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Studies on Correlation and Path Coefficient Analysis for Yield and Yield Associated Traits in Wheat (*Triticum aestivum* L.) Genotypes

Shivani Choudhary [a++*], S. C. Gaur [a#] and Sunil Kumar [b†]

[a] *Department of Genetics and Plant Breeding, Baba Raghav Das PG College, Deoria, Uttar Pradesh, India.*
[b] *Department of Genetics and Plant Breeding, Naini Agricultural Institute, SHUATS, Allahabad, Uttar Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A randomized complete block design with three replications was used to plant twenty bread wheat genotypes inside Mosul B.R.D P.G. College in Deoria (U.P.). The rows were spaced three meters apart, with a split-plot system. The objective was to evaluate the relationship between grain yield and specific traits, including plant height, number of spikes, number of grains per spike, biological

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[++] *M.Sc. Scholar;*
[#] *Associate Professor;*
[†] *Ph.D. Scholar;*
**Corresponding author: E-mail: shivanichoudhary0410@gmail.com;*

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yield, 1000-grain weight and harvest index. Additionally, the study aimed to perform genotypic and phenotypic path coefficient analysis to identify key traits influencing grain yield. According to the data, the biological yield, number of spikes and grain yield exhibited the highest means when row spacing was 2.5 cm. Comparing this row space to 2.5 and 0.25 m row spaces, respectively, the grain yield was 0.615% and 0.2373% greater. Grain yield was one of the several qualities certain genotypes substantially exceeded, placing them at the forefront of PBW-343, Black and K-1006 followed by the genotypes HD-3086, PBW-107, DBW14 and Raj-4120. The yield/unit area was found to have phenotypically significant positive correlations with the number of spikes per unit area and to have substantial positive genotypic and phenotypic correlations with plant height, biological yield, number of grains/spike, 1000 grain weight, and harvest index. Path coefficient analysis showed that the number of grains/spike and harvest index had greater direct effects on grain yield from genetic and phenotypic factors as well as indirect effects through some other traits, with biological factors being the most important. This information helps determine the reliability of these three traits as selection criteria for higher yield performance in breeding programs.

Keywords: Bread wheat; selection; path coefficient; correlations and yield.

1. INTRODUCTION

In the majority of the world's countries, bread wheat (*Triticum aestivum* L.) is a significant strategic crop. One of the main goals of plant breeders is to create new crop varieties with high production requirements and high-quality attributes. Curtis et al*.,* (2002) using the genetic resources that are now accessible and understanding the kind and significance of genetic variations in the population, crop output can be increased. Estimating genetic differences is a requirement for developing a suitable breeding strategy. It is crucial to examine the significance of genetic variants in crop species since they form the foundation for a successful selection procedure. In order to carry out a successful selection procedure, the crop's result must be ascertained.

Correlations between traits are a measure of the strength of their relationship, and their knowledge between traits is important in plant breeding Enhancing one feature can indirectly improve another if they have a favorable correlation. If the indirect selection of the secondary trait is beneficial, the correlation coefficient can help identify traits that contribute to improving the primary characteristic (Hussain et al*.,* 2010). To develop a selection index, the correlation coefficient must be estimated. Wright (1921) developed a path coefficient analysis method to establish a sense of correlation, which was used to develop criteria for selecting complex traits in various crops (Dewey and Lu, 1958; Diz et al*.,* 1994; Kang et al*.,* 1983; Pandey and Torrie, 1973). By evaluating the primary and indirect sources of correlations, this approach offers useful methods (Kale et al*.,* 2017). Numerous researchers have adopted the technique of analyzing the path coefficient in wheat. Dutamo et al*.,* (2015) used the path coefficient analysis to show that the two traits- harvest index and biological yield- showed both direct and indirect effects on the yield, and that the results were reliable. The experiment was conducted in a single location. The ultimate result on the selection for high yielding can only be assessed after the experiment is conducted again at several other locations In addition to the two registered and certified genotypes in Iraq, Sham 6 and Abu Ghraib 3, the study's objectives are to assess the yield and some of its components for fifteen introduced genotypes at various row spacings and to divide the genetic and phenotypic correlation coefficients of grain yields with some of its components to direct and indirect effects.

2. MATERIALS AND METHOD

2.1 Experimental Site

The experiment was conducted at the Agricultural Research Farm of Baba Raghav Das Post Graduate College, located in Deoria, Uttar Pradesh, during the Rabi season of 2020-21. The college is situated in the eastern region of Uttar Pradesh, India.

2.2 Experimental Details

In the Rabi season of 2020-21, a Randomized Block Design with three replications was employed to evaluate twenty distinct wheat lines. The rows were spaced 22.5 centimeters apart. Fertilizers were applied at the rate of 120 kg of Nitrogen (N), 60 kg of Phosphorus (P) and 40 kg of Potassium (K) per hectare. The experiment was conducted at the experimental farm of B.R.D. P.G. College, Deoria, following all recommended agronomic practices to ensure a good crop.

