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Estimation of Genetic and Phenotypic Correlation Coefficients Among Grain Yield and its Components in Bread Wheat

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ABSTRACT

Phenotypic and genetic correlation coefficients for nine yield components in two bread wheat crosses V-95199 x PARI-73 and Chakwal-86 x V-8060, as well as their reciprocals, were studied. The overall estimates of genetic correlation coefficients were found greater in value than the phenotypic correlation coefficients for all the indicated plant parameters for both the crosses and their reciprocals. In cross V-95199 x PARI-73 as well as its reciprocal cross the phenotypic correlation coefficients for grain yield per plant were found positive and significant for all the studied plant traits except harvest index. The estimates of genetic correlation coefficients for grain yield per plant in cross V-95199 x PARI-73 and its reciprocal cross were also found positive and much higher for most of plant traits except harvest index which showed negative association with grain yield per plant. Similarly, in cross Chakwal-86 x V-8060 and its reciprocal cross, grain yield per plant was found positively and significantly correlated with all the studied plant traits at phenotypic level, except with plant height in cross Chakwal-86 x V-8060 which was positive but non-significant. Whereas in reciprocal cross V-8060 x Chakwal-86, grain yield per plant showed negative and non-significant phenotypic correlation coefficient with number of grains per spike. The estimates of genetic correlation coefficients for grain yield per plant in cross Chakwal-86 x V-8060 as well as its reciprocal cross were positive for all studied plant traits except number of grains per spike in reciprocal cross V-8060 x Chakwal-86 which were negative with grain yield per plant. It was concluded that the inter-relationship among all the traits studied in both crosses revealed that grain yield could efficiently be increased by obtaining maximum expression of plant height, number of tillers per plant, spike length, 1000-grain weight and biomass per plant.

Key Words: Wheat; Direct and reciprocal crosses; Genetics

INTRODUCTION

The knowledge about the nature and magnitude of association among plant traits is essential for an efficient breeding programme to improve crop plants. The present study was undertaken to determine the extent of relationship between grain yield and its related plant traits in crosses of two tall and two dwarf wheat varieties/lines along with their reciprocals and the purpose of the study was to help in further decision making as to the promise and advisability of using the breeding material in developing new wheat lines with better potential.

MATERIALS AND METHODS

The experimental material comprised of four parental wheat varieties/lines. Two of them namely Chakwal-86 and V-95199 were taken as tall and the other two i.e. PARI-73 and V-8060 were as dwarf wheat varieties/lines. These genotypes were grown in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad to develop six generations for each cross as under:

	Cross I		Cross II	
Population	**Direct**	**Reciprocal**	**Direct**	**Reciprocal**
P_1	V-95199	PARI-73	Chakwal-86	V-8060
P_2	PARI-73	V-95199	V-8060	Chakwal-86
F_1	$P_1 \times P_2$	$P_1 \times P_2$	$P_1 \times P_2$	$P_1 \times P_2$
F_2	Self F_1	Self F_1	Self F_1	Self F_1
BC_1	$P_1 \times F_1$	$P_1 \times F_1$	$P_1 \times F_1$	$P_1 \times F_1$
BC_2	$P_2 \times F_1$	$P_2 \times F_2$	$P_2 \times F_1$	$P_2 \times F_1$

Fifty plants were selected from each tall and dwarf wheat variety/line and they were used as parents. Tall wheat line V-95199 was crossed with dwarf wheat variety PARI-73 to produce F_1 and its reciprocal. The F_1s, their reciprocals and parental seed were harvested separately at maturity. In the 2nd year a part of seed obtained from each of parents, two hybrids and their reciprocals were sown in the field to produce generation F_2 and back cross as (BC_1 and BC_2). At maturity seed from parents, F_1s BC_1s and BC_2s and their reciprocals were harvested.

The parents, F_1, F_2 and backcross (BC_1 and BC_2) generations and their reciprocals were sown in the field in triplicate by using randomized complete block design. A single row for parental and F_1 generations, two for each backcross and three for F_2 generations were planted. Ten plants were selected at random from each parent and each F_1, 20 from each backcross (BC_1 and BC_2) and 30 from each

F_2 generation in each replication to record the data on individual plant basis for the plant traits i.e. flag leaf area, plant height, number of tillers per plant, spike length, number of grains per spike, 1000-grain weight, biomass per plant, grain yield per plant and harvest index.

