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Characterization of almond varieties in irrigated and non-irrigated conditions

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SUMMARY – In Trás-os-Montes Region, almond orchards are usually planted in the dry soils of Upper Douro River Valley. Even so, they are traditionally cultivated under non-irrigated conditions, resulting in low and non-competitive production. This study aims to compare the physiological responses of five almond varieties ('Francolí', 'Ferragnès', 'Glorieta', 'Lauranne' and 'Masbovera') growing under non-irrigated and irrigated conditions and to find the specific leaf water potential value that maximizes the photosynthetic productivity. Under irrigated conditions, all the studied cultivars showed high photosynthetic potentials, with average daily rates in a range of 6.8 to 7.7 $\mu molCO_2/m^2/s$. Under non-irrigation, plants showed a strong photosynthesis reduction of 32, 42, 47, 51 and 58% in 'Glorieta', 'Lauranne', 'Francolí', 'Masbovera' and 'Ferragnès'. This general reduction suggests the benefits of an adequate irrigation programme leaded by leaf water potential.

Key words: Almond, water potential, photosynthesis, drought resistance.

RESUME – *"Caractérisation des variétés d'amandiers en conditions irriguées et non-irrigués". Dans la région de Trás-os-Montes, les vergers d'amandiers sont habituellement plantés dans les sols secs de la haute Vallée du fleuve Douro. Néanmoins, les amandiers sont typiquement cultivés sans irrigation, ce qui mène à une réduction de la production et perte de compétitivité. Cette étude vise à comparer les réponses physiologiques de cinq variétés d'amandier ('Francolí', 'Ferragnès', 'Glorieta', 'Lauranne' et 'Masbovera') dans des conditions non irriguées et irriguées, et à déterminer la valeur de potentiel hydrique qui maximise la productivité photosynthétique. Avec l'irrigation, toutes les variétés étudiées montrent une haute activité photosynthétique, avec des moyennes qui se trouvent entre 6,8 et 7.7 $\mu molCO_2/m^2/s$. Sur les plantes non irriguées nous avons détecté une forte réduction de la photosynthèse, étant de 32, de 42, de 47, de 51 et 58% sur 'Glorieta', 'Lauranne', 'Francolí', 'Masbovera' et 'Ferragnès'. Cette réduction suggère l'utilité d'établir un programme adéquat d'irrigation, ayant pour base le potentiel hydrique foliaire.*

Mots-clés : *Amande, potentiel hydrique, photosynthèse, résistance à la sécheresse.*

Introduction

In Portugal the almond (*Prunus amygdalus* Batsch syn. *Amygdalus communis* L. syn. *Prunus dulcis* Mill.) productive regions are mainly Trás-os-Montes and Algarve, representing the first region about 60% of the total area (22,747 ha in 1997), which 80% is located in the dry soils of Upper Douro River Valley, producing approximately 45% of the total Portuguese almond crop (Cordeiro, 1998). The restrictive environmental conditions characterize this region's edaphically and climatically and strongly limit almond's productivity to about 100 to 120 kg of kernel per hectare on older orchards. Although, on modern plantations with an adequate soil preparation and using the most indicated cultivars, the production can reach levels of kernel per hectare from 800 to 900 kg on dry soils, or 1400 to 1800 kg on irrigated orchards such as the Californian ones (Hernández and Moreno, 2002; Monteiro *et al.*, 2003).

The micro-sprinkler irrigation system is one of the many irrigation and water management technology tools now available. The use of this technique has several advantages because micro-sprinklers can reduce either the waste of water to a negligible amount and the transport of contaminants to surface and groundwater. Irrigation events can also be fine-tuned to spoon feed water and nutrients just in time to avoid plant stress. It can optimize crop productions, maximizing the economic yield for each unit of water and in many cases increase the quality of agriculture products.

Once each orchard and cultivar have unique characteristics, a relieve way to achieve those benefits could be the monitoring of trees water stress by measuring leaf water potential (at predawn or midday), witch could be a good strategy to save water, to improve a lower fruit drying ratio, to reduce excessive shoot growth and to save money (McCutchan and Shackel, 1992; Shackel, 2000; Schwankl *et al.*, 2000). Pressure chambers should then be used to manage irrigation, fine tuning the current irrigation practices by finding the best targets values for each cultivar and soil conditions. This is the first objective of this work, given that leaf water potential (Ψ_w) is a useful measure that combines the particularly influences of plant, soil and atmospheric conditions on the overall plant performance.

It is generally recognized that in many regions some crops are not physically or economically suitable without irrigation. Unfortunately, the Trás-os-Montes Region dry areas are no exception to this, being further efforts justified in order to reduce the economic impediments of a more widespread adoption of adequate irrigation systems. Drip-irrigation (daily irrigations) or micro-sprinkler irrigation (with 3 days interval) during the water use peak periods should be enough to steady Ψ_w (Schwankl *et al.*, 2000).

Once almond is considered a Mediterranean species, when planting new almond's orchards farmers always face the problem of which cultivar will be more adapted to the regional microclimate. Due so, this study was established in order to find a set of physiological parameters, allowing the characterization of five almond cultivars: 'Masbovera', 'Ferragnès', 'Francolí', 'Glorieta' and 'Lauranne', trying to establish the necessary knowledge that will make irrigation programs based on Ψ_w a reality.

