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Correlation and path analysis in yield and yield components in spring bread wheat (*Triticum aestivum* L.) genotypes under irrigated condition in Southern India

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Twelve elite bread wheat genotypes comprising of six lines (females) and six testers (males) were crossed in an L × T fashion to study correlation between yield and yield-components. The genotypic as well as phenotypic correlation between grain yield and other yield components such as number of tillers per plant, number of spikes per square meter, number of grains per spike, total biomass per plant, harvest index and 1000 kernel weight were highly significant. Path analysis indicated that biomass, harvest index, days to flowering and plant height imparted significant direct influence on grain yield. The remaining traits affected grain yield rather indirectly, mainly through impact on total biomass production. About 94% of the variability in the grain yield was determined by the component traits indicating the presence of perfect matching between the component traits and the grain yield; hence, can be used as selection indices for yield improvement.

Key words: Characters, correlation, direct and indirect effects, grain yield.

INTRODUCTION

Understanding of interrelationship between component characters helps in determining which character to select when improvement of the related complex character is desired. The correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for the improvement in associated complex character – yield (Sokoto et al., 2012; Mohammadi et al., 2012; Ahmad et al., 2010; Leilah and Al-Khateeb, 2005; Zecevic et al., 2004). Simple correlation is partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) and environmental (environmental deviation together with non-additive genetic variation) components (Singh and Chaudhary, 1985).

Abderrahmane et al. (2013) reported that total biomass, number of spikes per plant, number of grains per spike are positively correlated with grain yield. Grain yield per plant was positively correlated with grains per spike, harvest index, spikes per plant, spike length and 1000 grain weight (Majumder et al., 2008). In a study aimed to know relationships between grain yield and yield components in bread wheat under different water availability, Mohammadi et al. (2012) reported that grain yield was positively correlated with plant height, spike length, days to physiological maturity, agronomic score and test weight.

As yield is a complex trait, therefore, we have to find out which components contribute more to yield. The reason is that components are simple traits with higher

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Table 1. Pedigree of the Bread wheat genotypes used in crossing for the correlation and path analysis in yield and yield attributing traits.

Variables	Pedigree	Salient features
Lines		
Agra Local	-	-
Lal Bahadur	S543 X RS 31-1	A triple dwarf wheat having amber hard, medium-bold and lustrous grains.
NI 5439	REP 80/3* NP 710	A tall wheat of medium maturity. Grains are amber, hard, medium bold and attractive. Very good for *chappati* making. Protein over 13%.
C 306	REGENT 1974/3*CHZ//*2C591/3P 19/C281	A tall wheat of medium late maturity. Medium grain size, amber, hard, lustrous and attractive. Very good for *chappati* making. Protein over 12%. Does well under low fertility, limited irrigation.
Sonalika	(II 54-388-An) x (Yt 54 x N 10-B) LR	An early maturing single dwarf wheat of wide adaptability. Resistant to rusts in the field but ;ate;y became susceptible but showing tolerance. Susceptible to loose smut. Tolerance to soil salinity/ alkalinity. Grains are abmer, semi-hard, bold and attractive. Protein over 12%.
Pusa 4		
Testers		
HD 2189	HD 1963/HD 1931	A double dwarf wheat of medium maturity. Highly resistant to rusts. Grains hard, amber and bold. Ears attractive, slightly shy in tillering. Does well even under late sowings. Protein over 12%.
NIAW 34	CNO 79/PRL "S"	A semi-dwarf wheat of medium-late maturity. Amber, semi-hard grains. Susceptible to brown rust and black rusts. Highly susceptible to loose smut.
GW 324	DL 802-3/GW 503	
DWR 248	KAUZ*2/TRAP//KAUZ	
DWR 247	PRL/VEE#6//SONALIKA	
PBW 343	ND/VG1944//KAL//BB/3/YACO'S'/4/VEE#5'S'	A dwarf wheat of medium maturity. Amber, semi-hard grains. Moderately susceptible/ tolerant to rusts.

heritability than yield and easier for improvement; hence, the use of path coefficient analysis (Farshadfar et al., 2012). The concept of path coefficient analysis was originally developed by Wright in 1921, but the technique was first used for plant selection by Dewey and Lu (1959). Path analysis is simply standardized partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable. Anwar et al. (2009), Bhutta et al. (2005) and Ali and Shakor (2012) reported that estimation of the correlation between yield and its components alone is not sufficient to understand the importance of each one of these components in determining the grain yield. According to these authors, path analysis not only measures the direct influence of one variable upon another, but also provides means of partitioning both direct and indirect effects and effectively measuring the relative importance of causal factors which helps to build an effective selection program. The purpose of this study, therefore, is to estimate genotypic and phenotypic correlation between yield and yield attributing traits as well as the direct and indirect effects of these component traits on yield.

