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Excised-leaf Water Loss as a Simple Selection Criterion for Drought Resistance in Wheat

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Key words: Drought resistance, drought response index, excised-leaf water loss, *Triticum aestivum.*

Abstract

Excised-leaf water loss from excised leaves of 30 wheat cultivars was determined under irrigated and drought stressed conditions. It was then related to the drought response index characterised by comparing grain yield under irrigated and drought stress conditions. The water loss has been found to be an indicator of drought resistance and considerable genetic differences existed for this easily determinable trait at tillering and anthesis stages of plant growth. The drought response index had stronger associations with water loss under drought conditions which indicated that varieties showing less water loss also contributed to drought resistance. The cultivars C 306 and RL 7 had low water loss at both tillering and anthesis stages of plant growth and had high yield under drought stress conditions.

1 Introduction

Wheat cultivars differ in drought resistance but the mechanisms controlling these differences are not well understood (Blum, 1988). Control of leaf water stress is determined by a wide range of characters including, stomatal behaviour (Ludlow and Muchow, 1990; Basnayake *et* al,1996), leaf expansion, and the degree of leaf rolling (Dhanda *et al.,* 1995). The commonest measures of leaf water stress are excised-leaf water loss and leaf water potential (Jones *et al.,* 1991). The estimation of water stress by these methods tends to be slow and difficult in field conditions. It would be valuable, therefore, to have a rapid method for estimating plant water stress in the field. More recently, the excised-leaf water loss has been related to drought resistance in wheat (Clarke & McCaig, 1982; Schonfeld *et al.,* 1988; Winter *et al.,* 1988; Clarke et *al.,* 1989; McCaig & Romagosa, 1991), moderately heritable (Clarke and Townley Smith, 1986), and is a rapid method for estimating water loss in field conditions. Excised leaves provide a simple model for study of water loss from intact plants during periods of intense drought. Following excision, stomates close and water is lost from the cuticle and possibility from incompletely

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closed stomates (McCaig & Romagosa, 1991). Rawson and Clarke (1988) supported this phenomenon while comparing the nocturnal transpiration of drought stressed plants with the rate of water loss from excised leaves. The objective of the present study was to determine the excised-leaf water loss in a range of wheat genotypes with varying degree of drought resistance, and to relate this character to drought resistance and grain yield.

2 Materials and Methods

The experiment was conducted on 30 diverse cultivars of wheat *(Triticum aestivum* L.) which were grown under irrigated and drought stressed conditions under glass-house conditions during winter 1990-91 at the Himachal Pradesh Agricultural University, Palampur, India. The experiment was arranged in a completely randomised design with 3 replications. The plants were raised in plastic pots of 9.0 kg soil capacity on dry-weight basis. Single plant per pot was maintained for sampling purpose. The drought stress conditions were created by stopping irrigation on 20 days after sowing (pre-anthesis period), 60 days after sowing (during anthesis) and 90 days after sowing (during grain filling) in three separate experiments, respectively. The flag leaf along with penultimate leaf on the main culm of the plant were sampled in each of the 3 replicates for each cultivar from the irrigated and drought stressed pots in all the experiments. The leaves were weighed immediately after sampling, after putting in incubator at 28°C for 6 hours and after oven-drying for 24 hours at 90°C (Clarke, 1987). The excised-leaf water loss (ELWL) from the excised leaves was determined by the formula given below.

$$\text{ELWL}(\%) = \frac{\text{Fresh weight - weight after 6 hrs}}{\text{Dry weight}} \times 100$$

In order to avoid any complication due to variation in the level of mid-day water deficit, the data for excised-leaf water loss was recorded from predawn measurements. The plants were observed for temporary wilting in the evening and only those plants which did not recover during the following morning were selected for recording observations.

Soil moisture percentage was determined by weighing-pot method. The range of moisture percentage was between 14 to 18% at tillering stage, and 12.5 to 15% at anthesis stage. The soil of Palampur were clay type, of therefore, wilting point plant started relatively at higher moisture percentage level. The flag leaf with two preceding leaves from single plant were sampled for recording observations. The leaves were placed in polythene bags and transported to the laboratory. In order to relate the excised-leaf water loss to drought tolerance, the effect of the intervening factors, namely, ontogenic stages, and high yield potential on drought tolerance was nullified by calculating drought response index (DRI) suggested by Bidinger et al. (1987).