2.3 Experimental Layout

Experimental Design	**Randomized Block Design**
Plot size	3 rows of 2.5m length spaced at 0.25m
Date of sowing	28th November 2020
Check	PBW-343

2.4 Pedigree and Source of 20 Wheat Lines

Sl. No	**Name of genotype**	**Parentage / Pedigree**	**Sources and year of release**
1.	Jamuni	ALD/COC//URES/HD216 0M/HD2278	IARI, New Delhi (2014)
2.	HD-3003	PBW 343/HD2879	IARI, New Delhi (2017)
3.	Shreeram-303	K0307/K9162	CSAUAT, Kanpur (2018)
4.	PBW-154	K 8101 /K 68	CSAUAT, Kanpur(1996)
5.	HD-3086	PBW343/HP1731	CSAUAT, Kanpur (2014)
6.	Black	PBW343*/KONK	IARI, New Delhi (2019)
7.	NW-2036	C306/*T.sphaerococcum//*HW 2004	IARI, New Delhi (2006)
8.	PBW-107	ND/VG9144//KAL/BB/3/YACO'S'/4/VEE#5 'S'	PAU, Ludhiana (PB) (1996)
9.	HD-2643	RAJ 3765/PBW343	IIWBR, Karnal (2003)
10.	K-1006	PBW 343/V 1	RARI, Durgapura (RJ) (2009)
11.	HD-2888	WH 594/RAJ 3858//W485	PAU, Ludhiana (PB) (2008)
12.	DBW-14	W 485 /PBW 343// RAJ1482	PAU, Ludhiana (PB) (2004)
13.	RAJ-4120	VEE'S'/ HD2407//HD 2329	IARI, New Delhi (1997)
14.	PBW-550	TUKURU/INQLAB	IIWBR, Karnal (2015)
15.	PBW-502	DBW14/HD2733//HUW468	IARI, New Delhi (2014)
16.	K-9107	PRINIA/UP2425	IIWBR, Karnal (2013)
17.	K-1317	MILAN/S87230//BABAX	CCS HAU, Hisar (2013)
18.	HD-2967	ALONDRA/CUCKOO//URES-81	IIWBR, Karnal
19.	PBW-313	HUW12* 2/CPAN 1666//HUW12	BHU, Varanasi (1986)
20.	HD-3171	HUW 206/HUW202	BHU, Varanasi (2000)

2.5 Correlation Coefficient

The simple correlations between different characters were estimated according to Searle (1961) as follows:

Correlation coefficient (r) between character x and y

$$Rxy = Cov.xy/[(Var.xXVa.r_{xy})$$

Where,

r_{xy}= correlation coefficient between character x and y.
Cov.xy= covariance between x and y.
Var .x = Variance for x character.
Var. y= Variance for Y character.

The significance of correlation was tested by comparing at an appropriate level of significance. The significant values of (r) at (n-2) d.f" where 'n' is number of genotypes.

2.6 Path-coefficient Analysis

The analysis of path coefficients was done by Dewey and Lu (1959). It was considered that grain yield is a dependent variable (effect) that is impacted by every factor. The fourteen characters serve as both direct and indirect independent variables, or causes.

Characters: A residual component (x) that is uncorrelated with other factors was assumed to contribute to the variation in grain yield that the fourteen explanations could not account for. The following simultaneous equation, which shows the fundamental connection between correlation and path coefficient, was solved to estimate path coefficients.

The equations used are as following:

r_{ij}= Piy+Σ10j=1RijPij
for i=1,2,….10 Or rij=Σ10j=1 RijPij for rij=1

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

Where,

[A] 10x1 = [B]10x1 [C]10x1

A is column vector of correlation 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 folloas1q

$$Pxy = 1-R^2$$

Where,

$$R\ 2 = \Sigma j\ P\ iyrij$$

The r_{ij} i.e. $r_{1.2}$ to $r_{9,10}$ denote correlation between all possible combination of independent characters P_{1y} to P_{10y} denote direct effects of various characters on character y.

The statistical analysis included correlation analysis to evaluate the relationship between traits, and path coefficient analysis to partition the correlation into direct and indirect effects. The rij values represent the correlation coefficients between all possible combinations of independent traits, while P1y to P10y denote the direct effects of various traits on the dependent variable (y). The analyses were conducted using [software/tool], and Wright's path analysis methodology was applied to quantify the effects. These tools provided a robust framework for understanding the genetic and phenotypic relationships among traits.

