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Short Communication

Genetic architecture of quantitative traits in barley (*Hordeum vulgare* L.)

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Abstract

The nature and magnitude of gene effects for yield and its component traits were studied in barley using generation mean analysis in five crosses. In general, magnitude of dominance effect (h) has a greater value than additive effect (d) in all the traits. It is obvious that non-fixable gene effects (h), (j) and (l) were higher than the fixable (d) and (i) in all the crosses in all the characters, indicating greater role of non-additive effects in the inheritance of all the characters. The study revealed the importance of non-additive type of gene action for most of the traits, thereby suggesting that selection at later segregating generation could provide better results.

Key words: Barley, gene effects, generation mean analysis, quantitative trait, recurrent selection, scaling test

Introduction

Barley (*Hordeum vulgare* L.), a diploid species is cultivated in two distinct phenotypic forms, *viz*., two rowed and six rowed based on ear morphology. Initially these two forms were classified as two separate species, but now these have been grouped into one single species, i.e., *Hordeum vulgare* L. These two varieties have same chromosome number, and freely produce fertile hybrid. In India, barley crop is grown over an area of 7.60 lakh hectares with production of 13.70 lac tonnes and productivity of 19.40 q/ha. Most of the traits of economic importance in barley are quantitative in nature. Understanding of the genetics underlying these traits is imperative for efficient management of available genetic variability and formulation of systematic breeding programmes. Few genetic studies have been conducted to understand the genetic control of grain yield and its component traits in barley. These studies have shown that both additive and non-additive genes control the grain yield in barley. The detection and estimation of epistasis would also enable the breeders to understand the genetic cause of heterosis with greater reliability. The presence or absence of epistasis can be detected by the analysis of generation means using the scaling test, which measures epistasis accurately whether it is complementary (additive x additive) or duplicate (additive x dominance) at the digenic level [1]. The present research was aimed to generate information on the nature of gene action in barley to decide selection methods for the improvement of the barley.

The experimental material comprised ten genetically diverse and homozygous varieties/lines of barley (*Hordeum vulgare* L.), namely, DL 88, K 560, K 603, Azad, RD 2552, NDB 1020, RD 2618, PL 708, NDB 1173 and Lakhan. The seed of these genotypes were obtained from, IARI, New Delhi, C. S. A. University of Agriculture and Technology Kanpur, A.R.S., S.K.R.A.U., Durgapura, Jaipur, Rajasthan, N. D. U. A & T, Faizabad. The experiments involved six basic generations, *viz*., P_1 and P_2 (Parents), F_1 and F_2, B_1 and B_2 derived from five combinations of the parental cultivars namely, DL 88 x K 560 (Cross I), K 603 x Azad (Cross II), RD 2552 x NDB 1020 (Cross

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III), RD 2618 x PL 708 (Cross IV) and NDB 1173 x Lakhan (Cross V). Plant to plant and row to row distance were 15 cm and 25 cm, respectively. Non-experimental lines were also planted at the start and end of each replication to eliminate border effects. Observations were taken on days to ear emergence, plant height (cm), no. of effective tillers/plant, length of main spike (cm), days to maturity, weight of grains/spike, no. of grains/spike,1000-grain weight (g) and grain yield/plant (g). The data were recorded on 10 competitive plants for each trait at maturity except days to ear emergence for which observations were recorded on per row basis. The mean values, standard errors and variances of the different generations were subjected to weighed least-squares analysis using the scaling test [2] and the joint scaling test to estimate gene effects. The genetic effects were estimated using the models suggested earlier [3, 4]. The significance of the scales and gene effects were tested by using the t-test [5]. The A, B, C and D scaling tests were carried out for nine quantitative traits.

