Genetic Analysis of Yield and its Component Traits in Barley

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Combining ability analysis in six-rowed barley (*Hordeum vulgare* L.) involving 10 diverse parents and their 45 F_1's and F_2's progenies indicated significant differences among the parents for gca and crosses for sca for all the characters studied. The gca and sca components of variance were significant for all the traits. The gca:sca ratio showed that among the two types of genetic effects, the non-additive gene effects were more important in comparison to additive gene effects in controlling the inheritance of the characters under study. Among the parents RD 2052, RD 2503 and BL 2 were the best general combiners for grain yield and average to high combiners for other important traits. The best specific crosses for grain yield were BL 2 x ISBYT 17, RD 2503 x RD 2585, BL 2 x ISBYT 4, RD 2052 x BL 2, RD 2508 x ISBYT 4, RD 2053 x RD 2552, RD 2035 x RD 2052 and RD 2035 x BL 2 in both F_1 and F_2 generations. To ensure further increase in grain yield, combinations of desirable yield components is advocated. The exploitation of additive and non-additive gene actions through bi-parental mating and/or diallel selective mating systems are suggested for tangible advancement of grain yield in barley.

Key words: Barley, Variety, Gene Effects, Heterosis, Yield Components

Introduction

In India, barley (*Hordeum vulgare* L.) is grown on more than 7.28 lakh hectares, with a production of more than 14.56 lakh tones with productivity of 20.01 q/ha. In India, barley is grown as a rainfed or residual moisture crop. Barley is used as human food either for bread making or traditional recipes. The major use of barley grains is in the production of malt. Barley cultivation in India is now becoming oriented towards industrial utilization. For improving breeding population a thorough knowledge of gene action, heritability of the characters and genetic contents of the parents is needed. Improvement in breeding population achieved by reconstructions of genotypes, which is frequently accomplished by introduction of alien genes through hybridization followed by directional selection for that decision, should be made about the choice if the desirable parents for hybridization as superior segregates could result only from specific cross combinations involving apparently desirable parents. This emphasizes the necessity of testing the parent for their combining abilities. The isolation of superior and transgressive segregates in the advance generations equal or superior to the F_1 depends up on the type of gene action predominantly responsible for the expression of the characters. Several mating designs and models, which provide estimates of the effects and variances due to combining ability, are available and each of them has its advantages and disadvantages. The diallel method of analysis was developed in order to provide information on the genetic architecture of the breeding material, which helps in the identification of the parents/crosses to be including in a future breeding programme for tangible advancement of crops. The diallel analysis also provides a unique opportunity to test a number of lines in all possible combinations. Thus, the main objective of present studies was to identify best combining parents and their crosses on the basis of their general and specific combining ability for yield and its component traits under normal sown environment for further amelioration of grain yield in barley.

Materials and Methods

Ten varieties of six-rowed barley (*Hordeum vulgare* L.) namely, RD 2035, RD 2052, RD 2503, RD 2508, RD 2552, RD 2585, RD 387, BL 2, ISBYT 4 and ISBYT 17 were crossed in all possible combinations excluding reciprocals. The 10 parents and their resulting 45 F_1's and 45 F_2's were grown in a randomized block design with three replications at Asalpur Research Farm of SKN College of Agriculture, Jobner, Jaipur, Rajasthan. Plots of parents and F_1s consisted of two rows of 2 m length while each plot of F_2 consisted of four rows with the spacing of 30 cm between rows and 10 cm between plants. Ten competitive plants in parents and F_1's and 30 plants in F_2 progenies were selected randomly for recording observations on ten characters namely, days to heading (75%), plant height (cm), tillers per plant, flag leaf area (cm^2), spike length (cm), number of spikelets per spike, number of grains per spike, 1000-grain weight (g), harvest index (%) and grain yield per plant (g).

The mean of each plot was used for statistical analysis. The data were first subjected to the usual analysis followed for a randomized block design for pooled environments as well as for individual environment (Panse and Sukhatme, 1967). The combining ability analyses were carried out following Method II, Model I of Griffing's (1956).

Results and Discussions

Analysis of variance indicated significant differences among parents for all the characters. Similarly the differences among F_1 hybrids and F_2 progenies were found significant for all the traits indicating the presence of diversity in the material (Table 1). The significant differences between parents vs F_1s and parent vs F_2s were also found for all the traits revealed the existence of heterosis and inbreeding expression. Significant differences among genotypes for grain yield and its related traits in different sets of materials were also reported by Kudla *et al.,* (1988), Leistrumaite (1989), Bhatnagar and Sharma (1995) and Sharma *et al.*, (2002).

