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Effect of drought and fire on root development in *Quercus pubescens* Willd. and *Fraxinus ornus* L. seedlings

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Abstract

This paper casts light on the events taking place in the root system when seedlings of two deciduous woody Mediterranean species, *Quercus pubescens* Willd. and *Fraxinus ornus* L., are stressed by drought or fire or both. Stress treatment mimicked the conditions that often occur in natural Mediterranean ecosystems during dry summers. Allocation of resources to the root system is affected as shown by the fact that taproot biomass decreases under stress conditions only in *Fraxinus ornus* whereas lateral roots undergo a decrease in length, dry weight, number of apices in both species. An increase in electrolyte leakage from roots of both species during treatments suggests that morphological variations in the root system are associated with damages occurring in root tissue. All the effects observed are reversible if a critical threshold of stress duration is not reached but recovery starts when the aboveground parts are fully replaced. The alteration of a number of root traits suggests that both drought and fire affect root growth and root turnover. Differences in recovery patterns between the two species are observed and attributed to specific tolerances of the root systems. The knowledge of the events taking place at root level might help to understand better the tolerance mechanism to drought or fire characterizing species living in Mediterranean ecosystems.

Keywords: Drought; Fire; *Fraxinus ornus* L.; *Quercus pubescens* Willd.; Root

1. Introduction

Summer droughts are common in the Mediterranean region and they affect plants differently depending on stress intensity and duration. Summer fires are also frequent in the region and have an enormous impact on vegetation (Naveh, 1975; Trabaud, 1987; Trabaud and Casal, 1989). In addition, Mediterranean vegetation is often affected during a single summer by both drought and fire in sequence or in combination. The ecological implications of drought and fire in the Mediterranean ecosystem have been the object of several studies (references in Zedler et al., 1983; Keeley, 1991; Mazzoleni and Pizzolongo, 1990), but few studies have investigated the combined effects of both stresses on the same plants during the same growing season (Hogenbirk and Wein, 1991; Mazzoleni and Esposito, 1993). Moreover, previous studies focused on adult plants and provided little data on the effect of drought and fire on young seedlings.

It is known that drought inhibits growth (Kramer, 1980) with differences between species, developmental stages, organs and tissues (Plaut, 1995; Senaratua et al., 1995; Torrecillas et al., 1995; Chiatante et al., 1995). At the same time the literature has shown that Mediterranean vegetation is able to tolerate prolonged periods of drought thanks to various phenological and physiological adaptations (Oertli et al., 1990). For example, Mediterranean sclerophylls use physiological control of leaf gas exchange and structural adjustments of leaf area to achieve an appropriate water balance for specific environmental conditions (Tenhunen et al., 1990; Gucci et al., 1997). Phenological and physiological adaptations of roots to water shortage are less clear

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despite data available in literature suggest the occurrence of variation in root extension (Spollen and Sharp, 1991), root growth (Coutts et al., 1999), and distribution of lateral roots (Trewavas, 1986). Moreover, it seems that there is a different sensitivity of root categories to drought with fine roots drying out and dieing more quickly than thick roots (Insley and Buckley, 1985; Balneaves and Menzies, 1988). However, it remains to understand if all the variations observed in the roots might be regarded as elements of the same response mechanism to this stress.

In the case of fire, very little is known about how this stress affects root growth and turnover in Mediterranean vegetation, or how the root responds to a combination of drought and fire.

In this study, we have examined the responses to drought and fire of the root systems of *Quercus pubescens* Willd. (downy oak) and *Fraxinus ornus* L. (manna ash) seedlings, two species that occupy the sub-Mediterranean climate regions (500 m–900 m a.s.l.) of Italy. The seedlings used were grown in pots in the nursery before undergoing a combination of drought and fire treatments. The use of pots enabled us to collect intact root systems, which is important for the comparative analysis of morphological parameters. At the end of treatments we have measured the variation occurring in several root traits such as length, dry weight, number of apices and membrane integrity. The possible level of coordination existing between all these variations to form a single response mechanism is discussed.

2. Materials and methods

One-year-old seedlings of *Fraxinus ornus* L. and *Quercus pubescens* Willd. grown in small pots (diameter: 10 cm) were transplanted in larger pots (22 cm × 22 cm) in autumn 2001 to avoid "impedance" induced by the small containers. The pots were set on a plastic sheet to avoid water capillarity from the bottom, kept in the nursery under transparent plastic covers to protect from rain and used for the experiments during summer 2002. Pots were filled with a 2:1 mixture of clayey loam soil:moist peat and were randomly arranged across treatments.

2.1. Experimental design

The experiment was performed from May to September 2002 (100 days). At the beginning of May a normal watering regime was established for all seedlings, i.e., 300 ml of water every 3 days. Control seedlings received this normal watering regime throughout the study.

2.2. Separate drought and fire treatment

Drought treatment consisted in not watering the plants throughout the experiment which coincides well with the drought summer of the Mediterranean climate. Fifty days after beginning water stress, half the plants were returned to a normal watering regime (these served for the study of recovery rate), and the other half continued drought treatment. Fire treatment consisted of burning straw placed around the stem base until all leaves were burned. Also in this case the fire mimicked closely the intensity of fire that normally affects seedlings of these two species under natural conditions. In both treatments, seedling re-growth was monitored throughout the experiment (100 days). An aliquot of pots from water stress and control treatment was used to measure the water content at three different depths. The value of water content found in the pots at different depth is reported in Table 1 and indicates during water stress treatment the water content decreased progressively with the time despite this fall was different with the depth.

Table 1
The percentage of water content (g/g) in the soil was measured at different depth in the pots

Days	Depth (cm)	Water content (%)	
		Control	Water stress
0	0–7	23.74	–
	7–14	25.97	–
	14–21	28.93	–
50	0–7	22.33	9.65
	7–14	24.97	19.23
	14–21	28.56	27.15
100	0–7	23.86	5.08
	7–14	25.02	8.47
	14–21	28.27	18.53

Each value represent a mean of five replicates which showed very close values.

2.3. Combination of drought and fire treatments

To investigate the effect of combined drought and fire, fire was applied twice. A sub-sample of plants was burned on day 0. Immediately after burning, half of the sub-sample underwent drought treatment until the end of the experiment, and half of these (one-fourth of the total) were returned to a normal watering regime 50 days after beginning water stress (these plants were used to study recovery rate). Another sub-sample was deprived of water and burned on day 50. Then, one half remained without water and half of these (one-fourth of the total) were recovered 25 days later by rewatering. This second sub-sample was used to study how fire affected drought-stressed seedlings.

2.4. Analysis of root parameters

Root traits were measured with a scanner calibrated with the WhinRhizo software package, 3.10 version (Regent Instruments Inc., Quebec, Canada). After excavation, the root systems of five seedlings for each treatment were carefully washed by hand to minimize loss of fine root and scanned. The following parameters were measured: total root length (TRL), total number of root apices (RA). The computerised