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Correlation and path analysis for yield and yield attributing traits in advance wheat (*Triticum aestivum* L.) breeding lines

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Abstract
The current research was undertaken to study the character association with direct indirect effect and its influence on a set of fifty genotypes. The experiment was conducted at the farm of Wheat and Maize Research Unit, Parbhani (Maharashtra) during *Rabi* season 2023-24. The genotypes were grown in Randomized Block Design with two replications and data were collected on ten morphological traits. The genotypic correlation coefficient was higher than the phenotypic correlation coefficient. Correlation studies revealed that grain yield per plant was highly significant and positively correlated with harvest index, number of productive tillers per plant, number of grains per spike, spike length, 1000 grain weight and biological yield per plant at both the genotypic and phenotypic levels. The path coefficient analysis showed that number of grains per spike, number of productive tillers per plant, biological yield per plant and harvest index exhibited positive direct effect and significant positive genotypic correlation with grain yield per plant. Also, Maximum contribution through direct effect towards the grain yield shown by the biological yield followed by harvest index and 1000 grain weight. Therefore, direct selection for these characters would be easy and would be rewarding improvement in grain yield of wheat. These findings provide valuable insights for Wheat breeding strategies aimed at enhancing grain yield potential.

Keywords: Wheat (*Triticum aestivum* L.), correlation, direct effect, indirect effect, path analysis, grain yield

Introduction
Wheat (*Triticum aestivum* L. em. Thell; 2n=42), a member of Gramineae (Poaceae) family belongs to the genus *Triticum*, is the main cereal crop. It has unique place among the cereals. Bread wheat is an allohexaploid species with 2n=42 chromosome having genome AABBDD (Sleper and Poehlman, 2006) [18]. It exhibits remarkable adaptability, thriving across a wide range of soil types and agro-climatic conditions. Unlike rice, wheat is cultivated on all continents and is notably tolerant to both cold and drought stress, making it highly suitable for diverse environments. Wheat recognized as the "king of cereals," serves as a staple food for a significant portion of the global population and plays a crucial role in meeting their nutritional demands. Its wide adaptability and resilience make it a key focus in genetic improvement and plant breeding programs aimed at enhancing food security.
Wheat is a major staple food crop cultivated across the globe and holds significant importance in international trade. It ranks second after rice in terms of global food production. Worldwide, wheat is grown on approximately 224.05 million hectares, with a total production of 793.37 million tonnes. In India, wheat is cultivated on an area of 31.82 million hectares, producing around 112.74 million tonnes, with an average productivity of 35.43 quintals per hectare. The principal wheat-growing states in India include Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Rajasthan, and Madhya Pradesh. Among these, Uttar Pradesh ranks first in terms of both area under cultivation and total production, while Punjab leads in productivity (Anonymous, 2023) [3].
Grain yield and its quality are key traits in cereal crops and are considered complex quantitative characters influenced by multiple yield-contributing factors. Therefore, selecting superior genotypes should not rely solely on grain yield; associated yield components must also be taken into account.

In wheat, direct selection for yield can often be unreliable due to its polygenic inheritance. To effectively utilize genetic resources for crop improvement, it is essential to understand the relationships between yield and its component traits. Thus, studying the correlation between various yield-contributing characters and their association with yield is crucial for making selection decisions. (Majumder *et al.*, 2008) [12].

Correlation analysis combined with path coefficient analysis offers a more comprehensive understanding of the relationships between different traits and grain yield. While correlation helps in determining the strength and direction of the association between yield and its contributing characters, path analysis further partitions these correlations into direct and indirect effects. The path coefficient quantifies the direct influence of an independent variable on the dependent variable, while also accounting for the indirect effects mediated through other traits (Dewey & Lu, 1959) [6].

Materials and Methods

The present investigation was carried out at Wheat and Maize Research Unit, Parbhani (Maharashtra) during *Rabi* season 2023-24 under normal irrigated condition. The material used in the study consists of fifty bread wheat genotypes received from Wheat and Maize Research Unit, Parbhani (Maharashtra). The genotypes sown in a randomized block design with two replications having plot size 4.0 X 0.20 m^2 and plant spacing of 20cm and 10cm respectively. All the recommended practices were followed to grow a healthy crop. The data were recorded from five randomly selected plants from each genotype on ten distinct morphological characters *viz*., days to 50% heading, days to maturity, plant height (cm), number of effective tillers/plants, spike length (cm), number of grains/spike, 1000-grains weight (g), grain yield/plant (g), biological yield/plant (g) and harvest index (%). Days to 50% heading and days to maturity observations were recorded on plot basis only once.

