Role of some agronomic traits for grain yield production in wheat (*Triticum aestivum* L.) genotypes under drought conditions

Papel de algunos caracteres agronómicos en el rendimiento de semillas de genotipos de trigo (*Triticum aestivum* L.) bajo condiciones de sequía

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ABSTRACT

The association of some agronomic traits among wheat lines and their direct and indirect influence on the grain yield of wheat were investigated. In order to do this study, experiment with 25 breeding lines was conducted in a randomized complete block design with three replications. According to the results, the correlation and path analyses of grain yield and its components in promising wheat lines revealed that there is strong positive association of grain yield with number of tillers and number of spikes per plant. Grain yield was negatively associated with number of florets per spike. Comparatively, high genetic variation was found in grain yield, flag leaf area, and tillers per plant. Number of tillers per plant had direct effect on grain yield and majority of the traits affected grain yield through it.

Key words: Wheat, *Triticum aestivum*, cross breeding, path analysis

RESUMEN

La asociación de algunos caracteres agronómicos entre líneas de trigo y su influencia directa e indirecta sobre el rendimiento de semillas en trigo fue investigada. Se realizó un experimento con 25 líneas mejoradas en un diseño de bloques completos al azar con tres repeticiones. De acuerdo a los resultados, los análisis de correlación y de trayectoria del rendimiento de semillas y sus componentes en líneas promisorias de trigo revelaron que hay una fuerte asociación positiva del rendimiento de semillas con el número de hijuelos y número de espiguillas por planta. El rendimiento de semillas estuvo negativamente asociado con el número de florecillas por espiguilla. Comparativamente, se encontró una alta variación genética en el rendimiento de semillas, área foliar de la hoja bandera e hijuelos por planta. El número de hijuelos por planta tuvo un efecto directo sobre el rendimiento de semilla y la mayoría de los caracteres afectaron el rendimiento de semillas a través del número de hijuelos por planta.

Palabras clave: Trigo, *Triticum aestivum*, mejoramiento de plantas, análisis de trayectoria

INTRODUCTION

Wheat is grown both in arid and semi-arid regions of the world. Increasing wheat production under abiotic stress conditions has become important in recent years, since wheat production in areas with optimum growing conditions does not meet the needs of the increasing population. Drought resistance is a general term and could refer to any of several types of drought resistance such as drought escape, dehydration avoidance or dehydration tolerance. Breeding wheat for drought resistance is a difficult, long-term project. Present cultivars were developed by yield testing in a range of environment from fully irrigated to severely drought stressed. Perhaps physiologically based screening techniques can be utilized to improve selection of parental material or to rapidly screen large segregation populations to improve the level of drought resistance prior to yield testing. Morphological parameters like plant height, flag leaf area, days to heading, tillers per plant and grain yield etc. related to drought resistance has already been identified by plant physiologists. Grain yield is a product of several contributing factors and can be estimated on the basis of performance of various components.

The breeding procedure for drought tolerance depends upon the pattern of inheritance (qualitative or quantitative), the number of genes with major effects, and the nature of the action of those genes (Rao and McNeilly, 1999). There is now a considerable body of information about variation both between and within species in response to drought (Maas, 1986), and physiology of drought tolerance (Kingsbury *et al*. 1984). Evidences for inter and intraspecific variation in drought tolerance (Ashraf and McNeilly, 1988) as well as intra-varietal variation (Salam *et al*. 1999) has also been reported in wheat. Developing crop cultivars with high grain yield has been the principle aim of durum wheat breeding programs worldwide (Miralles *et al*., 2000). Earlier studies showed that grain yield per plant was positively correlated with number of tillers per plant. In the other hand, grain filing is maintained by high contribution from assimilation before and immediately after anthesis and remobilization of vegetative growth during kernel growth. The growth period is the most sensitive stage to drought stress, with respect to yield, is from double ridge to anthesis due to its negative impact on spike number and kernels per spike (Royo *et al*. 2000). The effect of high temperatures on wheat growth and development has been studied both in field environments (Zhong-hu and Rajaram, 1994) and in controlled growth chamber conditions. Thus, simple correlations may not provide a clear picture of the importance of each component in determining grain yield. Path coefficient analysis divides the correlation into direct and indirect effects. It allows, then, the separation of the direct influences each yield component on grain yield from the indirect effects caused by the mutual relationships among lied components themselves (Mujeeb-Kazi and Delgado, 1998).

