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Heritability and correlation studies of yield and yield related traits in bread wheat (*Triticum aestivum* L.)

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Abstract
The experiment was undertaken to study the correlation and path coefficient analysis for yield and yield attributing traits. Total of eight wheat genotypes were grown in Randomized Block Design along with three replications at Research Farm, Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India. The resultant analysis of variance revealed that treatments were significant for all the characters. The value of PCV was much higher than GCV for all the traits signifying varying expression of traits was due to both genotype as well as environment. High GCV and PCV value was recorded only for ear weight. Low heritability accompanied with high magnitude of genetic advance was observed for biological yield/plant indicates the trait was governed by additive gene effect but low heritability observed due to high environmental effects, so selection may be effective only to a certain extent. The correlation coefficient estimated positive and significant genotypic and phenotypic correlation for harvest index and ear weight, while negative and significant correlation between day to 50% heading and grain yield/plant. The path coefficient analysis showed highest positive direct effects for harvest index followed by biological yield/plant, days to maturity, plant height, ear weight, number of grains/plant and 1000 grain weight on the dependent character. Whereas highest negative direct effect imposed by ear length followed by number of ears/plant, number of productive tillers/plant, days to 50% heading and number of spiklets/plant.

Keywords: Genetic variability, PCV, GCV, correlation coefficient, path analysis and wheat

Introduction
Wheat (*Triticum aestivum* L. em. Thell.) is a highly self-pollinated crop belongs to Poaceae family. There are many type of wheat. These are Emmer wheat (*T. dicoccum*), Macaroni wheat (*T. durum*), Common bread wheat (*T. vulgare*), Indian dwarf wheat (*T. spherococcum*) and Bread Wheat (*T. aestivum*). *T. aestivum* is hexaploid (2n=6x=42) species. Mostly in India *T. aestivum* utilize as a major stable foods. Wheat is one of the most cultivated crops throughout the world in terms of both area and production, hence meet requirement of about 20% of food calories of global population (Nukasuni *et al*., 2013) [16]. It has relatively high content of niacin and thiamin which are principally concerned in providing the special protein called 'Gluten' which provides the framework of spongy cellular texture of bread and baked products (Bhushan *et al*., 2013) [4].
The first basic step for any hybridization programme is the assessment of genetic variability among the available genotypes for desirable traits (Rahman *et al*., 2016) [18]. High genetic advancement as well as high heritability offers the better scope for selection (Johnson *et al*., 1955) [13, 14]. Correlation and path analysis provide better estimation of the association of different traits with grain yield and correlation is useful in assessing the degree and direction of the relationship between various yield contributing traits and yield (Nukasuni *et al*., 2013) [16]. While path coefficient (or) standardized partial regression coefficient that measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable (Dewey and Lu, 1959) [9]. The various genetic parameters of variability, estimation of heritability and genetic advance were computed

according to the method suggested by Johnson *et al*., (1955) [13, 14]. The association among characters was estimated using variance and covariance components (Fisher, 1954 and Al-Jibouri *et al*., 1958) [2], whereas the direct and indirect effects of component traits up on grain yield were measured by path analysis as described by Dewey & Lu (1959) [9].

Material and Methods

The experimental material consisted of 8 different wheat varieties. The experiment was conducted at Research Farm, Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India. List of genotype and their pedigree/sources are given in table 1. Genotypes were grown according to RBD. Length of replication was 3 meter and row to row spacing was 20 cm with appropriate plant to plant distance is 4-6 cm. Agronomic practices were used in field is recommended by the PAU, *Rabi* package, 2017.

Taken out five random plants from each entry of genotype of replications and tagged for data recording. Data was recorded on whole plot basis for days to 50% heading and days to maturity whereas plant height (cm), number of productive tillers plant^{-1}, number of spikelets 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 plant^{-1} (g) and harvest index (%) from individual tagged plant. The mean performance of each genotype was subjected for statistical analysis. Panse and Sukhatme (1967) [17] gave methodology of analysis of variance to test the significance for various traits. Burton (1952) [7] gave methodology for estimation of GCV and PCV, heritability in broad sense (h^2) given by Burton and Vane (1953) [8] and genetic advance given by Johnson *et al*., (1955) [13, 14]. GCV, PCV and path coefficient of analysis work out as method suggested by Al-Jibouri *et al*., (1958) [2] and Dewey and Lu (1959) [9].

