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Studies on variability, correlation and path coefficient analysis of yield and yield traits in barley (*Hordeum vulgare* L.)

Brajendra Kumar [1], Akash Singh[2], Rajendra Kumar[2] and Atul Kumar Shukla[1]
Department of Genetics and Plant Breeding
[1]Brahamanand Post Graduate College, Rath (Hamirpur)
[2]Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut- 250 110
Corresponding E-mail: aakashsengar.1991@gmail.com

ABSTRACT
Ten divers of barley were evaluated for their variability with regards to yield and yield components. Estimates of heritability and genetic advance in per cent of mean were also obtained for the above traits. In addition, studies on character associations and path coefficients were also undertaken. The highest σ^2g was found for plant height (87.141) and the lowest magnitude of σ^2g was observed in 100 seed weight (0.092). The highest σ^2p was found for plant height (96.663) and the lowest magnitude of σ^2p was observed in 100 seed weight (0.124). High PCV and GCV for yield per plant (g), number of tiller per plant, number of ear per plant and plant height indicated that selection of these characters would be effective. Correlation of yield per plant was found to be highly significant and positive for number of ear per plant, number of seed per ear, plant height and number of spikelets per ear at both genotypic and phenotypic level and negatively significant for number of tillers per plant at both level. Significant positive correlation to imply that selection for these characters would lead to simultaneous improvement of yield in barley. Further, yield was observed to be positively associated with for 100 seed weight, number of seed per ear and number of spikelets per ear. These characters were noticed to exert high direct effects on yield per plant in this crop. High indirect effects of most of the traits were noticed mostly through number of tillers per plant indicating importance of the trait as selection criteria in crop yield improvement programs.
Keywords: *Genetic parameter, Correlation and Path coefficients, barley (Hordeum vulgure L.)*

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INTRODUCTION

Barley (*Hordeum vulgare* L.), is a major cereal grain commonly used in malting and brewing industries. The cultivated barley is a self-pollinating, diploid species 2n = 2x = 14 and one of the first domesticated crops. Barley is a renowned crop extensively grown under varying agro-climatic regions for food, feed and forage. It has superior nutritional qualities due to presence of beta-glucan (anti-cholesterol substance), acetylcholine carbohydrate substance which nourishes our nervous system and recovers memory loss, easy digestibility due to low gluten content and high lysine, thiamin and riboflavin render cooling effect in the body. Barley is a relatively drought tolerant crop and more tolerant of soil salinity than wheat. About 25% of the barley is used for malting, for which it is the best-suited grain. It is a key ingredient in beer and whisky production. Malting barley is usually lower protein which shows more uniform germination, needs shorter steeping, and has less protein in the extract that can make beer cloudy [2-4]. The association between two characters that can be directly observed is the correlation of phenotypic values, or the phenotypic correlation. This is determined from measurements of the two characters in a number of individuals of the population. The genotypic correlation is the correlation of breeding values, and the environmental correlation, the correlation of environmental deviations together with non-additive genetic deviations. Correlation coefficients measure the absolute value of the correlation between variables in a given body of data. Correlation does not say anything about the cause and effect relationship. Path coefficient analysis is a very important statistical tool that indicates which variables (causes) exert influence on other variables (effects), while recognizing the impacts of multi co linearity. A path coefficient measures the direct influence of one variable upon another and permits the

separation of correlation coefficient into components of direct and indirect effects. Path coefficient analysis specifies the cause and measures the relative importance of the characters, while correlation measures only mutual association without considering causation. In any breeding program of complex characters such as yield for which direct selection is not effective, it becomes essential to measure the contribution of each of the component variables to the observed correlation and to partition the correlation into components of direct and indirect effect. Information on the extent and nature of interrelationship among characters helps in formulating efficient scheme of multiple trait selection, as it provides a means of direct and indirect selection of component characters. Therefore, the objective of this study was to estimate the extent of association between pairs of characters in genotypic and phenotypic levels and thereby compare the direct and indirect effects of the characters. Grain yield is a complex of component traits and is greatly affected by many environmental conditions. Various physiological and morphological traits contribute to grain yield. Each of these component traits has its own genetic systems. In addition, these yield components are influenced by environmental variables. So, it is important to separate the total variation into non-heritable and heritable components with the help of genetic parameters such as; phenotypic and genotypic coefficient of variation, heritability and genetic advance.

MATERIAL AND METHODS

Plant materials

Plant materials of this research comprised of 10 cultivars (K – 1260, Jagrati, K – 560, K -508, Manjula, K – 1149, K – 1055, K – 409, K – 603 and Jyoti) of barley, these cultivars are adapted to drought conditions in U.P.

