EFFECT OF WATER AND NUTRIENT SUPPLY ON ROOT DISTRIBUTION
IN AN *EUCALYPTUS GLOBULUS* PLANTATION

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Abstract. Water and nutrients were supplied to an *Eucalyptus globulus* plantation in a controlled experiment in west central Portugal. The trees were planted in a sandy soil at a spacing of 3 x 3 m. The experiment consisted of four treatments: irrigation, irrigation plus fertilization, fertilization without irrigation, and a rain fed and unfertilized control. The quantification of root biomass was carried out 13 mo after planting. When the plantation was 31 mo old, a trench was dug in the soil to uncover the distribution of the roots of individual trees. In the irrigated treatments root biomass was higher than in the control and in the fertilized plots. Differences in fine and coarse root distribution along the soil profile were also observed. In both irrigated treatments roots were concentrated along tree rows, where the irrigation tubes were dripping water or water plus nutrients.

1. Introduction

Eucalyptus globulus Labill has been widely planted for pulpwood production in Portugal. The aboveground net primary productivity can reach 24 to 30 t ha⁻¹ yr⁻¹ at 10 yr in unfertilized plantations in central Portugal (Fabião, 1986). However, the productivity can be strongly influenced by soil water and nutrient availability (Cromer *et al.*, 1975, 1981; Cromer and Williams, 1982; Pereira *et al.*, 1989).

Most of the research on *E. globulus* in Portugal has focused on the growth of the aboveground parts. Few studies on root development were done. However, Fabião *et al.* (1985, 1987) studied root biomass and root growth dynamics in unfertilized plantations and stated that root biomass and its distribution in the soil profile could be related to physical properties of the soil and to soil water content (Fabião *et al.*, 1987).

The mechanisms that control the process of root growth in forests are not completely understood (Ahlström *et al.*, 1988; Deans, 1979; Fogel, 1983; Persson, 1980, 1983; Santantonio, 1989; Santantonio and Grace, 1987; Yin *et al.*, 1989). The objective of this paper is to present preliminary results of an experiment relating to root biomass and its distribution in the soil with water and nutrient availability in an *E. globulus* plantation.

2. Methods and Materials

The field experiment was carried out in an *E. globulus* plantation near Obidos, west central Portugal (lat. 39°20'N; long. 9°25'W). The annual mean temperature and precipitation are, respectively, 15.2°C and 607.2 mm at Caldas da Rainha, 12 km from the site. The dry season is from June to

September and averages less than 10% of the annual precipitation. The soils are Spodosols (FAO/UNESCO classification system), mostly sandy and with a low clay content (< 4%) throughout the profile. Exchangeable bases, organic matter and available P occur in low to very low concentration in the upper 90 cm of the soil profile. A uniform pH of 6 (in water) was measured through the soil depth (Pereira *et al.*, 1989).

The stand was planted at 3 x 3 m spacing in March 1986. The experiment consists of 2 blocks, each including 4 treatments: irrigation, irrigation plus fertilization, fertilization alone and a rain fed and unfertilized control. In both irrigation treatments water was supplied daily from April to October by drip irrigation in amounts estimated to maintain at least 80% of the field capacity. A complex nutrient solution was supplied weekly in the irrigation plus fertilization treatment. Higher amounts of nutrients were supplied in summer than in spring and autumn trying to match relative growth rates of the plants. In the only fertilized plots, nutrients were supplied twice per year. The amounts of N, K and P supplied in 1987 totaled 160, 123 and 51 kg ha⁻¹, respectively in the irrigated plus fertilized plots and 160, 141 and 51 kg ha⁻¹ in the only fertilized plots. Adequate amounts of micronutrients were also supplied (Pereira *et al.*, 1989).

The quantification of root biomass was done 13 mo after planting by excavation. Three trees in each plot (six per treatment) were cut and vertical monoliths (0.5 x 0.5 m) centered in the tree trunk were excavated up to a depth of 60 cm. Each monolith was divided into depth strata 10 cm thick, were cut horizontally and sifted sequentially through 2 mm and 1 mm mesh sieves. Laboratory procedures included dry cleaning, sorting of roots by diameter classes, oven drying at 85°C and weighting.

A study on root distribution in the soil started 31 mo after planting in block 2. One tree from each treatment was cut and a trench was dug to observe and describe root distribution between tree rows and between successive trees in a row. Iron poles were thrust horizontally in the soil walls to keep roots in their natural position as the soil particles were removed with a water jet. The exposed roots were then painted with a fluorescent yellow paint and photographed to show differences in root distribution in the soil.

3. Results

Total root biomass up to a depth of 60 cm averaged 4.4 kg m⁻² in the irrigation plus fertilization plots, 3.9 kg m⁻² in the irrigated plots and only 2.5 kg m⁻² both in the control and in the only fertilized plots. Fine root biomass (diameter ≤ 2 mm) averaged, respectively, 1.0, 0.9, 0.8 and 0.6 kg m⁻². Approximately 75% of fine root biomass was concentrated in the upper 30 cm soil layer in the control and in the solid fertilized plots. Such proportion was less in both irrigated treatments, attaining only 61% in the irrigated plots and 53% in the irrigation and fertilization treatment (Figure 1).

The study on root distribution showed that in the irrigated and in the irrigated-fertilized plots roots were concentrated along tree rows, where the dripping tubes were. In the space between rows roots were less abundant and belong mainly to the intermediate diameter classes (Figure 2). The control and the fertilized plots showed a more uniform horizontal root distribution.

Figure 1. Standing crop of different diameter classes of roots at different soil layers 13 mo after plantation. The results are not corrected for contamination with soil particles after dry sieving (Madeira *et al.* unpublished).

Figure 2. Exposed root systems showing the natural distribution of the main woody roots (most of the fine non-woody roots were damaged during excavation with water under pressure). From left to right and from top to bottom: control, fertilized plot, irrigated plot and irrigated plus fertilized plot.

4. Discussion and Conclusions

Root biomass responded positively to an increased availability of water and nutrients in the irrigated and in the irrigated-fertilized plots, when compared with the control. These results seem to be well-related with aboveground biomass found by Pereira *et al.* (1989) at the end of the first year in the same experiment: the standing biomass on a tree basis in the irrigated and in the irrigated-fertilized treatments were almost twice and more than 2.5 times as large as in the control, respectively. Although a clear positive response of the aboveground biomass to fertilization alone was reported, such response was not apparent in root biomass.

Increase in fine root biomass due to fertilization and irrigation was observed by Ahlström *et al.* (1988) and Persson (1980) in Scots pine stands in Sweden. Ericsson and Persson (1980) and Persson (1980, 1983) reported changes in fine root growth strategy related to the availability and location of moisture and nutrients along the soil profile.

In our experiment, a positive response of fine root biomass to treatments was not clear. However, the concentration of fine root biomass in the top soil in the non-irrigated treatments, when compared with those irrigated, agrees with some of the assumptions above. In addition, fine roots were more abundant along tree rows in both irrigated treatments, mainly in the soil volume influenced by the dripping tubes, where higher concentration of water or water plus nutrients occurred (Madeira *et al.*, unpublished).

Due to the coarse texture of the soil, water and nutrients tend to be spread vertically in a strip along tree rows in those plots with irrigation tubes. Thus an opportunistic root growth strategy, taking advantage of a deeper soil volume with optimum conditions for root development, should be expected. It may influence the capacity of the individual trees to survive and has implications to forest management, since tree fall caused by wind during winter storms is possible when the root system is not regularly developed, either on a horizontal or a vertical basis.

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