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Correlation and Path Coefficient Analyses for Grain Yield and Its Contributing Traits in Bread Wheat (*Triticum aestivum* L. em. Thell)

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Authors' contributions

This work was carried out in collaboration between all authors. Author PKS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SVS and RKY managed the analyses of the study. Author LS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study on bread wheat for fourteen characters viz., days to heading (50%), days to maturity, plant height (cm), number of productive tillers per plant, chlorophyll content , spike length (cm), number of spikelets per spike, number of grains per spike, weight of grain per spike(g), 1000 grain weight (g), biological yield (g), harvest index (%),protein content (%) and grain yield per plant (g) was conducted by making crosses among ten diverse genotypes in half diallel fashion grown in Randomized Block Design in three replication during Rabi 2022-2023 at SIF, C. S. Azad University

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of Agriculture & Technology, Kanpur, U.P. to assess the correlation and path coefficient. At genotypic level grain yield per plant showed positive and significant correlation with biological yieldper plant followed by number f productive tillers per plant, weight of grain per spike, harvest index, 1000 grain weight, chlorophyll content and days to maturity. In F2 generation correlation coefficients at genotypic level higher than the corresponding phenotype correlation coefficient for all characters and eight characters viz., biologic yield per plant, weight of grain per spike, number of productive tillers per plant, harvest index, 1000 grain weight, days to maturity, protein content and number of grain per spike showed positive and significant correlation with grain yield per plant. At genotypic level the highest positive direct effect on grain yield per plant was exerted by biological yield per plant followed by harvest index, number of spikelets per spike, spike length, days to 50% heading, 1000 grain weight, number of productive tiller per plant, weight of grain per spike, chlorophyll content and protein content in F1s.At phenotypic level the highest positive direct effect on grain yield per plant was exerted by biological yield per plant followed by harvest index, spike length, days to maturity, number of productive tiller per plant, weight of grain per spike, chlorophyll contend and protein content in F2s. Hence these characters may be considered for selection and improvement of grain yield in bread wheat.

Keywords: Correlation; path coefficient; genotype; phenotype; grain; protein content; grain yield; biometrical techniques.

1. INTRODUCTION

“Wheat (*Triticum aestivum* L.) is one of the most important cereal crop grown in different environments due to its versatile nature over the world. At global level, it’s cultivated over 219.15 million hectare and production of 808.44 million tons with an average productivity of 36.88 quintals per hectare. In India, it is grown in area of 30.45 million hectares with a production of 107.74 million tons and productivity of 35.37 quintals per hectare” [1]. “Wheat is grown under diverse agro-climatic conditions leading to wide fluctuation in productivity from region to region. Wheat is used for both human and animal nutrition and plays an important role in the nutrition of rapidly growing populations both in our country and the world. A number of biometrical techniques are extensively used for genetic evaluation of plants. Out of them, diallel analyses have been frequently used by breeders for genetic study because they provide more genetic information about the material studied. Wheat has been playing an important role in the economy of several countries. A number of biometrical techniques are extensively used for genetic evaluation of plants. Diallel analyses have been frequently used by breeders for genetic study because they provide more genetic information about the material studied. Achieving improvement in yield can be done through direct selection for grain yield and its component traits. The magnitude of genotypic correlation coefficient was greater than phenotypic correlation for all the characters except in few combinations. The result revealed that certain characters showed positive significant correlation at genotypic level such as days to heading with days to maturity, plant height, chlorophyll content, number of grain per spike, weight of grain per spike, 1000 grain weight, biological yield per plant, harvest index and protein content. Estimates of direct effect and indirect effect of different characters on seed yield per plant in path coefficient analysis at genotypic and phenotypic levels. In F1s, biological yield per plant had the highest positive direct effect on grain yield per plant, followed by harvest index, spike length, days to maturity, number of productive tiller per plant, weight of grain per spike, protein content, and chlorophyll content. In F2s, biological yield per plant was followed by harvest index, spike length, days to maturity, number of productive tiller per plant, weight of grain per spike, and protein content.