3 Results and Discussion

Analysis of variances were performed for the data under irrigated and drought stress conditions for excised-leaf water loss, days to heading and grain yield (Table 1). Under irrigated conditions, genotypes were not differing from each other for excised-leaf water loss at all the stages of plant growth observed. But under drought stress conditions, significant differences among genotypes were observed only at tillering and anthesis stages of plant growth. The data for days to heading and grain yield/plant was significant under both irrigated and drought stress conditions. Non significant differences among the genotypes, for excised-leaf water loss under irrigated conditions may be either due to high sampling error or poor expression of the water retention traits in the absence of drought stress conditions. It may be inferred that creation of drought stress conditions enabled the genotypes for greater solute accumulation and osmotic adjustment (MANETTE et al. 1988; LILLEY AND LUDLOW, 1996). In addition, drought stress environment also result in the expression of characters like waxyness, leaf rolling and glaucouness (MCCAIG AND ROMAGOSA, 1991; BASNAYKE *et* al., 1996). The comparison of excised-leaf water loss at different stages of plant growth revealed that the genotypes were differing from each other for relative water loss only at tillering and anthesis stages. But the differences disappeared at grain-filling stage. This was probably due to high succulence in vegetative stage and low succulence, leaf firing and other unknown physiological reasons at grain filling stage (CLARKE, 1987).

Table 1: Mean squares of 30 genotypes of wheat for excised-leaf water loss at different stages of plant growth under irrigated (E_1) and drought stress (E_2) conditions

Character	Stage	Genotype (29)+		Error (58)+	
		E_1	E_2	E_1	E_2
Excised leaf water loss	S_1	29.45	141.67**	13.26	4.22
	S_2	60.15	278.34**	81.91	18.09
	S_3	79.68	309.57	82.52	402.94
Days to heading		438.72**	251.58**	12.80	9.89
Grain yield/ plant		11.67**	0.51**	1.81	0.07

+ Represents degrees of freedom.
** : Significant at 5% and 1% level of significance.
S_1, S_2 and S_3 refers to tillering, anthesis and grain-filling stages, respectively.

Table 2: Mean squares values of 30 genotypes for excised-leaf water loss, days of flowering, grain yield and drought response index under irrigated (E_1) and/or drought stress (E_2) conditions

Genotype	Excised-leaf water loss at		Days to 50% flowering		Grain yield per plant		Index of drought
	tillering	anthesis					
	E_2	E_2	E_1	E_2	E_1	E_2	(DRI)
WH 147	76.0	71.6	82.0	75.0	17.0	6.3	1.7
WH 147(U)	74.1	68.1	84.3	74.0	18.3	6.9	2.0
Lok 1	73.0	68.9	91.7	84.0	15.8	4.3	0.3
Lok 1(U)	72.9	72.3	85.0	79.1	12.3	4.6	0.9
WH 157	82.2	77.9	95.1	87.0	16.3	5.0	0.5
Kharchia 65	73.6	62.3	100.0	88.9	11.4	5.5	2.6
HW2OO1	87.5	81.1	92.9	84.3	11.5	1.6	-1.8
CPANI992	85.1	82.2	100.3	80.0	18.6	3.7	-0.7
C 306	73.1	63.3	104.7	89.0	12.6	7.0	3.9
K 68	83.4	81.3	117.7	92.1	13.7	1.0	-2.1
WH 331	75.1	73.0	106.7	84.9	11.2	2.9	-0.1
WH 533	73.2	68.0	109.3	83.0	16.9	2.6	-1.4
Hindi 62	72.5	64.0	116.3	93.0	13.9	3.4	0.2
PBW 65	84.2	80.1	99.3	83.1	17.5	3.8	-0.6
WL 410	84.0	78.0	105.0	83.3	17.5	3.8	-0.6
WL 1562	76.0	63.9	111.1	82.8	16.7	4.4	0.1
Kundan	62.5	80.1	116.0	84.7	10.9	3.0	0.2
HPW (DL)	78.5	79.1	102.1	83.0	14.6	3.7	0.1
VL 421	74.1	61.9	106.0	88.3	9.6	3.2	0.7
HD 2329	86.9	68.9	89.9	76.0	18.1	4.0	-0.8
HD2329(U)	87.0	79.2	90.0	75.7	20.1	4.8	-0.2
HPW 42	82.1	67.0	86.1	74.3	19.4	4.5	-0.5
HS 295	80.1	81.0	111.7	82.3	14.5	2.5	-1.1
HPW 56	86.1	80.0	109.7	84.0	9.4	3.0	0.4
CPAN 3004	83.2	83.1	107.3	85.7	12.3	1.9	1.0
HPW 65	74.0	65.0	114.3	87.7	18.5	1.6	-1.2
RL 6	79.1	67.2	116.7	81.7	22.5	5.1	-0.2
RL 7	71.5	65.9	125.0	85.7	10.2	2.6	0.1
RL 68	84.2	61.0	125.0	84.0	14.2	2.3	-1.0
RL 84	77.8	71.1	110.3	83.0	12.4	3.0	-0.1
Mean	78.3	72.2	103.7	84.3	15.0	3.7	0.0
SE(m)	5.1	4.2	6.0	4.3	3.7	1.6	0.2
SE(d)	1.2	1.3	2.2	1.29	0.6	0.3	
Phenotypic correlations with DRI	-0.48**	0.42*	-0.29	0.02	-0.23	0.57**	1.00

