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Survival and early growth of mixed forest stands installed in a Mediterranean Region: Effects of site preparation intensity

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ABSTRACT

In Mediterranean environments, availability of water and nutrients are the main factors limiting the success of afforestation. As part of a wider project, an experiment was established in Northeast Portugal, aiming at testing the effect of several site preparation techniques on plant survival and growth (height and diameter) in a newly installed mixed forest stand. Results presented regard plant response during 42 months after plantation. The experimental protocol consisted in seven treatments described by mechanical operations that rank soil disturbance intensity from none to high, set in plots of 375 m^2, randomly distributed in three blocks, in different topographic positions (gentle slope plateau, moderate slope shoulder, and steep mid-slope). *Pseudotsuga menziesii* (*PM*) and *Castanea sativa* (*CS*) forest species were planted in a 4 m × 2 m scheme and in alternate rows with 12 plants on each row per plot, summing up 72 plant per specie and treatment at start of the experiment. The results show that: (i) the highest mortality was observed immediately after the plantation and before the dry season, on the lowest intensity treatments; (ii) after the dry season, the highest mortality was also observed in treatments with the lowest intensity of soil disturbance, while the lowest values were found on the intermediate intensity treatments; (iii) during the experimental period, the effect of treatments on plant growth (height and diameter) was statistically significant; however, experimental results do not lead yet to a clear quantitative relationship between soil disturbance intensity due to site preparation and plant response under the conditions tested.

1. Introduction

In Mediterranean environments, availability of water and nutrients are the main factors limiting the success of afforestation (Daget, 1977; Rey, 1998; Ojasvi et al., 1999; Bocio et al., 2004). Afforestation programmes in Portugal have to take into account these soil and climatic constraints, as Mediterranean climate prevails in most of the territory (Ribeiro, 1986; Costa et al., 1998). In Portugal the success and productivity of most forest plantations is limited by poor soil conditions, namely a low root support capacity, which has negative effects on the amount of available water and nutrients. Soil preparation operations are therefore required before planting, using more or less intense tillage in order to increase soil depth, as well as water and nutrient availability, and, so, improving soil conditions for plant growth (Worrell and Hampson, 1997; Fisher and Binkley, 2000; Querejeta et al., 2001).

Several studies have been made on the effect of surface soil tillage using scarification and herbicide application for weeds and shrub control and improving root depth (McLaughlin et al., 2000; Archibold et al., 2000; Burgess and Wetzel, 2000; Wetzel and Burgess, 2001). However, there are only few references on the effect of deep tillage on soil properties and plant response (Fernandes and Fernandes, 1998; Fisher and Binkley, 2000; Querejeta et al., 2001; Martins and Pinto, 2004; Carlson et al., 2006). New studies are therefore necessary to improve our knowledge and to support decisions on best operation selection according to site conditions. The wide diversity of mechanical site preparation techniques that may be applied emphasizes the need for studies on newly installed forest stands, especially in areas where information is still limited, as it is particularly the case of the Mediterranean Region (Varelides and Kritikos, 1995). Furthermore, most studies are performed in adult stands, and so the installation phase is less understood, often lacking important components of the initial dynamics of these systems (Canham, 1989; Lieberman et al., 1989).

This paper aims at presenting and discussing data collected 42 months after plantation in an experiment carried out to study mortality and growth (height and diameter) of a mixed stand of

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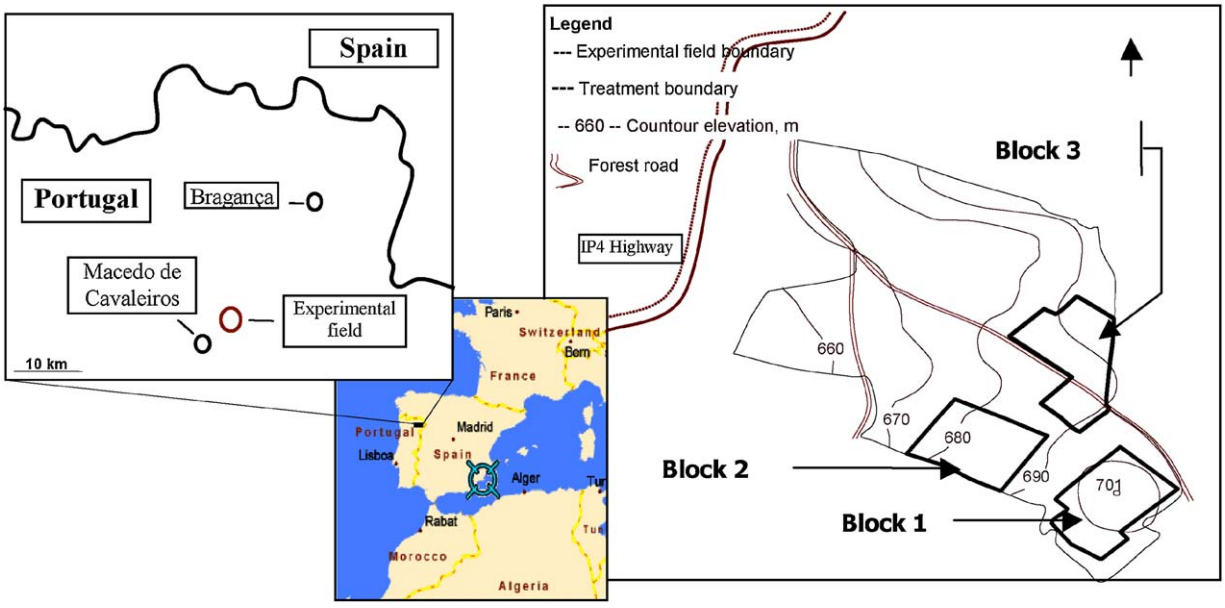

Fig. 1. Study area location.

