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CORRELATION AND PATH COEFFICIENT ANALYSES IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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Abstarct

Phenotypic and genotypic coefficients of variation (PCV, GCV), heritability, genetic advance (GA) and correlation and path coefficients for 13 characters were estimated in 47 genotypes of bread wheat *(Triticum aestivum* L.). The PCV was greater than GCV for all the characters which reflects the existing range of variability within the genotypes was not only due to varying influence of genotype but also environment. High heritability along with high genetic advance was observed for characters such as grain yield plant^{-1}, ear weight and number of ears plant^{-1} which indicates that improvement in these traits can be done by direct selection. In correlation analysis the highest positive and significant correlation was recorded in harvest index, biological yield plant^{-1}, number of ears plant^{-1}, number of productive tillers plant^{-1} and ear weight on the dependent character *i.e.* grain yield per plant. In the path analysis the highest positive direct effect was observed in biological yield plant^{-1}, harvest index, ear length, 1000-grain weight, days to 50% heading and number of spikelet's ear$^{-1.}$ Traits such as number of productive tillers plant^{-1} and plant height had negative direct effect on yield. Traits such as biological yield plant^{-1}, number of ears plant^{-1} and number of productive tillers plant^{-1} showed positive indirect effect on yield. Therefore these traits may be effective in selection during breeding programme for improving grain yield and quality.

Key words: Bread wheat, path, correlation coefficient, genetic variability, genetic advance, heritability

Introduction

Bread wheat (*Triticum aestivum* L. em Thell. 2n = 6x = 42) is a self-pollinating annual plant belonging to family Poaceae. Being the largest cereal crop it is known as the "king of cereals" due to high productivity and prominent position it holds in the international food grain trade. To satisfy the demands of the increasing population all over the world, increase in production has become a major priority over the years.

Information regarding the existing genetic variability among the genotypes forms the basic requirement for selection. In order to improve production, grain yield plays a vital role. However grain yield is a polygenic trait which is influenced by many genetic and environmental factor therefore direct selection of yield can lead to errors. Various morphological traits are taken under consideration which helps to study the association between the grain yield and hence results in effective selection. Correlation coefficient is an important statistical method which helps to select the best high yielding genotype by studying the strength of relationship among the considered traits as well as the magnitude and direction during selection. However simple correlation is not sufficient to provide the required information about the contribution of each character towards yield. Therefore path coefficient analysis is utilised which separates the direct effects from the indirect effects through other related characters (Dewey and Lu, 1959).

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Materials and methods

The experimental material consisted of 47 wheat genotypes *viz*. DPW-621-50, PBW- 625, DBW- 14, WH-

1105, DBW- 17, PBW- 723, JW- 3211, PBW- 550 , DBW- 71, DBW- 39, CBW- 38, DBW- 16, HD- 2967, HD- 3086, DBW-107, RUJ-4037, DBW-110, DBW- 93, WH- 703, PBW- 677, DBW- 90, DBW- 88, PBW- 343, MP- 3336, MP- 3382, HD- 2932, HI- 1500, JWS- 17, LOK- 4, C- 360, MP- 3288, HI- 8627, GW- 322, HI-1544, HI- 8713, GW-273, MP-3020, MP-4010, MP-1203, HI-8498, HI-1531, HW-2004, GW-3366, MP-3173, LOK-1, HD-3987 and HI-1418. The present experiment was carried out under field condition in the Agricultural Research Field, 2017-18, School of Agriculture, Lovely Professional University, Phagwara, Punjab during *Rabi* season. The genotypes were sown in Randomized Block Design with three replications. Length of line was 3 meter and row to row spacing was 20 cm with appropriate plant to plant distance is 4-6 cm. All the cultural practices were followed and weeds were removed manually as required. Data for days to 50% heading and days to maturity was recorded on plot basis. At maturity five plants were selected randomly from each plot in each replication for recording the quantitative data *viz.,* plant height, number of productive tillers plant^{-1}, number of spikelet's ear^{-1}, ear length(cm), ear weight(g), number of ears plant^{-1}, number of grains ear^{-1}, 1000-grain weight(g), biological yield plant^{-1}(g), grain yield per plant (g) and harvest index (%).

