Optimization of the Water Use in the Olive Tree: The Relationship Between Transpiration and Plant Water Status

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Abstract

Water stress is considered to be the most important factor limiting plant growth and production. Thus, monitoring of plant water status in field grown is considered of great interest, as it would allow the diagnoses of the onset and severity of water stress so as to schedule irrigation according to the actual plant needs. Changes in plant water status could be described by using a sensitive physiological indicator, which integrates both soil and climatic conditions. The most recent assessment techniques that can establish a quantitative relationship between plant water status and other physiological parameters, which can be monitored easily is the sap flow measurements. Theses measurements can be monitored continuously thus providing a continuous record of plant water losses and requirements in response to environmental variables. The aim of our study was to evaluate a quantitative direct relationship of the olive tree transpiration (using the measurement of the sap flow) and the environmental conditions and the plant water status that might be used to schedule irrigation so that plant water status can be maintained above certain thresholds in field grown olive trees.

The experiment was conducted from September 2007 until February 2008 in Kairounan region located in the centre est of the Tunisian country. The climate is arid where the mean yearly rain full is from 200 to 300 mm and the mean yearly evaporation rate from 1200 to 1500 mm. The plant material is the “Meski” local olive tree (8 year age).

Tow water levels were experimented and this through drip water supply.The first dose is that used by the farmer which is insufficient. The second dose is equivalent to 100 % of evapo transpiration.

The meteorological data was measured using an automatic weather station.

Keywords: Water Stress, Irrigation, Sap Flow.

Introduction

Water stress is considered to be the most important factor limiting plant growth and production. Thus, monitoring of plant water status in field grown is considered of great interest, as it would allow the diagnoses of the onset and severity of water stress so as to schedule irrigation according to the actual plant needs. Changes in plant water status could be described by using a sensitive physiological indicator, which integrates both soil and climatic conditions. The most recent assessment techniques that can establish a quantitative relationship between plant water status and other physiological parameters, which can be monitored easily is the sap flow measurements. Theses measurements can be monitored continuously thus providing a continuous record of plant water losses and requirements in response to environmental variables. The aim of our study was to evaluate a quantitative direct relationship of the olive tree transpiration (using the measurement of the sap flow) and the environmental conditions and the plant water status that might be used to schedule irrigation so that plant water status can be maintained above certain thresholds in field grown olive trees.

Materials and methods

The experiment was conducted from September 2007 until February 2008 in Kairounan region located in the centre est of the Tunisian country. The climate is arid where the mean yearly rain full is from 200 to 300 mm and the mean yearly evapotranspiration rate is around 1500 mm.

From February, measurements were made in the Enfidha region, belonging to semi arid climate where annual rainfall does not exceed 350 mm and evapotranspiration rate is around 1000 mm per annum.

The plant material is the "Meski" local olive tree (8 and 20 year age respectively in kairouan and Enfidha).

Tow water levels were experimented and this through drip water supply: The first dose is that used by the farmer which is insufficient. The second dose is equivalent to 100 % of evapo transpiration in Kairouan and in Enfidha the dose applied is that lost by transpiration estimated from sap flow measurements.

The meteorological data was measured using an automatic weather station.

For the transpiration rate of the olive tree, it was assumed that sap flow is equals total transpiration. Sap flow was measured using the Granier (1987) system. The sap flow measurements, according to this method, were based on the temperature differences between two cylindrical probes which were installed into the trunk. Measurements were taken at 20 s intervals and their average stored every 10 min on a data logger. The sap flow measurements are expressed in litre per hour.

Water relation parameters were measured using a pressure chamber. Predawn water potential (ΨPD) was measured early in the morning (06:00 am) in a mature fully expanded leaves of six randomly selected plants in each treatment. Photosynthetic rate (PN) and stomatal conductance (CS) were measured using respectively a portable gas exchange system (Li-Cor 6400, Li-Cor, Nebraska, USA) and a porometer (Delta T Device) on six leaves per treatment.

