Combining Ability over Environments for Yield and Yield Contributing Traits in Six-Rowed Barley (*Hordeum vulgare* L.)

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Ten parents and their 45 F_1s and F_2s were evaluated for grain yield and its component characters over three different environments (sowing dates). Highly significant variation was observed due to genotypes and environments for all 10 characters studied. Both *gca* and *sca* variances showed significant interactions. The genotypes RD-2552 and RD-2035 were found to be good general combiners and 15 crosses have been identified as good specific combiners for grain yield and other related traits. The crosses RD-2552 × RD-387, RD-2052 × RD-2508 and RD-2035 × RD-2552 were the best crosses for grain yield and most of the yield contributing traits.

Key Words: Barley, Combining Ability, *gca* × Environment Interaction, *sca* × Environment Interaction

Combining ability effects are considerably influenced by environments and for a more precise and valid conclusion, studies under different environments reveal the impact of genotype x environment interaction on the estimates. The present investigation was carried out in three different environments to study the combining ability of ten genotypes for different quantitative characters in six-rowed barley (*Hordeum vulgare*).

Materials and Methods

Ten varieties/strains of six-rowed barley, namely, RD-2035, RD-2052, RD-2503, RD-2508, RD-2552, RD-2585, RD-387 (Rajkiran), BL-2, ISBYT-4 and ISBYT-17 of diverse genetic origin were crossed in half diallel fashion. The parents along with 45 F_1s and F_2s were grown in randomized block design with three replications during *rabi* 2000-01 under early, normal and late sown conditions. Each plot consisted of two rows of 2 m length of non-segregating materials i.e. parents and F_1s and four rows of segregating materials *i.e.* F_2s with a spacing of 30 cm between the rows and 10 cm between plants. Ten competitive plants in parents and F_1s and 30 plants in F_2s progenies were selected randomly for recording observation under each environment separately. The statistical analysis for combining ability based on mean values was done as per method–II model–I of Griffing (1956). The pooled analysis over environments was carried out by the method of Singh (1973).

Results and Discussion

Pooled analysis of variance revealed significant variation among parents for all the traits, indicating adequate genetic variability among the parental lines used in the present study (Table 1). The genotype interacted significantly with the environments for all the traits. Combining ability analysis reveled that *gca* and *sca* variances were highly significant for all the traits. Both *gca* and *sca* showed significant interaction with environments for all the traits. The significant *gca* x environment and *sca* x environment interaction indicated that the estimates of both additive and non-additive gene

Table 1. Pooled analysis of variance for combining ability for various traits over three environments

Source of Variance	df	Days to heading	Plant height (cm)	Tillers/ plant	Flag leaf area(cm^2)	Spike length(cm)	Spikelets/ spike	Grains/ spike	1000-grain weight(g)	Harvest index	Grain yield/ plant (g)
GCA	9	17.50*	47.01**	0.44**	0.46**	0.30**	19.17**	17.82**	6.11**	1.71**	8.16**
SCA	45	13.09*	27.57**	0.29*	0.16*	0.19*	14.52**	15.82**	5.23**	1.26**	3.83**
Env.	2	28.78*	80.25**	1.33*	0.12	0.98**	11.81*	12.13*	0.97	4.39*	5.40*
GCA x Env.	18	14.42*	32.04*	0.83*	0.67*	0.36*	14.13**	13.11*	11.09**	1.86*	15.81**
SCA x Env.	90	15.01**	51.93**	0.51**	0.52**	0.27*	15.53**	14.71**	6.69**	2.06**	9.26**
Error	594	5.46	10.73	0.12	0.14	0.13	3.38	2.75	1.48	0.56	1.11

*, ** Significant at 5% and 1% respectively

effects are prone to change with the environment. Similar results were also reported by Vazquez and Sanchez (1987), Bhatnagar and Sharma (1995) and Singh *et al.* (1999).