The phenotypic (r_P) correlations among plant traits were calculated in F_2 using the formula of Kwon and Torrie (1964).

RESULTS AND DISCUSSION

A. Correlations

Phenotypic correlation coefficients. Flag leaf area of the cross V-95199 x PARI-73 (Table I) exhibited highly significant correlation coefficients with number of tillers per plant, spike length, number of grains per spike, biomass per plant and grain yield per plant. Flag leaf area was found to be positively and non-significantly correlated with harvest index but negatively and non-significantly correlated with plant height and 1000-grain weight.

In the reciprocal cross PARI-73 x V-95199 (Table II) flag leaf area showed highly significant correlation coefficients with spike length and number of grains per spike but significant with grain yield per plant. Non-significant positive correlation coefficient were found between flag leaf area and many other plant traits such as plant height, 1000-grain weight, biomass per plant and harvest index but negative with number of tillers per plant. These results are in agreement with the findings of Monyo and Whittington (1973), Singh *et al*. (1995) and Khan and Mohammad (1999) who reported significant positive correlation between grain yield per plant and flag leaf area..

Flag leaf area of cross Chakwal-86 x V-8060 (Table III) was found to be highly significantly and positively correlated with number of tillers per plant, spike length, number of grains per spike, biomass per plant, grain yield per plant and harvest index but non-significantly correlated with plant height. Its association with 1000-grain weight was negative and non-significant.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV) flag leaf area showed positive and highly significant correlation coefficients with number of tillers per plant, spike length, 1000-grain weight biomass per plant and grain yield per plant. But flag leaf area had non-significant positive correlation coefficients with plant height, number of grains per spike and harvest index. The results of this cross get support from the findings of Monyo and Whittington (1973). They found significant and positive association between flag leaf area and grain yield in wheat.

Plant height of the cross V-95199 x PARI-73 exhibited highly significant positive correlation coefficients with number of tillers per plant, spike length, number of grains per spike, 1000-grain weight, biomass per plant and grain yield per plant, but negative association with harvest index (Table I).

In the reciprocal cross PARI-73 x V-95199 (Table II) plant height was highly significantly correlated with 1000-grain weight, biomass per plant and grain yield per plant while only significantly correlated with number of tillers per plant. The phenotypic correlation of plant height with spike length was positive and non-significant. A negative highly significant association between plant height and harvest index was also found. The association of plant height with grain yield and other yield components are in conformity with the findings of Khan and Mohammad (1999) and Camargo *et al*. (2000) who concluded that correlation between plant height and grain yield was positive and significant.. Negative association between plant height and harvest index was also evident from the findings of Sharma and Smith (1986).

In the cross Chakwal-86 x V-8060 (Table III) highly significant and positive phenotypic correlation coefficient of plant height was observed only with 1000-grain weight. A significant and positive correlation coefficient was found between plant height and biomass per plant and significant but negative with spike length. It showed non-significant and positive correlation coefficients with number of grains per spike and grain yield per plant while negative with number of tillers per plant and harvest index.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), plant height was found to be highly significantly correlated with spike length, 1000-grain weight, biomass per plant and grain yield per plant while only significantly correlated with number of grains per spike but negatively and highly significantly correlated with harvest index. The correlation coefficient between plant height and number of tillers per plant was found positive and non-significant. Jaglan *et al*. (1997) and Camargo *et al*. (2000) observed that plant height showed highly significant positive correlation with grain yield in wheat.

Number of tillers per plant of the cross V-95199 x PARI-73 (Table I) showed positive and highly significant correlation coefficients with spike length, number of grains per spike, biomass per plant and grain yield per plant., whereas it had positive and non-significant correlation coefficients with 1000-grain weight but negatively non-significant with harvest index.

As apparent from the reciprocal cross PARI-73 x V-95199 (Table II) the number of tillers per plant was highly significantly correlated with spike length, number of grains per spike, biomass per plant and grain yield per plant. It had highly significant and negative phenotypic correlation with harvest index and significant negative correlation with 1000-grain weight. The results are in conformity with the findings of Jaglan *et al*. (1997) and Narwal *et al*. (1999). They reported that grain yield per plant was significantly and positively correlated with number of tillers per plant.