2. MATERIALS AND METHODS

Ten genetically divers genotypes were crossed in all possible combinations excluding reciprocal during *Rabi* 2022-2023, 10 parents, 45F_1s and 45F_2s were grown in RCBD (Randomized Complete Block Design) with three replications at Student’s Instructional Farm, C. S. Azad University of Agriculture & Technology, Kanpur-208002, Uttar Pradesh center. Basic material consisting of ten morphological diverse genotype *viz*., HD 2733,DBW 187, DBW 222,HD 3086,HUW 666,K 1317,KRL 19, HI 1563,DBW 14 and K 9423. For fourteen characters *viz*., days to heading (50 %), days to maturity, plant height (cm), number of productive tillers per plant, chlorophyll content , spike length (cm), number of spikelets per spike, number of grains per spike, weight of grain per spike(g), 1000 grain weight (g), biological yield (g), harvest index (%),protein content (%) and grain yield per plant (g) observations were recorded from the five randomly selected plants from each genotypes.

2.1 Estimation of Correlation and Path Coefficient

2.1.1 Estimation of correlation coefficient

The following formulae were used for calculating the genotypic and phenotypic coefficient of correlation in the experiment as suggested by Al-Jibouri et al*.* [2].

a) Genotypic correlation $[r_{xy}(\text{g})] = \frac{Cov_{.xy}(\text{g})}{\sqrt{[V_x(\text{g}).V_y(\text{g})}}$

Where,

Co $v_{.xy}$ (g)= genotypic covariance between characters x and y, andthis was obtained as follows:

$\text{Cov}_{.xy}(\text{g}) = \frac{[\text{Cov}_{.xy}(\text{p}) - \text{Cov}_{.xy}(\text{e})]}{\text{r}}$

V_x(g) and V_y (g) = genotypic variances for the characters x and y, respectively

r =number of replications

b) Phenotypic correlation [r_{xy} (p)] = $\frac{Cov_{.xy}(\text{p})}{\sqrt{[V_x(\text{p}).V_y(\text{p})}}$

Where,

$\text{Cov}_{.xy}$(p) =phenotypic covariance between the characters x and y, andthis was obtained as follows:

$\text{Cov}_{.xy}(\text{p}) = \text{Cov}_{.xy}(\text{p}) + \text{Cov}_{.xy}(\text{e})$

V_x (p) and V_y (p) = phenotypic variance for the characters x and y, r respectively

xy (e) = the error variance for characters x and y, respectively.

(ii) Estimation of Path analysis

Path coefficient analysis suggested by Dewey and Lu [3] was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following simultaneous equation indicating the basic relationship between correlation and path coefficient. The equations used are as follows:

$r_{ij} = P_{iy} + \sum_{j=1}^{10} r_{ij} P_{iy}$ for i =1, 2……………10

$r_{ij} = \sum_{j=1}^{10} r_{ij} P_{iy}$ for $r_{ij} = 1$

The above equations can be written in the form of matrix.

$[A]_{10\times1} = [B]_{10\times1}[C]_{10\times1}$

Where,

A is column vector of correlations r_{ij}

B is the correlation matrix of r_{ij} and

C is the column vector of direct effect, P_{iy}
Residual factor was calculated as follows:

$P_{xy} = \sqrt{1 - R^2}$

Where,

$R^2 = \sum_j P_{iy} r_{ij}$

The r_{ij} i.e. $r_{1.2}$ to $r_{9.10}$ denote correlation between all possible combinations of independent characters

$P_{1y} to P_{10y}$ denote direct effects of various characters on character y.

r_{ij} = correlation coefficient between i^{th} and y characters.

P_{iy} Direct effect of i^{th} character

3. RESULTS AND DISCUSSION

3.1 Correlation Coefficient

Correlation study was carried out between all the fourteen characters at genotypic and phenotypic levels. The phenotypic and genotypic correlation coefficient of F_1 and F_2 computed among the fourteen characters under study has been presented in Table 1 and Table 2 respectively.