MATERIALS AND METHODS

12 spring bread wheat genotypes comprising six lines and six testers were selected for the present study (Table 1). Crossing was made in a line by tester fashion to generate 36 F_1 hybrids during rabi 2001/02 at Wheat Improvement Project fields at Main Research Station; University of Agricultural Sciences, Dharwad, Karnataka, Southern India. The site is located between 15°26´ N latitude and 75°7´ E longitude with an altitude of 678 m above sea level. Parents, their F_1s and selected F_2s were sown in

randomized complete block (RCB) design with two replications. In each replication, single row of parents and F1 crosses and 12 rows of F2s were grown in 2 m row length with intra-row and inter-row spacing of 5 and 25 cm, respectively. The materials were grown under irrigated condition. For data collection, five randomly chosen plants from each F1 and parents and 200 plants from F2 progenies were used.

Genotypic coefficient of correlation (rg) and phenotypic coefficient of correlation (rp) were computed as per Robinson et al. (1951) and tested for statistical significance against the correlation table values at 5 and 1% levels of significance (Fischer and Yates, 1963). The statistical procedures were as follows:

$$r_g = \frac{Cov\ g(X\ Y)}{\sqrt{Var\ gX}\ .\sqrt{Var\ gY}}$$

where, $Covg(XY)$ is genotypic covariance between characters *X* and *Y;* $Var\,gX$ is genotypic variance of character *X;* $Var\,gY$ is genotypic variance of character *Y.*

$$r_p = \frac{Cov\ p(X\ Y)}{\sqrt{Var\ pX}\ .\sqrt{Var\ pY}}$$

where, $Covp(XY)$ is phenotypic covariance between characters *X* and *Y*; $Var\,pX$ is phenotypic variance of character *X*; $VarpY$ is phenotypic variance of character *Y.*

To test the significance of correlation coefficients, the following formula was adopted (Sharma, 1998):

$$t = \frac{r}{SE\ (r)}$$

where $SE(r) = \frac{1 - r^2}{\sqrt{n-2}}$

where, *r* is correlation coefficient; *n* is number of genotypes. Then calculated 't' – value was compared with standard (Table 1) value at *n*-2 degrees of freedom and α levels of probability (where α is 0.05 and 0.01).

A measure of direct and indirect effects of each character on grain yield was estimated using a standardized partial regression coefficient known as *path coefficient* analysis, as suggested by Dewey and Lu (1959). Thus, correlation coefficients of different characters with grain yield was partitioned into direct and indirect effects adopting the following formula.

$$r_{iy} = r1_iP_1 + r2_iP_2 + \ldots + rl_iP_i + \ldots + rn_iP_n$$

where r_{iy} is correlation of i^{th} character with grain yield; rl_iP_i is indirect effects of i^{th} character on grain yield through first character; rn_i is correlation between n^{th} character and i^{th} character; n is number of independent variables; P_i is direct effect of i^{th} character on grain yield; P_n is direct effects of n^{th} character on grain yield.

Direct effect of different component characters on grain yield were obtained by solving the following equations:

$$(r_{iy}) = (P_i)\ (r_{ij});\ \text{and}\ \ (P_i) = (r_{ij})^{-1}\ (r1_iP_i)$$

where, (P_i) is matrix of direct effect; (r_{ij}) is matrix of correlation coefficients among all the n^{th} component characters; (r_{iy}) is matrix of correlation of all component characters with grain yield; $(r1_iP_i)$ is indirect effect of i^{th} character on seed yield through first character.

The residual effect (P_R) is obtained by using the following formula:

$$P_R = \sqrt{1 - Pi - riy}$$

Where, P_i and *riy* are as indicated above.

Analysis was made on the following traits namely days to 50% flowering (DF), days to maturity (DM), plant height (PH) in cm, number of tillers per plant (TP), number of spike per square meter (SM), peduncle length (PL) in cm, spike length (SL) in cm, number of grains per spike (GS), total biomass per plant (BM) in grams, grain yield per plant (GY) in grams, harvest index (HI) and 1000 grain weight (TW) in grams.

RESULTS AND DISCUSSION

In this study, both the genotypic coefficient of correlation (r_g) and phenotypic coefficient of correlation (r_p) were found to be more or less consistent and, therefore, the term correlation signifies both genotypic and phenotypic unless and otherwise stated (Table 2).

