

Influence of Drought Stress Periods on Olive (*Olea europaea* L. cv. Zard) Leaves Stomata

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ABSTRACT

In order to study the stomatal behavior of olive cv. Zard under drought stress, irrigation intervals of 6 days was studied on potted olive trees and the resistance of stomata was measured at different hours on consecutive days and hours. Control plants had an every day irrigation intervals. Stomata opened in control plants during day hours and the highest stomatal resistance was observed in the evening (6:30 p.m.), when the light intensity highly reduced. However, plants under stress opened their stomata just at the first hour of morning and then the resistance increased, indicating the decrease in stomata opening during the rest of the day. After two cycles of stress, at the third cycle, stressed plants opened their stomata in the morning and in the afternoon at a higher rate than the second cycle. These observations showed that olive trees under dry land conditions could adopt their physiology with drought stress rapidly and recover their normal activities.

Key Words: *Olea europaea*; Porometer; Stomatal resistance; Drought stress; Adaptation

INTRODUCTION

Olive (*Olea europaea* L.), an ever-green fruit tree, is a native plant in the semi-arid Mediterranean climate. Growing under this type of climate subjects the plants to heat and drought stress during summer (Gimenez *et al.*, 1997). Plants native to this climate have developed some physiological and morphological tolerance mechanisms, resulting in better adaptation and surviving. The adaptation mechanisms in olive, as many other plants include decreasing leaf water potential, osmotic adjustment, stomatal closure, reduction of leaf size, leaf rolling, increasing mesophyll compactness, accumulation of mucilage and other secondary metabolites (Girio *et al.*, 1999; Bosabalidis & Kofidis, 2002).

There is a close relationship between stomatal behavior and plant survival ability under drought stress conditions. Stomatal closure significantly decreases transpiration rate and so, contributes to maintaining positive turgor pressure of the cells (Bosabalidis & Kofidis, 2002). Besides stomatal closure, in response to environmental or internal water deficit changes, plant's adaptation to drought stress occurs through stomata size reduction and deep stomata. The ability to control stomata opening and closure is important to avoid drought stress harms, while some plants close their stomata at early stages of stress and reduce stomatal conductance but some may not be able to do this and can be injured by the stress (Hurd, 1976).

Stomatal conductance in olive trees showed a fast increase at early hours of the day and its maximum values occurred early in the morning, before that the water vapor deficit became so high to cause stomata to be closed. In this case, the highest rate of photosynthesis occurred in early

hours of the day (Fernandez & Moreno, 1999). Similarly, stomatal conductance was highest in olive cv. Piccol with drip irrigation in the morning, then decreased and finally fixed (Gimenez *et al.*, 1997). Stomatal conductance differs between various plants even under irrigated conditions. The measured reported values are apple 3 - 8 mm/s, citrus 1 - 10 mm/s, apricot 2.7 - 11 mm/s, peach 1.5 - 7 mm/s, plum and cherry 1 - 7 mm/s and olive 1.8 - 10 mm/s (Jones, 1985). A positive correlation exists between stomatal conductance and photosynthesis rate in plants (Vitagliano & Sebastiani, 2002). Photosynthesis rate in most plants is reduced when subjected to drought, whereas olive, which is more drought tolerant maintains a high rate of photosynthesis during long drought stress periods (Dichio *et al.*, 2004). Decrease in photosynthesis rate under drought stress happens through stomatal closure and reduction of leaf area and protoplasm activity, but repetition of water stress cycles might cause photosynthetic adaptability (Mathews & Boyer, 1984). The amount of chlorophyll has not been affected by drought stress (de Herralde *et al.*, 1998). Measuring leaf water potential and gas exchange parameters in olive trees under different levels of water deficit, has shown that the maximum values of net photosynthesis rate and stomatal conductance occur early in the morning (Vitagliano & Sebastiani, 2002). Knowledge of tolerance mechanisms in olive is useful and more research should be pursued in this area.