Mean data and standard error of the six generations with five crosses for nine traits were calculated. Results showed that hybrid, NDB1173 x Lakhan was found earliest for days to emergence (80.35±0.88) and days to maturity (132.60±2.60) over rest of the hybrids. The earliness in ear emergence and days to maturity along with dwarf stature have been considered as desirable traits in barley as it is mainly grown as a rainfed crop. Crosses found superior to their respective parents were RD 2552 x NDB 1020 and NDB 1173 x Lakhan for effective tillers/plant (10.57±0.39 and 11.57±0.71). The crosses RD 2552 x NDB 1020 and RD 2618 x PL708 were found with maximum weight of grain/main spike (3.20±0.06 and 3.77±0.09 g) whereas crosses of DL 88 x K 560, RD 2552 x NDB 1020, RD 2618 x PL 708 and NDB 1173 x Lakhan recorded maximum number of grains/main spike (64.43±0.39, 92.03±0.46, 94.20±0.58 and 87.40±0.36 respectively). The crosses RD 2552 x NDB 1020 and NDB 1173 x Lakhan registered maximum 1000 grain weight (40.20±0.36 and 35.33±0.32 g) while DL 88 x K 560, RD 2618 x PL 708 and NDB 1173 x Lakhan gave maximum grain yield/plant (26.97±0.33, 27.23±0.69 and 32.83±1.20 g).

A simple additive-dominance model was inadequate as inferred from the significance of at least one or more than one scale for all traits except plant height in the DL 88 x K 560 cross indicating that an epistatic digenic interaction was the best fit. The additive, dominance and epistatic types of gene interaction in each cross for different traits were found different from each other (Table 1). Comparison of estimates of gene effect with respect to magnitude as well as significance reveled that additive (d) was of greater importance than to the dominance (h) gene effects for no. of effective tillers/plant, length of main spike, 1000-grain weight and grain yield/plant in the RD 2618 x PL 708 cross and no. of effective tillers/plant, length of main spike and grain yield/plant in the RD 2552 x NDB 1020 cross. Thus, selection for no. of effective tillers/plant and 1000-grain weight will be effective in early segregating generations. Both additive (d) and dominance (h) effects were pronounced in crosses NDB 1173 x Lakhan for days to ear emergence and grain yield/plant, DL88 x K560 for weight of grains/spike, grain yield/plant and RD 2552 x NDB 1020 for no. of grains/spike.

The dominance (h) effect was more important than additive gene effects (d) in the inheritance of no. of effective tillers/plant and 1000 grain weight for cross RD 2618 x PL 708, length of main spike and grain yield /plant in cross RD 2552 x Pl 708. Similar results were obtained for 1000-grain weight in the DL88 x K560 cross. The genetic effects for these characters suggested that selection for these characters will not be effective in segregating generations. Higher magnitude of dominance (h) component than the additive (d) component suggested that the parents involved in the crosses were in dispersion phase and dominance component was more important for these characters. Vimal and Vishwakarma [6]. also reported predominance of non-additive gene action for yield and yield components in barley.

Estimates of additive x additive (i), additive x dominance (j) and dominance x dominance (l) interactions indicated that the additive x additive (i) was more important in the inheritance of all the characters. Additive x additive (i) epistatic effect was more important and higher than the dominance x dominance (l) epistatic effect in the inheritance of no. of effective tillers/plant in DL88 x K560, length of main spike and grain yield/plant in RD 2552 x NDB1020. However, dominance x dominance (l) epistatic effect was also more important and higher than the additive x additive (i), dominance x dominance (l) epistatic gene interaction was significant and greater in magnitude than all the gene effects (d, h, i and j) in the inheritance of no. of grains/spike and grain yield/plant in NDB 1173 x Azad and no of effective tillers/plant, days to maturity

Table 1. Mean ±standard error, scaling test and genetic effects for different traits in barley

