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Pine plantation bands limit seedling recruitment of a perennial grass under semiarid conditions

J.A. Navarro-Cano*, G.G. Barberá, A. Ruiz-Navarro, V.M. Castillo

Department of Soil and Water Conservation, CEBAS-CSIC, PO BOX 164, Campus Universitario de Espinardo, E-30100, Espinardo, Murcia, Spain

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ABSTRACT

Pine plantations coexist with *Stipa tenacissima* grasslands in many semiarid western Mediterranean areas. We compared three microsites created by a 30-year-old *Pinus halepensis* plantation: below pine plantation line (BP), below canopy of pines (BC) and interline bare band (BA). They were evaluated in terms of soil properties, pine litter and suitability as recruitment niches for *S. tenacissima*. Next, in a manipulative experiment in growth chambers we tested the hypothesis that pine litter interferes with the seedling emergence of *S. tenacissima*. Three treatments in pots were compared: (a) soil from BA; (b) intact soil + litter from BP; and (c) soil + litter from BP, which was mixed in the laboratory (BPMX). In the field the main microsite differences were pine cover and litter cover and thickness. Seedling emergence was significantly greater in BA than in BP. Emergence and litter depth fits a linear regression model. In the growth chamber litter did not interfere with the emergence of *S. tenacissima*. However, seedlings grown without litter were 28% longer and their mass was 27% greater than in the litter treatments. The detected pine litter interference may be relevant for plant dynamics and might be considered in forestry management programs.

1. Introduction

Pinus halepensis Mill. formations occupy 2.5 million hectares in the western Mediterranean and are almost the only native forest landscape in many semiarid areas of the Mediterranean Basin (Quézel, 2000). Nevertheless, *P. halepensis* forests have massively extended their cover area in the last century favored by human-induced changes to fire regimes, rural exodus and abandonment of marginal agricultural lands (Richardson et al., 2007). Furthermore, *P. halepensis* is considered an invader in Australia, Israel, New Zealand and South Africa (Richardson and Rejmánek, 2004). In the Iberian Peninsula the predominance of this pine is due to the intense plantation activity carried out during the period 1940–1984 (over 495,000 ha). The extensive use of this species was based on its easy and cheap nursery production, its relatively fast growth and high resistance to environmental stress, as well as its supposed ability to promote plant succession in degraded areas (Ruiz de la Torre, 1973; Quézel, 2000). However, the effects of these plantations on pedogenesis and plant dynamics have rarely been evaluated (see e.g. Castillo et al., 2001; Goberna et al., 2007; Maestre and Cortina, 2004).

Studies on the capacity of *P. halepensis* plantations to improve soil properties and promote plant dynamics show different results (see Goberna et al., 2007; Maestre and Cortina, 2004). Otherwise, incident light and water availability reduction caused by the pine canopy is well documented (Belmonte et al., 1998; Maestre, 2002; Maestre et al., 2003). Both water and light interception by the canopy of *P. halepensis* have been suggested as main controlling factors of seedling emergence and performance (García-Fayos and Gasque, 2006; Gasque and García-Fayos, 2004; Izhaki et al., 2000). Likewise, below-ground competition between introduced saplings and herbaceous understorey facilitated by *P. halepensis* has been detected (Maestre et al., 2004). The factors described above are considered responsible for an overall negative effect of *P. halepensis* plantations on spontaneous vegetation recovery and plant dynamics (Maestre and Cortina, 2004). However, due to low litter decomposition rates (García-Plé et al., 1995; García-Pausas et al., 2004; Gholz et al., 2000), Mediterranean pine forests are prone to accumulate relatively thick needle layers below their canopies (Boydak, 2004; Izhaki et al., 2000) but this factor has rarely been related to the slow plant dynamics in these environments (Izhaki et al., 2000).

Germination and seedling establishment are the most critical stages for plant population dynamics (Harper, 1977; Kitajima and Fenner, 2000). Both can be positively or negatively affected by litter

* Corresponding author. Institute of Botany, University of Innsbruck, Sternwartestrasse 15, 6020 Innsbruck, Austria. Tel.: +43 5125075906; fax: +43 5125072715.
E-mail addresses: jose.navarro@uibk.ac.at (J.A. Navarro-Cano), gbarbera@cebas.csic.es (G.G. Barberá), rn012@cebas.csic.es (A. Ruiz-Navarro), victor@cebas.csic.es (V.M. Castillo).

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depending on environmental and species-specific factors (Facelli et al., 1999; Rice, 1979). In this way, changes in both light regime and soil temperature such as physical obstruction and allelopathy may affect the seedling stage, which has consequences for plant dynamics (Facelli and Pickett, 1991; Herr and Duchesne, 1996; Kitajima and Fenner, 2000). In the literature, contradictory results have been reported as regards the allelopathic effect of *P. halepensis* litter (Fernández et al., 2006; Maestre et al., 2004). On the other hand, a light control of pine litter on seedling emergence has been suggested by using vermiculite cover but a mechanical effect of needle layer cannot be ruled out (Izhaki et al., 2000).

Stipa tenacissima L. is a perennial grass that forms extensive grasslands in semiarid and arid areas over the western Mediterranean region. *S. tenacissima* grasslands evolve into pinewoods when they are protected from cutting, burning and overstocking (Le Houérou, 2001). Open woodlands of *P. halepensis* with an understorey dominated by *S. tenacissima* are common in Mediterranean semiarid areas and understanding the relationships between both dominant species is important for future forest management (Gasque and García-Fayos, 2004).

