Comparison of water relations and drought related flag leaf traits in hexaploid spring wheat (*Triticum aestivum* L.)

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ABSTRACT

Six wheat varieties/lines and six derived F_2 hybrids were studied to ascertain and compare heritability and genetic advance for flag leaf osmotic pressure, flag leaf water potential, flag leaf venation, flag leaf area and flag leaf thickness. Most of these characters had high heritabilities and expected a genetic advance. Prospects of a genetic improvement for all the characters studied are evident. The most promising cross combinations are PASBAN-90 × SARC-5 and SH-2002 × SARC-5. These traits therefore deserve a better attention in future breeding projects for evolving better wheat for stress environments.

Keywords: wheat genotype; heritability; drought; cross breeding

An enhancement in production and productivity of wheat (*Triticum aestivum* L.) has been largely hinged on irrigated crop lands, which was primarily possible through the adoption of short stature, fertilizer responsive and high input wheat. However, we have reached a production plateau for irrigated areas where further break through is not easy. Besides salinity, low soil moisture regimes with no reliable source of replenishment are perhaps the most prominent production constraint in the unirrigated land. In the recent past the efforts have therefore been made to breed a variety suited for such production situations. Several flag leaf morpho-genetic parameters contributing to the moisture stress tolerance of the wheat plant were identified (Sojka et al. 1979). The flag leaf has a lower water potential, solute potential and turgor pressure than the lower leaves, but has a high rate of photosynthesis, nitrogen assimilation and dry matter per unit area (Aggarwal and Sinha 1984). The flag leaf has also a different cellular structure than the lower leaves, the cells with thicker cell walls, as postulated for the flag leaf, are expected to show a sharper decline in their water potential in response to a given change in water content than the cells with less rigid cell walls, as in the other leaves (Cheung et al. 1976). Therefore, a flag leaf will reach lower values of water potential faster than the other leaves as the sun rises, and it would maintain this for the whole day although the water content would not decrease much (Weatherley 1970). Despite lower water potential, the physiological efficiency of a flag leaf seems to be the result of its structural rather than enzymatic characteristics (Aggarwal and Sinha 1984).

The present studies are thus designed to estimate the extent of heritability of the following morpho-physiological flag leaf characters: flag leaf osmotic pressure, flag leaf water potential, flag leaf venation, flag leaf area and flag leaf thickness. The measure of genetic variation and a sufficient understanding of their mode and extent of inheritance are therefore important in planning and execution of a potent breeding project.

Reliable heritability estimates obtained through this research will not only point to the scope of assembling genetic characters imparting stress tolerance, but will also enable us to make predictions about the possible progress in this effort. Considerable work done on drought related flag leaf characters of wheat was by Aggarwal and Sinha (1984), Eastham et al. (1984) and Clarke and Townleysmith (1986).

MATERIAL AND METHODS

The present research work was carried out in the AYUB Agriculture Research Center. Six varieties/strains of wheat (*Triticum aestivum* L.) were chosen for this study: SARC-5 (drought resistant), PASBAN-90, SH-2002, AS-2002, INQBAL-91, and CHENAB-2000 (drought sensitive).

The F_2 seeds of following crosses: 1. PASBAN-90 × SARC-5, 2. SH-2002 × SARC-5, 3. AS-2002 × SARC-5, 4. INQBAL-91 × SARC-5, 5. CHENAB-2000 × SARC-5.

Along with their parents were grown in the field with randomized complete block design. The seeds were dibbled under drought conditions keeping plant-to-plant and row-to-row distance of 22.5 cm and 30 cm, respectively. The experimental population received normal agronomic and plant protection care. To maintain the identity, each plant was tagged and numbered. Three hundred plants from F_2 population of each cross (100 plants from each replication) and thirty plants from each parent (10 plants from each replication) were taken at random and data were recorded on the following plant parameters:

Flag leaf osmotic pressure. Osmotic pressure of the flag leaf was measured in MPa by an isopiestic technique (Michelena and Boyer 1982). Leaf segments of 2 cm were placed on the bottom and sidewall of thermocouple psychrometer chambers that had been coated with melted and resolidified petrolatum. All tissue manipulations were carried out in a humid chamber to reduce the evaporation losses after the tissue had been excised. The psychrometer chamber was sealed quickly, frozen for 5 min on dry ice to rupture cell membranes, thawed and placed again in the thermocouple system for the determination of osmotic pressure.

Flag leaf water potential. Flag leaf water potentials were determined by a pressure chamber technique (Wayne and Joe 1971). The data were collected in the morning hours when the leaves were fully turgid. Leaves were cut from the plant and inserted immediately into the pressure chamber. Pressure from the tank of compressed nitrogen was applied at the rate of 0.2 to 0.3 MPa/s. The final reading was obtained within 60 to 90 s after removal from the plant.

Flag leaf venation. Flag leaf venation was recorded as the number of longitudinal veins falling in a unit area. Low power field of the microscope was used as a unit.

Flag leaf area. Flag leaf area of main tiller of each selected plant was obtained during morning hours when leaves were fully turgid. Flag leaf area was measured in centimeters by using the leaf area meter (LI-3000/Lambda Instr. Corp. Lincolin, Nebraska, USA).

