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Cuticular conductance, water use efficiency and drought tolerance of durum wheat isolines of differing glaucousness

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SUMMARY – Glaucousness is one characteristic that has been considered a plant adaptation to drought. Two near-isogenic lines of durum wheat differing in their degree of glaucousness of the spike and the upper vegetative parts of the plant were used to determine whether genetic variation in glaucousness traits reflects differences among durum wheat genotypes in cuticular conductance, leaf water status, photosynthesis and WUE. The importance of WUE in the Mediterranean environment is discussed with particular concern to the key role of wax bloom (glaucousness) in drought tolerance.

Key words: Glaucousness, water use efficiency, drought tolerance, isolines.

RESUME – *"Conductance cuticulaire, efficacité d'utilisation de l'eau et tolérance à la sécheresse chez des lignées isogéniques de blé dur de glauquescence différente". La glauquescence est considérée comme un caractère d'adaptation à la sécheresse. Deux lignées isogéniques de blé dur différant dans leur degré de glauquescence de l'épi et des parties aériennes de la plante ont été utilisées pour déterminer dans quelle mesure une variabilité génétique dans la glauquescence reflète des différences entre des génotypes de blé dur au niveau conductance cuticulaire, statut hydrique foliaire, photosynthèse et efficacité d'utilisation de l'eau. L'importance de l'efficacité d'utilisation de l'eau en conditions environnementales méditerranéennes est discutée particulièrement en fonction du rôle clé de la glauquescence dans la tolérance à la sécheresse.*

Mots-clés : *Glauquescence, efficacité d'utilisation de l'eau, tolérance à la sécheresse, lignées isogéniques.*

Introduction

Glaucousness is the waxy covering over the plant cuticle that imparts a dull-white or bluish-green cast commonly referred to as bloom. This characteristic has been cited as a plant adaptation to drought conditions (Blum, 1988; Qariani *et al.,* 1999).

An important function of epicuticular waxes is to increase the efficiency of stomatal control by reducing water loss after stomatal closure. Indeed, plant survival during severe water deficits depends on the ability to restrict water loss through the leaf epidermis (loss through cuticle plus loss due to incomplete stomata closure) may comprise up to 50% of total transpiration in water-stressed plants during the day and 100% during the night (Rawson and Clarke, 1988).

Glaucousness is believed to enhance yield in wheat by increasing water use efficiency (WUE) or transpiration efficiency (Richards *et al.,* 1986).

The present study provides a description of the water use and associated traits of two isogenic lines of durum wheat differing for glaucousness. It is an attempt to analyze the inter-relationships of physiological process at the whole-plant and organ level to gain insight in the key features determining water use efficiency and drought escape through limiting water loss.

Material and methods

Two isogenic lines of durum wheat (*Triticum turgidum* L. var. *durum*) differing for glaucousness (Low Glaucousness Line LGL, High Glaucousness Line HGL) were used. Plants were grown in pots during the crop season in the field in Meknès (Morocco), a region with a Mediterranean climate.

The experiment involved two treatments. Control plants were well-watered throughout the experiment. In the second treatment, soil water was maintained to about half the water content of control plants by withholding watering.

WUE was measured by weighing the pots, and growth by destructive sampling. WUE was calculated as the ratio of total plant dry mass and cumulative plant water use. Stomatal conductance was measured on the adaxial and abaxial sides of leaves using the LI-1600 porometer (LICOR Inc., Lincoln, NE, USA). The leaves were then cut, wrapped in plastic and immediately taken to the lab in a coolbox for measurements of osmotic potential with a microosmometer.

The “residual transpiration” (RT, the rate of water transpired at minimum stomatal aperture in total water limitation) was measured according to Clarke *et al.* (1991): leaves were excised and immediately brought to the laboratory. Then, they remained in the darkness for stomatal closure for half an hour under ambient room conditions. They were weighed (W_1 in g) after this period and again 180 min later (W_2 in g); the leaf area (LA in cm^2) was determined using an areameter (LI-3000, LICOR, Lambda Instruments Co., USA). Residual transpiration on leaf area basis (g $H_2O/min/cm^2/10^5$) was determined as follows: RT = $(W_1 – W_2)/(LA.180)$. The flag leaf dry weight (DW_1) was obtained after oven drying at 80ºC during 48 hours.

