Association analysis of some morphological traits of wheat (*Triticum aestivum* L.) under field stress conditions

W.M. Bhutta[1], M. Ibrahim[2], Tahira[3]

[1]*Centre of Advanced Study in Applied Genetics and Saline Agriculture, University of Agriculture, Faisalabad, Pakistan*
[2]*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan*
[3]*Pakistan Agriculture Research Council, Islamabad, Pakistan*

ABSTRACT

An association between yield components and their direct and indirect influence on the grain yield of wheat were investigated. 24 breeding lines were tested in a randomized complete block experiment design with three replications. According to the results the phenotypic correlation among the traits and their path coefficient were estimated. Positive significant correlation coefficients were obtained for association between survival rate treatment I (0.35*) and III (0.34*), leaf venation (0.51*), stomatal frequency (0.39*), osmotic pressure (0.30*), flag leaf area (0.85*), number of tillers per plant (0.70*) with grain yield per plant at both phenotypic and genotypic levels. A negatively significant correlation between hygrophilic colloids (–0.15*) and epidermal cell size (–0.22*) with grain yield per plant was obtained at phenotypic and genotypic levels. Path coefficients were also computed to estimate the contribution of character to the yield. Path coefficient analysis revealed that flag leaf area (1.34), root/shoot ratio (0.51) and survival rate II (0.56) had the highest positive direct effects on grain yield, while hygrophilic colloids (–0.24) and osmotic pressure (–0.07) had a negative direct effect on grain yield. The results thus obtained suggested that flag leaf area is an important component of yield and hence needs a special attention in selection strategies.

Keywords: wheat; drought resistance; yield; Pakistan

Wheat is the world's most important cultivated crop, being the foremost food staple of mankind. The evolution of short stature and fertilizer responsive wheat varieties has been a landmark in the annals of genetic improvement of wheat, which resulted in a remarkable increase in its potential for grain yield. The full realization of the elevated potential has ever since figured prominently in the development of procedures and practices of wheat production hiking per unit productivity to a level of grain production unparsed in recent decades. These have aimed in particular to breed a "wider adaptation into these cultivars and to put the resulting material in widespread geographical distribution. However, by and large a vast array of varieties have been developed to adapt to rather quite uniform environmental conditions, where temperatures are moderate and rainfall is either adequate or can be supplemented or substituted by irrigation" (Simane et al. 1999).

Drought is one of the major environmental factors reducing grain production of rained wheat in arid and semi-arid regions. Drought may be described as a period in which a scarcity of soil moisture is limiting normal growth of plants. A precise definition of drought is indescribable; no one may satisfy each one (Miralles et al. 2000). Drought has sometimes been referred to as "a period in which the soil contains little or no moisture". Agricultural drought is defined as a climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production or range productivity (Royo et al. 2000).

When plants are subjected to drought stress, a number of physiological responses may be observed. In some cultivated cereals, osmotic adjustment has been found to be one of the most effective physiology mechanisms underlying plant resistant to water deficit. Osmotic adjustment, as a process of active accumulation of compatible osmolytes in plant cells exposed to water deficit

may enable: a continuation of leaf elongation, though at reduced rates; stomatal and photosynthetic adjustments; delayed leaf senescence; better dry matter accumulation and yield production for crops in stressful environments (Zhong-hu and Rajaram 1994, Gibson and Paulsen 1999).

Half the area sown to wheat in developing countries and up to 70% of that grown in developed countries suffers from periodic drought. Drought can occur at any time during the cropping cycle in all rainfed environments. In developing the breeding programmed to improve the drought resistance of a crop, it is first necessary to gain an understanding of how the crop reacts to drought. This is best done under field conditions in the area where the crop is grown, since the seasonal timing of drought stress varies from one location to other. Phenotype is the outcome of the interaction of the genotype with the environment. It is impossible to make a firm recommendation of a method for breeding for drought resistance that will apply to all crops and environmental conditions (Mujeeb-Kazi and Delgado 1998).

MATERIAL AND METHODS

The research was carried at University of Agriculture, in Faisalabad Pakistan. Twenty four wheat genotypes/lines viz. Rawal-87, Chakwal-86, Rohtas-90, LU26S, 8512-1, 8499, 8467, 8482, 8479, 8475, 8471, 8464, 8470, 8469, 8467-2, 8453, 8454, 8460-1, 8461-2, 8464, 8466, 5039, 8522 and 8466-1 were studied for various morpho-physiological traits at seedling and mature plant stages. These genotypes were evaluated for seedling traits in the greenhouse (Drought Chamber).

