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Analysis of correlation and path coefficient in F_1 and F_2 generations of bread wheat (*Triticum aestivum* L.)

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Abstract
Wheat plays a crucial role in global food security, particularly in India, where it is the second most cultivated cereal. Enhancing wheat productivity requires a thorough understanding of the relationships among yield-contributing traits. This study assessed 67 wheat genotypes (27 F_1s, 27 F_2s, 9 lines, 3 testers, and 1 check) developed using a Line × Tester mating design. The experiment, conducted at BRD PG College, Deoria, followed a randomized block design with three replications, evaluating 14 agronomic traits. Correlation and path coefficient analyses were performed at genotypic and phenotypic levels. The results revealed significant associations between grain yield per plant (GYPP) and traits like biological yield per plant (BYPP), harvest index (HI), test weight (TW), and grains per spike (GPS). Path analysis confirmed that days to 50% flowering, plant height, and productive tillers per plant exerted notable direct and indirect effects on yield. These findings provide valuable insights for breeding programs aimed at improving wheat yield.

Keywords: Correlation coefficient, path coefficient, *Triticum aestivum*, grain yield

1. Introduction

Wheat (*Triticum aestivum* L.) is a staple cereal crop globally, renowned for its adaptability and significant contribution to human nutrition. In India, wheat holds a pivotal role in ensuring food security and is the second most cultivated cereal after rice (Anonymous, 2022) [1]. According to the latest data from the Ministry of Agriculture & Farmers Welfare, Government of India, during the 2022-2023 agricultural year, wheat was cultivated over an area of approximately 31.45 million hectares, yielding a production of about 110 million tonnes, with an average productivity of 3.5 tonnes per hectare (Anonymous, 2024) [2].

The prominence of wheat in India's agrarian economy is underscored by its contribution to the national food grain basket and its role in sustaining the livelihoods of millions of farmers. Enhancing wheat yield is thus a critical objective in agricultural research and development (Anonymous, 2022) [1].

To achieve higher yields, understanding the relationships between various yield components is essential. Correlation and path coefficient analyses serve as valuable statistical tools in this context. Correlation analysis identifies the strength and direction of associations between yield and its contributing traits (Searle, 1961) [11], while path coefficient analysis partitions these correlations into direct and indirect effects, providing deeper insights into the causal relationships (Dewey and Lu, 1959) [4].

In summary, wheat's central role in India's agriculture necessitates continuous efforts to enhance its productivity. Employing statistical analyses like correlation and path coefficient analysis enables breeders to identify key traits influencing yield, thereby facilitating the development of superior wheat varieties tailored to India's diverse agro-climatic conditions.

2. Materials and Methods

The experimental materials for this study consisted of 67 (27 F_1s + 27 F_2s + 9 lines + testers + 1 check) wheat genotypes. The crosses were generated through crossing 9 lines and 3 testers in Line X Tester mating design in 2019-20. Further F_1s were grown to raise F_2s in 2020-21.

The final experiment was conducted during rabi 2021-22 at departmental Research Farm of BRD PG College, Deoria (Affiliated with DDU Gorakhpur University, Uttar Pradesh) in three replications in randomized block design. All the necessary packages and practices were followed to raise a good crop health. The data were observed for fourteen metric traits as Days to 50% flowering (DFF), Days to maturity (DM), Plant Height (PH), No of effective tillers per plant (TPP), Flag leaf area (FLA), Spike length (SL), No. of spikletes per spike (SPS), Peduncle length (PL), No of grains per spike (GPS), Grain Weight per spike (GWPS), Test weight (TW), Biological yield per plant (BYPP), Harvest index (HI) and Grain yield per plant (GYPP). The observations were noted on plot basis for DFF and DM while rest were calculated from 5 randomly selected plants based on their phenotypic superiority. The relationships among different traits at both genotypic and phenotypic levels were assessed using the approach described by Searle (1961) [11]. Direct and indirect impacts were evaluated through path coefficient analysis as recommended by Wright (1921) [16] and further explained by Dewey and Lu (1959) [4].

3. Results and Discussion

The results based on genotypic and phenotypic analysis for correlation and path coefficients in both the generations have been presented in the tables 1-4 respectively.