Results and discussion

The diurnal changes in the sap flow over a typical 5 days indicated a marked difference between the days which testify the great sensibility of the sap flow to environmental conditions (Fig.1)

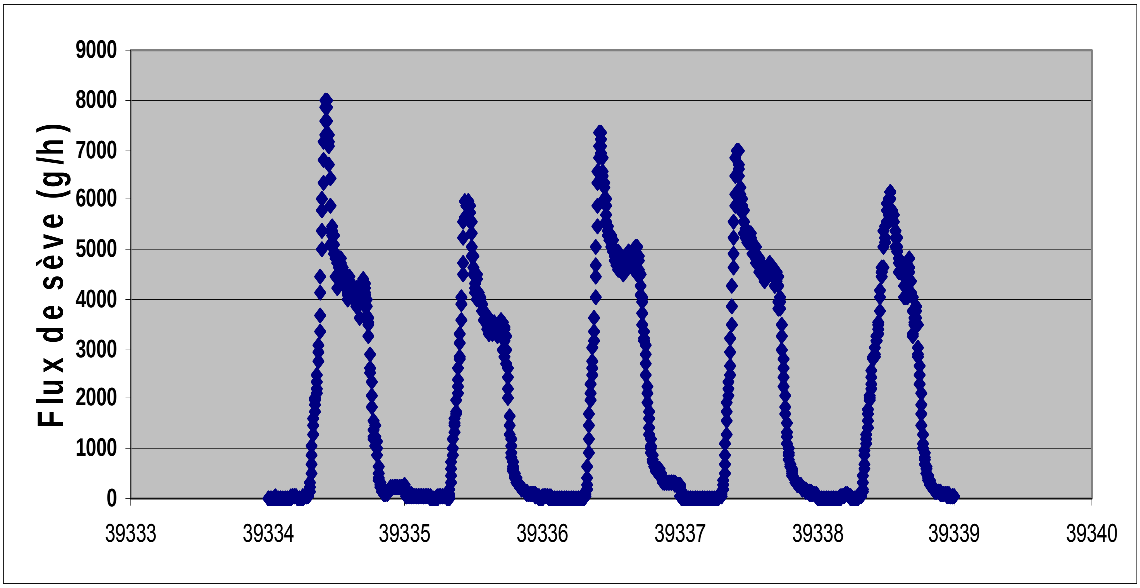

Figure1. Diurnal changes of the sap flow in the experimental plot of Kairouan during 5 consecutive days (9/09 until 13/09 2007 for the treatment A (dose of irrigation used by the farmer).

To illustrate the sap flow kinetics for different seasons, we chose the seasons when the climatic conditions are extreme: the winter and the summer seasons. As we do not have data during these two seasons at Enfidha and Kairouan, we present at figure 2, results raised in the experimental parcel of Jemmel for the Chemlali variety conducted in rainy conditions. We can see (fig.2) the high rate of sap flow for the summer period which corresponds to the period of great evaporative demand for comparison with the colder wintry time and which corresponds to the period of slowed down activity of this tree. The elevated transpiration level noted in the summer period may not be totally surprising as it has been reported that woody plants that grow well into summer drought frequently depend on the ability to tap water from permanent water tables (Canadell et al., 1996). The proportion of biomass allocated to below-ground tissues is usually increased as environment becomes more severe (Canadell et al.,1999).

