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Evaluation of Character Association in Barley (*Hordeum vulgare* L.) Genotypes for Yield and Yield Related Traits

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Authors' contributions

The work was conducted with collaboration of all authors. Author Sunil designed the study, conducted the research and wrote the protocol. Author KDS guided author Sunil during whole research period, managed the literature searches and wrote the first draft of the manuscript. Author MK performed and managed the statistical analyses. All authors read and approved the final manuscript.

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ABSTRACT

One hundred and seventy barley germplasm lines (101 two rowed and 69 six rowed) and three standard checks (BH393 six rowed, BH946 six rowed and BH885 two rowed) were evaluated for ten quantitative traits using augmented block design consisting of 10 complete blocks during *rabi* season of 2014-2015 at Wheat and Barley section research farm, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana. Grain yield per plant exhibited strong positive association with biological yield/plant, number of grains/spike, number of tillers/plant and 1000 seed weight for both the two rowed as well as six rowed barley genotypes. Path coefficient analysis revealed that all the characters had direct and positive association with grain yield/plant except peduncle extrusion length which had negative direct effect in case of two

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rowed barley. Biological yield/plant, harvest index, number of tillers/plant, days to 75% flowering and peduncle extrusion length had positive direct effects on grain yield/plant for the six rowed barley. This suggested that selection will be quite efficient in enhancing yield and its contributing traits in context of germplasm evaluated.

Keywords: Association; barley; checks; correlation; path coefficient.

1. INTRODUCTION

Global demand and consumption of agricultural crops, particularly cereals, for food and feed is increasing at a rapid pace. This demand for plant materials has been expanding for many years (Edgerton [1]). Crop breeding efforts are aimed at increasing the yield and economic value. However, yield is a complex character which is controlled by association of number of components most of which are under polygenic control. Thus the identification of important components and information about their association with yield and other traits are very useful for developing efficient breeding strategy for evolving high yielding varieties.

Correlation measures the mutual relationship between various plant characters and determines the components on which selection can be based for improvement. The knowledge of correlation that exists between important characters may facilitate proper interpretation of results and provide a basis for planning more efficient crop improvement programmes. The genetic architecture of grain yield can be better resolved through components rather than yield *per se*, as the yield is the end product of multiplicative interactions between various yield components.

Path coefficient is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects. The utility of path coefficient analysis in plant breeding was demonstrated by Dewey and Lu [2]. To better understand the cause and effect relationship between different pairs of characters, the study of correlation in conjunction with path analysis is essential. Hence, the understanding of the genetic diversity and knowledge of correlations combined with path analysis for the morphological characters along with the seed yield provides a rational approach for planning more efficient crop improvement programme.

If correlation between dependent and independent variable is due to the direct effects of the character, it reflects a true relationship between them and selection can be practiced for such character in order to improve the dependent variable. However, if the association is mainly through indirect effects of the characters via another component characters, the breeder has to select for the later one through which the indirect effect is exerted on the ultimate dependent character such as seed yield.

Barley belongs to genus *Hordeum* in the tribe Triticeae of the family, which is a most paramount cereal crop and considered as the first cereal domesticated for use by man as food and feed (Potla et al. [3]). It has been considered as poor men's crop because of its low input requirement and better adaptability to harsh environments, like drought, salinity-alkalinity and marginal lands. Because of its hardiness, in many countries around the world, it is often considered the only possible rainfed cereal crop under low input and stressful environments. It is grown in about hundred countries on nearly fifty six million hectares (Zhou [4]). In India also, barley is an important coarse cereal crop, being grown in *rabi* (winter) season in northern plains. Therefore, the present investigation was undertaken to evaluate association between yield and its contributing traits in barley crop for further utilization in breeding programmes.