A strong and positive correlation was observed between DF and DM, but the correlation of DF with GY was negative and non-significant (Table 2). Normally, inverse relationship between earliness characters and grain yield is desirable especially if stresses such as terminal heat and drought is expected. That means even if long duration of the growing period would mean that there would be more accumulation of dry matter over the extended growing period, there should be certain compromise between earliness as a stress escape mechanism and the possible yield reduction in moisture stress areas. Gautam and Sethi (2002), Mohammad et al. (2006), Mohammadi et al. (2012), Tsegaye et al. (2012) and Zafarnaderi et al. (2013) reported negative relationship between days to flowering and grain yield per plant in their studies in advanced wheat lines.

While correlation coefficient between DF and GY is negative, the direct effect was found to be positive (Table 3) indicating the indirect component to be the source of the undesirable effect. Singh and Chaudhary (1985) suggested that in such circumstances a restricted simultaneous selection model (to nullify the undesirable indirect effects) could be applied.

It was observed that DM had significant positive correlation with SM, SL and BM. The correlation with grain yield was also positive (Table 2). This positive relationship may be because the crop enjoyed favorable environmental conditions (sufficient irrigation, etc.) during growing season; and hence, the more the crop stayed green, the better photosynthetic (source-sink) advantage in terms of grain filling. This suggestion can be justified by earlier report of Anwar et al. (2009) in which correlation between days to maturity and grain yield was positive under favorable environmental conditions.

The direct effect of DM on grain yield, on the other hand, is negative and almost negligible (Table 3) indicating that indirect effects to be cause of correlation.

Table 2. Genotypic and phenotypic correlation coefficients for quantitative characters in bread wheat.

Characters		DF	DM	PH	TP	SM	PL	SL	GS	BM	GY	HI	TW
DM	r_g	0.775**											
	r_p	0.761**											
PH	r_g	0.234	0.394**										
	r_p	0.226	0.391**										
TP	r_g	-0.022	0.250	-0.057									
	r_p	-0.03	0.207	-0.041									
SM	r_g	0.140	0.308*	0.049	0.574**								
	r_p	0.132	0.306*	0.045	0.485**								
PL	r_g	0.072	0.217	0.707**	0.121	0.236							
	r_p	0.073	0.204	0.630**	0.071	0.227							
SL	r_g	0.299*	0.511**	0.376**	0.415**	0.449**	0.232						
	r_p	0.274	0.460**	0.341*	0.369**	0.398**	0.223						
GS	r_g	-0.057	0.103	0.224	0.454**	0.285*	0.159	0.154					
	r_p	-0.056	0.103	0.223	0.379**	0.281	0.145	0.138					
BM	r_g	0.194	0.384**	0.424**	0.639**	0.369**	0.250	0.518**	0.389**				
	r_p	0.173	0.355*	0.402**	0.598**	0.339*	0.199	0.450**	0.363*				
GY	r_g	-0.012	0.138	0.070	0.537**	0.379**	0.107	0.129	0.375**	0.661**			
	r_p	-0.02	0.119	0.066	0.476**	0.323*	0.080	0.140	0.333*	0.630**			
HI	r_g	-0.316*	-0.321*	-0.390**	0.089	0.178	-0.111	-0.365*	0.171	-0.173	0.614**		
	r_p	-0.240	-0.238	-0.290*	0.085	0.108	-0.071	-0.226	0.124	-0.121	0.640**		
TW	r_g	-0.119	-0.041	0.288*	0.310*	0.094	0.376**	0.346*	0.287*	0.321*	0.284	0.203	
	r_p	-0.11	-0.039	0.276	0.243	0.087	0.345*	0.305*	0.280	0.304*	0.255	0.156	

Genotypic coefficient of correlation (r_g) is shown on the top and the phenotypic correlation coefficient (r_p) is shown on the bottom of each cell corresponding the characters in a row. Significance: *5% = 0.284, **1% = 0.367, DM = Days to maturity, PH = Plant height , TP = No. of tillers per plant, PL = Peduncle length, SL = Spike length, GS = No. of grains per spike, BM = Total biomass per plant , GY = Grain yield per plant, HI = Harvest index, TW = 1000-kernel weight.

Table 3. Path coefficient analysis matrix of direct and indirect effects of twelve quantitative characters on grain yield in bread wheat.

