DEFENSE STRATEGIES OF OLIVE AGAINST WATER STRESS

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Abstract

The response of plants to water deficit varies with species. The olive tree is able to resist water stress by lowering the water content and water potentials of its tissues. This mechanism permits the plant to establish a high potential gradient between leaves and roots, and therefore to utilize soil water up to -2.5 MPa. In water stress conditions the olive tree stops shoot growth but not photosynthetic activity: net assimilation at -6.0 MPa predawn leaf water potential is 10% that of well-watered plants. This allows continued the production of assimilates as well as their accumulation in the various plant parts, in particular in the root system, creating a higher root/leaf ratio compared to well-watered plants.

Active and passive osmotic adjustment play an important role in maintaining cell turgor and leaf activities which depend on it. Sugars, especially mannitol and glucose, play a major part in the osmotic adjustment of leaves. Organic acids, such as citric and malic, also play a role in active osmotic adjustment, whereas minerals do not seem to be involved.

In addition, the osmotic adjustment observed in the root system allows maintenance of cell turgor, avoiding or delaying the separation of roots from soil particles. After a period of water stress and the following rewatering of the soil olive, like other tree species, shows a period of inertia of leaf activity. This is not due to a lack of cell turgor but to other causes related to the hormone balance and to the conductivity of the xylem system. How fast leaf functionality is restored depends on the level of stress reached previously.

Additional index word: Olea europaea, osmotic adjustment, transpiration, photosynthesis.

1. Introduction

Olive trees are able to resist water stress by lowering the water content and potentials of their tissue. This mechanism permits the plant to establish a high potential gradient between leaves and roots and therefore to utilize soil water up to - 2.5 MPa soil potential values. In this paper are reported some results of trials carried out in the last five years in South Italy using ownrooted plants of cv Coratina grown in pots and in open field.

2. Material and methods

2.1 Plants grown in pots

Trials were carried out using two-year old ownrooted trees (cv. Coratina) grown outdoors in 18 L pots.

The effects of different levels of soil water deficit on water relations, gas exchange and osmotic adjustment were studied.

Stress level was defined on the basis of predawn leaf water potential.

Once the desired levels of leaf water potential had been reached, all plants were rewatered to create optimal soil water conditions. All the above parameters were studied during the rewatering period.

1999 Acta Horticulturae 474: 423-426
3. Results and discussion

Water use efficiency of olive trees in good soil water conditions is higher than in most other fruit tree species (Xiloyannis et al. 1996). The responses of transpiration, stomata conductance, photosynthesis and internal CO$_2$ (Fig. 1) suggest that stomata progressively reduced their activity below -0.9 MPa predawn leaf water potentials values and stop their activity up to extreme values of -7.0 MPa.

A progressive closure of stomata as leaf water potential decreased was observed in other fruit tree species but their stomatal closure was reached at values ranged from -1.5 to -2.5 MPa of predawn leaf water potential (Lakso, 1979, Castel e Fereres, 1982).

Intercellular CO$_2$ during hottest hours of the day was lower, compared to the control, in plants with leaf water potentials of about -3.5 MPa and definitely higher at lower potentials. This could show that in the hottest hours of the day the decline in the rate of net photosynthesis was merely consequence of limited CO$_2$ supply to the chloroplast, due to partial stomatal closure at moderate stress levels (stomatal inhibition). In the severely stressed plants the high CO$_2$ values could be due to photoinhibition processes at the level of mesophyll cells. In severely water-stressed plants the inactivation of photosynthetic activity was accompanied by changes in the fluorescence characteristics of the upper intact leaf surface (Angelopoulos et al., 1996).

The capacity of tissues to give up in transpiration large amounts of water, accumulated during the afternoon and night, ensures a certain level of leaf functionality in drought conditions not only during the early morning but also during the hottest hours of the day (data not shown). Under drought conditions olive leaves can give up to transpiration about 60% of the water stored in their tissues contributing to the demands of transpiration as stress increases up to extreme values of -7.0 MPa (Fig. 2).

