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Pooja
Ph.D Student, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

SS Dhanda
Principal Scientist, Wheat & Barley Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

NR Yadav
Principal Scientist, Department of Molecular biology, Biotechnology and Bioinformatics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

RS Beniwal
Assistant Plant Pathologist, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Anu
Ph.D Student, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Correspondence
Pooja
Ph.D Student, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Correlation and path coefficient analysis of some quantitative traits in recombinant inbred lines of bread wheat

Pooja, SS Dhanda, NR Yadav, RS Beniwal and Anu

Abstract
Wheat (*Triticum aestivum* L.) is an important cereal crop of cool climates, and plays a key role in the food and nutritional security of India. The objective of this study was to establish the inter-relationship and direct and indirect effect of various wheat components on yield. Two hundred ten recombinant inbred lines were studied for correlation and path coefficient analysis of some quantitative traits in wheat at HAU Agricultural Research Farm during Rabi 2015-16 and 2016-17. Generally, the estimates of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for all the character combinations. Seed yield was significantly and positively associated with biological yield followed by harvest index, number of effective tillers per plant and ear length in both years. Number of tillers per plant indicated change of positive and significant correlation to non-significant for plant height and negative and non-significant for harvest index over the years. Plant height exhibited positive significant correlations with ear length, number of spikelets per ear and biological yield over the years. Weight of 100-grains was significantly and positively correlated with number of spikelets per ear over the years. In view of correlation studies over the years it was observed that number of grains per ear shifted negative and significant correlation to non-significant correlation with harvest index. Path coefficient analysis revealed that the magnitude of positive direct effect on seed yield was highest through biological yield followed by harvest index and number of tillers per plant. Weight of 100-grains, number of grains per ear, plant height, ear length and number of spikelets per ear showed low direct effects, but indirectly contributed towards grain yield per plant via biological yield in both years.

Keywords: Genotypic correlation, grain yield, *Triticum aestivum*

Introduction
Wheat (*Triticum aestivum* L.) is the major cereal crop on which the food security rests. It covers an area around 30.72 million hectares with the annual production of near 97.44 million tons in India (Anonymous, 2017) [1]. Environmental factors such as abiotic (soil, fertility, moisture, temperature, sowing time, day length) and biotic (diseases and pests) are not consistent across years and locations which ultimately affect the yield stability of wheat genotypes. Yield, as a function of various components, is a complex character. It was suggested that yield depends on the number of spikes per unit area, the number of kernels per spike and the average kernel weight (Poehlman, 1994) [3]. The grain yield and yield components of wheat are affected very much by the genotype and the environment. Therefore, as new cultivars are being produced by breeding, the relationships between yield and its components are studied by the breeders. To increase the yield, study of direct and indirect effects of yield components provides the basis for its successful breeding programme and hence the problem of yield increase can be more effectively tackled on the basis of performance of yield components and selection for closely related characters (Choudhry *et al.*, 1986) [2]. The aim of this study was to determine the correlations and path analysis of yield and yield components in bread wheat and evaluate their suitabilities in a breeding program.

Materials and Methods
The current experiment was conducted in the Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Geographically, Hisar is located at latitude of 29.090N, longitude of 75.430E in western Haryana. It has an average elevation of 705ft above sea level. Crop was grown in research area of Wheat Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar, during the Rabi season of

2015-16 and 2016-17. The experiment was carried out in Randomized Block Design (RBD) with three replications and plot was 3 m × 40cm size. The distance between row to row and plant to plant was maintained were 23 cm and 10 cm respectively. Recommended package of practices will be followed to raise the crop. Data will be recorded on the 5 plants/ replication/ genotype. Data were recorded on 11 characters, viz., yield/plant (g), number of tillers/ plant, number of grains/ear, number of spikelets/ear, 100-grain weight (g), Biological yield/plant (g), Harvest index (%), Plant height (cm), Ear length (cm), Days to 50% heading, Days to 75% maturity. Genotypic correlations were computed using variance and co-variances as suggested by Johnson *et al.* (1955) [4]. Path coefficient analysis was performed as suggested by Deway and Lu (1959) [5].