*, ** : Significant at 5% and 1% level of significance respectively

The comparison of mean values of the genotypes for excised- leaf water loss at tillering and anthesis stages of plant growth (Table 2) indicated that only two genotypes, viz., C 306 and RL 7 were significantly lower in water loss than overall mean values at both stages. The other entries which has lower water loss than overall mean at either of the growth stages were Lok 1, Kharchia 65, Hindi 62, WL 1562, Kundan, VL 4_{21} HPW 42, HP 65, RL 6 and RL 68. Majority of these genotypes are already well known sources of drought resistance in India (BEHL *et al.*, 1992; DHANDA *et al.*, 1995). This suggested that excised-leaf water loss could be an important component for selecting genotypes under drought stress conditions.

The overall mean values of excised-leaf water loss were higher at tillering (78 ± 1.2) than at anthesis stage (72.2 ± 1.3). This may be attributed to either high succulence at tillering or better retention of water at anthesis due to full development of leaves and expression of drought related characters at anthesis. The significant negative correlations of drought response index (DR1) with excised leaf water loss at tillering (-0.48*) and at anthesis stage (-0.42*) further confirmed that the genotypes having lower water loss contributed to the drought resistance (CLARKE *et* al., 1987; WINTER *et al.*, 1988). In order to nullify the antogenic effects and yield potential from the DRI the effects of these variables were reduced by multiple regression techniques as suggested by Bidinger *et al.*, (1987). The non-significant correlations of DR1 with days to 50% flowering under both conditions and with grain yield under irrigated conditions further confirmed that DRI was free from ontogenic effects as well as the increased yield due to irrigation. The significant positive correlation of DRI with grain yield under drought stress conditions revealed that high yield under drought stress conditions was due to drought resistance rather than yield potential. Thus, it may be concluded that the genotypes for excised-leaf water loss had sufficient genetic variability particularly under drought stress conditions. The differences for excised-leaf water loss were disappeared at later stages i.e. grain filling stage of plant growth. Therefore excised-leaf water loss could be utilised as an effective parameter for drought resistance in this set of material.

4 Der Wasserverlust des Blattes als ein einfaches Selektionskriterium für die Trockenheitsresistenz bei Weizen

Zusammenfassung

Der Wasserverlust von abgeschnittenen Blattstücken von 30 Weizensorten wurde unter beregneten und trocken Bedingungen getestet und in Beziehung gesetzt zu Felderträgen. Der Wasserverlust stellte sich als Indikator für die Trockenheitsresistenz bei genetisch unterschiedlichem Material dar, besonders gut beim Schossen und bei der Blüte der Pflanze. Der Index für die Trockenheitsresistenz zeigte eine stärkere Relation bei Wasserverlust unter Trockenheit, die zeigte, daß Varietäten mit weniger Wasserverlust auch resistenter waren. Die Varietäten C 306 und RL 7 hatten weniger Wasserverlust sowohl beim Schossen, als auch bei der Blüte und hatten einen hohen Ertrag unter trockenen Bedingungen.

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