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IDENTIFICATION OF TRAITS IN BREAD WHEAT GENOTYPES (*TRITICUM AESTIVUM* L.) CONTRIBUTING TO GRAIN YIELD THROUGH CORRELATION AND PATH COEFFICIENT ANALYSIS

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Abstract

The association among yield components and their direct and indirect influence on the grain yield (GY) of bread wheat were investigated in 144 advance lines tested in partially balance lattice design during 2002-03. Analysis of variance for individual plant characters revealed the existence of genetic variability among the genotypes for all the characters studied. Genotypic correlation of plant height (PH), biological yield (BY), harvest index (HI), thousand kernel weight (TKW), number of spikes/m^2 and hectoliter weight (HLW) were positive and significantly correlated with grain yield (GY) under normal and late planting respectively. However, non-significant correlations were observed for BY and TKW in genotypes planted late. Phenotypic correlation revealed that PH, BY, HI, TKW, number of spikes/m^2 and HLW were also positive and significantly associated with GY under normal and late planting respectively. Strong positive and highly significant correlations of GY were detected with HI, BY and HLW under normal planting while in late planted genotypes HI showed strong positive and highly significant association with grain yield. Path coefficient analysis revealed that HI and BY had the highest positive direct effect on GY under both normal and late planting. In addition, some other yield components had positive direct effect on grain yield. According to the magnitude of the direct effects on GY, the order of various characters was DH > TKW > DM. The increase in GY can be achieved, if the selection is based on HI, BY and HLW under both normal and late planting.

Introduction

Wheat is the most important cereal crop of Pakistan as being the staple food. Wheat is grown over 40% of the total cultivated area and 65% of the area under food crops in the country.

Late planting is one of many abiotic stresses limiting wheat productivity in Pakistan. Most of the available cultivars are suitable for early or midseason planting for exploiting their maximum yielding ability. However, when sown late, their yielding potential is adversely affected in several ways. Late emergence along with the shortening of the growth period, the late sown wheat crop is severely damaged by high temperatures at reproductive and grain filling stage forcing premature ripening, resulting in shriveled grains and ultimately severe yield losses. A potential yield loss of 1 to 1.5 % per day/ha for each day of delay has been reported after December 1. About 40-60% of the total wheat area is planted late in Pakistan, which results not only in substantial yield reduction but also results in poor grain quality. It is also evident from the analysis of the situation that we are losing approximately 30% yield just for not having the appropriate technology.

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Development of varieties with high yield potential accompanied with desirable combination of traits has always been the major objective of wheat breeding programmes. Wadington *et al.,* (1986) reported that TKW was reduced slightly in modern high grain number cultivars. Ihsanullah & Fida (2001) reported that correlations of days to heading (DH) with HI; TKW with HI and yield with HI were positive and significant. Thus the lines with medium height and higher HI would have potential for higher grain yield. Shahid *et al.,* (2002) reported that pH showed a strong negative genotypic correlation with grain yield. Path analysis identified that TKW and days to maturity (DM) had the positive direct effect on GY whereas DH and PH had negative direct influence on the grain yield. Hakam *et al.,* (1977) concluded that for increasing GY selection in the F_2 population should be for plants with high HI and BY because all these characters are positively correlated with grain yield. Belay *et al.,* (1993) carried out correlation studies between seed yield and nine components in durum wheat genotypes and considered that grain yield exhibited a strong positive association with all characters except DH and HI. Besides grain yield itself PH and 1000grain weight may also be considered good indirect selection criteria. Razzaq *et al.,* (1986) reported that duration of vegetative period has a positive influence on GY and negative influence on grain filling period. Cultivars with the highest HI were found superior and efficient in apportion their dry matter into GY and vegetative part in proper proportion. In view of the above-mentioned facts it is highly imperative to identify high yielding early maturing genotypes for normal and late planting through effective selections by exploiting the associations of yield with other characters through correlation and path coefficient analysis.