Results

Correlation coefficients

Genotypic and phenotypic correlation coefficients between all the traits were worked out (Table.1). The magnitudes of correlation coefficients at genotypic level were higher than corresponding correlation coefficients at phenotypic level. This revealed the strong inherent associations between different traits and influence of environment on various traits was under control. During the year 2015-16 grain yield per plant exhibited the highest positive and significant phenotypic correlation with biological yield (0.906**) followed by harvest index (0.340**) number of tillers per plant (0.315**), ear length (0.182**), number of spikelets per ear (0.138**), plant height (0.128**) and number of grains per ear (0.116**) whereas, negative and significant correlation with days to heading (-0.084*). During the year 2016-17 grain yield per plant showed positive and significant correlations with biological yield (0.883**) harvest index (0.351**), ear length (0.167**), number of spikelets per ear (0.132**), plant height (0.120**), number of tillers per plant (0.112**), number of grains per ear (0.109**) and 100-grain weight (0.080*), whereas negative and significant correlation with days to heading (-0.112**). Thus on the basis of both years, similar trend of correlations were observed except in case of 100-grain weight where grain yield per plant showed change of positive and significant correlation to non-significant for 100-grain weight over the years.

Number of tillers per plant showed positive and significant correlation with biological yield (0.293**), ear length (0.261**), plant height (0.218**), number of spikelets per ear (0.191**) and harvest index (0.082*), whereas negative and significant correlation with days to maturity (-0.116**) during the year 2015-16. During the year 2016-17 this trait indicated positive and significant correlations with number of grains per ear (0.134**), biological yield (0.122**), number of spikelets per ear (0.118**) and ear length (0.080*), whereas negative and significant correlation with days to heading (-0.083*). In view of impact of years on correlations, number of tillers per plant indicated change of positive and significant correlation to non-significant for plant height and negative and non-significant for harvest index over the years. Similarly, number of tillers per plant also showed change of negative and non-significant correlation to positive and significant for number of grains per ear, negative and significant correlation for days to heading over the years. Also days to maturity showed a shift of negative and significant correlation to non-significant with number of tillers per plant over the years.

100-grain weight was significantly and positively correlated with number of spikelets per ear during both years (0.096*) while with biological yield (0.114**) during the year 2016-17. Thus, similar types of correlations were observed for number of spikelets per ear over the years. Weight of 100 grains showed change of positive and non-significant to significant correlation with biological yield over the years. Number of grains per ear exhibited positive and significant correlations with biological yield (0.168**), number of spikelets per ear (0.134**) and negative significant correlation with harvest index (-0.105**) during the year 2015-16. It showed positive and significant correlations with number of spikelets per ear (0.125**) and biological yield (0.156*) during the year 2016-17. In view of correlation studies over the years it was observed that number of grains per ear shifted negative and significant correlation to non-significant correlation with harvest index.

During the year 2015-16 plant height exhibited positive significant correlations with ear length (0.340**) and number of spikelets per ear (0.258**) and biological yield (0.135**). Similarly during the year 2016-17 plant height exhibited positive significant correlations with ear length (0.335**) and number of spikelets per ear (0.222**) and biological yield (0.134**). Thus on the basis of both years plant height exhibited similar correlations. During the year 2015-16 ear length had significant and positive correlations with number of spikelets per ear (0.326**) and biological yield (0.175**), whereas significant and negative correlation with days to maturity (-0.094*). During the year 2016-17 ear length had significant and positive correlations with number of spikelets per ear (0.304**) and biological yield (0.197**). Thus on the basis of both years ear length exhibited change of negative and significant correlations with non-significant correlation for days to maturity.