In the cross Chakwal-86 x V-8060 (Table III) the correlation coefficients of number of tillers per plant with number of grains per spike, biomass per plant and grain yield per plant were found highly significant and positive

while significant and positive phenotypic correlation was observed with spike length. A highly significant and negative correlation coefficient was found between number of tillers per plant and harvest index. Its non-significant and negative correlation coefficient was observed with 1000-grain weight.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), number of tillers per plant also exhibited highly significantly positive correlation coefficient with number of grains per spike, biomass per plant and grain yield per plant while significantly positive with spike length but significantly negative with harvest index. It revealed non-significant positive correlation coefficient with 1000-grain weight. The results get support from the findings of Narwal *et al.* (1999). However, the results are contrary with the findings of Jaglan *et al.* (1997) who reported that 1000-grain weight and harvest index had positive association with number of tillers per plant.

Spike length of the cross V-95199 x PARI-73 (Table I) showed highly significant and positive correlation coefficients with number of grains per spike, biomass per plant, grain yield per plant and harvest index but only significant correlation coefficient with 1000-grain weight.

As evident from the reciprocal cross PARI-73 x V-95199 (Table II), spike length was highly significantly and positively correlated with number of grains per spike, biomass per plant and grain yield per plant while positively and non-significantly correlated with 1000-grain weight and negatively with harvest index. The results are in accordance with the findings of Narwal *et al*. (1999) who found positive and significant correlation between spike length and grain yield per plant.

In the cross Chakwal-86 x V-8060 (Table III), spike length exhibited highly and significant positive correlation coefficients with number of grains per spike, grain yield per plant and harvest index while only positive and significant association with biomass per plant. The association between spike length and 1000-grain weight was negative and non-significant.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), spike length showed highly significant and positive correlation coefficients with all other indicated plant traits except harvest index which showed significant and positive phenotypic correlation. Khan and Mohammad (1999) also observed positive and significantly correlation between grain yield and spike length..

Number of grains per spike of the cross V-95199 x PARI-73 (Table I) showed highly significant and positive correlation coefficients with biomass per plant and grain yield per plant but non-significantly and positively correlated with harvest index and negatively associated with 1000-grain weight.

In the reciprocal cross PARI-73 x V-95199 (Table II), number of grains per spike also exhibited highly significantly positive correlation coefficients with number of grains per spike, biomass per plant and grain yield per plant, while highly significantly negative association was observed with 1000-grain weight. A non-significant and positive association between number of grains per spike and harvest index was also found. Varying estimates of correlation between number of grains per spike and grain yield have been reported by Berwal *et al.* (1997) and Khan and Mohammad (1999) who reported that grain yield was positively and significantly associated with number of grains per spike.

In the cross Chakwal-86 x V-8060 (Table III), the phenotypic correlation coefficients of number of grains per spike were found to be highly significantly positive with biomass per plant, grain yield per plant and harvest index but non-significant with 1000-grain weight. The results are in agreement with the findings of Singh *et al.* (1995) and Berwal *et al.* (1997) who reported that grain yield was positively and significantly associated with number of grains per spike.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), the situation was different in which number of grains per spike showed highly significant and positive correlation coefficient with 1000-grain weight and was found to be positively and non-significantly correlated with biomass per plant, while negatively non-significant with grain yield per plant and harvest index. The results are contrary to the findings of Singh *et al.* (1995) and Narwal *et al.* (1999) who reported that number of grains per spike was positively correlated with grain yield.

The phenotypic correlation coefficients of 1000-grain weight were highly significant with biomass per plant and grain yield per plant while found to be non-significant with harvest index of the cross V-95199 x PARI-73 (Table I).

Similarly, in the reciprocal cross PARI-73 x V-95199 (Table II) 1000-grain weight was highly significantly correlated with biomass per plant. It was found to be significantly correlated with grain yield per plant while non-significantly correlated with harvest index. The results are in agreement with the findings of Singh *et al.* (1995) and Deswal *et al.* (1996). They found positive correlation between 1000-grain weight and grain yield per plant.

In the cross Chakwal-86 x V-8060 (Table III), 1000-grain weight exhibited highly significant correlation coefficients with biomass per plant, grain yield per plant and harvest index.

Similar trend was also observed in reciprocal cross V-8060 x Chakwal-86 (Table IV), in which all above indicated plant traits showed highly significant correlation coefficients with 1000-grain weight. The results are in accordance with Deswal *et al.* (1996) and Mondal *et al.* (1997) who reported that 1000-grain weight was significantly and positively associated with grain yield per plant. .

