GENOTYPIC AND PHENOTYPIC CORRELATION AMONG YIELD COMPONENTS IN BREAD WHEAT UNDER NORMAL AND LATE PLANTINGS

BASHIR AHMAD*, IFTIKHAR H. KHALIL**,
MUHAMMAD IQBAL* and HIDAYAT-UR-RAHMAN**

* *Cereals Cereal Crops Research Institute, Pirsabak, Nowshera – Pakistan.*
** *Department of Plant Breeding and Genetics, NWFP Agricultural University, Peshawar – Pakistan.*

ABSTRACT

Knowledge of genetic and phenotypic association among economic traits helps plant breeders in outlying efficient breeding strategies for development of high yielding wheat cultivars. Two diverse wheat cultivars forming two contrasting groups viz. tall stature with late maturity (cultivar "Fakhre Sarhad") vs short stature with early maturity (cultivar "Saleem-2000") were used to develop the F_1, F_2 and first backcross generations (BC_{11} and BC_{12}) from their direct and reciprocal crosses during crop seasons of 2005-06 and 2006-07 at Cereal Crops Research Institute (CCRI), Pirsabak, Nowshera (Pakistan). Significant genetic variation existed among the six generations for various spike and yield related traits of the direct as well as reciprocal crosses both under normal and late planting environments. Significant and positive genetic correlations among yield related traits predominated the phenotypic association for the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal under both planting conditions. The strong relationship of yield with yield component traits suggested that grain yield potential can be effectively improved by obtaining maximum expression of spike length, spikes plant^{-1}, number of grains spike^{-1}, biological yield and harvest index.

Key Words: ***Wheat, Genotypic and phenotypic correlation, Yield traits, planting environments***

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INTRODUCTION

Wheat (*Triticum aestivum* L.), being the most important food grain of Pakistan and valuable staple food, invites the attention of breeders, researchers and growers to raise the level of production to over come the food challenge due to increasing population. To overcome food shortage and to feed the ever-increasing population, it is important to increase per unit yield through the development of high yielding and relatively stable wheat genotypes for diverse environments. Ansari (2002) reported that wheat crop sown in mid November produces more tillers plant^{-1} and more grain yield compared to that planted in mid and late December. A considerable yield improvement in spring wheat is still possible through the use of better breeding techniques and advance agronomic practices.

The know-how regarding the nature and magnitude of association among plant traits is essential to improve crops yields. Singh *et al*. (1995) observed that wheat grain yield was positively correlated with productive tillers and flag leaf area. Similarly, Singh and Dewivedi (2002) have reported significant positive association of grain yield plant^{-1} with number of spikes bearing tillers plant^{-1} both at genotypic and phenotypic levels. Tammam *et al.* (2000) reported that grain yield plant^{-1} had a positive genetic correlation with number of spikes plant^{-1} and 1000-kernel weight. Shahid *et al.* (2002) observed that spike length had significant positive genotypic correlation with grain yield. Lad *et al.* (2003) reported that grain yield exhibited highly significant and positive correlation with tillering capacity, spikelets spike^{-1} at both the genotypic and phenotypic levels. Kashif and Khaliq (2004) reported that plant height, spike length, spikelets spike^{-1} and 1000-grain weight were positively and significantly correlated with grain yield at genotypic level. Therefore, the objective of this study was to assertion the genetic and phenotypic correlations among yield traits of the direct and reciprocal crosses derived from two diverse wheat cultivars under normal and late planting conditions.

MATERIALS AND METHODS

This study was conducted during 2005-06 to 2007-08 at Cereal Crops Research Institute (CCRI), Pirsabak, Nowshera, Pakistan. The experimental material was developed from two wheat cultivars Fakhre Sarhad and Saleem-2000. Fakhre Sarhad is a full season cultivar with tall stature and is recommended for normal planting (Muhammad and Khan, 1996), while Saleem-2000 is a short season cultivar with dwarf stature and is recommended for late planting conditions (Subhan *et al.* 2004).

Development of F_1 Generation

Crossing blocks were established in research area of the Wheat Breeding Section at CCRI, Pirsabak to develop the desired F_1 crosses during crop season 2005-06. About 80-100 spikes were selected from each parental cultivar for making crosses. Cultivar Fakhre Sarhad was used as female and Saleem-2000 as male parent to produce the direct F_1 seed. The same cultivars were also crossed in reciprocal fashion. The F_1 seed of each cross was harvested separately at maturity.