Fresh river sand 1-lb/bag was filled in 18 × 7 cm polythene bags, washed thoroughly with distilled water to make it free from nutrients. One seed of each variety/line was sown in each bag at a uniform depth of 3 cm. A completely randomized design with three repeats was used. Each repeat comprised of 10 seedlings of each genotype while each plant was in a separate polythene bag. Adequate sand moisture levels were maintained by watering the seedlings. A special attention was given to avoid saturation and water logging. Data on survival rate, root density and root/shoot ratio were recorded as follows.

Survival rate: The seedlings of each genotype in each repeat at a three leaf stage were placed in drought chamber under controlled conditions, i.e. different combinations of drought components. The following treatments of relative humidity, soil moisture and temperature were used for screening of genotypes.

Treatment 1: high temperature (40°C) + low soil moisture (25% FC) + low humidity (12%)

Treatment 2: high temperature + low soil moisture + normal humidity (60–70%)

Treatment 3: high temperature + normal soil moisture (50% FC) + low humidity

Treatment 4: high temperature + normal soil moisture + normal humidity

When 50% mortality was observed by visual observation, seedlings were taken out of drought chamber and Hoagland's solution was applied to them. After 10 days the numbers of survived seedlings were counted separately for each set of combination of drought components. The number

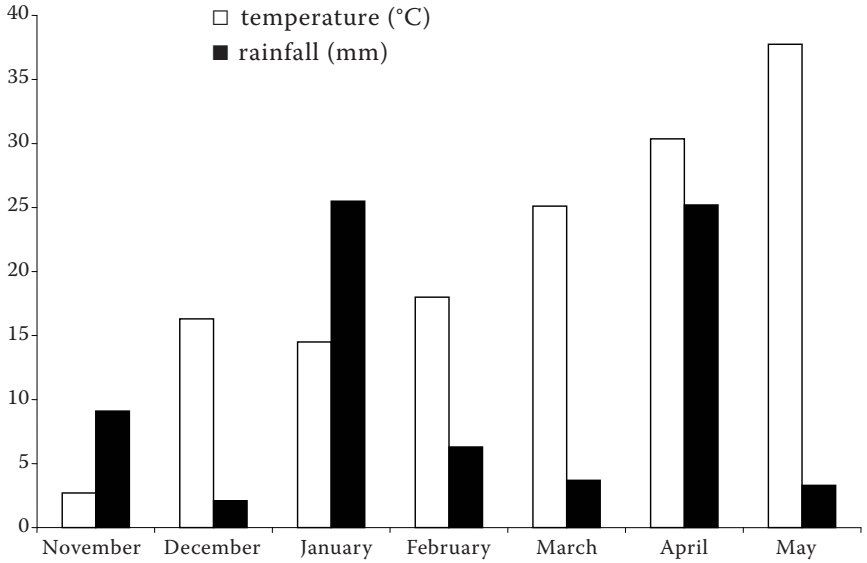

Figure 1. Meteorological data

of seedlings that survived was expressed as a percentage of total number of seedlings to obtain the survival rate as follows.

Survival rate = number of seedlings survived after 10 days/total number of seedlings × 100

Root density: At three leaf stage, 10 seedlings of each genotype were taken out from the polythene bags and washed thoroughly with tap water to remove adhesive soil from the roots. The root density was determined by taking the difference in water. The water volume in backer was 200 ml. Average root density was then calculated in cubic centimeters.

Root/shoot ratio: The 10 seedlings taken for root density were also used for root/shoot ratio. Fresh shoots and roots were separately put in kraft paper bags and dried at 60°C in an electric oven for 36 hours. Subsequently they were weighed and their weights expressed in milligrams.

Root/shoot ratio = root dry weight/shoot dry weight

The same genotypes were also planted in triplicate randomized block design 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 5 m length. Ten plants from each plot were randomly selected to record data on hygrophilic colloids, osmotic pressure, flag leaf area, number of tillers per plant and grain yield.

Hygrophilic colloids: Hygrophilic colloids were estimated indirectly by leaf powder method to assess its possible relationship with drought tolerance. About thirty disease free third nodal leaves were collected and oven dried at 70°C and then ground to make fine powder using an electric grinder. Powder leaves were filled in glass stoppered bottles and placed in the electric oven at 50°C to keep dry. About 1 g powder of each sample was subjected in small crucibles of known weight. After 24 hours the crucibles were weighed again and the moisture observed was noted and the absorption was calculated in percentage.