Biomass per plant showed positive and highly significant correlation coefficients with grain yield per plant and negative association with harvest index of the cross V-95199 x PARI-73 (Table I). Similar types of phenotypic associations of biomass per plant with grain yield per plant

Table I. Phenotypic (r_p) and genetic (r_g) correlation coefficients among various quantitative traits of the cross V-95199 x PARI-73 of wheat

Traits		Plant height	Number of tillers per plant	Spike length	Number of grains per spike	1000-grain weight	Biomass per plant	Grain yield per plant	Harvest index
Flag leaf area	r_p	-0.0017^{NS}	0.2356**	0.4654**	0.4522**	-0.0315^{NS}	0.2397**	0.2396**	0.0165^{NS}
	r_g	-0.0031	0.5616	0.7095	1.1355	0.0806	0.4003	0.6304	0.1502
Plant height	r_p		0.2031**	0.1606**	0.2751**	0.3616**	0.6297**	0.5300**	-0.1666**
	r_g		0.1980	0.1283	0.6852	0.4346	0.9416	0.9524	-0.1815
Number of tillers per plant	r_p			0.2362**	0.2062**	0.0674^{NS}	0.6361**	0.4621**	-0.0779^{NS}
	r_g			0.3765	0.4942	0.1113	0.9315	0.7022	-0.0947
Spike length	r_p				0.5965**	0.1303*	0.2926**	0.3529**	0.1712**
	r_g				1.0868	0.3190	0.2228	0.5777	0.3885
Number of grains per spike	r_p					-0.0596^{NS}	0.3384**	0.3593**	0.0247^{NS}
	r_g					-0.1035	0.5762	0.7652	0.1063
1000-grain weight	r_p						0.4133**	0.4184**	0.1094^{NS}
	r_g						0.8139	1.0197	-0.1343
Biomass per plant	r_p							0.8295**	-0.3945**
	r_g							0.5101	-0.6779
Grain yield per plant	r_p								-0.0195^{NS}
	r_g								-0.1594

Table II. Phenotypic (r_p) and genetic (r_g) correlation coefficients among various quantitative traits of the reciprocal cross PARI-73 x V-95199 of wheat

Traits		Plant height	Number of tillers per plant	Spike length	Number of grains per spike	1000-grain weight	Biomass per plant	Grain yield per plant	Harvest index
Flag leaf area	r_p	0.0097^{NS}	-0.0427^{NS}	0.5849**	0.3127**	0.105^{NS}	0.0971^{NS}	0.1465*	0.0486^{NS}
	r_g	-0.0392	-0.3280	1.0807	0.3353	0.1976	0.0846	0.1311	-0.0016
Plant height	r_p		0.2359*	0.0582^{NS}	0.1269*	0.2456**	0.6315**	0.4908**	-0.4371**
	r_g		0.2491	-0.1164	0.0589	0.4865	0.6578	0.5147	-0.6481
Number of tillers per plant	r_p			0.2909**	0.2662**	-0.1548*	0.6533**	0.6165**	-0.3114**
	r_g			0.6839	0.5403	-0.4164	1.0604	0.9696	-0.8601
Spike length	r_p				0.5279**	0.0941^{NS}	0.2999**	0.3617**	-0.0189^{NS}
	r_g				0.1982	-0.2504	0.4408	0.5519	-0.1176
Number of grains per spike	r_p					-0.1669**	0.2498**	0.3257**	0.0578^{NS}
	r_g					-0.3918	0.3449	0.4470	-0.0420
1000-grain weight	r_p						0.1669**	0.1572*	0.0129^{NS}
	r_g						0.1707	0.1663	0.0094
Biomass per plant	r_p							0.8886**	-0.4726**
	r_g							0.9233	-0.6772
Grain yield per plant	r_p								-0.0623^{NS}
	r_g								-0.3983

NS = Non-significant * = P ≤ 0.05 ** = P ≤ 0.01

and harvest index were observed in the reciprocal cross (Table II). The association of biomass per plant with grain yield per plant got support from Singh *et al.* (1995) and Budak and Yildirim (1999). The negative association between biomass and harvest index is evident from the findings of Rana and Sharma (1997).

In the cross Chakwal-86 x V-8060 (Table III), biomass per plant revealed highly significant and positive correlation coefficient with grain yield per plant while highly significant and negative with harvest index.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), biomass per plant also showed highly significant and positive correlation coefficient with grain yield per plant but negative and non-significant with harvest index. The positive association between biomass per plant and grain yield per plant is in accordance with Dhanda and Sethi (1996) and Budak and Yildirim (1999). The negative association between biomass and harvest index get conformity with the findings of Rana and Sharma (1997).