2. MATERIALS AND METHODS

Barley crop requires temperature of 12°C to 16 °C at growing stage and 30°C to 32°C at maturity. The crop is very sensitive to frost at any stage of growth and incidence of frost at flowering is highly detrimental for yield. The crop possesses vary high degree of tolerance to drought and sodic condition. The crop can be grown on wide range of soils including saline, sodic and lighter soils. Its propagation is done through seeds. Land should be prepared to fine tilth stage and weed free by giving 2-3 ploughing with cultivator followed by planking. Seed treatment is advisable to prevent the crop from smut diseases and termites. 2-3 irrigations are enough in barley cultivation for optimum yield. Broad leaf and narrow leaf are the main weeds of

this crop. Isoproturan (75% WP) and 2,4-D (Na-Salt 80%) are the major weedicides used in the crop. The major fertilizers of the crop are Nitrogen (60 kg/ha) and Phosphorus (30 kg/ha).

The weather conditions at experimental site had a continental, monsoonal and sub-tropical climate with comparatively hot summers and relatively cool winters. The main characteristics of climate in Hisar are dryness, extremes of temperature and scanty rainfall. The location of Hisar is on the outer margins of the South-West monsoon region with average annual rainfall of 450 mm. During crop season of 2014-2015, the mean weekly maximum temperature ranged between 13.8 to 35.3°C and minimum between 4.9 to 20.3°C. The mean weekly morning and evening relative humidity ranged between 63 to 92 per cent and 30 to 78 per cent. Daily sunshine ranged between 1.4 to 10 hours in 2014-2015. Total evaporation from open PAN was 436.3 mm and the total amount of rainfall received was 243.8 mm during crop season. The water table of the area fluctuated between 125 to 149 cm during 2014-2015, depending upon rainfall received during the monsoon and the input of irrigation water. The actual mean weekly meteorological data during the wheat crop in *rabi* season of 2014-2015, recorded at observatory located at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar is depicted in Fig. 1.

The material for the present study comprised of one hundred and seventy barley germplasm accessions (101 two rowed and 69 six rowed) along with three standard checks (BH393 six rowed, BH946 six rowed and BH885 two rowed), which were evaluated using augmented block design consists of ten complete blocks at Wheat and Barley section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Checks were repeated in each block along with 17 test entries in a 2.5 m long single row plot. Row to row distance of 30 cm and plant to plant distance of 10 cm was maintained during *rabi* season of 2014-2015.

Five competitive plants from each plot were randomly selected for recording observations on the ten morphological traits viz. days to flowering (75%), days to maturity (75%), plant height (cm), peduncle extrusion length (cm), number of tillers/plant, number of grains/spike, 1000 seed weight (g), grain yield/plant (g), biological yield/plant (g) and harvest index (%). Average of the data from the sampled plant of each plot in respect to different characters was used for various statistical analyses.

The simple correlations between different characters were estimated according to Searle [5]. Its significance was tested by comparing at an appropriate level of significance of correlation coefficient at (n-2) degree of freedom, where 'n' was number of genotypes. Path coefficient analysis was carried out according to Dewey and Lu [2]. Grain yield/plant was assumed to be dependent variable (effect) which was influenced

