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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences, 1 (4): 299-302, 1998 Research Article

Interrelationship among Some Polygenic Traits in Hexaploid Spring Wheat (*Triticum aestivum* L.)

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Abstract
Sixteen wheat varieties/lines were sown under normal field conditions. Phenotypic and genotypic correlations among various morphological characters were estimated. Direct and indirect effects of these traits on grain yield were determined through path-coefficient analysis. Flag leaf area, grains per spike and tillers per meter length had positive significant genotypic correlation but highly positive significant phenotypic correlation with grain yield whereas spike length, spikelets per spike and spike density exhibited positive significant genotypic and phenotypic correlation with grain yield per meter length. Path-coefficient determined that tillers per meter length and grains per spike are the characters which contribute largely to grain yield.

Key words: Interrelationship, path analysis, polygenic traits, wheat

Introduction
Wheat (*Triticum aestivum* L.) is an important rabi food crop. Grain yield in wheat is a complex character and is the product of several contributing factors affecting yield directly or indirectly and susceptible to environmental influences. Genotypic and phenotypic correlations are of value to indicate the degree to which various morpho-physiological characters are associated with economic productivity. The present study was conducted under normal conditions to evaluate the mutual relationship of different morphological characters and also the type and extent of their contribution to yield. Some pertinent researchers are reviewed as under.

Virk and Anand (1970) showed that in wheat grain yield was positively correlated with plant height and 1000-grain weight. Larik (1979) by using the path analysis showed that direct effect of tiller number on grain yield was high and positive. Lee (1984) concluded from path-coefficient analysis that grain yield was positively correlated with 1000-grain weight, number of grains per ear and number of ears per plant in early population. Chowdhry *et al*. (1991) observed positive genotypic and phenotypic correlation of grain yield with number of tillers per plant, plant height, grains per spike, 1000-grain weight and spike length. Alam *et al*. (1992) studied that flag leaf area, number of grains per spike and number of spikelets per spike are the characters which contribute largely to grain yield.

Materials and Methods
The experiment was conducted in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Experimental material comprised fourteen varieties/strains of spring wheat viz., 93032, 93104, 93105, 931-8, 93111, 94234, 92R10, 93CO66, 92B2535, 93BT022, 6544-6, T-93705, Pasban-90 and Inqalab-91 and two strains of durum wheat namely D-93620 and D-93640. These genotypes were sown in a randomized complete block design with three replications under normal irrigated conditions. Each plot consisted of six rows, each of 5 meter length, for each entry. Seeds were planted with the help of a rabi drill and the distance between row to row was kept 30 cm. Normal agronomic and cultural practices were applied to the experiment throughout the growing season. At maturity one meter area of central row from each plot was marked to study the parameters on area basis and five guarded plants from this marked areas were tagged at random to study the different traits on individual plant basis and data were recorded for the following plant traits; plant height, peduncle length, flag leaf area, spike length, number of spikelets per spike, number of gains per spike, spike density, number of tillers per meter length, 1000-grain weight and grain yield per meter length.

The data were recorded on the above mentioned ten characters and subjected to variance and cross product analysis (Steel and Torrie, 1980). Phenotypic and genotypic correlation coefficients between all the traits were computed according to Kwon and Torrie (1964). Standard errors of genotypic correlation coefficients were calculated by using the method of Reeve (1955). Direct and indirect path-coefficients were calculated according to Dewey and Lu (1959).

Results and Discussion
Correlation: In the most cases, the genotypic correlation coefficients were higher than their respective phenotypic ones. It indicates a greater contribution of the genetic factors in association development. The observations (Table 1) indicated that in most cases, sign of phenotypic correlation coefficient was same as was of genetic correlation coefficients.

A review of Table 1 indicated that plant height showed negative and non-significant correlation with grain yield m^{-1} length and tillers m^{-1}. Plant height had negative and significant correlation at genotypic level with flag leaf area, spike density and 1000-grain weight but non-significant at phenotypic level. While showed positive and

Table 1: Genotypic and phenotypic correlations among grain yield and its components in spring wheat

Traits		Peduncle length	Flag leaf area	Spike length	Spikelets per spike	Grains per spike	Spike density	Tillers m^{-1}	1000-grain weight	Grain yield m^{-1}
Plant height	G	0.1460	-0.3001*	0.4557*	0.0476	0.1346	-0.2229*	-0.0581	-0.2687*	-0.0763
	P	0.1665	-0.2381	0.2738	0.1291	0.1600	-0.1875	-0.0128	-0.2674	-0.0488
Peduncle length	G		0.4305*	0.1489	-0.2339*	0.1470	-0.0109	-0.0570	0.2731*	0.1812*
	P		0.4417**	0.0563	-0.0897	0.1817	0.0220	0.0055	0.2324	0.2029
Flag leaf area	G			0.2727*	-0.1255	0.2751*	-0.1506	-0.0632	0.3805*	0.4071*
	P			0.2269	-0.0092	0.3363*	-0.0855	0.0202	0.2950*	0.4167**
Spike length	G				0.6910*	0.6902*	-0.2927*	0.5677*	-0.6389*	0.5110*
	P				0.2111	0.3552**	-0.1960	0.2612	-0.4930**	0.2924*
Spikelets/spike	G					0.6879*	0.4260*	-0.0690	0.0888	0.2879*
	P					0.6092**	0.4160**	0.0607	-0.0681	0.2925*
Grains/spike	G					0.1656*	0.0231	-0.0649	0.5385*	
	P						0.1973	0.1245	-0.1002	0.5268**
Spike density	G							0.1203	0.3330*	0.3418*
	P							0.1620	0.3031*	0.3539*
Tillers m^{-1}	G								-0.4201*	0.5636*
	P								-0.4018**	0.5761**
1000-grain wt.	G									0.0305
	P									0.0138

