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Tillage induced differential morphometric responses and growth patterns in afforestation with *Quercus ilex*

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Abstract

This study describes the changes in height and diameter in *Quercus ilex* trees grown on agricultural land in a semi-arid Mediterranean climate, in response to different soil management practices: mechanical weeding (MW), chemical weeding (CHW) and no treatment (NT); and compares trees grown from 1-year-old saplings and from acorns. After 6 years, trees that had been mechanically weeded were largest; for trees grown from saplings the average height was 120 cm and diameter was 3.83 cm, for trees grown from acorns average height was 100 cm and diameter was 2.56 cm. Soil organic matter increased in all managed plots while phosphorus, nitrate, and water content oscillated between years. The no treatment plot had the highest values for nitrate and organic matter while the chemical weeding plot had the highest level of phosphorus. Annual mean on C/N ratios were higher in the mechanical weeding (12.6 ± 3.3) followed by the chemical weeding (12.0 ± 1.6). Also mechanical weeding treatment showed the lowest soil water content throughout the study. An old tillage-induced compaction zone appeared in all plots at a depth of 12.5–17.5 cm with mechanical weeding causing the greatest compaction. However, no relationships were found with tree heights, neither with spatial compaction zoning. All trees showed the same growth pattern, whether raised from saplings or acorns and irrespective of soil management system. The height and diameter of trees were linked to the sum of height and diameter ratios from previous years. Our study shows that soil management does influence tree growth rate. Mechanical weeding should be considered for afforestation of agricultural lands with *Q. ilex* in semiarid Mediterranean lands.

Keywords: Soil management; Afforestation; Land use change; Height; Diameter; Growth patterns; *Quercus ilex*

1. Introduction

Several studies have been carried out to determine the limiting factors (e.g., light, water and nutrients) for production in Mediterranean mature forest ecosystems (Comin et al., 1987; Zhang and Romane, 1988, 1991;

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McCarthy and Dawson, 1990; Nambiar, 1990; Gholz et al., 1990; Cartan-Son et al., 1992; Ducrey and Toch, 1992; Mayor and Rodá, 1992; Sabaté et al., 1992; Ocaña et al., 1997; Porporato et al., 2001). Studies that have assessed changes in morphometric variables were mainly concerned with the influence of climatic conditions, fertilizer and artificial irrigation on the diameter of established holm oaks (*Quercus ilex*) (Savé et al., 1988; Raison and Myers, 1992; Sabaté et al., 1992; Rasmussen et al., 1993; Mayor et al., 1994). However, few investigations have evaluated the effects of soil management on tree height and trunk diameter changes over the first few years of growth (Baeza et al., 1991; Rey, 1998).

In Mediterranean semi-arid systems, availability of water and nutrients (especially N and P) have been thought of as factors limiting growth of holm oaks (Zhang and Romane, 1988, 1991; Mayor and Rodá, 1992; Mayor et al., 1994). The use of soil water and nutrients by holm oaks is poorly understood, and information on their minimum requirements is scant. This information is required if the optimum geographical distribution, establishment and growth of these trees in afforestation projects is to be achieved (Terradas and Save, 1992). Not much is known about the effects of the temporal distribution of rainfall during the first few years of growth either (Zhang and Romane, 1988, 1991; Mayor and Rodá, 1992; Mayor et al., 1994). Fenner (1987) maintains that the survival and growth of plants depend only on their physiological and morphological characteristics. However, it is well known that environmental conditions can modify growth dynamics, although its importance is not known.

Some reports highlight the importance of soil management and edaphoclimatic conditions in the success of afforestation projects, whether on abandoned agricultural land, in mountainous areas or on marginal land (Capelli, 1966; Baeza et al., 1991; Berengena-Herrera, 1997; Navarro-Cerrillo et al., 1997). However, these authors do not report the influence of soil management neither the effects of external variables. In the European Union, an alternative to abandon low-productive agricultural land is afforestation with native species (e.g., with holm oak in the semi-arid regions of the Mediterranean). Unfortunately, the uncertainty surrounding the factors mentioned above has meant these projects have not always been successful. Further research is required if we are to understand the factors affecting tree growth and establish viable afforestation methods.

This study examines the effect of soil management alone on tree growth, as it affects the plant's ability to utilize existing soil resources. Different types of soil management were imposed and growth variables (height, diameter and height/diameter) were compared to investigate growth patterns during the early years of development.

2. Materials and methods

2.1. Study area

All assays were performed at "La Higueruela" research station in the province of Toledo, central Spain (40°3′N, 4°26′W). The climate here is semi-arid continental Mediterranean, with mean temperatures varying from 5 °C in winter to 25 °C in summer (Oliver et al., 1985). The mean annual precipitation over the last 50 years is 480 mm; 471 mm fell during the study period. Phytoclimatically, the area falls within the Mesomediterranean dry ombroclimate, and the potential vegetation corresponds to terminal associations of the siliceous Mesomediterranean Luso-Extremaduran holm oak series (Rivas Martínez, 1987). Following FAO (1998) the soil in the plots is a Calcic Luvisol (i.e., Alfisol–Calcic rhodoxeralf as in SSS (1998)). In the experimental area, the soil texture is sandy loam (4% clay, 20% silt and 76% sand) and the mean bulk density of top soil (0–30 cm) is 1.5 ± 0.10 g cm^{-3} (Sánchez-Andrés, 2002).

The agricultural systems in the area are typical of the rain-fed systems found in semi-arid Mediterranean areas. As suggested by De Juan (1995) and Cunningham et al. (1999) the climatic conditions are within the limits for attempting a change from agricultural use to afforestation with holm oaks (*Q. ilex* sp. *ballota* [Desf.] Samp.; Castroviejo et al., 1990). Over the last 30 years, the chosen plot had been used for dry-farming wheat cultivation.

2.2. Experimental design

A three parallel block experimental design (no repetitions) was chosen, given the characteristics of