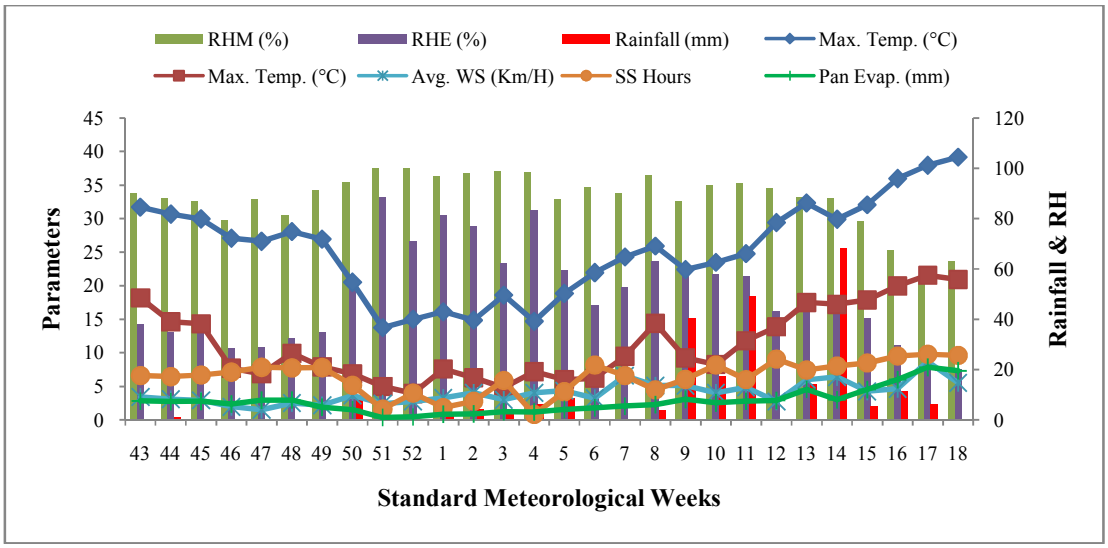

Fig. 1. Weekly meteorological data during rabi season 2014-2015

by all the nine characters and the independent variables (causes), directly as well as indirectly through other characters. The variation in grain yield/plant unexplained by the nine causes was presumed to be contributed by a residual factor effect (x) which was uncorrelated with other factors.

3. RESULTS AND DISCUSSION

The estimates of correlation coefficients among the different characters of barley germplasms are presented in Table 1. The grain yield/plant exhibited strong positive association with biological yield/plant, number of grains/spike, number of tillers/plant and 1000 seed weight in case of both two rowed as well as six rowed barley. However, plant height exhibited positive significant correlation in case of two rowed barley only. Thus, these characters emerged as important traits associated with grain yield. An improvement in above characters followed by selection effect is expected to positively affect the grain yield. The available literature also identified positive association on above characters with grain yield in barley by Kishor et al. [6], Najeeb and Wani [7], Ozturk et al. [8], Singh et al. [9], Pal et al. [10], Singh et al. [11] and Lodhi et al. [12]. Kumar et al. [13] observed significant and positive correlation of grain yield per plant with plant height, number of tillers per plant and test weight in wheat.

Positive significant association was obtained between grain yield and plant height in case of two rowed barley because these tall lines generally excelled in their capacity to support kernel growth by stem reserve mobilization (Blum et al. [14] and Al-Tabbal et al. [15]). Therefore, selection for tall plants tends to increase grain yield/plant. The present study suggests that a positive association between grain yield and plant height and a negative association with days to 75% flowering and days to 75% maturity were obtained in six rowed barley. Previous studies have confirmed these results (Gebeyehou et al. [16], Amin et al. [17], Oosterom and Acevedo [18], Gashaw [19] and Al-Tabbal et al. [15]), which means that early flowering and early maturing genotypes escape terminal moisture stress and thus give better grain yield.

Days to 75% maturity and biological yield/plant were negatively correlated with harvest index in case of the two rowed as well as six rowed barley and the similar results were obtained by Al-Tabbal et al. [15], Singh et al. [11], Yadav et al. [20] and Lodhi et al. [12]. Peduncle extrusion length had negative significant association with days to 75% flowering in six rowed barley. The previous studies by Singh et al. [11] and Lodhi et al. [12] also confirmed this result.

Similarly biological yield/plant had significant positive association with number of tillers/plant, number of grains/spike, 1000 seed weight, plant height and days to 75% maturity while 1000 seed weight was positively correlated with number of tillers/plant in case of six rowed barley. Number of grains/spike had significant positive correlation with number of tillers/plant in case of both the two rowed and six rowed barley genotypes. The available literature has also indicated the similar findings in barley (Ogunbayo et al. [21], Zahid et al. [22], Yadav et al. [23], Pratap et al. [24], Al-Tabbal et al. [15], Singh et al. [11], Yadav et al. [20] and Lodhi et al. [12]).

Simple correlation coefficient values do not make a complete picture of complex situation of association among different characters therefore the assessment of real contribution of each individual character towards seed yield/plant is important to decide about selection indices. Path coefficient analysis provides more realistic picture of the relationship among the characters. The path coefficient analysis reveals whether the association of each individual character with yield is due to its direct effect on yield or is a consequence of indirect effects via other component characters. Thus, path coefficient is essential to know the effectiveness of selection for simultaneous improvement in these characters. The direct and indirect effects of nine characters on grain yield per plant estimated under path coefficient analysis using simple correlations are given in Table 2 for two rowed barley genotypes and Table 3 for six rowed barley genotypes.

