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Association studies of yield and it's attributing traits in indigenous and exotic Barley (*Hordeum vulgare* L.) germplasm

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Abstract
The present study comprising of 101 barley genotypes was carried out at deportment of Genetics and Plant Breeding, BHU during rabi of 2016-17. Correlation and path analysis was carried considering traits viz., days to 50% flowering, days to maturity, flag leaf length, effective tillers per plants, SPAD value, stomatal conductivity, proline concentration, spike length with awn, spike length without awn, plant height, grain per ear, 1000 grain weight and grain yield per plant. Characters viz., grains per ear, plant height, 1000 grain weight, days to maturity, stomatal conductivity and spike length found highly significant and positive correlation with yield which indicated strong association of these traits with the yield. Path coefficient analysis suggested that spike length, plant height, grains per ear, 1000 grain weight had positive direct effects on yield per plant.

Keywords: Barley, correlation, association, path analyses

Introduction
Barley (*Hordeum vulgare* L.) was one of the first agricultural domesticated together with wheat (*Triticum aestivum* L.), pea (*Pisum sativum*), lentil (*Lens culinaris*), dating from about 10,000 years ago in the Fertile Crescent of the Middle East (Smith, 1998) [11]. It was presumably first used as human food but evolved primarily into a feed, malting and brewing grain due in part to the rise in prominence of wheat and rice. From eating, the importance of barley even extended to having religious significance in Europe and ritual significance in ancient Greece. It is fourth largest cereal crop after maize, wheat and rice in the world with a share of 7 per cent of the global cereal production. In recent times, about two-thirds of the barley crop has been used for feed, one-third for malting and about 2 per cent for food directly. It is a major source of food for large population of cool and semi-arid areas of the world, where wheat and other cereals are less adapted. Barley is an annual cereal grain crop that is consumed as a major feed for the animals. The rest is used as malt in whiskey or sugar as well as health food. Barley is used for manufacturing of liquors in western countries. The crop resembles white berries and is believed to be excellent for drought-like conditions. Other than playing its part as a major food crop, it is also used in beverages and beers. It is available in a variety of forms like whole barley, hulled barley, pearled barley as well as barley flakes. Barley contains about 75% carbohydrate, 9% protein and 2% fat. In energy terms, each gram provides about 3.3 calories. Barley grain is rich in zinc (up to 50 ppm), iron (up to 60 ppm) and soluble fibers, and has a higher content of Vitamins A and E than other major cereals.
Overall India's barley production was estimated to be 17.81 lakh MT spread over an area of 6.93 lakh ha for the year 2016-17 (Anonymous, 2017) [1]. Barley is an important winter cereal crop grown in the northern plains of India comprising the states of Uttar Pradesh, Bihar, Haryana, Rajasthan, Punjab, Madhya Pradesh, Himachal Pradesh and Uttarakhand that makes about 80% of total acreage of India. It is grown as a rainfed crop in poor marginal soils due to its low input demand and lower cost of cultivation. It occupies 0.46% of the total cropped area, 0.62% of the food grains and 0.76% of the cereals in the country. Similarly it contributes 0.86% of the total production of cereals and 0.81% of the food grains in India.
The most economically desirable use of barley is for the production of malt, the standards for which are quite stringent. Barley that does not meet malt quality standards often is utilized as feed for livestock, although some barley is produced solely as feed for animals, either as a grain or hay forage. Barley is also used in alternative settings such as for ethanol production for bio-fuels and for reducing algae in ponds and waterway. Even though being an important crop, barley has been neglected in our country due to priority on wheat, rice and other cash crops. As a result the harvested area,

production and productivity are falling down year by year.

A considerable number of grain production studies on barley include statistical correlations between agronomic and morphological characteristics and grain yield. Although these correlations are helpful in determining the principal components influencing final grain yield, they provide an incomplete representation of the relative importance of direct and indirect influences on the individual factors involved. It is known that the grain yield in cereals is determined by certain interrelated yield components. To identify the dimension of the effect of each yield component on grain yield is of importance for use in defining selection criteria for improving new varieties.

Path coefficient and correlation analyses are used widely in many crop species by plant breeders to define the nature of complex interrelationships among yield. Correlation coefficients measure the absolute value of the correlation between variables in a given body of data. 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. This information 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.

