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Correlation and path coefficient analysis for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L.)

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Abstract
The present experiment was carried out with fifty bread wheat genotypes to estimate correlation coefficients between grain yield and its components and to determine their direct and indirect effects on grain yield using path coefficient analysis. The analysis of variance revealed highly significant differences for all the characters studied. Grain yield per plant had significant and positive correlation with grain weight per main spike, number of grains per main spike, biological yield per plant and harvest index at both the genotypic and phenotypic levels. Days to maturity had significant and positive correlation with grain yield per plant at genotypic level only. The phenotypic and genotypic path coefficient analysis revealed that the biological yield per plant and harvest index exhibited positive and appreciable direct effects on grain yield per plant. Therefore, more emphasis should be given to both these characters for improvement of grain yield in bread wheat through selection programme.

Keywords: Bread wheat, correlation coefficients, path coefficient analysis, grain yield

Introduction

Wheat (*Triticum aestivum* L.) is the principal food crop in most areas of the world, cultivated over a wide range of agro-climatic conditions. It is the second most important staple food crop in India next to rice. It is mainly a rabi season crop in India. It is a nutritionally important cereal essential for food security, poverty alleviation and improved livelihoods. India is the second largest producer of wheat in the world after China with an annual production of 103.60 million metric tonnes from an area of 29.32 million hectares and productivity of 3.53 metric tonnes per hectare (Anon., 2020) [2].

Grain yield, being a complex polygenic character, is highly influenced by many environmental factors and is largely dependent on the interaction of several yield contributing characters. Thus, direct selection for grain yield could be misleading. A successful selection depends upon the information on the association of morpho-agronomic traits with grain yield (Kumar *et al*., 2013) [10]. Development of improved cultivar capable of producing better grain yield under various agro-climatic conditions depends upon the amount of genotypic variability present in a population for the traits (Kumar *et al*., 2017) [9]. Genotypic and phenotypic correlation reveals the degree of association between different characters and thus aid in selection to improve grain yield and yield attributing characters simultaneously (Verma *et al*., 2019) [20]. Path coefficient analysis as suggested by Dewey and Lu (1959) [6] provides an effective means of untangling the complex correlation into direct and indirect effects of the component characters on grain yield so as to find out the efficient characters contributing effectively towards grain yield. Thus, correlation studies along with path analysis provide a better understanding of the association of different characters with grain yield. Therefore, keeping in view the above facts, the present investigation was undertaken in bread wheat to estimate the genotypic and phenotypic correlation between grain yield and other yield contributing characters and to determine the direct and indirect effect of different characters on grain yield per plant using path coefficient analysis.

Materials and methods

The experimental material consisted of 50 diverse genotypes of bread wheat which were obtained from International Maize and Wheat Improvement Centre (CIMMYT) through Wheat Research Station, Junagadh Agricultural University, Junagadh.

The genotypes were evaluated in a Randomized Block Design (RBD) with two replications during *Rabi* 2019-20 at Wheat Research Station, Junagadh Agricultural University, Junagadh. Each genotype was sown in a six row plots of 2.5m length with inter-row spacing of 22.5 cm. The recommended package of practices were adopted timely to raise a good normal crop. Observations were recorded on fourteen quantitative traits *viz*., days to first flowering, days to maturity, plant height, number of effective tillers per plant, length of main spike, peduncle length of main spike, number of spikelets per main spike, number of grains per main spike, grain weight per main spike, grain yield per plant, biological yield per plant, harvest index, 100-grain weight and flag leaf area from five randomly selected competitive plants from each genotype in each replication except of days to first flowering and days to maturity which were recorded on plot basis. The phenotypic and genotypic correlation coefficients of all the pair of characters were worked out as per Al-Jibouri *et al.* (1958) [1]. The path coefficient analysis was carried-out as per the method suggested by Dewey and Lu (1959) [6].

Results and discussion

The analysis of variance revealed highly significant differences among the genotypes for all the 14 characters studied, thereby suggesting the presence of considerable amount of genetic variability among the fifty genotypes, with respect to the traits studied. Many researchers *viz*., Chimdesa *et al*. (2017) [5], Nagar *et al*. (2018) [14] and Mishra *et al*. (2019) [13] reported high variability for different traits in bread wheat. In the present investigation, most of the character pairs recorded higher values of genotypic correlations than their corresponding phenotypic correlations, indicating the influence of environmental factors on the degree of association between various yield components (Table 1). Majumder *et al*. (2008) [12] and Rathwa (2018) [18] also reported that genotypic correlations were higher than the phenotypic correlations in bread wheat.