MATERIALS AND METHODS

Four years old olive trees (*Olea europaea* L.) in pots were exposed to two irrigation regimes during summer. Control plants were daily irrigated to maintain soil water at

field capacity, while stressed plants were irrigated at 6 days intervals. Weather condition was warm and dry with temperature ranging between 20 - 40°C during the days. Five fully expanded leaves from the middle part of branches of each tree were selected and marked and then the stomatal resistance was measured daily at 90 min intervals from 8:00 a.m. till 6:30 p.m. using a porometer (AP4, Delta-T Company) and means were used for analysis. Measuring was performed for three consecutive stress periods (18 days). Air temperature and radiation intensity were also measured by the porometer.

RESULTS

Fig. 1 and 2 depict the means of light intensity and air temperature at different times of a day during the three irrigation periods. As it is seen, the maximum of day mean temperature during experimental period was 35.6°C at 2.00 p.m. and its minimum was 23.7°C early in the morning. The light intensity was in its highest point (1707.95 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$) at 14:00 p.m. and it was in its lowest point at 8:00 a.m. and 6:30 p.m. A significant difference was observed in stomatal resistance of olive leaves among different hours of a day (Fig. 3) and between two irrigation treatments (Fig. 4). During the first period, the amount of stomatal resistance was lower in control olive plants compared to the stressed plants and the lowest and highest stomatal resistance was observed on 9:30 - 11:30 a.m. and 6:30 p.m., respectively. Thus in control plants, which were daily irrigated, stomata opened early in the morning and by increasing temperature the stomata opening slightly reduced. In the evening, resistance increased and stomata started to close. In stressed plants stomatal resistance had the lowest value in the morning and sharply increased by progress of the day, however it slightly reduced in the afternoon by reducing the temperature. Thus, stressed plants closed their stomata in order to prevent transpiration and decrease water wasting. During the third stress period, control plants showed the same pattern in stomatal resistance as the first period, while stress plants showed a significant decrease in stomatal resistance in the third period compared to the first period (Fig. 3). Mean daily stomatal resistance in control plants was equal at both irrigation periods, while the difference between stressed plants was significant (Fig. 4).

Fig. 5 shows changes of the mean daily stomatal resistance during the first and third irrigation periods. While control plants showed a low stomatal resistance at a steady and similar procedure at both cycles, the stressed plants showed a higher resistance and different behavior. At the third period, the stomatal resistance of stressed plants just at the 5th and 6th days before irrigation increased slightly and in other days it was low.

Fig. 6 shows stomatal resistance at two definite times of day (8:00 a.m. & 12:30 p.m., minimum & maximum of stomatal resistance times) during the experiment. The high stomatal resistance values in stressed plants were maintained during the experiment although it was higher

Fig. 1. Mean of light intensity at different hours of the day during the experiment

