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Study on variability, relationships and path analysis for agro- morphological traits in elite wheat (*Triticum aestivum* L.) germplasm lines under northern hill zone conditions

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Most of the agro - morphological characters are quantitative in nature. Yield is a complex quantitative trait, significantly influenced by environmental conditions. Therefore, selection based on yield is not effective. Genotype selection has to be made on the basis of components of yield. Bhatt (1972) showed that correlation studies alone do not reveal such type of information and inadequate knowledge on inter-relationships between heritable traits may lead to negative results. On the other hand, path coefficient analysis measures the direct and indirect effect of different traits and allows separation of the correlation coefficient into direct and indirect effects (Dewey and Lu 1959). Hence, the information provided by correlations combined with path analysis for different characters along with the grain yield provides a better approach for planning efficient improvement programme. The present study was done to evaluate diverse wheat germplasm lines for various agro- morphological traits and to find out correlations among various traits to find out suitable selection criteria.

In order to evaluate various agro-morphological traits of elite wheat germplasm lines by variability, correlation and path analysis the work was conducted during *Rabi* 2014 - 15 at the experimental area of Rice and Wheat Research Centre, Malan. Thirty diverse lines of bread wheat (*Triticum aestivum* L.) were tested in alpha design with two replications. Observations recorded were based on five randomly selected plants from every genotype in both the replications. The data was subjected to analysis of variance utilizing online Statistical Analysis Package. Path analysis was calculated following the procedure given by Wright (1921) and applied by Dewey and Lu (1959).

The analysis of variance showed that mean squares due to genotypes were found to be significant for every character under study (Table 1). All the lines exhibited significant genetic differences for every trait. The presence of substantial variability for every character indicated the prevalence of adequate variability at the genetic level for selecting potential advance lines for wheat improvement. Earlier, Riaz-ud-Din *et al.* (2010) showed higher variation for different traits in wheat.

Grain yield showed significant positive correlation with 1000-grain weight, harvest index and biological yield at the phenotypic level. While, it showed non-significant negative correlation with peduncle length and days to heading (Table 2). These results corroborate the findings of earlier workers, Singh (2015) and Masood et al. (2014). Grain yield was found to be significantly correlated with biological yield and number of grains per spike as reported by Ebrahimnejad and Rameeh (2016). Thus, based on present and earlier findings, 1000-grain weight, biological yield and harvest index can be utilized as suitable criteria to select high yielding genotypes. Tillers per plant had significant positive correlation with biological yield and grain filling period. In recently research, Singh et al. (2016) showed positively significant correlation of grain yield with tillers number per plant and 100-grain weight.

Grains per spike had significant positive correlation with biological yield and days to maturity and non-significant positive correlation with harvest index and grain yield, while it had significant negative correlation with days to heading. The correlation coefficient between grain number and grain yield was found to be significantly

Table 1 Analysis of variance of wheat genotypes for different traits

Trait/source				
	Replication	Blocks with in replication	Genotypes	Error
D.F.	1	10	29	19
Grain yield/plant (g)	0.60	0.52	4.59**	0.35
Tillers/plant	0.02	0.14	0.24**	0.07
Grains/spike	4.27	22.39	111.03**	26.20
1000-grain weight (g)	9.60	10.65	84.03**	6.15
Biological yield/ plant (g)	7.56	1.26	15.20**	2.25
Harvest index (%)	0.20	15.72	52.57**	13.66
Flag leaf area (cm²)	4.04	7.20	109.13**	14.27
Plant height (cm)	20.89	7.57	107.62**	5.13
Peduncle length (cm)	4.99	4.08	19.11**	1.20
Days to heading	3.75	6.49	25.73**	3.78
Days to maturity	0.07	5.37	18.20**	2.91
Grain filling period	4.82	9.83	18.41**	6.13

^{*5%} level of significance, ** 1% level of significance

positive (Nabi *et al.* 1998; Aycicek and Yildirim 2006). Relationship between grains per spike and grain yield was positive and highly significant as reported by Shahid *et al.* 2002; Ashfaq *et al.* 2003; Aycicek and Yildirim 2006. 1000-grain weight showed significant positive correlation

with grain yield and significant negative correlation with days to heading and days to maturity as reported by Mohammadi et al. (2012). Biological yield had significant positive correlation with grain yield, flag leaf area and grain filling period. Direct positive correlation of biological yield with grain yield was also reported by Gupta et al. (2001). Tofiq et al. (2015) revealed the presence of significantly high and positively correlated grain yield with spikes number per plant, 1000-grain weight and biological yield. Harvest index revealed significant positive correlation with grain yield as reported by earlier research workers namely Donmez et al. (2001) and Avinashe et al. (2015). Flag leaf area revealed positive significant correlation with plant height. Plant height showed positively significant correlation with peduncle length, days to maturity and grain filling period. Bogale et al. (2011) also reported a significant positive correlation between peduncle length and plant height. Peduncle length revealed significantly positive correlation with days to maturity. Days to heading showed positively significant correlation with days to maturity, while it had negative significant correlation with grain filling period. On the contrary, studies conducted by Anwar et al. (2009) revealed that days to maturity and days to heading were non-significantly correlated to each other at phenotypic level.