Number of spikelets per ear had positive and significant correlations with biological yield (0.154**, 0.138**) during the year 2015-16 and 2016-17, respectively. Thus number of spikelets per ear showed similar type of correlations over the years. Biological yield showed negative and significant correlations with harvest index (-0.079*) and negative and non-significant correlation with days to heading (-0.066) during the year 2015-16. During the year 2016-17 it also exhibited negative and significant correlations with harvest index (-0.115**) and days to heading (-0.086*). Thus on the basis of both years biological yield showed shift of negative and non-significant to significant correlation with days to heading. During the year 2015-16 and 2016-17 Harvest index was not related to days to heading and days to maturity. Similarly days to heading was not related to days to maturity under both years.

Path coefficient analysis

During the year 2015-16 and 2016-17 the residual effects were 0.0056 and 0.0062 respectively, (Table.2). Low residual effect indicated that almost all of the traits contributing towards dependent trait have been considered under study. During the year 2015-16 biological yield (0.952) had the maximum direct contribution towards grain yield per plant followed by harvest index (0.373). During the year 2016-17 biological yield (0.958) had the maximum direct contribution towards grain yield per plant followed by harvest index (0.375). These traits were also had high significant positive phenotypic correlation with grain yield. Thus on the basis of both years biological yield and harvest index directly related to grain yield per plant. During the year 2015-16 number of tillers per plant indicated a low direct effect (0.0163) but significant positive phenotypic correlation (0.503**) with grain yield. It contributed to grain yield indirectly *via* biological yield (0.435) and harvest index (0.061). During the year 2016-17 number of tillers per plant indicated a low direct effect (0.009) towards grain yield per plant and significant positive correlation (0.133*) with grain yield. It contributed to grain yield indirectly *via* biological yield (0.131). During the year 2015-16 weight of 100 grains had negative direct effect (-0.003) and non-significant correlation with grain yield. During the year 2016-17 weight of 100 grains had negative direct effect (-0.006) and significant positive correlation coefficient (0.08*). It contributed to grain yield indirectly via biological yield (0.186).

During the year 2015-16 number of grains per ear showed negligible positive direct effect (0.004) towards grain yield, significant positive correlation (0.116*) with grain yield per plant and indirect effect through biological yield (0.179) on grain yield per plant. During the year 2016-17 number of grains per ear showed negligible positive direct effect (0.008) towards grain yield, positive significant correlation (0.109*) and indirect effect through biological yield (0.162) towards grain yield per plant. During the year 2015-16 plant height had low direct effect (0.001), significant positive phenotypic correlation (0.128*) which may be due to high indirect contribution to grain yield per plant *via* biological yield (0.142). During 2016-17 plant height had low direct effect (0.011), positive and significant phenotypic correlation (0.120*) which may be due to indirect contribution to grain yield per plant *via* biological yield (0.139). During the year 2015-16 ear length showed negative direct effect (-0.015) towards grain yield per plant and positive significant correlation (0.182**). Thus, it contributed to grain yield via biological yield (0.246). During the year 2016-17 ear length showed negative direct effect (-0.026) towards grain yield per plant and positive significant correlation (0.167**). It contributed to grain yield via biological yield (0.252). During the year 2015-16 number of spikelets per ear showed negligible positive direct effect (0.003) towards grain yield, positive significant correlation (0.138**) and indirect effect through biological yield (0.211) and harvest index (0.014). During the year 2016-17 number of spikelets per ear showed positive low direct effect (0.003) towards grain yield, positive significant correlation (0.132**) and indirect effect through biological yield (0.183) and harvest index (0.026) towards grain yield per plant. During the years 2015-16 and 2016-17 days to heading had very low direct effect on grain yield per plant and negative genotypic correlation with grain yield. Hence days to heading was not contributed to grain yield directly or indirectly. Similarly days to maturity also not contributed towards grain yield per plant via directly or indirectly during both the years.

Thus, biological yield and harvest index had maximum direct effects on grain yield per plant over the years, while number of tillers per plant contributed towards direct effect during the year 2015-16. Number of tillers per plant had positive significant correlation with grain yield per plant, low direct effects towards grain yield per plant. Indirectly it contributed to grain yield via biological yield and harvest index. Weight of 100-grains, number of grains per ear, plant height, ear length and number of spikelets per ear showed low direct effects, but indirectly contributed towards grain yield per plant via biological yield over the years.

