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Correlation and path coefficient analysis in bread wheat (*Triticum aestivum* L.)

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Abstract
The present investigation was carried out to assess the relationships among grain yield and its contributing traits in 48 diverse genotypes of bread wheat (*Triticum aestivum* L.). The genotypes were evaluated under a randomized block design with two replications at the farm of Wheat and Maize research Unit, Parbhani (Maharashtra) during *Rabi* season 2023-24. Observations were recorded on ten quantitative traits including days to 50% heading, days to maturity, plant height, number of tillers per plant, spike length, number of grains per spike, 1000 grain weight, biological yield per plant, harvest index, and grain yield per plant. Genotypic and phenotypic correlation analyses revealed highly significant positive associations of grain yield with traits such as number of tillers per plant, number of grains per spike, 1000 grain weight, harvest index, and spike length. Path coefficient analysis further established that biological yield and harvest index exerted the highest direct positive effects on grain yield, followed by number of grains per spike and 1000 grain weight. The results emphasized the importance of these traits in influencing yield directly and indirectly. Therefore, these traits should be prioritized in selection strategies aimed at enhancing wheat productivity through yield component improvement.

Keywords: Bread wheat (*Triticum aestivum*), correlation analysis, path coefficient analysis, trait association

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important cereal crops grown worldwide, serving as a staple food for more than one-third of the global population. It contributes significantly to caloric and protein intake, especially in developing countries, and plays a vital role in ensuring food and nutritional security. Globally, wheat occupies about 224.05 million hectares with an annual production of 793.37 million tonnes. In India, it covers approximately 31.82 million hectares, producing around 112.74 million tonnes with an average productivity of 35.43 quintals per hectare (Anonymous, 2023) [3]. In Maharashtra, the crop spans 1.05 million hectares with a production of 1.99 million tonnes and productivity of 1899 kg/ha during the 2023-24 season. The increasing demand for wheat due to population growth and changing climatic conditions necessitates sustained efforts for yield improvement. Yield, being a complex quantitative trait, is influenced by multiple morphological, physiological, and agronomic components. Understanding the relationships among these traits is crucial for effective selection and genetic enhancement.

Correlation analysis provides an estimate of the degree and direction of association between traits, but it does not explain the direct and indirect effects. Path coefficient analysis, introduced by Wright (1921) [10], allows the partitioning of correlation coefficients into their direct and indirect effects on yield. This dual analysis provides a better understanding of trait interdependencies and aids in identifying the most important yield-contributing characters.

The present study was undertaken to determine the correlation and path coefficients among yield and its component traits in bread wheat genotypes. The objective was to identify the key traits that can serve as reliable selection indices for enhancing grain yield in future breeding programs.

Materials and Methods
The experiment was conducted using 48 genotypes of bread wheat laid out in a randomized block design (RBD) with two replications during the *rabi* season (2023-24) at the farm of

Wheat and Maize research Unit, Parbhani (Maharashtra). Each genotype was sown in a plot measuring 4 × 0.20 m², with a row-to-row spacing of 20 cm and plant-to-plant spacing of 10 cm. Standard agronomic practices were followed throughout the cropping season to ensure uniform crop management, and appropriate plant protection measures were undertaken when necessary. Data were recorded for ten quantitative traits: days to 50% heading, days to maturity, plant height, number of tillers per plant, spike length, number of grains per spike, 1000 grain weight, biological yield per plant, harvest index, and grain yield per plant.

Phenotypic and genotypic correlation coefficients were computed following the method described by Al-Jibouri *et al*. (1958) [2]. Path coefficient analysis was carried out as per Wright (1921) [10] and Dewey & Lu (1959) [5], taking grain yield per plant as the dependent variable.