Characters	DF	DM	PH	TP	SM	PL	SL	GS	BM	HI	TW	Genotypic correlation
DF	0.067	-0.007	0.034	-0.003	-0.027	0.001	0.039	0.005	0.155	-0.308	0.027	-0.012
DM	0.052	-0.009	0.057	0.030	-0.061	0.002	0.066	-0.009	0.309	-0.313	0.010	0.138
PH	0.016	-0.004	0.145	-0.007	-0.010	0.006	0.049	-0.019	0.341	-0.381	-0.066	0.070
TP	-0.001	-0.002	-0.008	0.120	-0.113	0.001	0.054	-0.039	0.514	0.087	-0.072	0.537**
SM	0.009	-0.003	0.007	0.069	-0.195	0.002	0.058	-0.024	0.297	0.173	-0.022	0.379**
PL	0.005	-0.002	0.102	0.015	-0.046	0.009	0.030	-0.014	0.201	-0.108	-0.087	0.107
SL	0.020	-0.005	0.054	0.050	-0.088	0.003	0.129	-0.013	0.417	-0.357	-0.080	0.129
GS	-0.004	-0.001	0.032	0.055	-0.056	0.001	0.020	-0.085	0.313	0.167	-0.066	0.375**
BM	0.013	-0.004	0.061	0.077	-0.073	0.002	0.067	-0.033	0.805	-0.169	-0.074	0.661**
HI	-0.021	0.003	-0.056	0.011	-0.035	-0.001	-0.047	-0.015	-0.140	0.975	-0.047	0.614**
TW	-0.008	0.000	0.042	0.037	-0.019	0.003	0.045	-0.025	0.258	0.198	-0.229	0.284

Residual = 0.0650. Values in the main diagonal (bold face) indicate the direct effects; off diagonal shows indirect effects. DM = Days to maturity, PH = Plant height, TP = No. of tillers per plant, PL = Peduncle length, SL = Spike length, GS = No. of grains per spike, BM = Total biomass per plant, GY = Grain yield per plant, HI = Harvest index, TW = 1000-kernel weight.

This in turn, implies that the other traits through which it imparted the indirect effect need to be considered for selection. Cyprien and Kumar (2011) reported similar trend in rice cultivars.

Plant height had strong positive correlation with PL, SL and BM, but negatively correlated with HI and TW. Its correlation with grain yield is positive but non-significant (Table 2). The direct effect of plant height on grain yield was positive and larger than its correlation value (Table 3) indicating more indirect influence of the trait via other component characters. For example, the indirect effect through biomass production was high. This result is in perfect agreement with several other studies that reported positive correlation and direct effect of plant height with grain yield (Zecevic et al., 2004; Leilah and Al-Khateeb, 2005; Khan and DAR, 2010; Mohammadi et al., 2012; Peymaninia et al., 2012; Sokoto et al., 2012; Zafarnaderi et al., 2013).

Number of tillers per plant was strongly correlated with GY while the magnitude of the direct effect is by far less than that of correlation coefficient indicating importance of other traits via which tillers per plant contributed to grain yield (Tables 2 and 3). The significantly high magnitude of its effect through total biomass per plant substantiates this idea. Earlier reports from Gautam and Sethi (2002), Kumar et al. (2010); Khokhar et al. (2010), and several others indicate the existence of strong positive correlation of number of tillers per plant with grain yield.

The correlation coefficient of SM with GY was significant and positive, but the direct effect was negative (Tables 2 and 3) indicating the importance of indirect effect of this character via BM and HI. Majumder et al. (2008), Khan and DAR (2010), Sokoto et al. (2012) and Abderrahmane et al. (2013) reported highly significant positive correlation of this character with grain yield.

Although PL and SL had non-significant correlation with GY, their contribution via BM was positive (Tables 2 and 3). Particularly important observation about SL was that its correlation coefficient and its direct effect on GY were almost equal indicating that there is true relationship between the two traits (Singh and Chaudhary, 1985) and hence, selection through SL would be effective.

Strong positive correlation was observed between GS and GY but the direct effect was negative showing its interaction with other traits such as BM via which it had significant positive influence on GY (Tables 2 and 3). Similar trends were observed in other related studies (Leilah and Al-Khateeb, 2005; Sokoto et al., 2012; Zafarnaderi et al., 2013).