Table 1: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among various traits in RILs of bread wheat for the year 2015-16 & 2016-17

	YEAR	Grain yield per plant	Number of tillers per plant	100-grain weight	Number of grains per ear	Plant height	Ear length	Number of spikelets per ear	Biological yield	Harvest index	Days to heading	Days to maturity
Grain yield per plant	2015-16	1	0.315**	0.011	0.116**	0.128**	0.182**	0.138**	0.906**	0.340**	0.084*	-0.060
	2016-17		0.112**	0.080*	0.109**	0.120**	0.167**	0.132**	0.883**	0.351**	0.112**	-0.035
Number of tillers per plant	2015-16	0.503	1	-0.031	-0.010	0.218**	0.261**	0.191**	0.293**	0.082*	-0.072	-0.116**
	2016-17	0.133		0.066	0.134**	0.020	0.080*	0.118**	0.122**	-0.005	-0.083*	-0.025
100-grain weight	2015-16	-0.029	-0.008	1	-0.045	-0.017	0.045	0.096*	0.048	-0.072	-0.003	-0.037
	2016-17	0.101	0.163		-0.018	0.024	0.073	0.147**	0.114**	-0.057	-0.003	-0.052
Number of grains per ear	2015-16	0.131	-0.033	-0.090	1	0.039	-0.026	0.134**	0.168**	-0.105**	-0.074	0.016
	2016-17	0.118	0.151	-0.102		0.033	-0.024	0.125**	0.156**	-0.076	-0.070	0.021
Plant height	2015-16	0.147	0.276	-0.025	0.056	1	0.340**	0.258**	0.135**	0.007	0.001	0.051
	2016-17	0.133	0.037	-0.006	0.034		0.335**	0.222**	0.134**	0.014	0.048	0.056
Ear length	2015-16	0.278	0.393	0.094	-0.026	0.451	1	0.326**	0.175**	0.059	0.000	-0.094*
	2016-17	0.230	0.095	0.172	-0.020	0.455		0.304**	0.197**	-0.014	0.015	-0.066
Number of spikelets per ear	2015-16	0.220	0.379	0.128	0.076	0.395	0.492	1	0.154**	-0.002	-0.042	-0.050
	2016-17	0.204	0.109	0.255	0.066	0.350	0.457		0.138**	0.025	-0.003	-0.055
Biological yield	2015-16	0.925	0.457	0.032	0.189	0.150	0.259	0.222	1	-0.079*	-0.066	-0.051
	2016-17	0.923	0.137	0.195	0.170	0.145	0.263	0.192		-0.115**	-0.086*	-0.049
Harvest index	2015-16	0.300	0.166	-0.144	-0.138	0.015	0.117	0.038	-0.076	1	-0.045	-0.032
	2016-17	0.307	-0.006	-0.203	-0.106	-0.021	-0.008	0.072	-0.072		-0.058	0.009
Days to heading	2015-16	-0.145	-0.189	-0.074	-0.112	-0.004	-0.051	-0.098	-0.143		1	-0.002
	2016-17	-0.273	-0.207	-0.195	-0.148	0.004	-0.002	-0.054	-0.261	-0.037		0.021
Days to maturity	2015-16	-0.089	-0.156	-0.076	0.018	0.075	-0.105	-0.086	-0.065	-0.078	-0.142	1
	2016-17	-0.055	-0.041	-0.117	0.020	0.077	-0.063	-0.085	-0.049	-0.048	-0.055	

*, **: significant at 5% and 1% level of significance, respectively

Table 2: Genotypic path coefficient analysis of grain yield per plant with its component characters in recombinant inbred lines of bread wheat during the year 2015-16 & 2016-17

