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Kiran
Department of Genetic and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India

YPS Solanki
Department of Genetic and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India

Vikram Singh
Department of Genetic and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India

Corresponding Author:
Kiran
Department of Genetic and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India

Correlation and path coefficient analysis between yield and its contributing traits in advance wheat (*Triticum aestivum* L. em. Thell) genotypes under late sown conditions

Kiran, YPS Solanki and Vikram Singh

Abstract
To study the correlation and path coefficient analysis between yield and its contributing traits, an experiment was carried out with 60 bread wheat genotypes under late sown conditions during *Rabi* 2017-18. Data of contrasting traits *viz.* days to 50 per cent heading, days to anthesis, canopy temperature at heading and after anthesis, grain growth rate 14, 21 and 28 days after anthesis, plant height, peduncle length, peduncle extrusion, number of effective tillers m^{-1}, spike length, spikelet $spike^{-1}$, no. of grains $spike^{-1}$, 1000 grain weight, biological yield $plot^{-1}$, harvest index and grain yield $plot^{-1}$ were analysed. The results revealed that grain growth rate at 14 days after anthesis, effective tiller m^{-1}, spike length, grains $spike^{-1}$, biological yield $plot^{-1}$, 1000 grain weight and harvest index were positive and significantly correlated with grain yield $plot^{-1}$ with highest direct and positive effect on grain yield $plot^{-1}$ via biological yield $plot^{-1}$ followed by harvest index.

Keywords: Wheat, correlation analysis, path coefficient analysis, *Rabi* and late sown

Introduction
Wheat (*Triticum aestivum* L. em. Thell), is one among the top three cereal crops around the world with acreage 215.48 Mha, production 731.5 MT and productivity 33.9 t/ha (Anonymous, 2018a) [3]. Before starting any breeding program it is important to learn information regarding the yield and its contributing traits. Correlation is useful in revealing the magnitude and direction of the relationship between different grain yield contributing traits and grain yield. (Dewey and Lu, 1959) [7]. It provides better understanding of yield component which helps the plant breeder during selection. Path coefficient calculates the direct and indirect effect of a dependent variable on its independent variable (Dewey and Lu, 1959) [7] and also help in understanding cause of association between two variables. The information obtained by path coefficient analysis helps in indirect selection for genetic improvement of yield because direct selection is not effective for low heritable trait like yield. Thus, correlation studies together with path analysis provide a clearer understanding of the association of different characters with grain yield. The purpose of this study, therefore, was to estimate correlation between grain yield and its attributing traits as well as the direct and indirect effects of these component traits over grain yield. The information so derived could be exploited in framing further breeding strategies and selection procedures to develop new varieties of wheat crop with high yielding potential.

Materials and Methods
The experimental materials comprised of sixty genetically diverse bread wheat genotypes which were raised under late sown conditions in a Randomized Block Design (RBD) with three replications during *Rabi* 2017-18 at Wheat and Barley Research Area of the Department of Genetics and Plant Breeding, CCS HAU, Hisar. Each plot comprised of six rows of 6 m length with line to line distance 18 cm and is located in global geographical position between 29.09°N and 75.43°E in western Haryana. The information was recorded on five randomly chosen plants from every genotype in each replication for the morpho-physiological characters namely days to 50 per cent heading (DH), days to anthesis (DA), canopy temperature at heading(CTH) and after anthesis (CTA), grain growth rate (14, 21, 28 days after anthesis)(GGR14, GGR21, GGR28), plant height(PH), peduncle length(PL), peduncle extrusion(PE), number of effective tillers m^{-1} (T/M), spike length(SL), spikelet $spike^{-1}$(SS), no. of grains $spike^{-1}$(GS), 1000 grain weight(TGW), biological yield $plot^{-1}$(BY/P), harvest index(HI) and grain yield $plot^{-1}$(GY/P).

The correlation coefficient between characters was determined as per the method given by Al-Jibouri *et al.* (1958). Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as illustrated by Dewey and Lu (1959) [7].