The mean performance of each genotype was estimated for the statistical analysis. The statistical analysis was done by using the method put forth by Panse and Sukhatme (1954). Correlation coefficient and path coefficient was worked out as method suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

Results and discussion

The analysis of variance for the forty-seven genotypes revealed that the treatments were highly significant for all the traits (Table 1). This indicates that the genotypes were genetically variable and exhibits a wide range of variability among each other to measure traits. Similar findings were reported by Fellahi *et al.,* (2013).

The parameters of genetic variability of all the experimental material for all the characters studied were worked out and are presented in the table 2. Parameters such as GCV, PCV, heritability, genetic advance and genetic advance as percent of mean were analyzed. The PCV was greater than GCV for all the characters which reflects the existing range of variability within the genotypes in expression of traits was also due to environment. The GCV ranged from 0.623 to 26.153 and the PCV ranged from 1.565 to 35.123. High PCV was observed in grain yield plant^{-1} (35.123), which was followed by harvest index (29.602), biological yield plant^{-1} (28.484), number of productive tillers plant^{-1} (26.915), ear weight (26.580), number of ears plant^{-1} (24.470), 1000-grain weight (14.133), ear length (11.243), number of spikelets ear^{-1} (10.205), number of grains ear^{-1} (10.047), plant height (9.739), days to 50% heading (3.777), days to maturity (1.565). The genotypic coefficient of variance was highest in grain yield plant^{-1} (26.153) followed by ear weight (22.523), number of ears plant^{-1} (19.825), number of productive tillers plant^{-1} (17.825), harvest index (15.543), biological yield plant^{-1} (13.782), plant height (8.472), ear length (7.563), 1000-grain weight (6.714), number of spikelets ear^{-1} (6.579), number of grains ear^{-1} (6.422), days to 50% heading (1.508) and days to maturity (0.623). Similar findings of high PCV and GCV was reported for harvest index, biological yield plant^{-1}, 1000-grain weight and grain yield plant^{-1} by Kumar *et al.,* (2014) and Avinashe *et al.,* (2017). Abinasha and Ayana (2011) and Avinashe *et al.,* (2015) also reported similar findings for harvest index, plant height, biological yield plant^{-1}, grain yield plant^{-1} and 1000-grain weight.

To determine the expression of a trait, role of heredity and environment is very essential therefore heritability is considered as an important quantitative parameter (Allard, 1960). The result of heritability varied from 75.67% plant height to 15.86% days to maturity. High heritability was recorded for plant height (75.67%) which was followed by ear weight per plant (71.80%). Medium heritability was observed for number of ears plant^{-1} (65.64%) and

Table 1: Analysis of variance for various yield contributing characters in wheat

Characters	Mean sum of squares		
	Replication (d.f= 2)	Treatment (d.f= 46)	Error **(d.f= 92)**
Days to 50% heading	37.297	19.839**	12.645
Days to maturity	2.177	7.220**	4.612
Plant height (cm)	27.978	266.974**	25.843
No. of productive tillers plant^{-1}	13.054	14.130**	4.225
No. of Spikelets ear^{-1}	4.819	6.341**	2.023
No. of ears plant^{-1}	7.777	19.463**	2.891
No. of grains ear^{-1}	41.954	54.965**	17.888
Ear length (cm)	2.515	2.839**	0.816
Ear weight per plant (g)	0.242	1.857**	0.214
1000-grain weight (g)	55.432	49.297**	26.300
Biological yield plant^{-1}(g)	482.805	523.682**	273.167
Harvest index	109.689	96.362**	44.987
Grain yield plant^{-1} (g)	40.155	76.164**	16.090

*, ** significant at 5% and 1% levels, respectively

Table 2: Estimates of variability, heritability and genetic advance as per cent of mean in wheat

