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Correlation and Path Coefficient Analysis in Bread Wheat (*Triticum aestivum* L.) Genotypes for Morpho-physiological Traits along with Grain Fe and Zn Content

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Authors' contributions

The work was carried out in collaboration among all authors. Author MB conducted the field study, performed the laboratory analysis and prepared the first draft. Authors VKC and SKS supervised the entire study and gave technical support. Author RP helped in experimental layout and data compilation. Author AKG helped in statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Character association studies help in assessing the relationship among yield and its components to enhance the selection utility. In view of this, the present research was carried out for assessing correlation and path coefficients among 30 bread wheat (*Triticum aestivum* L.) genotypes using fifteen quantitative parameters. Correlation analysis demonstrated a noteworthy positive relationship of days to fifty per cent flowering, number of tillers/plant, flag leaf area, spike length, plant height, chlorophyll content, relative water content, number of grains/ ear, thousand-grain weight, days to maturity and harvest index, with grain yield per plant at both the phenotypic and genotypic level except canopy temperature which showed a significant negative relationship. Path coefficient analysis revealed that plant height, flag leaf area, relative water content and grain per ear had the

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maximum positive direct effect on grain yield. Hence, the present investigation can be helpful in executing a reliable selection of parental lines based on these above mentioned traits in addition to developing high-yielding varieties for further breeding programme.

Keywords: Correlation analysis; path coefficient analysis; bread wheat; phenotypic.

1. INTRODUCTION

Wheat (*Triticum* spp.) is considered as one key staple food crop in numerous places of the globe not only in terms of the area under cultivation but as a rich source of food also. It covers all the continents of the globe, engaging 17 per cent of the world acreage of crops and feeds almost 40 per cent population globally [1]. Cultivation of the crop is distributed geographically in such an abundant manner that it is being reaped in one country or another all around the year. More than 3 billion population worldwide experience the malnutrition problems [2,3]. Malnutrition of micronutrient, predominantly the deficiency in Zinc and Iron globally afflicts more than three billion people. Since the Green Revolution, the yields of cereal grains worldwide have been boosted spectacularly, but cereal-based diet falls petite to provide adequate nutrients. Plant breeding can be employed as a potent weapon against the evil named 'hidden hunger' [4]. Grain yield is the most economically importance-holding character in wheat but it is a complex trait involving many characters. Hence, direct selection of grain yield would not be effective as well as efficient. It is equally important to understand the relationship of grain micronutrient contents with grain yield and other traits contributing to yield in order to execute any breeding programme in a right direction. Study on correlation coefficient and path coefficient analysis can enhance the efficiency of breeding programme through the utilization of appropriate selection indices. Correlation coefficient analysis assesses the joint association between varieties of plant traits. It also finds out the component traits on which we can base selection for genetic enhancement in yield. To find the degree and direction of association of yield with the traits contributing to yield and inter-relationship among them, analysis of correlation coefficient (phenotypic and genotypic) was executed. Path coefficient analysis is a statistical device that has uniqueness to split the correlation co-efficient into the effects of direct as well as indirect contribution through other variables that are dependent. A breeder gets assist in understanding if direct effect is causing the causal variable to be associated with the resultant variable (grain yield) or their indirect effect is the reason via several other variables. Therefore, the present study has been carried out to study correlation and path coefficient analysis between morpho-physiological traits alongwith contents of grain zinc and iron affecting the grain yield and its associated traits in bread wheat.