3.1 Correlation coefficients

The results for DFF showed that it was positively associated with DM (G: 0.787, P: 0.628) in F_1 and (G: 0.947, P: 0.628) in F_2, while negatively associated with rest of the traits including grain yield (G: -0.568, P: -0.455) in F_1 and (G: 0.179, P: 0.130) in F_2 revealing early flowering genotypes should be preferred for higher yield. Singh *et al*. (2025) [13] notes similar results in their study for DFF with DM and GYPP. DM shows a strong negative correlation with yield in F_1 (G: -0.339, P: -0.235) and significant positive association in F_2 (G: 0.203, P: 0.199). While with remaining traits it showed negative association in both the generations. Selection for moderately early maturing genotypes is desirable. Singh *et al*. (2021) [12] also observed similar positive results in their study as grain yield per plant was interrelated with biological yield per plant followed by harvest index, test weight, days to 50% flowering and days to maturity.

PH exhibited significant positive association with SL (G: 0.254, P: 0.249), BYPP (G: 0.584, P: 0.482) and GYPP (G: 0.589, P: 0.489) in F_1 and positive correlation with SL (G: 0.301, P: 0.210) and BYPP (G: 0.864, P: 0.496) while negative correlation with HI (G: -0.249, P: -0.210) in F_2. Moderate plant height is ideal, as excessively tall plants may lead to lodging. TPP showed strong positive correlation with FLA (G: 0.508, P: 0.437), SL (G: 0.599, P: 0.514), SPS (G: 0.679, P: 0.629), PL (G: 0.592, P: 0.551), GPS (G: 0.701, P: 0.661),GWPS (G: 0.222, P: 0.212), TW (G: 0.614, P: 0.599), HI (G: 0.564, P: 0.551) and GYPP (G: 0.457, P: 0.406) in F_1 and negative association in F_2 with SL (G: 0.714, P: 0.641), SPS (G: 0.689, P: 0.605), PL (G: 0.640, P: 0.605), GPS (G: 0.835, P: 0.784), GWPS (G: 0.228, P: 0.217), TW (G: 0.222, P: 0.212), HI (G: 0.742, P: 0.719) and GYPP (G: -0.198, P: -0.209). The results indicated that more tillers enhance yield, but excessive tillering may cause competition for resources. GPS was positively correlated with FLA in the study of Sahu *et al*. (2021) [9]. Kumar *et al*. (2020) [5] observed positive association of plant height, productive tillers per plant with grain yield per plant.

FLA possessed significant and positive association with GYPP in F_1 (G: 0.206, P: 0.204) and while non-significant correlation in F_2 (G: 0.024, P: 0.036). It was also positively associated with other yield component traits like spike length, grains per spike, and peduncle length in both the generations. A larger flag leaf enhances photosynthesis and improves grain filling. SL had strong positive correlation with grain yield in F_1 (G: 0.591, P: 0.555) and it has non-significant F_2 (G: -0.016, P: 0.008). It showed positive correlation with other metric traits also *viz.*, SPS, PL, GPS, GWPS, TW, and HI in both the generations. Long spikes generally indicate higher grain-bearing capacity. Singh *et al*. (2021) [12] also observed similar positive results in their study as grain yield per plant was interrelated with biological yield per plant followed by harvest index, test weight, days to 50% flowering and days to maturity. Patel *et al*. (2025) [8] revealed that grain yield per plant showed significant positive correlations with spike length and grains per spike.

A moderately strong correlation of SPS with grain yield in F_1 (G: 0.430, P: 0.368) was notes but in F_2 (G: -0.094, P: -0.094) exhibited non-significant positive correlation. Other positively associated traits are GPS and TW. The results revealed that more spikletes generally mean higher yield, but excessive numbers may reduce grain size. Nageshwar *et. al.*, (2021) [7] and Chaurasia *et al*. (2023) [3] agreed with the results observed in this study. PL has positive but non-significant correlation with yield in F_1 (G: 0.158, P: 0.132) but significant negative correlation in F_2 (G: -0.405, P: -0.397). Moderate peduncle length is preferable to avoid lodging issues. Tarkeshwar *et al*. (2020) [14] noted that number of tillers per plant, number of spikelets per spike, plant height, biological yield per plant, yield per spike and number of grains per spike had high positive correlation with grain yield per plant.

GPS was positively correlated with GYPP in F_1 (G: 0.357, P: 0.330) as well as GWPS (G: 0.384, P: 0.354), TW (G: 0.777, P: 0.748), HI (G: 0.858, P: 0.832) and while negative correlation in F_2 with GYPP (G: -0.110, P: -0.111) and significant correlation with GWPS, TW and HI. Grains per spike remain a vital yield component. The traits ear length, yield per spike and peduncle length also possessed significant positive correlation with number of grains per spike, 1000 grains weight and number of grains per spike respectively in the studies of Kumar *et al*. (2020) [5] and Nageshwar *et. al.*, (2021) [7].

