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Estimate of Genotypic and Phenotypic Correlation and Path Coefficients in Bread Wheat (*Triticum aestivum* L.)

Ankitesh Kumar [a++*], Vijay Kumar Yadav [a#], C.L. Maurya [b#], Som Veer Singh [a†], Shweta [a†], Jayant Kumar [a++] and Bukke Sai Dev Naik [b++]

[a] Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) 208002, India.
[b] Department of Seed Science and Technology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) 208002, 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

The significant positive correlation of phenotypic and genotypic performance as well as path correlation of crops helps in selection of the superior cultivars. Based upon important significance of these estimates, it was applied in our research. For this an experiment was conducted on different genotypes during crop season of *Rabi* 2021-2022 and 2022-2023 under normal (non-stressed) or (heat-stressed) conditions. With the aim of to work out direct and indirect effects of different characters on yield. The field experiments were planted comprising 80 germplasm of

[++] *PhD Scholar;*
[#] *Professor;*
[†] *Assistant Professor;*
**Corresponding author: E-mail: ankiteshaditya@gmail.com;*

bread wheat. Therefore, our experimental trials were conducted in 12 environments (E1 to E12), for the identification of superior yielding and stable germplasm accessions possessing heat-stress tolerance. The field experiments were laid out in Augmented Block Design (ABD). Observations were recorded on twenty -six quantitative characters. Grain yield per plant showed significant positive association with Grain weight per spike (0.7998**), followed by Harvest index (0.7768**), Spike bearing tillers per plant (0.6627**), Number of grain per plant (0.658**), Plant biomass (0.5754**), Grain length (0.4203**), Spike length (0.3174**), Number of grain per spike (0.2734 *). And significant negative association with Peduncle length (-0.4282**), Plant waxiness (0.291**), Plant height (-0.258*), Chlorophyll content (-0.254*). Grain yield per plant showed highly significant positive association with spike bearing tillers per plant (0.634**), grain weight per spike (0.662**), number of grain per plant (0.550**), plant biomass (0.465**), number of grain per spike (0.166**), flag leaf area (0.1431*), flag leaf length (0.127*).

Keywords: Bread wheat (Triticum aestivum L.) correlation genotypic; phenotypic; path coefficient; quantitative trait.

1. INTRODUCTION

Most wheat types grown now are hexaploid (2n=42) species of the genus Triticum, which includes bread wheat (*Triticum aestivum* L.). The tetraploid durum wheat (*Triticum durum*), which has 2n=28, is the second-most important species of wheat. It is a self-pollinating, hexaploid (AABBDD) plant with an estimated genome size of 16 GB and a number of chromosomes 42 (2n = 6x = 42). Simple starches, or carbohydrates, make up 55–75% of the dry grain weight of mature wheat grains, with storage proteins making up the remaining 10–20% of the starchy endosperm. With a level of protein of around 13%, which is comparatively high when compared to other main cereals, it is the primary source of vegetarian protein in human meals and the most significant source of carbohydrates in most nations worldwide. In addition to their importance in nutrition, wheat accounts for 20% of global dietary calories and about 55% of carbs. Its main contribution is the distinctive material known as "gluten," which is vital for backers. Wheat straw is an excellent source of fodder for our country's cattle. The starchy endosperm of mature wheat grain is made up of carbohydrates (simple starches) that account for 55-75% of the total dry grain weight, as well as storage proteins that account for 10-20%. Wheat, when eaten whole, contains vitamins and dietary fibre. It includes minerals, vitamins, and lipids [1,2]. Correlation in grouping with path analysis will provide a better understanding of the cause-and-effect relationship between distinct pairs of characters [3]. Path analysis allows for the partitioning of total correlation into direct and indirect effects, which helps to make selection more successful. Correlation studies, along with path analysis, can offer a better knowledge of the interrelationship between different traits and grain yield, which can benefit breeders throughout the selection process. Correlation analyses are important for determining the degree and direction of the link between yield and its component qualities. Meanwhile, route coefficient analysis assesses the direct and indirect contribution of independent factors to dependent variables, which may help breeders determine yield components and identify the source of link between two variables. Path coefficient analysis provides information in indirect selection for yield genetic improvement, while direct selection does not supply enough information for a low heritable characteristic like yield.

2. MATERIALS AND METHODS

The current investigation entitled was conducted at three different locations; namely:

1. Crop research farm, Nawabganj,
2. Crop research farm, Araul
3. Crop research farm, Daleep Nagar.

during crop season of *Rabi* 2021-2022 and 2022-2023 under normal (non-stressed) and late sown (heat-stressed) conditions. The field experiments were planted comprising 80 germplasm of bread wheat. Therefore, our experimental trials were conducted in 12 environments (E1 to E12), for the identification of superior yielding and stable germplasm accessions possessing heat-stress tolerance. The field experiments were laid out in Augmented Block Design (ABD). Each experimental plot consisted of three rows of 2m length with 20 cm spacing between rows covering an area of 2 m x 0.20m (1.2 m^2) under irrigated condition. Observations were recorded on twenty- six quantitative characters *viz*., D50F, GFP, FLL, FLW, FLA, PH, PL, SBTPP, CC, CTD, PW, LR, SL, NSPS, PM, PB, GWPS, NGPS, NGPP, GL, GW, GLWR, TW, GYPP, HI, YPP. The analysis of variance for 26 quantitative traits among 80 genotypes showed significant variation for all the traits studied. This indicates the presence of high degree of variability among the genotypes and ample scope of improvement by selection.

In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. The phenotypic and genotypic correlation coefficients are ranged from -1 to +1 were calculated by following the method proposed by Goulden [4].

I. Genotypic correlation coefficient ($\mathbf{r_{g(xy)}}$):

$$\text{Genotypic correlation coefficient } r_{g(xy)} = \frac{\text{COV. } g(xy)}{\sqrt{\sigma^2 g_x \times \sigma^2 g_y}}$$

Where,

$r_{g(xy)}$ = Genotypic correlation coefficient
$\text{COV. } g(xy)$ = Genotypic covariance between the variables x and y
$\sigma^2 g_x$, $\sigma^2 g_y$= Genotypic variance of the variables x and y respectively
x, y = Independent variable and dependent variable respectively

The significance of phenotypic correlation coefficients was tested against (n-2) degrees of freedom at 5% and 1% probability level. Where, n is the number of germplasms on which the observations were recorded.

Table 1. Details of bread wheat accessions used in the study

Sl. No	Genotypes	Sl. No	Genotypes
1	C-306	41	KRL-1-4
2	K-0307	42	KRL-19
3	K-0402	43	KRL-210
4	K-0607	44	KRL-213
5	K-1006	45	KRL-283
6	K-1317	46	EC-576930
7	K-1616	47	NINGMAI
8	K-1711	48	IC-35143
9	K-1803	49	IC-113734
10	K-1805	50	IC-116276
11	K-1809	51	IC-122126
12	K-1903	52	IC-128150
13	K-1905	53	IC-252429
14	K-1907	54	IC-252772
15	K-1908	55	IC-252794
16	K-1910	56	IC-290186
17	K-2001	57	IC-290195
18	K-2003	58	IC-335683
19	K-2007	59	IC-401927
20	K-2010	60	IC-449061
21	K-2101	61	IC-542051
22	K-2103	62	IC-574388
23	K-2104	63	IC-574476
24	K-2105	64	HD-2359
25	K-2107	65	HD-2967
26	K-2108	66	HD-3086
27	K-2109	67	HD-3388
28	K-2121	68	HD-3392
29	K-7903	69	HD-3399
30	K-8027	70	DBW-107
31	K-8434	71	DBW-175
32	K-8962	72	DBW-187
33	K-9107	73	DBW-222
34	K-9162	74	DBW-316
35	K-9351	75	HI-1563
36	K-9423	76	HI-1612
37	K-9465	77	PBW-826
38	K-9533	78	PBW-833
39	K-9644	79	PBW-835
40	WH-1142	80	PBW-852

3. RESULTS AND DISCUSSION

3.1 Genotypic Correlation

Grain yield / plant had a significant positive correlation with grain weight per spike followed by harvest index, spike bearing tillers per plant, number of grain per plant, plant biomass, grain length, spike length and number of grain per spike. Yield per plot showed highly significant positive association with grain weight per spike, grain length and number of grain per plant. It was found that these results coincided with the findings of Laxman et al. [5], Diyali et al. [6], Abdul Hamid et al. [7], Shimelis et al. [8] and Akbarzai et al. [9] for grain weight per spike; Ahmad et al. [10] for spike length; Pooja et al. [11] for harvest index, Shehrawat et al. [12], Ezici et al. [13], Tanveer et al. [14], Akbarzai et al. [15] and Hussain et al. [16] for grain weight per spike, grain length and number of grain per plant. Traits such as grain weight per spike, grain length and number of grain per plant were found to be common in both grain yield per plant and yield per plot, thus selection based on these positively correlated characters will help in increasing the yield.