Materials and methods

This study was leaded on a South-facing orchard placed in Quinta do Valongo, Mirandela (lat. 41°29' and long. 1°57') in 2002 beneath the climatic conditions presented on Fig. 1.

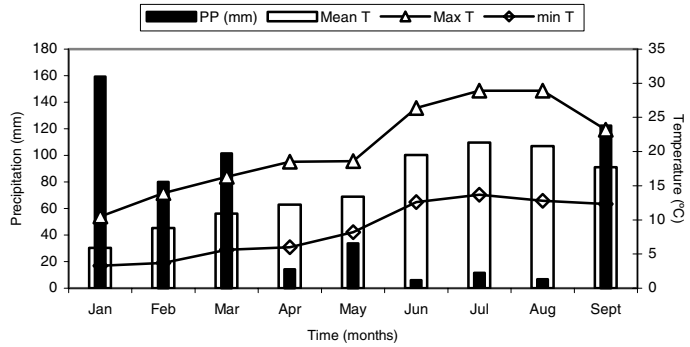

Fig. 1. Evolution of temperature and precipitation in Mirandela region between January and September (2002) (following the typical Mediterranean characteristics with dry and hot summer time). It's evident the disconnection of values before and after May, when a truly dry and hot conditions were imposed.

As usual in Trás-os-Montes region summer was very dry and hot. From June to August the average temperature was 20°C, with maximal and minimal values of 29°C and 13°C. Relatively to monthly precipitation, it must be noted that from June to August it only occurred 22 mm of precipitation, which is less than the 33 mm attained on May in a total of 536 mm from January to September. The evolution of medium day temperature and solar radiation are described in Fig. 2: 7 h readings were done with a medium temperature near 20°C, 9 h at 27°C, 11 h at 31°C and 13 h at 33°C. In all working days the sky was completely clean of clouds, meaning that all the determinations were made with as maximal PPFD (photosynthetic photon flux density) as possible (1500-2000 $\mu mol/m^2/s$) except for the 7 h registries, where the reduced PPFD (50-100 $\mu mol/m^2/s$) is a strong inhibitory factor.

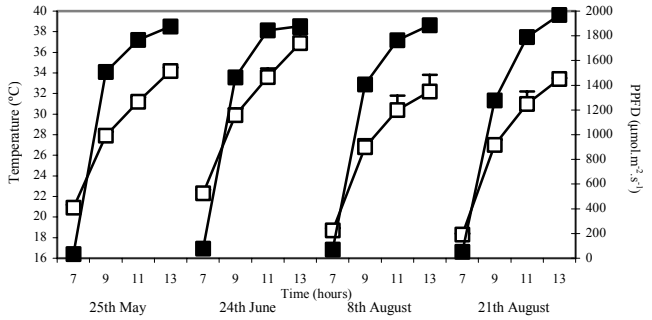

Fig. 2. Evolution of PPFD (black squares) and temperature (open squares) measured during each day of work by the LCA-2 at the same time of the physiological determinations during the vegetative cycle (from May to August). In each day, determinations were done at 7 h, 9 h, 11 h and 13 h. Bars representing the standard error (n = 80).

Plant material

Four trees, with five years old, of five almond cultivars, 'Masbovera', 'Ferragnès', 'Francolí', 'Glorieta' and 'Lauranne', grafted in GF677 rootstock and spaced 6x4 m.

Irrigation system

Irrigation system consisted in two micro-sprinklers per tree, each one 50 cm far from trunk. Plants were irrigated since the first week of May to the last week of August three times a week during one hour, providing almost 100 mm of additional water delivery, complementing the 500-600 mm precipitated per year.

Outline of experiments

Four fully irrigated and four non-irrigated plants of each cultivar were compared. Measurements where made at 25th May, 24th June, 8th and 21st August and the determinations were done at 7, 9, 11 and 13 hours. Eight leaves were collected to determine the Ψ_w with a Scholander Pressure Chamber (mod. ELLE International, England).

Photosynthetic productivity data were collected with an IRGA (mod. LCA-2, Analytical Development CO., Hoddesdon, UK) and the parameters were photosynthesis (A), foliar transpiration rate (E), atmospheric temperature (T) and photosynthetic photon flux density (PPFD). Water use efficiency (WUE) was calculated according to Salisbury and Ross (1992).

Two measurements of fluorescence were taken at 11 h on 24th June and 21st August with a fluorometer (PSM, Biomonitor): a 30 s flash frequency was applied from 0 to 270 s and each flash had 4 s of duration and 1500 µmol/m^2/s of intensity. For photosynthetic pigments concentration, 6 disks with 7 mm of diameter were removed from two leaves (five repetitions) and placed in 10 ml of acetone at 80%. The test tubes were kept at 4°C in a refrigerator, being periodically agitated. At the end of 3rd day the test tubes where centrifuged in a clinical centrifuge (MLW, ref. T54) at 2500 g during 5 minutes. Absorbance readings were taken in a dual beam spectrophotometer (PYE UNICAM mod. SP8-100, Cambridge). The Chl_{total} concentration, Chl_a/Chl_b ratio and Car_{total} were calculated according to Lichtenthaler (1987).

Analyses of variance were carried out using the StatView 4.0 software (Abacus concepts, Inc.). Comparisons were made with the Fischer test for a significance level of 0.05.