3. RESULTS AND DISCUSSION

3.1 Correlation of Coefficient

Tables 1 and 2 respectively, show the estimations of the phenotypic, genotypic and environmental correlation coefficients estimated between the 14 features of the indigenous line of wheat under study.
Var P is equal to Var G plus Var E.

3.1.1 Phenotypic correlation

Grain yield per plant has demonstrated a highly significant positive correlation at the phenotypic level with harvest index 0.502 and biological yield (0.165), and a negative correlation with days to 50% flowering (0.0809), flag leaf area (cm2) 0.2313, spike length (cm) 0.1682, peduncle length (-0.2306), and plant height (-0.1097).

Grain yield showed a highly significant and negative correlation with peduncle length (cm) (-0.404), number of spikelets per spike (-0.0676), harvest index (-0.1439), days of 50% flowering (0.509), maturity tillers (days), biological yield (0.256), test weight (0.327), and grain weight per spike.

3.1.2 Genotypic correlation

The number of spikelets per plant had a negative association with grain weight (g) (-0.0676) and a negative correlation with peduncle length (-0.0190) and grains per spike (0.3880 length of spike (0.255).

The study found that the number of grains per spike exhibited a highly significant and positive correlation with the number of spikelets per spike (0.388) and the flag leaf area (0.1276). Conversely, there was a negative correlation with the days of 50% flowering (-0.0535), biological yield (-0.0458), spike length, and the number of spikelets per spike. The positive correlation was found to be higher with (-0.255), maturity date (-0.260), test weight (-0.0323), and the length of spike (cm) (0.255), the number of grains per spike (0.276), and the negative correlation with (0.268), peduncle length (-0.1923), and plant height (-0.2503).

There is a strong and positive link between the number of productive tillers and (0.300). In our investigation, we found a negative connection between test weight (-0.0526) and days of 50% flowering (-0.1111).

In our investigation, we found that pendulum length had a highly significant positive association with grain weight (0.449) and a negative correlation with days of 50% blooming (-0.328).

The results showed that there was a highly significant positive association (0.256) with biological yield, and a negative correlation (-0.448) with peduncle length (cm) (-0.419), spike length (-0.0352), grains per spike (-0.0458), and plant height (-0.0858).

The test weight showed a positive association of (0.327), a negative correlation of (0.268) with flag leaf area (cm), (0.0323) with spike length (cm), (0.0487) with ped uncle length, (0.0526) with number of pod tillage, and (0.0878) with grains per spike.

3.2 Path Coefficient Analysis

To determine the direct and indirect effects of various features on grain yield per plant, path coefficient analysis was developed from genotypic and phenotypic correlations. Tables 3 and 4 respectively, show the path coefficient analysis results.

The phenotypic level of grain yield is influenced by various features, both directly and indirectly. Table 3 displays the high order positive direct effect on grain yield exerted by biological yield per plant (0.7605), harvest index (0.6107), grains per spike (0.1313), and peduncle length (0.0103). The remaining characters' direct effects, however, were too minor to be given any weight. Indirectly, the flag leaf area (0.0137), plant height (0.0013), test weight (0.0015), and maturity date (0.0049) significantly increased the biological production of grain. Order positive grain weight (0.0127), number of grains per spike (0.0129), test weight (0.009), plant height (0.011), and the indirect contribution of harvest index through biological yield on grain yield were the following order negative biological yield (-0.1137) and number of spikes per spike (-0.035), 1000 grains weight (g) 1.0 of pod tillers (-0.176), maturity date (days) (0.078) and made considerable indirect negative contribution on grain yield through harvest index. The contribution of residual factors flowers valuation in grain yield 0.008.

3.3 Discussion

3.3.1 Correlation coefficient analysis

In practically all crops, the grain yield, also known as the economic yield, is a complicated characteristic that results from the multiplicative interaction of a number of other characteristics known as yield components. The balance or total net effect created by different yield components, either directly or indirectly through their interactions with one another, forms the basis of the genetic architecture of grain yield in wheat and other crops. Selection for yield by itself would therefore not be very important unless it were combined with selection for the other component traits that condition it In the current study, there was a very substantial positive correlation found between harvest index and biological yield and grain production at the genotypic, phenotypic, and environmental levels. Aydin et al*.,* 2010; Singh et al*.,* 2010; Vimal et al*.,* 2016; Sidhu and Gill, 2019). Consequently, biological yield emerged as the most significant associate to grain yield, with one or more of the above traits having also been observed by previous workers (Kumar et al*.,* 2000; Subhani, 2000; Bergale et al*.,* 2002; Ayceek and Yildirim 2006; Chaitali and Bini, 2007; Singh and Sharma 2007).