Grain yield per plant showed negative and non-significant phenotypic correlation coefficient with harvest index of the cross V-95199 x PARI-73 as well as the reciprocal cross (Tables I & II). The results get support from the findings of Singh and Singh (1999) who revealed negative association between grain yield per plant and harvest index.

Grain yield per plant exhibited highly significantly positive correlation coefficient with harvest index in the cross Chakwal-86 x V-8060 as well as its reciprocal cross (Tables III & IV). The results are in agreement with Singh *et al.* (1995) and Iqbal and Redhu (1997) who reported

positive association between grain yield per plant and harvest index.

Genetic Correlation Coefficients. Flag leaf area of the cross V-95199 x PARI-73 (Table I) showed higher and positive genetic magnitude for correlation coefficient with number of grains per spike. Other plant traits with which flag leaf area shared genetic correlation coefficients were spike length, grain yield per plant, number of tillers per plant, biomass per plant, harvest index and 1000-grain weight. A negative association between flag leaf area and plant height was also found.

In the reciprocal cross PARI-73 x V-95199 (Table II), the flag leaf area exhibited positive genetic correlation coefficient with all indicated plant traits except plant height, number of tillers per plant and harvest index. These results are in agreement with the findings of Monyo and Whittington (1973), Singh *et al*. (1995) and Khan and Mohammad (1999). They observed that flag leaf area exhibited positive genetic correlation with grain yield and other yield components.

In the cross Chakwal-86 x V-8060 (Table III), the flag leaf area showed positive genetic correlation coefficients with harvest index, number of grains per spike, spike length, grain yield per plant and number of tillers per plant, while negative association was observed with plant height, 1000-grain weight and biomass per plant.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), flag leaf area shared positive genetic correlation coefficient with grain yield per plant, biomass per plant, 1000-grain weight, harvest index, number of tillers per plant, spike length and number of grains per spike. The negative association of flag leaf area at genotypic level was also evident with plant height. The results of this cross get support from the findings of Singh *et al*. (1995) who reported significant genetic correlation of flag leaf area with grain yield per plant.

Plant height of the cross V-95199 x PARI-73 (Table I), exhibited positive genetic correlation coefficients with all indicated plant traits except harvest index which showed negative association.

In the reciprocal cross PARI-73 x V-95199 (Table II), positive association of plant height was evident with biomass per plant, grain yield per plant, 1000-grain weight, number of tillers per plant and number of grains per spike, whereas these associations were altered to negative with spike length and harvest index. The genetic association of plant height with grain yield and other yield components are in conformity with the findings of Khan and Mohammad (1999) and Camargo *et al*. (2000). Negative association between plant height and harvest index was also evident from the findings of Sharma and Smith (1986).

Plant height in the cross Chakwal-86 x V-8060 (Table III) showed positive genetic correlation coefficients with 1000-grain weight, biomass per plant and grain yield per plant. Plant height, however, exhibited negative correlation coefficient with number of tillers per plant, spike length and harvest index.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), plant height showed negative association with number of tillers per plant and harvest index while its relationship was positive with remaining plant traits. The positive genetic correlation estimates of plant height with grain yield and other plant traits have been reported by Jaglan *et al*. (1997) and Camargo *et al*. (2000). The negative association of plant height with spike length is in conformity with the findings of Sharma and Smith (1986).

Number of tillers per plant showed positive association with all indicated plant traits of the cross V-95199 x PARI-73 (Table I) except with harvest index where its association was negative.

Similar type of positive genetic association of number of tillers per plant with other plant traits was observed in the reciprocal cross PARI-73 x V-95199 (Table II) except for 1000-grain weight and harvest index which showed negative behaviour with this trait. The results are in conformity with the findings of Jaglan *et al*. (1997) and Singh and Singh (1999) who also reported positive genetic correlation between number of tillers plant and grain yield.

In the cross Chakwal-86 x V-8060 (Table III), genetic correlation coefficients of number of tillers per plant were found to be positive with biomass per plant, grain yield per plant, spike length and number of grains per spike while negative with 1000-grain weight and harvest index.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), numbers of tillers per plant showed negative genetic association with harvest index while its correlation was positive with the remaining indicated plant traits. The results get support from the findings of Iqbal and Redhu (1997) and Singh and Singh (1999). They observed that number of tillers per plant showed positive genetic correlation with grain yield and other plant traits.