Path analysis disintegrates the correlation into direct and indirect contributions of a particular trait to yield. This disintegration helps in ranking the traits of plants, which can be utilized for indirect selection. The correlation and path analyses were estimated for different plant traits in promising lines of wheat to evolve high yielding wheat genotypes. Path analysis was performed as a supplement for correlation analysis to elucidate the interrelationships among characters determining grain yield.

MATERIAL AND METHODS

Genotypes

The experimental material comprised of 25 selected wheat lines *viz*. Hd-2169, Hd-2179, Hd-2204, Hd-2285, Hd-2329, C-271, C-273, C-518, C-591, Maxipak, Blue Silver, Wl-711, Chenab-70, Lyalpur-73, Pothowar, Punjab-81, Faisalabad-83, Shalimar-88, Pak-81, Punjab-85, Faisalabad-85, Kohnoor-83, Chakwal-86, Rawal-87 and Pasban-90 locally adapted cultivars were chosen for studied based on their reputed differences in yield performance and drought resistance.

Irrigation × Cultivar

Field irrigation studies were conducted. Irrigation was in level basins 8 m wide by 90 m long with water application measured by in line flow meters, cultivars were planted in early November as subplots within the irrigation plots in a randomized complete block design with three replications. Cultivar plots were 5m wide and 30 m long. A small plot combine was used to harvest the centre 1.6 m by 25 m of each plot .The drought stressed treatment was watered with 100 mm in the fall to wet the soil profile and establish a stand. No further irrigation was applied to this treatment. The irrigated treatment was established in the same manner but received 200 to 400 mm of irrigation in the spring. Irrigation amount in the spring varied because of differences in weather and was adequate to avoid major drought stress. Data taken from these plots were grain yield, flag leaf area.

Germination in Mannitol

Fungicide treated seed was germinated at 22 º C in 100 mm diameter covered Petri dishes. Filter paper was placed on both sides of 65 seeds in each Petri dish and moistened with distilled water. Strength of the mannitol solution was based on the work of Ashraf and Abu-Shakra (1978). Seedling in a total of six replications during two separate trails were counted to determine percent germination and were rated for vigor. Since results of the two trails were very similar, the data were combined for analysis.

Survival after desiccation

Wooden flats 425 x 550 x 65 mm deep were lined with paper and filled with clay loam topsoil. The cultivars were planted as single rows 25 mm apart with 50 seeds per 425 mm of row and guard rows on the outside. The plants were well watered until the 2 to 3 leaf stage. Water was then withheld until most of the seedling appeared to be dead. The flats were then dewatered and survival was counted after re-growth on two flats in each experiment with three replications per flat. The experiment was conducted in a greenhouse.

Water Loss of Excised Leaves

Plants were grown in greenhouse flats as described in the previous section and sampled at the tillering stage when 150 mm tall. Field grown plants from a non-stressed irrigation treatment were sampled at the early joining stage of development when 260 mm tall. Bulk leaf tissue was weighted, allowed to desiccate in a dark room at 22 º C for 24 h, reweighed, oven dried at 70 º C and weighted again. There were three replications in each experiment and 3 to 6 g of leaves, fresh weight per sample.

Root length

Ten seeds of each cultivar were planted in sand in 85 mm diameter by 245 mm deep cans. The seedling was thinned to three per cane, grown for 15 days after emergence at 26 º C day and 16 º C night temperatures in growth chamber, and washed from the sand. The length of all roots was measured with a ruler. There were three replications of each cultivar in each of two trails.

Rooting Depth

Wheat seedling was grown 40 d in 75 mm x 3 m clear tubes filled with a peat- vermiculite mix and angled 15 from vertical. The tubes were covered with Styrofoam to exclude light and were in a greenhouse with a temperature range from 20 to 28 º C. Plant were watered every 3 d and fertilized weekly with a Hoagland's solution. The experimental design was a randomized complete block with 10 replications. The experiment was not repeated over time. Maximum root depth was recorded at least once per week.

The same genotypes were also planted in triplicate randomized block design in the field under moisture stress conditions (zero irrigation). The genotypes were sown with the help of a Rabi drill in a randomized complete block design with four replications in the field under moisture stress conditions (zero irrigation). The distance between rows and plants was kept 22.5 and 15 cm respectively. Each plot consisted of 3 rows of 5m lengths. Various morpho-physiological traits at mature plant stages. Ten representative plants from each plot were randomly marked to record the data on plant height (cm), flag leaf area (cm^2), number of tillers per plant and grain yield (g).