The overall mean values of different characters were subjected to statistical analysis. Analysis of variance was done by subjecting the data to the statistical method on randomized block design (RBD) as described by Panse and Sukhatme (1985) [15]. The correlations at genotypic, phenotypic and environmental levels were estimated from the analysis of variance and covariance as suggested by Searle (1961) [16]. The analysis of path-coefficient was conducted following the procedure as suggested by Wright (1921) [21] and further elaborated by Dewey and Lu (1959) [6]. Grain yield was assumed to be dependent variable (effect) which is influenced by all other characters, the independent variables (causes), directly as well as indirectly through other. The yield contributing characters were considered in path coefficient analysis to estimate their direct and indirect effect on seed yield.

Results and Discussion

Correlation Analysis

In plant breeding, the correlation coefficient plays a vital role in assessing the relationships among different traits. It indicates the strength and direction of the association between yield and its contributing characteristics. Analyzing these correlations enables researchers to identify important traits that influence yield, thereby supporting effective selection decisions in breeding programs aimed at genetic improvement. The genotypic and phenotypic correlation coefficients between yield and its related components are presented in (Table 1 and Table 2).

A significant positive correlation were observed for grain yield per plant with number of effective tillers/plants, spike length, number of grains/spike, 1000-grains weight, biological yield/plant and harvest index at genotypic and phenotypic level. Correlation of days to heading and days to maturity showed negative non-significant association with the grain yield. Also plant height showed positive but non-significant association with grain yield at both the level. Spike length, number of grains per spike and number of productive tillers per plant showed positive significance with biological yield per plant and harvest index at both the levels. These results were in accordance with Jeannie *et al.* (2022) [9], Singh *et al.* (2021) [17], Mecha *et al.* (2017) [13], Meles *et al.* (2017) [14] and Wani *et al.* (2018) [20].

The genotypic correlation coefficient was higher than the phenotypic correlation coefficient indicates that the observed associations between traits are primarily governed by genetic factors rather than environmental influences. This suggests that the genetic relationship between traits is strong, and the environment has a lesser effect on their expression. Such findings are valuable for plant breeders, as they imply that selection based on these traits is likely to be effective and reliable across different environments. The results found were in accordance with Kumar *et al.* (2024) [10] and Varsha *et al.* (2019) [19].

Path Analysis

The correlation coefficient measures the strength and direction of the relationship between two traits. However, in complex situations, it may not fully reflect the true nature of these relationships. In such cases, path coefficient analysis offers a more detailed approach by breaking down the correlation coefficients into direct and indirect effects of independent traits on the dependent characters, here grain yield is dependent and others are independent characters. This method allows for a clearer understanding of each trait's contribution, thereby providing a more accurate basis for selection in breeding programs.

The direct and indirect effects of grain yield and its component traits are depicted in (Table 3 and Table 4). Also the diagram of path analysis showing direct and indirect effects represented in (Fig. 1 and Fig. 2) The genotypic path coefficient analysis revealed that 1000 grain weight, number of productive tillers per plant, biological yield per plant and harvest index had exhibited positive direct effect and significant positive genotypic correlation with grain yield per plant. In phenotypic path analysis number of number of grains per spike, productive tillers per plant, biological yield per plant and harvest index had exhibited positive direct effect and highly significant positive phenotypic correlation with grain yield per plant. Therefore, direct selection for these characters would be easy and would be rewarding. Days to maturity, spike length, number of grains per spike showed negative direct effect on grain yield at genotypic level. Maximum contribution towards the grain yield shown by the biological yield followed by harvest index and 1000 grain weight. These indicate the true relationship between these traits and grain yield. Days to maturity, days to heading and plant height contributed minimum towards grain yield. Similar results were found in Gupta and Nigam

(2023) [8], Alemu *et al.* (2020) [2], Dutamo *et al.* (2015) [7], Abinasa *et al.* (2011) [1] and Ayer *et al.* (2017) [4].