Characters	Range			Coefficient of variation(%)		Heritability (%)	Genetic Advance	Genetic sadvance as % of mean
	Min	Max	Mean	PCV	GCV			
Days to 50% heading	94.667	108.333	102.681	3.777	1.508	15.941	1.274	1.240
Days to maturity	148.000	152.667	149.631	1.565	0.623	15.863	0.765	0.511
Plant height(cm)	91.133	130.200	105.824	9.739	8.472	75.670	16.066	15.181
No. of Productive tillers plant^{-1}	6.200	15.000	10.194	26.915	17.825	43.860	2.479	24.318
No. of spikelets ear^{-1}	15.933	21.200	18.235	10.205	6.579	41.557	1.593	8.736
Ear length (cm)	8.767	14.033	10.859	11.243	7.563	45.252	1.138	10.481
Ear weight per plant (g)	2.097	4.742	3.286	26.580	22.523	71.804	1.292	39.316
No. of ears plant^{-1}	7.867	16.867	11.855	24.470	19.825	65.641	3.923	33.088
No. of grains ear^{-1}	47.800	63.600	54.742	10.047	6.422	40.860	4.629	8.457
1000-grain weight (g)	33.667	54.800	41.236	14.133	6.714	22.568	2.710	6.571
Biological yield plant^{-1}	41.000	92.333	66.304	28.484	13.782	23.412	9.108	13.738
Harvest index	14.480	40.567	26.624	29.602	15.543	27.571	4.476	16.813
Grain yield plant^{-1} (g)	10.017	31.349	17.110	35.123	26.153	55.446	6.864	40.117

grain yield plant^{-1} (55.44%). Low heritability was recorded for ear length (45.25%), number of productive tillers plant^{-1} (43.86%), number of spikelets ear^{-1} (41.55%) and number of grains ear^{-1} (40.86%). The present findings are similar with the earlier reported by Ali and Shakor (2012) for high heritable characters like plant height and grain yield plant^{-1}. Also similar reports were given by Tripathi *et al.,* (2011) for plant height.

Very low heritability was also recorded for characters like harvest index (27.57%), biological yield plant^{-1} (23.41%), 1000-grain weight (22.56%), days to 50% heading (15.94%) and days to maturity (15.86%). Genetic advance as per cent of mean was highest for grain yield plant^{-1} (40.11) followed by ear weight (39.31), number of ears plant^{-1} (33.088), number of productive tillers plant^{-1} (24.31), harvest index (16.81), plant height (15.18), biological yield plant^{-1} (13.73), ear length (10.48), number of spikelets ear^{-1} (8.73), number of grains ear^{-1} (8.45), 1000-grain weight (6.57), days to 50% heading (1.24) and days to maturity (0.51). High values of genetic advance are indicative of additive gene action whereas low values are indicative of non-additive gene action (Singh and Narayanan, 1993). High heritability along with high genetic advance was observed for characters such as grain yield plant^{-1}, ear weight and number of ears plant^{-1} which indicates that improvement in these traits can be done by direct selection. High heritability along with moderate genetic advance was recorded for plant height, number of productive tillers plant^{-1} and harvest index suggesting presence of additive and non-additive gene action. Similar findings were recorded by Fellahi (2013). This result showed close resemblance with the report by Dutamo (2015) for grain yieldplant^{-1} and harvest index.

Correlation coefficient is used to determine the component characters which are positively correlated to yield on which selection can be done for genetic yield improvement. Correlation helps breeders to develop the best high yielding plant type by studying the extent of association between different morphological characters. The data recorded for correlation coefficient among the 13 character is given in table 3. The study estimated the highest positive and significant correlation in harvest index (0.91, 0.56), followed by biological yield plant^{-1} (0.74, 0.55), number of ears plant^{-1} (0.65, 0.51), number of productive tillers plant^{-1} (0.60, 0.54) and ear weight (0.26, 0.22) at both genotypic and phenotypic level. The present study is in agreement with previous reports by Singh *et al.,* (2004) for biological yield plant^{-1}, ear weight and number of productive tillers plant^{-1} and Kumar *et al.* (2014) for harvest index and biological yield plant^{-1} which showed positive association with grain yield plant^{-1}. Thus it will be beneficial to select the above characters for higher yield.

