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Correlation and path coefficient studies in barley (*Hordeum vulgare* L.)

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Abstract
Experimental material constituted of 114 Barley genotypes was studied to detect genetic diversity using correlation coefficient and path analysis. The results obtained through correlation studies, shown that grain yield per plant was positively correlated with biological yield per plant, spike length and 1000-grain weight while, Path analysis identified biological yield per plant and harvest index, as major direct contributors towards expression of grain yield per plant, and 1000-grain weight and plant height showed substantial indirect effect via biological yield per plant on grain yield per plant.

Keywords: Correlation coefficient, path analysis, barley

Introduction
Barley is a cereal crop grown in *Rabi* season and it is one of the oldest domesticated crop by humans (Zohary, D., and Hopf, M. (1993) [14]. It was used for religious ceremonies in India and popularly called as Indra jau (sacred grain). Today barley has a number uses like animal feed, brewing malt, beer and as a constituent in health drinks like horlicks, maltova. Apart from this, barley is also used in making *chapattis* and roasted grains are grounded to make *sattu*, indicating that barley has versatile uses, from health drink or pharmaceutical industries to animal feed and human food and being 4th most grown cereal crop, it becomes an important indeed.

Correlation study on different traits facilitates in better planning of breeding programmes specially one which aim at improving traits which influence yield. And path coefficient unveils the direct and indirect effect of correlation studies and gives idea of true nature of character associations. Apprehending the importance of correlation and path coefficient analysis in assessing the potential genetic diversity, an investigation on 114 barley genotypes on 9 quantitative traits was done. The correlation coefficient is the measure of degree of linear association between two variables or characters and helps in understanding the nature and magnitude of association among yield and yield components. Path-coefficient analysis is a biometrical tool to observed correlation coefficient into direct and indirect effects of independent variables on the dependent variable. Path-analysis differs from simple correlation in that in points out the causes and their relative importance, whereas the later measures simply the mutual association ignoring the causation

Material and method
Experimental material constituted of 114 barley genotypes including 3 checks (Azad, Lakhan and NBD-1173) were sown in a partially reclaimed soil plot in augmented block design. The experimental plot was divided into 7 blocks containing 16 entries along with 3 checks. Spacing of barley seeds were kept at 10 cm plant to plant and 23 cm row to row respectively and recommended cultural practices were followed to raise a good and healthy crop stand. Data was carefully collected on 9 metric traits. ANOVA for different traits was done according Federer 1956 [3]. The simple correlations between different characters were estimated according to Searle (1961) [12]. Path coefficient analysis was carried out according to Dewey and Lu (1959) [2]. Formula suggested by Johnson *et al.,* (1955) [5] and Hanson *et al.,* (1956) [4] were adopted to calculate, the genotypic and phenotypic correlation coefficients.

Experimental results

The estimates of phenotypic correlation coefficients between 9 characters of indigenous lines of barley are given in Table 1. The grain yield per plant exhibited highly significant and positive correlation with biological yield per plant (0.7687), and plant height (0.3855). The correlation coefficient of grain yield per plant was negative highly significant for spike length (-0.2378), respectively. Harvest index showed significant and positively correlation with biological yield per plant (0.6093). Highly significant and positive correlation coefficients were observed for biological yield per plant, plant height (0.7687) and days to maturity (0.2240). Plant height had highly significant positive correlation with flag leaf area (0.3152). The direct and indirect effects of characters on grain yield per plant computed in path coefficient analysis using phenotypic and genotypic correlation are presented in Table 2. The plant height showed significant and positive correlation with biological yield/ plant, flag leaf area and spike length. Such as association between plant height and days to 50% flowering and maturity seems logical as genotypes with longer vegetative phase may ultimately reach reproductive phase later, thus, delaying the attainment of maturity. Fortunately, the correlation of days to maturity had highly significant and correlation with grain yield per plant and biological yield per plant. In order to take care of occurrence of negative as well as positive correlation between important yield components, a reasonable compromise is required for attaining their proper balance for maximum combined contribution towards manifestation of grain yield.

The highest positive direct effect on grain yield per plant was excreted by biological yield per plant (0.7936) followed by harvest index (0.7060) while lowest positive direct effect were exhibited by days to 50% flowering (0.0117). In contrast, days to maturity (-0.0074), spike length (-0.0035) and contributed considerable negative direct effect of grain yield per plant. 1000-grain weight (-0.0055) and plant height (-0.0011) showed substantial negative indirect effects on grain yield per plant via biological yield per plant. The remaining estimates of the indirect effects in the present analysis were too low to be considered important. The estimate of residual factors (0.0876) was also low.

Table 1: Estimates of simple correlation coefficients between nine characters in genotypes of barley (*Hordeum vulgare* L.)

Character	Days to 50% flowering	Flag leaf area (cm^2)	Plant height (cm)	Days to maturiy	Spike length (cm)	Biological yield/ plant (g)	Test weight (g)	Harvest index (%)	Grain yield/ plant (g)
Days to 50% Flowering	1.0000	0.2136*	0.2225*	0.7239***	0.1548	0.1744*	0.0858	0.1731*	0.2693**
Flag Leaf Area (cm2)		1.0000	0.3152***	0.1622	0.3061***	0.1667	0.1461	0.0194	0.1620
Plant Height (cm)			1.0000	0.2199*	0.3855***	0.7687***	0.1507	-0.0894	0.5500**
Days to Maturity				1.0000	0.1295	0.2240**	0.0032	0.2301**	0.3433**
Spike Length (cm)					1.0000	0.4518***	0.0613	-0.2378**	0.1925
Biological Yield/ Plant (g)						1.0000	0.1186	-0.1246	0.7058**
Test Weight (g)							1.0000	-0.1214	0.0060
Harvest Index (%)								1.0000	0.6093**
Grain Yield/ Plant (g)									1.0000

Table 2: Direct and indirect effects of nine characters in genotypes of barley (*Hordeum vulgare* L.) on grain yield per plant.