	Year	Number of tillers per plant	100-grain weight	Number of grains per ear	Plant height	Ear length	Number of spikelets per ear	Biological yield	Harvest index	Days to heading	Days to maturity	Genotypic Correlation	Phenotypic Correlation
Number of tillers per plant	2015-16	0.0163	<0.0001	-0.0001	>0.0001	-0.0060	-0.0012	0.4352	0.0619	-0.0014	-0.0015	0.503	0.315**
	2016-17	0.009	-0.0010	-0.0011	>0.0001	-0.0024	>0.0001	0.1316	0.0021	-0.0011	>-0.0001	0.133	0.112**
100-grain weight	2015-16	-0.0001	-0.003	>-0.0001	<-0.0001	-0.0014	>-0.0001	0.0308	-0.0535	>-0.0001	>-0.0001	-0.029	0.011
	2016-17	0.0014	-0.006	>0.0001	<-0.0001	-0.0044	>0.0001	0.1869	-0.0761	-0.0011	-0.0010	0.101	0.080*
Number of grains per ear	2015-16	>-0.0001	>0.0001	0.004	<0.0001	>0.0001	>-0.0001	0.1795	-0.0514	>-0.0001	0.0001	0.131	0.116**
	2016-17	0.0013	>0.0001	0.008	>0.0001	>0.0001	>0.0001	0.1624	-0.0396	>-0.0001	0.0001	0.118	0.109**
Plant height	2015-16	0.0045	<0.0001	>0.0001	0.001	-0.0069	-0.0012	0.1425	0.0056	<-0.0001	>0.0001	0.147	0.128**
	2016-17	>0.0001	<0.0001	>-0.0001	0.011	-0.0117	0.0010	0.1392	-0.0078	<0.0001	>0.0001	0.133	0.120**
Ear length	20p15-16	0.0064	>-0.0001	<-0.0001	>0.0001	-0.015	-0.0016	0.2466	0.0437	>0.0001	-0.0010	0.278	0.182**
	2016-17	>0.0001	-0.0010	0.0001	0.0051	-0.026	0.0014	0.2525	-0.0028	<-0.0001	>-0.0001	0.230	0.167**
Number of spikelets per ear	2015-16	0.0062	>-0.0001	>0.0001	>0.0001	-0.0076	0.003	0.2113	0.0143	>-0.0001	>-0.0001	0.220	0.138**
	2016-17	>0.0001	-0.0016	>-0.0001	0.0039	-0.0117	0.003	0.1838	0.0268	>-0.0001	>-0.0001	0.204	0.132**
Biological yield	2015-16	0.0074	<-0.0001	>0.0001	0.0001	-0.0040	>-0.0001	0.952	-0.0281	-0.0011	>-0.0001	0.925	0.906**
	2016-17	0.0011	-0.0012	-0.0012	0.0016	-0.0067	>0.0001	0.958	-0.0271	-0.0015	>-0.0001	0.923	0.883**
Harvest index	2015-16	0.0027	>0.0001	>-0.0001	<0.0001	-0.0018	-0.0001	-0.0719	0.373	>-0.0001	>-0.0001	0.300	0.340**
	2016-17	<-0.0001	0.0012	>0.0001	>-0.0001	0.0001	>0.0001	-0.0693	0.375	>-0.0001	>-0.0001	0.307	0.351**
Days to heading	2015-16	-0.0030	>0.0001	>-0.0001	< 0.0001	>0.0001	>0.0001	-0.1359	-0.0137	0.008	-0.0014	-0.145	0.084*
	2016-17	-0.0017	0.0012	0.0011	<0.0001	<0.0001	-0.0001	-0.2500	-0.0292	0.006	>-0.0001	-0.273	0.112**
Days to maturity	2015-16	-0.0025	>0.0001	<0.0001	<0.0001	0.0016	>0.0001	-0.0620	-0.0356	-0.0011	0.010	-0.089	-0.060
	2016-17	>-0.0001	>0.0001	-0.0001	>0.0001	0.0016	>-0.0001	-0.0473	-0.0180	>-0.0001	0.009	-0.055	-0.035