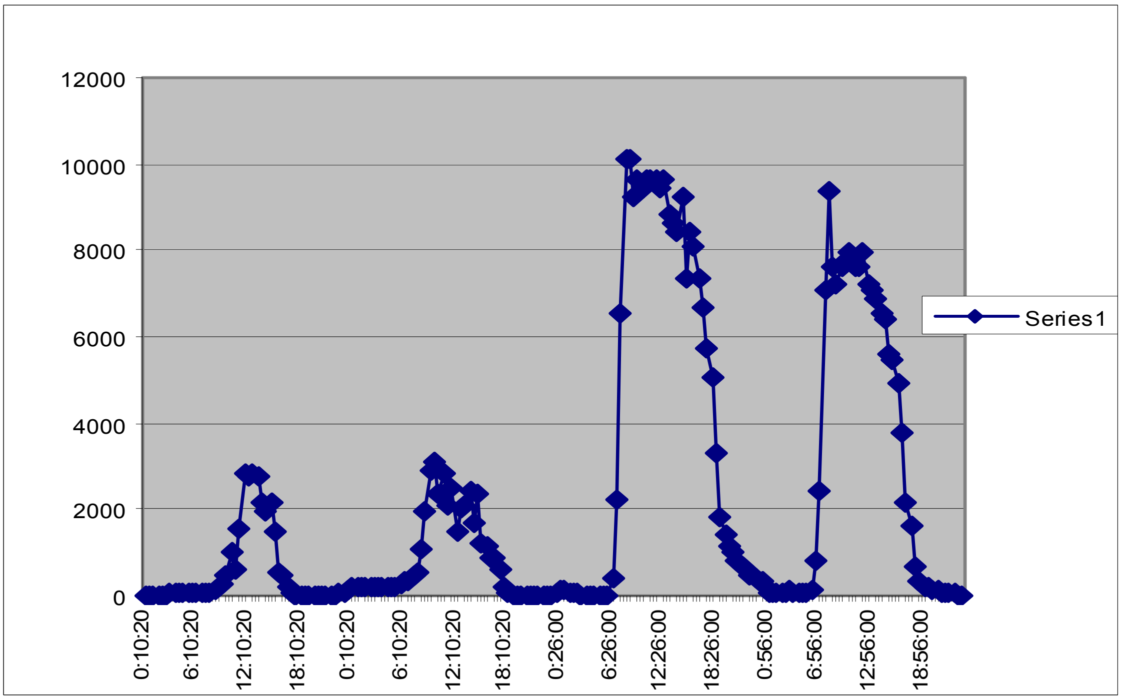

Figure 2. The diurnal changes in sap flow for various months of the year for the experimental parcell of Jemmel (Chemlali Variety)

The diurnal changes in sap flow over a typical 3 days in tow water level conditions indicated marked differences for the tow water treatment (Fig.3). The daily variation of sap flow recorded in the different tree water state situation show that we can have information on the intensity of water losses in the olive tree depending on the soil water situation.

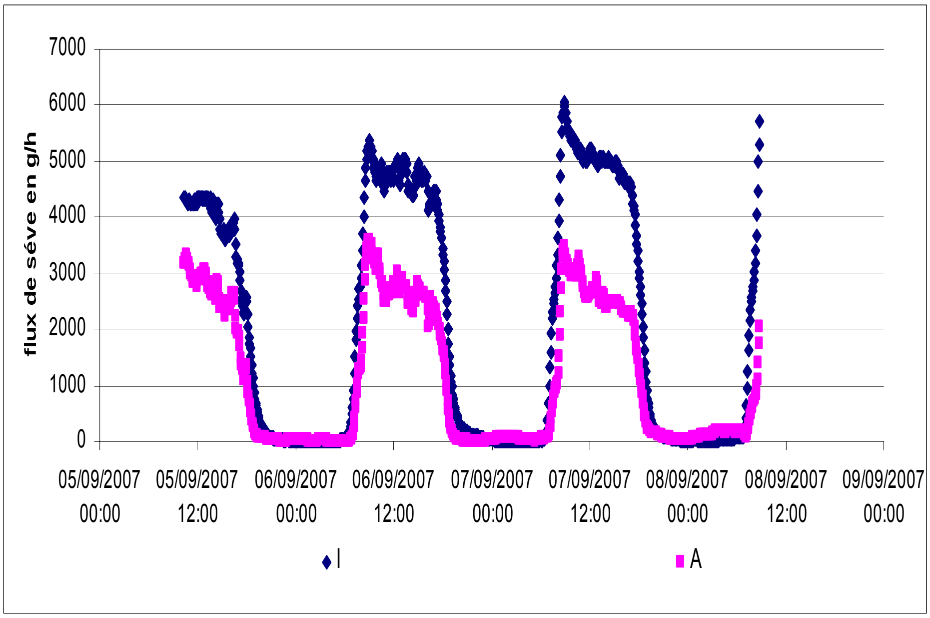

Figure3. Diurnal changes of the sap flow in the experimental plot of Kairouan during the period from 05/09 to 08/09 2007 for the treatment A (dose of irrigation used by the farmer) and the treatment I (dose equivalent to 100 % of evapo transpiration).

