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Gas exchange under water stress conditions in three almond cultivars

F. de Herralde*, C. Biel*, I. Batlle and R. Savé***
*Dept. de Tecnologia Hortícola, Institut de Recerca i Tecnologia Agroalimentàries (IRTA),
Centre de Cabrils, Ctra. de Cabrils s/n, 08348 Cabrils (Barcelona), Spain
**Dept. d'Arboricultura Mediterrània, Institut de Recerca i Tecnologia Agroalimentàries (IRTA),
Centre de Mas Bové, Apdo. 415, 43280 Reus (Tarragona), Spain
ignasi.batlle@irta.es

SUMMARY – Drought resistance is characteristic of almond trees. However, cultivars perform differently when they are submitted to water stress. The response of each cultivar growing under dry conditions leads to different water uses and productions. In Mediterranean climatic conditions, water use efficiency is one of the most desirable traits of any cultivar, and its use as a selection criterion is important for almond breeding programmes. The study of the ecophysiological response to water stress provides useful tools for plant breeders in order to select new plant material, which should be more drought resistant. With this aim, three almond cultivars were studied: 'Ferragnès', 'Francolí' and 'Glorieta'. On potted trees growing under semicontrolled conditions, two water treatments were applied: control (full irrigation) and stress (without irrigation). Midday leaf water potential and gas exchange were measured after a stressing period and later recovery. It seems that under fast water stress, the three cultivars showed a good avoidance strategy, reducing water losses through stomatal closure and leaf shedding. Reduction in leaf water potential in 'Francolí' could be attributed to some tolerance mechanisms. 'Glorieta' was the most sensitive cultivar to water stress since it was unable to recover water potential and gas exchange.

Key words: Drought resistance, ecophysiology, photosynthetic rates, *Prunus amygdalus*, stomatal conductance.

RESUME – *"Echange gazeux en conditions de stress hydrique chez trois cultivars d'amandier". La résistance à la sécheresse est une caractéristique des arbres d'amandier. Cependant, les cultivars se comportent différemment quand ils sont soumis au stress hydrique. La réponse de chaque cultivar mis en culture sous conditions sèches mène à différentes productions et utilisations de l'eau. En conditions climatiques méditerranéennes, l'efficacité d'utilisation de l'eau est l'un des traits les plus souhaitables de n'importe quel cultivar, ainsi, son emploi est souvent un critère de sélection important dans les programmes d'amélioration variétale. L'étude de la réponse écophysiologique au stress hydrique offre un outil pour les améliorateurs des plantes afin de choisir un nouveau matériel végétal, qui devrait être plus résistant à la sécheresse. Dans ce but, trois cultivars d'amandier ont été étudiés : 'Ferragnès', ' Francolí' et 'Glorieta'. Sur les arbres mis en pot se développant sous conditions semi-contrôlées, deux traitements hydriques ont été appliqués : témoin (pleine irrigation) et conditions de stress (sans irrigation). Le potentiel hydrique de la feuille et l'échange de gaz ont été mesurés à midi après une période de stress et un rétablissement postérieur. Il semble que sous un fort stress hydrique, les trois cultivars aient montré une bonne stratégie d'évitation, réduisant les pertes d'eau à travers la fermeture stomatique et la chute de feuilles. Des réductions du potentiel hydrique des feuilles de 'Francolí' ont pu être attribuées à quelques mécanismes de tolérance. 'Glorieta' s'est montré, parmi les trois cultivars étudiés, le plus sensible au stress hydrique, car il était incapable de rétablir le potentiel hydrique et l'échange de gaz.*

Mots-clés : *Résistance à la sécheresse, écophysiologie, taux photosynthétiques*, Prunus amygdalus*, conductance stomatique.*

Introduction

Almond (*Prunus amygdalus* Batsch) is a drought resistant species grown in the Mediterranean climate areas of the world. Due to the economic importance of the almond industry in the United States, Spain, and other countries, breeding programmes to obtain new better cultivars and methods of improving orchard management have been developed to increase the crop yield and nut quality. Drought resistance is characteristic of almond trees. However, cultivars perform differently when they are submitted to water stress. The response of each cultivar under dry conditions leads to different water uses and productions. Under Mediterranean conditions, water use efficiency is one of the most desirable traits of any cultivar, and its use as a selection criterion is important for almond breeding programmes. The study of the ecophysiological response to water stress provides useful tools for plant breeders in order to select new plant material, which should be more drought resistant.