Table 2 Estimates of correlation coefficient at Phenotypic and genotypic level among different traits studied

Characters		Gn/ spike	1000 GW	Biological yield	Harvest index	Flag leaf area	Plant height	Peduncle length	Days to heading	Days to maturity	Grain filling period	Grain yield
Effective tillers/	P	-0.155	0.174	0.419**	0.027	0.161	0.143	0.031	-0.156	0.171	0.333**	0.209
plant	G	-0.103	0.399**	0.477**	0.244	0.274*	0.195	0.06	-0.254	0.272*	0.659**	0.365**
Grains per	P		-0.071	0.261*	0.093	-0.081	-0.209	-0.078	-0.297*	0.290*	-0.051	0.169
spike	G		-0.115	0.303*	0.036	-0.206	-0.267	-0.117	0.405**	0.429**	-0.052	0.113
1000-grain	P			0.249	0.241	-0.063	-0.035	-0.081	-0.299*	-0.297*	0.047	0.280*
weight (g)	G			0.306*	0.304*	-0.056	-0.062	-0.161	-0.378**	-0.399**	0.051	0.320*
Biological	P				0.220	0.413**	0.182	-0.017	-0.173	0.181	0.362**	0.642**
yield(g)	G				0.547**	0.466**	0.216	0.018	-0.270*	0.280*	0.689**	0.829**
Harvest	P					-0.009	-0.060	-0.078	0.032	0.030	-0.006	0.879**
$\mathbf{index}(\%)$	G					0.019	-0.086	-0.209	0.010	-0.147	-0.185	0.915**
Flag leaf	P						0.373**	0.234	0.001	0.191	0.180	0.186
area(cm ²)	G						0.408**	0.292*	-0.063	0.197	0.314*	0.216
Plant	P							0.714*	0.093	0.395*	0.273*	0.045
height(cm)	G							0.818**	0.147	0.516**	0.398**	0.045
Peduncle	P								0.19	0.319*	0.095	-0.076
Length(cm)	G								0.168	0.301*	0.121	-0.140
Days to	P									0.531**	-0.594**	-0.068
heading	G									0.694**	-0.553**	-0.132
Days to	P										0.366**	0.095
maturity	G										0.216	0.029
Grain	P											0.165
filling period	G											0.212

Table 3 Estimates of direct and indirect effects of different characters at phenotypic and genotypic level

Character		Effective tillers/ plant	Grains per spike	Thousand grain weight	Biological yield	Harvest Index	Flag leaf area	Plant Height	Peduncle length	Days to heading	Days to maturity	Grain filling period	Correlation with grain yield
Effective tillers /plant	P	-0.0166	0.005	-0.007	0.210	0.021	-0.003	0.003	-0.000	-0.039	-0.040	0.076	0.209
	G	-0.202	0.059	0.025	0.470	0.121	-0.060	-0.119	0.0207	-0.364	-0.216	0.631	0.365**
Grains per spike	P	0.003	-0.033	0.003	0.131	0.073	0.001	-0.004	0.001	0.074	-0.068	-0.012	0.169
	G	0.021	-0.574	-0.007	0.299	0.018	0.045	0.163	-0.040	0.580	-0.341	-0.050	0.113
Thousand grain weight	P	-0.003	0.002	-0.040	0.128	0.189	0.001	-0.001	0.001	-0.075	0.069	0.011	0.280*
	G	-0.081	0.066	0.064	0.302	0.150	0.012	0.038	-0.056	-0.542	0.317	0.048	0.320*
Biological yield	P	-0.007	-0.009	-0.010	0.501	0.172	-0.007	0.003	0.000	-0.043	-0.042	0.082	0.642**
	G	-0.096	-0.174	0.020	0.986	0.271	-0.102	-0.132	0.006	-0.387	-0.222	0.660	0.829**
Harvest Index	P	-0.000	-0.003	-0.010	0.110	0.782	0.000	-0.001	0.001	0.008	-0.007	-0.001	0.879**
	G	-0.049	-0.021	0.019	0.540	0.494	-0.004	0.053	-0.073	0.015	0.117	-0.177	0.915**
Flag leaf area	P	-0.003	0.003	0.002	0.207	-0.007	-0.016	0.007	-0.004	0.000	-0.045	0.041	0.186
	G	-0.055	0.118	-0.004	0.460	0.009	-0.218	-0.250	0.102	-0.090	-0.157	0.300	-0.132
Plant height	P	-0.002	0.007	0.001	0.091	-0.047	-0.006	0.019	-0.010	0.023	-0.092	0.062	0.045
	G	-0.039	0.153	-0.004	0.212	-0.043	-0.089	-0.612	0.285	0.211	-0.410	0.381	0.045
Peduncle length	P	-0.001	0.003	0.003	-0.009	-0.061	-0.004	0.013	-0.015	0.047	-0.075	0.022	-0.076
	G	-0.012	0.067	-0.010	0.018	-0.103	-0.064	-0.501	0.348	0.240	-0.239	0.116	-0.140
Days to heading	P	0.003	-0.010	0.012	-0.087	0.025	-0.000	0.002	-0.003	0.250	-0.124	-0.135	-0.068
	G	0.051	-0.232	-0.024	-0.266	0.005	0.014	-0.090	0.058	1.433	-0.551	-0.530	-0.132
Days to maturity	P	-0.003	-0.009	0.012	0.091	0.024	-0.003	0.007	-0.005	0.133	-0.234	0.083	0.095
	G	-0.055	-0.246	-0.026	0.276	-0.073	-0.043	-0.316	0.105	0.994	-0.794	0.207	0.029
Grain filling period	P	-0.006	0.002	-0.002	0.181	-0.005	-0.003	0.005	-0.001	-0.148	-0.086	0.227	0.165
	G	-0.133	0.030	0.003	0.680	-0.091	-0.068	-0.243	0.042	-0.792	-0.172	0.957	0.212