The estimates of *gca* effects (Table 2) on the basis of pooled analysis revealed that the genotypes RD-2585, RD-2035 and RD-2552 for days to heading, BL-2 for plant height, RD-2508 and RD-2552 for tillers/plant, RD-2508, RD-2552 and RD-2052 for flag leaf area, RD-2503, RD-2035 and RD-2052 for spike length, RD-2552 for spikelets/spike, RD-2552 and RD-2035 for grains/spike, RD-2508, RD-2552, RD-2503 and RD-2585 for 1000-grain weight, RD-2503, RD-2508, RD-2052 and RD-2035 for harvest index and RD-2552, RD-2503, RD-2035 and RD-2052 for grain yield/plant.

Present finding revealed that the parent *viz.*, RD-2552 and RD-2035 offered the best possibilities of exploitation for development of improved high yielding genotypes of six-rowed barley.

Fifteen crosses which showed highest significant positive *sca* effects for grain yield are presented in Table 3. The crosses RD-2052 × RD-2508, RD-2503 × ISBYT-4 and RD-2503 × RD-387 exhibited desirable negative non significant *sca* effects for days to heading, whereas RD-2052 × RD-2508 and RD-2552 × RD-2585 showed desirable negative significant *sca* effects for dwarf ness. The cross RD-2552 × RD-387 exhibited positive and significant *sca* effects for tillers/plant, flag leaf area, spike length, spikelets/spike, grains/spike, harvest index and grain yield/plant. The crosses ISBYT-4 × ISBYT-17, RD-2035 × RD-2508, RD-2052 × ISBYT-17 and RD-2552 × BL-2 showed significant positive *sca* effects for 1000-grain weight. For the trait grain yield/plant the crosses, *viz.*, RD-2552

Table 2. Pooled estimates of general combining ability effects for various traits over different environments

Genotypes	Day to heading	Plant height (cm)	Tillers/ plant	Flag leaf area (cm²)	Spike length (cm)	Spikelets/ spike	Grains/ spike	1000-grain weight (g)	Harvest index	Grain yield/ plant (g)
RD-2035	-0.64*	-0.80	-0.07**	0.03	0.08**	0.35	0.56*	0.13	0.08*	0.17*
RD-2052	1.24**	0.30	0.02	0.06*	0.06**	0.42	0.33	-0.48**	0.18**	0.16*
RD-2503	0.21	-0.76	0.00	0.00	0.10**	0.36	0.14	0.30*	0.23**	0.27**
RD-2508	-0.38	0.11	0.16**	0.10**	-0.01	-0.71*	-0.64*	0.52**	0.23**	0.08
RD-2552	-0.63*	1.09*	0.12**	0.06*	0.07**	1.24**	1.35**	0.48**	0.05	0.63**
RD-2585	-.092**	1.51**	0.00	-0.05*	-0.05**	-0.88**	-0.93**	0.25**	-0.19**	-0.27**
RD-387	-0.30	0.41	-0.12**	-0.09**	-0.05**	-0.29	-0.27	-0.09	-0.12**	-0.31**
BL-2	0.15	-1.21*	-0.07**	-0.05*	-0.11**	-0.22	-0.03	-0.36**	-0.02	-0.19*
ISBYT-4	0.83*	-0.57	0.03	0.02	-0.07**	-0.46	-0.56*	-0.70**	-0.27**	-0.46**
ISBYT-17	0.45	-0.08	-0.08**	-0.09**	-0.02	0.18	0.05	-0.05	-0.19**	-0.09
SE(gi)±	0.26	0.42	0.02	0.02	0.01	0.23	0.20	0.09	0.03	0.07

*, ** Significant at 5% and 1%, respectively

Table 3. Estimates of specific combining ability effects of the best 15 specific crosses over different environments