GWPS showed positive correlation with GYPP in F_1 (G: 0.334, P: 0.324) and F_2 (G: 0.478, P: 0.467). A crucial trait for yield improvement. Chaurasia *et al*. (2023) [3] were in agreement with the results observed in this study. TW possessed weak correlation with yield in F_1 (G: 0.178, P: 0.134) but negative in F_2 (G: -0.270, P: -0.283). Heavy grains may limit yield due to fewer grains per spike. Sahu *et al*. (2021) [9] in his study noted positive correlation of TW with GYPP. BYPP exhibited strongly correlated in F_1 (G: 0.584) but negatively in F_2 (-0.002). Sahu *et al*. (2021) [9] noted similar results for BYPP as it was positively associated with GYPP. Patel *et al*. (2025) [8] revealed that grain yield per plant showed significant positive correlations with spike length, biological yield per plant (in N0 and N+ conditions), grains per spike.

HI showed weak association with GYPP in both generations. Saini *et al*. (2024) [10] studied correlation coefficients in F_2 generation and found 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 grains per spike showed positive and significant correlation with grain yield per plant. Kumar *et al*. (2020) [5] observed positive association of biological yield per plant, number of grains per spike and harvest index with grain yield per plant. Makwana *et al*. (2025) [6] positive relationship between grain yield per plant and spike length, grains per spike, filled grains per spike, straw yield per plant and harvest index at both genotypic and phenotypic levels.

3.2 Path coefficients

In F_1, DFF exerts a positive direct effect (0.1600) on grain yield, confirming its positive influence at genotypic level while negative effect (-0.0543) at phenotypic level. In F_2, it has a negative direct effect (-0.6816) at genotypic level whereas positive direct effects (0.1513), reinforcing that early flowering enhances yield potential. In F_1, DM has a positive direct effect (0.3082) at genotypic level, confirming its enhancing impact on grain yield while it exerts negative direct effect at phenotypic level. In F_2, the positive direct effect (0.2731) is stronger at genotypic level, suggesting that early maturity significantly hampers yield, while it exerts minute positive direct effect at phenotypic level. In F_1, PH exerts a positive direct effect (0.1253) at genotypic level as well as phenotypic level (0.1723), meaning taller plants contribute positively to yield. In F2, the positive direct effect (1.0000) at genotypic level and (0.1960) at phenotypic level suggesting tillers plants contribute positively to yield. In F_1, TPP has a positive direct effect (G:0.1829, P:0.2709) and in F_2 it was (G:0.3633, P:0.1538) confirming its significance in yield improvement. In F_1 FLA exerts weaker positive effects at both levels, while negative effect in F_2 at genotypic level (-0.1527) and moderate positive effects at phenotypic level (0.2195). Chaurasia *et al*. (2023) [3] agreed with the results observed in this study.

In F_1, SL has negative direct effect at genotypic and positive direct effect at phenotypic level (G: -0.3043, P:0.3879) and in F_2 it was (G: -0.0556, P:0.3404) confirming environmental influence in yield. In F_1, SPS has a positive direct effect (G:0.5879, P:0.0843) confirming its significance in yield improvement; and in F_2 it was (G: -0.1804, P:0.0973) confirming its negative effect in later generations. In F_1, PL has a negative direct effect (G: -0.2312, P: -0.2767) confirming its negative significance in yield improvement; and in F_2 it was (G: -0.1044, P: -0.5456) indicating longer PL will decrease the yield. In F_1, GPS has a positive direct effect (G:0.9919, P:0.5060) indicating increase in yield with increase in GPS improvement; and in F_2 it was (G: -0.0037, P:0.1112) confirming its negative effect in later generations. Zewdu *et al*. (2024) [17] found similar results and were agreed with the results as they noted that genotypic path analysis of the traits revealed that days to maturity, number of spikelets spike^{-1}, head weight, yield head^{-1}, biomass yield, test weight and harvest index exerted direct positive effect on grain yield.