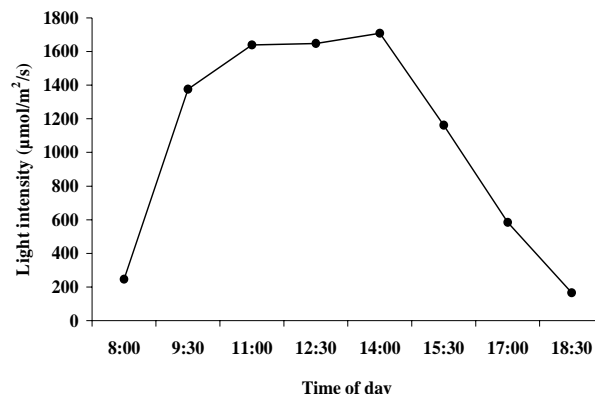


Fig. 2. Mean of temperature at different hours of the day during the experiment

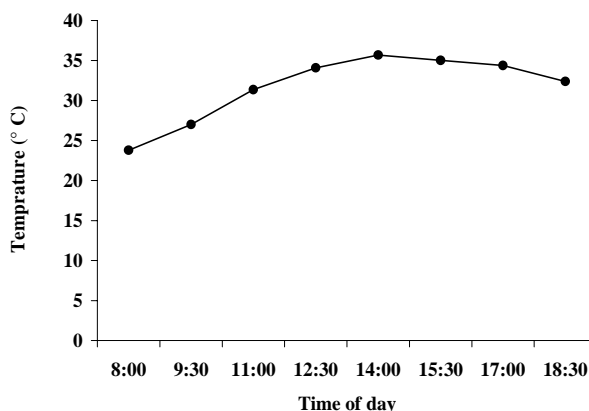
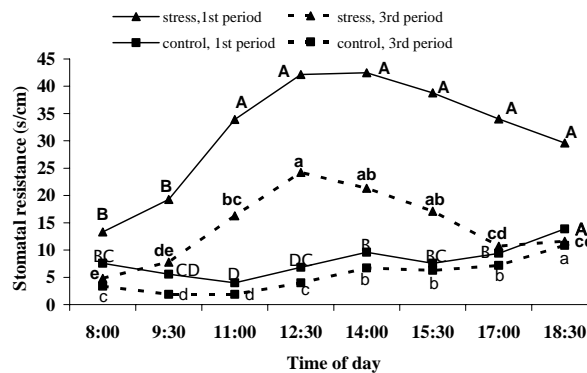


Fig. 3. Stomatal resistance of olive leaves at different hours of the day under two irrigation treatments in the first and third irrigation periods. Different letters on each line show significant difference of point on the same line at 5% level using DMRT



during the first and second periods and lower in the third period.

Fig. 4. Comparison of the effect of different irrigation treatments on mean daily stomatal resistance of olive leaves. Different letters show significant difference at 5% level using DMRT

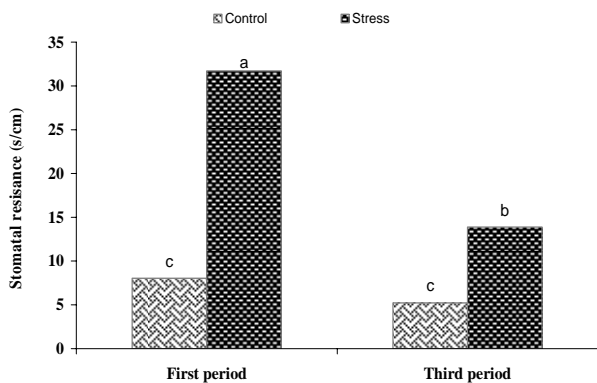


Fig. 5. Mean daily stomatal resistance of olive leaves under two irrigation treatments at consecutive days of the first and third irrigation periods. Points represent the means of measurements of each day, 8 measurements/day

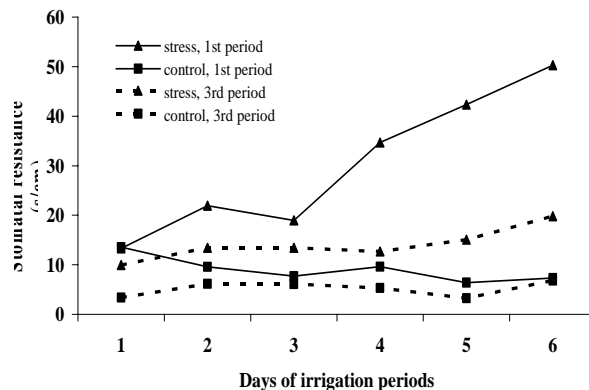
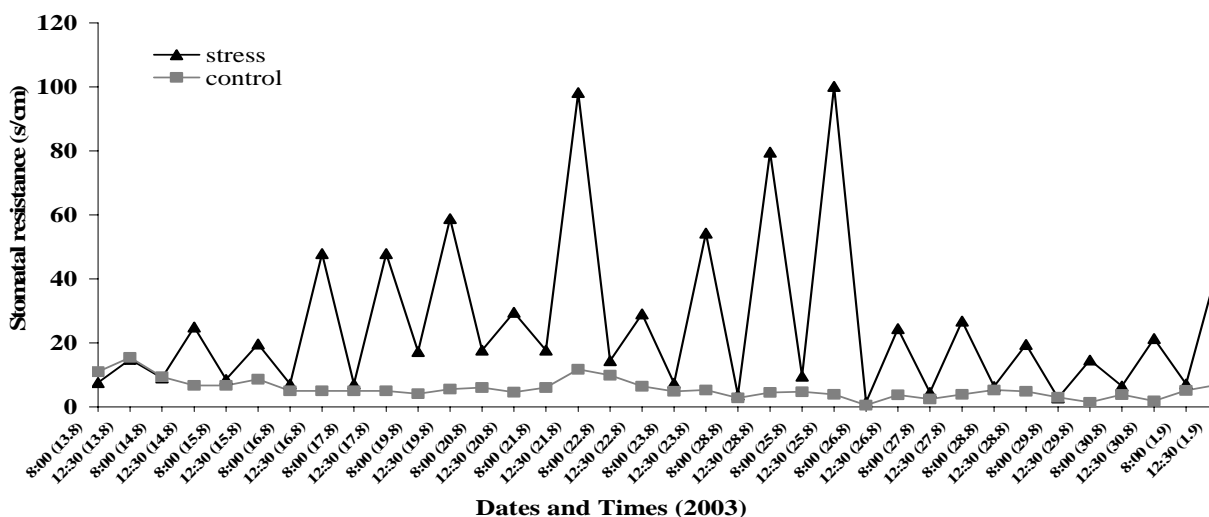