Result and Discussion

The analysis of variance in table 2 revealed that treatments are significant for all the traits. Suggesting that sufficient variability is present among the genotypes. Similar finding reported by Bhushan *et al*., (2013) [4], Ahmed *et al.,* (2018) [1], Saini *et al.,* (2017) [19], Avinashe *et al.*, (2017) [3].

The value of PCV was higher than GCV for all the traits indicating varying expression of traits was not only due to genotype but also environment (table 3). These are also reported by Avinashe *et al.,* (2017) [3]. Higher values of GCV and PCV were recorded for ear weight/plant, biological yield/plant, grain yield/plant and harvesting index. Moderate magnitude values of GCV and PCV were observed for spikelet/plant, ear length, ear/plant, grains/ear and 1000 grain weight/plant and values for traits days to 50% heading, days to maturity, plant height and productive tillers/plant. Suggesting that variability present among the varieties has scope for the genetic improvement. These results are in conformity with Bhushan *et al*., (2013) [4], Saini *et al.,* (2017) [19], Dwivedi *et al*., (2002) [10], Yausaf *et al.*, (2008) [22] and Tripathi *et al.,* (2011) [21]. Proportion of genetic variability which is transmitted from parents to all offspring is reflected by heritability (Lush *et al.,* 1949) [15]. Low heritability was recorded for the traits harvesting index (0.68), plant height (0.63), days to maturity (0.63), grain yield/plant (0.61), number of spikelets/plant (0.40), ear length (0.40), ear weight (0.57), number of ear/plant (0.45), 1000 grain weight (0.42), days to 50% heading (0.39), productive tillers/plant (0.39), number of grains/plant (0.37) and biological yield/plant (0.37). Heritability is low, it revealed that environment highly affects the traits and selection will be difficult because environment show masking effect on genotypic effects for genetic improvement. Medium value of genetic advance at 5% level for traits biological yield/plant (11.66). Low value for trait plant height (8.5), harvest index (8.36), 1000-grains weight (5.21), grain yield/plant (5.04), number of grains/plant (4.32), days to maturity (2.91), days to 50% heading (2.13), number of spikelets/ear (1.55), number of ears/plant (1.34), ear length (1.29), number of productive tillers/plant (0.88) and ear weight (0.85). Low value of genetic advance revealed that the character governed by non-additive genes and use for heterosis breeding. Similar finding reported by Bhushan *et al*., (2013) [4], Avinashe *et al*., (2017) [3]. Low heritability (0.37) accompanied with high genetic advance (11.66) was observed for biological yield/plant, indicating the character was governed by additive gene effect but low heritability observed due to high environmental effects. So selection may be effective only to certain extent.

Positive significant correlation on both genotypic and phenotypic level was observed for harvest index (0.722, 0.533) and ear weight (0.641, 0.282) is shown in table 4. While negative significant correlation for day to 50% heading (-0.926, -0.157). Similar finding reported by Bhushan *et al*., (2013) [4], Avinashe *et al.*, (2017) [3].