The residual effect in genotypic path analysis (0.0019) and phenotypic path analysis (0.0055) is below one, it indicates that the independent traits included in the analysis account for a large proportion of the variability in the dependent variable (e.g., grain yield). Same results were observed by the Kumar *et al.* (2023) [11] and Dashora *et al.* (2022) [5].

Table 1: Genotypic correlation coefficient for 10 different characters in wheat

Traits	DH	DM	PH	TPP	SL	NGS	TGW	BY	HI	GY
DH	1 **	0.5991 **	0.0194	-0.1509	-0.0742	-0.1245	0.0692	-0.2453	0.2251	-0.003
DM		1 **	0.3991 **	-0.3895 **	-0.3818 **	-0.4539 **	0.0277	-0.6712 **	0.2375	-0.2747
PH			1 **	0.2307	-0.0015	0.1782	0.1784	0.2009	0.0663	0.1773
TPP				1 **	0.5733 **	0.6868 **	0.5035 **	0.8097 **	0.4441 **	0.7772 **
SL					1 **	0.839 **	0.524 **	0.9905 **	0.4145 **	0.8653 **
NGS						1 **	0.4941 **	0.9501 **	0.4161 **	0.8425 **
TGW							1 **	0.5668 **	0.2956 *	0.5316 **
BY								1 **	0.3074 *	0.7947 **
HI									1 **	0.8234 **
GY										1 **

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

DH- Days to 50% heading, **DM-** Days to maturity, **PH-** Plant height, **TPP-** Number of productive tillers per plant , **SL-** Spike length , **NGS-** Number of grains per spike, **BY-** Biological yield per plant, **TGW-** 1000 grain weight,**HI-** Harvest index , **GY-** Grain yield per plant.

Table 2: Phenotypic correlation coefficient for 10 different characters in wheat

Traits	DH	DM	PH	TPP	SL	NGS	TGW	BY	HI	GY
DH	1**	0.4738 **	0.098	-0.0311	-0.0491	-0.0843	0.0417	-0.199 *	0.1374	-0.0146
DM		1**	0.1841	-0.2774 **	-0.2743 **	-0.3135 **	-0.0476	-0.3414 **	0.0802	-0.1655
PH			1**	0.0921	0.0725	0.1182	0.1144	0.11	0.0637	0.1198
TTP				1**	0.3711 **	0.5427 **	0.3356 **	0.4212 **	0.3166 **	0.5754 **
SL					1**	0.6812 **	0.3421 **	0.6643 **	0.1607	0.6013 **
NGS						1**	0.359 **	0.7057 **	0.2301 *	0.6968 **
TGW							1**	0.3274 **	0.2133 *	0.4083 **
BY								1**	-0.2096 *	0.514 **
HI									1**	0.7282 **
GY										1**

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

DH- Days to 50% heading, **DM-** Days to maturity, **PH-** Plant height, **TPP-** Number of productive tillers per plant , **SL-** Spike length , **NGS-** Number of grains per spike, **BY-** Biological yield per plant, **TGW-** 1000 grain weight,**HI-** Harvest index , **GY-** Grain yield per plant.

Table 3: Genotypic path coefficient analysis showing direct (diagonal) and indirect effects of nine causal variables on grain yield per plant in 50 genotypes of wheat

Trait	DH	DM	PH	TPP	SL	NGS	TGW	BY	HI	GY
DH	0.036206	-0.03889	0.000585	0.010901	0.007704	0.007656	0.001079	-0.18438	0.156143	-0.003
DM	0.021691	-0.06492	0.012046	0.028136	0.039648	0.027913	0.000432	-0.50441	0.164738	-0.2747
PH	0.000702	-0.02591	0.030187	-0.01666	0.00016	-0.01096	0.002784	0.150959	0.045997	0.1773
TPP	-0.00546	0.025291	0.006963	0.07223	-0.05954	-0.04223	0.007857	0.608532	0.308055	0.7772 **
SL	-0.00269	0.024785	-0.00005	-0.04141	-0.10386	-0.05159	0.008178	0.744399	0.287523	0.8653 **
NGS	-0.00451	0.02947	0.005381	-0.0496	-0.08713	-0.06149	0.007711	0.714059	0.288605	0.8425 **
TGW	0.002504	-0.0018	0.005385	-0.03636	-0.05442	-0.03038	0.015606	0.425993	0.205033	0.5316 **
BY	-0.00888	0.043573	0.006063	-0.05848	-0.10287	-0.05842	0.008846	0.751562	0.21326	0.7947 **
HI	0.00815	-0.01542	0.002002	-0.03208	-0.04305	-0.02558	0.004613	0.23106	0.693662	0.8234 **