Materials and Methods

One hundred and forty-four bread wheat genotypes acquired from different national and international sources with diverse genetic background were evaluated for different plant and yield characters under normal and late planting conditions at NIFA, Peshawar, Pakistan. These genotypes along with three check varieties (Bakhtawar-92, Fakhre Sarhad and Inqilab-91) were evaluated in NIFA Wheat Observation Nursery (NON). Each genotype was planted on a plot size of 2.5 x 0.60 meter having two rows 2.5 m long and 30 cm apart. The experimental design used was “Partially Balanced Lattice” with three replications. The nursery was planted under both normal (20.11.2002) and late planting (17-12-2002) conditions at NIFA, Peshawar, Pakistan. Normal cultural practices were carried out throughout the growth period of the crop. Data on days to heading (DH), days to maturity (DM), plant height (PH), number of spikes/m^2 and biological yield (BY) were recorded in the field while data on grain yield (GY), harvest index (HI), thousand kernel weight (TKW) and hectoliter weight (HLW) were recorded in the laboratory. HI was computed by formula i.e., (Economic Yield/Total BY) * 100 (Singa, 1977). The analyses of variances were carried out according to Steel & Torrie (1980). Phenotypic and Genotypic correlations coefficients were computed according to Kwon & Torrie (1964). Path coefficient analyses was performed according to Dewey & Lu (1959).

Results and Discussion

Analysis of variance for individual plant characters revealed the existence of significant genetic variability among the genotypes for all the characters studied (Table 1).

Table 1. Analysis of variance under normal and late planting of wheat genotypes during 2002-03 at NIFA, Peshawar.

Characters	Normal planting		Late planting	
	MSS		MSS	
	Entries	Error	Entries	Error
DH	25.98**	2.11	13.06**	1.155
DM	10.815**	1.99	2.142*	1.796
PH	112.97**	8.12	114.95**	38.8
BY	0.161**	0.174	0.082ns	0.093
GY	1442175**	497511	1341771**	180573
HI	43.074**	19.074	219.5**	113.02
TKW	40.107**	3.161	32.25**	3.603
Spikes	9639.30**	6435.34	24947*	18692
HLW	212.243**	24.276	9.931**	0.885

*= Significant at 5% level
**= Significant at 1% level

Genotypic correlations

Normal planting: The genotypic correlation for GY under normal planting was positive and highly significant with PH, BY, HI, TKW and HLW while highly significant negative correlations were detected with DH and DM (Table 2). However, number of spikes /m^2 was only significantly correlated with grain yield. Moreover highly significant positive correlations were also observed between DH and DM, BY and PH, BY and number of spikes/m^2, HI and HLW, HI and TKW, HLW and TKW, PH and TKW, DH and number of spikes/m^2, number of spikes/m^2 and DM, HLW and PH, HLW and BY. Highly significant negative correlations were recorded between HI and DH, HI and DM, DH and TKW, TKW and number of spikes/m^2. The coefficient of genotypic correlation showed highly significant and positive association of DH with DM (0.83411**) whereas positive but non-significant association observed between DH and PH (0.0765ns). Similar results were earlier reported by Shahid *et al.,* (2000).

Late planting: The genotypic correlations for GY under Late planting were positive and highly significant with PH, HI, number of spikes/m^2 and HLW while non-significant correlations were detected with DH, DM, BY and TKW (Table 2). Highly significant positive and strong genotypic correlations were recorded between PH and DM, BY and DM, number of spikes/m^2 and HI, HLW and DM, and HLW and number of spikes/m^2.

Phenotypic correlations

Normal planting: Strong positive phenotypic correlations Table 3 were recorded for GY and BY (0.52**) and GY with HI (0.63**). Positive correlations of GY were also recorded with PH (0.22**), TKW (0.29**), number of spikes /m^2 (0.29**), and HLW (0.37**). Significant negative correlations of GY with DH (-0.39**) and DM (-0.16*) were recorded. GY had a highly significant positive phenotypic correlation with PH, number of spikes/m^2, and TKW. Between characters highly significant strong positive correlation was only recorded for DM and DH (0.7021**). There was significant but weak correlations between BY and PH (0.23**), number of spikes/m^2 and DM (0.22**), number of spikes/m^2 and BY (0.27**). These results are in agreement with Akhtar (1991), Mohy-ud-Din (1995), Narwal *et al*., (1999), Uddin *et al*., (1997), Ashfaq *et al.*, (2003) and Nayeem-KA & Baig (2003).

