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*Translated from the original in spanish*

# Case study: the management of Mediterranean pyrophyte ecosystems dominated by Cistus ladanifer

# Estudio de caso: manejo de ecosistemas pirófitos mediterráneos dominados por *Cistus ladanifer*

**Pablo Martín-Pinto**[1]

[1]Instituto Universitario en Gestión Forestal Sostenible de la Universidad de Valladolid. E-mail: pmpinto@pvs.uva.es

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## ABSTRACT

The aim of this work is to review the research carried out on the prevention of forest fires in Mediterranean jarales through the enhancement of mycological resources. Cistus ladanifer (jara pringosa) is a Mediterranean pyrophyte scrub widely distributed in the Iberian Peninsula, which is associated with numerous species of fungi, some of which are highly valued, such as the Boletus edulis. Adequate management of these areas would contribute to reduce the risk of fire and increase the economic benefit derived from the use of fungi. Therefore, the main objective of this review is to find the best management practices of Mediterranean ecosystems dominated by C. ladanifer, to increase mycological production and prevent forest fires. An experimental design was established in which they analyzed the communities of fungi associated to different treatments, knowing the diversity and fungal production associated to the ecosystem, under different parameters of management focused on the prevention of fires. The production of the most interesting species was modelled. As a main result, the high fungal diversity associated with these ecosystems was demonstrated, supporting the conservation interest of these habitats. As a general conclusion, it can be deduced that the adequate management of these areas would produce important economic benefits derived from the mycological exploitation in these ecosystems that traditionally have been considered unproductive and are generally found in economically disadvantaged rural areas.

**Keywords:** *Boletus edulis*; fire; forest management; mushrooms; scrub.

## RESUMEN

El trabajo tiene como objetivo revisar la investigación realizada sobre la prevención de incendios forestales en jarales mediterráneos mediante la puesta en valor de los recursos micológicos. *Cistus ladanifer* (jara pringosa) es un matorral pirófito mediterráneo ampliamente distribuido en la Península Ibérica, que se asocia a numerosas especies de hongos, algunos de los cuales son muy valorados, como el *Boletus edulis*. Un adecuado manejo de estas zonas contribuiría a disminuir el riesgo de incendio y aumentar el beneficio económico derivado del aprovechamiento de hongos. Por lo tanto, el principal objetivo de esta revisión es encontrar las mejores prácticas de manejo de ecosistemas mediterráneos dominados por *C. ladanifer*, para incrementar la producción micológica y prevenir los incendios forestales. Se estableció un diseño experimental en el que analizaron las comunidades de hongos asociadas a distintos tratamientos, conociendo la diversidad y producción fúngica

asociada al ecosistema, bajo diferentes parámetros de gestión enfocados a la prevención de incendios. Se modelizó la producción de las especies más interesantes. Como resultado principal se demostró la elevada diversidad fúngica asociada a estos ecosistemas, respaldando el interés de conservación de estos hábitats. Como conclusión general se deduce que el manejo adecuado de estas áreas produciría importantes beneficios económicos derivados del aprovechamiento micológico en estos ecosistemas que tradicionalmente han sido considerados improductivos y generalmente se encuentran en zonas rurales económicamente desfavorecidas.

**Palabras clave:** *Boletus edulis*; fuego; gestión forestal; hongos; matorral.

## INTRODUCTION

The genus *Cistus* is one of the most characteristic among the Mediterranean scrub. It is distributed mainly around the Mediterranean, and in the Iberian Peninsula it is represented by twelve species (Águeda et al., 2008). Within this genus, the most abundant species is *Cistus ladanifer*, whose range is limited to the westernmost part of the Mediterranean Region (Guzmán and Vargas, 2009). It is a pyrophytic species that constitutes the first stages of succession in Mediterranean ecosystems. The senescent masses present optimal characteristics for the ignition and propagation of fires and have a high capacity to colonize burned areas (Bastida and Talavera, 2002).