Osmotic pressure: The samples were collected in the morning hours, when leaves were fully turgid and disease and rust free third nodal leaves were collected and put in small polythene bags and immediately stored in a deep freezer for 24 hours. The tissue sap was extracted from these samples with a rotary hand press and then centrifuged at 6500 rpm for about seven minutes. A portion of the centrifuged tissue sap was used to determine osmotic pressure in milli-osmometer.

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

Number of tillers: Number of tillers of selected plants was counted at maturity. The average was then computed.

Grain yield: Grain yield from each selected plant was recorded separately on an electronic scale and the average yield was then computed.

The average temperature and average rainfall during the growing season of the wheat crop are displayed in Figure 1.

Genotypic and phenotypic correlation coefficients were worked out according to the procedure given by Kwon and Torrie (1964). Genetic correlation (rg) was checked against the formula given by Reeve (1955). The procedure for path coefficient analysis was used as given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Genetic relationship of traits may result from pleotropic effects of a gene, linkage of two genes, chromogema, and regimental affiliation or due to the environmental influences (Bruns and Croy 1985). The relationship of plant yield and its various characters is represented in Table 1. Osmotic pressure was genetically and positively associated with a survival rate treat 2, survival rate treat 3, leaf venation and stomatal frequency. While other characters survival rate treat 1, survival rate treat 4, root density, root/shoot ratio and hydrophilic colloids showed a negative association with osmotic pressure. Flag leaf area was found positively associated with survival rate treatment 1, survival rate treatment 3, survival rate treatment 4, leaf venation, stomatal frequency and osmotic pressure. Small negative correlation coefficients were obtained for a combination of flag leaf area with survival rate treatment 2, root density, root/shoot ratio, hydrophilic colloids and epidermal cell size (Sojka et al. 1997).

Number of tillers per plant observed a positive significant correlation with survival rate treatment 1, survival rate treatment 3, hydrophilic colloids, leaf venation, stomatal frequency, osmotic pressure and flag leaf area, whereas other characters, namely survival rate treatment 2, survival rate treatment 4, root density, root/shoot ratio and

Table 1. Phenotypic and genotypic correlation coefficients between yield and other traits

Traits		Survival rate T2	Survival rate T3	Survival rate T4	Root density	Root/shoot ratio	Hygrophilic colloids	Leaf venation	Stomata frequency	Osmotic pressure	Epidermal cell size	Flag leaf area	No. of tillers/plant	Grain yield/plant
Survival rate T1	r_g	0.02	−0.06	−0.01	−0.36*	−0.32*	−0.32*	0.26*	0.31*	−0.008	−0.39*	0.13	0.56*	0.35*
	r_p	0.02	−0.05	−0.03	−0.33**	−0.29*	−0.30**	0.18	0.26*	−0.001	−0.33**	0.12	0.48**	0.32**
Survival rate T2	r_g		−0.09	−0.28*	0.18*	0.09	0.195*	0.19*	−0.37*	0.16*	0.12	−0.14	−0.18*	−0.18*
	r_p		−0.08	−0.28*	0.19	−0.00	0.16	0.11	−0.28*	0.16	0.10	−0.16	−0.13	−0.15
Survival rate T3	r_g			−0.03	−0.11	0.11	0.05	0.28*	0.19*	0.12	0.04	0.45*	0.09	0.34*
	r_p			0.03	−0.09	0.06	0.05	0.23*	0.15	0.11	0.05	0.33**	0.08	0.32**
Survival rate T4	r_g				−0.25*	−0.01	0.45*	−0.18*	−0.07	−0.33*	−0.02	0.20*	−0.12	0.09
	r_p				−0.20	0.00	0.41**	−0.13	−0.04	−0.31*	−0.01	0.19	−0.10	0.04
Root density	r_g					−0.12	−0.06	0.37*	−0.29*	−0.10	0.10	−0.08	−0.12	−0.17*
	r_p					−0.11	−0.08	0.21	−0.23*	−0.09	0.09	−0.06	−0.10	−0.12
Root/shoot ratio	r_g						−0.11	−0.06	−0.26*	−0.11	0.50*	−0.10	−0.47*	−0.28*
	r_p						−0.10	0.16	−0.22	−0.09	0.41**	−0.06	−0.37**	−0.20
Hygrophilic colloids	r_g							0.00	−0.04	−0.10	0.03	−0.007	0.03	−0.15*
	r_p							0.01	−0.06	−0.09	0.03	−0.03	0.03	−0.12
Leaf venation	r_g								0.07	0.02	−0.07	0.64*	0.52*	0.51*
	r_p								0.01	0.02	−0.006	0.26*	0.27*	0.24*
Stomatal frequency	r_g									0.30*	−0.04	0.27*	0.40*	0.39*
	r_p									0.23*	−0.02	0.24*	0.28*	0.31**
Osmotic pressure	r_g										0.14	0.07	0.26*	0.30*
	r_p										0.12	0.05	0.22	0.27*
Epidermal cell size	r_g											−0.11	−0.29*	−0.22*
	r_p											0.15	−0.25*	−0.17
Flag leaf area	r_g												0.37*	0.85*
	r_g												0.29*	0.64**
No. of tillers/plant	r_g													0.71*
	r_p													0.53**