Spike length showed positive genetic correlation coefficients with all indicated plant traits in the cross V-95199 x PARI-73 (Table I).

In the reciprocal cross (Table II), spike length showed negative genetic correlation coefficients with 1000-grain weight and harvest index, while positive correlation coefficients was found with the remaining indicated plant traits. The results are in accordance with the findings of Khan and Mohammad (1999) who found positive genetic correlation of spike length with grain yield per plant.

The genetic correlation coefficients of spike length were found to be positive with all indicated plant traits of the cross Chakwal-86 x V-8060 as well as its reciprocal cross (Tables III & IV). Similar type of positive genetic correlation between spike length and grain yield per plant was also observed by Singh *et al*. (1995) and Narwal *et al*. (1999).

The estimates of genetic correlation coefficients of number of grains per spike were found to be positive with grain yield per plant, biomass per plant and harvest index,

Table III. Phenotypic (r_p) and genetic (r_g) correlation coefficients among various quantitative traits of the cross Chakwal-86 x V-8060 of wheat.

Traits		Plant height	Number of tillers per plant	Spike length	Number of grains per spike	1000-grain weight	Biomass per plant	Grain yield per plant	Harvest index
Flag leaf area	r_p	0.0686^{NS}	0.2406**	0.3932**	0.3846**	-0.0557^{NS}	0.2892**	0.3535**	0.1992**
	r_g	-0.3527	0.2274	0.5329	0.6120	-0.0896	-0.8497	0.3319	0.9765
Plant height	r_p		-0.1204^{NS}	-0.1559*	0.1002^{NS}	0.2733**	0.1446*	0.1131^{NS}	-0.954^{NS}
	r_g		-0.2664	-0.2509	0.0059	0.4586	0.1688	0.1052	-0.1437
Number of tillers per plant	r_p			0.1603*	0.1658**	-0.0291^{NS}	0.6153**	0.4979**	-0.1753**
	r_g			0.3136	0.0340	-0.069	1.5576	1.2198	-0.3234
Spike length	r_p				0.4901**	-0.0962^{NS}	0.1400*	0.2166**	0.1992**
	r_g				0.7837	0.1109	0.2394	0.5194	0.3340
Number of grains per spike	r_p					0.0107^{NS}	0.4124**	0.5005**	0.2299**
	r_g					0.2264	0.4847	0.6027	0.2896
1000-grain weight	r_p						0.2391**	0.3285**	0.1763**
	r_g						0.5712	1.1170	0.5465
Biomass per plant	r_p							0.8713**	-0.1681**
	r_g							0.7075	-0.1804
Grain yield per plant	r_p								0.3165**
	r_g								0.5899

Table IV. Phenotypic (r_p) and genetic (r_g) correlation coefficients among various quantitative traits of the reciprocal cross V-8060 x Chakwal-86 of wheat

Traits		Plant height	Number of tillers per plant	Spike length	Number of grains per spike	1000-grain weight	Biomass per plant	Grain yield per plant	Harvest index
Flag leaf area	r_p	0.0045^{NS}	0.2792**	0.2415**	0.0860^{NS}	0.1800**	0.2042**	0.2135**	0.0162^{NS}
	r_g	-0.0091	0.3372	0.2448	0.0398	0.3851	0.4005	0.4879	0.3631
Plant height	r_p		0.0221^{NS}	0.2106**	0.1471*	0.4419**	0.2598**	0.2037**	-0.1882**
	r_g		-0.0249	0.2078	0.0976	0.6810	0.3128	0.2326	-0.5028
Number of tillers per plant	r_p			0.1522*	0.2782**	0.0793^{NS}	0.1966**	0.1594**	-0.1355*
	r_g			0.1568	0.3707	0.1552	0.2695	0.2731	-0.0724
Spike length	r_p				0.3087**	0.3353**	0.3160**	0.3542**	0.1449*
	r_g				0.2956	0.7855	0.4656	0.5842	0.6531
Number of grains per spike	r_p					0.1738**	0.0176^{NS}	-0.0180^{NS}	-0.085^{NS}
	r_g					0.4879	-0.0436	-0.1425	-0.4088
1000-grain weight	r_p						0.2357**	0.2726**	0.0953**
	r_g						0.0988	0.1612	0.3336
Biomass per plant	r_p							0.9273**	-0.0351^{NS}
	r_g							0.8935	0.1260
Grain yield per plant	r_p								0.3127**
	r_g								0.8096

NS = Non-significant * = $P \leq 0.05$ ** = $P \leq 0.01$

while negative with 1000-grain weight for the cross V-95199 x PARI-73 (Table I).