Although these ecosystems have traditionally provided little economic benefit, *C. ladanifer* is associated with a significant number of species of fungi, some of them with high market value, such as *Boletus edulis* (Voces *et al.,* 2012). These ecosystems can therefore be an important source of economic benefits for rural people. It is necessary to establish management guidelines that allow the conservation of this type of ecosystems, reducing the risk of fires and maximizing the benefit obtained by the use of mushrooms, which is the main objective of this study. The specific objectives of this study are:

1. To analyze the succession of the fungal community after the fire in a Mediterranean ecosystem dominated by *C. ladanifer*.
2. To study the effect of different fuel reduction treatments in these ecosystems on mushroom production and diversity.
3. To develop predictive empirical models based on climatic variables to predict the production and diversity of mushrooms in these ecosystems, paying special attention to the production of *B. edulis*. Determine the management practices that produce the greatest economic benefits, taking into account the production of fungi and biomass in these ecosystems.
4. To study the effect of fuel reduction treatments on the diversity of fungi present in the soil (mycelium).
   The work is divided into four sections published in different scientific journals (Hernández-Rodríguez *et al.,* 2017; 2015; 2015; 2013) and a manuscript in preparation, which respond to each of the specific objectives of the review (Figure 1).

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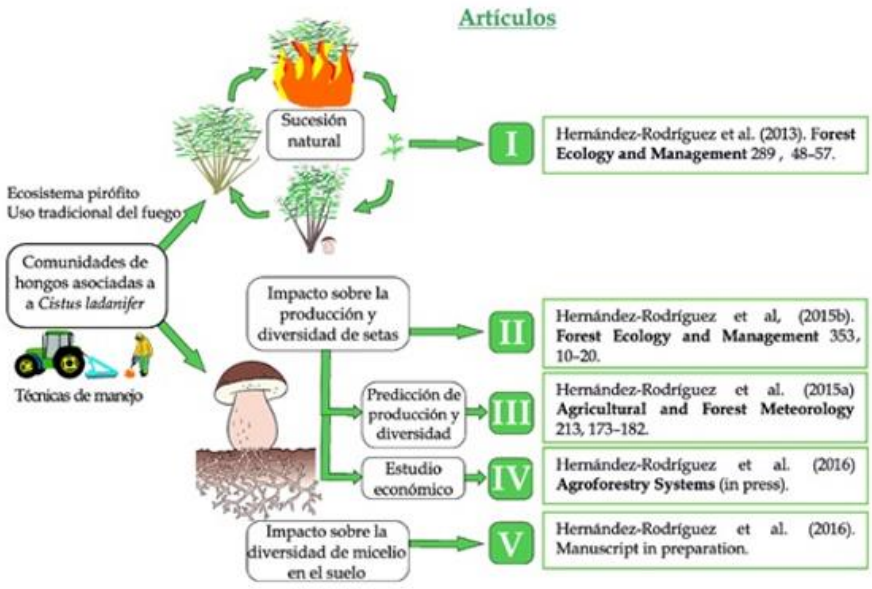


**Fig. 1**- Diagram of the review and each of the publications associated with it

## MATERIALS AND METHODS

The study area is located in the municipality of Rabanales, province of Zamora, in the northwest of the Iberian Peninsula. Within this area, several masses dominated by *C. ladanifer* were selected, where sampling plots in the form of linear transects 2m x 50 m were established. For the study of succession after fire, two zones were selected, one recently burned and one mature mass, and six plots were established in each of them. On the other hand, for the studies of fuel reduction treatments, plots were established in three areas, in which the age of *C. ladanifer* and the origin of the mass were different: a middle-aged area (eight years), whose origin was a forest fire; a middle-aged area (eight years), whose origin was the total weeding of the previous mass; and a senescent mass (20 years), whose origin was a forest fire. The treatments were chosen according to their applicability, according to the age of the stands and the characteristics of the vegetation. The following treatments were carried out on the two middle-aged stands: control, 50% manual weeding and total weeding. On the other hand, in the senescent mass, which presents optimal characteristics for fire ignition and propagation, the fuel reduction treatments studied were: control; total weeding; controlled burning.