Grain yield per plant had highly significant and positive correlation with biological yield per plant, harvest index and days to first flowering at both genotypic and phenotypic levels indicating that these attributes were more influencing the grain yield in bread wheat and therefore, were important for bringing genetic improvement in grain yield. Besides, grain yield per plant had significant and positive associations with number of grains per main spike and grain weight per main spike at both genotypic and phenotypic levels, and days to maturity had significant and positive correlation at genotypic level only. The positive genotypic association has been reported between grain yield per plant and biological yield per plant (Fellahi *et al.*, 2013; Rathwa, 2018; Nagar *et al*., 2018; Pooja *et al*., 2018) [8, 18, 14, 16]; harvest index (Zeeshan *et al.*, 2014; Nagar *et al*., 2018; Pooja *et al*., 2018; Rajput, 2019) [21, 14, 16]; number of grains per main spike (Nukasani *et al.*, 2013; Nagar *et al*., 2018) [15, 14]; and grain weight per main spike (Nukasani *et al.*, 2013; Rajput, 2019) [15, 17] at both genotypic and phenotypic levels. The grain yield per plant recorded significant and positive correlation at genotypic level with days to maturity (Kumar *et al*., 2014).

The days to first flowering had highly significant and positive correlation with days to maturity at both genotypic and phenotypic levels. Similar result was also reported by Ayer *et al*. (2017) [3] and Diyali *et al.* (2020) [7]. Harvest index had significant and positive correlation with days to first flowering at both genotypic and phenotypic levels, while that of plant height showed significant and positive correlation at genotypic level only. Flag leaf area had highly significant and negative association with days to first flowering at both the levels, which was confirmed by Ayer *et al*. (2017) [3]. The days to maturity had significant and positive association with harvest index at genotypic level only. Similar result has been reported earlier by Kumar *et al*. (2014). Days to maturity had significant and negative correlation with flag leaf area at genotypic level only. This result suggested that selection for early maturity would likely to provide genotypes with greater flag leaf area. Plant height exhibited highly significant and positive association with length of main spike and peduncle length of main spike at both

Genotypic and phenotypic levels. Zeeshan *et al*. (2014) [21] and Pooja *et al*. (2018) [16] reported that plant height had highly significant and positive association with length of main spike. Length of main spike had highly significant and positive association with number of spikelets per main spike at both genotypic and phenotypic levels, while with number of grains per main spike it had highly significant and positive correlation at genotypic level only. Similar results have also been noted by Zeeshan *et al*. (2014) [21] and Pooja *et al*. (2018) [16]. The interrelationship between number of spikelets per main spike and number of grains per main spike had highly significant and positive association at both levels. Similar results have also been reported by Pooja *et al*. (2018) [16]. Number of spikelets per main spike showed highly significant and negative correlation with 100-grain weight at both genotypic and phenotypic levels. Number of grains per main spike exhibited significant and positive correlation with biological yield per plant at both genotypic and phenotypic levels. Similar relationship has been reported earlier by Kumar *et al*. (2014) [2]. Number of grains per main spike had highly significant and negative correlation with 100-grain weight, while flag leaf area showed significant and negative correlation at both genotypic and phenotypic levels. Grain weight per main spike showed highly significant and positive correlation with biological yield per plant at both levels. Similarly, biological yield per plant and harvest index showed highly significant but negative association with flag leaf area at both levels. Similar result has also been reported by Verma *et al*. (2019) [20]. The phenotypic path coefficient analysis (Table 2) revealed that biological yield per plant and harvest index exhibited high and positive direct effect on grain yield per plant. This trait turned out to be major component of grain yield for direct selection. Similar results were obtained by Chimdesa *et al*. (2017) [5], Nagar *et al*. (2018) [14], Rajput *et al*. (2018) [17] and Baye *et al*. (2020) [4]. The residual effect was of low magnitude suggesting that majority of the yield attributes have been included in the study of path analysis. Characters like days to first flowering, days to maturity, number of effective tillers per plant, length of main spike, peduncle length of main spike, number of spikelets per main spike, number of grains per main spike, grain weight per main spike, 100-grain weight and flag leaf area exerted very low and positive direct effect on grain yield per plant. However, among these characters, number of grains per main spike and grain weight per main spike had low direct effects and supplemented yield through indirect effects via biological yield per plant, thus giving rise to significant and positive association of these traits with grain yield.