Flag leaf thickness. The thickness of the flag leaf was measured from the cross sections of the mother shoot flag leaf of each selected plant in microns under low power of the microscope. Data were tabulated and mean, standard deviations, variances and coefficients of variability for parents and F_2 populations were computed.

Heritability estimates in broad sense were computed using the formula described by Mahmud and Kramer (1951):

$$h^2 = \text{var. } F_2 - (Vp_1 \times Vp_2)/\text{var. } F_2$$

where: h^2 = heritability, p_1 = parent 1, p_2 = parent 2, var. F_2 = variance of F_2.

Genetic advance at 10% selection intensity was calculated according to formula given by Burton and Devane (1953):

$$A = SD \times h^2 \times i$$

where: SD = standard deviation, h^2 = heritability, i = constant value that reflects the selection intensity. The value for i (1.7) in this study was used in 10% selection intensity.

RESULTS AND DISCUSSION

Means, standard deviations, variances, coefficient of variability, heritability estimates and genetic advance values are presented in Tables 1 and 2.

A study of Table 2 shows that heritability estimates in broad sense for flag leaf osmotic pressure ranged from 22.11 to 74.16% for the crosses AS-2002 × SARC-5 and SH-2002 × SARC-5, respectively. The highest genetic advance value (1.16) was obtained from the cross SH-2002 × SARC-5, whereas the lowest genetic advance value (0.27) was recorded from the cross AS-2002 × SARC-5. Low heritability estimates coupled with genetic advance values indicate that a greater care is needed in selection of perspective parents for hybridization, whereas moderate heritability estimates in some crosses suggest the scope of quick improvement in these parameters. The situation would also demand a less rigid and expanded selection of progenies to make a sustained progress. According to Bayless et al. (1937) high osmotic pressure was found to be a good indicator of drought resistance. Low soil moisture tends to decrease moisture contents

Table 1. Mean and standard deviations for various flag leaf drought related characters in six wheat parents

Parents	Flag leaf osmotic pressure (MPa)		Flag leaf water potential (MPa)		Flag leaf venation		Flag leaf area (cm^2)		Flag leaf thickness (μm)	
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*	$\bar{x}$	*SD*
SARC-5	13.60	0.91	16.18	0.45	6.36	0.54	33.23	3.33	158.89	3.86
PASBAN-90	16.19	0.45	8.25	0.50	5.16	0.24	38.26	4.22	232.86	3.67
SH-2002	13.12	0.28	12.94	0.60	5.80	0.25	42.06	3.76	189.88	4.12
AS-2002	12.40	0.69	19.54	0.59	5.16	0.24	35.36	4.55	120.54	3.40
INQBAL-91	12.63	0.43	14.34	0.53	5.80	0.25	31.66	3.99	136.68	4.12
CHENAB-2000	13.20	0.47	12.64	0.46	4.93	0.42	45.11	4.01	146.00	4.71

$\bar{x}$ = mean, *SD* = standard deviation

of the leaves and increase the osmotic pressure (Bartel 1947). Migahid (1961) considered high osmotic pressure to be the main reason for desert plants to resist drought, as this enables the plant to develop a high suction force to absorb the available soil moisture more rapidly. Sojka et al. (1979) and Clarke and Townleysmith (1986) also reported 8 to 61% heritability estimates for this character in wheat and observed that the lines with high values of osmotic pressure better suited for stress conditions. Osmotic pressure, a measure of plant water status, has positive contributions to grain yield indirectly via spikelets per spike, kernels per spike and kernel weight (Keim and Kronstad 1981).

Perusal of Table 2 suggests that heritability estimates obtained for flag leaf water potential were moderate to high in following order. The highest estimate of 93.45% was obtained from the cross INQBAL-91 × SARC-5, followed by 85.16% ob-

Table 2. Coefficients of variability, heritability estimates and genetic advance values for various drought related flag leaf characters in five wheat crosses

Cross/line		Flag leaf osmotic pressure (MPa)	Flag leaf water potential (MPa)	Flag leaf venation	Flag leaf area (cm^2)	Flag leaf thickness (μm)
PASBAN-90 × SARC-5	*CV*%	3.58	9.03	13.32	25.54	7.36
	h^2	48.0	62.9	79.68	83.58	85.74
	GA	0.42	0.87	1.10	13.62	14.77
SH-2002 × SARC-5	*CV*%	9.67	10.43	6.29	27.89	9.45
	h^2	74.16	85.16	74.64	86.16	91.08
	GA	1.16	2.02	0.14	14.42	18.67
AS-2002 × SARC-5	*CV*%	5.37	15.0	13.32	19.34	5.66
	h^2	22.0	59.0	80.25	77.69	88.51
	GA	0.27	1.69	1.11	11.27	16.30
INQBAL-91 × SARC-5	CV%	6.41	11.25	6.29	29.16	9.45
	h^2	49.33	93.45	74.28	86.57	89.45
	GA	0.75	3.07	0.41	15.16	18.98
CHENAB-2000 × SARC-5	*CV*%	7.75	4.40	13.22	16.08	9.61
	h^2	47.21	54.47	65.0	72.04	91.42
	GA	0.72	0.72	0.90	8.76	23.02