2. MATERIALS AND METHODS

We executed the current experiment counting 30 bread wheat (*Triticum aestivum* L.) genotypes in the Wheat Breeding section fields of RPCAU, Pusa, Samastipur, Bihar during the *Rabi* season of 2019-20 under irrigated condition with 3 replications in a Randomized Block Design. Each of the genotypes was nurtured in a plot having five rows of 3-meter length each with 23 centimeter spacing between the rows and 10 centimeter between the plants (within rows) in each of the three replications. Irrigations were applied in the crown root-initiation, late jointing and milking stages respectively. Regular agronomic practices were followed in the experimental field for raising good crops. Observations were documented for fifteen characters from each replication *viz.* plant height, flag leaf area, number of tillers/plant, relative water content, canopy temperature, spike length, chlorophyll content, days to fifty percent flowering, thousand-grain weight, no. of grains/ ear, harvest index, days to maturity, grain yield/ plant, grain Fe content and grain Zn content. Grain zinc and iron contents were estimated at the ICRISAT, HP-MAL, Hyderabad, India, with the help of X-ray Fluorescence Spectrophotometer (XRF). WINDOSTAT version 7.0 was used for statistical analysis of the recorded data on different characters. Calculation of phenotypic as well as genotypic correlation coefficients was performed from the components of variance and covariance as suggested by [5,6]. The correlation coefficient of yield with different quantitative traits was divided into direct as well as indirect effects by analyzing path coefficients as per the method of [7].

2.1 Genotypic Correlation Coefficient

Genotypic correlations were calculated considering genotypic values (σ^2gi and σ^2gj):

$$r(g_i, g_j) = \frac{Cov(g_i, g_j)}{\sqrt{V(g_i).V(g_j)}}$$

Where,

$r(g_i, g_j)$ is the genetic correlation between g_i and g_j.
Cov $(g_i\ g_j)$ is the covariance between g_i and g_j.
V (g_i) is the variance of g_i
V (g_j) is the variance of g_j

Table 1. List of 30 evaluated bread wheat genotypes

Serial No.	Names of the genotypes	Sources
1.	DBW 16	RPCAU
2.	DBW 17	RPCAU
3.	HD 2985	RPCAU
4.	RAJ 3763	RPCAU
5.	BHU 25	RPCAU
6.	HD 2824	RPCAU
7.	PBW 648	RPCAU
8.	RAUW-16-4	RPCAU
9.	RAUW-18-9	RPCAU
10.	RAUW-18-12	RPCAU
11.	RAUW-17-9	RPCAU
12.	RAUW-18-15	RPCAU
13.	RAUW-18-11	RPCAU
14.	RAUW-118-4	RPCAU
15.	RAUW-18-13	RPCAU
16.	RAUW-16-11	RPCAU
17.	RAUW-16-9	RPCAU
18.	RAUW-18-7	RPCAU
19.	RAUW-16-5	RPCAU
20.	RAUW-16-7	RPCAU
21.	RAUW-16-9	RPCAU
22.	RAUW-16-10	RPCAU
23.	RAUW-16-15	RPCAU
24.	RAUW-16-17	RPCAU
25.	RAUW-18-18	RPCAU
26.	RAUW-18-21	RPCAU
27.	RAUW-18-25	RPCAU
28.	RAUW-18-26	RPCAU
29.	Rajendra Genhu-3	RPCAU
30.	HD 2967	RPCAU

2.2 Phenotypic Correlation Coefficient

This was estimated by taking the help of phenotypic variance and covariance by employing the following formula:

$$r(p_i, p_j) = \frac{Cov(p_i, p_j)}{\sqrt{V(P_i).V(p_j)}}$$

Where,

$r(p_i, p_j)$ = Phenotypic correlation between p_i & p_j
Cov $(p_i\ p_j)$ = Covariance between P_i & P_j
V (p_i) = variance of P_i
V (p_j) = variance of P_j