Development of F_2 and Backcross (BC_{11} and BC_{12}) Generations

Part of seed harvested at maturity from each of the two parents and its F_1 hybrids was planted at CCRI during 2006-07 to produce F_2 and backcross (BC_{11} and BC_{12}) generations. Details about development of various generations for the study are given in Table I. Normal cultural practices were applied to the experimental material throughout the growing period. Seed from parents, F_1, F_2, BC_{11}, and BC_{12} was harvested separately at maturity.

Table I *Crossing plan for the development of F_1, F_2, BC_{11} and BC_{12} generations from two parental wheat cultivars*

Generation	Direct Cross	Reciprocal Cross
P_1	Fakhre Sarhad	Saleem-2000
P_2	Saleem-2000	Fakhre Sarhad
F_1	$P_1 \times P_2$	$P_1 \times P_2$
F_2	F_1 Selfed	F_1 Selfed
BC_{11}	$F_1 \times P_1$	$F_1 \times P_1$
BC_{12}	$F_1 \times P_2$	$F_1 \times P_2$

Evaluation of Parents, F_1, F_2, BC_{11} and BC_{12} Generations

During 2007-08 crop season, parents, F_1, F_2 and backcross (BC_{11} and BC_{12}) generations were evaluated in a randomized complete block design with three replications under normal (planted in 1st week of November) and late (planted in 3rd week of December) planting conditions at CCRI, Pirsabak, Nowshera. Fifty kernels were planted by hand in 5 meter long row with two rows each for parental and F_1 generations, four for each backcross and eight for F_2 generations. Rows were spaced 30 cm apart, with plant-to-plant distance of 10 cm within row. Recommended cultural practices were used to the experimental material throughout the growing period. The number of plants for taking data varied depending on the generation. Ten plants each were selected at random from non-segregating generations (parents and F_{1s}), twenty from each backcross (BC_{11} and BC_{12}) and thirty from each F_2 generation in each replication for recording data. Data were recorded on plant basis for spike length, spikelets spike^{-1}, grains spike^{-1}, biological yield, grain yield and harvest index. Analysis of variance (ANOVA) and covariances (ANCOVA) for all traits were derived under each planting condition following procedures of Singh and Chaudhary (1985). Genetic and phenotypic variances and co-variances computed from ANOVA and ANCOVA were used to estimate genetic and phenotypic correlations among traits under normal and late planting conditions.

The genetic (r_G) and phenotypic correlations (r_p) between two characters, x_1 and x_2, were estimated according to Kwon and Torrie (1964).

$$r_G = \frac{COV_{G}(x_1\ x_2)}{\sqrt{V_G(x_1).\ V_G(x_2)}}$$

Where,

$COV_G(x_1x_2)$ = Genetic covariance among trait x_1 and x_2.

$V_G(x_1)$ and $V_G(x_2)$ = Genetic variance for trait x_1 and x_2, respectively.

$$r_p = \frac{COV_P(x_1\,x_2)}{\sqrt{V_P\,(x_1).\,V_P\,(x_2)}}$$

Where,

$COV_P\,(x_1x_2)$ = Phenotypic covariance among traits x_1 and x_2

$V_P(x_1)$ and $V_P(x_2)$ = Phenotypic variance for traits x_1 and x_2, respectively.

RESULTS AND DISCUSSION

Association among yield components at genotypic and phenotypic levels for the direct and reciprocal wheat crosses under normal and late planting conditions are presented in Table II. Significant genotypic correlations among yield and its components were generally more prevalent than the phenotypic in the direct as well as reciprocal wheat crosses.

