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Impact of fuel reduction treatments on fungal sporocarp production and diversity associated with *Cistus ladanifer* L. ecosystems

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ABSTRACT

Mediterranean *Cistus ladanifer* scrublands can provide an important fungal production, often in high demand. However, due to the pyrophytic characteristics of this species, forest fires are the main threat to these ecosystems. The aim of the study is to analyze the effects of different fuel reduction treatments on *C. ladanifer* scrublands on production and diversity of fungal communities in order to enhance mushroom production and diversity and prevent forest fires. Sporocarp sampling was carried out on a weekly basis during autumnal production periods between 2010 and 2013. Twenty-seven plots (100 m^2) were established in scrublands of different age and origin: (a) a middle-age scrubland (8 years old) whose origin was a forest fire, (b) a middle-age scrubland (8 years old) whose origin was the total clearing of the previous stand, and (c) a senescent scrubland (20 years old). Considered fuel reduction treatments were total clearing, 50% clearing and controlled burning. All the sporocarps were identified and fresh and dry weighed. A total of 63,436 sporocarps belonging to 157 taxa within 64 genera were collected during the four years' sampling. Higher total fungal fresh weight production was found in middle-aged compared with senescent scrublands. After the 50% clearing, production, diversity and species composition of fungal communities were very similar to the control plots in which no treatment was performed. It seemed to be the most appropriate treatment for the production of edible species, especially *Boletus edulis* and this treatment may also reduce fire intensity and severity. Furthermore, total clearing favors the fructification of new species, especially saprotrophic ones. Therefore, in this study, the rejuvenation of senescent scrublands and the alternation of different fuel reduction treatments in middle-aged stands seemed to be the best management guidelines for the sustainable management of this resource.

1. Introduction

Wild mushroom harvesting is becoming a very important socioeconomic resource in economically disadvantaged rural areas (Bonet et al., 2014). The benefit obtained from this resource is not limited to the marketing and processing of the product. It is also necessary to take mushroom picking into account as a recreational activity and environmental service (Martínez de Aragón et al., 2011; Schulp et al., 2014). There is also an important touristic activity associated with this resource that can provide high economic benefits in the production areas (de Frutos Madrazo et al., 2012). In Castilla y León (North-central Spain) mushroom picking involves 54% of the rural population and edible mushroom production can reach 65 million euros in potential income (Martínez-Peña et al., 2007).

Cistus species may form both ectomycorrhizas and vesicular arbuscular mycorrhizas and they are associated with more than 200 ectomycorrhizal fungal species of 40 different genera (Comandini et al., 2006). This genus comprises several obligate seeder shrub species of pyrophytic shrubs (12 in the Iberian Peninsula), which are mainly distributed around the Mediterranean basin and constitute early successional stages in Mediterranean forest ecosystems (Agueda et al., 2008). They can

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colonize highly degraded areas after fire as high temperatures generated by fire in the top layers of the soil trigger seed germination (Bastida and Talavera, 2002). The most abundant *Cistus* species in the Spain is *Cistus ladanifer* L., which has a distribution area of about 3 million hectares and is present in 15% of the forest area of the country (Martín Morgado et al., 2005).

The *C. ladanifer* ecosystem provides high production of edible mushroom species, some of them in great demand due to their gastronomic interest. Species belonging to the genus *Boletus* are the most economically valuable fungal species in these ecosystems (Oria-de-Rueda et al., 2008). *Boletus edulis* is a wild species widely marketed in many countries (Alonso Ponce et al., 2011). It is one of the highest priced species in Spanish markets, reaching 40–50 €/kg and significantly increasing each year. *B. edulis* is usually collected in forest areas dominated by species of *Pinus*, *Quercus* and *Castanea*. However, fruiting of these fungi in forest occurs only in mature stands (30–40 years old) (Oria-de-Rueda et al., 2008). Since fruiting in *C. ladanifer* ecosystems occurs at a much earlier age (3–4 years old), *C. ladanifer* scrubland conservation could be of interest in areas with poor and degraded soils, where the productivity of forested areas is very low and economic benefit scarce. The main problem for mushroom picking in these scrublands is that the high density reached in mature stands hampers harvester accessibility. Therefore, silvicultural management aimed at reducing shrub density could well facilitate mushroom harvesting and increase the economic benefit obtained from this resource.