Table 2. Values for genotypic correlations among different traits of wheat genotypes studied under normal and late planting at NIFA, Peshawar, 2002-03.

Character	Ent.	DH	DM	PH	BY	GY	HI	TKW	Spikes/m^2
DM	N	0.834**	--						
	L	-0.239**	--						
PH	N	0.076	0.188*	--					
	L	0.117	0.470**	--					
BY	N	-0.187*	-0.057	0.595**	--				
	L	-0.114	0.710**	-0.016	--				
GY	N	-0.668**	-0.476**	0.386**	0.626**	--			
	L	0.136	-0.017	0.219**	0.051	--			
HI	N	-0.677**	-0.531**	0.102	0.024	0.796**	--		
	L	0.057	-0.328**	0.211*	0.013	0.977**	--		
TKW	N	-0.465**	-0.391**	0.277**	0.097	0.484**	0.537**	--	
	L	-0.321**	0.081	0.142	-0.060	0.010	0.081	--	
Spikes/m^2	N	0.2745**	0.3914**	0.186*	0.505**	0.1953*	-0.124	-0.55**	--
	L	0.0638	0.2874**	0.362**	-0.15**	0.4492**	0.535**	-0.057	--
HLW	N	-0.304**	-0.187*	0.257**	0.384**	0.603**	0.501**	0.43**	0.172*
	L	-0.215**	0.706**	0.129	-0.33**	0.245**	0.329**	0.152*	0.432**

*= Significant at 5% level

**= Significant at 1% level

Table 3. Values for phenotypic correlations among different traits of wheat genotypes studied under normal and late planting at NIFA, Peshawar, 2002-03.

Character	Ent	DH	DM	PH	BY	GY	HI	TKW	Spikes/m^2	HLW
DM	N	0.702**	--							
	L	-0.064	--							
PH	N	-0.003	0.099	--						
	L	0.049	0.087	--						
BY	N	-0.0111	0.041	0.231**	--					
	L	0.001	-0.054	-0.042	--					
GY	N	-0.39**	-0.162*	0.222**	0.518**	--				
	L	0.052	0.006	0.235**	-0.001	--				
HI	N	-0.32**	-0.201*	0.053	-0.31**	0.630**	--			
	L	-0.032	0.032	0.191*	-0.184*	0.723**	--			
TKW	N	-.041**	-0.32**	0.178*	0.051	0.291**	0.282**	--		
	L	-0.24**	0.017	0.124	0.009	0.056	0.100	--		
Spikes/m^2	N	0.103	0.218**	0.112	0.271**	0.286**	0.0801	-0.189*	--	
	L	-0.042	0.104	0.308**	-0.127	0.423**	0.377**	-0.002	--	
HLW	N	-0.25**	-0.142	0.189*	0.182*	0.368**	0.254**	0.344**	0.076	--
	L	-0.071	0.037	0.098	-0.0023	0.154*	0.208**	0.071	0.196*	--

*= Significant at 5% level

**= Significant at 1% level

Late planting: Strong positive phenotypic correlation of GY was observed with only HI (0.723**). Highly significant but weak correlations of GY were recorded with PH (0.24**), number of spikes/m^2 (0.4236**). GY showed non-significant correlations with DH, DM and TKW. Between characters highly significant positive correlations among number of spikes/m^2, PH (0.31**) and HI (0.38**) were recorded. Significant positive but weak correlations were also recorded between HLW and HI (0.21**) and HLW and number of spikes/m^2 (0.20*).

Path analysis: Path coefficient analysis was conducted to assess the magnitude of contribution of various agro morphological characters to yield in the form of cause and effect. GY was taken as dependent variable, and DH, DM, PH (cm), number of spikes/m^2, BY, HI, TKW and HLW were treated as independent variables. The estimates of direct and indirect effects and correlation coefficients are presented in Table 5. Since the selection of characters has to be made in the light of their genotypic behavior, only genotypic correlation values are used for further analysis. However, genotypic correlation coefficients were higher than the respective phenotypic correlations indicating that phenotypic correlations were slightly influenced by environmental effects. Other than some characters, no significant environmental correlation coefficients were found for any characters (Table 4).