Table 2: Direct (diagonal) and indirect effects matrix (dependent variable is grain yield per meter). The last column shows genotypic correlation of independent variables with grain yield per meter length

Characters	Plant height	Peduncle length	Flag leaf area	Spike length	Spikelets per spike	Grain per spike	Spike density	Tillers m^{-1}	1000-grain weight	Grain yield correlation with grain yield m^{-1}
Plant height	0.0757	-0.0142	-0.0977	0.0524	-0.0078	0.0575	-0.0731	-0.0301	-0.0405	-0.0763
Peduncle length	0.0111	-0.0972	0.1402	0.0177	0.0384	0.0628	-0.0035	-0.0295	0.0412	0.1812
Flag leaf area	-0.0227	-0.0418	0.3258	0.0324	0.0206	0.1175	-0.0494	-0.0328	0.0575	0.4071
Spike length	0.0345	-0.0144	0.0888	0.1188	-0.1135	0.2950	-0.0960	0.2954	-0.0965	0.5110
Spikelets pe spike	0.0036	0.0227	-0.0409	0.0821	-0.1643	0.2940	0.1397	-0.0357	-0.0134	0.2878
Grains per spike	0.0102	-0.0142	0.0869	0.0820	-0.1130	0.4275	0.0543	0.0120	-0.0098	0.5385
Spike densty	-0.0168	0.0011	-0.0490	-0.0347	-0.0699	0.0707	0.3281	0.0623	0.0503	0.3418
Tillers m^{-1}	-0.0044	0.0055	-0.0206	0.0675	0.0113	0.0099	0.0395	0.5184	-0.0634	0.5636
1000-grain weight	-0.0203	-0.0265	0.1240	-0.0759	0.0146	-0.0277	0.1092	-0.2178	0.1510	0.0305

non-significant correlation with spikelets per spike and grains per spike. Whereas plant height was positively and significantly correlated with peduncle length and spike length at genotypic level while non-significant at phenotypic level. These results are almost similar to the earlier findings of Deotale *et al*. (1991).

Peduncle length showed positive and significant correlation with grain yield m^{-1} length and 1000-grain weight at genotypic level while non-significant at phenotypic level. While this trait showed positive and significant correlation with flag leaf area at genotypic level and highly significant at phenotypic level. The genotypic correlation between peduncle length and spikelets per spike was negative and significant at genotypic level and negative and non-significant at phenotypic level. A positive and non-significant correlation was observed between peduncle length, grains per spike and spike length. Negative and non-significant correlation was observed between peduncle length, spike density and tillers m^{-1} at genotypic level while positive and non-significant at phenotypic level.

A study of Table revealed positive and significant correlation coefficient between flag leaf area and grain yield m^{-1} at genotypic level while positive and highly significant at phenotypic level. Flag leaf area showed positive and significant correlations with grains per spike and 1000-grain weight. A negative and significant correlation existed between flag leaf area and spike density whereas negative and non-significant correlations were observed between flag leaf area and tillers m^{-1} and spikelets per spike. A positive and significant correlation was observed between flag area and spike length at genotypic level but non-significant at phenotypic level.

Spike length had positive and significant correlation with grain yield m^{-1} length at both genotypic and phenotypic levels. The characters like spikelets per spike and tillers m^{-1} had positive and significant genotypic correlations with spike length while positive and non-significant phenotypic correlations were found among these characters and spike length. The estimate of genotypic correlation between spike length and grains per spike was found to be positive and significant while at phenotypic level association was positive and highly significant. Spike length and spike density were found to be negatively but significantly correlated at genotypic level and non-significant at phenotypic level. Spike length as presented in Table 1 showed negative and significant association with 1000-grain weight at genotypic level while negative and highly significant at phenotypic level. It means an increase in spike length will cause decrease in 1000-grain weight.

The number of spikelets per spike showed positive and significant correlation with grain yield m^{-1} length at both genotypic and phenotypic levels. It indicates that increase in number of spikelets will also increase grain yield m^{-1} length. The characters like spike density and grains per spike showed positive and significant genotypic correlation while highly significant phenotypic association with spikelets per spike. The association between spikelets per spike and tillers per meter was recorded to be negative and non-significant at genotypic level whereas it was positive and non-significant at phenotypic level. A negative and non-significant correlation coefficient was observed between number of spikelets per spike and 1000-grain weight at both genotypic and phenotypic levels. This shows that if one trait is increased, the other will decrease. This confirms earlier findings of Mahmood (1989).