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis

3.1.1 Phenotypic correlation analysis

Grain yield per plant exhibited highly significant positive correlation with 1000-grain weight (0.670), number of tillers per plant (0.636), number of grains/ ear (0.635), flag leaf area (0.634), relative water content (0.582), plant height (0.540), days to maturity (0.599), days to fifty percent flowering (0.523), spikelet length (0.469), harvest index (0.539) and exhibited a significant negative correlation with canopy temperature (-0.426). No. of tillers/ plant demonstrated a significantly positive alliance with plant height (0.564). Flag leaf area revealed a highly significant positive relationship with no. of tillers per plant (0.751) and plant height (0.396). Spike length exhibited highly significant positive correlation with flag leaf area (0.614), no. of tillers/ plant (0.588) and plant height (0.296). Relative water content confirmed to be in significant positive correlation with flag leaf area (0.614), no. of tillers/ plant (0.733), plant height (0.658), and spike length (0.593). Canopy temperature exhibited a highly significant negative alliance with relative water content (-0.571), flag leaf area (-0.650), no. of tillers/ plant (-0.677), spike length (-0.438) and plant height (-0.450). Chlorophyll content revealed correspondence in a highly significant positive manner with relative water content (0.327) and significant positive correlation with no. of tillers/ plant (0.230), flag leaf area (0.262), plant height (0.220) and spike length (0.213). Days to maturity revealed highly significant positive association with days to fifty percent flowering (0.842). The number of grains/ ear explained a significant positive alliance with number of tillers per plant (0.614), flag leaf area (0.631), plant height (0.530), spike length (0.564), relative water content (0.617) and chlorophyll content (0.323) but it illustrated a significant negative connection with canopy temperature (-0.529). Harvest index evidenced highly significant positive alliance with 1000-grain weight (0.711), relative water content (0.692), number of tillers per plant (0.646), flag leaf area (0.770), number of grains per ear (0.614), spike length (0.641) and plant height (0.513). However, it explained a highly significant negative connection with canopy temperature (-0.560) and significant positive correlation with chlorophyll content (0.267). Thousand-grain weight illustrated highly significant positive relationship with flag leaf area (0.708), number of grains per ear (0.632), number of tillers per plant (0.708), chlorophyll content (0.270), relative water content (0.634), spike length (0.598) and plant height (0.527). Grain Fe content exhibited positive alliance with days to fifty per cent flowering (0.084), number of tillers/ plant (0.047), plant height (0.028), chlorophyll content (0.023), flag leaf area (0.104), relative water content (0.010), harvest index (0.081), days to maturity (0.070) and canopy temperature (0.004). Grain Zn content demonstrated a highly significant positive alliance with number of tillers/ plant (0.284) and significant negative correlation with canopy temperature (-0.313) but with flag leaf area (0.219), plant height (0.250) and relative water content (0.258), it displayed a significant positive association.

3.1.2 Genotypic correlation analysis

The data on genotypic correlation made known that grain yield per plant was in a strong positive relationship with harvest index (0.977), relative water content (0.980), number of tillers/ plant (0.934), plant height (0.969), spike length (0.924), thousand-grain weight (0.949), flag leaf area (0.923), number of grains per ear (0.921), days to 50 per cent flowering (0.349), chlorophyll content (0.554) and days to maturity (0.412). However, it was negatively associated with canopy temperature (-0.939). The number of tillers/ plant showed a strong positive association with plant height (0.920). Flag leaf area illustrated a strong positive alliance with the number of tillers per plant (0.801) and plant height (0.900). Days to fifty per cent flowering revealed a positive relationship with flag leaf area (0.061) and number of tillers/ plant (0.205) in a low estimate. At the same time, it demonstrated a negative association with plant height (-0.073). Spike length exhibited a strong positive alliance with flag leaf area (0.830), plant height (0.968) and the number of tillers per plant (0.992). Relative water content showed strong positive relationship with number of tillers per plant (0.923), plant height (0.997), spike length (0.950) and flag leaf area (0.990). Canopy temperature exhibited a strong negative association with relative water content (-0.987), flag leaf area (-0.990), plant height (-0.987), spike length (-0.974), number of tillers/ plant (-0.821). Chlorophyll content revealed a strong positive relationship with relative water content (0.964), plant height (0.926), spike length (0.768), number of tillers/ plant (0.514), flag leaf area (0.446). However, with canopy temperature (-0.615), it exhibited a strong negative correlation. Days to maturity displayed a strong positive correspondence with days to fifty percent flowering (0.972). The number of grains/ ear demonstrated a strong positive alliance with flag leaf area (0.777), plant height (0.934), spike length (0.993), no. of tillers per plant (0.856), relative water content (0.831) and chlorophyll content (0.556). However, it displayed a strong negative correlation with canopy temperature (-0.910). 1000-grain weight illustrated a strong positive correspondence with no. of grains per ear (0.918), spike length (0.899), no. of tillers/ plant (0.871), flag leaf area (0.998), relative water content (0.706), plant height (0.860) and chlorophyll content (0.681). Harvest index showed evidence of a strong positive alliance with 1000-grain weight (0.980), relative water content (0.913), flag leaf area (0.895), no. of grains / ear (0.864), spike length (0.841), no. of tillers/ plant (0.775), chlorophyll content (0.685) and plant height (0.635). Grain Fe content exhibited a strong positive relationship with days to fifty percent flowering (0.298). Grain Zn content exhibited a strong positive connection with flag leaf area (0.334), plant height (0.494), no. of tillers/ plant (0.318), harvest index (0.322) and relative water content (0.315).