All the direct effects were less than one except for the biological yield/plant which indicates that influences due to multicollinearity were minimal (Gravois and Helms [25]). Partitioning of genotypic correlation between grain yield per plant and its component characters revealed that the direct effects were, in general, of higher magnitude than that of their indirect effects for all the characters.

Table 1. Correlation coefficients in 2 rowed genotypes (above diagonal) and 6 rowed genotypes (below diagonal)

Character	Days to 75% flowering	Days to 75% maturity	Plant height (cm)	Peduncle extrusion length (cm)	No. of tillers/ plant	No. of grains/ spike	1000 seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield/ plant (g)
Days to 75% Flowering		-0.039	-0.087	-0.064	-0.076	-0.054	0.036	0.118	-0.006	0.123
Days to 75% Maturity	0.084		0.043	-0.040	0.038	0.031	0.088	0.210*	-0.198*	0.105
Plant Height (cm)	0.010	0.274*		0.057	0.207*	0.183	0.190	0.243*	-0.070	0.220*
Peduncle Extrusion Length (cm)	-0.274*	0.026	0.274*		-0.069	0.036	0.132	0.116	-0.044	0.097
No. of Tillers/ Plant	0.007	-0.049	0.074	0.085		0.279**	0.222*	0.474**	-0.011	0.505**
No. of Grains/ Spike	-0.076	-0.086	0.018	0.025	0.661**		0.358**	0.523**	0.106	0.627**
1000 Seed Weight (g)	-0.075	0.152	0.089	0.138	0.500**	0.374**		0.307**	0.174	0.444**
Biological Yield/ Plant (g)	0.003	-0.081	0.136	0.029	0.848**	0.686**	0.394**		-0.396**	0.828**
Harvest Index (%)	-0.101	-0.173	-0.024	0.131	-0.118	0.014	-0.042	-0.315**		0.181
Grain Yield/ Plant (g)	-0.022	-0.154	0.124	0.075	0.852**	0.723**	0.395**	0.937**	0.029	

*** Significant at 1% probability level and * at 5% probability level*

Table 2. Path coefficient analysis (direct and indirect effects) of grain yield per plant with its component characters in 2 rowed barley genotypes

Character	Days to 75% flowering	Days to 75% maturity	Plant height (cm)	Peduncle extrusion length (cm)	No. of tillers/ plant	No. of grains/ spike	1000 seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Genotypic correlation with seed yield/ plant
Days to 75% Flowering	**0.0027**	0.0000	-0.0001	0.0000	-0.0006	-0.0003	0.0005	0.1244	-0.0034	**0.1231**
Days to 75% Maturity	-0.0001	**0.0002**	0.0001	0.0000	0.0003	0.0002	0.0011	0.2208	-0.1177	**0.1050**
Plant Height (cm)	-0.0002	0.0000	**0.0014**	0.0000	0.0017	0.0011	0.0025	0.2552	-0.0415	**0.2201**
Peduncle Extrusion Length (cm)	-0.0002	0.0000	0.0001	**-0.0002**	-0.0006	0.0002	0.0017	0.1220	-0.0261	**0.0970**
No. of Tillers/ Plant	-0.0002	0.0000	0.0003	0.0000	**0.0085**	0.0017	0.0029	0.4982	-0.0067	**0.5047**
No. of Grains/ Spike	-0.0001	0.0000	0.0003	0.0000	0.0024	**0.0059**	0.0047	0.5503	0.0632	**0.6266**
1000 Seed Weight (g)	0.0001	0.0000	0.0003	0.0000	0.0019	0.0021	**0.0131**	0.3228	0.1037	**0.4439**
Biological Yield/ Plant (g)	0.0003	0.0001	0.0003	0.0000	0.0040	0.0031	0.0040	**1.0520**	-0.2355	**0.8283**
Harvest Index (%)	0.0000	0.0000	-0.0001	0.0000	-0.0001	0.0006	0.0023	-0.4166	**0.5947**	**0.1808**

Residual effect = 0.0814

Bold figures indicate the direct effects

Table 3. Path coefficient analysis (direct and indirect effects) of grain yield per plant with its component characters in 6 rowed barley genotypes