Table 1. Genotypic and Phenotypic correlation coefficient in F_1s

Characters		Days to heading (50%)	Days to maturity	Plant height (cm)	Chlorophyll content	No. of productive tillers/plant	Spike length (cm)	No. of spikelets/spike	No. of grains/spike	Weight of grain/ spike(g)	1000 grain weight (g)	Biological yield/plant (g)	Harvest index (%)	Protein content (%)	Grain yield /plant (g)
Days to heading (50%)	G	1.000	0.424**	-0.011	0.042	0.001	0.003	0.226**	0.230**	-0.050	0.012	-0.206**	0.156*	0.259**	-0.127
	P	1.000	0.379**	0.003	0.068	-0.017	0.011	0.188*	0.166*	-0.022	0.049	-0.163*	0.128	0.194*	-0.095
Days to maturity	G			-0.158*	0.107	0.272**	-0.185*	0.024	0.065	0.059	0.084	0.146	0.182*	0.242**	0.203**
	P			-0.147	0.105	0.244**	-0.172*	0.030	0.060	0.065	0.097	0.145	0.151	0.202**	0.196*
Plant height (cm)	G				-0.129	-0.140	0.181*	0.071	0.163*	-0.059	0.439**	-0.128	0.043	0.091	-0.116
	P				-0.109	-0.119	0.170*	0.067	0.145	-0.076	0.386**	-0.133	0.040	0.087	-0.119
Chlorophyll content	G					0.237**	-0.036	-0.198*	-0.051	0.203**	-0.065	0.235**	0.037	-0.071	0.234**
	P					0.188*	-0.039	-0.168*	-0.059	0.172*	-0.054	0.204**	0.007	-0.072	0.193*
No. of productive tillers/plant	G						-0.242**	0.212**	0.258**	0.386**	0.210**	0.551**	0.298**	0.186*	0.621**
	P						-0.217**	0.204**	0.249**	0.307**	0.173*	0.509**	0.260**	0.134	0.573**
Spike length(cm)	G							0.142	0.125	-0.075	0.081	-0.189*	0.066	0.149	-0.143
	P							0.138	0.104	-0.073	0.082	-0.181*	0.051	0.141	-0.138
No. of spikelets/spike	G								0.827**	0.284**	0.253**	0.099	0.065	0.127	0.122
	P								0.757**	0.254**	0.215**	0.092	0.074	0.096	0.119
No. of grains/spike	G									0.320**	0.381**	0.140	0.049	0.123	0.149
	P									0.255**	0.306**	0.132	0.061	0.112	0.147
Weight of grain/ spike(g)	G										0.405**	0.591**	0.099	0.159*	0.588**
	P										0.329**	0.544**	0.073	0.095	0.531**
1000 grain weight (g)	G											0.290**	0.150	0.325**	0.322**
	P											0.258**	0.092	0.273**	0.274**
Biological yield/plant (g)	G												0.017	0.106	0.934**
	P												0.004	0.092	0.921**
Harvest index (%)	G													0.101	0.370**
	P													0.049	0.389**
Protein content (%)	G														0.140
	P														0.111
Grain yield /plant (g)	G														1.000
	P														1.000

