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Differences in drought tolerance in two almond cultivars: 'Lauranne' and 'Masbovera'

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

SUMMARY – Almond is a well adapted nut tree crop to arid and semi-arid environments. Although native from southwest and middle Asia it is widely grown in most Mediterranean climatic areas of the world. Differences on drought tolerance between cultivars have been empirically observed. 'Lauranne' and 'Masbovera' are two cultivars selected in two Mediterranean countries, INRA Avignon and IRTA Reus respectively, which are being extensively planted. Ecophysiological characteristics determine the agronomic and commercial response of different varieties in distinct environments. Their features are also important both for breeding and orchard management. The aim of this study was to compare the water relations and photosynthesis pattern of 'Lauranne' and 'Masbovera' in field under the environmental conditions of northeastern Iberian Peninsula. The first experiment was carried out on adult trees, growing on seedling rootstocks; leaf water relations were studied determining pressure-volume curves. 'Masbovera' showed osmotic adjustment, reducing its $\Psi_{\pi 100}$ 24% whereas 'Lauranne' showed no significant variation. Cuticular transpiration rates were high in 'Lauranne' in June but it showed a 50% reduction in September (differences were not significant between cultivars). Results on specific leaf weight showed no differences from April to June and September. On young potted trees, growing on GF-677 clonal rootstocks, daily drip fertirrigated, photosynthesis-light saturation curves were obtained. 'Masbovera' showed higher photosynthetic rates (106%) and lower light compensation point (24%) than 'Lauranne'. In a drought resistance trial, 'Masbovera' showed higher water use efficiency and higher regulation regarding hydraulic resistance than 'Lauranne'. From the results obtained 'Masbovera' should be considered better adapted than 'Lauranne' to be grown without irrigation under Mediterranean climatic conditions.

Key words: Almond, canopy morphology, drought resistance, osmotic potential, photosynthesis, specific leaf weight, water relations.

RESUME – *"Différences dans le comportement de deux variétés d'amandier : 'Lauranne' et 'Masbovera', pour la résistance à la sécheresse". L'amandier est une culture qui est bien adaptée aux climats arides et semi-arides. Cette espèce est native du sud-est et de la partie centrale de l'Asie, pourtant, elle est largement cultivée dans la majeure partie des régions à climats méditerranéens. Pour la tolérance à la sécheresse, des différences dans le comportement des variétés sont observées empiriquement. 'Lauranne' et 'Masbovera' sont deux variétés sélectionnées dans deux pays méditerranéens, à l'INRA d'Avignon et l'IRTA de Reus respectivement, elles ont été extensivement plantées. Les caractéristiques écophysiologiques déterminent les réponses agronomiques et commerciales des différentes variétés dans différents milieux. Leurs caractéristiques sont aussi importantes pour l'amélioration et l'entretien de la plantation. Le but de cette étude est la comparaison entre les relations hydriques et la tendance photosynthétique de 'Lauranne' et 'Masbovera' eux champs sous différentes conditions environnementales du Nord-est de la Péninsule Ibérique. Le premier essai s'est réalisé sur des arbres adultes greffés sur des pieds francs. Les relations hydriques des feuilles ont été étudiées moyennant la détermination des courbes de pression-volume. 'Masbovera' a montré un ajustement osmotique en réduisant de 24% son* $\Psi_{\pi 100}$*, alors que 'Lauranne' n'a pas présenté de variations significatives. Les taux de transpiration cuticulaire étaient élevés en juin pour 'Lauranne' mais ils montraient une réduction de 50% en septembre (les différences entre cultivars n'ont pas été significatives). Les résultats concernant le poids foliaire spécifique n'ont pas montré de différences depuis avril jusqu'à juin et septembre. Pour les arbres jeunes en pot, greffés sur GF-677 avec fertirrigation journalière, on a obtenu les courbes de saturation de lumière-photosynthèse. 'Masbovera' a montré des taux plus élevés de photosynthèse (106%) et des points de compensation de lumière plus bas (24%) que 'Lauranne'. Dans un essai de résistance à la sécheresse 'Masbovera' a montré une efficience plus élevée de l'utilisation de l'eau et une meilleure régulation pour ce qui concerne la résistance hydraulique que 'Lauranne'. A partir des résultats obtenus 'Masbovera' devrait être considérée mieux adaptée que 'Lauranne' à la culture en sec sous conditions climatiques méditerranéennes.*