Figures 4 and 5 show the direct effect of temperature and relative humidity of the air and the total radiation on the sap flow which illustrates the sensitivity of this parameter to the environmental conditions and the possibility to use it for evaluating the effect of environment on the water state of the tree

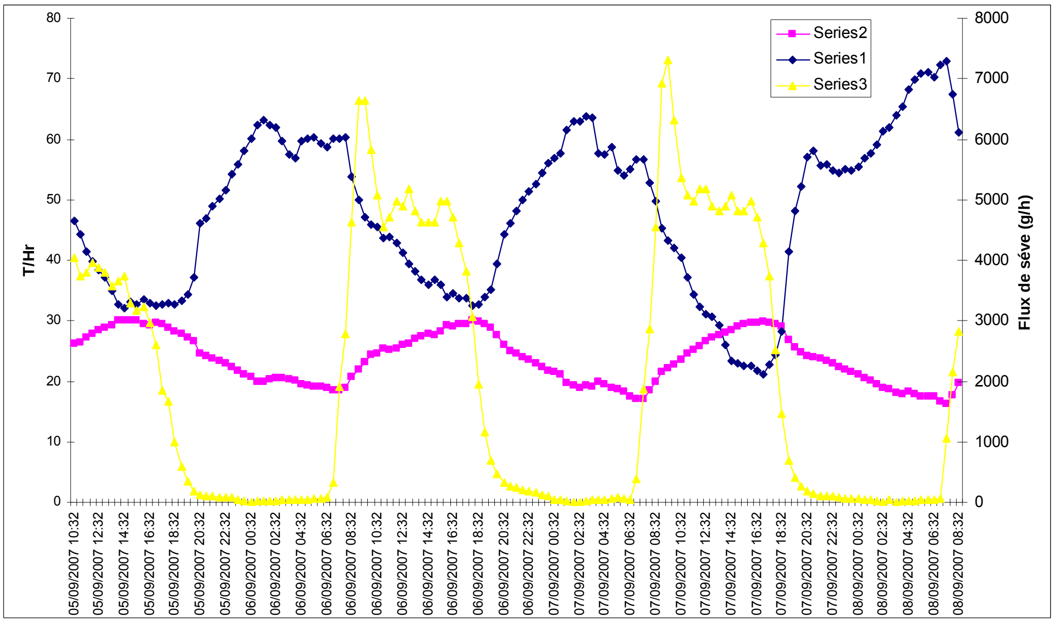

Figure 4. The relationship between the sap flow (series 3), air temperature (T: Series 2) and air relative humidity (Hr: Series 1) in the experimental plot of Kairouan during the period 05/09, 08/09 2007 for the treatment I (dose of irrigation used by the farmer)

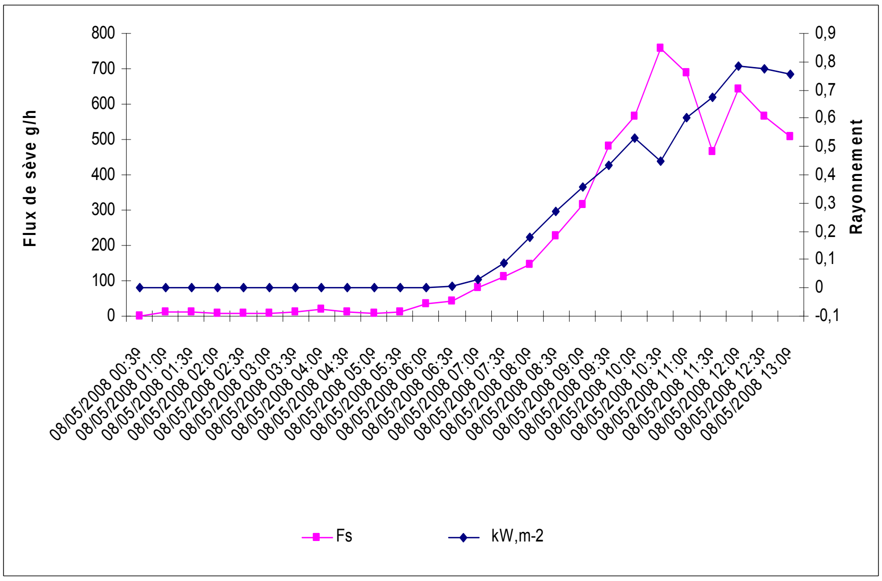

Figure 5. Evolution of the sap flows and the total radiation of May 8, 2008 in Enfidha (of 00:38 to 13:08).

