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Responses of five almond cultivars to irrigation: Photosynthesis and leaf water potential

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ABSTRACT

In the Trás-os-Montes region, almond orchards are usually planted in the dry soils on the upper valley of the Douro river and are typically cultivated under non-irrigated conditions, leading to low yields. This study aimed to compare the physiological responses of five almond varieties (Francoli, Ferragnès, Glorieta, Lauranne and Masbovera) growing under non-irrigated and irrigated conditions. In irrigated conditions, all cultivars had higher photosynthetic rates, with maximum rates in a range of 10–12 μmol CO_2 m^{-2} s^{-1}. Study of daily photosynthesis (June–August) indicates that, irrigated plants showed maximal values at 11 h (32 °C), while in water stressed ones highest values were found at 9 h (28 °C). The irrigation induced an increase in photosynthesis of around 173% in Lauranne, 187% in Francoli, 204% in Glorieta, 266% in Masbovera and 331% in Ferragnès. In relation to values of water potential that allow half-rate of photosynthesis (ψ_{w50}), they were calculated as −2.95, −2.50, −3.10, −3.20 and −3.30 MPa for Ferragnès, Glorieta, Masbovera, Francoli and Lauranne, respectively.

1. Introduction

Trás-os-Montes and the Algarve are the main almond-producing regions in Portugal (*Amygdalus communis* L.) (Cordeiro, 1998a). Although the almond is considered a drought-resistant crop because it exhibits xeromorphic characteristics (Torrecillas et al., 1996), restrictive environmental conditions are found limiting almond productivity to about 800–900 kg of kernels per hectare on dry soils. However, in irrigated orchards kernel production can reach 1400–1800 kg, such as those cultivated in California ones (Hernández and Moreno, 2002; Monteiro et al., 2003).

The purpose of the present work was to analyze the leaf water potential and gas exchange parameters in five almond cultivars: Masbovera, Ferragnès, Francoli, Glorieta and Lauranne, based on a comparative study between non-irrigated and irrigated plants. The leaf water potential values that allow maximal (ψ_{w100}) and half-rate (ψ_{w50}) of photosynthesis were also determined.

2. Material and methods

This study was conducted in 2002 at Quinta do Valongo, Mirandela (latitude 41°28′ and longitude 7°10′) in a south-facing orchard. Soils are well-drained, with textures from loamy sand to silty loam and the parent materials are base-poor (Portela et al., 2003). Two blocks of four trees with 5-year old, grafted on GF-677 rootstock, from Masbovera, Ferragnès, Francoli, Glorieta and Lauranne randomly distributed were

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compared under irrigation and non-irrigation conditions. Plants were irrigated with two micro-sprinklers per tree, each one 50 cm from the trunk in the period comprising the kernel-filling stage and pre-harvest (between early June and the third week of August), three times a week, providing almost 300 mm of additional water delivery to the 58 mm of precipitation from May to August.

Data were collected on 25th May, 24th June, 8th and 21st August at 7, 9, 11 and 13 h. As for temperatures, mean daily temperatures (7–13 h) were 28.6, 30.7, 27.0 and 27.4 °C, respectively, while mean values at 7, 9, 11 and 13 h were 20, 28, 32 and 34 °C, respectively.

Leaf water potential (ψ_w), was determined from six sunlight-exposed adult leaves in a Scholander Pressure Chamber (PMS Instrument®; Corvallis, Oregon, USA) according to Scholander et al. (1965) following the recommendations of Turner (1988). Predawn (ψ_{wpd}) and midday (ψ_{wmd}) leaf water potential were determined with values from 7 and 11 h, respectively. Leaf water potential values for each cultivar at maximal (ψ_{w100}) and half (ψ_{w50}) photosynthesis rates were determined with obtained water potential and photosynthesis rate values between 9 and 11 h. Gas exchange measurements were taken from sunlight-exposed leaves with an IRGA (mod. LCA-2, Analytical Development Co., Hoddesdon, UK) using a leaf chamber type PLC(b) for broad leaves in which a reduction on its window from 6.25 to 3.7 cm^{-2} was done.

Fruit analyses were done on four almond samples collected from four trees of each treatment (each sample corresponded to the entire production of each tree). For determination of dry matter, fruits were dried at 65 °C during 24 h (Cordeiro et al., 1998b).

Analysis of variance was carried out using the Microsoft Excel and StatView 4.0 programs (Abacus Concepts, Inc.). Comparisons were made with the Fischer's LSD test with a significance level of 0.05. As for second-degree polynomial regression models, they were obtained from Microsoft Excel, with the values of ψ_{w100} and ψ_{w50} for each variety, calculated from the respective equations.

3. Results and discussion

The irrigation of almonds between the end of June and the end of August sustained the predawn leaf water potential (ψ_{wpd}) at above −1.0 MPa (Table 1), the level of May without any irrigation, while in non-irrigated trees, values declined progressivly to those between −2.3 and −2.8 MPa until the beginning of August, which are very close to those obtained under severe water stress. These values correspond, except for Glorieta (ψ_{wpd} = −1.4 MPa), to the obtained values at midday in irrigated plants, suggesting that a decrease in ψ_{wpd} values would be very closely dependent on the soil moisture conditions as was described by Torrecillas et al. (1996).