Days of 50% Heading: Days to 50% Heading showed highly significant positive association with Physiological maturity (0.318 **), and Leaf rolling (0.295 **)**.**

Grain filling period (days): Grain filling period showed highly significant positive association with Number of spikelets per spike (0.625 **), followed by Physiological maturity (0.585 **), Leaf rolling (0.421**), Number of grain per spike (0.240 *), Chlorophyll content (0.236 *), and significant negatively associated with Grain length (-0.481 **), Grain L/W ratio (-0.359 **), Plant waxiness (-0.358 **).

Flag leaf length (cm): Flag leaf length showed highly significant positive association with Flag leaf area (0.891**), Chlorophyll content (0.385 **) and significant negatively associated with Physiological maturity (-0.392**).

Flag leaf width (cm): Flag leaf width showed highly significant positive association with flag leaf area (0.625**), peduncle length (0.321**), grain weight per spike (0.265*), and significant negatively associated with plant waxiness (-0.309**), 1000 grain weight (-0.259*).

Flag leaf area (cm^2): Flag leaf area showed highly significant positive association with grain weight per spike (0.334**), chlorophyll content (0.3**), number of spikelets per spikes (0.298*), harvest index (0.280*), grain yield per plant (0.244*) and significant negatively associated with plant maturity (-0.372), plant waxiness (-0.228*), plant height (-0.222*).

Plant height (cm): Plant height showed highly significant positive association with peduncle length (0.882**), chlorophyll content (0.281*), and significant negatively associated with grain weight per spike (-0.530**), leaf rolling (-0.363**), yield per plot (-0.244*), grain yield per plant (0.280*).

Peduncle length (cm): Peduncle length showed highly significant positive association with chlorophyll content (0.331**), and significant negatively associated with grain weight per spike (-0.624**), leaf rolling (-0.478**), physiological maturity (-0.435**), grain yield per plant (-0.428), yield per plot (-0.403**).

Spike bearing tillers per plant: Spike bearing tillers per plant showed highly significant positive association with number of grain per plant (0.738**), followed by grain yield per plant (0.662**), plant biomass (0.552**), canopy temperature depression (0.489**), harvest index (0.445**) and significant negatively associated with yield per plot (-0.481**), chlorophyll content (-0.354**), plant waxiness (-0.293**).

Chlorophyll content: Chlorophyll content showed highly significant positive association with number of grain per spike (0.246*), and significant negatively associated with grain length (-0.310**), plant biomass (-0.273*), and grain yield per plant (-0.254*).

Canopy temperature depression (°C): Canopy temperature depression showed highly significant positive association with harvest index (0.344**), grain length (0.341**), 1000 grain weight (0.320**), and significant negatively associated with number of grain per spike (-0.369**), physiological maturity (-0.311**), leaf rolling (-0.295**).

Plant waxiness (0-10 scale): Plant waxiness showed highly significant positive association with leaf rolling (0.233*),1000 grain weight (0.224*), and significant negatively associated with plant biomass (-0.454**), spike length (-

0.437**), number of spikelets per spike (-0.318**).

Leaf rolling (0-10 scale): Leaf rolling showed highly significant positive association with grain length (0.234*).

Spike length (cm): Spike length showed highly significant positive association with number of spikelets per spike (0.609**), followed by plant biomass (0.478**), grain yield per plant (0.317**), grain length (0.282*), number of grain per plant (0.231*), and significant negatively associated with 1000 grain weight (- 0.267*).

Number of spikelets per spike: Number of spikelets per spike showed highly significant positive association with grain width (0.298**), followed by yield per plot (0.231*), plant biomass (0.224*), and significant negatively associated with grain length (-0.674**), Grain L/W ratio (-0.496**).

Physiological maturity (days): Physiological maturity showed highly significant positive association with number of grain per spike (0.234*), and significant negatively associated with 1000 grain weight (- 0.370**), harvest index (-0.282*).

Plant biomass (gm): Plant biomass showed highly significant positive association with grain yield per plant (0.575**), grain length (0.522**), number of grain per plant (0.334**), grain weight per spike (0.333**).

Grain weight per spike: Grain weight per spike showed highly significant positive association with grain yield per plant (0.799**), followed by harvest index (0.728**), grain length (0.422**), yield per plot (0.367**), number of grain per spike (0.244*).

Number of grain per spike: Number of grain per spike showed highly significant positive association with number of grain per spike (0.638**), grain yield per plant (0.273*), harvest index (0.257*), and significant negatively associated with grain length (-0.743**), Grain L/R ratio (-0.401**).

Number of grain per plant: Number of grain per plant showed highly significant positive association with Grain yield per plant (0.658**), harvest index (0.481**), and significant negatively associated with yield per plot (-0.388**), grain length (-0.377**), Grain L/R ratio (-0.241*).

Grain length (mm): Grain length showed highly significant positive association with grain yield per plant (0.420**), followed by Grain L/R ratio (0.332**), yield per plot (0.255*), harvest index (0.225*), and significant negatively associated with grain width (-0.370**).

Grain width (mm): grain width negatively associated with Grain L/R ratio (-0.893**).

Grain L/W ratio: Grain L/R ratio showed highly significant positive association with grain length (0.332**) and significant negatively associated with number of spikelets per plant (-0.496**), number of grain per spike (-0.401**).

1000 grain weight (gm): 1000 grain weight showed highly significant positive association with canopy temperature depression (0.320**), plant waxiness (0.224*).

Grain yield / plant (gm): significant positive association with Grain weight per spike (0.7998**), followed by Harvest index (0.7768**), Spike bearing tillers per plant (0.6627**), Number of grain per plant (0.658**), Plant biomass (0.5754**), Grain length (0.4203**), Spike length (0.3174**), Number of grain per spike (0.2734 *). And significant negative association with Peduncle length (-0.4282**), Plant waxiness (0.291**), Plant height (-0.258*), Chlorophyll content (-0.254*).

Harvest index (%): harvest index showed highly significant positive association with grain weight per spike (0.728**), grain yield per plant (0.776**), number of grain per plant (0.481**).

Yield per plot (g): yield per plot showed highly significant positive association with grain weight per spike (0.367**), grain lenth (0.255*), number of grain per plant (0.231*), and significant negatively associated with spike bearing tillers per plant (-0.481**), peduncle length (-0.403**), plant height (-0.335**).

3.2 Phenotypic Correlation

Path coefficient analysis of different traits contributing towards grain yield per plant showed that flag leaf length had highest positive direct effect followed by number of grain per plant, flag leaf width, physiological maturity and yield per plot. Findings of Mohanty et al*.* [17] supported the direct effect of number of grain per plant and yield per plot for grain yield per plant. Amin et al*.* [18] also supported the direct effect of physiological maturity for grain yield per plant. Similar results were found by Khanal et al*.* [19]

for flag leaf width Sapi et al. [20], Meena et al. [21], Oliveira et al. [22], Rohith et al. [23], Abo-Elwafa et al. [24], Kumar et al. [25], Santhoshini et al. [26] and Singh et al. [27] for number of grain per plant, flag leaf width, physiological maturity and yield per plot. Selection focusing on these traits may result in yield improvement.

Days of 50% Heading: Days to 50% heading showed significant positive association with physiological maturity (0.160*), leaf rolling (0.153*).

Grain filling period (days): Grain filling period showed significant positive association with physiological maturity (0.147*), and significant negatively associated with grain length (-0.133*), harvest index (-0.129*).

Flag leaf length (cm): flag leaf length showed highly significant positive association with flag leaf area (0.804**), followed by grain weight per spike (0.174**), chlorophyll content (0.17**), leaf rolling (0.167**), harvest index (0.135*), and significant negatively associated with plant waxiness (-0.147*).

Flag leaf width (cm): flag leaf width showed highly significant positive association with flag leaf area (0.643**), grain weight per spike (0.148*), and significant negatively associated with plant waxiness (-0.180**), 1000 grain weight (-0.171**).

Flag leaf area (cm²): flag leaf area showed highly significant positive association with grain weight per spike (0.207**), chlorophyll content (-0.141*), grain yield per plant (0.143*), and significant negatively associated with plant waxiness (-0.193**).

Plant height (cm): plant height showed highly significant positive association with peduncle length (0.498**), and significant negatively associated with leaf rolling (-0.199**), grain weight per spike (-0.177**), number of spikelets per spike.

Peduncle length (cm): peduncle length showed highly significant positive association with chlorophyll content (0.149*), and significant negatively associated with grain yield per plant (-0.265**), grain weight per spike (-0.237**), leaf rolling (-0.168**).

Spike bearing tillers per plant: Spike bearing tillers per plant showed highly significant positive association with number of grain per plant (0.764**), followed by grain yield per plant (0.634**), harvest index (0.4485**), plant biomass (0.295**), and significant negatively associated with number of grain per plant.