All the carpophores were collected weekly during the autumn season from 2003 to 2006, for the succession study, and from 2010 to 2013 for the study of the effect of the treatments. Species were identified, classified according to trophic group (mycorrhizal or saprophytic) and fresh and dry weight (biomass) data were taken. In addition, the Shannon H' diversity index (Shannon and Weaver, 1948), based on the dry weight of the carpophores (Dahlberg, 1991), was calculated.

Finally, five soil samples were taken along each transect for the soil mycelium study. These samples were processed for DNA extraction and analyzed using mass sequencing techniques. All data were subjected to various statistical techniques, depending on their characteristics and the purpose of the study.

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## RESULTS AND DISCUSSION

This work addresses different ecological and economic aspects to acquire an in-depth knowledge of the fungal communities associated with the C. *ladanifer jarales*, providing a set of guidelines for the sustainable management of these areas.

A very high number of species of fungi that fructify in these ecosystems was found: 146 species in the fire succession study and 157 species in the treatment effect study. In addition, the study of soil samples showed that there is an enormous amount of fungi associated with the *rhizosphere* of *C. ladanifer*. According to the results of this research, there is a decrease in the richness and diversity of *carpophores* the first year after the fire. However, the number of species and diversity showed quite similar values in both stages of succession, two years after the fire (Figure 2).

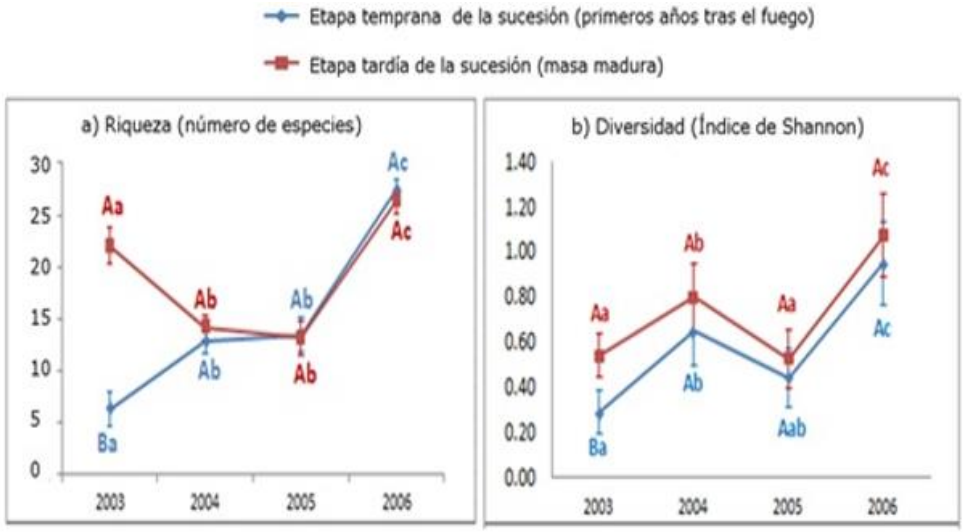


**Fig. 2 -** Number of species (a) and diversity (b) of fungi found in the two stages of succession after fire in masses dominated by *C. ladanifer*
**Source**: Hernández-Rodríguez *et al.,* (2013)

As for the effect of different fuel reduction treatments, the specific composition of the three different masses studied is significantly different from each other, considering both *carpophore* production and soil fungal communities (Figure 3) and (Figure 4). In addition, the effect of the treatments did not significantly affect the mycelium of fungi in the soil between treatments located in the same origin of the mass, but it did consider the production of mushrooms. Therefore, although the new conditions created by the removal of vegetation alter the fungal fructification, the mycelium of the different species is able to remain in the soil.