The relative water content (RWC) was calculated on flag leaf blades from the following equation: RWC (%) = $(FW – DW_2)/(TW – DW_2) \times 100$. The fresh weight (FW) was measured immediately after excision, the full turgid weight (TW) was determined after the rehydration of the leaves placing them in a test tube containing distilled water for 24 hours at 4ºC in darkness, and the dry weight (DW_2) after oven drying at 80ºC during 48 hours. The flag leaf dry matter (DW) was calculated by the average DW obtained for Rtand RWC measurements, as DW (mg) = $(DW_1 + DW_2)/2$. The specific leaf weight (SLW) was calculated as SLW = DW/LA.

Results and discussion

With regard to the physiological measurements, on the flag fully expanded leaves, HGL and LGL showed some differences in their reaction to drought (Table 1). Under well watered conditions the two isolines achieved approximatively similar WUE. Under water-stress, WUE of HGL tended to be higher than that of LGL. Under both treatments, residual transpiration was lower in the glaucous than in the non glaucous lines. HGL maintains higher grain yield in conditions of water stress compared to LGL. Relative water content was approximatively similar in the two well-watered isolines, however it was more reduced in the dry treatment in LGL than HGL. SLW tended to increase under stress in both isolines. Harvest index (HI) was higher in glaucous than non-glaucous isolines under stressed conditions.

Thus higher WUE is associated with glaucousness. WUE is determined by plant traits and (micro-) environmental conditions. These factors interact strongly (Veneklaas and Peacock, 1994). In our experiments, the high residual transpiration (RT) causes lower relative water content (RWC) and lower WUE in LGL. The combination of low RT (HGL) with slight reduction of RWC and osmotic potential, is expected to increase plant WUE. Leaf RWC is proposed as a more important indicator of water status than other water potential parameters under drought stress conditions: RWC is closely related with cell volume and it may closely reflect the balance between water supply to the leaf and transpiration rate. Variation of RT is generally attributed to differences in glaucousness (Fischer and Wood, 1979). Glaucousness would be advantageous in reducing water loss through the cuticle. Indeed Blum (1982) suggested that permeability of the cuticle to water is affected by glaucousness. The possible relation of specific leaf weight with WUE is based on the fact that SLW could be an indicator of leaf photosynthetic capacity. The increase of SLW could be due to carbohydrate and variation in mesophyll tissue density and/or leaf thickness, as proposed by Araus *et al.* (1986).

Table 1. Morphophysiological traits related to water-use efficiency of durum wheat isolines (HGL, LGL) of differing glaucousness under control (CT) and stressed (ST) treatments (values in brackets represent mean SD)

Durum wheat lines	HGL		LGL	
Traits	CT	ST	CT	ST
Residual transpiration ($g\ H_2O/min/cm^2/10^5$)	4.98 (0.5)	2.92 (0.4)	5.43 (0.16)	3.96 (0.14)
Relative water content (%)	90.8 (3.6)	84.6 (4.2)	91.6 (3.8)	78.4 (4.5)
Osmotic potential (MPa)	-1.12 (0.12)	-2.15 (0.29)	-1.22 (0.21)	-3.05 (0.44)
Flag leaf area (cm^2)	24.5 (3.2)	20.2 (2.8)	26.5 (3.4)	17.6 (2.8)
Specific leaf weight (g/cm^2)	89.2 (8.2)	92.6 (8.8)	72.8 (9.6)	78.4 (10.2)
Yield (g/plant)	4.24 (0.42)	3.32 (0.36)	4.08 (0.64)	2.46 (0.44)
Harvest Index	0.38 (0.06)	0.48 (0.05)	0.39 (0.06)	0.32 (0.08)
WUE (mg/g)	9.72 (1.08)	13.1 (1.41)	10.0 (1.14)	11.7 (1.32)

The better performance of glaucous lines concerning yield was magnified under water-limited conditions. This is in agreement with Dakheel *et al.* (1994) results in durum wheat. Febrero *et al.* (1998) suggested that a higher temperature in the non-glaucous lines could partially account for the lower yield of this line compared with the glaucous line.

Conclusion

Within the present group of isolines, the results show physiologically different responses; variation in both water use efficiency, residual transpiration is present, and physiological traits in relation with drought tolerance as osmotic potential and relative water content vary considerably. Such variation is linked to the rate of glaucousness. A higher glaucousness causes differences in WUE. Differences in WUE are related also to the treatments, as WUE increases with stress.

Glaucousness is a trait that may be useful to improve WUE in dryland conditions and it would be worthwhile to screen plants for this trait.The isolines with a higher rate of glaucousness and a higher WUE may be most suitable to be used in environments where water is the most limiting factor.

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