GWPS exerted positive direct effects on yield at genotypic level (0.2629) and weaker positive effects at phenotypic level (0.0336) in F_1 confirming its enhancing effects on yield while in later generation *viz*., F_2, it exerted negative effects on yield. TW showed negative direct effects on yield in both the generations at both levels as shown in tables. BYPP exerted positive direct effects on yield at genotypic and phenotypic level (G:0.5405 P: 0.2284) in F_1 confirming its enhancing effects on yield while it was negative in later generations. Tiwari and Singh (2024) [15] noted direct effects of TPP, BYPP and HI on GYPP in their investigation.

HI exerted negative direct effects on yield at genotypic and phenotypic level in F_1 while it was positive in later generations (G:0.8768 P: 0.2105) confirming its enhancing effects on yield. Patel *et al*. (2025) [8] showed that biological yield per plant, harvest index had the highest positive effects on grain yield under respective nitrogen conditions. In F_1, at genotypic level, DFF *via* DM (0.2427), SL (0.2268), PL (0.1299) and HI (0.3186) exerted substantial amount of positive indirect effects on yield. At genotypic level in F_1, DM *via* DFF (G:0.1260), SL (G:0.2163), PL (G:0.1774), and HI (G:0.4025) and in F_2 *via* FLA (G:0.1347), SPS (G:0.1544) and TW (G:0.6464). PH *via* BYPP (0.3159), TPS *via* SPS (0.3990) and GPS (0.6951), FLA *via* GPS (0.6731), SL *via* GPS (0.7230), GWPS (0.1433) and BYPP (0.1852), SPS *via* TPS (0.1241) and GPS (0.7462), PL *via* TPS (0.1083), SPS (0.3857) and GPS (0.8182), GPS *via* TPS (0.1281) and SPS (0.4422) exhibited positive indirect effects on GYPP. The traits GWPS *via* SPS (0.1318), TW *via* TPS (0.1124), SPS (0.3631) and GPS (0.7703), BYPP *via* HI (0.1593) and HI *via* TPS (0.1032), SPS (0.4115) and GPS (0.8515) exhibited considerable positive indirect effects on GYPP. At phenotypic level, the lower values for most of the traits showed minimum influence of environmental factors in the expression of these traits. The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits that showed a significant correlation with grain yield. This suggests a strong inherent association among these traits, indicating that selecting for them could lead to an improvement in grain yield. Chaurasia *et al*. (2023) [3] agreed with the results observed in this study.

In F_2, at genotypic level DFF exerted substantial amount of positive indirect effects on yield *via* DM (G: 0.2588), FLA (G:0.1150), SPS (G:0.1526), PL (P:0.2857), TW (G:0.9760, P: 0.3687) and BYPP (G:0.3409). Further, BYPP *via* TPS (0.2779), *via* PL (0.3567), HI (0.5036); HI *via* TPS (0.6569), FLA (0.6991), SL (0.4737), SPS (0.5695), PL (0.5950), GPS (0.6869) and GWPS (0.2055). At phenotypic level, most of the traits had higher values than genotypic level indicating the environmental influence in the expression of traits in F_2. Makwana *et al*. (2025) [6] revealed that harvest index had the most significant positive direct impact on grain yield per plant, filled grains per spike, days to heading, spike length and test weight at genotypic and phenotypic levels. Saini *et al*. (2024) [10] noted the highest positive direct effect on grain yield per plant in F_2 was exerted by biological yield per plant followed by harvest index, spike length, days to maturity, number of productive tillers per plant, weight of grain per spike.

Table 1: Genotypic and phenotypic correlation coefficients among fourteen metric traits of wheat in F_1