Cross	Gene effects and their interaction						Scaling tests				Types of epistasis
	m	[d]	[h]	[i]	[j]	[l]	A	B	C	D	
				Days to ear emergence							
I	-5.000** ±1.490	-3.670** ±0.940	11.170** ±3.070	10.000** ±2.980	2.830* ±1.330	-46.330** ±4.740	*	*	*	*	$D^{\#}$
II	-3.330 ±2.080	-1.330 ±1.100	9.670* ±4.200	6.670 ±4.160	0.670 ±1.270	-22.000** ±5.830	*	*	-	-	$D^{\#}$
III	6.330** ±2.000	1.000 ±0.940	12.670** ±4.100	12.670** ±4.000	8.000** ±1.300	-13.330** ±5.600	*	*	*	*	$D^{\#}$
IV	-20.670** ±2.540	0.670 ±1.050	48.500** ±5.240	41.330** ±5.080	-0.500 ±1.350	-61.000** ±6.870	*	*	*	*	$D^{\#}$
V	-1.340 ±1.000	2.660** ±0.740	7.340** ±2.210	2.670** ±2.000	6.340** ±0.810	-2.670 ±3.470	*	*	-	-	$D^{\#}$
				Plant height (cm)							
I	65.000** ±0.720	-0.733 ±1.084	-4.283 ±3.686	0.133 ±3.607	0.316 ±1.137	-5.967 ±5.422	-	-	-	-	$C^{@}$
II	76.233** ±0.762	-7.433** ±0.853	27.567** ±3.545	20.999** ±3.493	-11.36** ±0.91	1.667 ±4.731	*	-	*	*	D
III	81.467** ±0.296	-2.467** ±0.667	-10.583** ±1.932	0.799 ±1.785	0.517 ±0.799	-51.367** ±3.272	*	*	*	-	$C^{@}$
IV	76.067 ±0.593	-9.567** ±0.604	53.876** ±2.796	48.067* ±2.660	12.233** ±0.67	-10.733** ±3.797	*	*	*	*	$D^{\#}$
V	81.457** ±0.384	-0.267 ±0.459	-52.383** ±1.818	-32.000** ±1.791	-6.183** ±0.50	82.100** ±2.480	*	*	*	*	$D^{\#}$
				No. of effective tillers/plant							
I	10.700** ±0.208	-3.467** ±0.353	-10.717** ±1.134	-10.933** ±1.091	-4.383** ±0.35	8.233** ±1.753	*	*	*	*	$D^{\#}$
II	9.567** ±0.120	-1.467* ±0.667	8.933** ±1.498	7.200** ±1.417	-1.533* ±0.702	-5.599 ±2.879	*	-	*	*	$D^{\#}$
III	12.067** ±0.241	2.799** ±0.339	-5.583** ±1.246	6.933** ±1.178	2.183** ±0.359	5.167** ±1.856	*	*	*	*	$D^{\#}$
IV	9.933** ±0.088	3.667** ±0.286	0.667 ±0.774	1.467* ±0.673	4.433** ±0.371	-4.267** ±1.422	*	*	-	*	$D^{\#}$
V	10.300** ±0.493	-1.900** ±0.311	2.049 ±2.208	0.199 ±2.068	2.650** ±0.451	0.967 ±2.790	*	*	-	-	$D^{\#}$
				Length of main spike (cm)							
I	7.600** ±0.100	0.000 ±1.094	-0.250 ±0.486	-0.666 ±0.442	0.083 ±0.191	-0.299 ±0.683	-	*	*	*	$D^{\#}$
II	11.067** ±0.088	-2.767** ±0.278	-3.750** ±0.698	-4.733** ±0.659	-4.250** ±0.29	2.833* ±1.256	*	*	*	*	$D^{\#}$
III	8.133** ±0.176	0.833** ±0.067	1.417 ±0.730	2.333** ±0.718	1.250** ±0.121	7.099** ±0.801	*	*	*	*	$C^{@}$
IV	9.300** ±0.057	-0.167** ±0.302	-4.717** ±0.652	-3.533** ±0.647	-0.316 ±0.308	2.633** ±1.240	-	-	*	*	$D^{\#}$
V	8.867** ±0.233	-0.099 ±0.364	-2.567* ±1.223	-2.567 ±1.832	0.000 ±0.375	2.599 ±1.836	-	-	*	*	$D^{\#}$
				Days to maturity							
I	146.000** ±1.000	-3.000* ±1.290	12.830** ±4.780	10.000* ±4.760	-1.500 ±1.400	23.000** ±6.670	*	*	-	*	$C^{@}$
II	143.330** ±0.330	0.000 ±0.470	13.670** ±2.210	16.000** ±1.630	0.330 ±2.030	-30.000**±5.290	-	*	-	*	$D^{\#}$
III	144.330** ±0.330	0.330 ±1.250	19.170** ±2.850	16.670 ±2.830	0.830 ±1.270	-30.330** ±5.230	*	*	-	*	$D^{\#}$
IV	145.330** ±0.330	-1.330** ±0.470	29.330** ±2.030	26.670** ±1.630	-2.000** ±0.66	-45.330** ±3.460	*	*	*	*	$D^{\#}$
V	146.000** ±1.000	-1.670 ±1.490	-13.800** ±5.300	-14.000** ±4.900	2.100 ±2.100	-25.670** ±3.050	*	*	*	*	$C^{@}$