The aim of this work was to study the response of three commercial almond cultivars, 'Ferragnès', 'Francolí', and 'Glorieta', to sudden and severe water stress and their recovery.

Materials and methods

Twelve 2-year-old almond trees (*Prunus amygdalus* Batsch) of the cultivars 'Ferragnès' (FER), 'Francolí' (FRA) and 'Glorieta' (GLO), grafted onto the hybrid rootstock almond x peach GF-677, were grown at IRTA-Cabrils, North-eastern Spain (41°25' N, 2°23' E). Trees were grown in 40 l pots with peat (Floratoff) and perlite (Europerl A-13) (2:1, v/v) as a substrate, with a tree spacing of 1.5 m x 2.5 m. Trees were drip irrigated daily with a volume of water that varied with the weekly evaporative demand. Plants were fertilised with a nutrient solution [1:0.5:1.5 (N:P:K); pH = 6.5] added to irrigation water.

On August 2001, 6 plants of each cultivar were submitted to a cycle of drying/rewatering while 6 plants of each cultivar were daily drip fertirrigated (control plants). The water stress assay was imposed withdrawing water on the 30th of July for a week and then irrigating as control treatment for a week. Weather conditions of temperature and relative humidity are shown on Fig. 1.

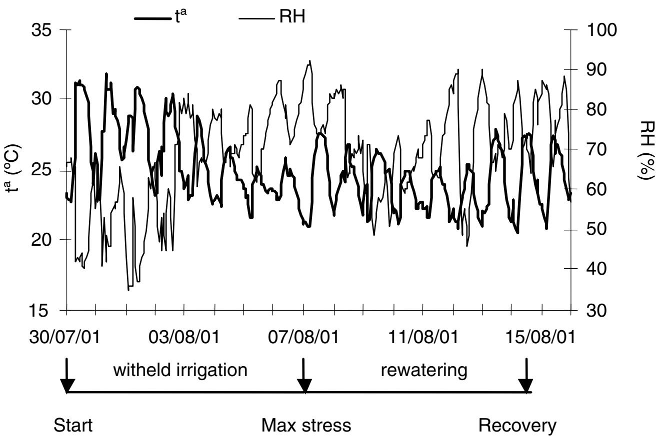

Fig. 1. Temperature (°C) and relative humidity (%) on the experimental plot during the water stress and rewatering cycle.

On the 30th of July, 7th and 14th of August, fully expanded and south-facing leaves were measured for midday leaf water potential (Pressure Chamber Soilmoisture 3005) and gas exchange (ADC LCA2; The Analytical Development Co. Ltd. Hoddeson, Herts, England). From gas exchange measurements instantaneous water use efficiency (WUEI) was calculated as net photosynthetic rate to transpiration rate.

The statistical analysis of data was conducted using The SAS System for Windows 8.1 [SAS Institute Inc. (Cary, NC 27513, USA)]. Analysis of variance was used when appropriate. Mean separations were by Duncan's multiple range test, $P \leq 0.05$.

Results and discussion

Midday leaf water potential (Ψ) was around -2.00 MPa for all the cultivars in control treatment, along the studied period (Fig. 2). These values have been recorded previously in other cultivars under similar conditions (de Herralde, 2000). 'Francolí' showed the highest reduction in water potential (-4.28 MPa) but recovered to control levels at the end of the trial (-2.23 MPa). 'Glorieta' showed the lowest reduction in water potential (-3.33 MPa) but did not recover a week after (-2.90 MPa). 'Ferragnès' showed an intermediate reduction in midday leaf water potential (-3.79 MPa), and also recovered control levels (-2.29 MPa) after a week of irrigation. Values were similar to those reported for cultivar 'Garrigues' under field conditions (Torrecillas *et al.*, 1989), and 'Garrigues' and 'Ramillete' with potted young trees (Torrecillas *et al.*, 1996).