Residual value for the year 2015-16 and 2016-17 respectively - 0.0056 and 0.0062

Discussion

The estimates of correlation coefficients revealed that, in general, the genotypic and the phenotypic correlation coefficients showed similar trend, but the genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients, which indicated that environmental variations were under control and indicating the presence of inherent association among these characters was under control and indicating the preponderance of genetic variance in expression of characters. The phenotypic correlations indicated that biological yield followed by harvest index, number of tillers per plant and ear length showed significant consistent correlations with grain yield per plant over the years. It showed that increase in biological yield followed by harvest index, number of tillers per plant and ear length may contribute towards high grain yield per plant in the present set of material in both the years. Also these traits had low to medium variability on the basis of GCV and PCV values. These results are similar with Inamullah *et al*., 2006 [6]**.** Other researchers also reported similar results like reported significant and positive association of grain yield with tillers per plant and 1000-grain weight. Number of tillers per plant indicated change of positive and significant correlation to non-significant for plant height and negative and non-significant for harvest index over the years. Similarly, number of tillers per plant also showed change of negative and non-significant correlation to positive and significant for number of grains per ear, negative and significant correlation for days to heading over the years. Significant positive association of grain yield with tillers per plant and plant height was noticed by Masood *et al*., 2014 [15]. Also days to maturity showed a shift of negative and significant correlation to non-significant with number of tillers per plant over the years. Plant height exhibited positive significant correlations with ear length, number of spikelets per ear and biological yield over the years. Weight of 100-grains was significantly and positively correlated with number of spikelets per ear over the years. Weight of 100-grains showed change of positive and non-significant to significant correlation with biological yield over the years. In view of correlation studies over the years it was observed that number of grains per ear shifted negative and significant correlation to non-significant correlation with harvest index. Ear length exhibited change of negative and significant correlations with non-significant correlation for days to maturity. Biological yield showed shift of negative and non-significant to significant correlation with days to heading over the years. However grain yield had not showed consistent over the years, this indicated a poor scope of improvement in grain yield through these traits in the present set of material. Iftikhar *et al*., 2012 [7] showed that grain yield is positively correlated with all characters except days to heading. Gelalcha and Hanchinal in 2013 [8] also presented similar results where grain yield was positively correlated with number of tillers per plant, number of spikelets per spike, number of grains per spike and biological yield per plant.

Path coefficient analysis: Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes into account the true relationship between the variables, in addition to the degree of such relationships, path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects (Anwar *et al*., 2009 and Ali & Shakor 2012) [10, 19]. Partioning of correlations provide direct and indirect contribution of characters on dependent trait and thus form the basis for improvement in plant breeding.

Considering grain yield as effect and other characters as causes, phenotypic correlation coefficients were partitioned by using path analysis to find out the direct and indirect effects of various traits on grain yield per plant. Biological yield followed by harvest index had the highest direct effects and significant positive correlations on grain yield per plant in both years. This indicated true relationships with grain yield, improvement in these traits lead to improvement in grain yield per plant. Biological yield per plant had direct positive effect on grain yield was depicted by Gelalcha and Hanchinal (2013) [8]. Similar findings were observed by Shrivastava and Sharma (1976) [20] suggested that only direct yield components should be used for selection purpose.Weight of 100-grains, number of grains per ear, plant height, ear length and number of spikelets per ear showed low direct effects, but indirectly contributed towards grain yield per plant via biological yield over the years. Number of tillers per plant had positive significant correlation with grain yield per plant, low direct effects towards grain yield per plant. This may be due to false positive correlation and in real sense it contributed to grain yield indirectly via biological yield and harvest index. Suleiman *et al.*, 2014 showed that all characters were having direct effect on yield except plant height and days to flowering. The path analysis results were also confirmed by Khan and Dar., 2010 [11], Sarutayophat., 2012 [12], Meyari *et al*., 2013 [14], Gholizadeh and Dehghani 2015 [18].

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