3.2 Path Coefficient Analysis

3.2.1 Phenotypic path coefficient analysis

Thousand-grain weight revealed the highest positive direct effect (0.364) and also substantial indirect effect in a positive manner via flag leaf area (0.209), plant height (0.108), no. of tillers per plant (0.150), chlorophyll content (0.043), no. of grains per ear (0.104), and relative water content (0.030). Plant height had a positive direct effect (0.205) on grain yield. Also, it illustrated positive indirect effect via 1000-grain weight (0.192), no. of tillers/ plant (0.119), no. of grains/ ear (0.087), chlorophyll content (0.035), flag leaf area (0.117) and relative water content (0.031). Number of tillers/ plant revealed a positive direct effect (0.211) on grain yield. It exhibited positive indirect effect via plant height (0.116), thousand-grain weight (0.258), relative water content

(0.035), flag leaf area (0.222), chlorophyll content (0.036). Flag leaf area expressed a positive direct effect on grain yield (0.295) and was built-up by indirect effect via 1000-grain weight (0.258), no. of tillers/ plant (0.159), no. of grains/ ear (0.104), plant height (0.081), chlorophyll content (0.041), relative water content (0.029). Although days to fifty percent flowering revealed negative direct effect (-0.134) with grain yield, but it had considerable positive indirect effect via thousand-grain weight (0.335), relative water content (0.324), plant height (0.019), no. of tillers/plant (0.028) and considerable negative indirect effect via days to maturity (-0.041). Spike length revealed negative direct effect (-0.019) on grain yield but depicted positive direct effect on grain yield per plant via the no. of tillers/ plant (0.124), flag leaf area (0.181), no. of grains per ear (0.093), thousand-grain weight (0.218), relative water content (0.028), plant height (0.061), and chlorophyll content (0.034). On grain yield, relative water content demonstrated direct effect as positive (0.047) and also considerable positive indirect effect via thousand-grain weight (0.231), flag leaf area (0.181), the no. of tillers per plant (0.155), chlorophyll content (0.051), no. of grains/ ear (0.102) and plant height (0.135). Canopy temperature demonstrated negative indirect effect via no. of grains/ ear (-0.087), 1000-grain weight (-0.223), no. of tillers/ plant (-0.143), flag leaf area (-0.192), plant height (-0.092), chlorophyll content (-0.037), and relative water content (-0.027). Chlorophyll content exhibited positive direct effect (0.157) on grain yield and positive indirect effect via thousand-grain weight (0.545), no. of tillers/ plant (0.049), number of grains/ ear (0.053), plant height (0.045), relative water content (0.016) and flag leaf area (0.077). Days to maturity, even though expressed direct effect as negative on grain yield (-0.049) but depicted indirect positive effect via thousand-grain weight (0.432), relative water content (0.284), no. of tillers/plant (0.030), plant height (0.015) and canopy temperature (0.010) along with indirect negative effect via days to fifty percent flowering (-0.113) and the no. of grains per ear (-0.011). The direct effect of the no. of grains per ear with grain yield (0.165) was accompanied by its indirect positive effect via thousand-grain weight (0.230), the no. of tillers/plant (0.130), chlorophyll content (0.051), flag leaf area (0.187), relative water content (0.029) and plant height (0.109). Harvest index showed negative direct effect (-0.226) but positive indirect effect via relative water content (0.033), chlorophyll content (0.042), no. of grains per ear (0.101), thousand grain weight (0.259), flag leaf area (0.228), plant height (0.105) and number of tillers/ plant (0.137) on grain yield. The indirect positive effect accompanied direct effect of grain Fe content with grain yield (0.053) via flag leaf area (0.031) and the number of tillers/ plant (0.010). Although grain Zn content revealed a negative direct effect with grain yield (-0.015), but showed its indirect positive effect via flag leaf area (0.065), 1000-grainiweight (0.062), no. of tillers/ plant (0.060), days to fifty percent flowering (0.026), plant height (0.051), no. of grains per ear (0.016) and relative water content (0.012).