Chlorophyll content: Chlorophyll content showed highly significant positive association with flag leaf length (0.17**), peduncle length (0.149*), flag leaf area (0.141*).

Canopy temperature depression (°C): Canopy temperature depression showed highly significant positive association with 1000 grain weight (0.202**), number of spikelets per spike (0.136*), and significant negatively associated with physiological maturity (-0.180**).

Plant waxiness (0-10 scale): plant waxiness showed highly significant positive association with 1000 grain weight (0.179**), and significant negatively associated with grain yield per plant (-0.156*).

Leaf rolling: leaf rolling showed significant positive association with flag leaf length (0.167**), days of 50% heading (0.153*).

Spike length(cm): spike length showed significant positive association with number of spikelets per spike (0.152*), and significant negatively associated with 1000 grain weight (-0.135*).

Number of spikelets per spike: Number of spikelets per spike showed highly significant positive association with plant biomass (0.143*), and significant negatively associated with harvest index (-0.173**).

Physiological maturity (days): Physiological maturity showed significant negatively associated with 1000 grain weight (- 0.145*).

Plant biomass (gm): plant biomass showed highly significant positive association with grain yield per plant (0.465**), grain weight per spike (0.270**), number of grain per plant (0.216**), and significant negatively associated with harvest index (-0.220**).

Grain weight per spike: Grain weight per spike showed highly significant positive association with grain yield per plant (0.662**), harvest index (0.498**), yield per plot (0.136*).

Number of grain per spike: Number of grain per spike showed highly significant positive association with number of grain per plant (0.687**), grain yield per plant (0.166**).

Number of grain per plant: Number of grain per plant showed highly significant positive association with grain yield per plant (0.550**), harvest index (0.388**) and significant negatively associated with yield per plot (-0.144*).

Grain length (mm): Grain length showed highly significant positive association with grain L/R ratio (0.433**).

Grain width (mm): Grain width showed highly significant negatively associated with grain L/R ratio (-0.716).

Grain L/W ratio: Grain L/W ratio showed highly significant positive association with grain length (0.437**), and significant negatively associated with grain width (-0.716**).

1000 grain weight (gm): 1000 grain weight showed highly significant positive association with canopy temperature depression (0.202**), plant waxing (0.179**), and significant negatively associated with physiological maturity (-0.145*).

Grain yield / plant (gm): Grain yield per plant showed highly significant positive association with spike bearing tillers per plant (0.634**), grain weight per spike (0.662**), number of grain per plant (0.550**), plant biomass (0.465**), number of grain per spike (0.166**), flag leaf area (0.1431*), flag leaf length (0.127*).

Harvest index (%): Harvest index showed highly significant positive association with grain yield per plant (0.667**), grain weight per spike (0.498**), and significant negatively associated with grain filling period (-0.129*).

Yield per plot (g): Yield per plot showed highly significant positive association with grain weight per spike (0.136*), and significant negatively associated with spike bearing tillers per plant (-0.213**), peduncle length (-0.161*).

3.3 Path Coefficient Analysis

The estimation of genotypic path coefficient is depicted in Tables 4 and 5.

3.3.1 Genotypic path

Direct effect: Path coefficient analysis of different traits contributing towards grain yield per plant showed that flag leaf length (24.356), had highest positive direct effect followed by number of grain per plant (17.724), flag leaf width (15.355), physiological maturity (4.701), yield per plot (4.355). All other traits showed direct effects which were mostly negative.

Days to 50% heading: Days to 50% heading had maximum positive indirect effect on grain yield per plant through physiological maturity (1.496), and flag leaf length (1.456). While, it had negative indirect effect on grain yield per plant via flag leaf width (-0.726), and flag leaf area (-0.452).

Grain filling period (days): Grain filling period had maximum positive indirect effect on grain yield per plant through number of grain per plant (2.905), physiological maturity (2.752), Grain weight per spike (1.465). While, it had negative indirect effect on Grain yield per plant via Plant waxiness (-0.897), flag leaf width (-0.628).

Flag leaf length (cm): Flag leaf length had maximum positive indirect effect on grain yield per plant through flag leaf width (3.421), plant height (1.194), While, it had negative indirect effect on grain yield per plant via flag leaf area (-23.111).

Flag leaf width (cm): Flag leaf width had maximum positive indirect effect on grain yield per plant through flag leaf length (5.427), number of grain per plant (1.021), While, it had negative indirect effect on Grain yield per plant via flag leaf area (-16.215), grain weight per spike (-2.574).

Flag leaf area (cm^2): Flag leaf area had maximum positive indirect effect on grain yield per plant through flag leaf length (21.722), flag leaf width (9.608), While, it had negative indirect effect on grain yield per plant via grain weight per spike (-3.251), physiological maturity (-1.753).

Plant height (cm): Plant height had maximum positive indirect effect on grain yield per plant through flag leaf area (5.772), followed by grain weight per spike (5.156), While, it had negative indirect effect on grain yield per plant via flag leaf length (-6.318), yield per plot (-1.461).

Peduncle length (cm): Peduncle length had maximum positive indirect effect on grain yield per plant through grain weight per spike (6.071), flag leaf width (4.934). While, it had negative indirect effect on grain yield per plant via plant height (-4.064), flag leaf length (-3.683).

Spike bearing tillers per plant: Spike bearing tillers per plant had maximum positive indirect effect on grain yield per plant through number of grain per plant (13.095), followed by canopy temperature depression (1.785), plant biomass (1.386). While, it had negative indirect effect on grain yield per plant via yield per plot (-2.097), grain weight per spike (-0.825).

Chlorophyll content: Chlorophyll content had maximum positive indirect effect on grain yield per plant through flag leaf length (9.377), followed by spike bearing tillers per plant (4.368), While, it had negative indirect effect on grain yield per plant via flag leaf area (-7.774), number of grain per plant (-2.481).

Canopy temperature depression: Canopy temperature depression had maximum positive indirect effect on grain yield per plant through number of grain per spike (3.084), number of grain per plant (1.948). While, it had negative indirect effect on grain yield per plant via: spike bearing tillers per plant (-6.036), physiological maturity (-1.462).

Plant waxiness: Plant waxiness had maximum positive indirect effect on grain yield per plant through flag leaf area (5.921), spike bearing tillers per plant (3.618), While, it had negative indirect effect on grain yield per plant via flag leaf width (-4.753), number of grain per plant (-4.907).

Leaf rolling: Leaf rolling had maximum positive indirect effect on grain yield per plant through flag leaf length (8.151), followed by plant height (1.673), spike per plant (0.602) While, it had negative indirect effect on grain yield per plant via flag leaf area (-5.139).

Spike length (cm): Spike length had maximum positive indirect effect on grain yield per plant through number of grain per plant (4.110), flag leaf length (1.679), number of grain per spike (1.490), While, it had negative indirect effect on grain yield per plant via spike bearing tillers per plant (-4.567).

Number of spikelets per spike: Number of spikelets per spike, had maximum positive indirect effect on grain yield per plant through flag leaf length (5.807), flag leaf width (3.379). While, it had negative indirect effect on grain yield per plant via flag leaf area (-7.738), grain filling period (-1.276).

Physiological maturity (days): Physiological maturity had maximum positive indirect effect on grain yield per plant through flag leaf area (9.664), number of grain per plant (1.610). While, it had negative indirect effect on grain yield per plant via flag leaf length (-9.550).

Plant biomass (gm): Plant biomass had maximum positive indirect effect on grain yield per plant through number of grain per plant (5.921), flag leaf width (1.34), While, it had negative indirect effect on grain yield per plant via peduncle length (-0.608).

Grain weight per spike: Grain weight per spike**,** had maximum positive indirect effect on grain yield per plant through flag leaf length (8.039), flag leaf width (4.067). While, it had negative indirect effect on grain yield per plant via flag leaf area (-8.667).

Number of grain per spike: Number of grain per spike**,** had maximum positive indirect effect on grain yield per plant through number of grain per plant (11.308), flag leaf width (2.695), While, it had negative indirect effect on grain yield per plant via flag leaf width (-2.464), grain weight per spike (-2.372).

Number of grain per plant: Number of grain per plant**,** had maximum positive indirect effect on grain yield per plant through harvest index (1.565), flag leaf width (0.884), plant biomass (0.838). While, it had negative indirect effect on grain yield per plant via number of grain per spike (-5.332).

Grain length (mm): Grain length**,** had maximum positive indirect effect on grain yield per plant through number of grain per spike (6.209), canopy temperature depression (1.243). While, it had negative indirect effect on grain yield per plant via number of grain per plant (-6.688), grain weight per spike (-4.102).