When characters with direct effect on yield are selected it is important to consider their association with other characters as they will indirectly affect the yield. Days to 50% heading showed positive significant association with biological yield plant^{-1} (0.62), number of ears plant^{-1} (0.59), number of productive tillers plant^{-1} (0.51) and plant height (0.18) at genotypic level and negative significant association with harvest index (-0.49), 1000-grain weight (-0.22), and days to maturity (-0.17) at genotypic level. Days to maturity showed positive significant association with plant height (0.16) at genotypic level and negative significant association with biological yield plant^{-1} (-0.65), ear weight (-0.45), harvest index

Table 3: Genotypic (G) and phenotypic (P) coefficient of correlation among different character in wheat genotypes

Characters		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	**G**	**1.000**	-0.173*	0.180*	0.515**	0.009	0.021	-0.096	0.595**	0.026	-0.229**	0.626**	-0.499**	0.102
	P	**1.000**	0.067	-0.001	0.069	0.090	-0.015	-0.093	0.069	0.079	-0.009	-0.033	0.091	0.045
X2	**G**		**1.000**	0.167*	-0.126	0.097	0.098	-0.453**	-0.197*	0.089	-0.093	-0.656**	-0.427**	-0.750**
	P		**1.000**	0.052	0.142	0.152	0.123	-0.042	0.048	0.139	-0.042	0.082	-0.069	-0.054
X3	**G**			**1.000**	0.390**	0.090	0.268**	0.018	0.429**	0.042	0.147	0.684**	-0.345**	0.068
	P			**1.000**	0.215*	0.103	0.173*	-0.047	0.316**	0.102	0.041	0.313**	-0.183*	0.045
X4	**G**				**1.000**	-0.210*	0.124	0.111	0.935**	-0.203*	-0.277**	0.831**	0.339**	0.609**
	P				**1.000**	-0.033	0.179*	0.106	0.796**	-0.050	-0.025	0.714**	-0.015	0.548**
X5	**G**					**1.000**	0.101	0.608**	-0.312**	1.000**	-0.198*	0.029	0.123	0.095
	P					**1.000**	0.396**	0.376**	-0.061	0.992**	-0.091	0.094	0.086	0.148
X6	**G**						**1.000**	0.193*	-0.061	0.110	-0.457**	-0.156	-0.123	-0.129
	P						**1.000**	0.109	0.100	0.398**	-0.075	0.130	-0.024	0.108
X7	**G**							**1.000**	0.120	0.624**	0.155	0.435**	-0.030	0.267**
	P							**1.000**	0.120	0.370**	0.122	0.290**	-0.058	0.228**
X8	**G**								**1.000**	-0.333**	0.035	1.015**	0.177*	0.658**
	P								**1.000**	-0.075	0.037	0.692**	-0.004	0.515**
X9	**G**									**1.000**	-0.196*	0.008	0.144	0.104
	P									**1.000**	-0.089	0.072	0.094	0.144
X10	**G**										**1.000**	0.295**	-0.336**	0.030
	P										**1.000**	0.153	-0.096	0.020
X11	**G**											**1.000**	0.404**	0.748**
	P											**1.000**	-0.267**	0.555**
X12	**G**												**1.000**	0.912**
	P												**1.000**	0.563**

*, ** significant at 5% and 1% levels, respectively

X1: Days to 50% heading, **X2:** Days to maturity, **X3:** Plant height, **X4:** No. of productive tillers plant^{-1}, **X5:** No. of spikelets ear^{-1}, **X6:** Ear length (cm), **X7:** Ear weight per plant (g), **X8**: Ears plant^{-1}, **X9:** Grains ear^{-1}, **X10:** 1000-grain weight (g), **X11:** Biological yield plant^{-1} (g), **X12:** Harvest index, **X13:** Grain yield plant^{-1} (g)