Spike Length

Spike length exhibited significant and positive genetic and phenotypic correlation with number of spikelets spike^{-1} both under normal and late planting for the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal (except r_P under late planting). Moreover, genetic correlations were greater in magnitude than phenotypic correlations under both planting conditions (Table II). Genetic and phenotypic correlation of spike length was also significant and positive with grains spike^{-1} for the direct cross Fakhre Sarhad × Saleem-2000 (r_G = 0.95 and r_P = 0.82) and its reciprocal (r_G = 0.81 and r_P = 0.67) under normal planting, but non-significant under late planting except the genetic correlation for the reciprocal cross (r_G = 0.95, $P \leq 0.01$). Both genotypic and phenotypic association among spike length and biological yield were significant and positive under normal planting for the direct cross (r_G = 0.53, $P \leq 0.05$ and r_P = 0.50, $P \leq 0.05$), whereas non-significant for the reciprocal cross. However spike length exhibited only moderate genetic association with grain yield (r_G = 0.55, $P \leq 0.05$) and highly significant with harvest index (r_G = 0.84, $P \leq 0.01$) under normal planting for direct cross Fakhre Sarhad × Saleem-2000 (Table II). In case of reciprocal cross (Saleem-2000 × Fakhre Sarhad), genetic correlation among spike length and grain yield was significantly negative (r_G = -0.75, $P \leq 0.01$) under normal planting. Similarly, genetic correlations of spike length with grain yield and harvest index were significantly positive under late plating (r_G = 0.88 to 0.93, $P \leq 0.01$) for the reciprocal cross but these correlations were not existent for the direct cross Fakhre Sarhad × Saleem-2000. But interestingly the phenotypic correlations of spike length with grain yield and harvest index were non-significant both under normal as well as late planting for the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal (Table II).

Number of Spikelets Spike^{-1}

The number of spikelets spike^{-1} and grains spike^{-1} showed strong genetic and phenotypic association (r_G = 0.64 to 0.99 and r_P = 0.54 to 0.84) both for the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal under normal planting, but these associations were not evident under late planting (Table II). Similarly, genetic and phenotypic correlations among spikelets spike^{-1} and biological yield were significantly positive under normal as well as late planting for the direct cross Fakhre Sarhad × Saleem-2000 (r_G = 0.88, $P \leq 0.01$; r_P = 0.51 to 0.55, $P \leq 0.05$) and its reciprocal (r_G = 0.92 to 1.00, $P \leq 0.01$; r_P = 0.81, $P \leq 0.01$). In contrast, genetic association of spikelets spike^{-1} with grain yield was significantly positive for direct cross Fakhre Sarhad × Saleem-2000 under normal (r_G = 0.86, $P \leq 0.01$) and its reciprocal under late planting (r_G = 0.91, $P \leq 0.01$), but phenotypic association among the two traits were non-existent except for reciprocal cross under late planting (r_G = 0.58, $P \leq 0.05$).

Number of Grains Spike^{-1}

Grains spike^{-1} is an important yield contributing component and is often used as a selection trait in wheat breeding programmes. In our study, grains spike^{-1} exhibited significant positive genetic correlation with biological yield under normal planting for the direct cross Fakhre Sarhad × Saleem-2000 only (r_G = 0.61, $P \leq 0.01$) (Table II). In contrast, genetic association of number of grains spike^{-1} with grain yield was significantly positive under both normal and late plantings for the direct cross Fakhre Sarhad × Saleem-2000 (r_G = 0.48 to 0.83), while only under normal planting for the reciprocal cross (r_G = 0.92, $P \leq 0.01$). Genetic relationship between grains spike^{-1} and harvest index were either non-existent or significantly negative both for the direct cross and its reciprocal under normal as well as late planting condition. For example, genetic correlation among number of grains spike^{-1} and harvest index was -0.74 ($P \leq 0.01$) under late planting for the direct cross Fakhre Sarhad × Saleem-2000, while -0.49 ($P \leq 0.05$) under normal planting for the reciprocal cross (Saleem-2000 × Fakhre Sarhad). Phenotypic association among grains spike^{-1} and harvest index was not evident under either planting condition both for direct and its reciprocal cross.

Biological Yield

Both genetic and phenotypic correlations among biological and grain yields were positive and significant for direct cross under normal planting ($r_G = 0.93$, $P \leq 0.01$; $r_P = 0.74$, $P \leq 0.01$) and its reciprocal cross (Saleem-2000 × Fakhre Sarhad) under late planting ($r_G = 0.92$, $P \leq 0.01$; $r_P = 0.64$, $P \leq 0.01$). Similarly, strong genetic association between biological yield and grain yield was also observed under normal planting for reciprocal cross Saleem-2000 × Fakhre Sarhad ($r_G = 0.95$, $P \leq 0.01$). Strong positive genetic association among biological yield and harvest index was evident only under normal planting condition for direct cross Saleem-2000 × Fakhre Sarhad ($r_G = 0.88$, $P \leq 0.01$) and its reciprocal ($r_G = 1.00$, $P \leq 0.01$), however phenotypic relationships among these two traits were non-significant under both planting conditions (Table II).