Analysis of variance for combining ability revealed that the variance due to general combining ability (gca) and specific combining ability (sca) were highly significant for all the traits studied in both F_1 and F_2 generations. Thus, both kinds of gene effects figured important in controlling the inheritance of all the characters studied. However, the gca:sca ratio tilted normally in favour of sca in all the traits in both F_1 and F_2 generations indicating the preponderance of non-additive gene effects in the genetic control of the traits (Table 2). The present findings thus supported the reports of Madic (1996), El-Seidy (1997), Bouzerzour and Djakoune (1998) and Sharma *et al.* (2002), which clearly indicated that non-additive genetic variance as the main component of genetic variance of various economic traits in barley. However, preponderance of additive effects were reported by Kalashnik and Smyalovskaya (1986) and Yang and Lu (1991) and role of both additive and non-additive effects were also reported by Choo *et al.* (1988) and Bhatnagar

Table 1. Analysis of variance showing mean squares for parents, F_1s and F_2s for different characters of barley

Characters	Replication	Genotype	Parents	F_1	F_2	P vs F_1	P vs F_2	Error
d.f.	**2**	**99**	**9**	**44**	**44**	**1**	**1**	**198**
Days to heading	2.90	55.97**	72.85**	48.88**	56.83**	209.60**	216.03**	8.63
Plant height	19.43	218.24**	227.90**	228.95**	202.98**	526.88**	258.98**	26.81
Tillers per plant	0.18	1.71**	0.70**	1.40**	1.80**	18.53**	20.92**	0.32
Flag leaf area	0.07	0.74**	2.03**	0.60**	0.54**	4.95**	3.56**	0.24
Spike length	0.43	0.98**	1.13**	0.80**	0.81**	16.30**	12.85**	0.51
Number of spikelets per spike	3.22	69.99**	21.03**	75.21**	68.00**	434.62**	259.83**	7.85
Number of grains per spike	2.65	69.68**	18.57**	79.88**	66.23**	297.70**	168.65**	5.48
1000-grain weight	0.18	15.30**	22.14**	14.81**	11.33**	144.11**	51.69**	1.59
Harvest index	2.71	8.06**	3.49**	7.36**	6.58**	144.72**	66.05**	1.37
Grain yield per plant	1.38	34.77**	4.85**	32.26**	29.44**	681.94**	491.85**	1.35

* and ** Significant at 5 and 1 per cent level, respectively

Table 2. Analysis of variance for combining ability for different characters of barley

Characters	Source							
	GCA		SCA		Error		GCA/SCA	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
d.f.	9		45		108		–	
Days to heading	39.06**	44.83**	14.53**	16.01**	1.37	2.07	0.205	0.241
Plant height	228.90**	207.22**	47.93**	41.83**	7.32	7.71	0.516	0.586
Tillers per plant	0.91**	1.13**	0.46**	0.56**	0.07	0.08	0.103	0.105
Flag leaf area	0.73**	0.73**	0.22**	0.19**	0.03	0.03	0.288	0.412
Spike length	0.54**	0.61**	0.35**	0.31**	0.08	0.08	0.084	0.159
Number of spikelets per spike	19.07**	15.15**	25.32**	22.46**	2.49	2.77	-0.023	-0.031
Number of grains per spike	18.67**	13.37**	25.74**	21.40**	1.94	2.07	-0.025	-0.035
1000-grain weight	13.13**	12.02**	4.75**	3.15**	0.53	0.65	0.165	0.296
Harvest index	4.77**	4.81**	2.75**	1.90**	0.42	0.47	0.073	0.169
Grain yield per plant	16.61**	15.99**	12.57**	9.83**	0.40	0.47	0.028	0.055

** Significant at 1 per cent level.

and Sharma (1995) for grain yield and its component characters in barley.