Days to 50% heading show positive and high significant correlation (genotypic and phenotypic) with number of grains/plant (0.980, 0.470) and number of spikelets/ear (0.954, 0.545), while negatively associated with 1000 grains weight (-0.572,-0.211) and harvest index (-0.803, -0.174). Days to 50% maturity had positive and high significant correlation with plant height (0.609, 0.250), while negatively associated with biological yield/plant (-0.757, -0.517) and ear weight (-1.032, 0.452). Plant height had positive and high significant correlation with ear length (0.618, 0.364), while negatively associated with biological yield/plant (-0.887, -0.381). Number of Productive Tillers/Plant had positive significant correlation with number of ears/plant (0.578, 0.245), while negatively associated with number of ear length (-0.489, -0.101) and 1000 grains weight (-0.761, -0.162). Number of spikelts/ear had positive significant correlation with number of grains/plant (0.997, 0.935), while negatively associated with biological yield/plant (-0.450, -0.125), 1000 grains weight (-0.782, -0.494) and number of ears/plant (-0.833, -0.204). Ear length had positive significant correlation with ear weight (0.874, 0.038), while negatively associated with number of ears/plant (-0.427, -0.112), 1000 grains weight (-0.622, -0.178) and biological yield (-0.868, -0.082). Ear weight had positive and high significant correlation with biological yield/plant (0.697, 0.085). Number of ears/plant had positive and high significant correlation with biological yield/plant (0.618, 0.578), while negatively associated with number of grains/plant (-0.974, -0.246). Number of grains/plant had negative and high significant correlation with 1000 grains weight (-0.695, -0.475). 1000 grains weight had positive and high significant correlation with biological yield/plant (0.468, 0.298). Biological yield/plant had negative and high significant correlation with Harvest index (-0.411, -0.471). Similar finding reported by Bhushan *et al*., (2013) [4], Burio *et al.,* (2004), Ahmed *et al.,* (2018) [1], Avinashe *et al.,* (2017) [3].

Path coefficient analysis split the correlation coefficient into direct and indirect effects. In table 5 highest positive direct effects was noted for harvest index (0.950) followed by biological yield/plant (0.867),days to maturity (0.162), plant

height (0.153), ear weight (0.142), number of grains/plant (0.139) and 1000 grains weight (0.002) on the dependent character. Highest negative direct effect was exerted by ear length (-0.026) followed by number of ears/plant (-0.031), number of productive tillers/plant (-0.047), days to 50% heading (-0.082) and number of spiklets/plant (-0.096). Similar finding were reported by Bhushan *et al*., (2013) [4].
Low positive indirect effect of number of grains/plant via number of spiklets/ear (0.138), days to 50% heading (0.136) on the dependent character i.e., grain yield/plant. Low positive indirect effect of ear weight via ear length (0.124) on the dependent character. Low positive indirect effect of harvest index via plant height (0.160). Moderate positive indirect effect of harvest index via plant height (0.299). Biological yield/plant had high positive indirect effect via ear weight (0.604), number of ears/plant (0.536) and 1000 grains weight (0.406). High positive indirect effect of harvest index via ear length (0.349). Similar finding were reported by Gupta *et al.*, (2007) [12]. High negative indirect effect of Biological yield/plant via plant height (-0.769), ear length (-0.753), days to maturity (-0.656), number of spikelts/ear (-0.390), harvest index (-0.356) on the dependent character i.e., grain yield/plant. High negative indirect effect of harvest index via days to 50% heading (-0.763), biological yield/plant (-0.390).Similar finding were reported by Bhushan *et al*., (2013) [4], Gupta *et al*., (2007) [12], Bhutta *et al.* (2005) [5] and Singh *et al.* (2012) [20].

Table 1: List of genotype and their pedigree/source

Sr. No.	Genotype	:	Pedigree/ Source
1.	MP-1203	:	FASN/2*TEPOCA/3/CHEN/TR.TA/TRANSVAAL-AFRICA
2.	LOK-1	:	S-308/S-331; SONALIKA/CHOTI-LERMA
3.	HD-2932	:	HD-2252/UP-262; KAUZ/STAR//HD-2643
4.	MP-3173	:	JNKVV, Jabalpur
5.	HI-1544	:	HINDI-62/BOBWHITE/CPAN-2099
6.	HI-8498	:	RAJ-6070/RAJ-911
7.	MP-4010	:	TEETER(SIB)/(SIB)JUNCO
8.	GW-273	:	CPAN-2084/VW-205

Table 2: ANOVA for various yield contributing characters in wheat

Characters	df	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
Replication	2	0.54^{NS}	5.38^{NS}	16.19^{NS}	1.24^{NS}	2.91^{NS}	0.24^{NS}	0.07^{NS}	4.06^{NS}	40.03^{NS}	42.88^{NS}	414.92^{NS}	2.49^{NS}	20.47^{NS}
Treatment	7	12.80*	11.47**	98.02**	2.09*	6.47*	4.40*	1.11**	3.93*	54.81*	66.21*	398.81*	84.89**	35.48**
Error	14	4.45	1.90	16.33	0.71	2.18	1.47	0.22	1.12	19.62	20.78	142.51	11.74	6.19
C.V.		2.05	0.92	3.89	6.53	7.93	11.03	16.00	7.04	7.90	10.97	15.56	12.71	12.26