3.2.2 Genotypic path coefficient analysis

Plant height displayed a positive direct effect (0.832) on grain yield and depicted positive genotypic relationship with grain yield (0.969) accompanied by its indirect effect via flag leaf area (0.907), the no. of grains/ ear (0.963), relative water content (0.934), no. of tillers per plant (0.832), 1000-grain weight (0.078), days to fifty percent flowering (0.073) and days to maturity (0.017). Number of tillers per plant revealed a positive direct effect (0.616) and positive indirect effect via flag leaf area (0.861), 1000-grain weight (0.051), relative water content (0.960), no. of grains/ ear (0.917), days to maturity (0.122). Flag leaf area expressed a positive direct effect on grain yield (0.961) in addition to positive indirect effect via no. of tillers per plant (0.716), no. of grains per ear (0.902), relative water content (0.982), 1000-grain weight (0.032), grain Fe content (0.014). Although days to fifty percent flowering showed evidence of direct effect as negative (-0.962) with grain yield per plant, but it had a positive genotypic association with grain yield (0.349) due to considerable positive indirect effect via flag leaf area (0.080), no. of tillers per plant (0.085), days to maturity (0.075), grain Zn content (0.075), 1000-grain weight (0.343), harvest index (0.016), relative water content (0.177), plant height (0.026) and grain Fe content (0.012). Spike length exerted positive direct effect (0.654) on grain yield and also positive indirect effect via relative water content (0.990), no. of tillers per plant (0.654), no. of grains per ear (0.986), flag leaf area (0.950) and thousand-grain weight (0.056). Relative water content showed a direct positive (0.999) effect on grain yield and it resulted due to considerable indirect effect via 1000-grain weight (0.047), flag leaf area (0.998), number of tillers/plant (0.483), no. of grains per ear (0.980), days to maturity (0.059). Canopy temperature showed a positive direct effect on

Table 2. The phenotypic and genotypic correlation coefficients for fifteen characters in bread wheat