In the reciprocal cross PARI-73 x V-95199, number of grains per spike showed positive association with grain yield per plant and biomass per plant, while negative relationship was observed with 1000-grain weight and harvest index (Table II). Berwal *et al*. (1997) and Khan and Mohammad (1999) reported positive genetic correlation between number of grains per spike and grain yield per plant.

Number of grains per spike showed positive genetic correlation coefficients with all indicated plant traits in the cross Chakwal-86 x V-8060 (Table III).

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), the situation was different in which number of grains per spike exhibited positive association with 1000-grain weight whereas negative association was observed with biomass per plant, grain yield per plant and harvest index. The results are contrary to the findings of Singh *et al*. (1995) and Narwal *et al*. (1999) who reported that number of grains per spike was positively correlated with grain yield.

The positive genetic correlation coefficients of 1000-grain weight with grain yield per plant and biomass per plant, while negative with harvest index were observed in the cross V-95199 x PARI-73 (Table I).

In the reciprocal cross (Table II), 1000-grain weight showed positive genetic correlation coefficients with all indicated plant traits. The results are in agreement with the findings of Singh *et al*. (1995), Mondal *et al*. (1997) and Rana and Sharma (1997) who reported that 1000-grain weight had positive genetic correlation with grain yield per plant. However, the findings of Khan and Mohammad

(1999) are contrary to the present results who reported the negative association between grain yield and 1000-grain weight.

The genetic correlation coefficients of 1000-grain weight were found positive with biomass per plant, grain yield per plant and harvest index in the cross Chakwal-86 x V-8060 as well as its reciprocal cross V-8060 x Chakwal-86 (Table III & IV). The results are in accordance with Deswal *et al.* (1996), Mondal *et al.* (1997) and Rana and Sharma (1997).

Biomass per plant revealed positive genetic correlation coefficient with grain yield per plant, while showed negative association with harvest index of the cross V-95199 x PARI-73 (Table I). The same trend was also observed in its reciprocal cross (Table II) where biomass per plant showed positive association with grain yield per plant and negative association with harvest index. The association of biomass per plant with grain yield per plant get support from Dhanda and Sethi (1996), Budak and Yildirim (1999) and Singh and Singh (1999).

Similarly in the cross Chakwal-86 x V-8060 (Table III) biomass per plant showed positive association with grain yield per plant and negative correlation with harvest index.

In the reciprocal cross V-8060 x Chakwal-86 (Table IV), the association of biomass per plant was positive with grain yield per plant and harvest index. Dhanda and Sethi (1996), and Singh and Singh (1999) found positive association between biomass per plant and grain yield per plant.

A negative association between grain yield per plant and harvest index was observed for the cross V-95199 x PARI-73 as well as its reciprocal cross (Tables I & II). The results get support from the findings of Singh and Singh (1999) who revealed negative association between grain yield per plant and harvest index. However, the results of Dhanda and Sethi (1996) and Iqbal and Redhu (1997) are contrary to the present findings who reported positive association between grain yield per plant and harvest index.

In the cross Chakwal-86 x V-8060 as well as the reciprocal cross (Tables III & IV), positive genetic correlation coefficient was observed between grain yield per plant and harvest index. The results are in agreement with Dhanda and Sethi (1996) and Iqbal and Redhu (1997) who reported positive association between grain yield per plant and harvest index.

It is concluded that the estimates of genetic correlation coefficients were found greater in value than the phenotypic correlation coefficients for all studied plant traits in both crosses and their reciprocals. In case of cross V-95199 x PARI-73 and its reciprocal cross grain yield per plant was found positively and significantly correlated at phenotypic level and strongly associated at genetic level with all studied plant traits except harvest index. The genetic and phenotypic correlation coefficients of cross Chakwal-86 x V-8060 and its reciprocal indicated that grain yield per plant was positively significant and strongly associated with flag leaf area, number of tillers per plant, spike length, 1000-grain weight and biomass per plant. The inter-relationship among all the traits studied in both crosses revealed that grain yield could efficiently be increased by obtaining maximum expression of plant height, number of tillers per plant, spike length, 1000-grain weight and biomass per plant.

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