The estimates of general combining ability (gca) effects revealed that among parents RD 2052, Rd 2503 and BL 2 were the best general combiners for grain yield and good to average combiner for most of the yield component characters (Table 3). However, rest of the parents were poor combiner for grain yield and average to poor general combiners for most of the yield contributing traits. Parent RD 2508 was the best general combiners for dwarfness, spike length, number of spikelets (F_1), number of grains per spike and 1000-grain weight. Parent RD 2035 was good general combiner for early heading (F_1), flag leaf area and 1000-grain weight. Almost similar trends of parents for general combining ability effects were observed in both F_1 and F_2 generations. Parent RD 2052 was also good general combiner for early heading, dwarfness, tillers per plant, flag leaf area, spike length, number of spikelets (F_1), number of grains per spike (F_1), 1000-grain weight and harvest index. RD 2503 was good combiner for dwarf ness, tillers per plant, number of grains per spike (F_1), 1000-grain weight (F_1), and harvest index. Parent BL 2 was the best general combiner for flag leaf area, number of spikelets (F_1), number of grains per spike (F_1), and harvest index (F_1). Parents RD 2552, RD 2585, RD 387, ISBYT 4 and ISBYT 17 were observed poor general combiners for grain yield as well as for yield components under study. Apparently therefore, there is still further scope for improving upon the combining ability for component traits, as none of high combiners for grain yields was a high combiner or at least an average combiner for all the desirable traits.

High gca effects are mostly due to additive gene effects or additive x additive interaction effects as earlier reported for Griffing (1956). In view of this, breeders may utilize the good general combiners in specific breeding programme for amelioration of grain yield in barley. It seems feasible, therefore, that the gca rank for grain yield is related to the gca for the useful yield components. It is, therefore, recommended that breeder should breed for superior combining ability for the component traits with an ultimate objective to improve the over all gca for grain yield in barley. The parents

Table 3. Estimates of general combining ability effects for different characters of barley

Parent	Days to heading		Plant height		Tillers per plant		Flag leaf area		Spike length	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
RD-2035	1.144**	-3.056**	-2.087*	-1.712	0.080	0.214*	0.218**	0.238**	0.107	0.143
RD-2052	-3.772**	-3.000**	-3.783**	-3.317**	0.458**	0.482**	0.414**	0.353**	0.252**	0.264**
RD-2503	1.256**	-0.139	-2.546**	-2.243*	0.369**	0.403**	0.031	0.123*	0.158	0.181*
RD-2508	-1.800**	-0.694	-3.494**	-3.310**	-0.234**	-0.256**	-0.029	-0.102	0.229*	0.233*
RD-2552	-0.133	2.222**	-1.435	-1.295	-0.370**	-0.322**	-0.151*	-0.293**	-0.230*	-0.254**
RD-2585	1.450**	1.972**	10.790**	10.575**	0.050	0.030	-0.249**	0.243**	0.035	0.027
RD-387	2.283**	1.889**	-1.318	-0.982	-0.161	-0.224*	-0.215**	-0.156**	-0.331**	-0.346**
BL-2	0.061	-0.778	3.130**	2.049*	0.158	0.165	0.354**	0.358**	0.140	0.128
ISBYT-4	-1.106**	0.278	-1.047	-1.248	-0.281**	-0.385**	-0.220**	-0.084	-0.136	-0.129
ISBYT-17	0.617	1.306**	1.790**	1.783*	-0.067	-0.106	-0.152*	-0.195**	-0.222*	-0.246**
SE (g_i) ±	0.320	0.394	0.741	0.760	0.072	0.077	0.047	0.047	0.077	0.077
SE $(g_i$-$G_j)$±	0.478	0.587	1.104	1.133	0.108	0.115	0.070	0.070	0.115	0.115

	Number of spikelets per spike		Number of grains per spike		1000-grain weight		Harvest index		Grain yield per plant	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
RD-2035	0.096	-0.778	0.447	-0.669	0.925**	1.118**	0.379	0.310	-0.026	0.015
RD-2052	1.566**	0.945	1.663**	0.718	0.761**	0.688**	1.007**	1.122**	1.863**	1.872**
RD-2503	1.318*	0.377	1.216*	0.275	0.538**	0.402	0.621**	0.424*	1.324**	1.004**
RD-2508	0.835	1.150*	0.955*	1.092*	1.422**	1.328**	0.055	-0.232	0.506*	0.423
RD-2552	-0.826	-0.074	-1.023*	0.200	-1.601**	-1.525**	-0.513*	-0.390	-1.020	-0.770**
RD-2585	0.785	0.831	0.688	0.769	-0.894**	-0.764**	-0.137	0.033	-0.025	-0.122
RD-387	-2.343**	-2.105**	-2.323**	-2.032**	-0.370	-0.354	-1.193**	-1.004**	-1.828**	-1.949**
BL-2	0.649	1.344*	0.186	1.294**	0.393	0.347	0.363	0.636**	0.990**	1.207**
ISBYT-4	-1.179*	-0.700	-1.076*	-0.867	0.347	0.229	-175	-0.292	-0.793**	-0.721**
ISBYT-17	-0.901	-0.989	-0.734	-0.780	-1.521**	-1.169**	-1.408*	-0.607*	-0.991**	-0.958**
SE (g_i)±	0.432	0.456	0.382	0.394	0.199	0.222	0.178	0.188	0.173	0.188
SE $(g_i$-$G_j)$±	0.644	0.680	0.569	0.587	0.297	0.330	0.265	0.280	0.258	0.280