*, ** significant at 5% and 1% levels, respectively and NS is not significant
X1: Days to 50% Heading; X2: Days to Maturity; X3: Plant Height (cm); X4: Number of Productive Tillers/Plant; X5: Number of spikelets/Ear; X6: Ear Length (cm); X7: Ear Weight (g); X8: Number of Ears/Plant; X9: Number of Grains/Plant; X10: 1000-grains Weight (g); X11: Biological Yield/Plant; X12: Harvest Index (%); X13: Grain Yield/Plant

Table 3: Estimates of variability, heritability and genetic advance as per cent of mean in wheat

Characters	Range		General Mean	Coefficient of variance		h² (Broad Sense)	Genetic Advancement 5%	Gen.Adv as % of Mean 5%
	Min	Max		GCV	PCV			
Days to 50% Heading	98.67	105.00	103.04	1.62	2.61	0.39	2.13	2.07
Days to Maturity	146.33	152.00	149.63	1.19	1.51	0.63	2.91	1.95
Plant Height (cm)	95.67	113.80	103.94	5.02	6.35	0.63	8.50	8.18
Number of Productive Tillers/Plant	11.03	13.70	12.91	5.25	8.38	0.39	0.88	6.79
Number of spikelets/Ear	15.63	20.20	18.60	6.43	10.21	0.40	1.55	8.35
Ear Length (cm)	8.77	12.30	11.00	8.98	14.23	0.40	1.29	11.69
Ear Weight (g)	2.35	4.05	2.93	18.55	24.49	0.57	0.85	28.94
Number of Ears/Plant	14.03	17.70	15.05	6.42	9.53	0.45	1.34	8.91
Number of Grains/Plant	48.67	62.97	56.07	6.11	9.99	0.37	4.32	7.70
1000-grains Weight (g)	35.93	47.93	41.56	9.36	14.42	0.42	5.21	12.52
Biological Yield/Plant	59.33	92.67	76.73	12.05	19.68	0.37	11.66	15.19
Harvest Index (%)	21.96	38.06	26.95	18.33	22.30	0.68	8.36	31.02
Grain Yield/Plant	13.27	24.90	20.29	15.40	19.69	0.61	5.04	24.82

Table 4: Genotypic (G) and phenotypic (P) coefficient of correlation among different character in wheat genotypes

Character	G/P	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	G	1.000	0.004	-0.253	-0.156	0.954**	-0.051	-0.349	-0.126	0.980**	-0.572**	-0.057	-0.803**	-0.926**
	P	1.000	0.201	-0.148	-0.134	0.545**	-0.097	-0.084	0.032	0.470*	-0.211	0.069	-0.174	-0.157
X2	G		1.000	0.609**	0.058	0.005	0.160	-1.032**	0.316	-0.203	-0.330	-0.757**	0.314	-0.296
	P		1.000	0.250	0.071	-0.020	-0.057	-0.452*	0.048	-0.122	-0.152	-0.517**	0.320	-0.183
X3	G			1.000	0.181	-0.210	0.618**	0.019	-0.372	-0.362	-0.286	-0.887**	0.168	-0.378
	P			1.000	-0.127	0.018	0.364	-0.019	0.014	-0.076	-0.437*	-0.381	0.172	-0.072
X4	G				1.000	-0.315	-0.489*	-0.203	0.578**	-0.229	-0.761**	-0.029	0.062	0.000
	P				1.000	-0.106	-0.101	-0.149	0.245	-0.066	-0.162	0.260	-0.229	-0.022
X5	G					1.000	-0.110	0.324	-0.833**	0.997**	-0.782**	-0.450*	0.061	-0.311
	P					1.000	0.290	-0.131	-0.204	0.935**	-0.494*	-0.125	0.152	-0.005
X6	G						1.000	0.874**	-0.427*	-0.048	-0.622**	-0.868**	0.367	-0.142
	P						1.000	0.038	-0.112	0.240	-0.178	-0.082	0.127	0.089
X7	G							1.000	-0.171	0.314	-0.093	0.697**	0.027	0.641**