CV = coefficient of variability, h^2 = heritability, GA = genetic advance tained from the cross SH-2002 × SARC-5. The lowest heritability estimates 54.47% was calculated from the cross CHENAB-2000 × SARC-5. The highest genetic advance value (3.07) was however obtained from the cross INQBAL-91 × SARC-5, while the lowest value (0.64) was recorded from the cross CHENAB-2000 × SARC-5. Leaf water potential is undoubtedly an important physiological trait imparting drought tolerance to plants. May and Milthorpe (1962) related moisture stress tolerance to high tissue water potential, while Fischer and Turner (1978) and Eastham et al. (1984) observed that water stressed plants had lower water potential compared to well irrigated plants. Blum et al. (1981) found that leaf water potential was correlated with number of grains per spike. Evidence of a good amount of genetic variability and high values of heritability obtained during these studies obviously suggest that varieties with appropriate water potential can be selected and a rapid progress is possible in this character. The heritability estimates found during these studies are in agreement with the findings of Aggarwal and Sinha (1984).

A study of Table 2 indicates the heritability estimates for flag leaf venation were medium to high in following order. The highest heritability estimate 80.25% was obtained in the cross AS-2002 × SARC-5, followed by PASBAN-90 × SARC-5 79.68%, while the lowest 65.00% was obtained from the cross CHENAB-2000 × SARC-5. The highest genetic advance value (1.11) was obtained in the cross AS-2002 × SARC-5. The lowest genetic advance value (0.14) was however observed from the cross SH-2002 × SARC-5.

Leaf venation of wheat is known to be directly related to drought resistance. Genotypes known for their drought resistance had a higher number of veins per unit area, which has also been reported by Kokin (1926) and Maximov (1929) and Bhutta and Chowdhry (1999).

Denser leaf venation helps in moisture economy through its judicious distribution. The character thus merits a special attention in projects focused at evolution of technology for low moisture areas. Moderate to high heritability estimates recorded in this study show that an effective selection of appropriate parents is very important to synthesize a variety having proper leaf venation. Medium to higher heritability estimates were observed for this characteristic. It was shown that genotypes having a higher number of veins per unit area were more resistant to drought.

It is evident from Table 2 that the cross combination AS-2002 × SARC-5 had the highest heritability 86.57% for flag leaf area, followed by the cross SH-2002 × SARC-5 with a value of 86.16%. The cross CHENAB-2000 × SARC-5 showed the lowest value (72.04%). The highest genetic advance value (15.16) was, however, obtained in the cross INQBAL-91 × SARC-5, while the lowest (8.76) was observed for the cross CHENAB-2000 × SARC-5.

The leaves of drought resistant varieties are generally smaller and have a lower surface area volume ratio than varieties adapted to adequate moisture environments (Foutz et al. 1974). Leaf area of a crop affects the amount of solar radiation intercepted by the crop canopy, which in turn affects photosynthesis, evapo-transpiration and final yield. Water deficits can cause a reduced growth rate and hence a smaller leaf area, which can adversely affect yield (Eastham et al. 1984). Leaf area is positively correlated with yield (Fischer and Kohn 1966). Smaller leaf area may be instrumental in moisture conservation through reduced transpiration. As an indicative for the present studies, selection can be effective in reducing an increase in flag leaf area.

Low to moderate heritability estimates for leaf area were reported by Lupton et al. (1967), Mornhinweg (1985) and Edwards and Emara (1970).

It is evident from Table 2 that heritability estimates for flag leaf thickness were high in following order. The cross CHENAB-2000 × SARC-5 had the highest heritability estimates (91.42%), closely followed by crosses SH-2002 × SARC-5 and INQBAL-91 × SARC-5 with heritability estimates 91.08% and 89.45%, respectively. The lowest value of 85.74% was observed in the cross PASBAN-90 × SARC-5. The highest genetic advance of 23.02 was obtained in the cross CHENAB-2000 × SARC-5, whereas the lowest value of 14.77 was recorded from PASBAN-90 × SARC-5.

The water deficit varieties have smaller and thicker leaves, decreased epidermal cell size and increased stomatal frequency with reduced stomatal size as compared to normal varieties. Flag leaf thickness is undoubtedly an important character imparting drought tolerance to plants reducing water losses (Maximov 1929). High heritability values obtained for this character indicate that the selection of an appropriate parent is very important in the evolution of varieties having proper leaf thickness and that the character can be fixed relatively easily.

The above-cited crosses might yield better drought resistant varieties but there remains the problem of selecting for drought resistance. Owing to its complexity a simple quantitative method may not cover all of the factors involved but may be of service in the selection of parental varieties or in obtaining information on promising selections.

Cross combinations PASBAN-90 × SARC-5 and SH-2002 × SARC-5 have shown high heritability for most of the drought related characters under focus in this study. It would be worthwhile to concentrate attention on these crosses to obtain recombinants with high yield potential, greater drought resistance and better adaptability.

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