Character	Days to 75% flowering	Days to 75% maturity	Plant height (cm)	Peduncle extrusion length (cm)	No. of tillers/ plant	No. of grains/ spike	1000 seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Genotypic correlation with seed yield/ plant
Days to 75% Flowering	**0.0112**	-0.0004	-0.0001	-0.0008	0.0001	0.0004	0.0004	0.0034	-0.0364	**-0.0221**
Days to 75% Maturity	0.0009	**-0.0043**	-0.0025	0.0001	-0.0008	0.0005	-0.0009	-0.0845	-0.0621	**-0.1536**
Plant Height (cm)	0.0001	-0.0012	**-0.0093**	0.0008	0.0011	-0.0001	-0.0005	0.1414	-0.0085	**0.1239**
Peduncle Extrusion Length (cm)	-0.0031	-0.0001	-0.0025	**0.0029**	0.0013	-0.0001	-0.0008	0.0304	0.0470	**0.0749**
No. of Tillers/ Plant	0.0001	0.0002	-0.0007	0.0002	**0.0154**	-0.0037	-0.0029	0.8855	-0.0423	**0.8519**
No. of Grains/ Spike	-0.0009	0.0004	-0.0002	0.0001	0.0102	**-0.0055**	-0.0022	0.7162	0.0051	**0.7232**
1000 Seed Weight (g)	-0.0008	-0.0007	-0.0008	0.0004	0.0077	-0.0021	**-0.0058**	0.4118	-0.0149	**0.3947**
Biological Yield/ Plant (g)	0.0000	0.0003	-0.0013	0.0001	0.0130	-0.0038	-0.0023	**1.0440**	-0.1134	**0.9368**
Harvest Index (%)	-0.0011	0.0007	0.0002	0.0004	-0.0018	-0.0001	0.0002	-0.3292	**0.3597**	**0.0291**

Residual effect = 0.0726

Bold figures indicate the direct effects

The high positive direct effects on grain yield/plant were exerted by biological yield/plant and harvest index in case of both the two rowed and six rowed barley. Thus these characters emerged as most important direct yield components on which emphasis should be given during simultaneous selection aimed at improving grain yield of barley (Table 2 and Table 3). These characters have also been identified as major direct contributors towards grain yield by Mishra and Verma [26], Jayasudha and Sharma [27], Yadav et al. [23] and Pratap et al. [24].

Biological yield/plant exerted considerable positive indirect effects on grain yield/plant via 1000 seed weight, number of tillers/plant and number of grains/spike, while negative indirect effect via harvest index in case of two rowed barley. Harvest index had positive indirect effect on grain yield/plant via 1000 seed weight and number of grains/spike in case of two rowed barley and harvest index had positive indirect effect on grain yield/plant via days to 75% maturity and peduncle extrusion length in case of six rowed barley. Janardanam et al. [28], Mahto et al. [29], Dadashi et al. [30], Carpc and Celk [31] and Yadav et al. [20] have also identified biological yield/plant and harvest index as most important yield contributing traits which merit due consideration at the time of devising selection strategy aimed at developing high yielding varieties in barley. The residual effect 0.0814 in case of two rowed barley and 0.0726 in six rowed barley indicate that the component characters under study were responsible for about 92% and 93% respectively, of variability in grain yield/plant.

4. CONCLUSION

Positive and significant correlations of grain yield/plant were recorded with biological yield/plant, number of grains/spike, number of tillers/plant and 1000 seed weight for both the two rowed as well as six rowed barley genotypes. Path coefficient analysis revealed that all the characters have direct and positive association with grain yield/plant except peduncle extrusion length which had negative direct effect in case of two rowed barley. While for the six rowed barley, the characters viz. biological yield/plant, harvest index, number of tillers/plant, days to 75% flowering and peduncle extrusion length have positive direct effects on grain yield/plant. The results of correlation and path coefficient analysis indicated that the traits like biological yield/plant, harvest index, number of tillers/plant and 1000 seed weight should be given due consideration while performing selection for grain yield in segregating generations of barley and in the prediction of possible merits for genetic recombination and would also be of value in formulating model plant type for selection in segregating generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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