Ecological Engineering 82 (2015) 349–354

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Differences in the facilitative ability of two Mediterranean shrubs on holm-oak seedling recruitment in Mediterranean savanna-forest ecosystems

María José Leiva, Juan Manuel Mancilla-Leyton*, Ángel Martín Vicente

Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, Apartado de Correos 1095, 41080 Sevilla, Spain

ARTICLE INFO

Article history:
Received 10 December 2014
Received in revised form 15 April 2015
Accepted 23 May 2015
Available online 5 June 2015

Keywords:
Quercus
Mediterranean shrubs
Leaf phenology
Photosynthetic photon flux density
Rock roses
Myrtus

ABSTRACT

This paper analyses the nurse effect of *Cistus salvifolius* and *Myrtus communis* on holm-oak seedling recruitment in Mediterranean savanna-like ecosystems. Changes in microenvironmental conditions beneath the shrubs canopies, leaf phenology and nurse effect of the two shrubs on holm-oak seedlings emergence and survival in the field were studied. *C. salvifolious* exhibited a null effect on holm-oak seedlings recruitment in the field, showed a high seasonal variability in leaf area (52% decrease during summer), and high variability in photosynthetic photon flux density (PPF) beneath the understory. By contrast, *M. communis* exhibited the opposite characteristics: had a positive effect on holm-oak seedlings recruitment in the field and showed big changes on air temperature and PPF beneath the understory (94% reduction), small seasonal variability in leaf area, and small variability in PPF beneath the understory. It is discussed that grazing abandonment that leads to the expansion of *C. salvifolus* and other early succesional chamephites does not guarantee sexual self-regeneration of holm-oaks in dehesas. Strategies to enhance late-successional evergreen and some different potentially occurring, pioneer shrub species that facilitate holm-oak seedling recruitment should be taken into account.

1. Introduction

Facilitative interactions among plants are broadly documented in many plant communities (Connell and Slatyer, 1977; Brooker et al., 2008). Among them, protection against herbivory (e.g., Pulido and Díaz, 2005; Smit et al., 2008, 2009) and enhance seedling survival through amelioration of environmental stress have been frequently studied. Under dry conditions, the negative effect of light reduction below the canopy of a nurse plant would be compensated by the improvement of plant water status for the target species, resulting in net facilitation (Bertness and Callaway, 1994; Callaway et al., 1997; Holmgren et al., 1997). In Mediterranean and other seasonally dry environments, where severe drought causes high early seedling mortality (Di Castri et al., 1981; Herrera et al., 1994; Pausas et al., 2004; Rodríguez-Calcerrada et al., 2010), plant facilitation is still a research issue rather than a common practice in ecosystem restoration. Seedlings of oaks and other woody species are planted beneath a shrub canopy which ameliorates microclimate during summer, decreasing seedling mortality (Gómez-Aparicio et al., 2004; Castro et al., 2002, 2004, 2006; Castro and Zamora Hódar, 2006). However, shrubs do not always have a positive effect on the recruitment of woody seedlings under seasonally dry climates (e.g., Badano et al., 2009). In mid-mountain Mediterranean areas in Spain, shrub species mainly in the rock rose family (i.e., *Cistus albidus, Cistus* ladanifer, *Cistus* monspeliensis) but also in the mint families, exhibited null or negative effect on the recruitment of oaks and other woody seedlings (Gómez -Aparicio et al., 2004; Puerta-Piñero et al., 2007) while N_2–fixing shrub species in the legume family exhibited a positive effect on oak recruitment (e.g., Rolo et al., 2012).

In the Mediterranean area of south-western Iberian peninsula, the so called dehesa (local Spanish name, also named montado in Portugal) is a representative savanna-like ecosystem type that derives from a long history of human transformation of Mediterranean forests through clearing, browsing and ploughing to provide food for livestock rearing. They currently occupy over 3 million ha and are devoted to extensive livestock grazing and wild game (San-Miguel 1994; Costa et al., 2006). The dehesas are typically composed of scattered oaks (mainly holm-oak *Quercus ilex* subsp. ballota L. and secondary cork oak *Quercus* suber L.), at

* Corresponding author. Tel.: +34 95 4557066; fax: +34 954 626308.
E-mail addresses: leiva@us.es (M.J. Leiva), jmancilla@us.es (J.M. Mancilla-Leyton), angelm@us.es (Á. Martín Vicente).

http://dx.doi.org/10.1016/j.ecoleng.2015.05.019
0925-8574/

20–30 trees/ha density, and a grassland layer. Shrubs interspersed with the grassland matrix may also occur although their frequency is highly variable (Costa et al., 2006). Shrubs are usually abundant in those stands where grazing has ceased (abandoned stands hereinafter) and in stands that have been less intensively transformed by man which are generally, used for wild game hunting (moderately transformed stands hereinafter) (Leiva et al., 2013). On the contrary, shrubs are absent or scarce in intensive grazing stands.

Dehesas are considered as a model of sustainable resource use to all fragile areas across the Mediterranean region (Joffre et al., 1988). They are of high environmental value because they support high plant and animal biodiversity and provide important environmental services (Costa et al., 2006). However, the long term persistence of dehesas is currently threatened due to holm-oaks low to null self-regeneration capacities (e.g., Pulido et al., 2001). In addition, this species undergoes a severe decline process in many dehesas due to pathogens, former inappropriate soil management, and or climate change (Brasier et al., 1993; Barberó et al., 1992; Peñuelas et al., 2001; Moreira and Martins, 2005).