Grain width (mm): Grain width**,** had maximum positive indirect effect on grain yield per plant through number of grain per plant (3.548), flag leaf area (3.046). While, it had negative indirect effect on grain yield per plant via flag leaf length (-2.412).

Table 2. Genotypic correlation

	D50F	GFP	FLL	FLW	FLA	PH	PL	SBTPP	CC	CTD	PW
D50F	1 **	-0.0392	0.0598	-0.0472	0.0175	-0.0286	-0.1693	-0.0542	-0.1439	-0.0724	-0.1521
GFP	-0.0392	1 **	-0.0032	-0.0408	-0.0295	-0.1593	0.056	-0.037	0.2368 *	0.1839	-0.3581 **
FLL	0.0598	-0.0032	1 **	0.2226 *	0.8919 **	-0.2594 *	-0.1512	0.0011	0.385 **	0.0551	-0.1447
FLW	-0.0472	-0.0408	0.2226 *	1 **	0.6253 **	-0.0219	0.321 **	-0.024	0.0328	-0.1623	-0.3093 **
FLA	0.0175	-0.0295	0.8919 **	0.6253 **	1 **	-0.2228 *	0.0035	0.0171	0.3 **	-0.0179	-0.2285 *
PH	-0.0286	-0.1593	-0.2594 *	-0.0219	-0.2228 *	1 **	0.8824 **	0.1134	0.2819 *	0.1472	-0.0926
PL	-0.1693	0.056	-0.1512	0.321 **	0.0035	0.8824 **	1 **	-0.1126	0.3312 **	0.0907	-0.2741 *
SBTPP	-0.0542	-0.037	0.0011	-0.024	0.0171	0.1134	-0.1126	1 **	-0.3542 **	0.4895 **	-0.2934 **
CC	-0.1439	0.2368 *	0.385 **	0.0328	0.3 **	0.2819 *	0.3312 **	-0.3542 **	1 **	0.0109	0.0284
CTD	-0.0724	0.1839	0.0551	-0.1623	-0.0179	0.1472	0.0907	0.4895 **	0.0109	1 **	0.0777
PW	-0.1521	-0.3581 **	-0.1447	-0.3093 **	-0.2285 *	-0.0926	-0.2741 *	-0.2934 **	0.0284	0.0777	1 **
LR	0.2952 **	0.421 **	0.3347 **	-0.145	0.1983	-0.3634 **	-0.4873 **	-0.0054	0.0155	-0.2955 **	0.2333 *
SL	-0.0673	0.0924	0.0689	-0.0708	-0.0316	0.1472	-0.0594	0.3704 **	-0.0524	0.1817	-0.4373 **
NSPS	-0.057	0.6253 **	0.2384 *	0.2197	0.2986 **	0.0446	0.0556	0.0541	-0.0365	0.2138	-0.3183 **
PM	0.3184 **	0.5855 **	-0.3925 **	-0.1134	-0.3729 **	-0.1196	-0.4358 **	-0.1453	-0.1168	-0.311 **	-0.099
PB	0.0764	-0.1575	-0.0257	0.0876	-0.0392	-0.0871	-0.3038 **	0.5525 **	-0.2732 *	0.0185	-0.4549 **
GWPS	-0.061	-0.1508	0.3301 **	0.2656 *	0.3344 **	-0.5303 **	-0.6245 **	0.0848	-0.0942	0.0494	-0.0524
NGPS	-0.0492	0.2404 *	-0.1012	0.1754	0.0174	-0.1706	-0.0541	-0.032	0.246 *	-0.369 **	-0.0178
NGPP	-0.07	0.1639	-0.0655	0.0576	0.0077	0.0168	-0.0861	0.7388 **	-0.14	0.1099	-0.2769 *
GL	0.1124	-0.4816 **	0.0438	-0.1184	-0.0197	-0.0268	-0.0817	0.2617 *	-0.3101 **	0.341 **	0.0937
GW	0.0542	0.1917	-0.099	-0.0662	-0.1175	-0.1091	-0.114	0.1378	-0.0011	0.203	0.1504
GLWR	0.0864	-0.3596 **	0.0892	0.0734	0.116	0.1874	0.101	-0.0014	-0.0567	-0.0826	-0.1275
TW	-0.0832	0.0654	0.0282	-0.2595 *	-0.0651	-0.1988	-0.1424	0.0217	0.0285	0.3201 **	0.2241 *
GYPP	-0.0245	-0.1834	0.1971	0.2127	0.244 *	-0.2589 *	-0.4282 **	0.6627 **	-0.254 *	0.178	-0.2915 **
HI	-0.0837	-0.3129 **	0.2723 *	0.1251	0.2809 *	-0.184	-0.2519 *	0.455 **	-0.1431	0.344 **	0.0168
YPP	-0.1091	-0.0952	0.097	0.0042	0.0627	-0.3355 **	-0.4034 **	-0.4816 **	-0.0479	-0.1593	0.129

Cont.

	LR	SL	NSPS	PM	PB	GWPS	NGPS	NGPP	GL	GW	GLWR
D50F	0.2952 **	-0.0673	-0.057	0.3184 **	0.0764	-0.061	-0.0492	-0.07	0.1124	0.0542	0.0864
GFP	0.421 **	0.0924	0.6253 **	0.5855 **	-0.1575	-0.1508	0.2404 *	0.1639	-0.4816 **	0.1917	-0.3596 **
FLL	0.3347 **	0.0689	0.2384 *	-0.3925 **	-0.0257	0.3301 **	-0.1012	-0.0655	0.0438	-0.099	0.0892
FLW	-0.145	-0.0708	0.2197	-0.1134	0.0876	0.2656 *	0.1754	0.0576	-0.1184	-0.0662	0.0734
FLA	0.1983	-0.0316	0.2986 **	-0.3729 **	-0.0392	0.3344 **	0.0174	0.0077	-0.0197	-0.1175	0.116
PH	-0.3634 **	0.1472	0.0446	-0.1196	-0.0871	-0.5303 **	-0.1706	0.0168	-0.0268	-0.1091	0.1874
PL	-0.4873 **	-0.0594	0.0556	-0.4358 **	-0.3038 **	-0.6245 **	-0.0541	-0.0861	-0.0817	-0.114	0.101
SBTPP	-0.0054	0.3704 **	0.0541	-0.1453	0.5525 **	0.0848	-0.032	0.7388 **	0.2617 *	0.1378	-0.0014
CC	0.0155	-0.0524	-0.0365	-0.1168	-0.2732 *	-0.0942	0.246 *	-0.14	-0.3101 **	-0.0011	-0.0567
CTD	-0.2955 **	0.1817	0.2138	-0.311 **	0.0185	0.0494	-0.369 **	0.1099	0.341 **	0.203	-0.0826
PW	0.2333 *	-0.4373 **	-0.3183 **	-0.099	-0.4549 **	-0.0524	-0.0178	-0.2769 *	0.0937	0.1504	-0.1275
LR	1 **	-0.0751	-0.164	0.1182	0.0036	0.046	0.0144	-0.0028	0.2341 *	0.1547	0.0443
SL	-0.0751	1 **	0.6093 **	0.0124	0.4783 **	0.207	-0.1783	0.2319 *	0.2822 *	0.1584	-0.062
NSPS	-0.164	0.6093 **	1 **	-0.1344	0.2249 *	0.0428	0.0653	0.1839	-0.6746 **	0.2983 **	-0.4963 **
PM	0.1182	0.0124	-0.1344	1 **	0.0303	0.0058	0.2341 *	0.0909	-0.0491	0.0907	-0.0653
PB	0.0036	0.4783 **	0.2249 *	0.0303	1 **	0.3331 **	-0.1327	0.3341 **	0.5221 **	0.0512	0.1392
GWPS	0.046	0.207	0.0428	0.0058	0.3331 **	1 **	0.244 *	0.1914	0.4222 **	-0.0598	0.1434
NGPS	0.0144	-0.1783	0.0653	0.2341 *	-0.1327	0.244 *	1 **	0.638 **	-0.743 **	0.1848	-0.4013 **
NGPP	-0.0028	0.2319 *	0.1839	0.0909	0.3341 **	0.1914	0.638 **	1 **	-0.3774 **	0.2001	-0.2419 *
GL	0.2341 *	0.2822 *	-0.6746 **	-0.0491	0.5221 **	0.4222 **	-0.743 **	-0.3774 **	1 **	-0.3702 **	0.3322 **
GW	0.1547	0.1584	0.2983 **	0.0907	0.0512	-0.0598	0.1848	0.2001	-0.3702 **	1 **	-0.8933 **
GLWR	0.0443	-0.062	-0.4963 **	-0.0653	0.1392	0.1434	-0.4013 **	-0.2419 *	0.3322 **	-0.8933 **	0.9996 **
TW	0.0853	-0.2679 *	0.2084	-0.3708 **	-0.0702	-0.0188	0.0398	0.061	-0.1192	-0.1688	0.0893
GYPP	0.1251	0.3174 **	-0.0319	-0.0923	0.5754 **	0.7998 **	0.2734 *	0.658 **	0.4203 **	0.1148	0.0363
HI	0.0752	0.2109	-0.2161	-0.2821 *	0.1179	0.728 **	0.2573 *	0.4814 **	0.2258 *	0.0623	-0.0553
YPP	0.0824	-0.0908	0.2319 *	-0.1034	-0.1034	0.367 **	-0.0135	-0.3881 **	0.2553 *	-0.0892	0.1163

Cont.