Result and Discussion

Generally, correlation among different characters is due to the presence of linkage and pleiotropic effect between different genes. In some cases, environment affects both the traits simultaneously in same direction or some time in opposite directions and thus environment plays an important role in the development of phenotypic correlation (Ali *et al.,* 2009) [1]. By analyzing the Table 1 and Table 2 of correlation and path coefficient analysis respectively it is found out that biological yeild plot^{-1}(BY/P) and harvest index (HI), highly significant and positive correlation was observed with grain yield with values of 0.481** and 0.589** respectively and the direct effects were also positive and highest with values of 0.9224 and 0.8690 respectively. This suggests that there were very less or no indirect effects of these characters on grain yield plot^{-1} and direct relationship exist with the grain yield plot^{-1}. Similar results were obtained by Zare *et al.* (2017) [18] for harvest index, Tripathi *et al.* (2011) [16] and Subhani *et al.* (2000) [15] for effective tillers m^{-1}, spikelets spike^{-1}, biological yield plot^{-1} and harvest index. Singh and Chaudhary (1979) [14] suggested that if the correlation coefficient between a causal factor and the effect is nearly similar to its direct effect, the correlation explains the true relationship and the direct selection through these traits is effective. Grain growth rate at 14 days after anthesis(GGR14), effective tiller meter^{-1} (T/M) and 1000 grain weight (TGW) are significantly and positively correlated with grain yield plot^{-1} with negligible direct effect but they have high positive indirect effect over grain yield plot^{-1}(GY/P) via biological yield plot^{-1}(BY/P). This indicates that these traits are essential in plant breeding programme of wheat crop and genotype having more GGR14, TGW and T/M should be selected for crop improvement. Hence for selection breeding indirect causal factor i.e. BY/P and other positively contributing factor should be considered if selection is made for GGR14, TGW and T/M. Spike length (SL) is significantly positively correlated with GY/P and has more positive indirect effect via BY/P on it whereas, it has direct negative effect on grain yield plot^{-1} which means increase in the spike length will increase grain yield by increasing the biomass of genotype of wheat crop. Grains spike $^{-1}$(GS) was found to be significantly positively correlated with positive direct effect as well as more positive indirect effect via harvest index on GY/P. Similar results were also reported by Khan and Hassan, (2017) [9] for spike length, tillers m^{-1}, and grain spike^{-1}, Neeru *et al.* (2017) [11] for effective tiller m^{-1}, Nukasani *et al.* (2013) [12] for tillers m^{-1} and grain spike^{-1}, Fellahin *et al.* (2013) [8] for spike length and harvest index, and D. K. Baranwal *et al.* (2012) [6] for effective tillers m^{-1}, grain spike^{-1} and 1000 grain weight. This indicates that indirect effect seems to be the cause of high correlation, traits showing positive correlation due to the indirect more positive effect via BY and HI on GY/P. DH, DA, GGR21, GGR28, CTH and CTA were negatively correlated with GY/P with more indirect negative effect via BY/P and HI on GY/P than there direct effect.

Table 1: Phenotypic correlation coefficients among morpho-physiological traits of wheat genotypes

	DH	DA	GGR (14)	GGR (21)	GGR (28)	CTH	CTA	PH	T/M	PL	PE	SL	SS	GS	BY/P	TGW	HI
DH																	
DA	0.817**																
GGR14	-0.109	0.010															
GGR21	0.037	0.045	-0.347**														
GGR28	0.168*	0.099	-0.234**	0.086													
CTH	0.036	0.000	-0.134	0.101	-0.014												
CTA	0.088	0.073	-0.213**	0.138	-0.066	0.485**											
PH	0.011	0.064	0.187*	0.005	-0.056	-0.05	-0.154*										
ET/M	-0.162*	-0.096	0.194**	-0.373**	-0.083	-0.181*	-0.315**	0.075									
PL	0.123	0.116^{NS}	0.145	-0.052	0.146	0.021	-0.080	0.303**	0.031								
PE	-0.026	0.028	0.097	0.168*	-0.020	-0.028	-0.035	0.173*	-0.040	0.450**							
SL	-0.229**	-0.042	0.258**	-0.053	-0.210**	-0.070	0.004	0.441**	0.052	0.097	0.111						
SS	0.062	0.131	0.132	0.044	0.001	-0.080	-0.060	0.327**	-0.071	0.092	-0.005	0.582**					
G/S	-0.002	0.014	0.067	-0.153*	-0.087	0.117	0.106	0.039	0.001	0.130	-0.260**	0.272**	0.487**				
BY/P	-0.211**	-0.068	0.210**	-0.146	-0.173*	-0.229**	-0.211**	0.268*	0.361**	-0.012	0.023	0.288**	0.177**	0.070			
TGW	0.081	0.102	0.249**	0.048	0.031	-0.280**	-0.220**	0.313**	0.071	0.208**	0.213**	0.236**	0.104	-0.225**	0.126		
HI	-0.133	-0.171*	0.004	-0.049	-0.026	-0.042	-0.038	-0.155*	0.070	-0.095	-0.050	-0.051	-0.046	0.116	-0.397**	0.078	
GY/P	-0.296**	-0.213**	0.211**	-0.199**	-0.181*	-0.237**	-0.237**	0.106	0.409**	-0.109	-0.022	0.212**	0.111^{N}	0.170*	0.481**	0.165*	0.509**