Table 2. Direct (diagonal) and indirect effect matrix (dependable variable is grain yield)

	Survival rate T1	Survival rate T2	Survival rate T3	Survival rate T4	Root density	Root/shoot ratio	Hygrophilic colloids	Leaf venation	Stomata frequency	Osmotic pressure	Epidermal cell size	Flag leaf area	No. of tillers/plant
Survival rate T1	0.02	0.01	–0.00	–0.002	–0.66	–0.66	0.07	–0.36	0.04	0.05	0.05	0.18	0.72
Survival rate T2	0.00	0.56	–0.00	–0.04	0.00	0.09	–0.04	–0.26	–0.05	–0.01	–0.01	–0.20	–0.23
Survival rate T3	0.00	–0.05	0.07	0.01	0.05	0.05	–0.01	–0.39	0.02	–0.09	–0.07	0.60	0.12
Survival rate T4	0.00	0.15	0.00	0.14	–0.00	–0.05	–0.11	0.25	–0.01	0.02	0.03	0.27	–0.15
Root density	0.00	0.10	–0.00	–0.03	–0.06	–0.06	0.01	–0.51	–0.04	0.08	–0.01	–0.10	–0.16
Root/shoot ratio	0.00	0.01	0.08	–0.00	0.51	0.51	0.28	0.08	–0.03	0.08	–0.07	–0.13	–0.60
Hygrophilic colloids	0.00	0.10	0.04	0.06	–0.05	–0.05	–0.24	–0.08	–0.06	0.08	–0.05	–0.09	0.04
Leaf venation	0.00	0.11	0.02	–0.02	–0.03	–0.03	–0.01	–1.37	0.01	–0.01	0.01	0.86	0.67
Stomata frequency	0.00	–0.20	0.01	–0.01	–0.13	–0.13	0.01	–0.10	0.13	–0.24	0.06	0.36	0.51
Osmotic pressure	0.00	0.09	0.00	–0.04	–0.05	–0.05	0.02	–0.03	0.04	–0.07	–0.02	0.10	0.33
Epidermal cell size	0.01	0.06	0.00	–0.00	0.25	0.25	–0.08	0.10	–0.06	–0.01	–0.14	–0.15	–0.37
Flag leaf area	0.00	–0.08	0.03	0.02	–0.05	–0.05	0.01	0.88	0.03	–0.06	0.01	1.34	0.47
No. of tillers/plant	0.01	–0.10	0.00	–0.01	–0.24	–0.24	–0.09	–0.71	0.05	–0.21	0.04	0.49	1.28

epidermal cell size showed negatively associated with numbers of tillers per plant (Sharma et al. 1989). Grain yield per plant exhibited a positively significant association with survival rate treatment 4, leaf venation, stomatal frequency, osmotic pressure, flag leaf area and numbers of tillers per plant, while the other characters showed a negative association with grain yield per plant (Keim and Kronstad 1981).

Path coefficient analysis

Results pertaining to the path analysis are presented in (Table 2). Direct effects of osmotic pressure on grain yield per plant were negative (–0.07), indirect effects of osmotic pressure through rate treatment 4, root density, leaf venation and epidermal cell size appeared negative, whereas indirect effects through other traits were positive. The main contribution of osmotic pressure to grain yield per plant was through flag leaf area and numbers of tillers per plant. Maximum positive direct effect was made to grain yield by flag leaf area. Its own indirect effects via survival rate treatment 1, survival rate treatment 3, survival rate treatment 4, hydrophilic collides, and leaf venation, stomatal frequency, epidermal cell size and numbers of tillers per plant were positive, although leaf venation and numbers of tillers per plant made their maximum indirect contribution to yield through this traits (Alderfasi 2001).