For BM and HI, the correlations with GY were strong and positive and the direct effects were also positive and high (Tables 2 and 3). This suggests that, there was little or no indirect effect of these traits on grain yield and whatever relationship existed with grain yield was direct. This means that correlation explains the true relationship and a direct selection through these

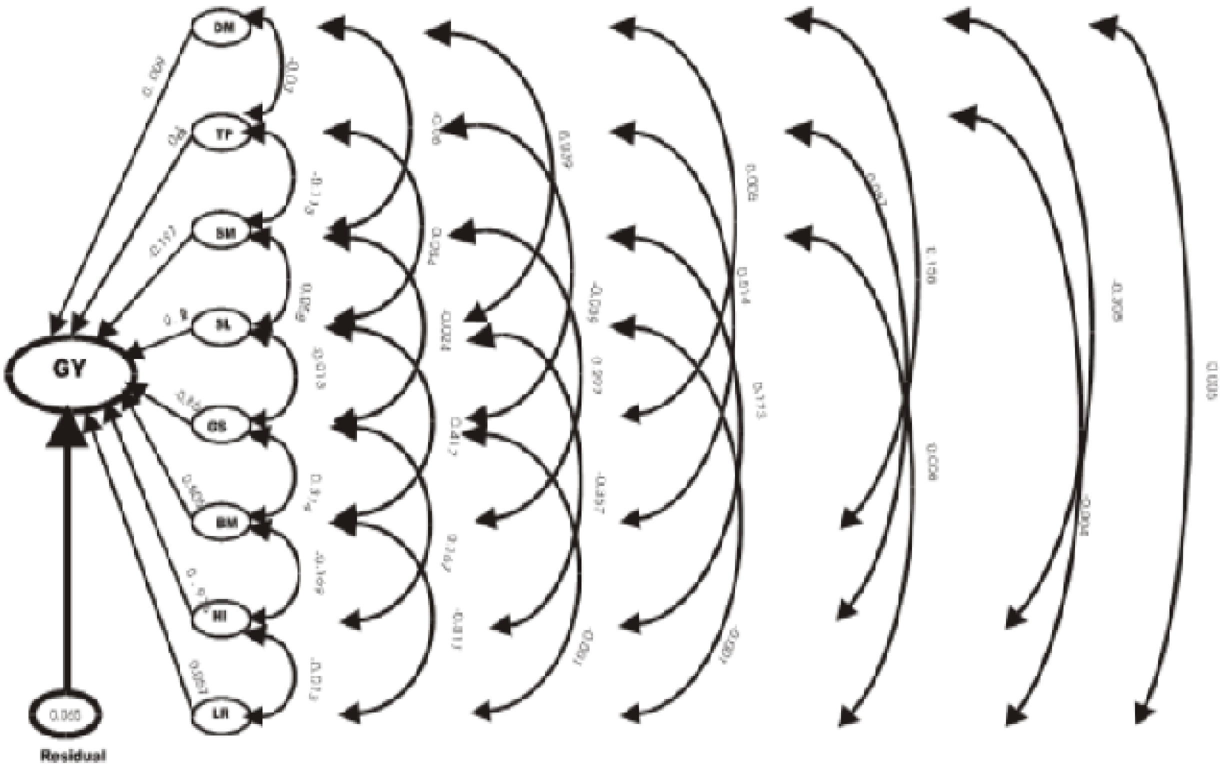

Figure 1. Genotypic path diagram of quantitative characters influencing grain yield in bread wheat. Single arrowed straight lines indicate direct effect; while double arrows show indirect effects. GY,Grain yield per plant; SM, Number of spikes per square meter; BM, Total biomass per plant; DM, Days to maturity; SL, Spike length; HI , Harvest index; TP, Number of tillers per plant; GS, Number of grains per spike; LR, Leaf rust score.

traits will be effective. Other related studies such as Ahmad et al. (2010), Akcura (2011), Ali and Shakor (2012) and Peymaninia et al. (2012) also reported strong positive correlation and direct effect of total biomass and harvest index on grain yield.

The residual effect in path analysis determines how best the component (independent) variables account for the variability of the dependent variable, grain yield per plant (Singh and Chaudhary, 1985). To this end, residual effect in the present study was 0.065 (Table 3 and Figure1), showing that 93.5% of the variability in grain yield was explained by the component factors. This further elucidated that the choice of yield attributing traits in the study was quite perfect.

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 number of tillers per plant, number of spikes per square meter, number of grains per spike, biomass and harvest index, which showed highly significant correlation with grain yield, can be used as selection indices in grain yield improvement. Except days to flowering and plant height, all the traits affected grain yield indirectly, mainly through impact on total biomass production. Therefore, selection for biomass will possibly improve other component characters thereby improving grain yield.

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