Field investigated characters

This trial was conduct in season *Rabi* 2016-17 at agriculture research farm, Brahamanand Post Graduate College, Rath (Hamirpur). All the genotypes were planted in two rows of 5 m length with spacing of 22.5 x 10 cm. Data on 5 randomly selected plants from each genotype in each replication were recorded days to flowering, plant height, number of tillers per plant, number of ear per plant, number of spikelets per ear, length of ear, days to maturity, number of seed per ear, 100 seed weight and yield per plant.

Statistical analysis

Combined analysis of variance was performed for all evaluated characters. Simple statistics (*i.e.* mean, maximum, minimum and coefficient of variation) were used in order to compare genetic variation among these lines. Correlation was performed among the values of the barley lines for different agronomic and morphological characters across one season. The variance components, phenotypic, genotypic coefficients of variation, and genetic again were determined as suggested by Burton and de vane [4] and Johnson *et al*. [8]. The extent of genetic variation was also estimated as broad sense heritability, which is defined as the ratio of the genetic variance arising between barley lines to the total phenotypic variance. Phenotypic as well as genotypic correlations between characters were worked out from the means of different characters following Panse and Sukhatme [10]. The significance of phenotypic correlations was tested against table values at n-2 degrees of freedom as given by Fisher and Yates [7]. Path coefficient analysis was performed according to Dewey and Lu [5] using phenotypic correlation coefficients.

RESULTS AND DISCUSSION

Analysis of variance revealed highly significant different among genotypes for all the traits *viz.,* days to flowering, plant height, number of tillers per plant, number of ear per plant, number of spikelets per ear, length of ear, days to maturity, number of seed per ear, 100 seed weight and yield per plant. These results are in agreement with [12, 14]. Those indicating wide spectrums of variation among the lines are presented in table-1. The extent of variability for all the characters is very important for the improvement of a crop through breeding. The estimates of genotypic variation (σ2g), phenotypic variation (σ2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance (GA) for different characters have been presented in Table-2. The highest σ^2g was found for plant height (87.141) and the lowest magnitude of σ^2g was observed in 100 seed weight (0.092). The highest σ^2p was found for plant height (96.663) and the lowest magnitude of σ2p was observed in 100 seed weight (0.124). The genetic variation constituted a high proportion of the total variation for most of the traits. Thus, selection for these characters is expected to be highly effective. The GCV and PCV were the highest for yield per plant (g) (21.36 and 19.57) followed by number of tiller per plant (18.19 and 15.29), number of ear per plant (17.86 and 13.27) and plant height (10.79 and 10.24). High GCV and PCV for yield per plant (g), number of tiller per plant (Shtaya et al, 2015), number of ear per plant and plant height indicated that selection of these traits would be effective. The GCV and PCV were the lowest for days to flowering (7.89 and 7.54) and days to maturity (2.39 and 2.03). PCV were slightly higher than GCV

in case of all the attributes, indicating presence of environmental influence to some degrees in the phenotypic expression of the characters [12] also reported similar result (Table-2). Heritability estimates were (more than 60) for all the characters studied [13] except number of ear per plant (55.20) and number of seed per ear (58.90). The values were especially high for days to flowering (91.2) followed by plant height (90.1), yield per plant (83.9), number of spikelets per ear (80.4), 100 seed weight (73.6) days to maturity (71.8) and number of tillers per plant (70.7). [12] expect genetic advance per cent of mean noted high for yield per plant (25.98) followed by length of ear (17.83), number of spikelets per ear (17.09), number of seed per ear (16.90) [12], days to maturity (15.98), plant height (15.89) and 100 seed weight (14.89). It can be find out with greater degree of accuracy when heritability in conjunction with genetic advance is studied. Thus a character possessing high heritability along with high genetic advance will be valuable in the selection programme. high heritability and high genetic advance is an indicative of additive gene action and selection based on these parameters would be more reliable. [6]. In the present investigation, high heritability estimates in conjunction with high genetic advance in present of mean were observed for plant height, yield per plant, number of spikelets per ear, 100 seed weight and days to maturity. That result was similar finding by Yadav et al. 2015 and suggesting preponderance of additive gene action in the expression of these characters. Therefore, selection may be effective through these characters in segregating generations for genetic improvement of barley.