Grain Yield

Like biological yield, similar trend of association between grain yield and harvest index was also observed under both the planting conditions. For-example, genetic correlation among grain yield and harvest index was positive and highly significant only under the normal planting condition for direct cross Fakhre Sarhad × Saleem-2000 ($r_G = 0.88$, $P \leq 0.01$) and its reciprocal ($r_G = 0.91$, $P \leq 0.01$). Genetic correlations among these two traits under late planting and phenotypic correlations under both planting conditions for the direct cross as well as its reciprocal were non-significant (Table II).

Spike length exhibited significant association of positive nature with spikelets spike^{-1} both at genotypic and phenotypic level under both planting environments in the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal. The positive and significant association of spike length with spikelets spike^{-1} indicates that increased spike length would simultaneously increase the number of spikelets spike^{-1} and hence directly improve the grain yield. Positive and significant association among these two traits in the present study corresponds with the results reported by Khaliq *et al*. (2004) and Akram *et al*. (2008) who observed that spike length was positively correlated with spikelets spike^{-1} in wheat.

Highly significant correlation between spike length and grains spike^{-1} was observed at both the genotypic and phenotypic levels in the direct cross and its reciprocal under both normal and late planting conditions. The strong relationship is indicative of simultaneous genetic improvement in these two traits to develop wheat cultivars with longer spikes and more grains. Several researchers like Khaliq *et al.* (2004) and Akhtar and Chaudhery (2006) have also reported similar positive association between spike length and grains spike^{-1}.

Spike length and biological yield are important yield components influencing the final grain yield and are, therefore, used as selection indices in breeding programs. Association between spike length and biological yield was of positive nature and significant in the direct cross under normal planting both at genotypic and phenotypic levels, whereas in reciprocal cross this association was positive and significant at genotypic level under late planting only. Similar positive and significant association among spike length and biological yield has also been reported by Akhtar and Choudhary (2006).

Spike length showed significant positive genotypic relationship with grain yield under normal planting in direct cross Fakhre Sarhad × Saleem-2000 and under late planting in its reciprocal. The strong positive genetic relationship among these traits indicates that genes controlling these traits in the present source populations could be utilized for the development of high yielding wheat genotypes with longer spikes. Similar significant positive association among yield and spike length was also observed by Khaliq *et al.* (2004), Akhtar and Chaudhary (2006) and Saleem *et al.* (2006) in populations derived from simple and complex wheat crosses. Strong positive genetic association of spike length and harvest index was found under normal planting in direct cross Fakhre Sarhad × Saleem-2000 and under late planting in its reciprocal. Such strong positive genetic and phenotypic association among spike length and harvest index was also observed by Akhtar and Chaudhary (2006) in wheat.

The genetic and phenotypic correlation among spikelets spike^{-1} and grains spike^{-1} were highly significant and positive for the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal under normal planting only. The significant and positive relation between these two traits suggests that selection of wheat genotypes with longer spikes having more spikelets spike^{-1} and grains spike^{-1} can be developed as shown by Bangarwa *et al.* (1987), Kinyua and Ayiecho (1991) and Akram *et al.* (2008) in their studies in wheat. Spikelets spike^{-1} and biological yield in the direct cross (Fakhre Sarhad × Saleem-2000) and its reciprocal exhibited significant positive correlations at both the genotypic and phenotypic levels under both normal and late planting environments. The positive and significant association between spikelets spike^{-1} and biological yield in the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal revealed that these populations are good combiners and could be used for the improvement of wheat yields.

Genetic association of spikelets spike^{-1} with grain yield was significantly positive for direct cross Fakhre Sarhad × Saleem-2000 under normal and its reciprocal under late planting. Khaliq *et al.* (2004) and Akram *et al.* (2008) have also reported positive and significant association between these two traits in wheat. It may be concluded from the present study that spikelets spike^{-1}, grains spike^{-1}, biological yield and harvest index contributed to final grain yield. Therefore, indirect selection for these traits may be effective in developing high yielding wheat cultivars. Negative correlation was detected among grains spike^{-1} and biological yield in the direct cross Fakhre Sarhad × Saleem-2000 and its reciprocal. The negative association of grains spike^{-1} with biological yield is reported by Akhtar and Chowdhary (2006), while Singh *et al.* (1995) and Narwal *et al.* (1999) have reported that grains spike^{-1} were positively correlated with grain yield in wheat.