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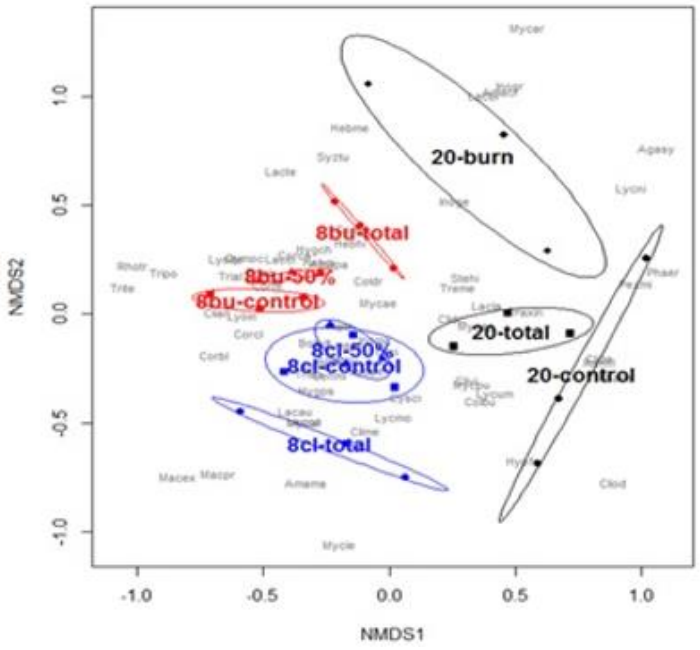


**Fig. 3 -** Management of fungal species, plots and treatments according to NMDS analysis. The distribution of treatments is expressed by standard error ellipses (95 % confidence intervals). 8 cl: middle-aged mass from weeding; 8bu: middle-aged mass from fire; 20: senescent mass 50 %: weeding at 50 %; total: total weeding; burn: controlled burning.
**Source:** Hernández-Rodríguez *et al.,* (2015).

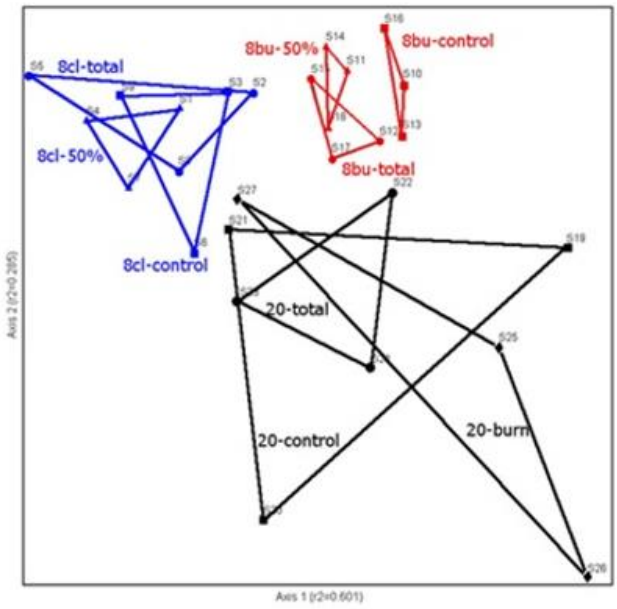


**Fig. 4 -** NMDS management graph for soil fungal communities, based on the abundance of taxonomic units in the soil 8 cl: middle-aged mass from weeding; 8bu: middle-aged mass from fire; 20: senescent mass. 50 %: 50 % weeding; total: total weeding; burn: controlled burning

A higher production of fungi was observed in the two young shrubs, compared to the senescent soil, which can be explained by the lower photosynthetic activity of the senescent shrub and its lower growth. Therefore, to increase mushroom production, management should be aimed at rejuvenating senescent shrubs.

The production, richness and diversity of mushrooms of mycorrhizal species were significantly greater in treatments in which the vegetation was not completely eliminated (Figure 5). This is an expected result, considering that this type of species requires the presence of a host plant for survival (Dahlberg, 2002). However, no differences were found in the richness of saprophytic species within the two young thickets. The new soil and light conditions created by removing vegetation may facilitate the establishment of pioneer species (Clark and St. Clair, 2011), many of which have saprotrophic ecology.

