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Path coefficient and correlation studies of yield and yield associated traits in diverse genotypes of bread wheat (*Triticum aestivum L.*)

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Abstract
A study was conducted to examine relationship between important traits of bread wheat and their direct and indirect effects on grain yield. Forty diverse genotypes of bread wheat were studied for correlation and path coefficient analysis of some morpho-physiological traits in wheat at HAU Agricultural Research Farm during Rabi 2013-14. All the characteristics studied differed significantly from one another. Generally, the estimates of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for all the character combinations. The correlation coefficients were estimated among all the traits studied at both genotypic and phenotypic levels. At phenotypic level, the results indicated that tillers per plant, biological yield and harvest index were positively associated with grain yield per plant. At genotypic level, tillers per plant, 1000-grain weight, harvest index and biological yield were found to be positively correlated while plant height and days to maturity were negatively correlated with grain yield per plant. Biological yield, harvest index, days to heading, number of tillers per plant and ear length had significant positive direct effects on grain yield. Harvest index exhibited high direct effect on grain yield and medium indirect effect via plant height, days to maturity and 1000-grain weight. No. of spikelets per ear had poor direct effect on grain yield but moderate indirect effect *via* ear length and days to 50 per cent heading. It can be concluded that more emphasis should be given on heading days and tillers per plant along with biological yield per plant and harvest index during selection for bread wheat improvement.

Keywords: Bread wheat, correlation, path analysis, direct and indirect effects

Introduction
The production of wheat has always been the main occupation of the farmers in the diversified agro-climatic conditions of India. Wheat is an important food crop for people over the entire world, which occupies 28% area under cereals and contributing 33 percent of the total food grain production in the country (Rangare *et al*., 2010) [10]. Materialization of wheat yield fluctuates widely as a result of its interaction with environment because grain yield in wheat is a polygenic inherited trait and is the product of several contributing factors affecting yield directly or indirectly (Akram *et al*., 2008) [3]. Use of varieties with better yield potential and wide range of adaptability is of prime importance for increasing wheat production (Rudra Naik *et al*., 2015) [17]. Grain yield is a complex trait and highly influenced by many genetic and environmental factors. So, direct selection for yield as such could be misleading. A successful selection depends upon the information on the association of morpho agronomic traits with grain yield (Kumar *et al*., 2013) [12]. Yield is complex trait; therefore, we have to find out which components contribute more to yield. The estimates of correlation coefficients alone may be often misleading due to mutual cancellation of component characters. So, study of correlation coupled with a path analysis is more effective tool in the study of yield contributing characters (Mahajan *et al*., 2011) [14]. Path coefficient analysis is an important technique for partitioning the correlation coefficient into direct and indirect effect of the causal components on the complex component. The adequate information on extent of variability may also be helpful to improve the yield by selecting the yield component traits (Mehandi *et al*., 2013) [15]. Identification and selection of major yield components is an essential prerequisite for wheat improvement. Path coefficient analysis divides the correlation coefficients into direct and indirect effect. Thus, it is possible to calculate both direct and indirect effects of yield components on grain yield through the other components. It has been suggested that yield

components have either a direct or indirect effects on grain yield or both. Therefore, it was essential to determine the effects of yield components on grain yield. Path coefficient analysis is a reliable statistical technique, which provides means to quantify the interrelationship of different yield components and indicates weather the influence is directly reflected in the yield or takes some other pathways to produce an affect (Ahmad *et al*., 2003) [1]. Therefore, the objective of present study is to estimate genotypic correlation among the yield components and path analysis between direct and indirect effects of these component traits on yield.

Materials and Methods

The current experiment was conducted in the Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar. Geographically, Hisar is located at latitude of 29.090N, longitude of 75.430E in western Haryana. It has an average elevation of 705ft above sea level. Crop was grown in research area of Wheat Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar, during the Rabi season of 2013-14. The experimental material of forty diverse genotypes of bread wheat was carried out in Randomized Block Design (RBD) with three replications and plot was 3 m × 40cm size. The distance between row to row and plant to plant was maintained were 23 cm and 10 cm respectively. Recommended package of practices will be followed to raise the crop. Data will be recorded on the 5 plants/ replication/ genotype. Data were recorded on 11 characters, viz., yield/plant (g), number of tillers/ plant, number of grains/ear, number of spikelets/ear, 1000-grain weight (g), Biological yield/plant (g), Harvest index (%), Plant height (cm), Ear length (cm), Days to 50% heading, Days to maturity. Genotypic correlations were computed using variance and co-variances as suggested by Johnson *et al.,* (1955) [11]. Path coefficient analysis was performed as suggested by Deway and Lu (1959) [7].

Results and Discussion

The analysis of variance indicated that there was highly significant variation among the genotypes for all the traits studied in Table.1. It means that, there was sufficient variability present in the material studied which could be utilized in further breeding programme. Interestingly, the magnitudes of mean sum of squares of all traits were more which indicated directly that the amount of variation for these traits was more desirable. Many earlier workers Ahmadizadeh *et al*., (2011) [2], Farshadfar *et al*., (2011) [9] and Lonbani and Arzani (2011) [13] reported high variability for different traits in wheat.