**, ** significant at 5% and 1% level, respectively*

Table 2. Genotypic and phenotypic correlation coefficient in F_2s

Characters		Days to heading (50%)	Days to maturity	Plant height (cm)	Chlorophyll content (%)	No. of productive tillers/plant	Spike length (cm)	No. of spikelets/spike	No. of grains/spike	Weight of grain/ spike(g)	1000 grain weight (g)	Biological yield/plant (g)	Harvest index (%)	Protein content (%)	Grain yield /plant (g)
Days to heading (50%)	G	1.000	0.649**	0.022	-0.017	0.120	-0.069	-0.094	-0.025	0.094	0.013	0.116	0.103	0.184*	0.136
	P	1.000	0.589**	0.016	-0.004	0.098	-0.063	-0.093	-0.032	0.089	0.014	0.112	0.044	0.157*	0.114
Days to maturity	G			-0.151	0.009	0.253**	-0.192*	-0.029	0.219**	0.236**	0.018	0.284**	0.163*	0.178*	0.320**
	P			-0.141	0.019	0.223**	-0.174*	-0.021	0.204**	0.189*	0.012	0.267**	0.120	0.182*	0.295**
Plant height (cm)	G				-0.220**	-0.189*	0.321**	0.024	-0.045	0.107	0.341**	-0.178*	0.077	0.207**	-0.147
	P				-0.165*	-0.157*	0.287**	0.025	-0.022	0.086	0.311**	-0.170*	0.052	0.157*	-0.145
Chlorophyll content (%)	G					0.052	-0.066	-0.076	-0.125	-0.033	-0.011	-0.046	0.086	-0.095	-0.007
	P					0.080	-0.071	-0.054	-0.124	-0.036	-0.005	-0.037	0.085	-0.111	0.003
No. of productive tillers/plant	G						-0.223**	0.225**	0.199*	0.147	0.313**	0.418**	0.253**	0.186*	0.473**
	P						-0.196*	0.184*	0.140	0.128	0.280**	0.394**	0.198*	0.130	0.438**
Spike length(cm)	G							0.020	0.019	0.186*	0.132	0.077	0.046	0.121	0.093
	P							0.037	0.032	0.176*	0.127	0.081	0.008	0.116	0.085
No. of spikelets/spike	G								0.848**	0.198*	0.208**	0.157*	0.029	0.050	0.146
	P								0.779**	0.176*	0.182*	0.147	0.030	0.051	0.138
No. of grains/spike	G									0.318**	0.232**	0.165*	0.038	0.075	0.160*
	P									0.253**	0.210**	0.160*	0.014	0.073	0.148
Weight of grain/ spike(g)	G										0.447**	0.491**	0.352**	0.302**	0.574**
	P										0.414**	0.441**	0.257**	0.219**	0.503**
1000 grain weight (g)	G											0.241**	0.473**	0.230**	0.376**
	P											0.233**	0.396**	0.195*	0.359**
Biological yield/plant (g)	G												0.045	0.166*	0.939**
	P												0.019	0.149	0.924**
Harvest index (%)	G													0.116	0.383**
	P													0.100	0.395**
Protein content (%)	G														0.191*
	P														0.175*
Grain yield /plant (g)	G														1.000
	P														1.000

**, ** significant at 5% and 1% level, respectively*

Genotype correlation coefficient: In F_1 generation, at genotypic level grain yield per plant showed positive and significant correlation with biological yield per plant followed by number productive tillers per plant, weight of grain per spike, harvest index, 1000 grain weight, chlorophyll content and days to maturity while positive and non significant correlation with number of grain per spike, protein content and number of spikelets per spike [4,5]. At genotypic level grain yield per plant showed negative and non significant correlation with plant height, days to 50% heading and spike length Similar findings were earlier reported by Singh [6], Muhammad et al. [7], Majumder et al. [8] and Gaurav et al. [9].

In F_2 generation correlation coefficients at genotypic level higher than the corresponding phenotype correlation coefficient for all characters [10]. Eight characters *viz.,* biologicalyield per plant, weight of grain per spike, number of productive tillers per plant, harvest index, 1000 grain weight, days to maturity, protein content and number of grain per spike showed positive and significant correlation with grain yield per plant Kumar et al. [11] and Ozukum et al. [12] got the same result while remaining character showed non-significant values of correlation [13,14,15].

Phenotype correlation coefficient: "At phenotypic level all the character showed similar association as genotypic ones in direction but lower in magnitude in both F_1 and F_2 generation" [16].

3.2 Path Coefficient Analysis

"The path coefficient analysis was estimated on genotypic as well as phenotypic level (Tables 3 and 4) to resolve the direct indirect effects of different characters on grain yield per plant. The path analysis is simple regression coefficient which split correlation coefficient values into direct and indirect effect".

Genotypic path coefficient: at genotypic level The highest positive direct effect on grain yield per plant was exerted by biological yield per plant(0.9208) followed by harvest index (0.3481), number of spikelets per spike (0.0147), spike length (0.0122), days to 50% heading(0.0091), 1000 grain weight (0.0085), number of productive tiller per plant(0.0081), weight of grain per spike(0.0046), chlorophyll content (0.0032) and protein content (0.0011) in F_1s while number of grain per spike (-0.0168) followed by plant height (-0.0160) and days to maturity (-0.0022) showed negative and direct effect on grain yield per plant in F_1 [17,18,19,20].