Crosses	Day to Heading	Plant height (cm)	Tillers/ plant	Flag leaf area (cm²)	Spike length (cm)	Spikelets/ spike	Grains/ spike	1000-grain weight(g)	Harvest index	Grain yield/ plant(g)	*gca* status
RD-2035 x RD-2052	0.44	-0.54	0.32	0.32*	0.46**	3.06**	3.32**	0.67	0.79*	2.39**	H × H
RD-2035 x RD-2508	-0.27	-0.39	-0.06	0.01	0.09	2.22	1.18	1.73**	0.62	0.92	H × M
RD-2052 x RD-2508	-1.37	-5.55*	0.24	0.16	0.10	4.79**	4.37**	1.29*	0.69	3.06**	H × M
RD-2052 x ISBYT-17	3.79**	3.40	0.67**	0.70**	0.14	0.54	-0.12	1.64*	1.31**	2.07**	H × L
RD-2503 x RD-2585	2.64*	1.06	0.65**	0.62**	0.21	2.41*	1.57	-2.13**	0.67	1.53**	H × L
RD-2503 x RD-387	-1.10	3.94	0.14	0.02	0.42**	1.34	1.54	-0.38	0.62	1.10	H × L
RD-2503 x ISBYT-4	-1.11	-0.68	0.40	0.34*	0.35**	1.96	1.52	-0.94	0.40	1.41*	H × L
RD-2508 x ISBYT-4	2.03	0.15	0.34	0.35*	0.19	-1.10	-2.27	-0.30	0.70	1.06	M × L
RD-2508 x ISBYT-17	2.19	5.41*	0.71**	0.61**	0.19	1.59	1.39	0.12	0.68	1.32*	M × L
RD-2552 x RD-2585	2.70*	-5.05*	0.41*	0.53**	-0.08	-0.93	-1.00	0.49	1.50**	0.81	H × L
RD-2552 x RD-387	2.08	-0.58	0.76**	0.49**	0.53**	5.84**	5.40**	0.37	1.10**	3.34**	H × L
RD-2552 x BL-2	0.63	4.77	0.22	0.14	0.12	5.75**	5.55**	1.41*	0.94*	2.48**	H × L
RD-2552 x ISBYT-4	0.28	-1.64	0.25	0.22	0.53**	3.04**	3.63**	0.45	0.77*	2.04**	H × L
BL-2 x ISBYT-17	-0.79	-2.68	-0.08	-0.17	0.28*	3.20**	3.02**	0.50	0.46	1.46*	L × L
ISBYT-4 x ISBYT-17	-0.13	-0.03	0.04	-0.10	0.16	2.75**	2.60*	2.05**	0.74*	1.81**	L × L
Se (gi) ±	1.24	2.42	0.20	0.15	0.13	1.11	1.03	0.64	0.37	0.56	

*, ** Significant at 5% and 1%, respectively

× RD-387, RD-2052 × RD-2508, RD-2552 BL-2, RD-2035 × RD-2052 and RD-2052 × ISBYT-17 exhibited positive significant *sca* effects.

The crosses with significant positive *sca* effects for grain yield/plant involved parent with low × low or low × high *gca* effects indicating the presence of non-allelic interactions and also manifested heterosis of higher magnitude. Both parents with high *gca* effects when crossed had probably low magnitude of non-additive gene effects resulting in the small degree of *sca* effects and heterosis. The present findings are in agreement with the earlier results of Singh (1983) and Bhatnagar and Sharma (1995). Therefore, recurrent selection for *sca* could be followed in the segregating generation of the crosses RD-2035 × RD-2508, RD-2052 × RD-2508, RD-2052 × ISBYT-17, RD-2503 × RD-2585, RD-2503 × RD-387, RD-2503 × ISBYT-4, RD-2552 × RD-2585, RD-2552 × RD-387, RD-2552 × BL-2 and RD-2552 × ISBYT-4, as this type of relation was proposed on the assumption that an important part of heterosis results from the non-linear interaction of genes at different loci, from interaction between alleles at the same locus or from both causes in combination. It is possible to obtain substantial improvement with regard grain yield in addition to other desirable traits like tillers/plant, spike length, grains/spike, 1000-grain weight and harvest index. Heterosis breeding could be suggested for hybrid development but are not utilized so far in barley for commercial exploitation of heterosis.

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