To enhance holm-oak regeneration in dehesas, temporary grazing abandonments have been proposed. This management strategy leads to shrub encroachment that could potentially increase seedlings recruitment through aforementioned facilitation mechanism, but also improve the activity of natural acorn dispersers and protect seedlings from predation (Rupérez, 1957; Montero et al., 1998; Pulido and Díaz, 2005; Ramírez and Díaz, 2008). However, abandoned dehesas become dominated by pioneer shrubs, typically in the rock rose family (Vacher, 1984; Ramírez and Díaz, 2008). These species are semideciduous chamephites (sensu Raunkiaer) whose morphology and leaf phenology is likely sub-optimal to enable microclimate improvement, and thus, to facilitate holm-oak seedlings recruitment. Conversely, late successional closed-canopy evergreen shrubs such as many of the occurring species in moderately transformed dehesas provide proper conditions to enhance holm-oak seedling recruitment (Leiva et al., 2013).

In this study, we analyse the effect on holm-oak seedling recruitment of two representative Mediterranean shrub species, *C. salvifolius* L. and *Myrtus communis* L. We focus this study on: (i) changes in micro environmental conditions attributable to shrub canopy effect, (ii) phenological characteristics of the shrubs that potentially influence micro environmental conditions and (iii) nurse effect of the two shrub species on holm-oak seedlings emergence and survival under climatologically contrasted years.

2. Methods

2.1. Shrub species selected

C. salvifolius L. and *M. communis* L. are common species in dehesas of south-western Spain as well as representative species of the Mediterranean Basin (Tutin et al., 1964–1980). They both show different pheno-morphological strategies (Orshan et al., 1989; Monserrat Martí et al., 2004), life histories and reproductive traits. *C. salvifolius* is a medium sized (i.e., 30–100 cm tall) early successional chamephyte that re-establishes by seeds after disturbance. Leaves are non-sclerophillous and semideciduous and the canopy is quite open. The roots are shallow without access to moist soil layers during summer. *M. communis* is a large-sized (i.e. 60–200 cm tall) late successional fanerophyte that slowly re-establishes by resprout after disturbance. Leaves are sclerophillous and evergreen and the canopy is quite closed. The roots are deep, able to reach the moist soil layer during summer (Mooney and Dunn, 1970).

2.2. Study area description

The study has been conducted in a dehesa located in a mid-mountain area in south-western Spain (Sierra Norte de Sevilla Natural Park, 37°40N, 5°59W). Climate is Mediterranean with 600–950 mm mean annual rainfall and 17.6–13.4 °C mean annual temperature (IMA, 2006). Rain falls mainly between mid-September and mid-May and is negligible during the summer in an average year. The study area was at a mean altitude of 415 m amsl on flat areas with moderately developed soils (45 cm in depth). The vegetation is composed of holm-oaks at mean density of 20 individuals/ha. The understorey consists of annual grasslands and interspersed shrubs, of which *C. salvifolius* and *M. communis* are the major species, forming scattered patches.

In order to determine the effect of Mediterranean shrubs on holm-oak seedling recruitment, 10 monospecific, similar-sized patches (7–9 m^2) of each shrub species (*C. salvifolius* and *M. communis)* were randomly selected. These patches were distributed through the area and were 100–300 m apart. In addition, 20 open patches devoid of shrub species were selected, each one close (i.e., 2–2.5 m apart) to one of the aforementioned *C. salvifolius* and *M. communis* patches. Thus, a total of four patch types(treatments) were included: (i) CS, dominated by *C. salvifolius*; (ii) Open CS, occupied by annual grasslands and close to a *C. salvifolius* patch, (iii) MC, dominated by *M. communis*, and (iv) Open MC, occupied by annual grasslands and close to a *M. communis* patch.

2.3. Leaf phenology and microhabitat characterization

In order to identify temporal patterns of maximum and minimum leaf area in the two shrub species, ten 40–50 cm tall stems of each species (i.e., 10 *C. salvifolius* stems in CS treatment and 10 *M. communis* stems in MC treatment, each ones from a different monospecific patch) were randomly selected, at the end of 2004/05 winter. A 50 cm-height position mark was placed in each stem. The leaves above this mark were also marked and their individual length was measured. Leaf area of each individual leaf was estimated based on a correlations leaf area-leaf length for each shrub species. The correlations were determined on different subsamples of fresh leaves of each species that were collected from adjacent stems, transported to the laboratory, scanned and analyzed using the software Hojas 1.0 (Taguas and Rivero, 1989). Sampling was monthly repeated from March to December 2005 on the same 20 stems. Total leaf area, in each time, was calculated as $\sum$ *leaf X area* for each stem. Data on leaf area and leaf number has been expressed as percentage of the initial values to allow comparisons among the two shrub species.

Photosynthetic photon flux density (PPF) beneath the understory was measured in 5 patches of each shrub species and 5 open patches near to each shrubby patch (20 patches in total). A portable 1-m long line quantum sensor (LI 191 Line Quantum Sensor) was punctually placed once a month, on fixed supports (10 cm in height) installed in each patch. Measurements were taken at noon in clean days during 2005.

2.4. Holm-oak seedlings emergence and survival in different microhabitats

To analyse the nurse effect of the two shrub species on holm-oak seedlings emergence and survival, a field experiment was conducted using the aforementioned selected patches (i.e., CS, Open CS, MC, and Open MC) with 10 replicates per treatment. Forty holm-oak acorns were sown in each patch in December 2004 and 2005 at sowing space of 0.5 × 0.33 m. Thus, experimental design included two holm-oak seedling cohorts (2005- and 2006-cohort hereinafter) and four treatments each year. The acorns were buried