With regard to midday leaf water potential (ψ_{wmd}), at the end of May, all trees presented values in the range of −2.3 to −2.7 MPa, increasing in irrigated ones, from this date until 8th August, to values between −1.7 and −1.9 MPa. As for non-irrigated plants, values significantly decreased from May to August, to −3.5 MPa except for Glorieta (−2.8 MPa), with the difference between treatments significant for all varieties ($P > 0.05$) (Table 1). Consequently, the comparison between treatments demonstrates that the introduction of irrigation

Table 1 – Study of predawn (ψ_{wpd}) and midday (ψ_{wmd}) leaf water potential in watered and non-watered treatments

Variety	Time (day)	ψ_{wpd} (MPa)			ψ_{wmd} (MPa)		
		Watered	Non-watered		Watered	Non-watered	
Glorieta	25 May	−0.89 ± 0.15 *b*	−0.98 ± 0.18 *a*	A	−2.59 ± 0.23 *c*	−2.59 ± 0.12 *a*	A
	28 June	−0.78 ± 0.19 *a,b*	−1.28 ± 0.12 *b*	B	−2.05 ± 0.14 *b*	−2.63 ± 0.14 *a*	B
	08 August	−0.64 ± 0.09 *a*	−1.87 ± 0.17 *c*	B	−1.72 ± 0.13 *a*	−2.71 ± 0.42 *a*	B
	21 August	−0.57 ± 0.12 *a*	−1.17 ± 0.07 *b*	B	−2.00 ± 0.25 *a,b*	−2.60 ± 0.09 *a*	B
Ferragnes	25 May	−0.84 ± 0.22 *a*	−0.97 ± 0.13 *a*	A	−2.34 ± 0.10 *b,c*	−2.49 ± 0.12 *a*	A
	28 June	−0.87 ± 0.19 *a*	−1.79 ± 0.19 *b*	B	−2.12 ± 0.14 *b*	−3.13 ± 0.11 *b*	B
	08 August	−0.67 ± 0.09 *a*	−2.23 ± 0.17 *c*	B	−1.71 ± 0.13 *a*	−3.53 ± 0.13 *c*	B
	21 August	−0.76 ± 0.07 *a*	−2.16 ± 0.15 *c*	B	−2.40 ± 0.25 *c*	−3.48 ± 0.18 *c*	B
Francoli	25 May	−0.95 ± 0.24 *a*	−0.85 ± 0.23 *a*	A	−2.72 ± 0.23 *c*	−2.74 ± 0.32 *a*	A
	28 June	−0.78 ± 0.08 *a*	−2.40 ± 0.19 *b*	B	−2.23 ± 0.14 *b*	−3.11 ± 0.11 *b*	B
	08 August	−0.73 ± 0.10 *a*	−2.81 ± 0.17 *c*	B	−1.91 ± 0.19 *a*	−3.49 ± 0.29 *c*	B
	21 August	−0.86 ± 0.11 *a*	−2.62 ± 0.10 *b,c*	B	−2.34 ± 0.25 *b*	−3.51 ± 0.44 *c*	B
Lauranne	25 May	−1.03 ± 0.25 *a*	−1.11 ± 0.19 *a*	A	−2.34 ± 0.19 *b*	−2.53 ± 0.37 *a*	A
	28 June	−1.02 ± 0.22 *a*	−2.53 ± 0.20 *c*	B	−2.10 ± 0.14 *b*	−3.03 ± 0.14 *f,e*	B
	08 August	−0.89 ± 0.13 *a*	−2.59 ± 0.17 *c*	B	−1.97 ± 0.38 *a*	−3.49 ± 0.43 *c*	B
	21 August	−0.92 ± 0.26 *a*	−1.99 ± 0.35 *b*	B	−2.26 ± 0.26 *b*	−3.26 ± 0.16 *c*	B
Masbovera	25 May	−0.78 ± 0.18 *a*	−0.91 ± 0.16 *a*	A	−2.39 ± 0.29 *a*	−2.51 ± 0.15 *a*	A
	28 June	−0.76 ± 0.14 *a*	−1.69 ± 0.21 *b*	B	−2.06 ± 0.14 *a*	−3.52 ± 0.21 *c*	B
	08 August	−0.82 ± 0.24 *a*	−2.11 ± 0.32 *c*	B	−1.88 ± 0.13 *a*	−3.49 ± 0.19 *c*	B
	21 August	−0.72 ± 0.30 *a*	−1.63 ± 0.23 *b*	B	−1.92 ± 0.15 *a*	−3.05 ± 0.30 *b*	B

Measurements were done in 25th May (1), 28th June (2), 8th (3) and 21st August (4). Values are displayed with standard error ($n = 6$ for ψ_{wd} and ψ_w; $n = 24$ for $\Delta\psi_w$).