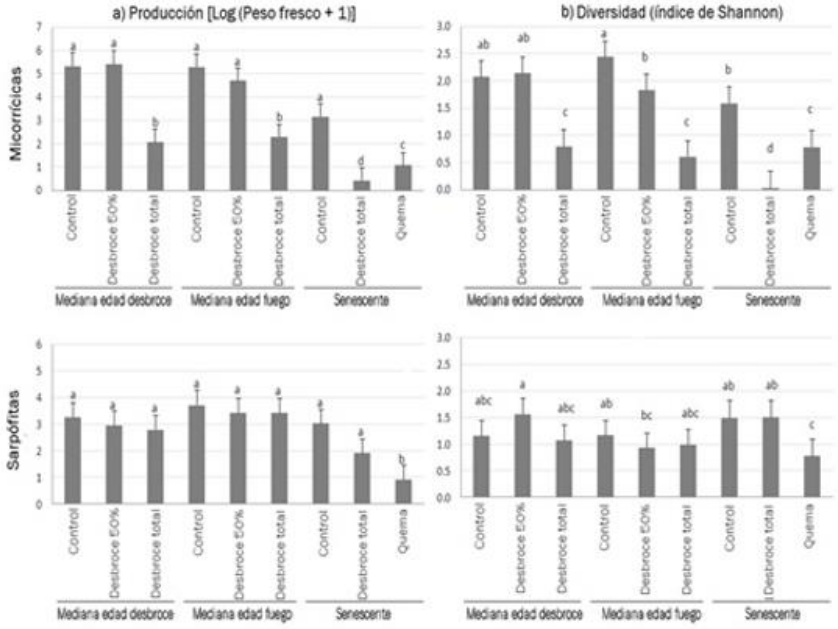


**Fig. 5 -** Production (a) and diversity (b) of fungal species according to their trophic characteristics (mycorrhizal and saprophytic), for each of the treatments. Treatments with the same letter are not significantly different
**Source:** Hernández-Rodríguez *et al.* (2015).

The weeding at 50 % was the treatment with the least impact on the fungal community (production and diversity), associated with a significant production of edible fungi. This treatment reduces the amount of fuel, thus decreasing the intensity of the forest fire and facilitating its extinction. In addition, it allows the accessibility and collection of fungi by decreasing the density of scrub. However, its high implementation cost makes its practical application very difficult.

The treatment that produced the greatest benefit was total weeding at the end of the jarales' life cycle (19 years) (Table 1). This management would ensure that all stages of the shrub are present in the area. Therefore, the optimal solution from an economic point of view would also be adequate from an ecological point of view.

**Table 1. -** Results of the analysis of optimal rotation of the five prescriptions considered. VES: Expected Value of Soil

| Año | Escenario tradicional | Desbroce total | Quema controlada | Desbroce total + Desbroce parcial | Quema controlada + Desbroce parcial |
|---|---|---|---|---|---|
| Año | 6 | 19 | 21 | 25 | 25 |
| VES (€/ha) | 182.8 | 1403.6 | 1200.3 | 801.1 | 659.0 |

**Source**: Hernández-Rodríguez *et al.* (2017).

This economic analysis supports that the collection of *B. edulis* can considerably increase the economic benefits in these ecosystems. Furthermore, the integration of fungal resources into forest management plans would ensure their conservation over time and halt depletion, according to Aldea *et al.,* (2012).

The simulation of all the models adjusted in the study, to predict the production and diversity of fungi both mycorrhizal and saprophytic, depending on the age and characteristics of the mass and considering the average climatic conditions found in the study period, are shown in figures #6 and #8. In addition, a specific model was adjusted for the species *B. edulis*, whose simulation can be seen in figure #7.

The production of mycorrhizal species showed a rapid increase after weeding or fire, reaching a maximum of eight years after treatment. From this point on, mycorrhizal production decreases, reaching values close to zero from the age of 20 (Figure 6). On the other hand, the production of saprophytic species is lower than in the case of mycorrhizal species, being decreasing throughout the development cycle of the rockrose. The treatments increased the amount of organic matter available, so that this type of species can fructify quickly after treatment.