Materials and Methods

The present investigation was conducted at Genetics and Plant Breeding, Research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during *rabi* of 2016-17. Geographically, Banaras Hindu University is situated between 25º18' N latitude, 83º 03´E longitudes and at an altitude of 128.93 meters above the mean sea level in the North Gangetic plain of eastern part of Uttar Pradesh. The experimental materials comprised of 101 exotic and indigenous genotypes which were maintained by BHU under All India Co-ordinated Wheat and Barley Improvement Project. These were laid in Randomized Block Design with three replications for the investigation. Each treatment (genotype) was sown in line having 2.75 m length. The row to row and plant to plant distance of 25 cm and 10 cm, respectively was followed. All the recommended agronomic practices for respective experimental conditions were followed to raise a good normal crops. Five competitive plants, in each plot were randomly selected and tagged well in advance for recording the observations. Data were recorded on the following characters *viz*., days to 50 per cent flowering, days to maturity, number of effective tillers/plant, number of grains/ear, spike length with awns (cm), spike length without awns (cm), stomatal conductivity (m Mol M^{-2} S^{-1}), SPAD values, proline concentration (μ mol g^{-1}), 1000-grain weight (gm) and grain yield/plant (gm). Correlation coefficient was computed using formula given by Johnson *et al*. (1955) and direct and indirect effects of yield contributing factors were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959) [5, 14].

Results and Discussion

Correlation analysis

The genotypic correlation coefficient between yield and its component traits viz., days to 50% flowering, days to maturity, flag leaf length, effective tillers per plants, SPAD value, stomatal conductivity, proline concentration, spike length with awn, spike length without awn, plant height, grain per ear, 1000 grain weight are presented in table 1.

Table 1: Correlation matrix of 13 quantitative traits in a diverse collection of 101 barley genotypes

Character	DF	D M	FL	ET	SPAD	SC	PC	SL	SLW/O	PH	G/E	GW	GY
DF	1.0000	0.4811***	-0.0125	0.0213	0.2950***	-0.1368*	-0.0440	-0.0880	0.1270*	0.1469*	0.0158	-0.1178*	-0.0109
DM		1.0000	0.0454	0.0343	0.2224***	0.2003***	0.0488	0.1039	0.2494***	0.5477***	0.3039***	0.2118***	0.2364***
FL			1.0000	-0.0076	0.1872	0.1356*	-0.0629	0.0848	0.2723***	0.1367*	0.1477*	0.1006	0.1145*
ET				1.0000	0.1057	0.1097	0.0056	0.0921	0.1262*	0.1782**	0.1824**	0.1338*	0.0565
SPAD					1.0000	0.0186	0.0709	0.0022	0.2250***	0.1627**	0.1200*	0.0819	0.1111
SC						1.0000	0.0707	0.0842	0.1394*	0.3232***	0.2270***	0.8066***	0.2095***
PC							1.0000	0.1147*	-0.0404	0.0578	-0.0355	0.1615**	-0.0378
SL								1.0000	0.3335***	0.3306***	0.1255*	0.1822**	0.2055***
SL W/O									1.0000	0.4616***	0.1545**	0.1607**	0.1933***
PH										1.0000	0.3926***	0.3348***	0.4334***
G/E											1.0000	0.2424***	0.7202***
GW												1.0000	0.2769***
GY													1.0000

*Significant at p<0.05; **Significant at p<0.01; ***Significant at p<0.001

DF=Days to 50% flowering, FL=flag leaf length, ET=effective tillers/plant, SPAD, SC=stomatal conductivity, PC= proline concentration, SL=splike length with awn, SLW/O=spike length without awn, PH=plant height, G/E=grain per ear, GW=1000 grain yield, DM= days to maturity, GY =grain yield

Table 2: Direct (Bold) and Indirect effects of 12 quantitative traits on grain yield per plant in diverse collection of 101 barley genotypes