Correlation Studies

In the present study the estimates of correlation coefficients revealed that, in general, the genotypic and the phenotypic correlation coefficients showed similar trend but the genotypic correlation coefficients were of higher in magnitude than the corresponding phenotypic correlation coefficients, which indicated that environmental variations were under control. This revealed a strong inherent association between different traits. However, the direction of correlation was the same at both genotypic and phenotypic levels. The correlation coefficients were estimated among all the traits studied at both genotypic and phenotypic levels, the results are presented in Table 2. At phenotypic level, the results indicated that tillers per plant (0.373**), biological yield (0.679**) and harvest index (0.295**) were positively associated with grain yield per plant. At genotypic level, the results illustrated the association of different traits as given below. Tillers per plant (0.481**), 1000-grain weight (0.198*), harvest index (0.243**) and biological yield (0.823**) were found to be positively correlated while plant height (0.258**) and days to maturity (0.225*) were negatively correlated with grain yield per plant. Plant height was found to be positively correlated with ear length (0.494**), number of spikelets per ear (0.338**), days to 50 per cent heading (0.271**), days to maturity (0.273**) while with grain yield per plant (-0.258**) and harvest index (-0.258**) were negatively correlated. Ear length was positively correlated with numbers of spikelets per ear (0.543**), days to maturity (0.214*) and biological yield (0.299**) but with harvest index it showed negative value (-0.356**) of correlation coefficient. Tillers per plant were positively corre lated with number of grains per ear (0.241**) and biological yield (0.425**) whereas with days to maturity (-0.347**) and harvest index (-0.215*) negative correlation coefficients were observed. Number of spikelets per ear was positively correlated with days to maturity (0.197*) and number of grains per ear (0.474**). Days to 50 per cent heading (0.473**) and ear length (0.214*) were positively correlated with days to maturity. Harvest index (-0.194*) had negative correlation with days to maturity. Number of grains per ear was positively correlated with number of spikelets per ear (0.474**), tillers per plant (0.241**), 1000-grain weight (0.259**) and harvest index (0.231*). Biological yield showed negative association with harvest index (0.734**). Nofouzi *et al*., (2008) also reported significant and positive correlation between grain yield and plant height. Moreover, significant and positive correlation among number of productive tillers per plant and grain yield was noticed by Ali *et al*., (2008) [5] in wheat. This result was also corroborated with the findings of Dogan (2009) [8] and Gashaw *et al*. (2007) [10]. They had reported significant and positive correlation between grain yield and 1000-grain weight.

Path coefficient analysis

Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes into account the true relationship between the variables, in addition to the degree of such relationships, path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects (Anwar *et al.,* 2009 and Ali & Shakor 2012) [6, 4]. Partioning of correlations provide direct and indirect contribution of characters on dependent trait and thus form the basis for improvement in plant breeding.

The Residual effect (0.017) in path coefficient analysis was considerably low indicating a high contribution of independent traits to the dependent trait (grain yield) as shown in Table 4.3. Biological yield (1.287) had the highest direct contribution towards grain yield per plant followed by harvest index (0.758), days to heading (0.173), number of tillers per plant (0.111) and ear length (0.092). Days to maturity had negative effect (-0.034) on grain yield. It contributed to grain yield indirectly *via* ear length (0.019), days to 50 per cent heading (0.081) and 1000-grain weight (0.01). Biological yield exhibited highest direct effect (1.287) on grain yield and indirect effect *via* tillers per plant (0.047) and ear length (0.027), number of grains per ear (0.018). Harvest index exhibited high direct effect (0.758) on grain yield and medium indirect effect via plant height (0.011), days to maturity (0.006) and 1000-grain weight (0.001) grains per ear (.01). No. of spikelets per ear had poor direct effect (-0.040) on grain yield but moderate indirect effect *via* ear length (0.050) and days to 50 per cent heading (0.023). Plant height had poor direct effect (-0.044) and medium indirect effect *via* days to 50 per cent heading (0.046) and ear length (0.045) towards grain yield per plant. Dogan (2009) [8] had reported direct positive effect for grain number/spike and 1000-grain weight on yield. Ali *et al*., (2008) [5] suggested that preference must be given on the number of productive tillers/plant and number of grains/spike in selection along with optimum plant height to select superior wheat genotypes.

From the result of this experiment, it can be concluded that the genotypic and phenotypic correlations were consistent and hence, there was little intervention of environmental effects in expression of the characters. Traits such as biological yield, harvest index and root weigh, which showed highly significant correlation with grain yield, can be used as selection indices in grain yield improvement. The path analysis indicated that the effectiveness of selection for high grain yield can be done by practicing direct selection on characters like total biomass per plant, harvest index and root weight since, these characters exhibited positive correlation with grain yield as well as positive direct effects. Therefore, selection for biomass will possibly improve other component characters thereby improving grain yield.