Plant height (cm)

Plant height of central spike (mother shoot) of each plant was measured in cm from the Ground level to the apex of the spike excluding awns.

Flag leaf area (cm^2)

Flag leaf area of mother shoot of randomly selected plants in each replication was measured in cm^2 with electric leaf area meter and then average was calculated

Number of tillers per plant

Numbers of tillers per plant were counted on each plant in each family.

Grain Yield (g)

Grain yield in gram from each selected plants was recorded separately on electronic balance, average yield was then computed. The average temperature and average rain fall during the growing season of the wheat crop is shown in Figure 1.

Statistical Analysis

Variances and covariance analyses for all the traits studied were performed using the method given by Steel and Torrie (1980). The estimates of genotypic correlations were computed according to the method given by Kwon and Torrie (1964). The sampling of genetic correlations was tested as suggested by Reeve (1955). Path coefficient analysis was performed as described by Dewey and Lu (1959). Grain yield was kept as resultant variable and other traits as causal ones. Heritability in broad sense as a ratio of genotypic to phenotypic variance and Standard Error (S.E.) for heritability was computed for each trait. Genetic advance was calculated at 20 per cent selection intensity (i = 1.4). Genotypic and phenotypic coefficients of variation were calculated for the estimation of variability.

RESULTS AND DISCUSSION

Heritability and Genetic advance

Results pertaining to various genetic parameters *viz*., coefficient of genotypic (GCV) and phenotypic variation (PCV) and the estimates of heritability and genetic advance are presented in (Table 1). The significant estimates of heritability in broad sense associated with all the traits under study except root length. High genetic advance was obtained by 20 % selection intensity for plant height (7.58 cm), grain per plant (5.7 g), water loss excised leaves (3.61) and germination in mannitol (3.05

days). High heritability coupled with high genetic advance for plant height provides enough confidence for selection of desirable types (Ali *et al*., 2002). Genotypic and phenotypic coefficients of variation (Table 1) provided a glance of variability available at breeding material for various plant traits. Relatively high genetic variability was estimated for grain yield per plant, flag leaf area, tiller number per plant and root depth per plant. In the rest of the traits studied, genotypes showed almost consistent performance that is in agree with report of Khan *et al*. (2003). The study showed that little differences in genotypic and phenotypic coefficients of variability reflecting greater role of genetic factors than environmental in the expression of character which provide ample chances for selection of desirable types.

Correlation analysis

Genotypic correlation coefficients along with their standard errors are presented in (Table 2). The results indicate that plant height was positive and significantly correlated with germination in mannitol, water loss of excised leaves and root length but

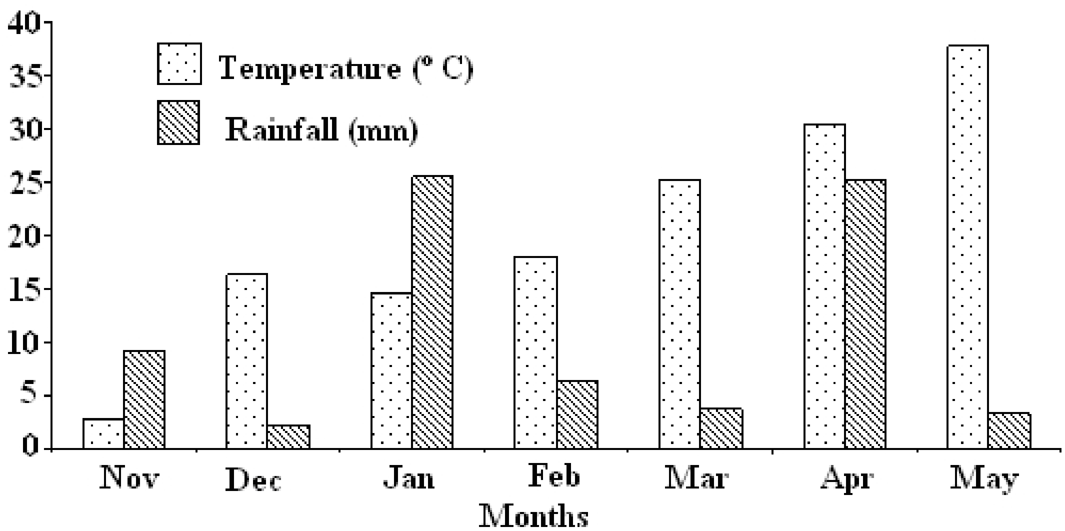

Figure 1. Average temperature and average rainfall during the growing season of wheat (*Triticum aestivum* L.) crop at Saline Agriculture Research Center, University of Agriculture, Faisalabad, Pakistan in November 2005.