Characters	Gen	Days to 50% flowering	Days to maturity	Plant Height (cm)	No of effective tillers per plant	Flag leaf area (cm)	Spike length (cm)	No. of spikletes per spike	Peduncle length (cm)	No of grains per spike	Grain Weight per spike (g)	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% flowering	G	1.000	0.787**	-0.174	-0.723**	-0.731**	-0.745**	-0.889**	-0.562**	-0.714**	-0.431**	-0.701**	-0.254**	-0.647**	-0.568**
	P	1.000	0.675**	-0.375**	-0.512**	-0.653**	-0.661**	-0.583**	-0.503**	-0.576**	-0.307**	-0.563**	-0.217*	-0.471**	-0.455**
Days to maturity	G			0.016	-0.697**	-0.762**	-0.711**	-0.811**	-0.767**	-0.905**	-0.446**	-0.854**	0.093	-0.818**	-0.339**
	P			-0.085	-0.564**	-0.634**	-0.618**	-0.569**	-0.694**	-0.801**	-0.307**	-0.782**	0.138	-0.671**	-0.235**
Plant Height (cm)	G				0.162	-0.150	0.254**	0.157	-0.159	0.053	0.010	0.089	0.584**	-0.107	0.589**
	P				0.045	0.018	0.249**	0.073	-0.037	0.040	-0.002	0.045	0.482**	-0.119	0.448**
No of effective tillers per plant	G					0.508**	0.599**	0.679**	0.592**	0.701**	0.222*	0.614**	0.056	0.564**	0.457**
	P					0.437**	0.514**	0.629**	0.551**	0.661**	0.212*	0.589**	0.040	0.551**	0.406**
Flag leaf area (cm)	G						0.531**	0.728**	0.640**	0.679**	0.186*	0.650**	-0.049	0.744**	0.206*
	P						0.506**	0.577**	0.605**	0.654**	0.165	0.585**	-0.016	0.684**	0.204*
Spike length (cm)	G							0.697**	0.552**	0.729**	0.545**	0.719**	0.343**	0.475**	0.591**
	P							0.542**	0.528**	0.688**	0.498**	0.685**	0.265**	0.428**	0.555**
No.of spikletes per spike	G								0.656**	0.752**	0.224*	0.618**	-0.041	0.700**	0.430**
	P								0.535**	0.636**	0.222*	0.525**	0.031	0.611**	0.368**
Peduncle length (cm)	G									0.825**	0.195*	0.619**	-0.237**	0.691**	0.158
	P									0.797**	0.167	0.594**	-0.229*	0.672**	0.132
No of grains per spike	G										0.384**	0.777**	-0.156	0.858**	0.357**
	P										0.354**	0.748**	-0.180*	0.832**	0.330**
Grain Weight per spike (g)	G											0.312**	0.142	0.276**	0.334**
	P											0.274**	0.149	0.254**	0.324**
Test weight (g)	G												-0.113	0.700**	0.178
	P												-0.155	0.678**	0.134
Biological yield per plant (g)	G													-0.324**	0.584**
	P													-0.334**	0.542**
Harvest index (%)	G														0.110
	P														0.078
Grain yield per plant (g)	G														1.000
	P														1.000

Table 2: Direct and indirect effects of thirteen metric traits on grain yield at genotypic and phenotypic level in F_1

Characters	Gen	Days to 50% flowering	Days to maturity	Plant Height (cm)	No of effective tillers per plant	Flag leaf area (cm)	Spike length (cm)	No. of spikletes per spike	Peduncle length (cm)	No of grains per spike	Grain Weight per spike (g)	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% flowering	G	0.1600	0.2427	-0.0218	-0.1322	-0.0609	0.2268	-0.5229	0.1299	-0.7087	-0.1133	0.0505	-0.1372	0.3186	-0.568**
	P	-0.0543	-0.0204	-0.0645	-0.1386	-0.0071	-0.2564	-0.0492	0.1391	-0.2915	-0.0103	0.2712	-0.0495	0.0769	-0.455**
Days to maturity	G	0.1260	0.3082	0.0020	-0.1275	-0.0635	0.2163	-0.4769	0.1774	-0.8978	-0.1172	0.0615	0.0504	0.4025	-0.339**
	P	-0.0367	-0.0302	-0.0147	-0.1528	-0.0069	-0.2398	-0.0480	0.1920	-0.4053	-0.0103	0.3766	0.0315	0.1095	-0.235**
Plant Height (cm)	G	-0.0278	0.0050	0.1253	0.0296	-0.0125	-0.0772	0.0925	0.0368	0.0525	0.0027	-0.0064	0.3159	0.0527	0.589**
	P	0.0203	0.0026	0.1723	0.0122	0.0002	0.0967	0.0061	0.0101	0.0203	-0.0001	-0.0219	0.1100	0.0194	0.448**
No of effective tillers per	G	-0.1157	-0.2149	0.0203	0.1829	0.0423	-0.1822	0.3990	-0.1369	0.6951	0.0584	-0.0442	0.0304	-0.2778	0.457**