				Weight of grains/main spike (g)							
I	2.033** ±0.0667	0.133* ±0.0667	0.733* ±0.315	0.933** ±0.298	0.199* ±0.084	-1.867** ±0.429	*	-	-	*	$D^{\#}$
II	2.666** ±0.088	0.099 ±0.094	2.950** ±0.413	3.400** ±0.400	0.117 ±0.108	-5.100** ±0.556	*	*	*	*	$D^{\#}$
III	1.633** ±0.088	0.033 ±0.120	4.667** ±0.447	5.533** ±0.0427	0.667** ±0.131	-6.800** ±0.051	*	-	*	*	$D^{\#}$
IV	2.700** ±0.115	-0.633** ±0.094	0.649 ±0.509	-1.000* ±0.498	-0.817** ±0.10	2.967** ±0.630	*	-	-	*	$D^{\#}$
V	2.700** ±0.058	-0.100 ±0.111	1.067** ±0.342	1.133** ±0.319	-0.167 ±0.129	-0.533 ±0.553	-	-	*	*	$D^{\#}$
				No. of grains/spike							
I	50.267** ±0.498	8.567** ±0.917	27.150** ±2.746	22.200** ±2.706	10.083** ±0.95	2.367 ±4.276	-	*	*	*	$D^{\#}$
II	100.667** ±1.006	-20.73** ±1.812	40.533** ±5.439	-23.999** ±5.423	26.433** ±1.83	10.933 ±8.336	*	*	*	*	$D^{\#}$
III	63.667** ±0.669	5.467** ±1.290	15.083** ±4.439	14.667** ±3.718	22.883** ±1.34	8.233 ±7.573	*	*	*	*	$D^{\#}$
IV	67.200** ±0.723	-2.533** ±1.292	50.749** ±4.086	22.933** ±3.880	1.550 ±3.880	6.500 ±6.455	*	*	*	*	$D^{\#}$
V	90.567**±2.111	7.900**±0.567	-66.567**±8.537	-84.733**±8.517	13.433**±0.730	120.467**±8.819	*	*	*	*	$D^{\#}$
				1000-grain weight (g)							
I	30.500**±0.057	5.233**±0.715	-10.433**±1.750	-6.601**±1.450	5.066**±0.742	44.067**±3.478	*	*	*	*	$D^{\#}$
II	32.767**±1.334	-0.899±0.704	11.150*±5.557	7.667±5.521	1.826*±0.828	-2.699±6.168	-	*	*	-	$C^{@}$
III	30.500**±0.208	-2.800**±0.610	4.333**±1.591	4.933**±1.478	6.199**±0.714	-2.000±2.855	*	*	*	*	$D^{\#}$
IV	32.100±0.435	3.167**±0.883	-7.867**±2.626	-7.000**±2.481	0.067±1.207	28.933**±4.296	*	*	*	*	$D^{\#}$
V	39.400**±0.493	-1.067±0.717	12.950**±2.465	18.133**±2.439	-0.983±0.736	9.633**±3.555	*	*	*	*	$C^{@}$
				Grain yield/plant (g)							
I	20.500**±0.513	11.933**±0.398	13.533**±2.262	11.200**±2.202	14.800**±0.457	12.267**±2.797	*	*	*	*	$C^{@}$
II	21.067**±0.338	-15.07**±0.638	62.649**±1.956	43.467**±1.861	-17.88**±0.727	-51.567**±3.133	*	*	*	*	$D^{\#}$
III	36.067**±0.134	4.000**±0.505	-5.600±1.295	-20.000**±1.143	-9.999**±0.620	14.267**±2.419	*	*	*	*	$D^{\#}$
IV	30.333**±0.296	-13.93**±0.745	-29.900**±2.051	-35.333**±1.904	-16.73**±0.813	47.399**±3.551	*	*	*	*	$D^{\#}$
V	33.433**±0.617	8.533**±0.937	16.833**±3.334	19.333**±3.103	9.567**±0.969	31.267**±5.117	*	*	*	*	$C^{@}$