Result and Discussion

Correlation Analysis

The genotypic and phenotypic correlation coefficients between yield and its related components are presented in (Table 1 & Table 2). Grain yield per plant had positive and highly significant correlations with almost all key yield-contributing traits at both genotypic and phenotypic levels. At the genotypic level, it was high significantly associated with Spike length (0.6868**), Number of grains per spike (0.6906**), 1000 grain weight (0.6757**), Number of tillers per plant (0.4306**), Harvest index (0.5852**) and significantly correlated with biological yield per plant (0.3501*). It also showed positive non-significant correlation with plant height (0.2627) and negative non-significant correlation with days to 50% heading (-0.083). While days to maturity (-0.2924*) express negative significant association. The observations are in accordance with the reports of Zakirullah *et al.* (2017) [11] and Rajput R.S (2018) [8]. At phenotypic level, grain yield per plant was positively highly significant with Number of grains per spike (0.4392**), Spike length (0.4775**), 1000 grain weight (0.3789**), Biological yield (0.4836**), Number of tillers per (0.4147**) and harvest index (0.2623**). While days to maturity (0.022), days to 50% heading (0.0183) and plant height (0.1526) express positive non-significant association. In the present study, Grain yield per plant had positive and highly significant correlations with almost all key yield-contributing traits at both genotypic and phenotypic levels *viz*. Number of grains per spike, Spike length, 1000 grain weight, biological yield, Number of tillers per and harvest index. These finding are in accordance with those reported by Singh *et al*. (2021) [9], Chauhan *et al*. (2022) [4], Muhammad *et al*. (2010) [7] and Abdulhamed *et al*. (2021) [1].

Path Analysis

Path coefficient analysis was carried out to estimate the direct and indirect effects of yield-contributing traits on grain yield per plant at both genotypic and phenotypic levels Presented in (Table 3 & 4). At the genotypic level, the highest positive direct effect on grain yield was exerted by Harvest index (0.43869), followed by Biological yield (0.38443), Number of grains per spike (0.38206) and 1000 grain weight (0.36324). At the phenotypic level, biological yield (0.46896) showed the highest direct effect on grain yield, followed by Harvest index (0.30053) and1000 grain weight (0.2422). These results suggest that these traits are the most important contributors to grain yield and can be prioritized in selection.

The path analysis revealed that positive direct effect for the traits such as days to 50% heading, plant height, spike length, number of grains per spike, 1000 grain weight, biological yield per plant and harvest index on grain yield per plant. Similar finding was recorded by Rajput R.S (2018) [8], Chauhan *et al.* (2022) [4], and Meherbabu *et al.* (2023) [6]. While for the characters days to maturity and number of tillers per plant, it was negative direct effect on grain yield per plant. Similar results were identified by Zakirullah *et al.* (2017) [11].

Table 1: Estimates of genotypic correlation coefficients for yield and yield contributing traits in wheat

Characters	Days to 50 percent sheading	Days to maturity	Plant height (cm)	Number of tillers per plant	Spike length (cm)	Number of grains per spike	1000 grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% heading	1 **	0.5227 **	-0.2287	-0.6952 **	0.0444	0.1862	-0.5226 **	0.2482	-0.2917 *	-0.083
Days to maturity		1 **	-0.4093 **	-0.6604 **	0.3601 *	-0.2225	-0.471 **	0.0464	-0.2929 *	-0.2924 *
Plant height (cm)			1 **	0.2183	0.0989	0.165	0.1126	0.2423	0.123	0.2627
Number of tillers per plant				1 **	0.1436	0.3078 *	0.5623 **	0.1129	0.1979	0.4306 **
Spike length (cm)					1 **	0.439 **	0.5403 **	0.3208 *	0.1322	0.6868 **
Number of grains per spike						1 **	0.2001	-0.0363	0.3933 **	0.6906 **
1000 grains weight (g)							1 **	0.1427	0.3085 *	0.6757 **
Biological yield per plant (g)								1 **	-0.309 *	0.3501 *
Harvest index (%)									1 **	0.5852 **
Grain yield per plant (g)										1 **

** - Significant at p = 0 .01 * - Significant at p = 0. 05

Table 2: Estimates of phenotypic correlation coefficients for yield and yield contributing traits in wheat.