*Significant at p= 0.05, ** Significant at p= 0.01

DH-Days to 50% heading, DA-Days to anthesis, GGR14-Grain growth rate at 14 day(mg grain^{-1}day^{-1}), GGR21-Grain growth rate at 21 day(mg grain^{-1}day^{-1}), GGR28-Grain growth rate at 28 day(mg grain^{-1}day^{-1}), CTH-Canopy temperature at heading, CTA- Canopy temperature after anthesis, PH-Plant height(cm),T/M- Effective tillers m^{-1}, PL- Peduncle length, PE- Peduncle extrusion, SL-Spike length(cm), S/S-Spikeletsspike^{-1}, G/S-No. of grains spike^{-1}, TGW-1000 grain weight(g), GY/P- Grain yield plot^{-1}(g), BY/P-Biological yield plot^{-1}(g), HI-Harvest Index (%)

Table 2: Direct (diagonal) and Indirect (off-diagonal) effects of morpho-physiological traits on grain yield

	DH	DA	GGR (14)	GGR (21)	GGR (28)	CTH	CTA	PH	T/M	PL	PE	SL	SS	GS	BY/P	TGW	HI	GY/P
DH	-0.0002	0.003	-0.0012	-0.0007	0.0019	0.0007	-0.0014	0.0000	-0.001	-0.0045	-0.0007	0.0019	-0.0011	-0.0001	-0.1951	0.0004	-0.0981	-0.296
DA	-0.0002	0.0037	0.0001	-0.0009	0.0011	0.0000	-0.0011	0.0002	-0.0006	-0.0043	0.0007	0.0003	-0.0022	0.0003	-0.0625	0.0005	-0.1486	-0.213
GGR(14)	0.0000	0.0000	0.0108	0.0069	-0.0027	-0.0027	0.0033	0.0007	0.0012	-0.0053	0.0024	-0.0021	-0.0023	0.0016	0.1942	0.0012	0.0035	0.211
GGR(21)	-0.0000	0.0002	-0.0038	-0.0198	0.001	0.0020	-0.0021	0.0000	-0.0022	0.0019	0.0041	0.0004	-0.0008	-0.0036	-0.1347	0.0002	-0.0425	-0.199
GGR(28)	-0.0000	0.0004	-0.0025	-0.0017	0.0115	-0.0003	0.0010	-0.0002	-0.0005	-0.0053	-0.0005	0.0017	-0.0000	-0.0021	-0.1598	0.0002	-0.0226	-0.181
CTH	-0.0000	0.0000	-0.0015	-0.002	-0.0002	0.0202	-0.0074	-0.0002	-0.0011	-0.0008	-0.0007	0.0006	0.0014	0.0028	-0.2109	-0.0014	-0.0362	-0.237
CTA	-0.0000	0.0003	-0.0023	-0.0027	-0.0008	0.0098	-0.0153	-0.0006	-0.0019	0.0029	-0.0009	-0.0000	0.0010	0.0025	-0.1949	-0.0010	-0.0333	-0.237
PH	-0.0000	0.0002	0.0020	-0.0001	-0.0007	-0.0012	0.0024	0.0037	0.0004	-0.0111	0.0043	-0.0036	-0.0056	0.0009	0.2474	0.0015	-0.1350	0.106