** - Significant at p = 0 .01 * - Significant at p = 0. 05 Residual effect= 0.0019

DH- Days to 50% heading, **DM-** Days to maturity, **PH-** Plant height, **TPP-** Number of productive tillers per plant , **SL-** Spike length , **NGS-** Number of grains per spike, **BY-** Biological yield per plant, **TGW-** 1000 grain weight, **HI-** Harvest index , **GY-** Grain yield per plant.

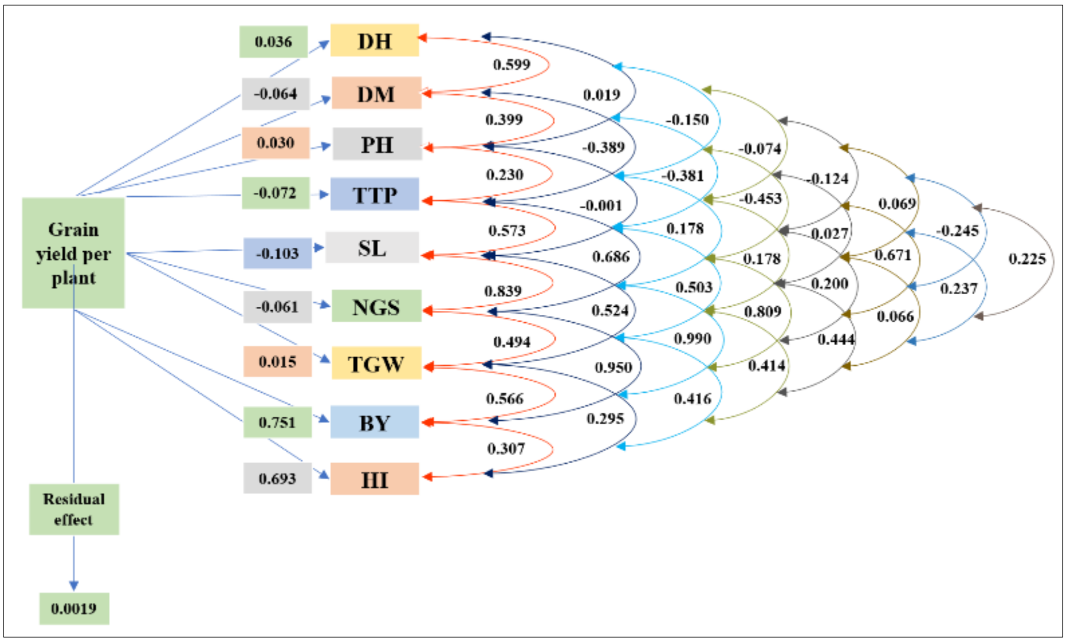

Fig 1: Genotypic path analysis diagram showing direct and indirect effects of nine independent variables on grain yield per plant.

Table 4: Phenotypic path coefficient analysis showing direct (diagonal) and indirect effects of nine causal variables on grain yield per plant in 50 genotypes of wheat