plant															
	P	0.0278	0.0170	0.0078	0.2709	0.0047	0.1994	0.0530	-0.1524	0.3344	0.0071	-0.2834	0.0091	-0.0898	0.406**
Flag leaf area (cm)	G	-0.1169	-0.2349	-0.0188	0.0929	0.0833	-0.1617	0.4278	-0.1480	0.6731	0.0489	-0.0468	-0.0264	-0.3660	0.206*
	P	0.0354	0.0191	0.0031	0.1183	0.0109	0.1964	0.0487	-0.1673	0.3307	0.0055	-0.2818	-0.0037	-0.1115	0.204*
Spike length (cm)	G	-0.1192	-0.2191	0.0318	0.1095	0.0443	-0.3043	0.4100	-0.1276	0.7230	0.1433	-0.0518	0.1852	-0.2337	0.591**
	P	0.0359	0.0186	0.0429	0.1393	0.0055	0.3879	0.0457	-0.1462	0.3484	0.0167	-0.3300	0.0605	-0.0699	0.555**
No. of spikletes per spike	G	-0.1424	-0.2501	0.0197	0.1241	0.0606	-0.2123	0.5879	-0.1517	0.7462	0.0590	-0.0445	-0.0222	-0.3446	0.430**
	P	0.0317	0.0172	0.0125	0.1704	0.0063	0.2104	0.0843	-0.1481	0.3218	0.0074	-0.2530	0.0071	-0.0997	0.368**
Peduncle length (cm)	G	-0.0899	-0.2365	-0.0200	0.1083	0.0533	-0.1680	0.3857	-0.2312	0.8182	0.0512	-0.0446	-0.1280	-0.3401	0.158
	P	0.0273	0.0209	-0.0063	0.1492	0.0066	0.2049	0.0451	-0.2767	0.4035	0.0056	-0.2859	-0.0524	-0.1096	0.132
No of grains per spike	G	-0.1144	-0.2790	0.0066	0.1281	0.0565	-0.2218	0.4422	-0.1908	0.9919	0.1009	-0.0559	-0.0845	-0.4226	0.357**
	P	0.0313	0.0242	0.0069	0.1790	0.0071	0.2670	0.0536	-0.2206	0.5060	0.0119	-0.3601	-0.0411	-0.1357	0.330**
Grain Weight per spike (g)	G	-0.0689	-0.1374	0.0013	0.0406	0.0155	-0.1658	0.1318	-0.0450	0.3808	0.2629	-0.0225	0.0766	-0.1359	0.334**
	P	0.0167	0.0093	-0.0004	0.0575	0.0018	0.1930	0.0187	-0.0461	0.1791	0.0336	-0.1319	0.0341	-0.0415	0.324**
Test weight (g)	G	-0.1122	-0.2632	0.0112	0.1124	0.0541	-0.2189	0.3631	-0.1432	0.7703	0.0822	-0.0720	-0.0610	-0.3448	0.178
	P	0.0306	0.0236	0.0078	0.1595	0.0064	0.2658	0.0443	-0.1643	0.3784	0.0092	-0.4815	-0.0355	-0.1105	0.134
Biological yield per plant (g)	G	-0.0406	0.0287	0.0732	0.0103	-0.0041	-0.1043	-0.0241	0.0548	-0.1550	0.0372	0.0081	0.5405	0.1593	0.584**
	P	0.0118	-0.0042	0.0830	0.0108	-0.0002	0.1028	0.0026	0.0634	-0.0911	0.0050	0.0748	0.2284	0.0544	0.542**
Harvest index (%)	G	-0.1036	-0.2520	-0.0134	0.1032	0.0620	-0.1445	0.4115	-0.1597	0.8515	0.0726	-0.0504	-0.1749	-0.4923	0.110
	P	0.0256	0.0202	-0.0205	0.1492	0.0074	0.1662	0.0515	-0.1860	0.4210	0.0085	-0.3263	-0.0762	-0.1631	0.078

Genotypic residuals are 0.29367
Phenotypic residuals are 0.34466

Table 3: Genotypic and phenotypic correlation coefficients among fourteen metric traits of wheat in F_2