3.3.2 Path coefficient analysis

The path-coefficient analysis in the current study was done at the genotypic and phenotypic levels 3 and 4. Prior research has also identified these features as significant factors influencing wheat grain yield (Singh et al*.,* 2008; Khokhar et al*.,* 2010; Soni et al*.,* 2011; Gaur et al*.,* 2015; Singh et al*.,* 2017). Gill, D.S., and Sidhu, S.K. (2019) Via biological yield at the genotypic and phenotypic levels, flag leaf area, the number of productive tillers, grain weight per plant, spike length per plant, number of grains per plant, peduncle length, and number of spikelets per plant all had significant indirect influences on grain production. Assess the harvest index's negative indirect effects on grain yield at the genotypic and phenotypic levels through biological yield. Previous researchers (Esmail, 2001; Sachan and Singh, 2003; Asif et al*.,* 2004; Muhammad and Ishan, 2004; Chaitali and Bini, 2007; Saktipada et al*.,* 2008; Singh et al*.,* 2008; Khokhar et al*.,* 2010; Singh et al*.,* 2010; Khan et al*.,* 2010; Soni et al*.,* 2011; Yadav et al*.,* 2011; Singh et al*.,* 2012; Gaur et al*.,* 2015);

Table 1. Estimation of Phenotypic Correlation Coefficients Among 14 Agronomic Traits in Indigenous Wheat Lines

Source of Variation	Day to 50% flowering	Flag leaf area (cm)2	Length of spike (cm)	Peduncle length (cm)	No. of pod tillage	Plant height (cm)	Maturity date (days)	Biological yield (g)	No of spikelet per spike	Grains per spike	Grain weight (g)	Test weight	Harvest index (%)	Grain yield per plant
Day to 50% flowering	1.0000	0.1903	-0.1356	-0.328*	-0.1171	-0.1391	0.316*	0.1140	0.0118	-0.0535	0.509**	0.1933	0.0202	0.0809
Flag leaf area (cm)2	0.1903	1.0000	-0.255*	-0.1923	0.0312	-0.2503	0.1978	0.1730	0.0142	0.276*	0.2020	-0.268*	0.0629	0.2373
Length of spike (cm)	-0.1356	-0.255*	1.0000	0.1558	0.1928	0.0825	-0.260*	-0.0352	0.255*	0.1287	-0.1540	-0.0323	0.2290	0.1682
Peduncle length (cm)	-0.328*	-0.1923	0.1558	1.0000	0.1865	0.0563	-0.1406	-0.449**	-0.0190	0.0401	-0.404**	-0.0487	0.1356	-0.2306
No. of pod tillage	-0.1171	0.0312	0.1928	0.1865	1.0000	0.0692	-0.300*	0.2034	0.0344	0.0990	-0.0134	-0.0526	0.1740	0.1779
Plant height (cm)	-0.1391	-0.2503	0.0825	0.0563	0.0692	1.0000	0.0055	-0.0858	0.0681	0.1470	-0.2048	0.1823	-0.0703	-0.1097
Maturity date (days)	0.316*	0.1978	-0.260*	-0.1406	-0.300*	0.0055	1.0000	0.0996	0.1718	0.1908	0.304*	-0.0348	-0.1569	0.0130
Biological yield (g)	0.1140	0.1730	-0.0352	-0.449**	0.2034	-0.0858	0.0996	1.0000	0.1089	-0.0458	0.256*	0.0586	-0.1495	0.615**
No of spikelet per spike	0.0118	0.0142	0.255*	-0.0190	0.0344	0.0681	0.1718	0.1089	1.0000	0.388**	-0.0676	0.0647	0.2100	0.1387
Grains per spike	-0.0535	0.276*	0.1287	0.0401	0.0990	0.1470	0.1908	-0.0458	0.388**	1.0000	-0.0200	-0.0878	0.0979	0.1259
Grain weight (g)	0.509**	0.2020	-0.1540	-0.404**	-0.0134	-0.2048	0.304*	0.256*	-0.0676	-0.0200	1.0000	0.327*	-0.1439	0.0511
Test weight	0.1933	-0.268*	-0.0323	-0.0487	-0.0526	0.1823	-0.0348	0.0586	0.0647	-0.0878	0.327*	1.0000	0.1589	0.0920
Harvest index (%)	0.0202	0.0629	0.2290	0.1356	0.1740	-0.0703	-0.1569	-0.1495	0.2100	0.0979	-0.1439	0.1589	1.0000	0.502**
Grain yield per plant	0.0809	0.2373	0.1682	-0.2306	0.1779	-0.1097	0.0130	0.615**	0.1387	0.1259	0.0511	0.0920	0.502**	1.0000

Table 2. Estimation of genotypic correlation coefficients among 14 agronomic traits in indigenous wheat lines