Table 1. Various genetic parameters in wheat (*Triticum aestivum* L.) at Saline Agriculture Research Center, University of Agriculture, Faisalabad, Pakistan in November 2005.

Traits	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability † ± S.E.	Genetic advance
Plant height (cm)	15.46	19.76	0.61 ± 0.08	1.4
Leaf area (cm^2)	6.70	7.17	0.87 ± 0.03	7.5
Germination in mannitol	2.17	2.23	0.94 ± 0.08	3.05
Survival desiccation	12.33	14.87	0.68 ± 0.06	2.33
Water loss excised leaves	12.19	14.85	0.67 ± 0.06	2.23
Root length (cm)	4.92	6.57	0.56 ± 0.03	3.6
Root depth (cm)	5.24	6.64	0.62 ± 0.09	139
Tiller number/plant	1.02	1.69	0.36 ± 0.60	1.65
Grain yield/Plant (g)	22.88	24.47	0.87 ± 0.04	5.70

† Heritability estimate is significant if its calculated value exceeds twice of its standard error (S.E)

negative and significantly with survival after desiccation, root depth, tiller number per plant and grain yield at genotypic level that is in agree with Khan *et al*. (2003). Flag leaf area was positive and significantly correlated with germination in mannitol, survival after desiccation, and water loss of excised leaves, tiller number per plant and grain yield. Flag leaf area showed negatively significant genotypic correlation with root length and root depth. In the other hand, germination in mannitol had positive genotypic correlation with water loss of excised leaves, root length, root depth and grain yield but tiller number per plant showed negative and significantly correlation with germination in mannitol (Munns *et al*., 2003).

Survival after desiccation has a positive and significant correlation with water loss of excised leaves, root length, tiller number per plant and grain yield, but root depth was only negatively non-significant with survival after desiccation. Water loss of excised leaves was show significant positive relation with tiller number per plant and grain yield. It is suggested that genotypes having better contribution and utilization of soil moisture can produce more number of tillers per plant ultimately adding to grain yield. Therefore, results suggested that grain yield was correlated positively with flag leaf area, germination in mannitol, survival desiccation, water loss of excised leaves and tiller number per plant at genotypic level. Grain yield showed a negative significant genotypic correlation with plant height and root length but root depth negatively non-significant correlated with grain yield under drought conditions. The results obtained for mature plant showed that grain yield was positive and significantly correlated with flag leaf area at genotypic level and with number of tillers per plant at the genotypic level but flag leaf area non-significant correlated with grain yield at phenotypic level (Muraila *et al*., 2001).

Path analysis

The results pertaining to path analysis are presented in (Table 3) and discussed here under: Direct effect of plant height on grain yield was negative, whereas its indirect effects via germination in mannitol was positive while all the other traits were negative. The direct effects of flag leaf area on grain yield was positive (Ali *et al*., 2002; Masauskiene *et al*., 2001). The indirect effect via plant height, germination in mannitol, survival after desiccation, water loss of excised leaves and no of tiller per plant were positive while the other traits indirect effect of flag leaf area via root length and root depth were negative. The results thus obtained suggest that flag leaf area is an important component of yield and hence needs special attention in selection strategies (Singh, 1999). The direct effects of germination in mannitol on grain yield was positive and low and indirect effects germination in mannitol via plant height, flag leaf area and no of tiller per plant were also positive while all the other traits were negative indirect effects with germination in mannitol. Survival after desiccation influenced yield negatively direct and indirectly through root length and root depth. Mainly these traits contributed to yield through plant height (Kamal *et al.*, 2003; Kumar and Ramesh, 2001). This may be attributed to the differences in experimental material and environmental conditions under which the experiment was conducted. The direct effect of root length to grain yield was negative. Whereas, its indirect effects through all other traits were positive except the root depth. Tillers per plant contributed grain yield directly at the maximum level. However, its own indirect effects via flag leaf area, germination in mannitol and water loss of excised leaves (Huang Zuliu *et al*., 2000). While the other traits plant height, root length and root depth made their maximum negative indirect effect to number of tiller per plant through these traits (Khattab *et al*., 2001; Hanchinal and Ramed, 1999).