Character	Days to 50% flowering	Flag leaf area (cm^2)	Plant height (cm)	Days to maturity	Spike length (cm)	Biological yield/ plant (g)	Test weight (g)	Harvest index (%)	Correlation with grain yield (g)
Days to 50% Flowering	0.0117	0.0036	-0.0002	-0.0054	-0.0005	0.1384	-0.0005	0.1222	0.2693
Flag Leaf Area (cm2)	0.0025	0.0169	-0.0003	-0.0012	-0.0011	0.1323	-0.0008	0.0137	0.1620
Plant Height (cm)	0.0026	0.0053	-0.0011	-0.0016	-0.0013	0.6101	-0.0008	-0.0631	0.5500
Days to Maturity	0.0085	0.0027	-0.0002	-0.0074	-0.0005	0.1778	0.0000	0.1624	0.3433
Spike Length (cm)	0.0018	0.0052	-0.0004	-0.0010	-0.0035	0.3586	-0.0003	-0.1679	0.1925
Biological Yield/ Plant (g)	0.0020	0.0028	-0.0008	-0.0017	-0.0016	0.7936	-0.0007	-0.0880	0.7058
Test Weight (g)	0.0010	0.0025	-0.0002	0.0000	-0.0002	0.0941	-0.0055	-0.0857	0.0060
Harvest Index (%)	0.0020	0.0003	0.0001	-0.0017	0.0008	-0.0989	0.0007	0.7060	0.6093

Residual factor = 0.0876,

Bold figures indicate direct effects.

Conclusion

The genetic architecture of grain yield in barley as well as in other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, selection for yield *per se* done would not matter much as such unless accompanied by the selection for various component characters responsible for conditioning it. Thus, identification of important component characters and information about their association with yield and also with each other are very useful for developing efficient breeding strategy for evolving high yielding varieties. The correlation coefficient is the measure of degree of linear association between two variables or characters and helps in understanding the nature and magnitude of association among yield and yield components. In the present investigation, simple correlation coefficients were computed among 9 characters (Table 1). The grain yield per plant showed highly significant and positive correlation with biological yield per plant and plant height. Thus, biological yield per plant and plant height emerged as closely correlated yield attributes. The strong positive association of grain yield with one or more of the above 9 traits has also been observed by Bhutta *et al.,* (2005). Biological yield per plant, plant height and spike length exhibited positive association with one another and indicated highly favorable situation for obtaining high response through selection. Thus, selection practiced for improving these traits individually or simultaneously is likely to bring improvement in others due to correlated response. This suggested that selection would be quite efficient in improving yield and these five yield components in barley, especially in context of the germplasm evaluated.

The results of path coefficient analysis achieved using simple correlation among 9 characters are given in table 2. The highest positive direct effect on grain yield per plant was exerted by biological yield per plant followed by harvest index. The highest indirect effect on grain yield to plant was exerted by 1000 grain weight followed by plant height via biological yield per plant. Thus, biological yield per plant followed by harvest index emerged as most important direct contributors towards grain yield per plant. (Karami, 2005; Singh *et al*., 2008; Mittal *et al.*, 2009, Zaefizade *et al*., 2011) [6, 11, 8, 13] Have also identified biological yield per plant as a character making substantial direct positive contribution towards manifestation of grain yield in barely. The indirect effects of 1000-grain weight and plant height exerted substantial positive indirect effects on grain yield per plant via biological yield per plant. Thus above mentioned characters emerged as most important indirect yield contributing characters because they showed substantial positive indirect effects towards grain yield per plant via biological yield per plants (Butta *et al.*, 2005; Karami *et al.*, 2005; Singh *et al.*, 2008, Pal *et al*., 2010 and Mandal *et al.* 1993) [1, 6, 11, 9, 7] had also supported the above findings. Spike length exerted substantial negative direct effects on grain yield. The existence of negative as well as positive direct/indirect effects by some character on grain yield per plant via one or other character simultaneously, present a complex situation where a compromise is needed to attain proper balance of different yield components in determining ideotype for high grain yield in barley. In contrary to most of the previous reports in barley comparatively smaller proportion of direct and indirect effects of different characters attained high order values in the present study. Majority of the estimates of direct and indirect effects were too low to be considered of any consequence. Thus it may be attributed to presence of very high genetic variability and diversity in the fairly large number of indigenous lines. The existence of different character combinations in diverse germplasm lines might have led to different types of character associations in different lines. Thus, presence of several contrasting types of character association and interrelationship might have resulted into cancellation of contrasting association by each other ultimately leading to lowering of the net impact or effect. In the present study, path analysis identified biological yield per plant and harvest index as important direct yield contributing characters 1000-grain weight plant height and spike length as most important indirect yield components. The character mentioned above, may be considered at the time of devising selection strategy aimed at developing high yielding varieties in barley.

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