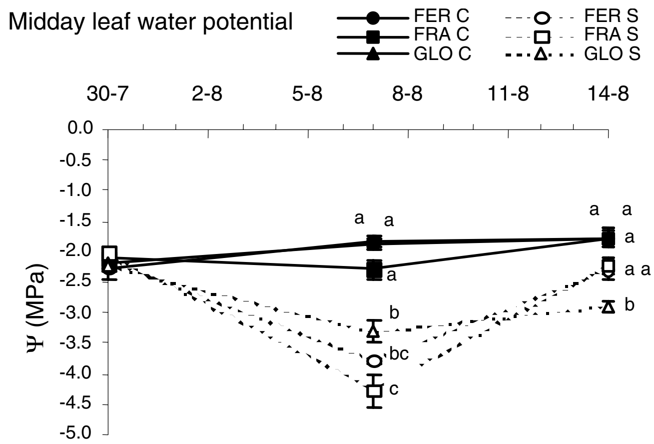

Fig. 2. Midday leaf water potential (Ψ (MPa)) for the three cultivars 'Ferragnès' (circles), 'Francolí' (squares), and 'Glorieta (triangles), and two treatments: control (black symbols and lines) and stress (white symbols and dashed lines). Each point represents the mean of six measurements and the vertical bars the standard error. Different letters represent significant differences between treatments and cultivars within each day (Duncan's multiple range test, P≤0.05).

Gas exchange measurements are shown as net photosynthetic rate (Pn) (Fig. 3), stomatal conductance (Gs) (Fig. 4) and water use efficiency (WUE) (Fig. 5). Under control treatment, 'Ferragnès' showed lower photosynthetic rate, stomatal conductance, and water use efficiency than 'Glorieta' and 'Francolí'. In general, Pn were lower than maximum photosynthetic rates described for other cultivars (DeJong, 1983; de Herralde *et al.*, 2003), but similar to those found under field conditions in young trees (Matos *et al.*, 1997; de Herralde, 2000).

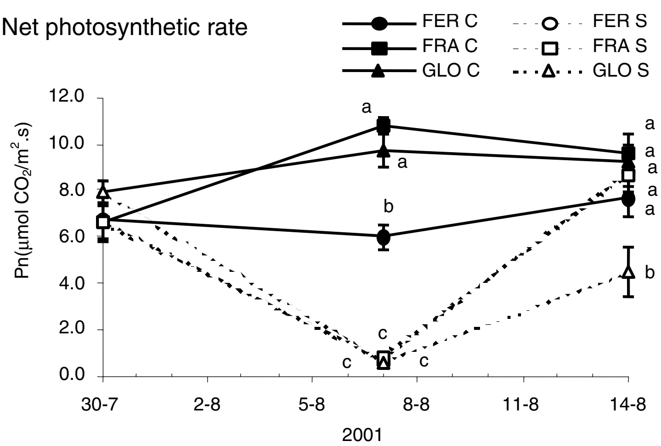

Fig. 3. Net photosynthetic rate [Pn (μmol CO_2/m^2·s)] for the three cultivars 'Ferragnès' (circles), 'Francolí' (squares), and 'Glorieta (triangles), and two treatments: control (black symbols and lines) and stress (white symbols and dashed lines). Each point represents the mean of six measurements and the vertical bars the standard error. Different letters represent significant differences between treatments and cultivars within each day (Duncan's multiple range test, P≤0.05).