^{*}Significant at P≤0.05, **Significant at P≤0.01. Bold figures denote the direct effects,

Residual effects (Phenotypic) = 0.01474, Residual effect (Genotypic) = -0.01945

At phenotypic level, harvest index followed by biological yield, days to heading and grain filling period had the highest positive direct effects, while days to maturity had the highest negative direct effect on grain yield (Table 3). These findings are similar to earlier research workers Kotal et al. (2010) and Singh et al. (2010). Though grains per spike has low magnitude of direct effects but it exhibited high positive indirect effects mainly via biological yield, days to heading and harvest index, whereas low magnitude of negative indirect effects via days to maturity and grain filling period were observed. Mohsin et al. (2009) found in his studies from path coefficient analysis that spike length and grains per spike had positive direct effects on grain yield. The significant positive correlation of 1000-grain weight with grain yield was mainly due to positive indirect effects via biological yield and harvest

index, whereas the indirect effects via other traits were low in magnitude. 1000-grain weight exhibited the low magnitude of negative indirect effects via days to heading. Highly significant positive correlation of biological yield with grain yield was mainly due to its positive direct effect on grain yield and also indirect effect via harvest index and grain filling period, whereas it exhibited low magnitude of negative indirect effects via days to heading and days to maturity. These findings are similar to earlier research workers Bagrei and Bybordi (2015) and Kumar et al. (2016). Harvest index had high positive direct effect on grain yield and low magnitude of positive indirect effect via biological yield. Therefore, significant positive correlation of harvest index is mainly attributable to its high positive direct effect. Importance of harvest index as selection criterion has also been highlighted in studies by researchers namely Subhani and Chowdhry (2000), Kumar *et al.* (2014) and Kumar *et al.* (2019). Plant height exhibited positive indirect effects via biological yield and grain filling period, while low magnitude of negative indirect effects were exhibited via harvest index, days to maturity and peduncle length. The direct positive effects of height of plant and weightof grain per spike, negatively direct effects of days to heading associated with grain yield suggested that yield components may be good selection criterion to improve yield of wheat genotypes (Aycicek and Yildirim 2006). Peduncle length had low positive indirect effects via days to heading, plant height and grain filling period. Grain filling period had high magnitude of indirect effects via biological yield, also low magnitude of negative indirect effects via days to heading.

Simple correlation analysis coupled with path analysis, therefore, suggested that biological yield, harvest index and 1000-grain weight are the traits of greater importance for improving performance of genotypes.

Analysis of variance indicated that mean squares due to genotypes were highly significant for all the characters under study. Correlation studies indicated significant positive correlations of grain yield with harvest index, biological yield and 1000-grain weight. Further, harvest index and biological yield had positively high direct effects on grain yield. This indicated that selection of these traits under normal conditions will be effective of improvement of grain yield. Thus, based on present findings,1000-grain weight, biological yield and harvest index can be utilized as suitable criteria to select high yielding genotypes under northern hill zone conditions.

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