Figure 5 shows the effect of the tree water level on the stomatal resistance and influence the stomata movement on the sap flow. Figure 6 shows the effect of the tree water level on the stomatal resistance and the correlation between the stomata movement and the sap flow.

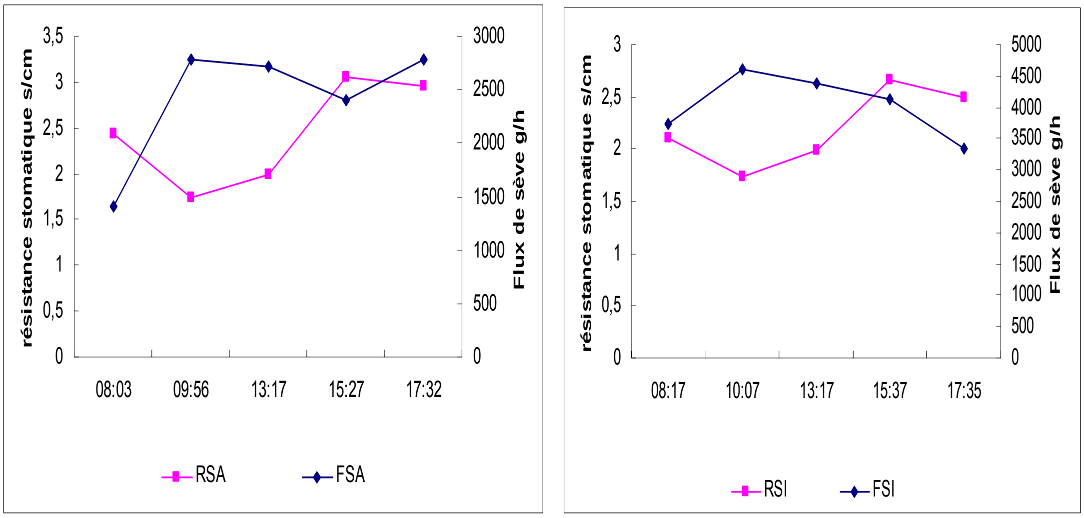

Figure 6. Relationship between sap flow (FS) and stomatal resistance (RS) in the experimental plot of Kairouan during the day on 03/09/2007 for treatment A (dose of irrigation used by the farmer) and I treatment (dose equivalent to 100 % of evapo transpiration).

When water started to become limiting, an increase in vapour pressure deficit (VPD) seemed to lead to stomatal closure and thus reducing sap flow of plants that receive less water (Fig. 6). Stomatal closure in response to increasing VPD might be an effective strategy to avoid excessive water loss under drought conditions and prevent leaf water potential from falling to dangerous levels (Tyree and Sperry, 1988). However, the physiological mechanisms of stomatal response are very complex and not fully understood. Hypotheses involving hydraulic and/or biochemical signals have been proposed and verified in many studies (Stoll et al., 2000 and Davies et al., 2002).