Grain yield vs. days to maturity: The correlation between DM and GY in normal planting was highly significant but negative (-.4766**) showing 23% contribution of DM towards the total variation in GY while non-significant negative correlation (-0.0177ns) was recorded for late planting which shows non significant contribution of this character on grain yield. The direct effect of DM on GY for normal planting was positive while it was negative for late planting. The indirect effects *via* DH and HLW were positive for normal planting while PH, BY and HLW were also positive for late planting. Moreover, negative indirect effects were recorded the DH, HI, PH, BY, TKW and number of spikes/m^2 on the GY for both normal and late planting.

Grain yield vs. days to heading: The correlation between DH and GY in normal planting Table 5 was highly significant but negative (-.6687**) showing 45% contribution of DH towards the total variation in GY while non-significant positive correlation (0.1365ns) was recorded for late planting which is only 2% of the contribution of this character on grain yield. The direct effect of DH on GY for normal and late planting was positive Table 5. The indirect effects *via* DM and HLW were positive for normal planting while DM, PH, HI and TKW were also positive for late planting. However, negative indirect effect was recorded by the rest of the characters on the GY for both normal and late planting.

Grain yield vs. plant height: The correlation between GY and PH was highly significant and positive for both normal and late planting showing 15 and 5% respective contribution of PH towards the total variation in grain yield. The direct effect of PH on GY for normal planting was negative while it was positive for late planting. PH directly affected the GY in negative direction. Similar results were reported by Chowdry *at al*., (1986). It is due to high percentage of dry matter accumulation towards the height of plant and tillers/plant affecting the GY. PH had direct effect coupled with positive genotypic and phenotypic correlation with GY. These results are in agreement with Ashfaq *et al.,* (2002). The indirect effects *via* days to heading, maturity, BY, HI and TKW were positive for normal planting while days to heading, HI and HLW were also positive for late planting. However, negative indirect effect was recorded by the rest of the characters on the GY for both normal and late planting.

Table 4. Values for environmental correlations among different traits of wheat genotypes studied under normal and late planting at NIFA, Peshawar, 2002-03.

Character	Ent.	DH	DM	PH	BY	GY	HI	TKW	Spikes/m^2	HLW
DM	N	0.473**	--							
	L	-0.037	--							
PH	N	-0.123	0.022	--						
	L	-0.136	0.0001	--						
BY	N	-0.093	0.102	0.098	--					
	L	0.046	-0.091	-0.068	--					
GY	N	-0.076	0.117	0.121	0.494**	--				
	L	-0.25**	0.021	0.288**	-0.022	--				
HI	N	0.003	0.032	0.028	-0.412**	0.549**	--			
	L	-0.164*	0.098	0.192*	-0.227**	0.542**	--			
TKW	N	-0.199*	-0.172*	0.007	0.034	0.068	0.057	--		
	L	-0.019	0.003	0.083	0.037	0.196*	0.136	--		
Spike/m^2	N	0.025	0.175*	0.094	0.224**	0.330**	0.1368	--	--	
	L	-0.209*	0.084	0.277**	-0.132	0.486**	0.282**	0.064	--	
HLW	N	-0.051	-0.052	0.133	0.081	0.095	0.022	0.015	0.044	--
	L	0.133	-.0083	0.068	0.031	0.044	0.043	-0.027	0.041	--

*= Significant at 5% level

**= Significant at 1% level

Table 5. Path analysis showing direct and indirect effect of traits on grain yield in normal and late planting during 2002-03 at NIFA, Peshawar.