Fig. 6. Stomatal resistance of olive leaves under two irrigation treatments at definite times of day (two hours of each day 8:00 a.m. and 12:30 p.m., the minimum and maximum of daily resistance) for three periods from 13-Aug-2003 through 1-Sep-2003



DISCUSSION

Because leaves are the most important organs, which lose water, plants under drought stress undergo some changes in their leaves in order to save water (Chartzoulakis *et al.*, 1999). The main change is closing the stomata in order to reduce transpiration rate and prevent water loss. Investigating the daily stomatal behavior of potted olive leaves, which were exposed to natural environmental conditions showed that stomata opened early in the morning and towards noon the rate of opening decreased and it was almost steady all afternoon (Angelopoulos *et al.*, 1996). Stomata opening are dependant on vapor pressure deficit

(VPD), which is an environmental variable and its reduction causes midday closure of stomata and reduces photosynthesis in temperate woody plants (Levitt, 1980). There are different reports about reaction of olive trees under field condition. Fernandez *et al.* (1997) reported that there is a high correlation between stomatal conductance and VPD in olive trees. However, Girio *et al.* (1999) found no correlation between stomatal conductance and VPD in young olive trees.

In present experiment drought stress had a significant effect on stomatal behavior of olive leaves and caused an increase in stomatal resistance and closed them (Fig. 3 & 4). Stomatal closure in plants is an adaptation mechanism to

water deficit, which causes water saving and protect plants against drought stress (Moriani *et al.*, 2002). Two mechanisms appear to operate for stomatal closure in response to water stress: active control, which is applied through increasing abscisic acid and reducing cytokinin and the second one is inactive control, called hydro-passive and performs in the absence of hormones (Levitt, 1980).

Plants adapted to environments that are naturally exposed to water deficit have evolved a series of adaptive mechanism, which confer tolerance to water stress. To preserve photosynthesis under drought stress, plants have evolved physiological processes to maintain to some extent tissue turgor and thus stomatal opening. Lowering of osmotic potential in response to water stress is a well established mechanism where-by many plants adjust to low soil water availability (Bosabalidis & Kofidis, 2002). In this experiment, difference in stomatal resistance between two irrigation treatments during the first period was higher at 9:30 a.m. - 6:30 p.m. and lower at 8 - 9:30 a.m. Since plants have not been adapted to water deficit during this period, they closed their stomata with increasing temperature. But during the third period, stomatal resistance significantly decreased compared to the first period. The decrease in stomatal resistance after an initial increase during the early days of stress may be an adaptive mechanism to drought stress in olive. Such mechanism has also been reported in almond (Zamani *et al.*, 2002). This behavior can be due to an osmotic adjustment in plants.

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