Table 1: Genotypic (r_g) and phenotypic (r_p) correlation coefficients among 14 characters of bread wheat

Characters		Days to first flowering	Days to Maturity	Plant height (cm)	No. of effective tillers per plant	Length of main spike (cm)	Peduncle length of main spike (cm)	No. of spikelets per main spike	No. of grains per main spike	Grain weight per main spike (g)	Biological yield per plant (g)	Harvest index (%)	100-grain weight (g)	Flag leaf area (cm^2)
Grain yield per pplant (g) Biological yield per plant	r_g	0.3893**	0.2931*	0.1366	0.2139	0.2013	0.0325	0.0321	0.3028*	0.3190*	0.8410**	0.6189**	0.0281	-0.9896**
plant (g)	r_p	0.3619**	0.2587	0.1163	0.1748	0.1793	0.0158	0.0521	0.2870*	0.3257*	0.8177**	0.6122**	0.0333	-0.9604**
Days to first flowering	r_g		0.5971**	0.2864*	-0.0638	0.2601	-0.1977	0.0612	0.1808	-0.0662	0.2723	0.3377*	-0.1150	-0.3967**
Days to Maturity	r_p		0.4394**	0.2645	-0.0378	0.2343	-0.1546	0.0461	0.1748	-0.0545	0.2574	0.2896*	-0.1072	-0.3836**
Days to maturity	r_g			0.0939	0.1158	0.1053	-0.1431	-0.0774	0.1348	-0.1586	0.1727	0.2897*	-0.1310	-0.3161*
	r_p			0.0870	0.0416	0.1018	-0.1075	-0.0438	0.1057	-0.1372	0.1387	0.2607	-0.0989	-0.2452
Plant height (cm)	r_g				-0.0154	0.4161**	0.5567**	0.0459	0.0938	0.1588	0.2092	-0.0790	-0.1730	-0.1635
	r_p				-0.0245	0.3912**	0.5613**	0.1010	0.0952	0.1347	0.1910	-0.0764	-0.1501	-0.1509
No. of effective tillers per plant Length of main spike (cm)	r_g					-0.1740	0.0323	-0.2437	-0.0779	-0.1941	0.1414	0.2057	-0.1169	-0.1985
	r_p					-0.1339	0.0277	-0.1736	-0.0992	-0.1864	0.1346	0.1392	-0.1021	-0.1873
Length of main spike (cm)	r_g						0.1905	0.3732**	0.3651**	0.0381	0.2156	0.0472	-0.2547	-0.1836
	r_p						0.1975	0.3763**	0.3492*	0.0473	0.2132	0.0098	-0.2318	-0.1792
Peduncle length of main spike (cm)	r_g							0.1082	0.0389	0.2022	0.1768	-0.2552	-0.0369	-0.0223
	r_p							0.1445	0.0507	0.1823	0.1755	-0.2551	-0.0187	-0.0202
No. of spikelets per main spike	r_g								0.5988**	0.0356	0.0922	-0.0931	-0.4273**	-0.0847
	r_p								0.5395**	0.0662	0.1174	-0.0841	-0.3605**	-0.0862
No. of grains per main spike	r_g									0.1750	0.2870*	0.1672	-0.6467**	-0.2974*
	r_p									0.1646	0.2900*	0.1241	-0.6194**	-0.2891*
Grain weight per main spike (g)	r_g										0.4331**	-0.1023	0.1086	-0.2576
	r_p										0.4232**	-0.0739	0.1043	-0.2543
Biological yield per plant (g)	r_g											0.1035	0.0354	-0.8309**
	r_p											0.0547	0.0344	-0.8012**
Harvest index (%)	r_g												-0.0580	-0.6320**
	r_p												-0.0398	-0.5827**
100-grain weight (g)	r_g													-0.0077
	r_p													-0.0064