Characters		PH	TP	FLA	DFF	SL	RWC	CT	CC	DM	GPE	TGW	HI	Fe	Zn
PH															
TP	P	0.564**													
	G	0.920													
FLA	P	0.396**	0.751**												
	G	0.900	0.801												
DFF	P	0.093	0.134	-0.025											
	G	-0.073	0.205	0.061											
SL	P	0.296**	0.588**	0.614**	-0.013										
	G	0.968	0.992	0.830	0.001										
RWC	P	0.658**	0.733**	0.614**	0.088	0.593**									
	G	0.997	0.923	0.990	0.098	0.950									
CT	P	-0.450**	-0.677**	-0.650**	-0.016	-0.438**	-0.571**								
	G	-0.987	-0.821	-0.990	0.064	-0.974	-0.987								
CC	P	0.220*	0.230*	0.262*	-0.015	0.213*	0.327**	-0.233*							
	G	0.926	0.514	0.446	0.011	0.768	0.964	-0.615							
DM	P	0.074	0.143	0.011	0.842**	0.022	0.086	0.044	-0.031						
	G	0.033	0.242	-0.005	0.972	-0.009	0.117	0.112	-0.017						
GPE	P	0.530**	0.614**	0.631**	-0.052	0.564**	0.617**	-0.529**	0.323**	-0.064					
	G	0.934	0.856	0.777	-0.044	0.993	0.831	-0.910	0.556	-0.090					
TGW	P	0.527**	0.708**	0.708**	0.097	0.598**	0.634**	-0.614**	0.270**	0.087	0.632**				
	G	0.860	0.871	0.998	0.064	0.899	0.706	-0.944	0.681	0.090	0.918				
HI	P	0.513**	0.646**	0.770**	-0.031	0.641**	0.692**	-0.560**	0.267*	0.015	0.614**	0.711**			
	G	0.635	0.775	0.895	-0.018	0.841	0.913	-0.856	0.685	-0.086	0.864	0.980			
Fe	P	0.028	0.047	0.104	0.084	-0.056	0.010	0.004	0.023	0.070	-0.071	-0.010	0.081		
	G	-0.020	0.061	0.119	0.298	-0.059	-0.032	0.028	0.102	0.101	-0.114	0.062	0.077		
Zn	P	0.250*	0.284**	0.219*	-0.197	0.047	0.258*	-0.313**	0.056	-0.184	0.112	0.171	0.192	-0.197	
	G	0.494	0.318	0.334	-0.232	0.225	0.315	-0.399	0.153	-0.220	0.200	0.269	0.322	-0.207	
GY	P	0.540**	0.636**	0.634**	0.523**	0.469**	0.582**	-0.426**	0.379**	0.599**	0.635**	0.670**	0.539**	0.062	0.167
	G	0.969	0.934	0.923	0.349	0.924	0.980	-0.939	0.554	0.412	0.921	0.949	0.977	0.091	0.052

** * Significant at one percent level = 0.270, * Significant at five percent level = 0.207*

PH=Plant height, TP= number of tillers/plant, FLA=Flag leaf area, DFF=Days to fifty percent flowering, SL=Spike length, RWC=Relative water content, CT=Canopy temperature, CC=Chlorophyll content, DM=Days to maturity, GPE= no. of grains/ ear, TGW=Thousand-grain weight, HI=Harvest index, Fe=Grain Fe content, Zn=Grain Zn content, GY= Grain yield/ plant

Table 3. Direct (diagonal) and indirect phenotypic effect of fifteen traits on grain yield in bread wheat genotypes

Characters	PH	TP	FLA	DFF	SL	RWC	CT	CC	DM	GPE	TGW	HI	Fe	Zn
PH	**0.205**	0.116	0.081	0.019	0.061	0.135	-0.092	0.045	0.015	0.109	0.108	0.105	0.006	0.051
TP	0.119	**0.211**	0.159	0.028	0.124	0.155	-0.143	0.049	0.030	0.130	0.150	0.137	0.010	0.060
FLA	0.117	0.222	**0.295**	-0.007	0.181	0.181	-0.192	0.077	0.003	0.187	0.209	0.228	0.031	0.065
DFF	-0.013	-0.018	0.003	**-0.134**	0.002	-0.012	0.002	0.002	-0.113	0.007	-0.013	0.004	-0.011	0.026
SL	-0.006	-0.011	-0.011	0.0002	**-0.019**	-0.011	0.008	-0.004	-0.001	-0.011	-0.011	-0.012	0.001	-0.001
RWC	0.031	0.035	0.029	0.324	0.028	**0.047**	-0.027	0.016	0.284	0.029	0.030	0.033	0.001	0.012
CT	-0.106	-0.160	-0.153	-0.004	-0.103	-0.135	**0.236**	-0.055	0.010	-0.12	-0.145	-0.132	0.001	-0.074
CC	0.035	0.036	0.041	-0.002	0.034	0.051	-0.037	**0.157**	-0.005	0.051	0.043	0.042	0.004	0.009
DM	-0.004	-0.007	-0.001	-0.041	-0.001	-0.004	-0.002	0.001	**-0.049**	0.003	-0.004	-0.001	-0.003	0.009
GPE	0.087	0.101	0.104	-0.009	0.093	0.102	-0.087	0.053	-0.011	**0.165**	0.104	0.101	-0.012	0.016
TGW	0.192	0.258	0.258	0.335	0.218	0.231	-0.223	0.098	0.432	0.230	**0.364**	0.259	-0.004	0.062
HI	-0.116	-0.146	-0.174	0.007	-0.145	-0.156	0.126	-0.060	-0.003	-0.139	-0.161	**-0.226**	-0.018	-0.043
Fe	0.002	0.003	0.006	0.004	-0.003	0.001	0.0002	0.001	0.004	-0.004	-0.001	0.004	**0.053**	-0.010
Zn	-0.539	-0.004	-0.003	0.003	-0.001	-0.004	0.005	-0.001	0.003	-0.002	-0.003	-0.003	0.003	**-0.015**
GY	**0.540****	**0.636****	**0.634****	**0.523****	**0.469****	**0.582****	**-0.426****	**0.379****	**0.599****	**0.635****	**0.670****	**0.539****	**0.062**	**0.167**