Mots-clés : *Amandier, morphologie de la cime, résistance à la sécheresse, potentiel osmotique, photosynthèse, poids spécifique foliaire, relations hydriques.*

Introduction

Almond (*Prunus amygdalus* Batsch, syn. *P. dulcis* (Miller) D.A. Webb) is a drought tolerant nut tree species grown along most Mediterranean climatic areas of the world. 'Masbovera' and 'Lauranne' are two almond cultivars bred and selected in the Mediterranean region. 'Lauranne' was obtained by INRA-Avignon, from a cross ('Ferragnes' x 'Tuono') made in 1978. Its advantages are self-compatibilty, late flowering and early production. Its production capability is good but it alternates (Grasselly and Duval, 1997). 'Masbovera' was obtained by IRTA-Mas Bové, from a cross ('Primorskiy' x 'Cristomorto') made in 1975. It is vigorous, early cropping, gives high and constant production and shows some drought tolerance (Vargas and Romero, 1994). The study of the ecophysiological characteristics that determine the success of a cultivar in a particular environment is a powerful tool for both, agricultural management and breeding purposes. The aim of this work was to compare the tree water relations and photosynthesis in two almond cultivars under the climatic and growing conditions of the northeastern Iberian Peninsula.

Materials and methods

Water relations and morphology on adult trees

Plant material and growing conditions

The experiments were carried out from April to September in 1997 on two almond tree cultivars ['Lauranne' (LAU) and 'Masbovera' (MBO)], growing in the almond collection at IRTA-Mas Bové (Tarragona, Spain) (41° 10' 16'' N, 1° 11' 30'' E), under field conditions on calcareous soils (1997 climatic records were: rainfall 634 mm; average temperature 15.9°C) (Table 1).

Table 1. Cultivars and their abbreviations, rootstocks, ages (years) and tree spacing (m) of the studied trees. (Data from Vargas and Romero, 1993)

Cultivar		Rootstock (seedling)	Age (years)	Tree spacing (m)
'Lauranne'	LAU	'Tuono' x 'Mena d'en Musté'	16	4.0 x irregular
'Masbovera'	MBO	'Garrigues'	10	6.3 x 6.3

Measurements

Pressure-volume isotherms (Savé *et al.*, 1994) on mature leaves of each cultivar were recorded in July and September. Osmotic potential at turgor loss point (Ψ_{tlp}) and full turgor ($\Psi_{\pi 100}$), and also bulk modulus of elasticity ($\in$) were calculated. Cuticular transpiration rate (CT_r) was gravimetrically measured at the same time in the same leaves.

Mature leaves of each cultivar were sampled in April, July and September in 1997. The area of each leaf was measured with an image analyser (DIAS, Delta-T Devices, UK). The same leaves were dried and weighed, in order to calculate the specific leaf weight (*SLW*) (Savé *et al.*, 1993). Crown architecture was measured on branches oriented to south, grown in the same year, in which was measured branch orientation angle, with an angle measurer (GEOSTAT3, Acme Proggetti, Firenze, Italy), branch length and number of leaves. From these values crown density was calculated. Crown density is used here as *cd = number of leaves in a current year stem/length of the same stem* (leaves/cm).

Photosynthetic characterization

Plant material and growing conditions

One year old almond trees of the cultivars 'Masbovera' and 'Lauranne' grafted onto GF-677 rootstocks, were grown at IRTA-Cabrils, northeastern Spain (41° 25' N, 2° 23' E). Twenty trees of each cultivar were grown in 16.5 l. pots with peat (Floratoff) and perlite (Europerl A-13) (2:1, v/v) as substrate, with a tree spacing of 0.8 m x 1.25 m. Trees were daily drip irrigated. Water amount depended on the evaporative demand. From February to July plants were fertilised with Nitrofoska azul especial® (BASF) (12+12+17s+2) and from July to the end of season with a nutrient solution [1:0.5:1.5 (N:P:K; pH = 6.5)] added to irrigation water. Weather conditions and monthly irrigation amounts during the year are expressed on Table 2.