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

Table 2: Phenotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield per plant of bread wheat

Characters	Days to first flowering	Days to Maturity	Plant height (cm)	No. of effective tillers per plant	Length of main spike (cm)	Peduncle length of main spike (cm)	No. of spikelets per main spike	No. of grains per main spike	Grain weight per main spike (g)	Biological yield per plant (g)	Harvest index (%)	100-grain weight (g)	Flag leaf area (cm^2)	Phenotypic correlation with grain yield per plant
Days to first flowering	0.0030	0.0061	-0.0009	-0.0002	0.0019	-0.0036	0.0010	-0.0014	-0.0023	0.2001	0.1713	-0.0035	-0.0095	0.3619**
Days to maturity	0.0013	0.0139	-0.0003	0.0003	0.0008	-0.0025	-0.0010	-0.0009	-0.0058	0.1078	0.1542	-0.0032	-0.0061	0.2587
Plant height (cm)	0.0008	0.0012	-0.0033	-0.0002	0.0031	0.0129	0.0022	-0.0008	0.0057	0.1485	-0.0452	-0.0049	-0.0037	0.1163
No. of effective tillers per plant	-0.0001	0.0006	0.0001	0.0065	-0.0011	0.0006	-0.0038	0.0008	-0.0079	0.1046	0.0824	-0.0033	-0.0046	0.1748
Length of main spike (cm)	0.0007	0.0014	-0.0013	-0.0009	0.0079	0.0046	0.0082	-0.0028	0.0020	0.1657	0.0058	-0.0076	-0.0044	0.1793
Peduncle length of main spike (cm)	-0.0005	-0.0015	-0.0019	0.0002	0.0016	0.0230	0.0031	-0.0004	0.0077	0.1364	-0.1509	-0.0006	-0.0005	0.0158

No. of spikelets per main spike	0.0001	-0.0006	-0.0003	-0.0011	0.0030	0.0033	0.0218	-0.0044	0.0028	0.0912	-0.0498	-0.0118	-0.0021	0.0521
No. of grains per main spike	0.0005	0.0015	-0.0003	-0.0007	0.0028	0.0012	0.0117	-0.0081	0.0070	0.2254	0.0734	-0.0203	-0.0072	0.2870*
Grain weight per main spike (g)	-0.0002	-0.0019	-0.0004	-0.0012	0.0004	0.0042	0.0014	-0.0013	0.0424	0.3290	-0.0437	0.0034	-0.0063	0.3257*
Biological yield per plant (g)	0.0008	0.0019	-0.0006	0.0009	0.0017	0.0040	0.0026	-0.0024	0.0180	0.7773	0.0324	0.0011	-0.0199	0.8177**
Harvest index (%)	0.0009	0.0036	0.0003	0.0009	0.0001	-0.0059	-0.0018	-0.0010	-0.0031	0.0425	0.5916	-0.0013	-0.0144	0.6122**
100-grain weight (g)	-0.0003	-0.0014	0.0005	-0.0007	-0.0018	-0.0004	-0.0078	0.0050	0.0044	0.0267	-0.0236	0.0328	-0.0002	0.0333
Flag leaf area (cm^2)	-0.0011	-0.0034	0.0005	-0.0012	-0.0014	-0.0005	-0.0019	0.0023	-0.0108	-0.6227	-0.3447	-0.0002	0.0248	-0.9604**

*, ** Significant at 5 and 1% levels, respectively Residual effect: R= 0.0713

Table 3: Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield per plant of bread wheat