Although traditionally, forest planning and management has paid little attention to mushroom harvesting, the growing interest in this non-wood forest product has made the management of forest stands for mushroom production (mycosilviculture) increasingly more important (Savoie and Largeteau, 2011). This has led scientists to study the state of conservation of diversity and production of wild mushroom communities and the effect of silvicultural treatments on them (Martínez-Peña et al., 2011). Most of these studies are focused on the effect of thinning on fungal communities in tree stands. Shaw et al. (2003) found little effect of fungal productivity five years after thinning under *Pinus sylvestris*. A temporal relationship between tree growth reaction after thinning and the production of associated fungal community was observed in a mixed old-growth forest in Switzerland (Egli et al., 2010). These authors found low production during the first 3 years after thinning and a recovery during the fourth year. On the contrary, Bonet et al. (2012) found an immediate positive effect of thinning on *Lactarius deliciosus* production in a *Pinus pinaster* plantation, and de-Miguel et al. (2014) found greater mushroom yields in pine stands with more intensive management practices. Regarding *B. edulis* production, Salerni and Perini (2004) studied the effect of tree canopy and presence/absence of litter in order to increase the productivity of this species in different forest stands in Italy. These authors found a positive effect of medium thinning and a negative effect of litter layer removal in *B. edulis* fructification.

Azul et al. (2011) tested the influence of land use practices used to control shrub density on macromycetes fruiting in *Quercus suber* woodlands. These authors found that current practices used to control shrub density account for considerable variation in mushroom fruiting. The effects of permanent grazing or soil tillage were more severe than cutting practices without soil tillage.

However, to our knowledge, this is the first study of the effect of fuel reduction treatments on fungal communities associated with *C. ladanifer* scrublands. Some regions in the northwest of the Iberian Peninsula are characterized by the traditional use of fire to control shrubs. This fact, together with the pyrophytic ecology of *C. ladanifer*, results in a very high incidence of wildfires in these areas. In some cases, the existence of forest fires may be linked to mushroom harvesting either because mushroom pickers try to favor some species fructification or because they seek to improve transit and visibility through the stands, thus facilitating sporocarp collection (Martínez de Azagra et al., 1998). Different fuel reduction treatments can be used in the management of scrublands to prevent wildfires and reduce their negative effects. Studying the effect of these treatments on mushroom production may lead to finding a suitable option for managing *C. ladanifer* scrublands, improving edible mushroom production and preventing fires in adjacent forests. The present study was requested by the forest managers of this area. The aim of this study is to analyze the effects of different fuel reduction treatments in *C. ladanifer* scrublands on associated fungal communities in order to enhance sporocarp production and diversity and prevent forest fires. Our specific objectives are to analyze the influence of these treatments on: (1) sporocarp production; (2) fungal richness and diversity; and (3) the similarity of the specific composition of the fungal communities.

2. Materials and methods

2.1. Study site

The study area is located in Zamora province in North-western Spain (0730462–0731929 Longitude-UTM, 4619644–4621757 Latitude-UTM 29T Grid).

It is a Mediterranean ecosystem dominated by *C. ladanifer* situated at 750–780 m above sea level. The soil in this area is constituted by Paleozoic metamorphic rocks, Ordovician and Silurian shales being predominant (García Rodríguez et al., 1964). The soil is classified as Inceptisol suborder Xerept (Soil Survey Staff, 2010) and is characterized by stoniness, acidity (pH 5.0–5.5), and lack of calcium and phosphorous. Nitrogen and potassium availability is variable and the level of humification is generally good (García Rodríguez et al., 1964). The area is characterized by a sub-Mediterranean climate with a dry season of three months in the summer and a mean annual rainfall of 450–700 mm. Mean temperatures range from 14.5 to 15.8 °C.

Climatic data were provided by the closest meteorological station (Alcañices, 0724617 Longitude-UTM, 4618218 Latitude-UTM, 29T Grid and 806 m above sea level, Spanish Meteorological Agency).

2.2. Fuel reduction treatments

Plots were established in three areas where *C. ladanifer* age and stand origin were different: (a) a middle-age stand (8 years old) whose origin was a forest fire, (b) a middle-age stand (8 years old) whose origin was the clearing of the previous stand, and (c) an senescent stand (20 years old) whose origin was a forest fire. Treatments were chosen based on their applicability in accordance with the age of the stands and vegetation characteristics. The study site was not replicated across several sites.

C. ladanifer mean height in the middle-age stands (a and b) was 1.30 m when the treatments were carried out. Mechanized cutting practices (clearing) are used to control shrub density in these stands. In the two middle-age stands the following treatments were carried out: (1) Control; (2) 50% clearing; and (3) Total clearing.

In the senescent stand (c), *C. ladanifer* mean height was 2 m. It is a senescent stand with characteristics (high density, presence of dead plants and branches and lichens – *Evernia prunastri*-covering the stems) that are optimal for the ignition and spread of fire. Destroying dead plants by mechanical tools or by controlled burning can be the means to avoid forest fires and reduce their negative effects in these ecosystems (Oria-de-Rueda et al., 2008). Thus, in the senescent stand the studied fuel reduction treatments were: (1) Control; (2) Total clearing; and (3) Controlled burning.

Total clearing was carried out in spring 2010 with a New Holland TS115 tractor with a brush thrasher mower, whereas