Source of Variation	Day to 50% flowering	Flag leaf area (cm)2	Length of spike (cm)	Peduncle length (cm)	No. of pod tillage	Plant height (cm)	Maturity date (days)	Biological yield (g)	No of spikelet per spike	Grains per spike	Grain weight (g)	Test weight	Harvest index (%)	Grain yield per plant
Day to 50% flowering	1.0000	0.273*	-0.2051	-0.1142	0.1569	-0.508**	0.621**	0.1407	0.0116	0.287*	0.742**	0.327*	0.0859	0.0692
Flag leaf area (cm)2	0.273*	1.0000	-0.408**	-0.337**	0.0884	-0.433**	0.282*	0.2412	-0.0067	0.570**	0.2272	-0.314*	0.0652	0.271*
Length of spike (cm)	-0.2051	-0.408**	1.0000	0.467**	0.366**	0.2053	-0.425**	0.0387	0.536**	0.0605	-0.1389	0.0005	0.338**	0.1761
Peduncle length (cm)	-0.1142	-0.337**	0.467**	1.0000	-0.1645	0.1780	-0.297*	-1.009**	0.1003	-0.350**	-0.768**	-0.1712	0.425**	-0.531**
No. of pod tillage	0.1569	0.0884	0.366**	-0.1645	1.0000	0.0341	-0.691**	0.315*	0.1079	0.1942	-0.0987	-0.0035	0.369**	0.470**
Plant height (cm)	-0.508**	-0.433**	0.2053	0.1780	0.0341	1.0000	-0.0836	-0.276*	0.357**	0.405**	-0.341**	0.354**	-0.2477	-0.347**
Maturity date (days)	0.621**	0.282*	-0.425**	-0.297*	-0.691**	-0.0836	1.0000	0.1618	0.607**	0.609**	0.391**	0.264*	-0.2342	0.0143
Biological yield (g)	0.1407	0.2412	0.0387	-1.009**	0.315*	-0.276*	0.1618	1.0000	0.0255	0.1501	0.409**	0.0590	0.1771	0.936**
No of spikelet per spike	0.0116	-0.0067	0.536**	0.1003	0.1079	0.357**	0.607**	0.0255	1.0000	1.0626	-0.1276	0.0166	0.496**	0.339**
Grains per spike	0.287*	0.570**	0.0605	-0.350**	0.1942	0.405**	0.609**	0.1501	1.0626	1.0000	-0.0749	-0.347**	0.0866	0.0720
Grain weight (g)	0.742**	0.2272	-0.1389	-0.768**	-0.0987	-0.341**	0.391**	0.409**	-0.1276	-0.0749	1.0000	0.427**	-0.268*	0.0339
Test weight	0.327*	-0.314*	0.0005	-0.1712	-0.0035	0.354**	0.264*	0.0590	0.0166	-0.347**	0.427**	1.0000	0.2391	0.1172
Harvest index (%)	0.0859	0.0652	0.338**	0.425**	0.369**	-0.2477	-0.2342	0.1771	0.496**	0.0866	-0.268*	0.2391	1.0000	0.592**
Grain yield per plant	0.0692	0.271*	0.1761	-0.531**	0.470**	-0.347**	0.0143	0.936**	0.339**	0.0720	0.0339	0.1172	0.592**	1.0000

Table 3. Phenotypic path matrix showing direct and indirect effects of 14 traits in indigenous wheat lines