In F_2s generation at genotypic level highest positive direct effect on grain yield per plant was exerted by biological yield per plant(0.9161) followed by harvest index (0.3405), spike length (0.0124), days to maturity(0.0119), number of productive tiller per plant(0.0086), weight of grain per spike(0.0072), chlorophyll content (0.0034) while days to 50% heading (-0.0137) followed by plant height (-0.0080), 1000 grain weight (-0.0082), number of spikelets per spike (-0.0065), number of grain per spike (-0.0040) and protein content (-0.0017) showed negative and direct effect on grain yield per plant in F_2. Similar result found by Anwar et al. [21].

High indirect positive effect on grain yield per plant was exhibited by number of grains per spike *via*. biological yield per plant (0.1287) followed by harvest index (0.0171) number of spikelets per spike (0.0122), 1000 grain weight (0.0032),number of productive tiller per plant (0.0021), days to heading (0.0021), spike length (0.0015), weight of grain per spike (0.0015) and protein content (0.0004) in F_1s while in F_2s biological yield per plant (0.1513) followed by harvest index (0.0129), days to maturity (0.0026), weight of grain per spike (0.0023), number of productive tiller per plant (0.0017), days to heading (0.0003),spike length (0.0002).In contrast high orders of negative indirect effects were exhibited by number of grains per spike on grain yield per plant *via*. plant height (-0.0026), chlorophyll content (-0.0002), days to maturity (-0.0001) in F_1s while number of spikelets per spike (-0.0055),1000 grain weight (-0.0019) chlorophyll content (-0.0004) and protein content (-0.0001) in F_2s [22,23].

3.3 Phenotypic Path Coefficient

Bhushan et al. [24] and Bhutto et al. [25] reported the similar results in accordance with results "from the current study at phenotypic level the highest positive direct effect on grain yield per plant was exerted by biological yield per plant(0.9131) followed by harvest index (0.3816), spike length (0.0102), number of spikelets per spike (0.0100), number of productive tiller per plant(0.0072), 1000 grain weight (0.0070), protein content (0.0043),chlorophyll content (0.0034),days to 50% heading(0.0025), days to maturity(0.0006) and weight of grain per spike(0.0002) in F_1s while in F_2s biological yield per plant(0.9099) followed by harvest index