RESIDUAL EFFECT = 0.5887

Table 4. Direct (diagonal) and indirect genotypic effect of fifteen traits on grain yield in bread wheat genotypes

Characters	PH	TP	FLA	DFF	SL	RWC	CT	CC	DM	GPE	TGW	HI	Fe	Zn
PH	**0.832**	-0.552	-0.418	0.026	-0.751	-0.391	0.340	-0.373	-0.012	-0.521	-0.603	-0.364	0.007	-0.179
TP	-0.363	**0.616**	0.716	0.085	-0.625	0.483	-0.730	0.213	0.101	0.656	0.098	0.497	0.025	0.132
FLA	0.907	0.861	**0.961**	0.080	0.950	0.998	-0.998	-0.316	-0.006	0.918	0.940	0.938	0.156	0.437
DFF	0.073	-0.205	-0.061	**-0.962**	-0.001	-0.099	-0.097	-0.011	-0.974	0.044	-0.045	0.018	-0.099	0.232
SL	-0.940	-0.847	-0.765	-0.001	**0.654**	-0.962	0.951	-0.717	0.012	-0.915	-0.988	-0.612	0.078	-0.298
RWC	0.934	0.960	0.982	0.177	0.990	**0.999**	-0.978	0.964	0.410	0.996	0.979	0.920	-0.058	0.566
CT	-0.120	-0.083	-0.080	0.005	-0.095	-0.080	**0.081**	-0.050	0.009	-0.074	-0.034	-0.093	0.002	-0.032
CC	-0.560	-0.280	-0.243	-0.046	-0.319	-0.326	0.335	**0.584**	0.009	-0.303	-0.201	-0.261	-0.055	-0.303
DM	0.017	0.122	-0.011	0.591	-0.005	0.059	0.056	-0.009	**0.505**	-0.046	0.085	-0.043	0.051	-0.111
GPE	0.963	0.917	0.902	-0.052	0.986	0.980	-0.921	0.680	-0.107	**0.988**	0.990	0.928	-0.136	0.238
TGW	0.078	0.051	0.032	0.343	0.056	0.047	-0.069	0.029	0.304	0.043	**0.545**	0.056	0.003	0.013
HI	-0.690	-0.530	-0.998	0.016	-0.840	-0.621	0.958	-0.402	0.078	-0.787	-0.910	**-0.911**	-0.070	-0.294
Fe	-0.002	0.007	0.014	0.012	-0.005	-0.005	0.003	0.012	0.012	-0.013	0.139	0.009	**0.118**	-0.024
Zn	-0.160	-0.103	-0.108	0.075	-0.071	-0.102	0.130	-0.050	0.071	-0.065	-0.046	-0.105	0.069	**-0.325**
GY	**0.969**	**0.934**	**0.923**	**0.349**	**0.924**	**0.980**	**-0.939**	**0.554**	**0.412**	**0.921**	**0.949**	**0.977**	**0.091**	**0.052**