Pseudotsuga menziesii and *Castanea sativa*, as affected by different mechanical operations performed for soil preparation.

2. Materials and methods

The experimental field was established near the municipality of Macedo de Cavaleiros, Northeast Portugal, at 41°35′N and 6°57′W, local altitude ranging from 660 to 701 m (Fig. 1). Climate is Mediterranean, with 12 °C mean annual temperature and 678 mm mean annual rainfall at Macedo de Cavaleiros (INMG, 1991). During the experimental period, annual rainfall was 665 mm, monthly distributed according to Fig. 2, averages being computed from data recorded by an automatic rain gauge installed in the experimental site.

The experimental design consisted of six treatments representing different intensities of soil disturbance by mechanical operations for site preparation, randomly distributed on each one of three blocks, which cover the range of soil and topographic conditions commonly found in afforested areas in NE Portugal (Agroconsultores and Coba, 1991), described as follows: Block 1 on a gentle slope plateau (6% slope gradient), over sedimentary parent material Dystric Cambisols; Block 2 on a moderate slope shoulder (12%); and Block 3 on a steep slope (22%). Blocks 2 and 3 were installed in neighbouring west facing hillslopes, over schists, Dystric Leptosols (FAO/UNESCO, 1987; Agroconsultores and Coba, 1991). The treatments, described in Table 1, ranked from lowest (SMPC) to highest (RCLC) soil disturbance, induced by different soil preparation operations. Table 1 includes also a treatment without disturbance (TSMO), which corresponds to the original soil and is taken as a reference for comparison with the remainder treatments in what concerns the tillage effects on soil properties. Soil characteristics of experimental area prior to experiment installation (represented by TSMO, Table 1) were determined in previous work by the first author (Fonseca, 2005). Accordingly, soil texture varied between loam and sandy loam (63–73% sand, 15–24% silt, 9–13% clay), effective soil depth between 50 and 55 cm, bulk density (0–15 cm) between 1.4 and 1.5, organic carbon between 14 and 33 g kg^{-1}, total nitrogen between 0.7 and 1.1 g kg^{-1}, sum of exchangeable bases between 1.3 and 2.1 $cmol_c$ kg^{-1} and pH (H_2O) between 5.0 and 5.2.

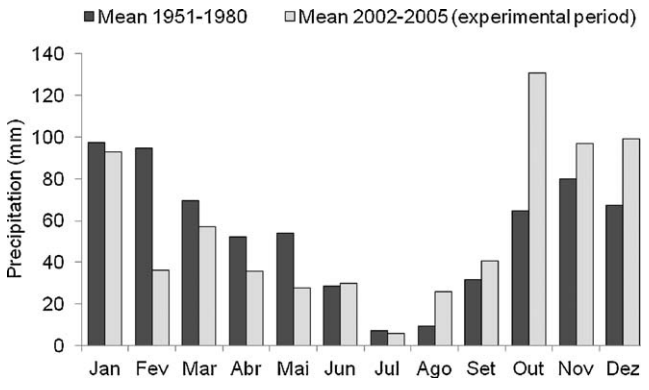

Fig. 2. Monthly average precipitation during the experimental period (2002–2005) and long term means (1951–1980).

Plots 25 m × 15 m in size (wider in contour) were taken as the experimental units in this study. A total of 21 plots were installed in the experimental field, accounting for 6 treatments plus one non planted reference in 3 blocks. The plots were separated by wide buffer belts of 3 m. The species selected were *P. menziesii* (*PM*) and *C. sativa* (*CS*), planted in alternate contour rows, in a 4 m × 2 m scheme (rows × plants in rows), each plot summing up two rows per specie, 12 plants per row in a total of 24 plants per species, and each treatment including 72 plants per species at the experiment start. The plantation was made by hand, in February 2002, using nursery seedlings, containerized in the case of *PM* and bareroot in the case of *CS*.

For the evaluation of plant response, mortality was quantified according to the percentage of dead plants in the total in each treatment, at plantation, and in May (before the dry season, bds) and in September (after the dry season, ads) of 2002, 2003, 2004 and 2005. Plant growth was quantified as height and diameter at ground level, measured on all plants of each plot, at plantation, and after 12, 24, 27, 30, 36, 39 and 42 months, corresponding to four growing seasons. In the third and fourth growing season measurements were performed to further assess spring growth (24–27 and 36–39 month periods) and summer growth (27–30 and 39–42 months). SMPC and RCAV treatments were excluded from these measurements, because most of the plants died after plantation. As