Source of variation	Day to 50% flowering	Flag leaf area (cm)2	Length of spike (cm)	Peduncle length (cm)	No. of pod tillage	Plant height (cm)	Maturity date (days)	Biological yield (g)	No of spikelet per spike	Grains per spike	Grain weight (g)	Test weight	Harvest index (%)	Grain yield per plant
Day to 50% flowering	0.006	0.0011	-0.0008	-0.002	-0.0007	-0.0008	0.0019	0.0007	0.0001	-0.0003	0.003	0.0012	0.0001	0.0809
Flag leaf area (cm)2	0.0151	0.0794	-0.0202	-0.0153	0.0025	-0.0199	0.0157	0.0137	0.0011	0.0219	0.016	-0.0212	0.005	0.2373
Length of spike (cm)	-0.0164	-0.0308	0.1209	0.0188	0.0233	0.001	-0.0315	-0.0043	0.0308	0.0156	-0.0186	-0.0039	0.0277	0.1682
Peduncle length (cm)	-0.0034	-0.002	0.0016	0.0103	0.0019	0.0006	-0.0014	-0.0046	-0.0002	0.0004	-0.0042	-0.0005	0.0014	-0.2306
No. of pod tillage	0.0119	-0.0032	-0.0195	-0.0189	-0.1013	-0.007	0.0304	-0.0206	-0.0035	-0.01	0.0014	0.0053	-0.0176	0.1779
Plant height (cm)	0.0021	0.0038	-0.0013	-0.0009	-0.0011	-0.0152	-0.0001	0.0013	-0.001	-0.0022	0.0031	-0.0028	0.0011	-0.1097
Maturity date (days)	0.0156	0.0098	-0.0129	-0.0069	-0.0148	0.0003	0.0494	0.0049	0.0085	0.0094	0.015	-0.0017	-0.0078	0.0130
Biological yield (g)	0.0867	0.1315	-0.0268	-0.3416	0.1547	-0.0652	0.0757	0.7605	0.0828	-0.0348	0.1948	0.0445	-0.1137	0.615**
No of spikelet per spike	-0.002	-0.0024	-0.0424	0.0032	-0.0057	-0.0114	-0.0286	-0.0182	-0.1667	-0.0646	0.0113	-0.0108	-0.035	0.1387
Grains per spike	-0.007	0.0362	0.0169	0.0053	0.013	0.0193	0.0251	-0.006	0.0509	0.1313	-0.0026	-0.0115	0.0129	0.1259
Grain weight (g)	-0.045	-0.0179	0.0136	0.0357	0.0012	0.0181	-0.0269	-0.0227	0.006	0.0018	-0.0885	-0.0289	0.0127	0.0511
Test weight	0.0049	-0.0068	-0.0008	-0.0012	-0.0013	0.0046	-0.0009	0.0015	0.0016	-0.0022	0.0083	0.0253	0.004	0.0920
Harvest index (%)	0.0124	0.0384	0.1399	0.0828	0.1062	-0.043	-0.0958	-0.0913	0.1282	0.0598	-0.0879	0.097	0.6107	0.502**
Grain yield per plant	0.0809	0.2373	0.1682	-0.2306	0.1779	-0.1097	0.0130	0.615**	0.1387	0.1259	0.0511	0.0920	0.502**	1.0000
Partial R^2	0.0005	0.0188	0.0203	-0.0024	-0.018	0.0017	0.0006	0.4677	-0.0231	0.0165	-0.0045	0.0023	0.3062	-

