for flag leaf length, Harmal × RD-2508 for flag leaf width, HUB-174 × K-603 for number of effective tillers per plant, INBON-67 × RD-2508 for spike length with awn, INBON-18 × K-603 for spike length excluding awn, 11th HBSN-146 x Lakhan for a number of grain per spike, INBON-65 × RD-2508 for grain yield per plant and HUB-174 × K-603 for 1000 grain weight respectively. Farshadfar *et al.,* (2012) reported similar finding some traits and concluded that the high heterotic effect for different traits might be due to over dominance or epistatic effect of different dominant genes present in the parents. Therefore, based on outstanding performance of selective parents and crosses in present study, can be concluded that desirable lines (parents) could be used as donors to get high yield and the selective crosses were identified as outstanding for grain yield and its component traits due to possessing high SCA effect and high heterosis for grain yield may further be utilized in future under breeding programme.

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