I ='DL 88' x 'K 560'; **II =**'K 603' x 'Azad'; **III =**'RD 2552' x 'NDB 1020'; **IV =**'RD 2618' x 'PL 708'; **V = '**NDB1173'x'Lakhan'
[m] =midpoint; [d] =additive; [h] =dominance; [i] =additive x additive; [j] = additive x dominance; [l] = dominance x dominance.
An asterisk (*) indicates that the value was significantly by the t-test at the 5% probablity level.
$D^{\#}$ = duplicate epistasis and $C^{@}$ = complementary epistasis

and 1000-grain weight in DL 88 x K560. The length of main spike, weight of grains/main spike,1000-grain weight and grain yield/plant were significantly higher in RD 2618 x Pl 708 and RD 2552 x NDB 1020. These findings are in agreement with those reported earlier [7, 8]. Thus, these characters were mainly under the control of dominance x dominance (l) type of epistasis. Therefore, selection for these characters would be fruitful, if delayed till dominance and epistatic effects are reduced to minimum.

The dominance (h) and dominance x dominance (l) effects were in the opposite direction indicating predominantly dispersed alleles at the interacting loci [4] and suggesting that duplicate-type epistasis (D#) occurred in most cases. In cross, DL88 x K560 for plant height, days to maturity and grain yield/plant, cross RD2552 x NDB 1020 for plant height and length of main spike and cross, NDB1173 x Lakhan for days to maturity, 1000-grain weight and grain yield/plant were observed with complementary epistasis (C@). This suggested the possibility of considerable amount of heterosis in these three crosses for plant height, days to maturity, grain yield/plant and 1000-grain weight.

On the basis of present study, it could be concluded that grain yield/plant and the component characters like days to ear emergence, plant height , no. of effective tillers/plant, length of main spike, days to maturity, weight of grains/main spike, no. of grains/spike, 1000-grain weight were mainly under the control of non-additive gene action *viz*., dominance (h) gene action and dominance x dominance (l) gene interaction which indicated their poor amenability to simple selection procedure, under such a situation, maximum gain could be achieved by maintaining considerable hetrozygosity through inter-mating of selected plant in early segregating generation or by fallowing some form of recurrent selection [9]. This will increase the possibility of various recombinants, which may result in accumulation of favorable genes in the ultimate homozygous line with higher grain yield. Therefore, few cycles of recurrent selection followed by pedigree breeding will be effective in the improvement of grain yield/plant in barley.

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