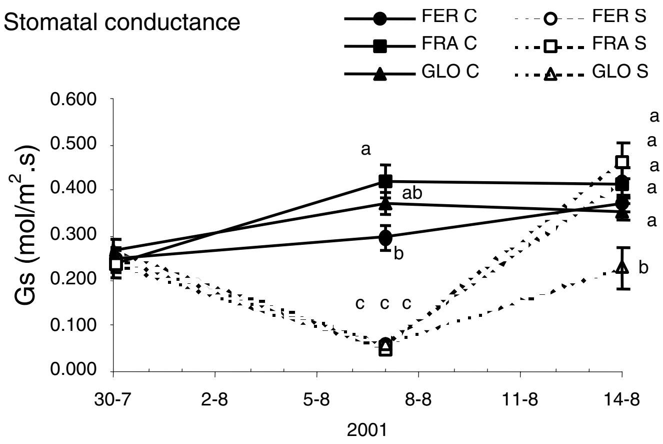

Fig. 4. Stomatal conductance [Gs (mol/m^2·s)] for the three cultivars 'Ferragnès' (circles), 'Francolí' (squares), and 'Glorieta (triangles), and two treatments: control (black symbols and lines) and stress (white symbols and dashed lines). Each point represents the mean of six measurements and the vertical bars the standard error. Different letters represent significant differences between treatments and cultivars within each day (Duncan's multiple range test, P≤0.05).

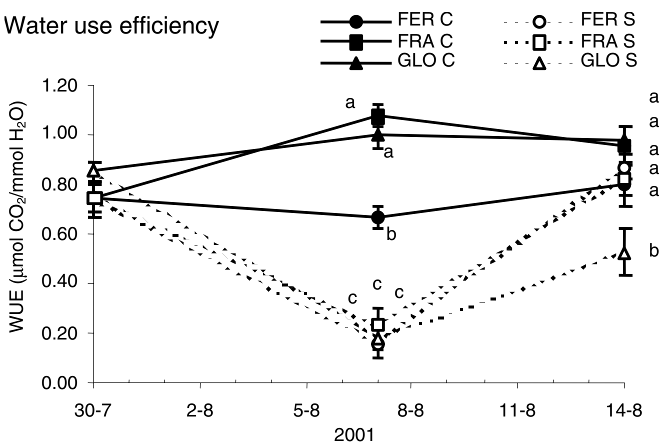

Fig. 5. Water Use Efficiency [WUE (µmol CO_2/mmol H_2O)] for the three cultivars 'Ferragnès' (circles), 'Francolí' (squares), and 'Glorieta (triangles), and two treatments: control (black symbols and lines) and stress (white symbols and dashed lines). Each point represents the mean of six measurements and the vertical bars the standard error. Different letters represent significant differences between treatments and cultivars within each day (Duncan's multiple range test, P≤0.05).

Under stress treatment, the three cultivars showed a quick and efficient response to water stress, reducing water losses. Stomatal closure was reduced leaving only a residual conductance about 0.0600 mol/m^2·s. Leaf abscission was observed for the three cultivars (but was not quantified), it was apparently higher in 'Glorieta'. Stomatal control led to a reduction of photosynthetic rates (0.6 µmol CO_2/m^2·s), but still allowing some assimilation. The recovery process was up to control level for 'Ferragnès' and 'Francolí', but 'Glorieta' did only recover its gas exchange for a 50% Pn and, 65% Gs respect to its control. Similar reductions in stomatal conductance have been widely described (Castel and Fereres, 1982; Torrecillas *et al.,* 1989; Torrecillas *et al.,* 1996; de Herralde, 2000).

It seems that under fast water stress, the three cultivars showed a good avoidance strategy, reducing water losses through stomatal closure and leaf shedding. Reductions in leaf water potential in 'Francolí' could be attributed to some tolerance mechanisms, such as osmotic adjustment that takes place in other cultivars like 'Masbovera' (de Herralde *et al*., 2001). 'Glorieta' appears to be the most sensitive cultivar of the three to water stress since it was unable to recover water potential and gas exchange.

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