# Bolete Productivity of Cistaceous Scrublands in Northwestern Spain[1]

Juan Andrés Oria-de-Rueda*, Pablo Martín-Pinto, and Jaime Olaizola

Fire and Applied Mycology Laboratory, Departments of Agroforestry Sciences, Vegetal Production, and Natural Resources, University of Valladolid (Palencia), Avda. Madrid 44, 34071, Palencia, Spain
*Corresponding author; e-mail: oria@agro.uva.es

**Bolete Productivity of Cistaceous Scrublands in Northwestern Spain**. Cistaceous scrublands dominated by *Cistus ladanifer* and *Halimium lasianthum* are widely distributed in northwestern Spain and are known to harbor the popular edible mushrooms *Boletus edulis* and *B. aereus*. As commercial harvest of these species is an important activity in Spain's forests, in some cases generating greater revenue than timber production, we tried to determine whether there is commercial potential for bolete harvest in young cistaceous scrublands. Transects of 50 m × 2 m were randomly established in cistaceous scrublands and bolete yield was measured. High production of these valuable mushrooms was associated with 3-year-old plants, a much earlier onset than observed for *Pinus* and *Quercus* stands. Management recommendations for the studied scrub ecosystems are proposed that take into account the economic value of the mushrooms.

**Producción de Boletus asociados a matorrales de Cistaceas en el Noroeste de España**. Grandes masas de Cistaceas dominadas por Cistus ladanifer and Halimium lasianthum están ampliamente distibuidas por el Noroeste de la península ibérica y es posible encontrar hongos apreciados como Boletus edulis y B. aereus. Nosotros intentamos determinar el potencial comercial del aprovechamiento de estas especies en matorrales jóvenes ya que en muchas zonas puede suponer una actividad económica que supere los beneficios procedentes de la madera. La producción de Boletus se recogió en parcelas de 2×50 metros. Se pudo observar una alta producción de estas especies asociada a plantas de 3 años, una edad mucho más temprana que la necesaria en masas de Pinus o Quercus. Finalmente, se proponen alternativas de gestión para estas particulares zonas teniendo en cuenta el valor económico de los hongos.

**Key Words:** *Boletus edulis*, *Boletus aereus*, Cistaceae, scrub, mushroom production, mushroom income.

## Introduction

Boletes, particularly *Boletus edulis* Bull. and its close relatives, *B. aereus* Secr., *B. aestivalis* (Paulet) Fr., and *B. pinophilus* Pilát and Dermek, are highly prized culinary mushrooms in many countries (Arora 1986; Boa 2004). The gastronomic importance of *Boletus edulis* and allied species in Spain was cited as long ago as the 1st century A.D. by the Roman-Hispanic writer Marcus Valerius Martialis (Marcial 1969), and today the harvesting and marketing of these boletes contribute significantly to the rural economies of northern and southwestern Spain (de Román and Boa 2004).

The amount of boletes harvested annually in Spain varies from 2 million kilograms (kg) fresh weight in the poorest years to 20 million kg in exceptionally productive years, with a mean of about 8 million kg (Oria-de-Rueda 1989). Rigueiro (2000) reported that 100,000–800,000 kg of *B. edulis* and allies are marketed and exported annually from Lugo Province (Galicia) in northwestern Spain. In the Castilla y León Autonomous Community of Spain, more than 2 million kg of *B. edulis* and allies are marketed annually, with

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250,000 kg harvested from the pine forests of Soria Province alone (Martínez-de-Azagra et al. 1998). In the Navarra Autonomous Community of northeastern Spain, Oria-de-Rueda and Garcia (1998) found that some families collected more than 1,000 kg per year. The mean annual amount per harvester was 500 kg (as much as 40 kg per person per day!), with resulting income of up to €6,000 annually per family.

Most of the boletes cited above are collected from forested areas dominated by species of *Pinus, Quercus*, and/or *Castanea*. Yet both *B. edulis* and *B. aereus* also occur in scrubland dominated by shrubs of the rockrose family (Cistaceae). In the study area (northwestern Zamora Province), thousands of kilograms of *Boletus edulis* and *B. aereus* are harvested from these native cistaceous scrublands and sold nationally under the name "*zamoranitos.*" These boletes are renowned for their uniformly small size (as the regional appellation suggests) as well as for their attractive appearance and low frequency of infestation by insect larvae. Yet scrubland boletes tend to be harvested only in those areas of Spain with a long history of mushroom gathering, such as Zamora Province. In many areas of Spain they appear not to be harvested, and given the preponderance of cistaceous scrublands, they constitute an underappreciated and underexploited resource.

## Cistaceous Shrubs and their Mushroom Associates

*Cistus, Halimium, Fumana, Helianthemum*, and *Xolantha* are all genera belonging to the Cistaceae. Members of this family are widely distributed in the Mediterranean region and are able to form ectomycorrhizae with a number of different mushroom species. Among the noteworthy mycorrhizal associates of *Helianthemum* and *Xolantha* are truffles of the genus *Terfezia* (Honrubia et al. 1992); in fact, artificially mycorrhized *Terfezia* plantations have been established using these shrubs (Dieste et al. 2003).