(-0.42) and number of ears plant^{-1} (-0.19) at genotypic level. Plant height showed positive significant association at both levels with biological yield plant^{-1} (0.68, 0.31), number of ears plant^{-1} (0.42, 0.31), number of productive tillers plant^{-1} (0.39, 0.21) and ear length (0.26, 0.17) whereas negative significant association with harvest index (-0.34) at genotypic level. Number of productive tillers plant^{-1} showed positive significant association at both levels with number of ears plant^{-1} (0.93, 0.79) and biological yield plant^{-1} (0.83, 0.71) whereas ear length (0.17) at phenotypic level and harvest index (0.33) at genotypic level. Number of productive tillers plant^{-1} showed negative significant association at genotypic level with 1000-grain weight (-0.27), number of spikelet's ear^{-1} (-0.21) and number of grains ear^{-1} (-0.20). Number of spikelet's ear^{-1} showed positive significant association at both levels with ear weight (0.60, 0.37) and number of grains ear^{-1} (1.00, 0.99) whereas ear length (0.39) at phenotypic level. Moreover it showed negative significant association with number of ears plant^{-1} (-0.31) and 1000-grain weight (-0.19). Ear length showed positive significant association with number of grains ear^{-1} (0.39) at phenotypic level whereas ear weight per plant (0.19) at genotypic level. It also showed negative significant association with 1000-grain weight (-0.45) at genotypic level. Ear weight showed positive significant association at both levels with number of grains ear^{-1} (0.62, 0.37) and biological yield plant^{-1} (0.43, 0.29). Number of ears plant^{-1} showed positive significant association at both levels with biological yield plant^{-1} (1.01, 0.69) whereas at genotypic level with harvest index (0.17). It also showed negative significant association with number of grains ear^{-1} (-0.33) at genotypic level. Number of grains ear^{-1} showed negative significant association with 1000-grain weight (-0.19) at genotypic level. 1000-grain weight showed positive significant association at genotypic level with biological yield plant^{-1} (0.29) whereas negative significant association with harvest index (-0.33) at genotypic level. Biological yield plant^{-1} showed positive significant association at genotypic level with harvest

Table 4: Path coefficient showing direct (diagonal) and indirect effect (off diagonal) of different characters on grain yield plant^{-1} in wheat

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	**0.10257**	-0.00994	-0.06280	-0.20947	0.00062	0.00739	0.01751	0.15650	0.00145	-0.04721	0.50650	-0.36094
X2	-0.01774	**0.05749**	-0.05813	0.05108	0.00631	0.03495	0.08245	-0.05173	0.00488	-0.01927	-0.53120	-0.30896
X3	0.01851	0.00960	**-0.34805**	-0.15866	0.00587	0.09505	-0.00335	0.11278	0.00229	0.03031	0.55350	-0.24944
X4	0.05284	-0.00722	-0.13581	**-0.40659**	-0.01372	0.04416	-0.02028	0.24601	-0.01118	-0.05711	0.67238	0.24505
X5	0.00097	0.00556	-0.03130	0.08551	**0.06523**	0.03580	-0.11070	-0.08204	0.05512	-0.04095	0.02321	0.08898
X6	0.00214	0.00566	-0.09320	-0.05059	0.00658	**0.35494**	-0.03508	-0.01613	0.00605	-0.09434	-0.12610	-0.08922
X7	-0.00987	-0.02605	-0.00641	-0.04530	0.03968	0.06842	**-0.18199**	0.03168	0.03436	0.03206	0.35196	-0.02141
X8	0.06100	-0.01130	-0.14917	-0.38010	-0.02033	0.06100	-0.01130	**-0.14917**	-0.38010	-0.02033	0.06100	-0.01130
X9	0.00270	0.00509	-0.01446	0.08246	0.06524	0.03894	-0.11347	-0.08770	**0.05511**	-0.04049	0.00638	0.10421
X10	0.02345	-0.00536	-0.05108	0.11245	-0.01293	-0.16215	-0.02825	0.00927	-0.01080	**0.20651**	0.23872	-0.24328
X11	0.06418	-0.03773	-0.23799	-0.33774	0.00187	-0.05529	-0.07913	0.26712	0.00043	0.06090	**0.80947**	0.29209
X12	0.05115	-0.02454	0.11994	-0.13765	0.00802	-0.04375	0.00538	0.04653	0.00793	-0.06941	0.32663	**0.72385**