Table 2. Irrigation treatment and climatic conditions in Cabrils during 1998 growing season

Month	Irrigation treatments (l/tree)	Rainfall (mm)	ET_0 (mm)	Average temperature (°C)
Feb.	17.9	17.0	41.7	10.4
Mar.	14.0	22.7	67.3	12.1
Apr.	21.3	36.9	103.0	13.6
May	49.3	93.6	116.4	17.3
June	59.6	63.9	137.0	20.8
July	73.5	48.5	153.0	23.6
Aug.	85.9	84.8	133.0	24.0
Sept.	83.4	71.2	102.0	21.1
Oct.	66.8	59.6	62.2	16.5
Nov.	38.9	17.2	38.4	11.7
Total	510.7	515.4	954.0	17.0

Measurements

Photosynthesis-light curves were made on trees (June, 1998). Different light intensities were achieved with sun radiation at different times of day and/or using shading screens. Net photosynthesis rates were measured using an infrared gas analyser (LCA-2. ADC Ltd. Hoddeson, Herts, UK).

Statistical analysis

The statistical analysis of data was made using The Sas System for Windows 6.12 [Sas Institute Inc. (Cary, NC 27513, USA)]. Analysis of variance was used when appropriate. Mean separations were by Duncan's multiple range test, $P \leq 0.05$. Photosynthesis curves were adjusted by MSExcel 97.

Results and discussion

Seasonal patterns of plant water relations showed significant differences between both cultivars 'Lauranne' and 'Masbovera' (Table 3). Thus, 'Masbovera' showed osmotic adjustment reducing its $\Psi_{\pi 100}$ 24% whereas 'Lauranne' shows no significant variation. Elastic adjustment was absent in both cultivars. The decrease in osmotic potential at full turgor is known as osmotic adjustment and permits turgor maintenance, under water deficit conditions, by means of accumulation of osmotically active compounds (Morgan, 1984, 1992). Another tolerance mechanism is the decrease in water potential at turgor loss point. It is considered a good indicator of stomatal closure time (Jones and Turner, 1978; Jane and Green, 1983), and a decrease in this value allows to maintain gas exchange at low water potentials (Parker and Pallardy, 1985).

Cuticular transpiration rates were significantly higher in 'Lauranne' in June but it showed a 50% reduction in September (differences were not significant between cultivars). 'Masbovera' showed an avoidance mechanism, because decreasing cuticular transpiration rate allows to minimise water losses when stomata are closed (Savé *et al.*, 1994; Blum, 1997).

Table 3. Leaf water relations of 'Masbovera' and 'Lauranne' in June and September (n = 5; α = 0.05; different letters mean significant differences)

	Cultivar	June	September
Ψ_{tlp} (MPa)	'Masbovera'	–1.75 ± 0.09 b	–2.1 ± 0.15 c
	'Lauranne'	–1.59 ± 0.11ab	–1.57 ± 0.04 a
$\Psi_{\pi 100}$ (MPa)	'Masbovera'	–1.482 ± 0.05 a	–1.83 ± 0.15 b
	'Lauranne'	–1.38 ± 0.10 a	–1.15 ± 0.15 ab
$\in$ (MPa)	'Masbovera'	8.12 ± 0.93 a	11.37 ± 1.51 a
	'Lauranne'	6.96 ± 0.18 a	1.88 ± 0.25 a
TR_C (mg H_2O/min/g DW)	'Masbovera'	$4.20 \times 10^{-3} \pm 4.10 \times 10^{-4}$ b	$3.85 \times 10^{-3} \pm 4.09 \times 10^{-4}$ b
	'Lauranne'	$6.43 \times 10^{-3} \pm 5.67 \times 10^{-4}$ a	$5.46 \times 10^{-3} \pm 7.41 \times 10^{-4}$ ab

Specific leaf weight was significantly increased seasonally, but this didn't show significant differences between cultivars. Leaf area was significantly higher in 'Masbovera' than in 'Lauranne' (Table 4).