Correlation coefficient

The genotypic and phenotypic correlations among yield and its contributing traits in barley are given in Table-3. It is evident that in majority of the cases, the genotypic correlation coefficients were higher than their phenotypic correlation coefficients indicating that of a strong inherent association between the characters studied and suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. In few cases, however, phenotypic correlation coefficients were same with or higher than their corresponding genotypic correlation coefficients suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level. Character association Correlation of yield per plant was found to be highly significant and positive for number of ear per plant (0.940, 0.753), number of seed per ear (0.866, 0.826) plant height (0.430, 0.422) [9] and number of spikelets per ear (0,387, 0.380) at both genotypic and phenotypic level [2] and negatively significant for number of tillers per plant (-0.258, -0.218) at both level. Significant positive correlation of yield per plant with number of tillers per plant, number of ear per plant, number of seed per ear and number of spikelets per ear imply that selection for these characters would lead to simultaneous improvement of yield in barley. Grain yield in barley was most significantly correlated with plant height [11]. Number of seed per ear recorded significant negative correlation with 100 seed weight at genotypic and phenotypic level. Number of tillers per plant recorded significant positive correlation with number of ear per plant, number of spikelets per ear and number of seed per ear at genotypic and phenotypic level. It is observed that number of ear per plant was significantly and positively associated with number of seed per ear followed by number of spikelets per ear and length of ear at both genotypic and phenotypic level.

Path analysis

Associations of characters determined by correlation coefficient could not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on yield per plant. As a matter of fact, in order to find out a clear picture of the interrelationship between yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at both genotypic and phenotypic level. Genotypic path coefficient analysis showing direct and indirect effects of different characters and the results are presented in Table 4. From the path coefficient analysis expressed that number of tillers per plant (1.270 and 1.062) had maximum direct effect on yield followed by 100 seed weight (0.857 and 0.835) number of seed per ear (0.674 and 0.591) and number of spikelets per ear (0.298 and 0.249). The highest negative indirect effects on yield were obtained by number of tillers per plant at both levels. The results prescribed that highly significant positive correlation with positive indirect effect was observed in number of tillers per plant, number of ear per plant, number of seed per ear and number of spikelets per ear. The genotypic residual effect of the present study was 0.0991 and phenotypic residual effect 0.1208.

Table: 1- Analysis of variance for 10 quantitative characters in barley (*Hordeum Vulgure* L.)

Sources of variation	d.f.	Days to flowering	Plant height	Number of tillers per plant	Number of ear per plant	Number of spikelet per ear	Length of ear	Days to maturity	Number of seed per ear	100 seed weight	Yield per plant
Replication	2	2.53	22.62	0.69	0.53	0.84	0.46	0.68	2.53	0.41	0.23
Treatment	9	80.51**	270.94**	7.58**	5.39**	6.98**	2.33**	20.60**	36.57**	0.30**	36.53**
Error	18	1.25	1.53	0.55	0.60	0.11	0.23	0.53	1.61	0.18	2.82

Table 2: Estimates of variability parameter for ten characters in barley genotypes

Character	Heritability	Genetic Advance	G A % of mean	PCV	GCV	α^2g	α^2p
Days to flower	91.2	10.04	8.76	7.89	7.54	26.039	28.536
Plant height	90.1	18.26	15.89	10.79	10.24	87.141	96.663
No. of tiller per plant	70.7	2.58	12.78	18.19	15.29	2.221	3.143
No. of ear per plant	55.2	1.82	7.89	17.86	13.27	1.416	2.564
No. of spikelet per ear	80.4	2.71	17.09	9.28	8.32	2.152	2.677
Length of ear	60.5	1.28	17.83	10.57	8.23	0.64	1.057
Days to maturity	71.8	4.30	15.98	2.39	2.03	6.012	8.459
No. of seed per ear	58.9	4.97	16.90	8.24	6.32	9.890	16.790
100 seed weight	73.6	0.54	14.89	8.84	7.58	0.092	0.124
Yield per plant	83.9	6.38	25.98	21.36	19.57	11.448	13.644

Table-3 Genotypic and Phenotypic correlation coefficient among character.

