WATER STATUS OF OLIVE TREES UNDER DRY-FARMING AND DRIP-IRRIGATION

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Abstract

Leaf water potential (Ψ) and leaf conductance (g_l) were measured in the field in 20-year-old olive trees subjected to two treatments of soil water content (dry-farming and drip-irrigation). Differences between treatments of up to 0.35 MPa were observed in predawn Ψ values. At midday, these differences were of up to 0.83 MPa. However, no significant differences between treatments were observed in g_l values. Maximum g_l values of about 0.77 cm s^{-1} were found early in the morning, clossing the stomata afterwards. In just 12 hours after rewatering following the drought period, the differences between treatments on Ψ values were reduced from 0.29 MPa to 0.14 MPa for predawn values, and from 0.64 MPa to 0.23 MPa for midday values. The recovery was virtually total at the third day after rewatering.

1. Introduction

Water supply by irrigation is widely used in olive crop, specially in table varieties. However, no satisfactory answer has yet been found for important questions related to the response of the crop to this practice. Some interesting work has been carried out about the effects of the irrigation on the plant (Agabbio et al., 1983; Natali et al., 1985) but just a few cases refer to mature trees in field conditions (Abdel-Rahman and El-Sharkawi, 1974; Fernández et al., 1991). The study of the response of some physiological parameters -related to the water status of the plant and the transpiration rate- to the water supply is considered to be a valid approach for the proper control of the irrigation (Kaufmann and Levy, 1976; Fereres et al., 1979).

The objective of the present study was to see the physiological response of the olive tree to different soil water regimes. Water potential and conductance to water vapour diffusion were measured in the field on leaves of 20-year-old manzanillo olive trees under two different soil water regimes, dry-farming and drip-irrigation, throughout the dry season. Recovery of water status after rewatering following the drought period was also studied.

2. Material and Methods

Experiments were carried out in an experimental 0.5 ha plot placed in the Aljarafe area (Seville, Spain), with 20-year-old olive trees (*Olea europaea* L., var. manzanillo) planted at 7x7 m spacing. A drip-irrigation system was installed in the plot twelve years after plantation, with a line of drippers along the trees and four, 4 l h^{-1} emitters per tree, being two of them on each side of the tree and separated 1 m from each other. The soil is a sandy loam soil (27.5% coarse sand, 36.5% fine sand, 13.4% silt and 22.6% clay) of 2 m depth (Moreno et al., 1983). Annual rainfall in the area (550 mm on average) takes place mainly from October to May, being the rest of the year dry and hot.

Two soil-water regimes were imposed in the plot: (a) Treatment D: dry-farming. Non-irrigated trees, which surrounding soil surface (8x8 m) was covered with a two layer plastic, to avoid the water supply due to the rainfall. (b) Treatment I: drip-irrigation. Trees were irrigated with a pan coefficient of 0.4. The experimental period started at the end of April of 1988 and ended in the middle of September. Leaf water potential (Ψ) and leaf conductance (g_l) were measured one day of each month, starting in May, from before dawn to sunset and with two and a half hour intervals. Leaf water potential was estimated by using a pressure chamber, in leaves removed from the trees inmediatelly before the measurement. Leaf conductance was measured just before Ψ measurements, by using a dynamic diffusion porometer. In both cases, sampled leaves were healthy fully developed leaves placed at the level of 1.5-1.8 m on the sun-orientated side of the canopy. In each measurement, the number of replications were 4 and 8 for Ψ and g_l respectively (coefficients of variation: 7.5 for Ψ and 14.9 for g_l).

Soil water content was measured in both treatments on the days in which Ψ and g_l were measured, by using a neutron scattering method. Tubes for the neutron probe were installed at different distances from the trunk (Moreno et al., 1988). Meteorological data were measured in a meteorological station placed at the experimental plot (temperature and humidity of the air: psycrometer; solar radiation: pyranometer).