	TW	GYPP	HI	YPP
D50F	-0.0832	-0.0245	-0.0837	-0.1091
GFP	0.0654	-0.1834	-0.3129 **	-0.0952
FLL	0.0282	0.1971	0.2723 *	0.097
FLW	-0.2595 *	0.2127	0.1251	0.0042
FLA	-0.0651	0.244 *	0.2809 *	0.0627
PH	-0.1988	-0.2589 *	-0.184	-0.3355 **
PL	-0.1424	-0.4282 **	-0.2519 *	-0.4034 **
SBTPP	0.0217	0.6627 **	0.455 **	-0.4816 **
CC	0.0285	-0.254 *	-0.1431	-0.0479
CTD	0.3201 **	0.178	0.344 **	-0.1593
PW	0.2241 *	-0.2915 **	0.0168	0.129
LR	0.0853	0.1251	0.0752	0.0824
SL	-0.2679 *	0.3174 **	0.2109	-0.0908
NSPS	0.2084	-0.0319	-0.2161	0.2319 *
PM	-0.3708 **	-0.0923	-0.2821 *	-0.1034
PB	-0.0702	0.5754 **	0.1179	-0.1034
GWPS	-0.0188	0.7998 **	0.728 **	0.367 **
NGPS	0.0398	0.2734 *	0.2573 *	-0.0135
NGPP	0.061	0.658 **	0.4814 **	-0.3881 **
GL	-0.1192	0.4203 **	0.2258 *	0.2553 *
GW	-0.1688	0.1148	0.0623	-0.0892
GLWR	0.0893	0.0363	-0.0553	0.1163
TW	1 **	-0.0536	-0.0741	0.1499
GYPP	-0.0536	1 **	0.7768 **	0.0252
HI	-0.0741	0.7768 **	1 **	0.0273
YPP	0.1499	0.0252	0.0273	1 **

Table 3. Phenotypic correlation

	D50F	GFP	FLL	FLW	FLA	PH	PL	SBTPP	CC	CTD	PW
D50F	1 **	-0.0213	0.022	-0.019	0.0029	-0.018	-0.1184	-0.0458	-0.0851	-0.0506	-0.1151
GFP	-0.0213	1 **	-0.012	0.0768	0.0328	-0.0528	-0.0064	-0.0901	0.033	0.0054	-0.07
FLL	0.022	-0.012	1 **	0.0897	0.8041 **	-0.1525 *	0.0031	0.017	0.17 **	0.1085	-0.1475 *
FLW	-0.019	0.0768	0.0897	1 **	0.6435 **	0.044	0.1207	-0.1024	0.0309	-0.0757	-0.1808 **
FLA	0.0029	0.0328	0.8041 **	0.6435 **	1 **	-0.1118	0.0661	-0.0375	0.1416 *	0.0431	-0.1939 **
PH	-0.018	-0.0528	-0.1525 *	0.044	-0.1118	1 **	0.4984 **	0.064	0.0208	0.053	-0.0808
PL	-0.1184	-0.0064	0.0031	0.1207	0.0661	0.4984 **	1 **	-0.0965	0.1496 *	0.0637	-0.1327 *
SBTPP	-0.0458	-0.0901	0.017	-0.1024	-0.0375	0.064	-0.0965	1 **	-0.1004	0.1993 **	-0.1266
CC	-0.0851	0.033	0.17 **	0.0309	0.1416 *	0.0208	0.1496 *	-0.1004	1 **	0.0841	0.0099
CTD	-0.0506	0.0054	0.1085	-0.0757	0.0431	0.053	0.0637	0.1993 **	0.0841	1 **	0.0835
PW	-0.1151	-0.07	-0.1475 *	-0.1808 **	-0.1939 **	-0.0808	-0.1327 *	-0.1266	0.0099	0.0835	1 **
LR	0.1537 *	0.0189	0.1674 **	-0.0483	0.1241	-0.1991 **	-0.1686 **	-0.0661	0.0088	0.011	0.0621
SL	-0.0319	0.0468	0.0244	-0.0483	-0.0291	0.0596	-0.0788	0.1078	-0.0573	0.0788	-0.1082
NSPS	-0.0016	0.0782	0.0838	-0.0154	0.0495	-0.1304 *	0.0262	0	-0.0205	0.1365 *	-0.0637
PM	0.1606 *	0.1476 *	-0.0657	-0.0595	-0.0994	-0.0216	-0.0779	-0.0587	0.0068	-0.1804 **	-0.0802
PB	0.0421	-0.0133	-0.0177	0.0765	0.0072	-0.0862	-0.1367 *	0.2956 **	-0.0982	0.0591	-0.0583
GWPS	-0.0503	-0.0098	0.174 **	0.1484 *	0.2076 **	-0.1772 **	-0.2375 **	0.0286	-0.1135	0.0444	-0.027
NGPS	-0.0344	-0.0197	0.0115	-0.0128	0.0217	-0.0406	-0.0106	0.0797	0.0752	-0.1172	0.0199
NGPP	-0.0477	-0.0678	0.0126	-0.0886	-0.0237	0.0441	-0.0657	0.7649 **	-0.0255	0.0651	-0.0888
GL	0.0379	-0.1335 *	-0.0693	-0.054	-0.0886	-0.0172	-0.0441	0.0768	-0.1266	-0.0078	0.0241
GW	0.0347	0.0513	-0.1102	-0.0558	-0.1215	0.0186	-0.0714	0.0369	-0.0183	0.0843	0.0837
GLWR	0.0466	-0.1209	0.0803	-0.0179	0.0442	-0.0044	0.0296	-0.005	-0.0769	-0.081	-0.0567
TW	-0.0786	0.0214	0.0035	-0.1719 **	-0.0711	-0.1184	-0.1068	0.0094	0.0293	0.2024 **	0.1794 **
GYPP	-0.0325	-0.0977	0.1278 *	0.101	0.1431 *	-0.109	-0.2651 **	0.6341 **	-0.1212	0.0919	-0.1565 *
HI	-0.0734	-0.1293 *	0.1359 *	-0.0047	0.0972	-0.0529	-0.1633 *	0.4485 **	-0.0571	0.1128	-0.0992
YPP	-0.0521	0.008	0.0202	0.0032	0.0036	-0.132 *	-0.1612 *	-0.2133 **	-0.1088	-0.1125	-0.0082

Cont.