	P							1.000	-0.169	-0.043	-0.097	0.085	0.094	0.282
X8	G								1.000	-0.974**	0.265	0.618**	-0.198	0.226
	P								1.000	-0.246	-0.011	0.578**	-0.231	0.317
X9	G									1.000	-0.695**	-0.310	-0.040	-0.346
	P									1.000	-0.475*	-0.173	0.074	-0.122
X10	G										1.000	0.468*	-0.254	0.125
	P										1.000	0.298	-0.188	0.059
X11	G											1.000	-0.411*	0.328
	P											1.000	-0.471*	0.469*
X12	G												1.000	0.722**
	P												1.000	0.533**

*,** significant at 5% and 1% level of significance

X1: Days to 50% Heading; X2: Days to Maturity; X3: Plant Height (cm); X4: Number of Productive Tillers/Plant; X5: Number of spikelets/Ear; X6: Ear Length (cm); X7: Ear Weight (g); X8: Number of Ears/Plant; X9: Number of Grains/Plant; X10: 1000-grains Weight (g); X11: Biological Yield/Plant; X12: Harvest Index (%); X13: Grain Yield/Plant

Table 5: Path coefficient showing direct (diagonal) and indirect effect (off diagonal) of different characters on grain yield/plant in wheat

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
X1	-0.082	0.000	0.021	0.013	-0.078	0.004	0.029	0.010	-0.081	0.047	0.005	0.066	-0.926**
X2	0.001	0.162	0.098	0.009	0.001	0.026	-0.167	0.051	-0.033	-0.053	-0.122	0.051	-0.296
X3	-0.039	0.093	0.153	0.028	-0.032	0.095	0.003	-0.057	-0.056	-0.044	-0.136	0.026	-0.378
X4	0.007	-0.003	-0.009	-0.047	0.015	0.023	0.010	-0.027	0.011	0.036	0.001	-0.003	0.000
X5	-0.091	0.000	0.020	0.030	-0.096	0.010	-0.031	0.080	-0.095	0.075	0.043	-0.006	-0.311
X6	0.001	-0.004	-0.016	0.013	0.003	-0.026	-0.023	0.011	0.001	0.016	0.023	-0.010	-0.142
X7	-0.050	-0.147	0.003	-0.029	0.046	0.124	0.142	-0.024	0.045	-0.013	0.099	0.004	0.641**
X8	0.004	-0.010	0.012	-0.018	0.026	0.013	0.005	-0.031	0.031	-0.008	-0.019	0.006	0.226
X9	0.136	-0.028	-0.050	-0.032	0.138	-0.007	0.043	-0.135	0.139	-0.096	-0.043	-0.006	-0.346
X10	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	0.000	0.000	-0.001	0.002	0.001	0.000	0.125
X11	-0.050	-0.656	-0.769	-0.025	-0.390	-0.753	0.604	0.536	-0.269	0.406	0.867	-0.356	0.328
X12	-0.763	0.299	0.160	0.059	0.058	0.349	0.026	-0.188	-0.038	-0.242	-0.390	0.950	0.722**

R SQUARE = 1.0102 RESIDUAL EFFECT =SQRT (1- 1.0102)

*, ** significant at 5% and 1% level of significance

X1: Days to 50% Heading; X2: Days to Maturity; X3: Plant Height (cm); X4: Number of Productive Tillers/Plant; X5: Number of spikelets/Ear; X6: Ear Length (cm); X7: Ear Weight (g); X8: Number of Ears/Plant; X9: Number of Grains/Plant; X10: 1000-grains Weight (g); X11: Biological Yield/Plant; X12: Harvest Index (%); X13: Grain Yield/Plant

Hence it can be concluded that in wheat, traits like harvest index and ear weight having positive significant correlation with grain yield/plant along with positive direct effect, can be used as selection indices in wheat to bring about the improvement in yield.

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