Table 3. Genotypic and phenotypic path with grain yield per plant (g)- F_1s

Characters		Days to heading (50%)	Days to maturity	Plant height (cm)	Chlorophyll content (%)	No. of productive tillers/plant	Spike length (cm)	No. of spikelets/spike	No. of grains/spike	Weight of grain/ spike(g)	1000 grain weight (g)	Biological yield/plant (g)	Harvest index (%)	Protein content (%)	Grain yield /plant (g)
Days to heading (50%)	G	**0.0091**	-0.0009	0.0002	0.0001	0.0000	0.0000	0.0033	-0.0039	-0.0002	0.0001	-0.1896	0.0544	0.0003	-0.127
	P	**0.0025**	0.0002	0.0000	0.0002	-0.0001	0.0001	0.0019	-0.0014	0.0000	0.0004	-0.1487	0.0490	0.0008	-0.095
Days to maturity	G	0.0038	**-0.0022**	0.0025	0.0003	0.0022	-0.0023	0.0004	-0.0011	0.0003	0.0007	0.1344	0.0634	0.0003	0.203**
	P	0.0009	**0.0006**	0.0023	0.0004	0.0018	-0.0018	0.0003	-0.0005	0.0000	0.0007	0.1328	0.0577	0.0009	0.196*
Plant height (cm)	G	-0.0001	0.0004	**-0.0160**	-0.0004	-0.0011	0.0022	0.0011	-0.0028	-0.0003	0.0037	-0.1180	0.0151	0.0001	-0.116
	P	0.0000	-0.0001	**-0.0154**	-0.0004	-0.0009	0.0017	0.0007	-0.0012	0.0000	0.0027	-0.1214	0.0151	0.0004	-0.119
Chlorophyll content (%)	G	0.0004	-0.0002	0.0021	**0.0032**	0.0019	-0.0004	-0.0029	0.0009	0.0009	-0.0006	0.2159	0.0127	-0.0001	0.234**
	P	0.0002	0.0001	0.0017	**0.0034**	0.0014	-0.0004	-0.0017	0.0005	0.0000	-0.0004	0.1859	0.0027	-0.0003	0.193*
No. of productive tillers/plant	G	0.0000	-0.0006	0.0022	0.0008	**0.0081**	-0.0030	0.0031	-0.0044	0.0018	0.0018	0.5077	0.1036	0.0002	0.621**
	P	0.0000	0.0002	0.0018	0.0006	**0.0072**	-0.0022	0.0021	-0.0020	0.0001	0.0012	0.4644	0.0993	0.0006	0.573**
Spike length(cm)	G	0.0000	0.0004	-0.0029	-0.0001	-0.0020	**0.0122**	0.0021	-0.0021	-0.0003	0.0007	-0.1738	0.0229	0.0002	-0.143
	P	0.0000	-0.0001	-0.0026	-0.0001	-0.0016	**0.0102**	0.0014	-0.0009	0.0000	0.0006	-0.1651	0.0196	0.0006	-0.138
No. of spikelets/spike	G	0.0021	-0.0001	-0.0011	-0.0006	0.0017	0.0017	**0.0147**	-0.0139	0.0013	0.0022	0.0910	0.0227	0.0001	0.122
	P	0.0005	0.0000	-0.0010	-0.0006	0.0015	0.0014	**0.0100**	-0.0062	0.0001	0.0015	0.0837	0.0282	0.0004	0.119
No. of grains/spike	G	0.0021	-0.0001	-0.0026	-0.0002	0.0021	0.0015	0.0122	**-0.0168**	0.0015	0.0032	0.1287	0.0171	0.0001	0.149
	P	0.0004	0.0000	-0.0022	-0.0002	0.0018	0.0011	0.0076	**-0.0082**	0.0001	0.0022	0.1206	0.0233	0.0005	0.147
Weight of grain/ spike(g)	G	-0.0005	-0.0001	0.0009	0.0007	0.0031	-0.0009	0.0042	-0.0054	**0.0046**	0.0034	0.5439	0.0344	0.0002	0.588**
	P	-0.0001	0.0000	0.0012	0.0006	0.0022	-0.0008	0.0025	-0.0021	**0.0002**	0.0023	0.4965	0.0278	0.0004	0.531**
1000 grain weight (g)	G	0.0001	-0.0002	-0.0070	-0.0002	0.0017	0.0010	0.0037	-0.0064	0.0019	**0.0085**	0.2668	0.0521	0.0004	0.322**
	P	0.0001	0.0001	-0.0059	-0.0002	0.0012	0.0008	0.0022	-0.0025	0.0001	**0.0070**	0.2354	0.0349	0.0012	0.274**
Biological yield/plant (g)	G	-0.0019	-0.0003	0.0020	0.0008	0.0045	-0.0023	0.0015	-0.0024	0.0027	0.0025	**0.9208**	0.0060	0.0001	0.934**
	P	-0.0004	0.0001	0.0020	0.0007	0.0037	-0.0018	0.0009	-0.0011	0.0001	0.0018	**0.9131**	0.0017	0.0004	0.921**
Harvest index (%)	G	0.0014	-0.0004	-0.0007	0.0001	0.0024	0.0008	0.0010	-0.0008	0.0005	0.0013	0.0160	**0.3481**	0.0001	0.370**
	P	0.0003	0.0001	-0.0006	0.0000	0.0019	0.0005	0.0007	-0.0005	0.0000	0.0006	0.0041	**0.3816**	0.0002	0.389**
Protein content (%)	G	0.0023	-0.0005	-0.0015	-0.0002	0.0015	0.0018	0.0019	-0.0021	0.0007	0.0028	0.0974	0.0351	**0.0011**	0.140
	P	0.0005	0.0001	-0.0013	-0.0002	0.0010	0.0014	0.0010	-0.0009	0.0000	0.0019	0.0842	0.0187	**0.0043**	0.111