Table 4. Leaf morphological characteristics in the two almond cultivars and months (n = 5; α = 0.05; different letters mean significant differences)

		June	September
SLW (mg/cm^2)	'Masbovera'	9.58 ± 0.47 b	12.43 ± 0.51 a
	'Lauranne'	9.36 ± 0.24 b	12.04 ± 0.60 a
Leaf area (cm^2)	'Masbovera'	20.28 ± 2.38 a	24.16 ± 2.78 a
	'Lauranne'	13.75 ± 0.63 b	13.78 ± 0.50 b

Canopy architecture was measured resulting on more close, dense and vertically distributed canopy in 'Masbovera' than in 'Lauranne' (Table 5).

Table 5. Canopy morphological characteristics in the two almond cultivars

	'Masbovera'	'Lauranne'
Canopy density (leaves/cm)	1.10 ± 0.22 a	0.95 ± 0.125 a
Shoot insertion angle (°)	35 ± 9.1	23 ± 6.2

Photosynthesis-light saturation showed that 'Masbovera' had higher photosynthetic rates than 'Lauranne' (106%), higher light saturation point (87%) and lower light compensation point (24%) (Fig. 1). In a drought assay 'Masbovera' showed higher water use efficiency and a higher regulation in hydraulic resistance (unpublished data).

This fact, together with the characteristics of the canopy architecture of 'Masbovera' trees provides a more efficient strategy for controlling water loss than 'Lauranne' (Savé *et al.*, 1993, 1995). Also the canopy architecture of 'Masbovera' suggests a strategy for increasing the efficiency of light absorption (Morris, 1989; Savé *et al.*, 1999).

Conclusions

It seems that 'Masbovera' uses its tolerance mechanisms (osmotic adjustment, low rate of cuticular transpiration, decrease in water potential at turgor loss point) to maintain water status and gas exchange under water deficit conditions as it occurs in some other species (Monneveux and Belhassen, 1996). Thus 'Masbovera' should be considered better adapted than 'Lauranne' to grow without irrigation under Mediterranean conditions.

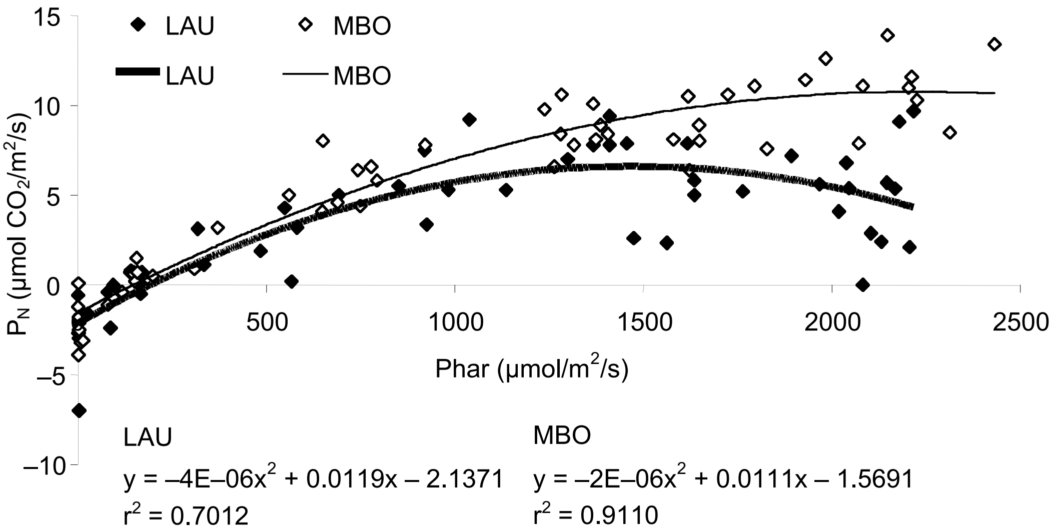

Fig. 1. Light-photosynthesis curves in 'Masbovera' and 'Lauranne' (n = 53; both r^2 are significant at α = 0.01).

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