Residual Effect = **-0.05855**

X1: Days to 50% heading, **X2:** Days to maturity, **X3:** Plant height, **X4:** No. of productive tillers plant^{-1}, **X5:** No. of spikelets ear^{-1}, **X6:** Ear length (cm), **X7:** Ear weight per plant (g), **X8**: Ears plant^{-1}, **X9:** Grains ear^{-1}, **X10:** 1000-grain weight (g), **X11:** Biological yield plant^{-1}(g), **X12:**Harvest index

index (0.40) whereas negative significant association with harvest index (-0.26) at phenotypic level. All these results were in close resemblance to the findings reported by Ali and Shakor (2012) and Rajput (2018). Very close findings to the result were reported were given by Mecha *et al.,* (2017).

Path coefficient analysis is more important as it helps to estimate both direct and indirect causes of correlation and also enables to compare the component factors on the basis of their relative contributors (Dewey and Lu, 1959). The path coefficient analysis (Table 4) revealed the highest positive direct effect was imposed by biological yield plant^{-1} (0.80) followed by harvest index (0.72), ear length (0.35), 1000-grain weight (0.20), days to 50% heading (0.10) and number of spikelet's ear^{-1} (0.06) on the dependent character *i.e.* grain yield per plant. This results were in conformity with findings reported by Bhushan *et al.* (2013) who observed highest contribution towards grain yield with harvest index, biological yield per plant and days to maturity. Baranwal and Mishra (2012) also observed similar findings in ear length and 1000-grain weight. Selection of these characters as main component in breeding programmes can be beneficial for higher grain yield. The highest negative direct effect on yield was observed in number of productive tillers plant^{-1} (-0.40) followed by plant height (-0.34), ear weight per plant (-0.18) and number of ears plant^{-1} (-0.14). Similar findings was reported by Bhushan *et al.* (2013) that plant height has direct but negative effects on grain yield.

Days to 50% heading exhibited positive indirect effect via characters like biological yield plant^{-1} (0.50), number of ears plant^{-1} (0.15) and ear weight (0.01); days to maturity showed positive indirect effect *via* ear weight (0.08), number of productive tillers plant^{-1} (0.05) and ear length (0.03); plant height exhibited positive indirect effect *via* biological yield plant^{-1} (0.55), number of ears plant^{-1} (0.11) and 1000-grain weight (0.03); number of productive tillers plant^{-1} positive indirect effect via biological yield plant^{-1} (0.67), number of ears plant^{-1} (0.24) and days to 50% heading (0.05); number of spikelets ear^{-1} showed positive indirect effect *via* harvest index (0.08) and number of productive tillers plant^{-1} (0.08); ear weight showed positive indirect effect via biological yield plant^{-1} (0.35), ear length (0.06) and number of spikelets ear^{-1} (0.03); number of ears plant^{-1} showed positive indirect effect via days to 50% heading (0.06), ear length (0.06) and biological yield plant^{-1} (0.06); number of grains ear^{-1} showed positive indirect effect via harvest index (0.10) and number of productive tillers plant^{-1} (0.08); 1000-grain weight showed positive indirect effect via biological yield plant^{-1} (0.23) and number of productive tillers plant^{-1} (0.11); biological yield plant^{-1} showed positive indirect effect via harvest index (0.29) and number of ears plant^{-1} (0.26) and harvest index showed positive indirect effect via biological yield plant^{-1} (0.32) and plant height (0.11). Khan *et al.,* (2009), Khan and Alam (2013) reported similar results for positive indirect effect on the grain yield. These results showed close resemblance to findings of Mecha *et al.,* (2017).

Therefore it can be concluded that in wheat the highest positive and significant correlation was recorded in harvest index, biological yield plant^{-1}, number of ears plant^{-1}, number of productive tillers plant^{-1} and ear weight on the dependent character *i.e.* grain yield per plant. In the path analysis the highest positive direct effect was observed in biological yield plant^{-1}, harvest index, ear length, 1000-grain weight, days to 50% heading and number of spikelet's ear^{-1}. So traits like harvest index and biological yield plant^{-1} show both positive correlation as well as positive direct effect on grain yield per plant. Hence selection of these traits can bring about yield improvement in wheat.

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