Trait	DH	DM	PH	TPP	SL	NGS	TGW	BY	HI	GY
DH	0.003595	0.003474	-0.00145	-0.00026	0.000332	-0.00101	-0.00036	-0.1387	0.119773	-0.0146
DM	0.001703	0.007332	-0.00272	-0.00231	0.001854	-0.00374	0.000414	-0.23795	0.069911	-0.1655
PH	0.000352	0.00135	-0.01479	0.000765	-0.00049	0.00141	-0.00099	0.076667	0.055528	0.1198
TPP	-0.00011	-0.00203	-0.00136	0.008311	-0.00251	0.006476	-0.00292	0.293564	0.275983	0.5754 **
SL	-0.00018	-0.00201	-0.00107	0.003084	-0.00676	0.008129	-0.00297	0.462998	0.140084	0.6013 **
NGS	-0.0003	-0.0023	-0.00175	0.00451	-0.00461	0.011933	-0.00312	0.491853	0.20058	0.6968 **
TGW	0.00015	-0.00035	-0.00169	0.002789	-0.00231	0.004284	-0.00869	0.228188	0.185936	0.4083 **
BY	-0.00072	-0.0025	-0.00163	0.003501	-0.00449	0.008421	-0.00285	0.696971	-0.18271	0.514 **
HI	0.000494	0.000588	-0.00094	0.002631	-0.00109	0.002746	-0.00185	-0.14609	0.871709	0.7282 **

** - Significant at p = 0 .01 * - Significant at p = 0. 05 Residual effect= 0.0055

DH- Days to 50% heading**, DM-** Days to maturity**, PH-** Plant height**, TPP-** Number of productive tillers per plant **, SL-** Spike length **, NGS-** Number of grains per spike**, BY-** Biological yield per plant**, TGW-** 1000 grain weight**, HI-** Harvest index **, GY-** Grain yield per plant.

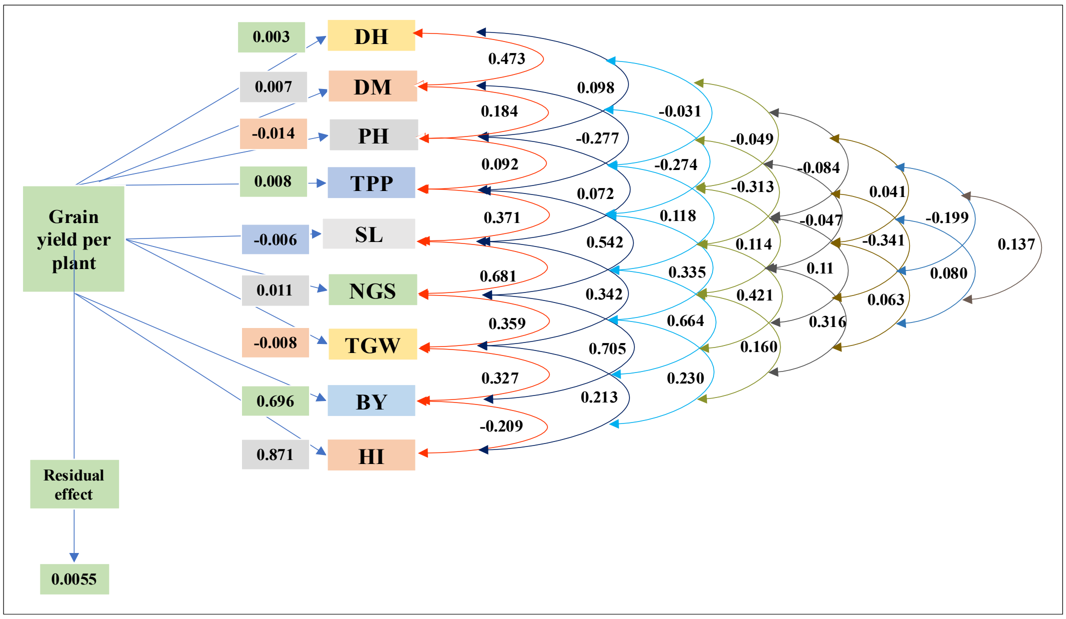

Fig 2: Phenotypic path analysis diagram showing direct and indirect effects of nine independent variables on grain yield per plant.

Conclusion

The present study demonstrated the presence of wide range of variations for all of the traits among wheat genotypes and which provide the opportunities of the genetic gain through selection or hybridization. Phenotypic and genotypic correlation analysis showed the positive correlation of grain yield with studied agro-morphological characters. Hence, improving one or more of the traits could result in high grain yield for wheat variety. Biological yield, harvest index and number of tillers per plant had positive phenotypic and genotypic direct effect and correlation with grain yield suggesting the possibility of improving grain yield through direct selection of these traits.

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