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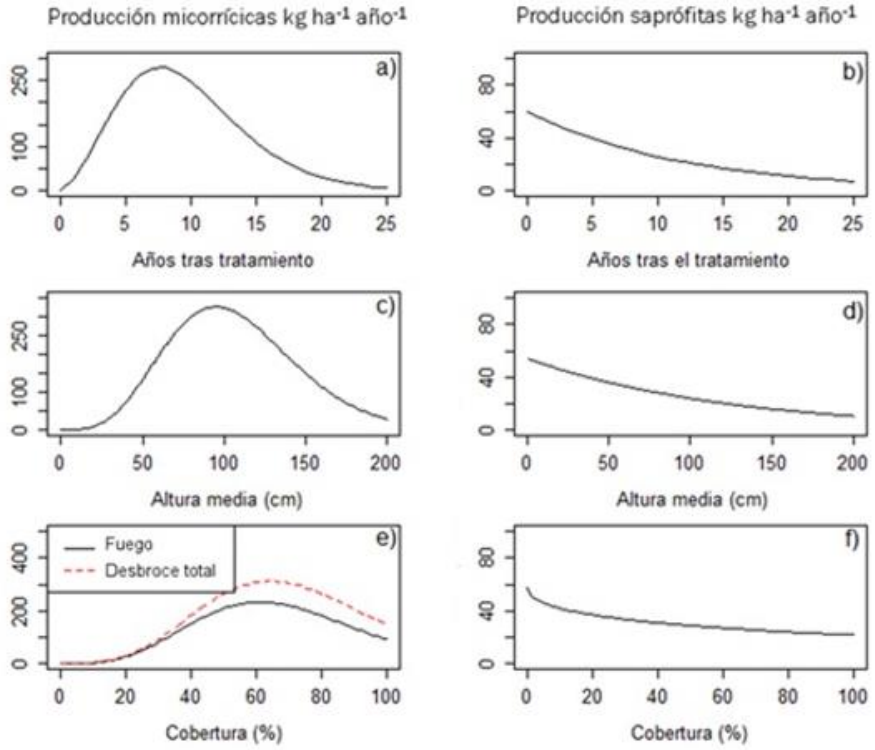
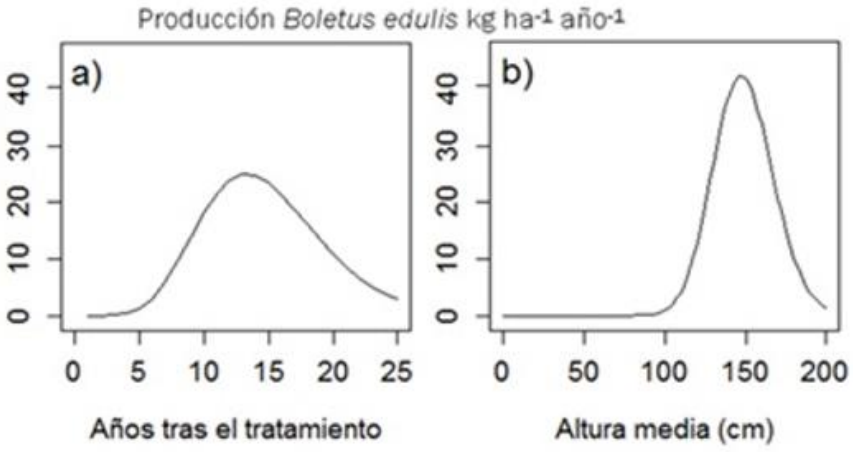



**Fig. 6 -** Production of mycorrhizal (left) and saprophytic (right) species taking into account the years after treatment (a and b), the characteristics of the vegetation (c and d) and the effect of the two treatments studied (e and f).
**Source**: Hernández-Rodríguez *et al.,* (2015).

The same trend as for mycorrhizal species was found for the production of *B. edulis,* although the maximum in this case was delayed until 14 years (Figure 7). *B. edulis* is normally associated with mature forest stands (Martín-Pinto *et al.,* 2006), although when associated with jarales it may fruitify much earlier (Oria-de-Rueda et al., 2008).




Similar to the production of mycorrhizal species, the diversity of these species shows a clear increase during the first years of the succession of *C. ladanifer*, with a decrease in the senescent rockroses. However, maximum diversity occurs several years after peak production.