At the end of the experimental period, a tree representative of treatment D was flood irrigated until about field capacity, to study the recovery of its water status. Irrigation was carried out on September 12th, at sunset. Measurements of Ψ on trees of both treatments were carried out twice a day, before dawn and at 13 h in the afternoon, four days after rewatering.

3. Results

3.1. Leaf water potential and leaf conductance

No significant differences between treatments were observed from May to July, except in predawn values (In May: -0.36 MPa in treatment D; -0.15 MPa in treatment I. Similar values were measured in June and July). On that period, atmospheric demand was anormally low for the area, with frequent rains (708 mm in the hydrological year 1987-88; 152 mm from the end of April until the middle of June, uniformly distributed). Increasing differences between treatments were observed from July to September. Figure 1 shows the daily changes of Ψ values measured in August, in D and I trees. Soil water content for both treatments and air temperature and humidity values are given in figures 2 and 3 respectively. Differences of predawn values were very high, with -0.56 MPa and -0.21 MPa measured in trees D and I, respectively. Similar values were found in September (treatment D: -0.53 MPa; treatment I: -0.26 MPa). The minimum measured value in the experimental period was -2.87 MPa measured in August, at 13:30 h. Up to 0.83 MPa difference were found between treatments, also in August, at midday. At sunset, these differences decreased, but still were greater than the observed at sunrise.

Values of Ψ showed to be very sensitive to atmospheric demand. Lower values of Ψ were found in September than in August, in both treatments, despite the highest differences between treatments in soil water content. This may be due to the fact that the measuring day in September was partially cloudy and with lower temperatures and higher air humidities than in August (meteorological data of measuring days in August/September: average solar radiation: 396/324 W m^{-2}; hours of sunshine: 11.4/6.5 h; maximum air temperature: 36.5/26.0 C; minimum relative humidity of the air: 18/43 %).

Figure 4 shows the daily changes of g_l values measured in August on the abaxial surface of leaves of D and I trees. No water vapour diffusion was found on the adaxial surface. Leon and Bukovac (1978) studied the morphology of olive leaves and found that stomata were present only on the abaxial surface and that the thickness of the cuticle was greater on the adaxial than on the abaxial surface. The g_l curve presents a maximum in the morning, at about 10 h, decreasing along the day. No significant differences were observed between treatments, at any moment of the day and in any of the considered months. Maximum values were found in September, with 0.77 cm s^{-1} and 0.76 cm s^{-1} measured at 10:30 h in D and I trees, respectively. In figure 5 data of Ψ

measured between 10 and 13 h, the measuring days of August and September, are plotted with their counterparts of g_l. No good correlation was found between both parameters, either for the whole pool of data or for irrigation and non-irrigation data separately (D and I data: $r^2 = 0.08$; D data: $r^2 = 0.34$; I data: $r^2 = 0.11$). Fereres et al. (1979) drew the same kind of curve for orange trees and found a clear reduction of g_l as Ψ decreased. Castel and Fereres (1982) observed in almond a fair correlation between both parameters, but allowed them to drawn some conclusions about the stomata behaviour. In our case, figure 5 shows which has already been deduced from the analysis of the diurnal course of Ψ and g_l: values of g_l were similar on D and I trees, despite of the fact that more negative values of Ψ were measured on D than on I trees. A certain scatter has also been observed by other authors in different species when plotting Ψ versus g_l values (Fereres et al., 1979; Castel and Fereres, 1982).

3.2. Recovery after the drought period

Figure 6 shows the changes of predawn and midday Ψ values measured in D and I trees throughout the experimental period. The increasing differences between treatments mentioned in former section is clearly shown in this figure. On the 12th of September these differences were of 0.29 MPa before dawn and 0.64 MPa at midday. One D tree was irrigated at the end of this day (Section 2) and Ψ was measured in trees of both treatments just about 12 hours after the irrigation, in the morning of the next day. The predawn values shown a difference between treatments of only 0.14 MPa. At midday, the difference was 0.23 MPa. No significant differences between treatments were observed both at predawn and midday three days after the irrigation.