T/M	0.0000	-0.0004	0.0021	0.0074	-0.001	-0.0037	0.0048	0.0003	0.0059	-0.0011	-0.001	-0.0004	0.0012	0.0000	0.3331	0.0003	0.0611	0.409
PL	-0.0000	0.0004	0.0016	0.0010	0.0017	0.0004	0.0012	0.0011	0.0002	-0.0366	0.0111	-0.0008	-0.0016	0.0031	-0.0108	0.0011	-0.0825	-0.109
PE	0.0000	0.0001	0.0011	-0.0033	-0.0002	-0.0006	0.0005	0.0006	-0.0002	-0.0165	0.0247	-0.0009	0.0001	-0.0062	0.0208	0.0010	-0.0433	-0.022
SL	0.0001	-0.0002	0.0028	0.0011	-0.0024	-0.0014	-0.0001	0.0016	0.0003	-0.0035	0.0027	-0.0081	-0.0099	0.0064	0.2656	0.0012	-0.0442	0.212
SS	-0.0000	0.0005	0.0014	-0.0009	0.0000	-0.0016	0.0009	0.0012	-0.0004	-0.0034	-0.0001	-0.0047	-0.0170	0.0115	0.1635	0.0005	-0.0404	0.111
GS	0.0000	0.0001	0.0007	0.0030	-0.0010	0.0024	-0.0016	0.0001	0.0000	-0.0048	-0.0064	-0.0022	-0.0083	0.0237	0.0646	-0.0011	0.1010	0.170
BY	0.0000	-0.0003	0.0023	0.0029	-0.002	-0.0046	0.0032	0.001	0.0021	0.0004	0.0006	-0.0023	-0.0030	0.0016	0.9224	0.0006	-0.3448	0.481
TGW	-0.0000	0.0004	0.0027	-0.001	0.0004	-0.0057	0.0032	0.0012	0.0004	-0.008	0.0053	-0.002	-0.0018	-0.0054	0.1160	0.0049	0.0357	0.165
HI	0.0000	-0.0006	0.0000	0.001	-0.0003	-0.0008	0.0006	-0.0006	0.0004	0.0035	-0.0012	0.0004	0.0008	0.0028	-0.3661	0.0002	0.8690	0.509

Residual:0.082 DH-Days to 50% heading, DA-Days to anthesis, GGR14-Grain growth rate at 14 day (mg grain^{-1}day^{-1}), GGR21-Grain growth rate at 21 day(mg grain^{-1}day^{-1}), GGR28-Grain growth rate at 28 day(mg grain^{-1}day^{-1}), CTH-Canopy temperature at heading, CTA- Canopy temperature after anthesis, PH-Plant height(cm),T/M- Effective tillers m^{-1}, PL- Peduncle length, PE- Peduncle extrusion, SL-Spike length(cm), S/S-Spikeletsspike^{-1}, G/S-No. of grains spike^{-1}, TGW-1000 grain weight(g), GY/P- Grain yield plot^{-1}(g), BY/P-Biological yield plot^{-1}(g), HI-Harvest Index.

The negative correlation of DA and DH with gain yeild was also reported by Mohammadi *et al*. (2012) [10] and Zafarnaderi *et al.* (2013) [17]. The negative correlation is due to negative indirect contribution of DH, GGR21, GGR28, CTH and CTA by BY/P (-0.2109,-0.1347,-0.1598 and -0.1949 respectively). But in case of DA, negative correlation more negative indirect contribution via HI (-0.1486) was observed on GY/P. DA have negative correlation as well as more negative indirect effect on GY/P and negatively contributing factors indicating early heading with long reproductive phase, low canopy temperature at heading and after anthesis are better for obtaining high grain yield. The finding obtained by Neeru *et al.* (2017) [11] for canopy temperature, effective tiller m^{-1} and 1000 grain weight, Ayer *et al.* (2017), Phaugat *et al.* (2016), Fellahin *et al.* (2013) [8] were obtained similar results as obtained in present investigation. The traits indicating relative non-significant correlation and negligible direct and indirect effect on GY/P are of less importance as selection criteria for high yielding genotypes in plant breeding strategies.

Conclusion

Correlation analysis revealed that harvest index followed by biological yield plot^{-1}, spike length, effective tillers meter^{-1} and grain growth rate at 14 days after anthesis were positive and highly significant whereas grain spike^{-1} and 1000 grain weight were positive and significantly correlated with grain yield plot^{-1} indicating that these traits were yield determinative traits. Besides path analysis reported that biological yield plot^{-1} followed by harvest index had positive effect on grain yield plot^{-1} and traits such as grain growth rate at 14 days after anthesis, effective tillers meter^{-1} had positive direct effect and more positive indirect effect via biological yield plot^{-1}. Under late sown conditions, it has been found that canopy temperature at anthesis was strongly negatively correlated and had direct negative effect on grain growth rate at 14 days after anthesis as well as on grain yield plot^{-1} indicating genotypes having low canopy temperature at anthesis will have high grain growth rate at 14 days after anthesis and ultimately that genotype will have high yield potential. 1000 grain weight and grains spike^{-1} were negatively correlated and had negative direct effect on each other but both are positively correlated and have positive direct and more positive indirect effect on grain yield via biological yield and harvest index respectively means those genotypes showing yielding potential but have low number of grains spike^{-1} then its yield potential is contributed by the 1000 grain weight and vice versa.

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