Characters		Days to flower	Plant height	No. of tillers per plant	No. of ear per plant	No. of spikelets per ear	Length of ear	Days to maturity	No. of seed per ear	100 seed weight	Yield per plant
Days to flower	G	1.000	-0.483*	0.011	-0.041	-0.597*	-0.063	0.513*	0.400*	-0.170	0.273
	P	1.000	-0.401*	0.143	0.106	-0.456	0.066	0.498	0.394	-0.038	0.307
Plant height	G		1.000	-0.275	-0.108	0.352*	0.707*	-0.544*	-0.041	-0.724*	0.430**
	P		1.000	-0.110	0.091	0.337	0.601	-0.299	0.157	-0.485	0.422**
No. of tillers per plant	G			1.000	0.907**	0.585**	0.256	-0.016	0.763**	-0.026	-0.258**
	P			1.000	0.900**	0.580**	0.412	0.219	0.743**	0.213	-0.218**
No. of ear per plant	G				1.000	0.685**	0.535**	-0.154	0.763**	-0.278	0.940**
	P				1.000	0.600**	0.468**	-0.201	0.690**	-0.080	0.753**
No. of spikelets per ear	G					1.000	0.507**	-0.520*	-0.422	-0.121	0.387**
	P					1.000	0.479**	-0.259	-0.408	-0.028	0.380**
Length of ear	G						1.000	-0.366	0.567**	-0.985	0.111
	P						1.000	-0.092	0.547**	-0.460	0.207
Days to maturity	G							1.000	0.055	0.264	0.266
	P							1.000	0.331	0.386	0.314
No. of seed per ear	G								1.000	-0.021**	0.866**
	P								1.000	-0.018**	0.826**
100 seed weight	G									1.000	0.211
	P									1.000	0.311

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

Table-4 Direct and Indirect effect of yield components on yield per plant

Characters		Days to flower	Plant height	No. of tillers per plant	No. of ear per plant	No. of spikelet per ear	Length of ear	Days to maturity	No. of seed per ear	100 seed weight	Genotypic and phenotypic correlation with yield
Days to flower	G	**-0.373**	0.227	0.014	-0.440	-0.178	-0.045	-0.082	0.270	0.146	0.273
	P	**-0.050**	0.121	0.109	-0.032	-0.022	-0.005	-0.008	0.193	0.009	0.307
Plant height	G	0.180	**0.470**	-0.350	0.103	0.105	-0.505	-0.087	-0.027	0.621	0.430**
	P	0.120	**0.303**	-0.084	-0.028	0.017	-0.042	-0.005	-0.077	-0.003	0.422**
No. of tillers per plant	G	-0.004	0.129	**1.270**	-0.963	0.174	-0.183	-0.003	0.515	0.023	-0.258**
	P	-0.007	0.033	**1.062**	-0.284	0.029	-0.029	-0.003	0.365	0.001	-0.218**
No. of ear per plant	G	0.015	0.051	1.280	**-0.956**	0.204	-0.382	-0.024	0.515	0.238	0.940**
	P	-0.005	-0.028	0.709	**-0.905**	0.030	-0.033	-0.003	0.388	0.000	0.753**
No. of spikelets per ear	G	0.223	-0.165	0.743	-0.654	**0.298**	-0.362	-0.083	0.284	0.104	0.387**
	P	0.023	-0.102	0.449	-0.183	**0.249**	-0.034	0.004	0.200	0.000	0.380**
Length of ear	G	0.024	-0.332	0.326	-0.512	0.151	**-0.714**	-0.058	0.382	0.845	0.111
	P	-0.003	-0.182	0.314	-0.143	0.024	**-0.700**	0.001	0.269	-0.002	0.207
Days to maturity	G	-0.191	0.256	-0.021	0.147	-0.155	0.261	**0.159**	0.037	-0.226	0.266
	P	-0.025	0.090	0.167	-0.061	-0.013	0.006	**0.015**	0.162	0.002	0.314
No. of seed per ear	G	-0.149	0.019	0.970	-0.729	0.126	-0.405	0.009	**0.674**	0.352	0.866**
	P	-0.020	-0.048	0.567	-0.241	0.020	-0.39	-0.005	**0.591**	0.000	0.826**
100 seed Weight	G	0.064	0.340	-0.033	0.265	-0.036	0.703	0.042	-0.277	**0.857**	0.211
	P	0.002	0.147	0.162	-0.024	0.001	0.032	-0.006	-0.009	**0.835**	0.311

Bold value indicated direct effect, Residual effect genotypic = 0.0991% and Phenotypic = 0.1208%

CONCLUSION

Ten local varieties of barley along with one standard check were evaluated for ten yield and yield attributing traits. Results of the present investigation on variability, heritability and genetic advance indicated a scope for improvement of yield through selection. Further, studies on character association and path coefficient revealed the importance of number of tillers per plant, number of ear per plant, number of seed per ear and number of spikelets per ear as selection criteria for effective yield improvement. The study also indicated the need for balanced selection in light of negative association of plant height for crop yield improvement programs.

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