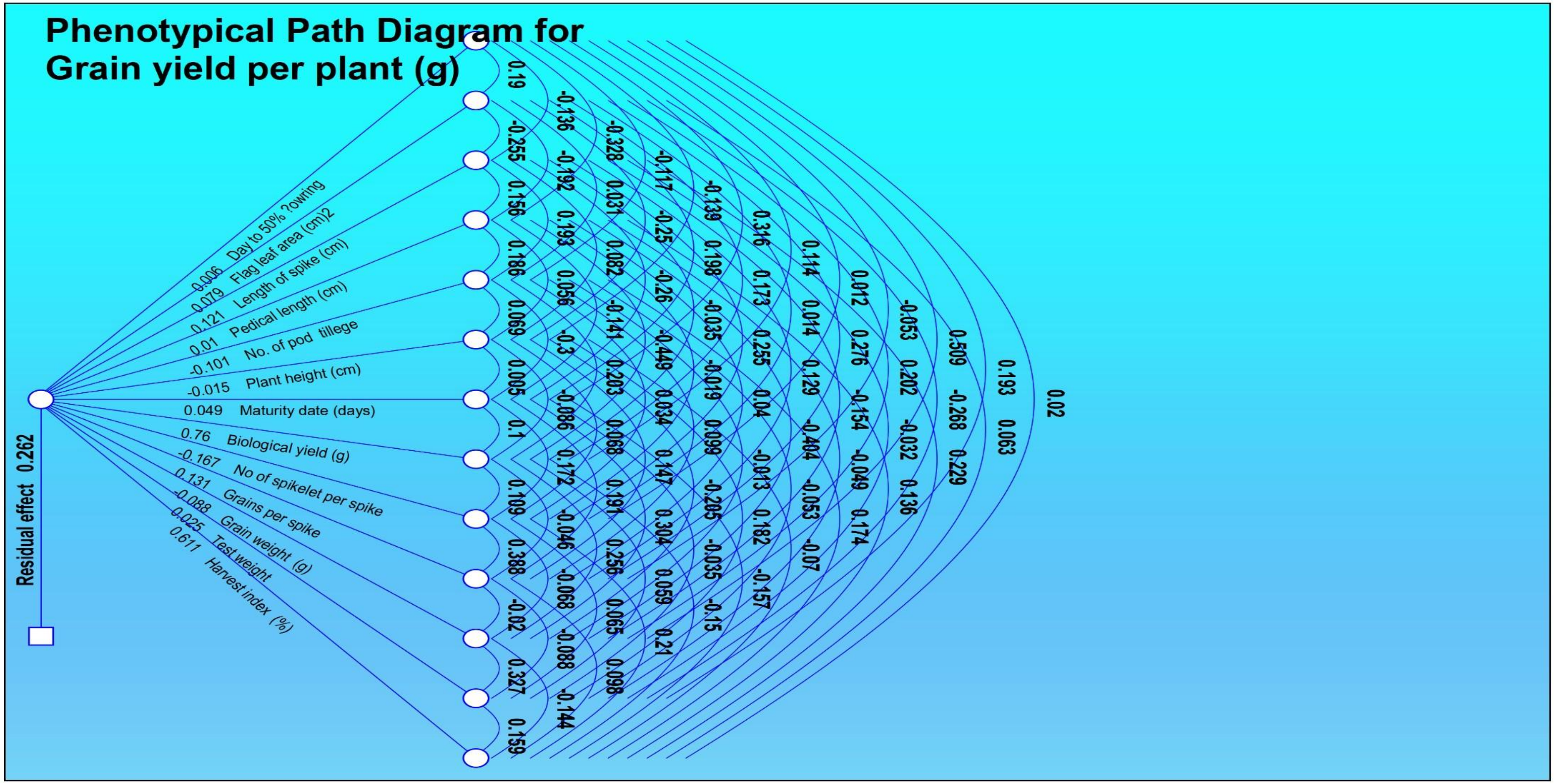

Fig. 1. Phenotypical path diagram

Table 4. Genotypic Path Matrix Showing Direct and Indirect Effects of 14 Traits in Indigenous Wheat Lines

Source of variation	Day to 50% flowering	Flag leaf area (cm)2	Length of spike (cm)	Peduncle length (cm)	No. of pod tillage	Plant height (cm)	Maturity date (days)	Biological yield (g)	No of spikelet per spike	Grains per spike	Grain weight (g)	Test weight	Harvest index (%)	Grain yield per plant
Day to 50% flowering	2.1236	0.5793	-0.4356	-0.2425	0.3332	-1.0791	1.3189	0.2988	0.0247	0.6089	1.5759	0.6934	0.1825	0.0692
Flag leaf area (cm)2	-0.1491	-0.5467	0.223	0.1843	-0.0483	0.2365	-0.1543	-0.1319	0.0036	-0.3117	-0.1242	0.1717	-0.0356	0.271*
Length of spike (cm)	0.0634	0.1261	-0.309	-0.1443	-0.113	-0.0634	0.1312	-0.012	-0.1655	-0.0187	0.0429	-0.0002	-0.1045	0.1761
Peduncle length (cm)	-0.1278	-0.3773	0.5227	1.1192	-0.1841	0.1992	-0.3319	-1.1288	0.1122	-0.3911	-0.8595	-0.1916	0.4758	-0.531**
No. of pod tillage	-0.3827	-0.2156	-0.8922	0.4013	-2.4394	-0.0831	1.6864	-0.7671	-0.2632	-0.4738	0.2408	0.0084	-0.9012	0.470**
Plant height (cm)	-1.6598	-1.4131	0.6705	0.5815	0.1113	3.2664	-0.2732	-0.9002	1.1654	1.3212	-1.1141	1.1552	-0.8092	-0.347**
Maturity date (days)	-0.9021	-0.41	0.6166	0.4307	1.0042	0.1215	-1.4525	-0.235	-0.8814	-0.884	-0.5674	-0.3839	0.3402	0.0143
Biological yield (g)	0.4012	0.6877	0.1103	-2.8755	0.8966	-0.7857	0.4613	2.8511	0.0726	0.4279	1.165	0.1682	0.505	0.936**
No of spikelet per spike	-0.0255	0.0146	-1.1737	-0.2197	-0.2365	-0.7818	-1.3298	-0.0558	-2.1914	-2.3285	0.2797	-0.0363	-1.0862	0.339**
Grains per spike	0.3451	0.6863	0.0728	-0.4207	0.2338	0.4869	0.7326	0.1806	1.279	1.2037	-0.0901	-0.4176	0.1043	0.0720
Grain weight (g)	0.8671	0.2655	-0.1624	-0.8973	-0.1154	-0.3985	0.4564	0.4775	-0.1491	-0.0875	1.1685	0.4989	-0.3132	0.0339
Test weight	-0.7214	0.6939	-0.0012	0.3783	0.0076	-0.7814	-0.584	-0.1304	-0.0366	0.7666	-0.9433	-2.2095	-0.5283	0.1172
Harvest index (%)	0.2374	0.1801	0.9343	1.1742	1.0204	-0.6842	-0.6469	0.4892	1.3691	0.2392	-0.7404	0.6605	2.7621	0.592**
Grain yield per plant	0.0692	0.271*	0.1761	-0.531**	0.470**	-0.347**	0.0143	0.936**	0.339**	0.0720	0.0339	0.1172	0.592**	1.0000
Partial R^2	0.147	-0.148	-0.0544	-0.594	-1.1473	-1.1328	-0.0207	2.6692	-0.7437	0.0867	0.0396	-0.2589	1.634	-

