Soil Water Availability and Relationship between Canopy and Roots in Young Olive Trees (cv Coratina)

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Abstract

Trials were carried out in the Basilicata region (41°03' N, 15°42' E, Southern Italy) using ownrooted plants of the cultivar Coratina planted in 1992 at distances of 6 x 3 m. During 1992, the whole plot (about 7000 m^2) was irrigated. From 1993 onwards, irrigation was suspended in part of the plot. A representative number of plants during 1992, 1993, 1994 and 1998 was destroyed in order to carry out dry weight measurements on roots and canopy.

The ratio between root and leaf dry weight was always greater in non-irrigated plants compared to irrigated ones.

Roots explored a soil volume ranged from 0.5 m^3 in the first year to 16.8 m^3 in the seventh year for irrigated plants and from 0.5 m^3 to 13.4 m^3 for non-irrigated ones.

The study showed that in deep soil, with a greater capacity for water storage during the rainfall season, limited water supply (220-1350 m^3 ha^{-1}) during the first seven years from planting increased canopy growth by 79% compared to non-irrigated plants, but made little difference to root growth. In non-irrigated plants, canopy growth (but not root growth) was drastically reduced, as a defence strategy against water deficit, making for a better root/leaf ratio and consequently greater water availability for leaves.

INTRODUCTION

The olive tree, being able to grow and produce satisfactorily in environments with water shortage, can be considered a drought-resisting species (Turner, 1979). The mechanisms by which it resists more or less extended drought periods are many, and have already been widely studied (Turner, 1979; Xiloyannis et al.,1999). The different pattern of dry matter distribution between canopy and roots allows the plant to maximise the efficiency of assimilates in water deficit conditions. This work studied the variations in distribution of dry matter between canopy and roots in olive, in relation to soil water availability.

MATERIALS AND METHODS

Trials were carried out in the Basilicata region (41° 03' N, 15° 42' E, Southern Italy) on ownrooted olive plants cv. 'Coratina' planted in 1992 at distances of 6 x 3 m.

The area is characterized as semi-arid, with average annual rainfall of 670 mm concentrated in the October-February period and monthly average temperatures ranging from 5.7 to 24.1 °C (Resina et al., 1990).

Soil is loamy with an available water capacity of 19.7% (on dry weight basis), calculated as the difference between the soil water content at field capacity (-0.03 MPa) and that at permanent wilting point (-2.5 MPa) measured on potted plants (Xiloyannis et al., 1999).

During 1992 the whole plot of approximately 7000 m^2 was irrigated. From 1993 onwards, irrigation was suspended in part of the plot (1370 m^2 for 38 trees). The rest was irrigated using a localized system (microjets discharging 80 l h^{-1} over 1 m radius) when soil water potential, measured using gypsum blocks (Boujoucos) 35 cm deep, reached an average value of – 0.08 MPa. Soil water potentials were measured weekly; the gypsum blocks were installed for three plants per treatment at three positions 60 cm from the trunk and at 35 and 60 cm depths. Fertilisation was carried out as reported by Xiloyannis et al. (2000).

At the end of annual growth in 1992, 1993, 1994 and 1998 two plants per treatment were uprooted by total excavation. In 1992 roots were recovered from the whole volume of soil explored, while in the following years, the total soil volume explored by the roots was divided into 30 cm cubes using the trench method (Böhm, 1979).

Roots were separated from the soil using sieves of 2 and 5 mm mesh. To measure the dry weight of each part, trees were divided into fruits, leaves, shoots, trunk, stump and roots. Leaves and shoots were classified according to age, and roots in relation to diameter (large: $\varnothing > 5$ mm, medium: $\varnothing$ from 1 to 5 mm and fine: $\varnothing < 1$ mm). Length and diameter were measured on all large roots, while for medium roots these parameters were measured on 5 samples per plant in order to draw a regression line between dry weight, volume and length. Total length of fine roots per plant was estimated considering total root dry weight and the linear regression between length and dry weight obtained from 59 samples having dry weights from 0.08 to 1.0 g chosen at random.

The total leaf area per tree was estimated considering the total leaf dry weight per each group of leaves and the linear regression between leaf area and dry weight obtained from 5 samples per age of leaves.