**, ** significant at 5% and 1% level, respectively*

Table 4. Genotypic and Phenotypic path with Grain yield per plant (g) - F_2s

Characters		Days to heading (50%)	Days to maturity	Plant height (cm)	Chlorophyll content (%)	No. of productive tillers/plant	Spike length (cm)	No. of spikelets/spike	No. of grains/spike	Weight of grain/ spike(g)	1000 grain weight (g)	Biological yield/plant (g)	Harvest index (%)	Protein content (%)	Grain yield /plant (g)
Days to heading (50%)	G	**-0.0137**	0.0077	-0.0002	-0.0001	0.0010	-0.0009	0.0006	0.0001	0.0007	-0.0001	0.1060	0.0350	-0.0003	0.136
	P	**-0.0125**	0.0075	-0.0002	0.0000	0.0006	-0.0008	0.0007	0.0001	0.0004	0.0000	0.1018	0.0165	0.0001	0.114
Days to maturity	G	-0.0089	**0.0119**	0.0012	0.0000	0.0022	-0.0024	0.0002	-0.0009	0.0017	-0.0002	0.2599	0.0555	-0.0003	0.320**
	P	-0.0074	**0.0128**	0.0014	0.0000	0.0013	-0.0023	0.0002	-0.0004	0.0008	0.0000	0.2432	0.0453	0.0002	0.295**
Plant height (cm)	G	-0.0003	-0.0018	**-0.0080**	-0.0008	-0.0016	0.0040	-0.0002	0.0002	0.0008	-0.0028	-0.1627	0.0263	-0.0004	-0.147
	P	-0.0002	-0.0018	**-0.0102**	-0.0004	-0.0009	0.0038	-0.0002	0.0000	0.0004	-0.0006	-0.1550	0.0197	0.0001	-0.145
Chlorophyll content (%)	G	0.0002	0.0001	0.0018	**0.0034**	0.0005	-0.0008	0.0005	0.0005	-0.0002	0.0001	-0.0421	0.0293	0.0002	-0.007
	P	0.0001	0.0002	0.0017	**0.0024**	0.0005	-0.0009	0.0004	0.0003	-0.0002	0.0000	-0.0334	0.0321	-0.0001	0.003
No. of productive tillers/plant	G	-0.0017	0.0030	0.0015	0.0002	**0.0086**	-0.0028	-0.0015	-0.0008	0.0011	-0.0026	0.3825	0.0862	-0.0003	0.473**
	P	-0.0012	0.0029	0.0016	0.0002	**0.0058**	-0.0026	-0.0014	-0.0003	0.0005	-0.0006	0.3587	0.0743	0.0001	0.438**
Spike length(cm)	G	0.0010	-0.0023	-0.0026	-0.0002	-0.0019	**0.0124**	-0.0001	-0.0001	0.0013	-0.0011	0.0707	0.0158	-0.0002	0.093
	P	0.0008	-0.0022	-0.0029	-0.0002	-0.0011	**0.0131**	-0.0003	-0.0001	0.0007	-0.0003	0.0737	0.0032	0.0001	0.085
No. of spikelets/spike	G	0.0013	-0.0003	-0.0002	-0.0003	0.0019	0.0002	**-0.0065**	-0.0034	0.0014	-0.0017	0.1437	0.0099	-0.0001	0.146
	P	0.0012	-0.0003	-0.0003	-0.0001	0.0011	0.0005	**-0.0076**	-0.0016	0.0007	-0.0004	0.1340	0.0111	0.0001	0.138
No. of grains/spike	G	0.0003	0.0026	0.0004	-0.0004	0.0017	0.0002	-0.0055	**-0.0040**	0.0023	-0.0019	0.1513	0.0129	-0.0001	0.160*
	P	0.0004	0.0026	0.0002	-0.0003	0.0008	0.0004	-0.0059	**-0.0020**	0.0010	-0.0004	0.1456	0.0053	0.0001	0.148
Weight of grain/ spike(g)	G	-0.0013	0.0028	-0.0009	-0.0001	0.0013	0.0023	-0.0013	-0.0013	**0.0072**	-0.0036	0.4499	0.1198	-0.0005	0.574**
	P	-0.0011	0.0024	-0.0009	-0.0001	0.0007	0.0023	-0.0013	-0.0005	**0.0041**	-0.0008	0.4017	0.0967	0.0002	0.503**
1000 grain weight (g)	G	-0.0002	0.0002	-0.0027	0.0000	0.0027	0.0016	-0.0014	-0.0009	0.0032	**-0.0082**	0.2211	0.1610	-0.0004	0.376**
	P	-0.0002	0.0002	-0.0032	0.0000	0.0016	0.0017	-0.0014	-0.0004	0.0017	**-0.0020**	0.2120	0.1489	0.0002	0.359**
Biological yield/plant (g)	G	-0.0016	0.0034	0.0014	-0.0002	0.0036	0.0010	-0.0010	-0.0007	0.0035	-0.0020	**0.9161**	0.0155	-0.0003	0.939**
	P	-0.0014	0.0034	0.0017	-0.0001	0.0023	0.0011	-0.0011	-0.0003	0.0018	-0.0005	**0.9099**	0.0070	0.0001	0.924**
Harvest index (%)	G	-0.0014	0.0019	-0.0006	0.0003	0.0022	0.0006	-0.0002	-0.0002	0.0025	-0.0039	0.0416	**0.3405**	-0.0002	0.383**
	P	-0.0006	0.0015	-0.0005	0.0002	0.0012	0.0001	-0.0002	0.0000	0.0011	-0.0008	0.0169	**0.3761**	0.0001	0.395**
Protein content (%)	G	-0.0025	0.0021	-0.0017	-0.0003	0.0016	0.0015	-0.0003	-0.0003	0.0022	-0.0019	0.1522	0.0396	**-0.0017**	0.191*
	P	-0.0020	0.0023	-0.0016	-0.0003	0.0008	0.0015	-0.0004	-0.0002	0.0009	-0.0004	0.1355	0.0377	**0.0009**	0.175*