Considering total weeding or controlled burning as the two economically viable management options, modeling results suggest an opposite trend in fungal diversity compared to production. Shannon's diversity index for both mycorrhizal and saprophytic species was higher after burning than after weeding, while mushroom production was higher after total weeding. Therefore, if the management objective is economic (to increase mushroom production), total weeding may be a better treatment alternative. Conversely, if the objective is to favour greater diversity, burning may be better than weeding.

After this review work, and from the analyzed data, it is concluded that the adequate management of these ecosystems, especially pyrophytes and frequently affected by forest fires, could give rise to the obtaining of important economic benefits derived from mycological exploitation. On the other hand, these ecosystems, generally installed in poor and scarcely productive soils, are frequently linked to impoverished rural areas. For all these reasons, it is considered that the mycological resource derived from an adequate management could bring an important complement of income to the rural populations of these especially disadvantaged areas.

## BIBLIOGRAPHICAL REFERENCES

ÁGUEDA, B., PARLADÉ, J., FERNÁNDEZ-TOIRÁN, L.M., CISNEROS, Ó., DE MIGUEL, A.M., MODREGO, M.P., MARTÍNEZ-PEÑA, F. y PERA, J., 2008. Mycorrhizal synthesis between Boletus edulis species complex and rockroses (Cistus sp.). *Mycorrhiza*, vol. 18, no. 8, pp. 443-449. ISSN 0940-6360. DOI 10.1007/s00572-008-0192-3.

ALDEA, J., MARTÍNEZ-PEÑA, F. y DIAZ-BALTEIRO, L., 2012. Integration of fungal production in forest management using a multi-criteria method. *European Journal of Forest Research* [en línea], vol. 131, no. 6, pp. 1991-2003. [Consulta: 4 abril 2019]. ISSN 1612-4677. DOI 10.1007/s10342-012-0649-y. Disponible en: https://doi.org/10.1007/s10342-012-0649-y.

BASTIDA, F. y TALAVERA, S., 2002. Temporal and Spatial Patterns of Seed Dispersal in Two Cistus Species (Cistaceae). *Annals of Botany* [en línea], vol. 89, no. 4, pp. 427-434. [Consulta: 5 noviembre 2019]. ISSN 0305-7364. DOI 10.1093/aob/mcf065. Disponible en: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233877/.

CLARK, A.L. y ST. CLAIR, S.B., 2011. Mycorrhizas and secondary succession in aspenconifer forests: Light limitation differentially affects a dominant early and late successional species. *Forest Ecology and Management* [en línea], vol. 262, no. 2, pp. 203-207. [Consulta: 4 abril 2019]. ISSN 0378-1127. DOI 10.1016/j.foreco.2011.03.024. Disponible en: http://www.sciencedirect.com/science/article/pii/S0378112711001678.

DAHLBERG, A., 2002. Effects of Fire on Ectomycorrhizal Fungi in Fennoscandian Boreal Forests. *Silva Fenn* [en línea], [Consulta: 4 abril 2019]. DOI 10.14214/sf.551. Disponible en: https://www.semanticscholar.org/paper/Effects-of-Fire-on-Ectomycorrhizal-Fungi-in-Boreal-Dahlberg/1fd0f451a6d436aaff757c23b44101adab6cf438.

DAHLBERG, A. (Sveriges L., 1991. *Ectomycorrhiza in coniferous forest - structure and dynamics of populations and communities* [en línea]. Doctoral Thesis. S.l.: Swedish University of Agricultural Sciences, Department of Forest Mycology and Pathology. Disponible en: http://agris.fao.org/agris-search/search.do?recordID=SE9200028.

GUZMÁN, B. y VARGAS, P., 2009. Long-distance colonization of the Western Mediterranean by Cistus ladanifer (Cistaceae) despite the absence of special dispersal mechanisms. *Journal of Biogeography* [en línea], vol. 36, no. 5, pp. 954-968. [Consulta: 4 abril 2019]. ISSN 1365-2699. DOI 10.1111/j.1365-2699.2008.02040.x. Disponible en: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2699.2008.02040.x.