Characters	Days to 50 percent heading	Days to maturity	Plant height (cm)	Number of tillers per plant	Spike length (cm)	Number of grains per spike	1000 grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% heading	1 **	0.3164 **	-0.1667	-0.361 **	0.0653	0.0961	-0.3804 **	0.0932	-0.1971	0.0183
Days to maturity		1 **	-0.2256 *	-0.0396	0.0831	-0.1562	-0.1823	0.1794	-0.1826	0.022
Plant height (cm)			1 **	0.1004	0.0903	0.1593	0.0574	0.1811	0.1172	0.1526
Number of tillers per plant				1 **	0.1405	0.1815	0.1872	0.3277 **	0.0549	0.4147 **
Spike length (cm)					1 **	0.3121 **	0.2677 **	0.204 *	0.0706	0.4775 **
Number of grains per spike						1 **	0.1392	-0.0013	0.3231 **	0.4392 **
1000 grains weight (g)							1 **	0.0026	0.2674 **	0.3789 **
Biological yield per plant (g)								1 **	-0.3362 **	0.4836 **
Harvest index (%)									1 **	0.2623 **
Grain yield per plant (g)										1 **

** - Significant at p = 0 .01 * - Significant at p = 0. 05

Table 3: Direct and indirect effects (genotypic) of different characters on grain yield per plant in wheat.

Characters	Days to 50 percent heading	Days to maturity	Plant height (cm)	Number of tillers per plant	Spike length (cm)	Number of grains per spike	1000 grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50% heading	0.06615	-0.00602	-0.00209	0.00386	0.00633	0.07112	-0.18982	0.09542	-0.12795	-0.083
Days to maturity	0.03458	-0.01152	-0.00375	0.00367	0.05138	-0.08502	-0.1711	0.01783	-0.12848	-0.2924
Plant height (cm)	-0.01513	0.00471	0.00916	-0.00121	0.01411	0.06302	0.04089	0.09313	0.05397	0.2627
Number of tillers per plant	-0.04599	0.00761	0.002	-0.00555	0.02049	0.11759	0.20425	0.0434	0.08681	0.4306
Spike length (cm)	0.00294	-0.00415	0.00091	-0.0008	0.14268	0.16772	0.19625	0.12333	0.05799	0.6868
Number of grains per spike	0.01231	0.00256	0.00151	-0.00171	0.06263	0.38206	0.0727	-0.01395	0.17251	0.6906
1000 grains weight (g)	-0.03457	0.00543	0.00103	-0.00312	0.07708	0.07646	0.36324	0.05485	0.13532	0.6757
Biological yield per plant (g)	0.01642	-0.00053	0.00222	-0.00063	0.04577	-0.01386	0.05182	0.38443	-0.13554	0.3501
Harvest index (%)	-0.01929	0.00337	0.00113	-0.0011	0.01886	0.15024	0.11205	-0.11877	0.43869	0.5852

** - Significant at p = 0 .01 * - Significant at p = 0. 05 Residual effect= 0.0035

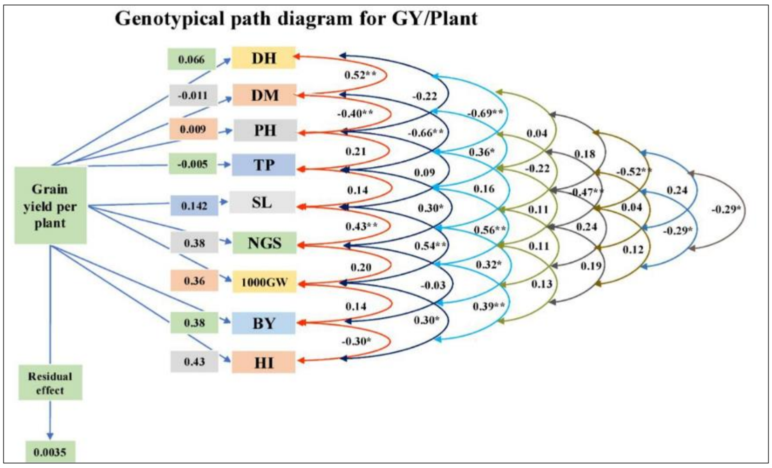

Fig 1: Genotypic path diagram

Table 4: Direct and indirect effects (phenotypic) of different characters on grain yield per plant in wheat