	LR	SL	NSPS	PM	PB	GWPS	NGPS	NGPP	GL	GW	GLWR
D50F	0.1537 *	-0.0319	-0.0016	0.1606 *	0.0421	-0.0503	-0.0344	-0.0477	0.0379	0.0347	0.0466
GFP	0.0189	0.0468	0.0782	0.1476 *	-0.0133	-0.0098	-0.0197	-0.0678	-0.1335 *	0.0513	-0.1209
FLL	0.1674 **	0.0244	0.0838	-0.0657	-0.0177	0.174 **	0.0115	0.0126	-0.0693	-0.1102	0.0803
FLW	-0.0483	-0.0483	-0.0154	-0.0595	0.0765	0.1484 *	-0.0128	-0.0886	-0.054	-0.0558	-0.0179
FLA	0.1241	-0.0291	0.0495	-0.0994	0.0072	0.2076 **	0.0217	-0.0237	-0.0886	-0.1215	0.0442
PH	-0.1991 **	0.0596	-0.1304 *	-0.0216	-0.0862	-0.1772 **	-0.0406	0.0441	-0.0172	0.0186	-0.0044
PL	-0.1686 **	-0.0788	0.0262	-0.0779	-0.1367 *	-0.2375 **	-0.0106	-0.0657	-0.0441	-0.0714	0.0296
SBTPP	-0.0661	0.1078	0	-0.0587	0.2956 **	0.0286	0.0797	0.7649 **	0.0768	0.0369	-0.005
CC	0.0088	-0.0573	-0.0205	0.0068	-0.0982	-0.1135	0.0752	-0.0255	-0.1266	-0.0183	-0.0769
CTD	0.011	0.0788	0.1365 *	-0.1804 **	0.0591	0.0444	-0.1172	0.0651	-0.0078	0.0843	-0.081
PW	0.0621	-0.1082	-0.0637	-0.0802	-0.0583	-0.027	0.0199	-0.0888	0.0241	0.0837	-0.0567
LR	1 **	-0.0625	-0.0635	0.0333	-0.0176	-0.0199	0.0202	-0.0391	-0.0671	0.0329	-0.049
SL	-0.0625	1 **	0.1521 *	0.0201	0.0921	0.0991	-0.0918	0.0332	0.0299	0.0376	-0.0206
NSPS	-0.0635	0.1521 *	1 **	-0.0081	0.1439 *	0.0059	-0.074	-0.0309	-0.0131	-0.0428	0.0333
PM	0.0333	0.0201	-0.0081	1 **	-0.0497	-0.0348	0.0253	-0.0221	-0.0771	-0.0034	-0.0405
PB	-0.0176	0.0921	0.1439 *	-0.0497	1 **	0.2703 **	0.0216	0.2161 **	0.0422	0.0198	-0.0236
GWPS	-0.0199	0.0991	0.0059	-0.0348	0.2703 **	1 **	0.0998	0.0728	-0.0389	-0.0351	-0.0097
NGPS	0.0202	-0.0918	-0.074	0.0253	0.0216	0.0998	1 **	0.6807 **	-0.0999	0.0838	-0.1287 *
NGPP	-0.0391	0.0332	-0.0309	-0.0221	0.2161 **	0.0728	0.6807 **	1 **	-0.0291	0.0757	-0.0864
GL	-0.0671	0.0299	-0.0131	-0.0771	0.0422	-0.0389	-0.0999	-0.0291	1 **	0.0423	0.4377 **
GW	0.0329	0.0376	-0.0428	-0.0034	0.0198	-0.0351	0.0838	0.0757	0.0423	1 **	-0.7169 **
GLWR	-0.049	-0.0206	0.0333	-0.0405	-0.0236	-0.0097	-0.1287 *	-0.0864	0.4377 **	-0.7169 **	0.9999 **
TW	0.0302	-0.1358 *	0.0892	-0.1451 *	-0.0441	-0.0116	0.0301	0.0328	-0.0561	-0.1023	0.0366
GYPP	-0.0659	0.1096	-0.0335	-0.0831	0.4658 **	0.6627 **	0.1662 **	0.5506 **	0.0116	0.0377	-0.0288
HI	-0.0714	0.0497	-0.173 **	-0.106	-0.2203 **	0.498 **	0.1062	0.3885 **	-0.013	0.0065	-0.0126
YPP	0.0033	-0.037	-0.0723	-0.0173	-0.0512	0.1366 *	-0.0115	-0.144 *	0.028	-0.0092	0.0091

Cont.

	TW	GYPP	HI	YPP
D50F	-0.0786	-0.0325	-0.0734	-0.0521
GFP	0.0214	-0.0977	-0.1293 *	0.008
FLL	0.0035	0.1278 *	0.1359 *	0.0202
FLW	-0.1719 **	0.101	-0.0047	0.0032
FLA	-0.0711	0.1431 *	0.0972	0.0036
PH	-0.1184	-0.109	-0.0529	-0.132 *
PL	-0.1068	-0.2651 **	-0.1633 *	-0.1612 *
SBTPP	0.0094	0.6341 **	0.4485 **	-0.2133 **
CC	0.0293	-0.1212	-0.0571	-0.1088
CTD	0.2024 **	0.0919	0.1128	-0.1125
PW	0.1794 **	-0.1565 *	-0.0992	-0.0082
LR	0.0302	-0.0659	-0.0714	0.0033
SL	-0.1358 *	0.1096	0.0497	-0.037
NSPS	0.0892	-0.0335	-0.173 **	-0.0723
PM	-0.1451 *	-0.0831	-0.106	-0.0173
PB	-0.0441	0.4658 **	-0.2203 **	-0.0512
GWPS	-0.0116	0.6627 **	0.498 **	0.1366 *
NGPS	0.0301	0.1662 **	0.1062	-0.0115
NGPP	0.0328	0.5506 **	0.3885 **	-0.144 *
GL	-0.0561	0.0116	-0.013	0.028
GW	-0.1023	0.0377	0.0065	-0.0092
GLWR	0.0366	-0.0288	-0.0126	0.0091
TW	1 **	-0.0452	-0.0543	0.0911
GYPP	-0.0452	1 **	0.6677 **	-0.0222
HI	-0.0543	0.6677 **	1 **	0.0155
YPP	0.0911	-0.0222	0.0155	1 **

Cont.

	TW	GYPP	HI	YPP
D50F	-0.0832	-0.0245	-0.0837	-0.1091
GFP	0.0654	-0.1834	-0.3129 **	-0.0952
FLL	0.0282	0.1971	0.2723 *	0.097
FLW	-0.2595 *	0.2127	0.1251	0.0042
FLA	-0.0651	0.244 *	0.2809 *	0.0627
PH	-0.1988	-0.2589 *	-0.184	-0.3355 **
PL	-0.1424	-0.4282 **	-0.2519 *	-0.4034 **
SBTPP	0.0217	0.6627 **	0.455 **	-0.4816 **
CC	0.0285	-0.254 *	-0.1431	-0.0479
CTD	0.3201 **	0.178	0.344 **	-0.1593
PW	0.2241 *	-0.2915 **	0.0168	0.129
LR	0.0853	0.1251	0.0752	0.0824
SL	-0.2679 *	0.3174 **	0.2109	-0.0908
NSPS	0.2084	-0.0319	-0.2161	0.2319 *
PM	-0.3708 **	-0.0923	-0.2821 *	-0.1034
PB	-0.0702	0.5754 **	0.1179	-0.1034
GWPS	-0.0188	0.7998 **	0.728 **	0.367 **
NGPS	0.0398	0.2734 *	0.2573 *	-0.0135
NGPP	0.061	0.658 **	0.4814 **	-0.3881 **
GL	-0.1192	0.4203 **	0.2258 *	0.2553 *
GW	-0.1688	0.1148	0.0623	-0.0892
GLWR	0.0893	0.0363	-0.0553	0.1163
TW	1 **	-0.0536	-0.0741	0.1499
GYPP	-0.0536	1 **	0.7768 **	0.0252
HI	-0.0741	0.7768 **	1 **	0.0273
YPP	0.1499	0.0252	0.0273	1 **

Table.4. Phenotypic Path Analysis

Traits	D50F	GFP	FLL	FLW	FLA	PH	PL	SBTPP	CC	CTD	PW	LR	SL
D50F	**-0.07405**	-0.00013	-0.05729	0.03858	0.00994	-0.00131	0.00259	-0.00266	-0.00961	0.00445	0.01601	-0.00697	-0.00045
GFP	0.00158	**0.00605**	0.03071	-0.1598	0.11344	-0.00386	0.00013	-0.00527	0.0037	-0.00055	0.00968	-0.00084	0.00065
FLL	-0.00164	-0.00007	-**2.58083**	-0.17949	2.75572	-0.01115	-0.00006	0.00101	0.01917	-0.0096	0.02056	-0.00758	0.00034
FLW	0.00141	0.00048	-0.22815	**-1.99716**	2.20396	0.00316	-0.00256	-0.00599	0.00362	0.00689	0.02522	0.00176	-0.00083
FLA	-0.00021	0.0002	-2.07524	-1.30579	**3.42743**	-0.00817	-0.00145	-0.0022	0.01599	-0.00377	0.02702	-0.00563	-0.00041
PH	0.00133	-0.00032	0.39383	-0.08792	-0.38315	**0.07304**	-0.01092	0.00376	0.00236	-0.0047	0.01127	0.00904	0.00083
PL	0.00876	-0.00004	-0.00748	-0.23695	0.22653	0.0364	**-0.02191**	-0.00568	0.01688	-0.00562	0.0185	0.00762	-0.00109
SBTPP	0.00336	-0.00054	-0.04439	0.20711	-0.12852	0.00467	0.00212	**0.05869**	-0.01137	-0.01762	0.01753	0.00301	0.00147
CC	0.00631	0.0002	-0.43874	-0.06518	0.48596	0.00153	-0.00328	-0.00591	**0.1128**	-0.00743	-0.00137	-0.00039	-0.0008
CTD	0.00373	0.00004	-0.28079	0.15858	0.14668	0.00389	-0.0014	0.01172	0.0095	**-0.08819**	-0.01161	-0.00056	0.00112
PW	0.00851	-0.00042	0.38093	0.36751	-0.66451	-0.00591	0.00291	-0.00738	0.00111	-0.00735	**-0.13944**	-0.00281	-0.00152
LR	-0.01139	0.00011	-0.43126	0.07878	0.42564	-0.01456	0.00368	-0.00389	0.00096	-0.00108	-0.00864	**-0.04527**	-0.00089
SL	0.00241	0.00028	-0.06271	0.12203	-0.1011	0.00435	0.00173	0.00622	-0.00647	-0.00715	0.01524	0.0029	**0.01389**
NSPS	0.00013	0.00047	-0.21653	0.02904	0.16998	-0.00953	-0.00057	0.0000	-0.00229	-0.01203	0.00881	0.00284	0.00211
PM	-0.01189	0.0009	0.17033	0.11919	-0.34065	-0.00158	0.00171	-0.00346	0.00076	0.01589	0.01113	-0.00152	0.0003
PB	-0.00313	-0.00008	0.04568	-0.15513	0.02467	-0.0063	0.00299	0.01735	-0.01108	-0.00521	0.00812	0.0008	0.00128
GWPS	0.00392	-0.00007	-0.44158	-0.39655	0.70324	-0.01288	0.00523	0.00178	-0.01241	-0.0041	0.00301	0.00105	0.00124
NGPS	0.00255	-0.00012	-0.02968	0.02904	0.07471	-0.00297	0.00023	0.00469	0.00848	0.01032	-0.00277	-0.00092	-0.00127
NGPP	0.00353	-0.00041	-0.03252	0.1801	-0.08122	0.00322	0.00144	0.04488	-0.00288	-0.00573	0.01237	0.00177	0.00046
GL	-0.00274	-0.00077	0.18505	0.0000	-0.30638	-0.0012	0.00104	0.00453	-0.0141	0.00149	-0.00327	0.00342	0.00027
GW	-0.00282	0.00031	0.29344	0.0000	-0.40474	0.00136	0.00151	0.00256	-0.00233	-0.00788	-0.01297	-0.00151	0.00036
GLWR	-0.00344	-0.00065	-0.20853	0.0000	0.14394	-0.00024	-0.00058	0.0000	-0.00911	0.0063	0.00691	0.00241	-0.00038
TW	0.00581	0.00013	-0.00877	0.35391	-0.24401	-0.00865	0.00234	0.00056	0.0033	-0.01779	-0.02502	-0.00138	-0.00188
HI	0.00543	-0.00078	-0.35073	0.00893	0.33311	-0.00387	0.00358	0.02632	-0.00645	-0.00993	0.01382	0.00323	0.00068
YPP	0.00386	0.00005	-0.05213	-0.0065	0.01234	-0.00964	0.00353	-0.01252	-0.01227	0.00992	0.00114	-0.00015	-0.00051