The genetic association of grains spike^{-1} with grain yield was significantly positive under both normal and late planting for the direct cross (Fakhre Sarhad × Saleem-2000) and its reciprocal. These results are supported by the findings of Akhtar and Chowdhary (2006) and Akram *et al.* (2008) who observed significantly positive association between these traits. Positive associations suggest that increased grain yield could be achieved if the selection is based on grains spike^{-1} and biological yield.

Biological yield of the cross Fakhre Sarhad × Saleem-2000 and its reciprocal exhibited significantly positive correlation at genetic and phenotypic level with grain yield under normal planting condition. However, this association was only significant under late planting condition in the reciprocal cross Saleem-2000 × Fakhre Sarhad. The significant and positive correlations of biological yield and grain yield plant^{-1} suggest that indirect selection for biological yield will also increase the wheat yield. The positive association of biological yield with grain yield was also reported earlier by Singh *et al.* (1995) and Akhtar and Chowdhary (2006).

Highly significant and positive genotypic correlation was observed between biological yield plant^{-1} and harvest index for direct cross and its reciprocal under normal plating condition. The results of this study are in close conformity with the findings of Iqbal and Redhu (1997) and Akhtar and Chowdhary (2006) who also reported positive and significant association between biological yield and harvest index. The genetic correlation of grain yield with harvest index was positive and highly significant in the direct cross and its reciprocal under normal planting condition. However under late planting these crosses exhibited non significant correlations between grain yield plant^{-1} and harvest index. The phonotypic correlations among these traits were positive but could not reach the level of significance. These findings indicated that increase in harvest index will increase grain yield in wheat. The results reported by Sharma and Smith (1986) and Akhtar and Chowdhary (2006) also support our findings of positive correlations between grain yield and harvest index in early segregating and backcross generations in wheat.

Table II ***Genotypic (r_G) and phenotypic (r_P) correlations among yield components of direct cross Fakhre Sarhad × Saleem-2000 (above diagonal) and its reciprocal Saleem-2000 × Fakhre Sarhad (below diagonal) under normal and late planting environment***

Traits	Planting	Spike length		Spikelets spike^{-1}		Grains spike^{-1}		Biological yield		Grain yield		Harvest index	
		r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P
Spike length	Normal	--	--	0.95**	0.87**	0.95**	0.82**	0.53*	0.50*	0.55*	0.18	0.84**	0.15
	Late	--	--	0.95**	0.50*	0.15	0.20	-0.27	-0.05	-0.12	-0.01	0.25	-0.08
Spikelets spike^{-1}	Normal	0.83**	0.74**	--	--	0.99**	0.84**	0.88**	0.55*	0.86*	0.33	0.21	-0.18
	Late	0.87**	0.42	--	--	-0.29	0.25	0.88**	0.51*	0.33	0.04	-0.11	-0.21
Grains spike^{-1}	Normal	0.81**	0.67**	0.64**	0.54*	--	--	0.61**	0.39	0.83**	0.54*	0.17	0.11
	Late	0.95**	-0.03	0.15	0.38	--	--	0.03	0.04	0.48*	0.45	-0.74**	-0.01
Biological yield	Normal	0.23	0.09	0.92**	0.44	-0.07	0.05	--	--	0.93**	0.74**	0.88**	-0.21
	Late	0.61**	0.32	1.00**	0.81**	-0.18	-0.32	--	--	-0.04	0.01	0.36	-0.24
Grain yield	Normal	-0.75**	-0.17	-0.47*	-0.12	0.92**	-0.08	0.95**	0.35	--	--	0.88**	0.10
	Late	0.88**	0.22	0.91**	0.58*	-0.23	-0.01	0.92**	0.64**	--	--	-0.26	0.02
Harvest index	Normal	0.17	-0.16	0.36	-0.02	-0.49*	0.29	1.00**	0.24	0.91**	0.16	--	--
	Late	0.93**	0.45	0.79**	0.23	0.20	-0.15	0.15	-0.30	0.39	0.06	--	--

*, ** = Significant at 5 and 1% probability level, respectively

CONCLUSION

It is concluded that grain yield could be effectively increased by maximum genetic expression of spike length, spikes plant^{-1}, grains spike^{-1}, biological yield and harvest index. Indirect selection of these yield contributing traits in early generations will enhance genetic potential of newly bred wheat genotypes for grain yield.

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