Characters	Days to 50 percent heading	Days to maturity	Plant height (cm)	Number of tillers per plant	Spike length (cm)	Number of grains per spike	1000 grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50 % heading	0.15903	0.00107	0.00393	-0.07043	0.01294	0.01932	-0.09213	0.04381	-0.05923	0.0183
Days to maturity	0.0503	0.00339	0.00532	-0.00774	0.01654	-0.03137	-0.04413	0.08406	-0.05488	0.022
Plant height (cm)	-0.02649	-0.00077	-0.02357	0.01956	0.01791	0.03199	0.0139	0.08505	0.03522	0.1526
Number of tillers per plant	-0.05742	-0.00013	-0.00236	0.19505	0.02772	0.03643	0.04532	0.15391	0.0165	0.4147

Spike length (cm)	0.0104	0.00028	-0.00213	0.02733	0.19766	0.06268	0.06489	0.09551	0.02119	0.4775
Number of grains per spike	0.0153	-0.00053	-0.00375	0.03538	0.06175	0.20082	0.03369	-0.00056	0.0971	0.4392
1000 grains weight (g)	-0.06049	-0.00062	-0.00135	0.03649	0.05301	0.02793	0.2422	0.00127	0.08036	0.3789
Biological yield per plant (g)	0.01485	0.00061	-0.00427	0.06399	0.04028	-0.00024	0.00065	0.46896	-0.10104	0.4836
Harvest index (%)	-0.03134	-0.00062	-0.00276	0.01071	0.01395	0.06489	0.06476	-0.15771	0.30053	0.2623

** - Significant at p = 0 .01 * - Significant at p = 0. 05 Residual effect= 0.3394

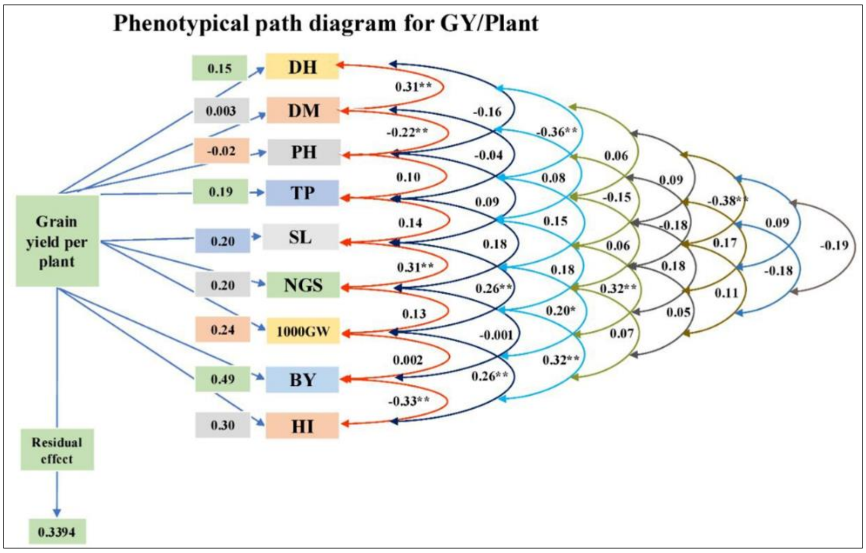

Fig 2: Phenotypic path diagram

Conclusion

Grain yield in bread wheat is influenced by multiple interrelated traits. This study highlights that harvest index, biological yield, number of grains per spike, and 1000 grain weight are the most important direct contributors to yield. These traits should be emphasized in selection strategies to enhance wheat productivity. The combined use of correlation and path coefficient analysis offers a comprehensive understanding of trait interrelationships, thereby aiding breeders in formulating effective selection indices for yield improvement.

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