Table 1: ANOVA for various traits in different genotypes of wheat

Source of variation	DF	Mean Squares										
		Plant height	**Ear length**	**Tillers per plant**	**No. of spikelets per ear**	**Days to 50% heading**	**Days to maturity**	**No. of grains per ear**	**1000 Grain weight**	**Grain yield Per plant**	**Biological yield**	**Harvest index**
Replication	2	293.44	5.34	3.20	28.54	683.15	1,375.22	487.08	3.47	43.24	52.56	200.64
Genotypes	39	140.39**	4.26**	4.05**	8.23**	37.56**	50.67**	209.24**	20.98**	9.93**	131.65**	73.62**
Error	78	16.61	0.28	0.22	1.27	11.62	11.04	22.43	1.60	2.24	6.00	21.26

Table 2: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among various traits of wheat genotypes

	Plant height	**Ear length**	**Tillers per plant**	**No. of spikelets per ear**	**Days to 50% heading**	**Days to maturity**	**No. of grains per ear**	**1000 grain weight**	**Grain yield per plant**	**Biological yield**	**Harvest index**
Plant height	1	0.407**	0.039^{NS}	0.250**	0.173^{NS}	0.164^{NS}	0.178^{NS}	-0.030^{NS}	-0.143	-0.015^{NS}	-0.158^{NS}
Ear length	0.494**	1	0.147^{NS}	0.446**	-0.047^{NS}	0.118^{NS}	0.131^{NS}	0.063^{NS}	0.085^{NS}	0.243**	-0.201*
Tillers per plant	-0.033^{NS}	0.118^{NS}	1	0.013^{NS}	-0.033^{NS}	-0.200*	0.211*	-0.033^{NS}	0.373**	0.370**	-0.066^{NS}
No. of spikelets per ear	0.338**	0.543**	-0.029^{NS}	1	0.042^{NS}	0.140^{NS}	0.598**	-0.061^{NS}	-0.051^{NS}	-0.063^{NS}	0.015^{NS}
Days to 50% heading	0.271**	-0.167^{NS}	-0.139^{NS}	0.132^{NS}	1	`0.229*	0.087^{NS}	-0.019^{NS}	0.044^{NS}	-0.059^{NS}	0.091^{NS}
Days to maturity	0.273**	0.214*	-0.347**	0.197*	0.473**	1	0.088^{NS}	-0.013^{NS}	-0.144	-0.045^{NS}	-0.098^{NS}
No. of grains per ear	0.218*	0.149^{NS}	0.241**	0.474**	0.168^{NS}	0.077^{NS}	1	-0.241**	-0.101^{NS}	-0.188*	0.116^{NS}
1000 grain weight	-0.045^{NS}	0.057^{NS}	-0.111^{NS}	-0.018^{NS}	0.010^{NS}	-0.029^{NS}	0.259**	1	0.120^{NS}	0.051^{NS}	0.060^{NS}
Grain Yield per Plant	-0.258**	0.131^{NS}	0.481**	-0.155^{NS}	0.021^{NS}	-0.225*	0.209*	0.198*	1	0.679**	0.295**
Biological yield	-0.054^{NS}	0.299**	0.425**	-0.123^{NS}	-0.057^{NS}	-0.063^{NS}	-0.278**	0.079^{NS}	0.823**	1	-0.477**
Harvest index	-0.258**	-0.356**	-0.215*	0.035^{NS}	-0.005^{NS}	-0.194*	0.231*	0.113^{NS}	0.243**	-0.734**	1

Table 3: Direct (diagonal) & indirect (off-diagonal) effects of traits of wheat on grain yield per plant

	Plant height	**Ear length**	**Tillers per plant**	**No. of spikelets per ear**	**Days to 50% heading**	**Days to maturity**	**No. of grains per ear**	**1000 grain weight**	**Biological yield**	**Harvest index**
Plant height	-0.044	0.045	-0.003	-0.013	0.046	-0.009	-0.014	0.000	-0.069	-0.195
Ear length	-0.021	0.092	0.013	-0.021	-0.028	-0.007	-0.009	-0.002	0.385	-0.269
Tillers per plant	0.001	0.011	0.111	0.001	-0.024	0.012	-0.016	0.001	0.547	-0.163
No. of spikelets per ear	-0.015	0.050	-0.003	-0.040	0.023	-0.007	-0.031	0.000	-0.158	0.026
Days to 50% Heading	-0.012	-0.015	-0.015	-0.005	0.173	-0.016	-0.011	-0.001	-0.073	-0.003
Days to maturity	-0.012	0.019	-0.039	-0.008	0.081	-0.034	-0.005	0.001	-0.081	-0.147
No. of grains per ear	-0.009	0.014	0.027	-0.019	0.029	-0.002	-0.066	0.001	-0.358	0.175
1000-Grain weight	0.002	0.005	-0.012	0.001	0.002	0.001	0.017	-0.005	0.101	0.085
Biological yield	0.002	0.027	0.047	0.005	-0.010	0.002	0.018	-0.003	1.287	-0.557
Harvest index	0.011	-0.033	-0.024	-0.001	-0.001	0.006	-0.015	-0.001	-0.945	0.758

Residual effect 0.017

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