CONCLUSION

The overall results indicated that there is genetic variability present in the material studied. The genotypes C-591 and Blue Silver appeared to be drought tolerant whilst the other genotypes. The drought stress showed drastic effect on plant growth and grain yield. The results suggested that the traits like Flag leaf area, Germination in mannitol and tiller number per plant due to their genetic basis and significant correlation with grain yield, could be used as selection criteria to identify drought tolerant wheat genotypes, The genetic information derived from these studies further suggested that the traits having additive type of gene action would be helpful to improve drought tolerance in wheat. Further investigations are needed to derive sounder conclusion for the development of drought tolerant wheat genotypes, to bring the droughty prone areas under wheat cultivation. Such type of breeding programme may lead to improve the economic condition of stack-holders in general and farmers living in drought-affected areas in particular.

Table 2. Genotypic correlation matrix along with their standard errors in two rowed wheat (*Triticum aestivum* L.) at Saline Agriculture Research Center, University of Agriculture, Faisalabad, Pakistan in November 2005.

Traits	Plant height (cm)	Flag leaf area (cm^2)	Germination in mannitol	Survival desiccation	Water loss excised leaves	Root length	Root depth	Tiller number/plant	Grain yield plant (g)
Plant height (cm)	1	- 0.079 0.049	0.225 * 0.023	- 0.479 * 0.046	0.483 * 0.063	0.336 * 0.053	- 0.206 0.099	- 0.501* 1.808	- 0.2626 0.2860
Flag leaf area (cm^2)		1	0.609 * 0.025	0.266 * 0.028	0.273 0.038	- 0.760 * 0.018	- 0.725 * 0.024	0.307 * 1.090	0.2815 * 0.1409
Germination in mannitol			1	0.200 0.047	0.213 * 0.064	0.403 * 0.058	0.402 * 0.070	- 0.351* 2.424	0.2141 * 0.2370
Survival desiccation				1	0.999 * 0.001	0.449 * 0.029	- 0.303 0.057	0.881 * 1.137	0.889 * 0.0390
Water loss excised leaves					1	- 0.417 0.039	- 0.323 0.076	0.862 * 0.512	0.8924 * 0.0518
Root length						1	0.946 * 0.006	- 0.472 * 1.137	- 0.414 * 0.1540
Root depth							1	- 0.157 2.439	- 0.232 0.3009
Tiller number/plant								1	0.926 * 1.050

* Significant ($p \leq 0.05$)

Table 3. Direct (in parenthesis) and indirect effect matrix in two rowed wheat (*Triticum aestivum* L.). Dependent variable is grain yield/plant. The last column shows genotypic correlations of independent variables with grain yield/plant at Saline Agriculture Research Center, University of Agriculture, Faisalabad, Pakistan in November 2005.

Traits	Plant height (cm)	Flag leaf area (cm^2)	Germination in mannitol	Survival desiccation	Water loss from excised leaves	Root length	Root depth	Tiller number/plant	Grain yield plant (g)
Plant height (cm)	(- 0.0908)	0.0102	0.0148	0.2558	4.3747	0.0767	- 0.0553	-4.9803	-0.2626
Leaf area (cm^2)	- 0.0072	(0.1278)	0.0402	- 0.1565	- 2.4696	0.1739	- 0.1941	2.767	0.2815
Germination in mannitol	0.0204	0.078	(0.0659)	0.1794	- 1.9369	- 0.0921	0.1075	2.0797	0.2741
Survival desiccation	- 0.0435	0.034	- 0.0132	(- 0.4496)	- 9.0561	0.1027	- 0.0811	(10.3958)	0.889
Water loss from excised leaves	- 0.0439	0.0349	- 0.0141	- 0.4398	(- 9.0572)	0.1046	- 0.0864	10.3944	0.8924
Root length (cm)	- 0.0305	- 0.0973	- 0.0266	0.2407	4.1447	(- 0.2286)	0.2532	- 4.6696	- 0.414
Root depth (cm)	- 0.0188	- 0.0928	- 0.0265	0.0802	2.9267	- 0.2163	(0.2675)	- 3.1522	- 0.232
Tiller number/plant	- 0.0456	0.0392	0.0230	- 0.5099	- 7.8127	0.1079	- 0.0421	(9.1661)	0.9263

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