Our aims were to distinguish between the effects of soil properties, pine canopy and litter layer on the seedling emergence of *S. tenacissima*. We report the results of two experiments: (i) we compare existing microsites created by a *P. halepensis* plantation and then evaluate their suitability as recruitment niches for *S. tenacissima* by using seed sowing at microsite level; (ii) by means of a manipulative growth chamber experiment we test the hypothesis that pine litter layer interferes with the seedling emergence and fitness of *S. tenacissima*.

2. Methods

2.1. Field experiment

The field study was carried out in a 100 × 200 m stand in the Cárcavo catchment, Murcia, SE Spain (38°12′16″N, 1°31′43″W). The stand, on soils developed from marls, is at an average height of 299 m a.s.l. on a north-facing footslope with a slope gradient of 2–5°. Until its reforestation using subsoiling in 1975, the plot was a dryland cereal field. The density of pines was 1000 pines ha^{-1} in 2005, with a median height of 3.5 m. This kind of system was chosen because previous vegetation was absent and the seedbank depleted, creating an excellent scenario for testing whether *P. halepensis* reforestations promote or hamper understorey colonization.

The climate is semiarid Mediterranean; the annual average temperature and average rainfall are 16.5 °C and 298 mm, respectively (1966–2000; Spanish Agency of Meteorology).

Evergreen sclerophillous shrubland (maquis) of *Pistacia lentiscus* L., *Rhamnus lycioides* L. and *Quercus coccifera* L. is the potential vegetation of the study area. The vegetation of the catchment is actually dominated by *S. tenacissima* grassland communities and *P. halepensis* plantations (Castillo et al., 2001). Other relevant species are the shrubs *Rosmarinus officinalis* L., *Anthylllis cytisoides* L. and dwarf shrubs including *Fumana thymifolia* (L.) Spach ex Webb and *Thymus zygis* L. subsp. *gracilis* (Boiss.) R. Morales.

2.2. Soil properties, plant cover and litter

P. halepensis reforestations show a maximum tree cover close to the plantation line and a minimum at the mid point between plantation lines. This is reflected by the concomitant variations in litter layer thickness and cover. We implemented a field experiment with three adjacent microsites reflecting this gradient: (i) beneath *Pinus* plantation line, in a 50-cm radius around the pine trunk (BP); (ii) below pine canopy, between the edge of BP and the canopy edge (BC); iii) the interline bare band between the tree canopies (BA) (Fig. 1). Eight plots (2 × 5 m) were established in early January 2004. Each plot was divided into three microsites, as already described. One soil sample (10 × 10 × 10 cm) per microsite and plot was collected and the following variables were analyzed: total organic carbon (TOC), total N (TN), available P, available Na, available K, electrical conductivity (EC) and pH (Page et al., 1982). The available water content (AWC) was estimated by the Richards pressure membrane method (Richards, 1947). The percentage of surface coarse rocky fragments, pine and plant cover, pine litter cover and thickness, and biological soil crust cover were measured in a 20 × 25-cm rectangle at each microsite.

2.3. Seedling emergence in the field

Diaspores (referred to here as “seed”) of *S. tenacissima* each consisting of a lemma with a long awn, a palea and the caryopsis were collected on 20/05/04 10 km NE of the experimental area. They were stored in paper envelopes at laboratory temperature until field sowing on 11/03/05. One white strip (25 × 0.5 cm each) per plot and microsite was placed on the ground and, parallel to each strip, 25 seeds were sown without the awn at regular intervals. Each seed was pushed into the needle bed in BP and BC (Fig. 1), and into the soil in BA. We previously checked the soil seed bank to be sure that there were no seeds of *S. tenacissima* (Navarro-Cano, 2007). The plots were not irrigated during the experiment. Seedling emergence was recorded every 7 days until November 2005.

2.4. Seedling emergence and growing in the growth chamber

We randomly chose five of the eight plots and then took samples in two of the three microsites: one homogenized sample (50 × 50 × 10 cm) per plot was collected in the BA microsite on 02/06/05; five unaltered adjacent BP samples (10 × 10 × 10 cm) per plot were collected; finally, five adjacent BP samples (10 × 10 × 10 cm) per plot were collected, and the soil and pine litter layer were mixed in the laboratory (BPMX). Samples were stored at 5 °C until sowing. Sowing was carried out on 10/06/05. Five pots with 25 seeds each were set. To separate the physical effect of litter from its allelopathic effects we manipulated the litter layout in the soil. The seeds were sown in 15 pots (10 × 10 × 12 cm) on three types of substrate: (i) BA, containing the soil of the BA

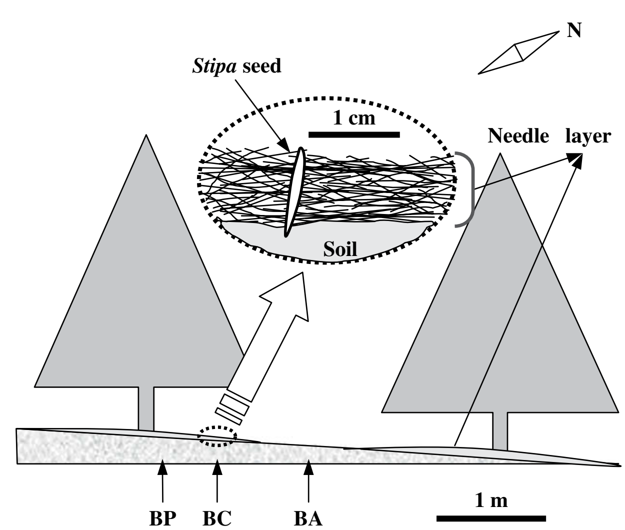

Fig. 1. Position of the experimental sowing microsites in relation to plantation lines in the Plantation. BP, beneath *Pinus* plantation line; BC, below crown canopy; BA, interline bare band. Enlarged image is a detail of the position of a *Stipa* seed sowed in BC microsite.