Characters	Days to first flowering	Days to Maturity	Plant height (cm)	No. of effective tillers per plant	Length of main spike (cm)	Peduncle length of main spike (cm)	No. of spikelets per main spike	No. of grains per main spike	Grain weight per main spike (g)	Biological yield per plant (g)	Harvest index (%)	100-grain weight (g)	Flag leaf area (cm^2)	Genotypic correlation with grain yield per plant
Days to first flowering	0.0373	-0.0069	-0.0163	-0.0020	0.0118	-0.0086	-0.0026	0.0056	-0.0043	0.0884	0.0807	-0.0036	0.2098	0.3893**
Days to maturity	0.0223	-0.0116	-0.0053	0.0036	0.0048	-0.0062	0.0033	0.0042	-0.0102	0.0561	0.0693	-0.0041	0.1672	0.2931*
Plant height (cm)	0.0107	-0.0011	-0.0569	-0.0005	0.0188	0.0243	-0.0020	0.0029	0.0102	0.0679	-0.0189	-0.0054	0.0865	0.1366
No. of effective tillers per plant	-0.0024	-0.0013	0.0009	0.0313	-0.0079	0.0014	0.0104	-0.0024	-0.0125	0.0459	0.0492	-0.0036	0.1050	0.2139
Length of main spike (cm)	0.0097	-0.0012	-0.0237	-0.0055	0.0453	0.0083	-0.0159	0.0113	0.0025	0.0700	0.0113	-0.0079	0.0971	0.2013
Peduncle length of main spike (cm)	-0.0074	0.0017	-0.0317	0.0010	0.0086	0.0436	-0.0046	0.0012	0.0130	0.0574	-0.0610	-0.0011	0.0118	0.0325
No. of spikelets per main spike	0.0023	0.0009	-0.0026	-0.0076	0.0169	0.0047	-0.0425	0.0185	0.0023	0.0299	-0.0223	-0.0133	0.0448	0.0321
No. of grains per main spike	0.0067	-0.0016	-0.0053	-0.0024	0.0165	0.0017	-0.0254	0.0309	0.0113	0.0932	0.0400	-0.0201	0.1573	0.3028*
Grain weight per main spike (g)	-0.0025	0.0018	-0.0090	-0.0061	0.0017	0.0088	-0.0015	0.0054	0.0645	0.1406	-0.0245	0.0034	0.1363	0.3190*
Biological yield per plant (g)	0.0102	-0.0020	-0.0119	0.0044	0.0098	0.0077	-0.0039	0.0089	0.0279	0.3247	0.0248	0.0011	0.4394	0.8410**
Harvest index (%)	0.0126	-0.0034	0.0045	0.0064	0.0021	-0.0111	0.0040	0.0052	-0.0066	0.0336	0.2391	-0.0018	0.3342	0.6189**
100-grain weight (g)	-0.0043	0.0015	0.0099	-0.0037	-0.0115	-0.0016	0.0182	-0.0200	0.0070	0.0115	-0.0139	0.0310	0.0040	0.0281
Flag leaf area (cm^2)	-0.0148	0.0037	0.0093	-0.0062	-0.0083	-0.0010	0.0036	-0.0092	-0.0166	-0.2698	-0.1511	-0.0002	-0.5289	-0.9896**

*, ** Significant at 5 and 1% levels, respectively Residual effect: R= 0.0746

The genotypic path coefficient analysis (Table 3) revealed that biological yield per plant exhibited high and positive direct effect on grain yield per plant. This trait turned out to be major component of grain yield for direct selection. Similar results were obtained by Ayer *et al*. (2016), Chimdesa *et al*. (2017) [5], Nagar *et al*. (2018) [14], Pooja *et al*. (2018) [16], Tabassum *et al*. (2018) [19] and Verma *et al*. (2019) [20]. Harvest index showed positive and moderate direct effect towards grain yield per plant, while flag leaf area showed high but negative direct effect on grain yield per plant. The residual effect was of low magnitude suggesting that majority of the yield attributes have been included in the study of path analysis. Characters like days to first flowering, number of effective tillers per plant, length of main spike, peduncle length of main spike, number of grains per main spike, grain weight per main spike and 100-grain weight exerted very low and positive direct effect on grain yield per plant. However, among these characters, number of grains per main spike and grain weight per main spike had low direct effects and supplemented yield through indirect effects via flag leaf area and biological yield per plant, respectively, thus giving rise to significant and positive association of these traits with grain yield. The negative direct effect of low magnitude of days to maturity was nullified by positive indirect effect of flag leaf area.

It was apparent from both phenotypic and genotypic path analysis that higher direct effect as well as appreciable indirect influence was exerted by biological yield per plant and harvest index towards grain yield per plant. Biological yield per plant and harvest index also exhibited significant and positive association with grain yield per plant and hence, both characters may be considered as the most important yield contributing characters and due emphasis should be placed on both component traits while breeding for higher grain yield in bread wheat.

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