Cont.

Traits	NSPS	PM	PB	GWPS	NGPS	NGPS	GL	GW	GLWR	TW	HI	YPP
D50F	-0.00002	0.0146	0.02415	-0.01871	0.0041	-0.00728	-0.01453	0.03942	0.05049	-0.00007	-0.0412	-0.00243
GFP	0.00082	0.01345	-0.00778	-0.00414	0.00231	-0.01035	0.05012	0.05235	-0.11741	0.00002	-0.07279	0.00037
FLL	0.00089	-0.00600	-0.01013	0.06052	-0.00137	0.00192	0.02816	-0.11763	0.08792	0.0000	0.07639	0.00094
FLW	-0.00015	-0.00534	0.04373	0.06908	0.00171	-0.01354	0.0000	0.0000	0.0000	-0.00016	-0.00247	0.00015
FLA	0.00053	-0.00904	0.00412	0.07258	-0.0026	-0.00362	0.03511	-0.12218	0.0457	-0.00007	0.05463	0.00017
PH	-0.00139	-0.00196	-0.04934	-0.06236	0.00484	0.00673	0.00644	0.01924	-0.00359	-0.00011	-0.02979	-0.00616
PL	0.00028	-0.00708	-0.07824	-0.08446	0.00126	-0.01003	0.01858	-0.07118	0.02905	-0.0001	-0.09179	-0.00752
SBTPP	0.0000	-0.00535	0.16924	0.01075	-0.00953	0.11678	-0.03032	0.04521	0.0000	0.00001	0.25214	-0.00995
CC	-0.00022	0.00061	-0.0562	-0.03891	-0.00897	-0.00389	0.0491	-0.02142	-0.08792	0.00003	-0.03215	-0.00508
CTD	0.00145	-0.01638	0.03383	0.01645	0.01395	0.00992	0.00664	0.09239	-0.07769	0.00019	0.06329	-0.00525
PW	-0.00067	-0.00726	-0.03337	-0.00764	-0.00237	-0.01356	-0.00923	0.09632	-0.05397	0.00017	-0.05576	-0.00038
LR	-0.00067	0.00305	-0.01013	-0.00817	-0.00241	-0.00597	0.02962	0.03435	-0.05778	0.00003	-0.04008	0.00015
SL	0.00162	0.00195	0.05266	0.03166	0.01091	0.00507	-0.00766	0.02669	-0.02992	-0.00012	0.02765	-0.00173
NSPS	0.01066	-0.00077	0.08236	0.00301	0.00881	-0.00472	0.00365	-0.0508	0.04276	0.00008	-0.09729	-0.00337
PM	-0.00009	0.09088	-0.0285	-0.01238	-0.00302	-0.00337	0.02993	-0.00869	-0.04864	-0.00013	-0.05958	-0.00081
PB	0.00153	-0.00453	0.57235	0.09518	-0.00258	0.03299	-0.01693	0.02059	-0.02644	-0.00004	-0.12382	-0.00239
GWPS	0.00009	-0.00318	0.15402	0.34959	-0.01182	0.01111	0.02486	0.0000	0.0000	-0.00001	0.28008	0.00637
NGPS	-0.00079	0.0023	0.01236	0.03505	-0.11927	0.10392	0.03877	0.08432	-0.14189	0.00003	0.05964	-0.00054
NGPP	-0.00033	-0.00201	0.12368	0.02575	-0.08118	0.15267	0.01143	0.07811	-0.09423	0.00003	0.21836	-0.00672
GL	-0.0001	-0.00693	0.02467	-0.02239	0.01177	-0.00444	-0.37923	0.0000	0.52882	-0.00005	-0.00804	0.0013
GW	-0.00052	-0.00076	0.01139	0.0000	-0.00972	0.01153	0.0000	0.9972	-0.83871	-0.00009	0.00214	-0.00044
GLWR	0.00042	-0.00406	-0.01391	0.0000	0.01555	-0.01322	-0.19089	-0.79743	1.04338	0.00003	-0.0068	0.00042
TW	0.00095	-0.0132	-0.02536	-0.0035	-0.00359	0.00501	0.02325	-0.10304	0.04124	0.00092	-0.03058	0.00425
HI	-0.00184	-0.00964	-0.12609	0.17625	-0.01265	0.05931	0.00562	0.00393	-0.01317	-0.00005	0.56207	0.00072
YPP	-0.00077	-0.00157	-0.0293	0.04828	0.00137	-0.02198	-0.01096	-0.00972	0.0099	0.00008	0.00871	0.04665