Meteorological parameters were measured from a standard weather station close to the trial field, and monthly ETo was calculated using the Penman-Monteith method.

RESULTS AND DISCUSSION

Over the years of trials the ETo values were very similar, while amount and distribution of rainfall determined different levels of water deficit (Table 1). Soil water potential in the upper 60 cm of the non-irrigated treatment reached a minimum value of -1.8 MPa for a short period.

Lower water availability determined a greater reduction of growth in the above-ground organs than in the underground organs (roots and stump). At the seventh year after planting the under/above-ground ratio in non-irrigated trees was 0.81 in comparison to 0.72 in irrigated ones (Table 2). This reduction involved all the epigean organs but was particularly marked in leaf area which at the seventh year was 47% lower in non-irrigated plants.

The volume of soil explored by roots and root length in non-irrigated plants were always lower, while root density remained similar in the two treatments (Table 3). At the seventh year, the volume of soil explored by roots and root length were respectively 20% and 34% smaller in non-irrigated trees, whose root system was deeper (up to 150 cm) but less-developed in the upper soil layers (data not shown) compared to irrigated ones. These results highlight the positive effect of water availability on the growth of both canopy and roots, and also the ability of olive trees to explore even the deeper soil layers when grown in water deficit conditions.

For a better understanding of olive tree defence mechanisms against limited water availability, root dry weight/leaf area ratio, volume of explored soil/leaf area ratio and water supply/leaf area were also taken into account (Table 4). Non-irrigated trees showed higher values in these ratios, and therefore had greater water availability per unit of leaf area, to the extent of an average 28% over the trial period.

The greater decrease in canopy growth compared to root growth in water deficit conditions is a mechanism which improves water availability per unit of leaf area, enabling plants to resist long water deficit periods while keeping the leaves photosynthetically active. This is particularly important in olive as this species is able to absorb water from the soil having up to –2.5 MPa potentials (Xiloyannis et al., 1999).

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Tables

Table 1. Irrigation volumes, evapotranspiration and rainfall during the period April-October over the years of trials

	1992	1993	1994	1995	1996	1997	1998
Irrigation (mm)	48	92	62	22	103	128	135
ETo (mm)	1401	1362	1435	1323	1312	1340	1459
Rainfall (mm)	222	132	191	359	170	287	146

Table 2. Dry matter (g p^{-1}) partitioning between above- and underground (stump and roots) tree parts in irrigated (I) and non-irrigated (NI) trees

Treatment	Part of the tree	1992	1993	1994	1998
Irrigated (I)	Above-ground	440	1668	4382	34044
	Underground	123	534	1479	24646
	Under/above-ground ratio	0.28	0.32	0.34	0.72
Non-irrigated (NI)	Above-ground		982	2714	19024
	Underground		444	1235	15411
	Under/above-ground ratio		0.45	0.50	0.81

Table 3. Root length, soil volume explored by roots and root density in irrigated and non-irrigated plants

YEAR	Explored volume ($m^3\ p^{-1}$)		Root length ($m\ p^{-1}$)		Root density ($cm\ cm^{-3}$)	
	I	NI	I	NI	I	NI
1992	0.5		193.4		0.039	
1993	2.9	2.3	528.0	511.0	0.018	0.022
1994	8.6	5.1	1263.5	806.0	0.015	0.016
1998	16.8	13.4	3739.7	2477.1	0.022	0.018

Table 4. Leaf area and ratios to other parameters in the two treatments

		1992	1993	1994	1998
Leaf area ($m^2\ p^{-1}$)	I	0.6	2.0	6.1	28.2
	NI		1.2	3.8	14.9
Dry weight of roots / leaf area ($mg\ cm^{-2}$)	I	15.2	16.3	11.8	50.1
	NI		27.4	20.1	60.2
Soil volume explored by roots / leaf area ($m^3\ m^{-2}$)	I	0.83	1.53	1.41	0.60
	NI		2.09	1.54	0.90
Water available / leaf area ($l\ m^{-2}$)	I	262.7	481.1	442.9	188.0
	NI		659.1	485.7	284.4