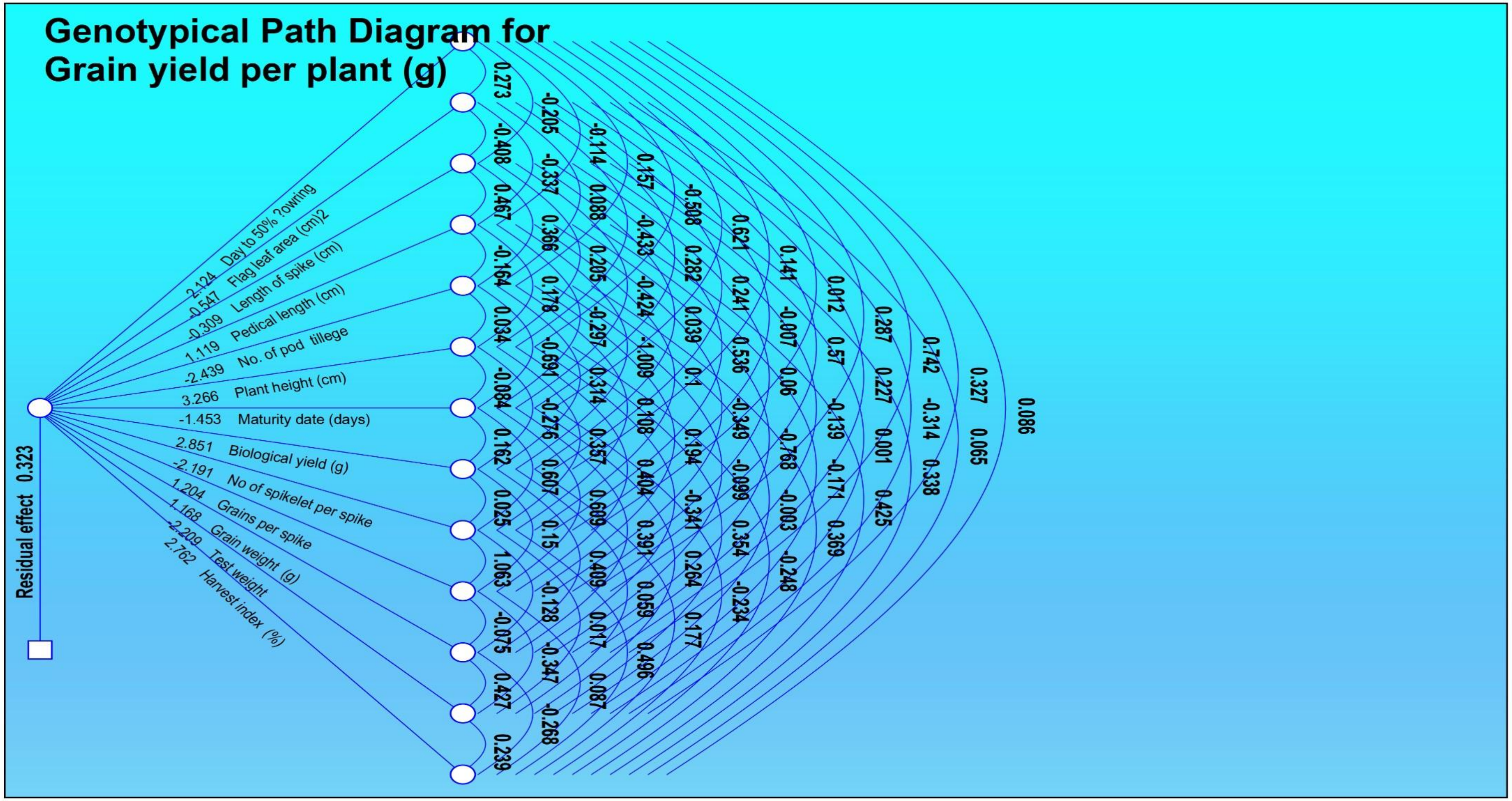

Fig. 2. Genotypical path diagram

The analysis's residual estimates of indirect impacts were extremely low, suggesting that they had little indirect influence on each plant's grain yield.

4. CONCLUSIONS

This study underscores the significance of traits like the number of grains per spike, biological yield, and harvest index as effective selection criteria for enhancing grain yield in bread wheat. Genotypes such as PBW-343 Black and K-1006 exhibited superior yield performance, demonstrating their potential for future breeding efforts. Additionally, a 2.5 cm row spacing was found to optimize yield-related traits, reinforcing its importance in breeding strategies aimed at improving wheat yield and overall productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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