**, ** significant at 5% and 1% level, respectively*

(0.3761), spike length (0.0131), days to maturity(0.0128), number of productive tiller per plant(0.0058), weight of grain per spike(0.0041), chlorophyll content (0.0024) and protein content (0.0009). The highest negative direct effect was exerted by plant height (-0.0154) and number of grain per spike (-0.0082) in F_1s while in F_2s 1000 grain weight (-0.0020) followed by number of grain per spike (-0.0020), number of spikelets per spike (-0.0076), plant height (-0.0102) and days to 50% heading (-0.0125)".

Number of grains per spike exhibited high order of positive indirect effect on grain yield per plant *via*. Biological yield per plant (0.1206) followed by harvest index (0.0233) number of spikelets per spike (0.0076), 1000 grain weight (0.0022),number of productive tiller per plant (0.0018), spike length (0.0011), protein content (0.0004), days to heading (0.0004) and weight of grain per spike (0.0001) in F_1s while in F_2s biological yield per plant (0.1456) followed by harvest index (0.0053), days to maturity (0.0026), weight of grain per spike (0.0010), number of productive tiller per plant (0.0008), days to heading (0.0004), spike length (0.0004) and plant height (0.0001) [26]. In contrast high orders of negative indirect effects were exhibited by number of grains per spike on grain yield per plant *via*. number of spikelets per spike (-0.0059) and chlorophyll content (-0.0003) in F_1s while plant height (-0.0022) and chlorophyll content (-0.0001) in F_2s [27].

"Thus, on the basis of genotypic and phenotypic path coefficient analysis, biological yield per plant, number of productive tiller per plant, weight of grain per spike, harvest index, 1000 grain weight, chlorophyll content and days to maturity were identified as most important positive direct contributors towards grain yield per plant. Path coefficient has emerged as a powerful and widely use in breeding programme to understanding the direct and indirect contribution of different traits to economic yield in crop plant. Emphasis on selection in favour of these traits would help breeders for having desirable correlated response for higher productivity" [28,29,30].

4. CONCLUSION

The most important characteristics in this study were found to be biological yield per plant, number of productive tillers per plant, weight of grain per spike, harvest index, 1000 grain weight, chlorophyll content, protein content, and days to maturity. These characteristics demonstrated significant positive correlations at both the genotypic and phenotypic levels, as well as high positive direct effects on grain yield per plant in both generations. In breeding programs, path coefficient has become a potent and popular tool for determining the direct and indirect contributions of various qualities to bread wheat's economic output. Thus, in order to optimize grain, we should think about employing these features as the selection criterion.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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