The effects of numbers of tillers per plant to grain yield (1.28). Numbers of tillers per plant contributed to grain yield positively through stomatal frequency, epidermal cell size and flag leaf area, whereas its indirect effects upon all other traits were negative.

The study suggests that the selection for high grain yield should be based upon the flag leaf area with an optimistic compromise of number of tillers per plant followed by osmotic pressure (Serivastava et al. 1988). Hence in order to obtain high yielding segments it is concluded that the future hybridizing programme should include wheat strains 8499 and 8512-1.

Durum wheat yield in the cooler environments of Pakistan appears to be most determined by mean kernel weight while under the warmer conditions of Pakistan, the number of tillers per plant seems to be the most important factor in determining grain yield both under irrigated and rainfed conditions. Selection for these traits may contribute to important increases in grain yield, particularly in drought-prone environments at both temperature regimes. The virtual absence of compensatory effects among yield components in favorable environments and the important negative compensatory effects of the number of tillers per plant on both the flag leaf area and osmotic pressure registered in the warmer environments may explain the restricted success in durum wheat improvement observed in water-limited environments.

REFERENCES

Alderfasi A.A. (2001): Evaluation of certain traits association with drought resistance in wheat under field condition. Ann. Agri. Sci. Cairo, *46*: 71–83.

Bruns H.A., Croy L.I. (1985): Root volume and root dry weight measuring system for wheat cultivars. Cereal Res. Commun., *13*: 177–183.

Dewey D.R., Lu R.H. (1959): A correlation and path coefficient analysis of components of crested wheat grass production. Agron. J., *51*: 515–518.

Gibson L.R., Paulsen G.M. (1999): Yield components of wheat grown under high temperature stress during reproductive growth. Crop Sci., *39*: 1841–1846.

Keim D.L., Kronstad W.E. (1981): Drought response of winter wheat cultivars grown under field stress conditions. Crop. Sci., *21*: 11–15.

Kwon S.H., Torrie J.H. (1964): Heritability and interrelationship among traits of two soybean populations. Crop Sci., *4*: 196–198.

Miralles D.J., Richards R.A., Slafer G.A. (2000): Duration of the stem elongation period influences the number of fertile florets in wheat and barley. Aust. J. Plant Physiol., *27*: 931–940.

Mujeeb-Kazi A., Delgado R. (1998): Bread wheat/D genome synthetic hexaploid derivative resistant to *Helminthosporium sativum* spot blotch. In: Slinkard A.E. (ed.): Proc. 9th Int. Wheat Genet. Symp., vol. 3, Sec. 6. Univ. Ext. Press, Saskatoon, SK, Canada: 297–299.

Reeve E.C.R. (1955): The variance of the genetic correlation coefficients. Biometrics, *11*: 357–374.

Royo C., Abaza M., Blanco R., Garcia del Moral L.F. (2000): *Triticale* grain growth and morphometry as affected by drought stress, late sowing and simulated drought stress. Aust. J. Plant Physiol., *27*: 1051–1059.

Serivastava R.B., Singh V.P., Singh D. (1988): Component characteristics of grain yield and harvest index in wheat. Indian J. Agric. Res., *22*: 65–74.

Sharma S.K., Randhawa A.S., Dhiliwal H.S. (1989): Association analysis under spaced and dense sowing in wheat. Indian J. Genet. Plant Breed., *49*: 423–428.

Simane B., Struik P.C., Nachit M.M., Peacock J.M. (1993): Ontogenic analysis of field components and yield stability of durum wheat in water-limited environments. Euphytica, *71*: 211–219.

Sojka R.E., Stolzy L.H., Fischer R.A. (1997): Comparison of diurnal drought response of selection, wheat cultivars. Agron. J., *71*: 329–335.

Zhong-hu H., Rajaram S. (1994): Differential responses of bread wheat characters to high temperature. Euphytica, *72*: 197–203.

Received on April 18, 2005

Corresponding author:

Waqas Manzoor Bhutta, Centre of Advanced Study in Applied Genetics and Saline Agriculture, University of Agriculture, 38040 Faisalabad, Pakistan
e-mail: wmbhutta4052@yahoo.co.in