Characters	Ent	DH	DM	PH	BY	HI	TKW	Spike/m^2	HLW	GY	r^2
DH	N	**0.016**	0.0176	-0.0088	-0.1332	-0.5547	-0.0129	-0.0079	0.014	-0.66**	45.0
	L	**0.105**	0.063	0.017	-0.038	0.043	0.015	-0.002	-0.006	0.1365	2.0
DM	N	0.014	**0.021**	-0.021	-0.041	-0.435	-0.011	-0.011	0.008	-0.47**	23.0
	L	-0.02	**-0.264**	0.071	0.241	-0.251	-0.003	-0.009	0.223	-0.017	0.0
PH	N	0.001	0.004	**-0.115**	0.422	0.084	0.007	-0.005	-0.012	0.386**	15.0
	L	0.012	-0.124	**0.152**	0-.005	0.161	-0.006	-0.012	0.041	0.219	5.0
BY	N	-0.003	-0.001	-0.068	**0.709**	0.02	0.002	-0.014	-0.018	0.626**	39.0
	L	-0.01	-0.187	-0.002	**0.339**	0.011	0.002	0.005	-0.104	0.051*	0.0
HI	N	-0.01	-0.011	-0.011	0.017	**0.819**	0.014	0.003	-0.023	0.796**	63.0
	L	0.006	0.086	0.032	0.004	**0.765**	-0.003	-0.018	0.104	0.977**	96.0
TKW	N	-0.007	-0.008	-0.032	0.068	0.441	**0.027**	0.015	-0.021	0.484	23.0
	L	-0.03	-0.021	0.021	-0.021	0.062	**-0.047**	0.011	0.048	0.011	0.0
Spikes/m^2	N	0.004	0.008	-0.021	0.358	-0.102	-0.015	**-0.028**	-0.008	0.195	4.0
	L	-0.006	-0.007	0.055	-0.052	0.411	0.002	**-0.033**	0.136	0.449	20.0
HLW	N	-0.005	-0.004	-0.029	.272	0.411	0.011	-0.005	**-0.047**	0.603	36.0
	L	-0.02	-0.186	0.019	-0.112	0.252	-0.007	-0.014	**0.316**	0.245	6.0

Grain yield vs. biological yield: The correlation between GY and BY was highly significant and positive for both normal and late planting showing 39% contribution of BY towards the total variation in GY for normal planting. The direct effect of BY on GY for normal and late planting was positive. The indirect effects *via* HI and TKW were positive for normal planting and were also positive for HI, TKW and number of spikes/m^2 in late planting, while negative indirect effects of DH, DM and PH on the GY were recorded under normal and late planting.

Grain yield vs. harvest index: The correlation between GY and HI was highly significant and positive for both normal and late planting showing 63 and 96% respective contribution of PH towards the total variation in grain yield. The direct effect of HI on GY for normal and late planting was also positive. The indirect effects *via* BY, TKW and number of spikes/m^2 were positive for normal planting while DH, DM, PH, BY and HLW were also positive for late planting. However, negative indirect effects were also recorded *via* DH, DM, PH, for normal planting and TKW and number of spikes/m^2 for late planting on the GY.

Grain yield vs. thousand-kernel weight: The correlation between HI and GY was highly significant and positive for both normal and late planting showing 23% contribution of PH towards the total variation in GY for normal planting. The direct effect of TKW on GY for normal planting was positive while it was negative for late planting. The indirect effects *via* BY, HI and number of spikes/m^2 were positive for normal planting while PH, HI, number of spikes/m^2 and HLW were also positive for late planting. Moreover, negative indirect effect was recorded by the rest of the characters on the GY for both normal and late planting.

Grain yield vs. number of spikes/m^2: The correlation between number of spikes/m^2 and GY was significant and positive for normal planting while highly significant and positive for late planting showing 4 and 20% respective contribution of number of spikes/m^2 towards the total variation in grain yield. The direct effect of number of spikes/m^2 on GY for normal and late planting was negative. The indirect effects *via* days to heading, maturity and BY were positive for normal planting while PH, HI, TKW and HLW were also positive for late planting. Negative indirect effect was recorded for the rest of the characters on the GY under normal and late planting.

Grain yield vs. hectoliter weight: The correlation between HLW and GY was highly significant and positive for both normal and late planting showing 36 and 6% respective contribution of HLW towards the total variation in grain yield. The direct effect of HLW on GY for normal was negative while positive for late planting. The indirect effects *via* BY, HI and TKW were positive for normal planting while PH and HI were also positive for late planting. However, negative indirect effect was recorded by the rest of the characters on the GY under both normal and late planting.

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