HERNÁNDEZ-RODRÍGUEZ, M., DE-MIGUEL, S., PUKKALA, T., ORIA-DE-RUEDA, J.A. y MARTÍN-PINTO, P., 2015. Climate-sensitive models for mushroom yields and diversity in Cistus ladanifer scrublands. *Agricultural and Forest Meteorology* [en línea], vol. 213, pp. 173-182. [Consulta: 4 abril 2019]. ISSN 0168-1923. DOI 10.1016/j.agrformet.2015.07.001. Disponible en: http://www.sciencedirect.com/science/article/pii/S0168192315002087.

HERNÁNDEZ-RODRÍGUEZ, M., MARTÍN-PINTO, P., ORIA-DE-RUEDA, J.A. y DIAZ-BALTEIRO, L., 2017. Optimal management of Cistus ladanifer shrublands for biomass and Boletus edulis mushroom production. *Agroforestry Systems* [en línea], vol. 91, no. 4, pp. 663-676. [Consulta: 4 abril 2019]. ISSN 1572-9680. DOI 10.1007/s10457-016-9994-z. Disponible en: https://doi.org/10.1007/s10457-016-9994-z.

HERNÁNDEZ-RODRÍGUEZ, M., ORIA-DE-RUEDA, J.A. y MARTÍN-PINTO, P., 2013. Post-fire fungal succession in a Mediterranean ecosystem dominated by Cistus ladanifer L. *Forest Ecology and Management* [en línea], vol. 289, pp. 48-57. [Consulta: 4 abril 2019]. ISSN 0378-1127. DOI 10.1016/j.foreco.2012.10.009. Disponible en: http://www.sciencedirect.com/science/article/pii/S0378112712006068.

HERNÁNDEZ-RODRÍGUEZ, M., ORIA-DE-RUEDA, J.A., PANDO, V. y MARTÍN-PINTO, P., 2015. Impact of fuel reduction treatments on fungal sporocarp production and diversity associated with Cistus ladanifer L. ecosystems. *Forest Ecology and Management* [en línea], vol. 353, pp. 10-20. [Consulta: 4 abril 2019]. ISSN 0378-1127. DOI 10.1016/j.foreco.2015.05.007. Disponible en: http://www.sciencedirect.com/science/article/pii/S0378112715002765.

MARTÍN-PINTO, P., VAQUERIZO, H., PEÑALVER, F., OLAIZOLA, J. y ORIA-DE-RUEDA, J.A., 2006. Early effects of a wildfire on the diversity and production of fungal communities in Mediterranean vegetation types dominated by Cistus ladanifer and Pinus pinaster in Spain. *Forest Ecology and Management* [en línea], vol. 225, no. 1, pp. 296-305. [Consulta: 4 abril 2019]. ISSN 0378-1127. DOI 10.1016/j.foreco.2006.01.006. Disponible en: http://www.sciencedirect.com/science/article/pii/S0378112706000144.

ORIA-DE-RUEDA, J.A., MARTÍN-PINTO, P. y OLAIZOLA, J., 2008. Bolete Productivity of Cistaceous Scrublands in Northwestern Spain. *Economic Botany* [en línea], vol. 62, no. 3, pp. 323-330. [Consulta: 4 abril 2019]. ISSN 0013-0001. Disponible en: https://www.jstor.org/stable/40390471.JSTOR.

SHANNON, C.E., 1948. A Mathematical Theory of Communication. *Bell System Technical Journal* [en línea], vol. 27, no. 3, pp. 379-423. [Consulta: 4 abril 2019]. ISSN 1538-7305. DOI 10.1002/j.1538-7305.1948.tb01338.x. Disponible en: https://onlinelibrary.wiley.com/doi/abs/10.1002/j.1538-7305.1948.tb01338.x.

VOCES, R., DIAZ-BALTEIRO, L. y ALFRANCA, Ó., 2012. Demand for wild edible mushrooms. The case of Lactarius deliciosus in Barcelona (Spain). *Journal of Forest Economics* [en línea], vol. 18, no. 1, pp. 47-60. [Consulta: 4 abril 2019]. ISSN 1104-6899. DOI 10.1016/j.jfe.2011.06.003. Disponible en: http://www.sciencedirect.com/science/article/pii/S110468991100047X.