High potential gradients between leaves, roots and soil enable olive to extract water even at soil water potentials of around -2.5 MPa allowing it to survive long periods of drought in soils with good water storage capacity. If we consider a soil volume explored by roots of approximately 15,000 m$^3$ per hectare with a field capacity of 40% in volume, water storage capacity between field capacity and -2.5 MPa is about 570 m$^3$ per hectare greater than that between field capacity and -1.5 MPa, the value at which most fruit tree species die. This amount of water is sufficient to maintain a minimum level of activity on stressed plants for approximately 60 days.

Drought tolerance at low water potentials is primarily a question of turgor maintenance. The most effective mechanism for turgor maintenance is osmotic adjustment. Osmotic adjustment increased with water deficit, reaching values of -2.40 and -3.24 MPa at predawn and at midday respectively. The maximum osmotic adjustment by active elevation of solute concentration, at full turgor, measured by osmometer was 1.04 MPa compared with 0.4 MPa in apple trees (Lakso et al., 1984) and about 0.5 MPa in cherry rootstock (Ranney et al. 1991). With the pressure-volume (p-v) curves technique we found for the same leaves values of 0.75 MPa of active osmotic adjustment (Dichio et al. 1997).

In addition osmotic adjustment in the roots allows maintenance of cell turgor avoiding or delaying the separation of roots from the soil.

At predawn leaf water potential of -5.2 MPa active osmotic adjustment was 1.7 MPa and 1.4 MPa for roots with diameter higher than 4mm and between 1 and 4 mm respectively. The solutes playing a major role in active adjustment were mannitol and glucose (Fig. 3) while there were no differences among treatments as regards concentrations of potassium, sodium, calcium and magnesium.
3.1 Rewatering

Leaf water potentials the day after rewatering shows differences in values measured predawn and at 7:30 AM between controls and recovering plants. During the rest of the day and particularly during the hottest hours, potentials in rewatering plants were the same as or higher than those in controls (Data not shown). The rapid recovering of tissue water status during the day is partly due to the non-recovery of leaf functionality. Transpiration and photosynthesis were in fact much lower than in controls. This phenomenon lasted several days and proved to be related to the level of stress reached previously (Fig. 4). Persisting deficits in leaf gas exchange were not due to non-recovery of cell turgor but to other factors probably involving the hormonal and biochemical balance, the efficiency of the conducting system and the water absorption capacity of roots. Turgor pressure after rewatering was the same as or higher than in controls above all during the hottest hours of the day (Data not shown).

The lack of recovery of stomatal functionality might not be the main cause of non-recovery of the photosynthetic activity during the first days after rewatering. To the lack of recovery of photosynthesis contributed also the lack of immediate recovery of non-stomatal factors of photosynthesis, particularly of those linked with the functionality of the primary photochemistry associated with photosystem II (Angelopoulous et al. 1996;).

3.2. Plants grown in open field

The trials were carried out for four years after planting ownrooted plants of the cultivar Coratina. During the first year (1992) the whole plot (7,000 m²) was irrigated. From 1993 on irrigation was withheld in part of the plot. The rest of the plants were irrigated when soil potential reached -0.08 MPa. Drought reduced leaf area by approximately 60% but not root growth, consequently the ratio root/canopy increased in non-irrigated trees making for a better defense of the plants to drought conditions (Celano et al. 1997)

Acknowledgments: Research supported by National Research Council of Italy, special Grant R.A.I.S.A., Subproject n. 2

References


Figure 1 Correlation between predawn leaf water potential and (a) transpiration, (b) assimilation, (c) stomatal conductance and (d) internal CO₂.

\[ Y = 8.6498x + 100.79 \]
\[ R^2 = 0.9635 \]

Figure 2. Correlation between predawn leaf water potential and RWC

Figure 3. Concentration of mannitol and glucose in leaves of different treatments.

Figure 4. Transpiration (a) and assimilation (b) in the various treatments during recovery.