Character	DF	DM	FL	ET	SPAD	SC	PC	SL	SL W/O	PH	G/E	GW
DF	-0.0048	-0.0023	0.0001	-0.0001	-0.0014	0.0007	0.0002	0.0004	-0.0006	-0.0007	-0.0001	0.0006
DM	-0.0459	-0.0954	-0.0043	-0.0033	-0.0212	-0.0191	-0.0047	-0.0099	-0.0238	-0.0522	-0.0290	-0.0202
FL	0.0003	-0.0011	-0.0242	0.0002	-0.0045	-0.0033	0.0015	-0.0021	-0.0066	-0.0033	-0.0036	-0.0024
EL	-0.0025	-0.0040	0.0009	-0.1171	-0.0124	-0.0129	-0.0007	-0.0108	-0.0148	-0.0209	-0.0214	-0.0157
SPAD	0.0084	0.0064	0.0054	0.0030	0.0286	0.0005	0.0020	0.0001	0.0064	0.0047	0.0034	0.0023
SC	0.0155	-0.0227	-0.0154	-0.0124	-0.0021	-0.1132	-0.0080	-0.0095	-0.0158	-0.0366	-0.0257	-0.0913
PC	0.0022	-0.0025	0.0032	-0.0003	-0.0036	-0.0036	-0.0511	-0.0059	0.0021	-0.0030	0.0018	-0.0083
SL	-0.0053	0.0062	0.0051	0.0055	0.0001	0.0050	0.0069	0.0599	0.0200	0.0198	0.0075	0.0109

SL W/O	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0002	0.0005	0.0002	0.0001	0.0001
PH	0.0305	0.1137	0.0284	0.0370	0.0338	0.0671	0.0120	0.0686	0.0958	0.2076	0.0815	0.0695
G/E	0.0105	0.2019	0.0981	0.1211	0.0797	0.1508	-0.0236	0.0834	0.1027	0.2608	0.6643	0.1610
GW	-0.0201	0.0361	0.0171	0.0228	0.0139	0.1374	0.0275	0.0310	0.0274	0.0570	0.0413	0.1703
GY	-0.0109	0.2364***	0.1145*	0.0565	0.1111	0.2095***	-0.0378	0.2055***	0.1933***	0.4334	0.7202	0.2769

*Significant at $p<0.05$; **Significant at $p<0.01$; ***Significant at $p<0.001$
$R^2 = 0.577$, Residual value= 0.650

In the present investigation, the characters *viz.*, grains per ear (0.72), plant height (0.43), 1000 grain weight (0.27), days to maturity (0.23), stomatal conductivity (0.20), spike length with awn (0.20), and spike length without awn (0.19) found highly significant and positive correlation with yield which indicated strong association of these traits with the yield. Similar affiliation of traits were reported by Tofiq *et al.* (2015) [13] and Desheva (2016) [4]. Grain yield per plant exhibited positive and highly significant correlation with days to maturity, stomatal conductivity, spike length with awn, spike length without awn, plant height, grain per ear and 1000 grain weight which are in harmony with earlier findings of Hailu *et al.* (2016) [6].

Grain yield per plant exhibited negative and significant correlation with days to 50% flowering and leaf rolling similar result was reported by Bhutta *et al.* (2005) [2]

Path coefficient analysis

The correlation coefficient indicates the degree of relationship between characters but it alone does not give clear picture of measure of association between yield and its components. It is most important to know the direct and indirect influences of yield components for selecting suitable genotypes for improving the yield. Selection for yield is more effective when it is based on component characters which are highly heritable and positively correlated with yield.

In our study, spike length with awn, spike length without awn, plant height, grains per ear, 1000 grain weight exhibited positive direct effects on yield per plant. The grains per ear had a positive and significant direct effect with the grain yield per plant. The indirect effect through flag leaf length (0.005), effective tillers per plant (0.04), SPAD value (0.0003), stomatal conductivity (0.36), spike length with awn (0.001), plant height (0.02), leaf rolling (0.002), and 1000 grain weight (0.006) were low but positive. Similar uncovering of effects were reported by Tofiq *et al.* (2015) [13] and Srivastava *et al.* (2012) [12].

Grain per ear revealed positive direct effect with the grain yield per plant in both late and early condition. The indirect effect through SPAD value, proline concentration, spike length with awn, spike length without awn, plant height, 1000 grain weight this was in accordance with the findings of Desheva (2016) [4], Mohammad *et al.*, (2011) and Mittal *et al.* (2009) [8].

The direct effect of 1000 grain weight with grain yield per plant was high and positive was reinforced by the earlier findings of Binod *et al.* (2013) [3]; the indirect effect of 1000 grain weight through days to 50% flowering (0.0006), SPAD value (0.002), spike length with awn (0.01), spike length without awn (0.0001), plant height (0.06), grain per ear (0.16) were low but positive. This was in accordance with the findings of Singh *et al.* (2014) [10].

Therefore, grain per ear, effective tillers per plant, plant height, spike length with awn and 1000 grain weight can be identified as major characters contributing towards yield directly and indirectly and selection based on these characters are effective in improving yield.

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