Characters	Gen	Days to 50% flowering	Days to maturity	Plant Height (cm)	No of effective tillers per plant	Flag leaf area (cm)	Spike length (cm)	No. of spikletes per spike	Peduncle length (cm)	No of grains per spike	Grain Weight per spike (g)	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% flowering	G	1.000	0.947**	-0.263**	-0.753**	-0.754**	-0.838**	-0.846**	-0.557**	-0.682**	-0.356**	-0.839**	-0.217*	-0.548**	0.179
	P	1.000	0.628**	-0.321**	-0.594**	-0.692**	-0.764**	-0.619**	-0.524**	-0.589**	-0.268**	-0.713**	-0.192*	-0.431**	0.130
Days to maturity	G			0.048	-0.949**	-0.882**	-0.817**	-0.856**	-0.761**	-0.894**	-0.364**	-0.990**	0.125	-0.871**	0.203*
	P			-0.051	-0.589**	-0.610**	-0.631**	-0.465**	-0.596**	-0.661**	-0.204*	-0.761**	0.141	-0.606**	0.199*
Plant Height (cm)	G				-0.160	0.118	0.301**	0.217*	-0.240**	-0.052	-0.122	0.105	0.864**	-0.249**	0.039
	P				-0.166	0.126	0.210*	0.075	-0.076	-0.055	-0.024	0.031	0.496**	-0.210*	0.072
No of effective tillers per plant	G					0.714**	0.689**	0.640**	0.835**	0.830**	0.228*	0.777**	-0.177	0.742**	-0.198*
	P					0.641**	0.605**	0.605**	0.784**	0.795**	0.217*	0.740**	-0.171	0.719**	-0.209*
Flag leaf area (cm)	G						0.744**	0.781**	0.596**	0.782**	0.336**	0.734**	0.042	0.797**	0.024
	P						0.706**	0.648**	0.565**	0.755**	0.304**	0.664**	0.054	0.734**	0.036
Spike length (cm)	G							0.693**	0.557**	0.796**	0.468**	0.793**	0.204*	0.540**	-0.016
	P							0.554**	0.530**	0.752**	0.427**	0.745**	0.164	0.486**	0.008
No.of spikletes per spike	G								0.552**	0.648**	0.058	0.714**	0.065	0.650**	-0.094
	P								0.454**	0.564**	0.067	0.622**	0.102	0.571**	-0.094
Peduncle length (cm)	G									0.746**	0.115	0.708**	-0.227*	0.679**	-0.405**
	P									0.722**	0.087	0.675**	-0.226*	0.664**	-0.397**
No of grains per spike	G										0.329**	0.772**	-0.101	0.783**	-0.110
	P										0.304**	0.743**	-0.121	0.759**	-0.111
Grain	G											0.198*	0.033	0.234**	0.478**

Weight per spike (g)															
	P											0.162	0.045	0.207*	0.467**
Test weight (g)	G												-0.101	0.750**	-0.270**
	P												-0.139	0.721**	-0.283**
Biological yield per plant (g)	G													-0.321**	-0.002
	P													-0.333**	0.020
Harvest index (%)	G														-0.058
	P														-0.083
Grain yield per plant (g)	G														1.000
	P														1.000

Table 4: Direct and indirect effects of thirteen metric traits on grain yield at genotypic and phenotypic level in F_2