The correlation between number of grains per spike and grain yield m^{-1} was found to be positive and significant at genotypic level and highly significant at phenotypic level indicating that increase in grains per spike will cause an increase in grains yield. The association between grains per spike and 1000-grains weight was found to be negative and non-significant at both genotypic and phenotypic levels. It means if number of grains per spike is increased the grain yield will decrease. Genotypic and phenotypic correlation coefficients between grains per spike and tillers per plant were positive and non-significant. A study of Table 1 shows that genotypic correlation among number of grains per spike and spike and density was positive and significant whereas at phenotypic level this association was positive non-significant. These results are in close agreement with the findingd of Larik (1979).

Spike density showed positive and significant correlation with grain yield per meter at both genotypic and phenotypic levels (Table 1). The correlation between spike density and 1000-grains weight was examined to be positive and significant at both genotypic and phenotypic levels. A positive and non-significant correlation was observed between spike density and number of tillers per meter at genotypic and phenotypic levels.

A positive correlation was found between tiller number and grain yield per meter length which was significant at genotypic level and highly significant at phenotypic level. Correlation between tillers per meter length and 1000-grain weight was negative and significant at genotypic and highly significant at phenotypic levels. The results obtained from present study are in agreement with the finding of Singh *et al*. (1973) and Ali *et al*. (1984). It is obvious from Table 1 that 1000-grain weight had positive and non-significant correlation with grain yield per meter length at both genotypic and phenotypic levels. These results are similar to the findings of Bhullar *et al*. (1985).

Path-coefficient analysis: The data presented in Table 2 revealed that direct effect of plant height on grain yield per meter was positive. Indirect effects of plant height via peduncle length, flag leaf area, spikelets per spike, spike density, tillers per meter and 1000-grain weight were negative. But indirect effects of plan height via spike length and grains per spike were positive. Almost similar views have earlier been expressed by Nematullah (1993).

According to Table 2 the direct effect of peduncle length on grain yield was negative. Indirect effects of peduncle length via plant height, flag leaf area, spike length, spikelets per spike, grains per spike and 1000-grain weight were positive. Whereas indirect effects via spike density and tillers per meter length were negative.

Direct effect of flag leaf area on grain yield per meter length was positive. Indirect effects via plant height, peduncle length, spike density and tillers per meter length were negative. While indirect effects via spike length, spikelets per spike, grains per spike and 1000-grain weight were positive. These results are in close agreement with the finding of Alam *et al*. (1992).

Path-coefficient analysis (Table 2) indicates that spike length had a positive direct effect on grain yield m^{-1}. Similarly positive values were obtained from the indirect effects through plant height, flag leaf area, grains per spike and tillers per meter length. Whereas peduncle length, spikelets per spike, spike density and 1000-grain weight had negative indirect effects of spike length on grain yield.

Similar results have already been reported by Arshad (1985).

It is evident from Table 2 that direct effect of spikelets per spike on grain yield m^{-1} was negative. The indirect effects via plant height, peduncle length, spike length, grains per spike and spike density were, however, positive. While the indirect effects via flag leaf area, tillers per meter length and 1000-grain weight were negative. Findings of Mohy-ud-Din (1995) are contradictory with the present study.

A review of Table 2 reveals that direct effect of number of grains per spike on grain yield was positive. Indirect effects via peduncle length, spikelets per spike and 1000-grain weight were negative. While indirect effects via plant height flag leaf area, spike length, spike density and tillers per meter length were positive. The present studies are in agreement with those of Shelembi and Wright (1991).

The results presented in Table 2 revealed that direct effect of spike density on grain yield m^{-1} was positive. Indirect effects via plant height, flag leaf area, spike length and spikelets per spike were negative, whereas indirect effects via peduncle length, grains per spike, tillers per meter length and 1000-grain weight were positive. Similar findings have also been reported by Chowdhry *et al*. (1991)

According to Table 2 the direct effect of number of tillers on grains yield was positive. The indirect effects via peduncle length, spike length, spikelets per spikes grains per spike and spike density were positive. While plant height, flag leaf area and 1000-grain weight had negative indirect effects. Almost similar views have earlier been expressed by Larik (1979).

The results given in Table 2 indicate that the direct effect of 1000-grain weight on grain yield m^{-1} was positive. Indirect effects via plant height, peduncle length, spike length, grains per spike and tillers per meters length were negative. While indirect effects via flag leaf area, spikelets per spike and spike density were positive. The findings of Hadjichristodoulou (1990) and Wei (1993) confirm the present results. Whereas the findings of Zaheer and Ahmad (1991) disagreed with the present studies.

Keeping in view the results of the present studies, it is suggested that tillers per meter length, grains per spike, spike density, flag leaf area, 1000-grain weight and spike length alongwith their indirect causal factors should be considered simultaneously as an effective selection criteria for evolving high yielding cultivars because of their direct positive contribution to grain yield.

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