RESIDUAL EFFECT = 0.520

grain yield (0.081) but negative indirect effect via flag leaf area (-0.998), relative water content (-0.978), no. of grains/ ear (-0.921), days to 50% flowering (-0.097) and thousand-grain weight (-0.069). Chlorophyll content exhibited a positive direct effect (0.584) and positive indirect effect via a number of grains per ear (0.680), flag leaf area (0.584), relative water content (0.964), no. of tillers/ plant (0.213), 1000-grain weight (0.029), grain Fe content (0.012) on grain yield. Days to maturity expressed the direct effect as positive (0.505) on grain yield accompanied by indirect effect via no. of tillers/ plant (0.101), 1000-grain weight (0.304), relative water content (0.410), grain Fe content (0.012), grain Zn content (0.071), harvest index (0.078) and spike length (0.012). The direct effect of the no. of grains/ ear on grain yield (0.988) was accompanied by its positive indirect effect via days to 50 percent flowering (0.044), relative water content (0.996), flag leaf area (0.918), no. of tillers per plant (0.656) and 1000-grain weight (0.043) on grain yield. Thousand-grain weight had direct positive effect (0.098) on grain yield per plant and had positive indirect effect via no. of tillers per plant (0.545), flag leaf area (0.940), no. of grains per ear (0.990), relative water content (0.979), grain Fe content (0.139) and days to maturity (0.085). Harvest index showed negative direct effect (-0.911) and positive indirect effect via flag leaf area (0.938), no. of grains/ ear (0.928), thousand-grain weight (0.056), relative water content (0.920) and days to fifty percent flowering (0.018) on grain yield. Grain Fe content had a positive direct effect on grain yield (0.118) and positive indirect effect via flag leaf area (0.156), grain Zn content (0.069), spike length (0.078), no. of tillers/plant (0.025) and days to maturity (0.051). Although grain Zn content revealed a negative direct effect with grain yield (-0.325) but showed positive genotypic association with grain yield (0.052). Its positive indirect effect on grain yield was accompanied via relative water content (0.566), no. of grains per ear (0.238), no. of tillers per plant (0.132), flag leaf area (0.437), days to fifty percent flowering (0.232), 1000-grain weight (0.013).

The values of phenotypic correlation coefficient were lesser as compared to the genotypic values in general. This was the indication that environmental effects masked strong intrinsic associations at the phenotypic level. The results were similar to [8,9]. A significant positive association was revealed by grain yield/plant with flag leaf area, days to maturity, no. of tillers/ plant, thousand-grain weight, no. of grains/ ear, days to fifty percent flowering, relative water content, harvest index, plant height, spikelet length at both the phenotypic along with genotypic levels. The association of grain yield/ plant with grain Zn content and grain Fe content were non-significant.. These results were followed earlier works of [10-16]. At phenotypic level, the traits *viz.* flag leaf area, no. of tillers/ plant, thousand-grain weight, canopy temperature, plant height exhibited high positive direct effect. At genotypic level, plant height, relative water content, no. of grains/ ear, flag leaf area, no. of tillers/ plant, thousand-grain weight demonstrated maximum positive direct effect on grain yield/ plant, but grain Fe content and canopy temperature showed the positive direct effect to a moderate extent. These findings were in line with [17-21].

4. CONCLUSION

We can conclude from the findings that canopy temperature revealed negative alliance with chlorophyll content, no. of grains per ear, harvest index, 1000-grain weight, grain Fe content and grain Zn content. This finding signifies that superior canopy temperature steered fall in yield potential. We should give importance on the characters *viz.* plant height, flag leaf area, relative water content, grain per ear, has a positive, strong association and direct effect at genotypic level. Whereas, in addition to the above no. of tiller/plant, spike length, thousand grain weight and harvest index, are strongly correlated with grain yield. Therefore, in the course of selection for improving the yield potential in view of the fact that not only positively correlated with grain yield as well as among themselves but also showed high direct effect and via these traits, all other traits revealed indirect contribution towards grain yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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