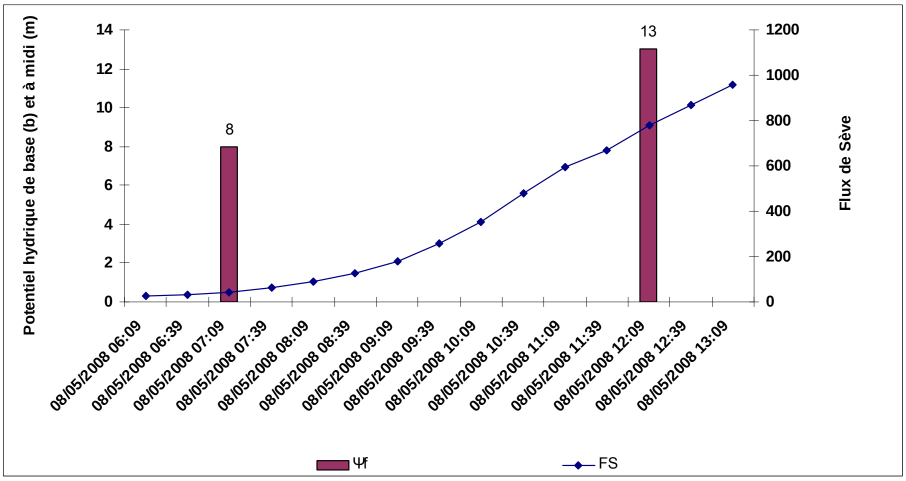

Figure 7. Sap Flows (FS) and predawn (8) and midday (13) water potential in the leaf (Ψ_f) in the experimental parcel of Enfidha for the day of May 8, 2008

Ψf measurements have long been used as an index of water stress as it reflects a combination of many factors such as vapour pressure deficit, leaf intercepted radiation, soil water availability, internal plant hydraulic conductivity and stomatal regulation (Patakas et al., 1997). The close relationship between Ψf and the sap flow levels recorded in the morning and at midday (Fig.7) indicates that this last parameter could be used as it's the case of the Ψf to schedule irrigation in order to maintain plant water status within a favourable range (Patakas et al., 1997, Greenspan et al., 1996).

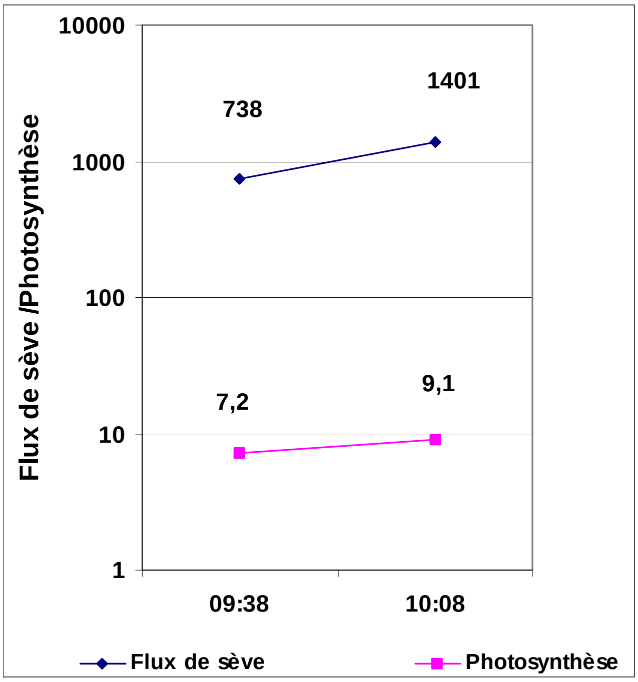

Figure 8. Sap Flows and the corresponding photosynthesis level at a half hour intervals in the experimental plot of Enfidha for the day of 23 April 2008

One of the primary processes affected by drought is photosynthesis, a fact due primarily to stomatal closure which decreases water loss but also carbon flux to the sites of carboxylation (Flexas et *al*., 1998 and Escalona et al., 2002). Thus, monitoring of plant water status in field grown olive tree is considered of great interest and as show figure 8 the sap flux level is a sensitive parameter regarding the variations of the photosynthesis.

The physiological data reported show a good correlation of the sap flow data with, particularly the stomatal resistance and leaf water potential.

The results of this experiment show the direct influence of changes in environmental factors, water state and the physiological parameter of the tree on the sap flow level among the olive tree. So using this technique to assess the water state of the tree and determine the real plant water needs (in space and the time) is important in the context of a rational exploitation of the available water and as a precise and relatively simple method to assess continuously and instantaneously the variation of the water tree state.

The next step for this work is to determine, through correlations between sap flow and a meteorological and physiological parameters, a threshold to trigger the irrigation in order to resituate to the tree water lost by transpiration according to this real needs, taking into account its biological status (over time).

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