** and ** Significant at 5 and 1 per cent level, respectively

RD 2052, RD 2503, and BL 2 could be utilized extensively in the hybridization programme to accelerate the pace of genetic improvement of grain yield in six rowed barley under heat stress environment.

In order to synthesize a dynamic population with most of the favourable gene accumulated, it will be pertinent to make use of the aforesaid parents, which are good general combiner for several characters, in multiple crossing programmes. Apart from conventional breeding methods resting slowly upon additive or additive x additive type of gene action, population improvement appears to be hopeful alternative. Diallel selective mating system of Jensen (1970) is a good technique, which delays quick fixation of gene complexes, permit break down of linkage, general fostering of recombination and concentration of favorable genes / gene complexes, into central gene pool, by a series of multiple crosses.

Normally the sca effects do not contribute tangibly in the improvement of self-fertilizing crops, except where commercial exploitation of heterosis is feasible. The sca represent the dominance and epistatic interaction, which can be related with heterosis. However, in self-pollinated crops like barley, the additive x additive type of interaction component is fixable in later generations. Breeder's interest, therefore, vests in obtaining transgressive segregants through crosses and producing more potent homozygous lines. Jinks and Jones (1958) emphasized that the superiority of the hybrids might not indicate their, ability to yields transgressive segregants, rather sca would provide satisfactory criteria.

The estimates of specific combining ability (sca) revealed that out of 45 crosses, 25 crosses in F_1's and 21 crosses in F_2's were found to be good specific combiners for grain yield. It is noteworthy that 21 crosses showed positive and significant sca effects for grain yield in both F_1 and F_2 generations. The generation effects were also noticed in the sca effects of the crosses. The highest positive significant sca effect was exhibited by the cross BL 2 x ISBYT 17 in both the generations. Other good combinations, which showed significant sca effects for grain yield in both the generations were RD 2503 x RD 2585, BL 2 x ISBYT 4, RD 2052 x BL 2, RD 2508 x ISBYT 4, RD 2503 x RD 2552, RD 2035, RD 2052, RD 2035 x BL 2, RD 2052 x RD 2552, RD 2508 x RD 2552 and RD 2508 x RD 387 in both F_1 and F_2 generations. These crosses were higher yielder and also in most of the crosses one of the parents involved was good combiner indicated that such combinations are expected to throw desirable transgressive segregants. All the best crosses for grain yield also showed average to high sca effects for most of the yield components. It is, therefore, recommended that new materials should be used in future breeding programmes for recombining the desirable traits in the envisaged elite genotypes.

It is noteworthy that the crosses, which exhibited consistently positive sca in both generations, also exhibited positive significant heterosis. Thus, the results of the present study indicated some relationship between sca effects and heterosis. It is, therefore, suggested that sca performance may be considered as a criterion for selecting the best crosses in barley. It may also be worthwhile to attempt bi-parental mating in the segregating generation among selected crosses to permit superior recombinations. All the important crosses involving parents with high x average, average x average and average x poor general combiners, indicated that non-additive type of gene actions, which are unfixable in nature were involved in selected cross combinations.

The study demonstrates that both additive (fixable) and non-additive (non-fixable) components of genetic variances were involved in governing the inheritance of almost all the quantitative and quality traits although additive genetic variance was predominant. Therefore, bi-parental mating and/or diallel selective mating which may allow inter-mating of the selects in different cycles and exploit both additive and non-additive gene effect could be useful in the genetic improvement of the characters of six rowed barley. Inclusion of F_1 hybrids showing high sca and having parents with good gca, into multiple crosses, could also prove a worthwhile approach for tangible advancement of grain yield in six-rowed barley.

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