4. Discussion

Predawn values of Ψ show that the water status of olive trees under dry-farming conditions do not fully recover at night. This agree with the observations made in young trees by authors like Agabbio et al. (1983) and Natali et al. (1985). Also, the differences between treatments found at sunset show that trees under dry-farming conditions have a slower recovery of their water status in the afternoon than the drip-irrigated trees. These findings, together with the fact that higher Ψ values were measured on irrigated trees than on trees under dry-farming, show that the water supply during the drought period can mean a significant benefit to the crop. In fact, the size of irrigated trees was bigger than the size of dry-farming trees (non-irrigated/irrigated trees: height= 4.1±0.21 / 4.4±0.23 m; canopy diameter: 3.6±0.3 / 4.6±0.3 m; trunk diameter: 8.5±0.9 / 8.5±0.8 cm. Data are average ± standard deviation of 10 rainfed trees and 30 drip-irrigated trees), which can be a consequence of the higher rate of growth due to more positive Ψ values detected in irrigated trees. When analysing Ψ data obtained at light hours, however, the strong dependency of Ψ on atmospheric water demand has to be taken into account, since Ψ data measured on different days with different conditions of radiation, air temperature and air humidity can be significantly different, even if the soil water content has not changed.

The changes of g_l along the day show a good adaptation of the olive tree to the high demanding conditions of the area. The decrease of g_l values after the first hours in the morning shows the clossing of the stomata when atmospheric demand increases, to avoid excessively high transpiration rates. Moreover, the fact that no significant differences on g_l values were observed between treatments shows a high capacity of water absorption by the roots. This agrees with observations made by other authors. Abdel-Rahman and El-Sharkawi (1974) found higher values of g_l in trees under dry-farming than in irrigated trees; also, Natali et al. (1985) measured high g_l values in trees grown in soils with a very low water content. Fernández et al. (1991) observed an effective radicular system in olive trees grown under dry-farming conditions and a very positive response of the development and functioning of the roots to the water supply. The number of leaves, however, is usually higher in irrigated trees than in trees under dry-farming, so the total transpiration rate can be greater in trees under drip-irrigation.

Several factors may contribute to the scatter observed when plotting Ψ versus g_l, already pointed out by several authors. Jarvis (1976) suggested that environmental factors such as vapour pressure, temperature and radiance can have a strong effect on stomata response. Castel and Fereres (1982) considered that measurements of water potential in the stomatal apparatus could be of interest, since it may change differently to the bulk leaf Ψ.

The speed of recovery of the water status of D trees after irrigation is similar to the one observed in lemon trees by Kaufmann and Levy (1976) and in orange trees by Fereres et al. (1979). The fast recovery after rewatering is important for the tree to quickly recover after the first autum rains.

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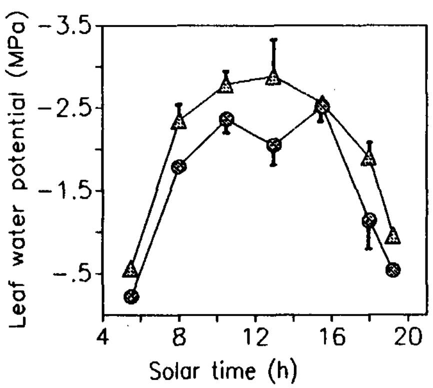

Figure 1 - Daily changes of Ψ values measured on the 26 th of August (▲ treatment D; ● treatment I).

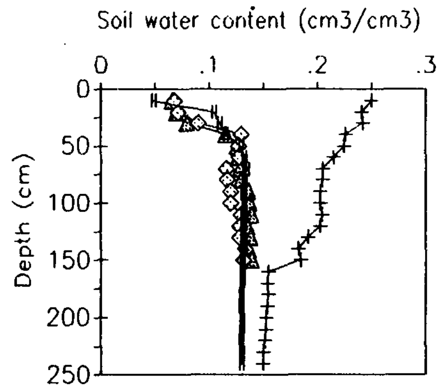

Figure 2 - Soil water content profiles measured on the 26th of August (treat./distance from trunk:
▲ D / 0.5 m
◈ D / 2.5 m
+ I / 0.5 m
‖ I / 3.5 m).