Residual effect = 0.0764

Table. 5. Genotypic Path Analysis

	D50F	GFP	FLL	FLW	FLA	PH	PL	SBTPP	CC	CTD	PW	LR	SL
D50F	-0.5585	0.0800	1.4560	-0.7265	-0.4525	0.1318	-0.3389	0.6680	0.0395	-0.2641	-0.3813	-0.2761	-0.1566
GFP	0.0219	-2.0408	-0.0775	-0.6282	0.7634	0.7335	0.1121	0.4564	-0.0650	0.6706	-0.8979	-0.3937	0.2154
FLL	-0.0334	0.0065	24.3561	3.4216	-23.1114	1.1949	-0.3028	-0.0139	-0.1057	0.2011	-0.3628	-0.3131	0.1606
FLW	0.0264	0.0835	5.4272	15.3552	-16.2150	0.1007	0.6434	0.2966	-0.0090	-0.5931	-0.7763	0.1358	-0.1645
FLA	-0.0098	0.0601	21.7222	9.6084	-25.9134	1.0260	0.0070	-0.2104	-0.0823	-0.0652	-0.5730	-0.1855	-0.0737
PH	0.0160	0.3250	-6.3189	-0.3357	5.7725	-4.6058	1.7668	-1.3985	-0.0774	0.5369	-0.2323	0.3399	0.3428
PL	0.0945	-0.1143	-3.6836	4.9344	-0.0907	-4.0642	2.0022	1.3881	-0.0909	0.3309	-0.6873	0.4558	-0.1383
SBTPP	0.0303	0.0755	0.0275	-0.3693	-0.4421	-0.5223	-0.2254	-12.3322	0.0972	1.7854	-0.7357	0.0050	0.8625
CC	0.0804	-0.4834	9.3770	0.5041	-7.7740	-1.2986	0.6631	4.3680	-0.2744	0.0397	0.0712	-0.0145	-0.1221
CTD	0.0404	-0.3752	1.3430	-2.4968	0.4631	-0.6780	0.1816	-6.0364	-0.0030	3.6474	0.1948	0.2764	0.4233
PW	0.0849	0.7308	-3.5238	-4.7538	5.9212	0.4267	-0.5488	3.6182	-0.0078	0.2833	2.5074	-0.2182	-1.0183
LR	-0.1649	-0.8591	8.1519	-2.2290	-5.1399	1.6736	-0.9757	0.0661	-0.0043	-1.0779	0.5849	-0.9353	-0.1749
SL	0.0376	-0.1888	1.6796	-1.0844	0.8202	-0.6781	-0.1189	-4.5677	0.0144	0.6630	-1.0964	0.0702	2.3287
NSPS	0.0319	-1.2760	5.8076	3.3791	-7.7383	-0.2052	0.1114	-0.6672	0.0100	0.7798	-0.7982	0.1533	1.4189
PM	-0.1778	-1.1948	-9.5587	-1.7417	9.6641	0.5509	-0.8726	1.7914	0.0320	-1.1344	-0.2482	-0.1106	0.0289
PB	-0.0427	0.3214	-0.6247	1.3457	1.0161	0.4012	-0.6083	-6.8134	0.0750	0.0674	-1.1407	-0.0034	1.1139
GWPS	0.0341	0.3077	8.0399	4.0670	-8.6670	2.4433	-1.2507	-1.0469	0.0259	0.1797	-0.1314	-0.0430	0.4823
NGPS	0.0275	-0.4906	-2.4646	2.6956	-0.4512	0.7856	-0.1083	0.3946	-0.0675	-1.3461	-0.0447	-0.0135	-0.4152
NGPP	0.0391	-0.3345	-1.5956	0.8848	-0.1990	-0.0772	-0.1724	-9.1114	0.0384	0.4010	-0.6943	0.0026	0.5401
GL	-0.0628	0.9823	1.0653	-1.8001	0.5115	0.1235	-0.1637	-3.2262	0.0851	1.2436	0.2348	-0.2189	0.6584
GW	-0.0303	-0.3914	-2.4120	-1.0466	3.0466	0.5028	-0.2284	-1.7016	0.0003	0.7407	0.3772	-0.1448	0.3697
GLWR	-0.0483	0.7345	2.1757	1.1357	-3.0091	-0.8637	0.2024	0.0162	0.0156	-0.3006	-0.3196	-0.0413	-0.1448
TW	0.0465	-0.1335	0.6873	-3.9865	1.6870	0.9157	-0.2852	-0.2676	-0.0078	1.1675	0.5619	-0.0798	-0.6237
HI	0.0468	0.6386	6.6311	1.9220	-7.2778	0.8474	-0.5044	-5.6114	0.0393	1.2549	0.0422	-0.0704	0.4911
YPP	0.0610	0.1943	2.3635	0.0651	-1.6243	1.5453	-0.8077	5.9397	0.0131	-0.5810	0.3233	-0.0771	-0.2115

Cont.

	NSPS	PM	PB	GWPS	NGPS	NSPS	GL	GW	GLWR	TW	HI	YPP
D50F	0.2096	1.4969	0.1918	0.5935	0.4111	-1.2412	0.0174	-0.0360	-0.0140	-0.1270	-0.2722	-0.4754
GFP	-2.2970	2.7527	-0.3953	1.4655	-2.0092	2.9053	-0.0746	-0.1273	0.0583	0.0998	-1.0173	-0.4146
FLL	-0.8760	-1.8452	-0.0644	-3.2087	0.8457	-1.1611	0.0068	0.0657	-0.0145	0.0431	0.8852	0.4227
FLW	-0.8084	-0.5333	0.2200	-2.5746	-1.4672	1.0213	-0.0182	0.0452	-0.0120	-0.3962	0.4070	0.0185
FLA	-1.0971	-1.7535	-0.0984	-3.2511	-0.1455	0.1361	-0.0031	0.0780	-0.0188	-0.0994	0.9131	0.2730
PH	-0.1637	-0.5623	-0.2186	5.1565	1.4256	0.2972	-0.0042	0.0724	-0.0304	-0.3034	-0.5982	-1.4613
PL	-0.2044	-2.0491	-0.7625	6.0719	0.4522	-1.5262	-0.0127	0.0757	-0.0164	-0.2174	-0.8191	-1.7569
SBTPP	-0.1988	-0.6830	1.3866	-0.8252	0.2675	13.0951	0.0405	-0.0916	0.0002	0.0331	1.4794	-2.0978
CC	0.1341	-0.5491	-0.6856	0.9158	-2.0561	-2.4810	-0.0480	0.0008	0.0092	0.0435	-0.4653	-0.2085
CTD	-0.7854	-1.4623	0.0464	-0.4788	3.0845	1.9484	0.0528	-0.1348	0.0134	0.4885	1.1186	-0.6938
PW	1.1695	-0.4655	-1.1418	0.5096	0.1489	-4.9076	0.0145	-0.0998	0.0206	0.3420	0.0548	0.5616
LR	0.6022	0.5557	0.0090	-0.4473	-0.1208	-0.0495	0.0363	-0.1027	-0.0071	0.1302	0.2445	0.3588
SL	-2.2384	0.0583	1.2005	-2.0130	1.4901	4.1109	0.0438	-0.1053	0.0101	-0.4088	0.6856	-0.3957
NSPS	-3.6737	-0.6318	0.5644	-0.4151	-0.5461	3.2598	-0.1046	-0.1980	0.0804	0.3181	-0.7026	1.0101
PM	0.4937	4.7017	0.0760	-0.0553	-1.9568	1.6108	-0.0076	-0.0603	0.0106	-0.5659	-0.9171	-0.4503
PB	-0.8261	0.1424	2.5098	-3.2385	1.1090	5.9211	0.0809	-0.0340	-0.0225	-0.1071	0.3833	-0.4504
GWPS	-0.1569	0.0268	0.8362	-9.7205	-2.0397	3.3936	0.0654	0.0402	-0.0232	-0.0288	2.3675	1.5988
NGPS	-0.2400	1.1008	-0.3330	-2.3722	-8.3579	11.3083	-0.1151	-0.1227	0.0650	0.0607	0.8366	-0.0589
NGPP	-0.6757	0.4273	0.8384	-1.8612	-5.3325	17.7241	-0.0585	-0.1329	0.0392	0.0932	1.5653	-1.6904
GL	2.4783	-0.2313	1.3103	-4.1025	6.2097	-6.6887	0.1550	0.2467	-0.0538	-0.1820	0.7342	1.1119
GW	-1.0959	0.4272	0.1286	0.5893	-1.5446	3.5484	-0.0576	-0.6636	0.1447	-0.2578	0.2026	-0.3886
GLWR	1.8243	-0.3071	0.3494	-1.3951	3.3553	-4.2892	0.0515	0.5931	-0.1619	0.1363	-0.1796	0.5067
TW	-0.7656	-1.7435	-0.1761	0.1833	-0.3326	1.0819	-0.0185	0.1121	-0.0145	1.5261	-0.2410	0.6531
HI	0.7939	-1.3262	0.2959	-7.0780	-2.1507	8.5331	0.0350	-0.0414	0.0089	-0.1131	3.2513	0.1187
YPP	-0.8520	-0.4861	-0.2595	-3.5681	0.1130	-6.8787	0.0396	0.0592	-0.0188	0.2289	0.0886	4.3555

Residual effect = 0.8297

Grain L/W ratio: Grain L/W ratio, had maximum positive indirect effect on grain yield per plant through number of grain per spike (3.355), flag leaf length (2.175). While, it had negative indirect effect on grain yield per plant via number of grain per plant (-4.289).

1000 grain weight (gm): 1000 grain weight, had maximum positive indirect effect on grain yield per plant through flag leaf area (1.687), canopy temperature depression (1.167). While, it had negative indirect effect on grain yield per plant via flag leaf width (-3.986).

Harvest index (%): Harvest index had maximum positive indirect effect on grain yield per plant through number of grain per plant (8.533), flag leaf length (6.631). While, it had negative indirect effect on grain yield per plant via; flag leaf area (-7.277).

Yield per plot (g): Yield per plot had maximum positive indirect effect on grain yield per plant through spike bearing tillers per plant (5.939), flag leaf length (2.363). While, it had negative indirect effect on grain yield per plant via Number of grain per plant (-6.878), grain weight pes pike (-3.568).

4. CONCLUSION

Based on the above result of correlation studies it could be concluded that characters like Yield per plot showed highly significant positive association with grain weight per spike, grain length and number of grain per plant. Path coefficient analysis of different traits contributing towards grain yield per plant showed that flag leaf length had highest positive direct effect followed by number of grain per plant, flag leaf width, physiological maturity and yield per plot. Thus, this finding indicated that these traits could utilize in various breeding as well as improvement programmes. The information may further help the breeders in formulating appropriate strategy aimed at getting higher yield and character improvement in Bread wheat.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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