Characters	Gen	Days to 50% flowering	Days to maturity	Plant Height (cm)	No of effective tillers per plant	Flag leaf area (cm)	Spike length (cm)	No. of spikletes per spike	Peduncle length (cm)	No of grains per spike	Grain Weight per spike (g)	Test weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% flowering	G	-0.6816	0.2588	-0.4709	-0.2735	0.1150	0.0466	0.1526	0.0582	0.0025	-0.2643	0.9760	0.3409	-0.4809	0.179
	P	0.1513	0.0339	-0.0629	-0.0913	-0.1519	-0.2600	-0.0602	0.2857	0.0655	-0.1086	0.3687	0.0508	-0.0908	0.130
Days to maturity	G	-0.6458	0.2731	0.0863	-0.3447	0.1347	0.0454	0.1544	0.0795	0.0033	-0.2699	0.6464	-0.1959	-0.7636	0.203*
	P	0.0951	0.0539	-0.0100	-0.0906	-0.1339	-0.2150	-0.0452	0.3250	0.0735	-0.0827	0.3937	-0.0372	-0.1277	0.199*
Plant Height (cm)	G	0.1794	0.0132	1.0000	-0.0582	-0.0181	-0.0168	-0.0392	0.0250	0.0002	-0.0903	-0.1728	-1.3551	-0.2181	0.039
	P	-0.0486	-0.0028	0.1960	-0.0255	0.0278	0.0716	0.0073	0.0414	0.0061	-0.0099	-0.0160	-0.1312	-0.0443	0.072
No of effective tillers per plant	G	0.5132	-0.2592	-0.2866	0.3633	-0.1090	-0.0383	-0.1155	-0.0872	-0.0030	0.1694	-1.2742	0.2779	0.6509	-0.198*
	P	-0.0899	-0.0317	-0.0325	0.1538	0.1407	0.2059	0.0589	-0.4276	-0.0884	0.0880	-0.3829	0.0453	0.1515	-0.209*
Flag leaf area (cm)	G	0.5136	-0.2410	0.2118	0.2595	-0.1527	-0.0413	-0.1410	-0.0622	-0.0029	0.2490	-1.2030	-0.0651	0.6991	0.024
	P	-0.1047	-0.0329	0.0248	0.0986	0.2195	0.2402	0.0630	-0.3081	-0.0840	0.1233	-0.3433	-0.0144	0.1545	0.036
Spike length (cm)	G	0.5714	-0.2232	0.5394	0.2501	-0.1135	-0.0556	-0.1251	-0.0582	-0.0029	0.3472	-1.2999	-0.3193	0.4737	-0.016
	P	-0.1156	-0.0340	0.0412	0.0930	0.1548	0.3404	0.0539	-0.2890	-0.0836	0.1728	-0.3853	-0.0435	0.1024	0.008
No.of spikletes per spike	G	0.5765	-0.2337	0.3884	0.2325	-0.1193	-0.0385	-0.1804	-0.0576	-0.0024	0.0432	-1.1706	-0.1014	0.5695	-0.094
	P	-0.0937	-0.0250	0.0147	0.0931	0.1421	0.1886	0.0973	-0.2477	-0.0628	0.0273	-0.3216	-0.0270	0.1202	-0.094
Peduncle length (cm)	G	0.3798	-0.2079	-0.4287	0.3034	-0.0910	-0.0310	-0.0995	-0.1044	-0.0027	0.0855	-1.1601	0.3567	0.5950	-0.405**
	P	-0.0792	-0.0321	-0.0149	0.1205	0.1239	0.1803	0.0442	-0.5456	-0.0803	0.0352	-0.3488	0.0597	0.1398	-0.397**
No of grains per spike	G	0.4651	-0.2442	-0.0932	0.3016	-0.1194	-0.0443	-0.1169	-0.0779	-0.0037	0.2439	-1.2656	0.1578	0.6869	-0.110
	P	-0.0892	-0.0356	-0.0107	0.1222	0.1657	0.2559	0.0549	-0.3940	-0.1112	0.1231	-0.3842	0.0321	0.1598	-0.111
Grain Weight per spike (g)	G	0.2429	-0.0994	-0.2180	0.0830	-0.0512	-0.0260	-0.0105	-0.0120	-0.0012	0.7416	-0.3244	-0.0523	0.2055	0.478**
	P	-0.0406	-0.0110	-0.0048	0.0334	0.0668	0.1453	0.0066	-0.0474	-0.0338	0.4048	-0.0840	-0.0119	0.0437	0.467**
Test weight (g)	G	0.5720	-0.2743	0.1887	0.2823	-0.1120	-0.0441	-0.1288	-0.0739	-0.0028	0.1467	-1.0000	0.1578	0.6578	-0.270**
	P	-0.1079	-0.0410	0.0061	0.1139	0.1457	0.2537	0.0605	-0.3680	-0.0826	0.0658	-0.5171	0.0368	0.1518	-0.283**
Biological yield per plant (g)	G	0.1481	0.0341	0.5460	-0.0644	-0.0063	-0.0113	-0.0117	0.0237	0.0004	0.0247	0.1649	-1.0000	-0.2815	-0.002
	P	-0.0291	0.0076	0.0973	-0.0264	0.0120	0.0560	0.0099	0.1234	0.0135	0.0182	0.0720	-0.2642	-0.0702	0.020
Harvest index (%)	G	0.3739	-0.2379	-0.4453	0.2697	-0.1217	-0.0300	-0.1172	-0.0709	-0.0029	0.1738	-1.2302	0.5036	0.8768	-0.058
	P	-0.0652	-0.0327	-0.0412	0.1106	0.1610	0.1656	0.0555	-0.3623	-0.0844	0.0839	-0.3728	0.0881	0.2105	-0.083

Genotypic residuals are 0.26298
Phenotypic residuals are 0.44455

4. Conclusion

The present study revealed that the traits such as effective tillers, grains per spike, spike length, and biological yield are crucial in F_1. In F_2, harvest index and test weight become more important. Selection should focus on moderate plant height, early flowering, and high tillering ability.

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6. Conflict of Interest Declaration

The authors declare no conflicts of interest.

Ethical issues

None.

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