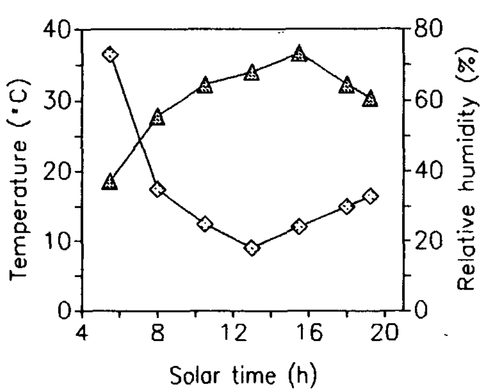

Figure 3 - Daily changes of air temperature (▲) and humidity (◈) measured on the 26th of August at the experimental plot.

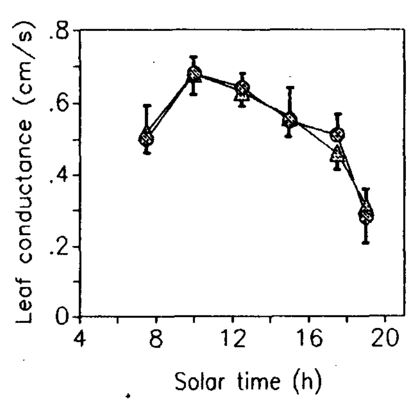

Figure 4 - Daily changes of g_l values measured on the 26th of August (▲ treatment D; ● treatment I).

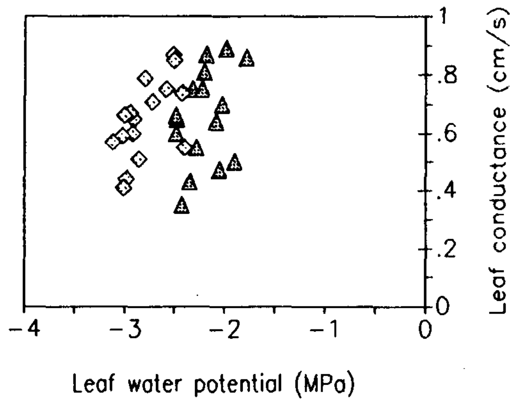

Figure 5 - Relation between Ψ and g_1 values measured in D (◇) and I (▲) trees. Points represent single observations measured in August and September, between 10:00 and 13:00 hours.

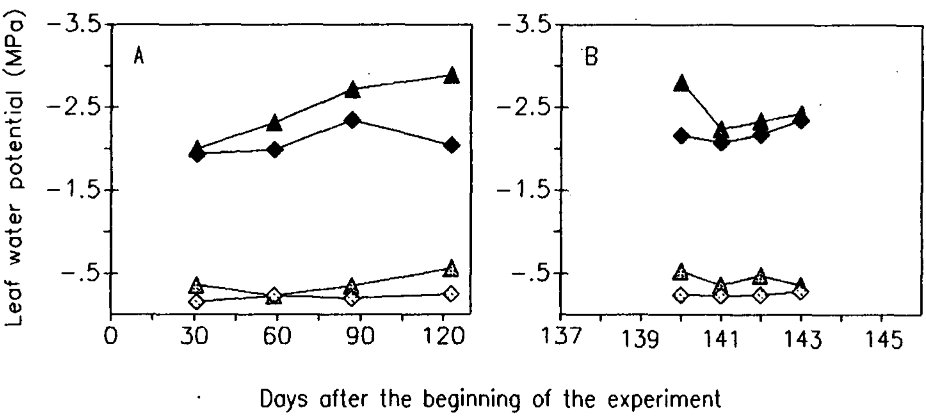

Figure 6 - Changes of Ψ values measured at predawn (blank symbols) and midday (black symbols) in D (triangle) and I (diamond) trees (A) throughout drought period (B) after rewatering of D trees, 140 days after the beginning of the experiment.