Species of *Cistus* are also known to form mycorrhiza with esteemed culinary mushrooms, including *Cantharellus cibarius* Fr., *Amanita caesarea* (Scop.) Pers., *Tricholoma terreum* (Schaeff.) P. Kumm., *Lactarius deliciosus* (L.) Gray, and *Russula cyanoxantha* (Schaeff.) Fr. Even the famed Perigord or European black truffle (*Tuber melanosporum* Vittad.) is known to occur with *Cistus* spp. in limestone sites (Olivier et al. 1996). Mycorrhizal associations between *Cistus* and *Boletus* spp. (including *Boletus edulis* and *B. aereus*) have been reported from Italy (Lavorato 1991) and western Spain (Oria-de-Rueda 2002). Other boletes also associate with *Cistus*, e.g., *Leccinum corsicum* (Rolland) Sing. and *Chalciporus piperatus* (Bull.) Bataille.

Our study focused on two particular cistaceous shrubs, *Cistus ladanifer* L. and *Halimium lasianthum* (Lam.) Spach. *Cistus ladanifer* has a circum-Mediterranean distribution. In Spain, this species covers an area of approximately 1,500,000 hectares (ha), of which 50,000 ha are located in Castilla y León Autonomous Community. It can either form pure stands or exist as part of the mixed understory which covers large areas dominated by Mediterranean forests.

The second shrub, *Halimium lasianthum*, is widespread on degraded forest areas, abandoned fields, and pasturelands in the western Iberian Peninsula, western France, and northwestern Africa. This species is not as xerophilous as *C. ladanifer*, but pyrophytic communities composed mainly of *H. lasianthum* and other cistaceous as well as ericaceous shrubs are common in the study area. The mushroom community associated with these two plants include species associated only with cistaceous shrubs, e.g., *Hebeloma cistophilum* Maire, *Lactarius tesquorum* Malencon, *Leccinum corsicum*, and *Russula cistoadelpha* M.M. Moser & Trimbach, as well as cosmopolitan species able to form mycorrhiza with a broad range of tree and shrub hosts, e.g., *Amanita muscaria* (L.) Lam., *A. pantherina* (DC.) Krombh., *Boletus edulis*, and *B. aereus* (Milne 2002; Moreno et al. 2003; Oria-de-Rueda 2002).

The harvest of edible ectomycorrhizal mushrooms from forests can be an important source of rural income, in some cases generating higher revenues than timber production (Oria-de-Rueda 1991). But little is known about the bolete-producing potential of the extensive cistaceous scrublands so characteristic of the Mediterranean region. Conversations with commercial mushroom pickers indicated that mature *Cistus* and *Halimium* scrublands in the western portion of Castilla y León Autonomous Community regularly yield *Boletus edulis* and *B. aereus* (Martínez-de-Azagra et al. 1998). In their study of the effects of wildfire on fungal communities, Martin-Pinto et al. (2006) noted the presence of *B. edulis* associated with

young *Cistus ladanifer*. A high production of *Boletus aereus* has also been observed in areas dominated by *Cistus monspeliensis* L. and *C. albidus* L. in the region of Catalonia in northeastern Spain (Vila and Llimona 2002). Yet these scrublands have typically been ignored by land management agencies because they lack timber and other obvious commodities, and their mushroom potential has not been recognized. This study is a first step in determining whether these scrublands are truly "unproductive," as characterized by Ruiz de la Torre (1981), or whether they might reliably generate significant seasonal income in the form of boletes.

## Study Site

Our study was carried out at elevations of 600–1,200 meters (m) in the Carballeda and Valle de Benavente areas of northwestern Zamora Province (Castilla y León Autonomous Community) in northwestern Spain (Fig. 1). Native forest stands in this area are formed mainly by *Quercus ilex* subsp. *ballota* (Desf.) Samp. and *Q. pyrenaica* Willd., while degraded areas are occupied by Mediterranean scrub dominated by *Cistus ladanifer* and *Halimium lasianthum*, together with *Q. pyrenaica* and *Erica australis* L.

Scrublands dominated by *Cistus ladanifer* and *Halimium lasianthum* were analyzed in each area. The *Cistus* and *Halimium* plants were mainly two to three years old, since the ground had up until recently been dedicated to agriculture. Other prevalent plants in the study areas included *Agrostis castellana* Boiss. and Reut., *Carlina corymbosa* L., *Centaurea castellana* Boiss. & Reut., *Cladonia foliacea* (Huds.) Willd., *Cytisus scoparius* (L.) Link, *Dactylis glomerata* L., *Erica scoparia* L., *Eryngium campestre* L., *Evernia prunastri* (L.) Ach., *Genista florida* L., *Halimium umbellatum* subsp. *viscosum* (Willk.) O. Bolòs & Vigo, *Rosa canina* L., *Sanguisorba minor* Scop., and *Thymus mastichina* L.

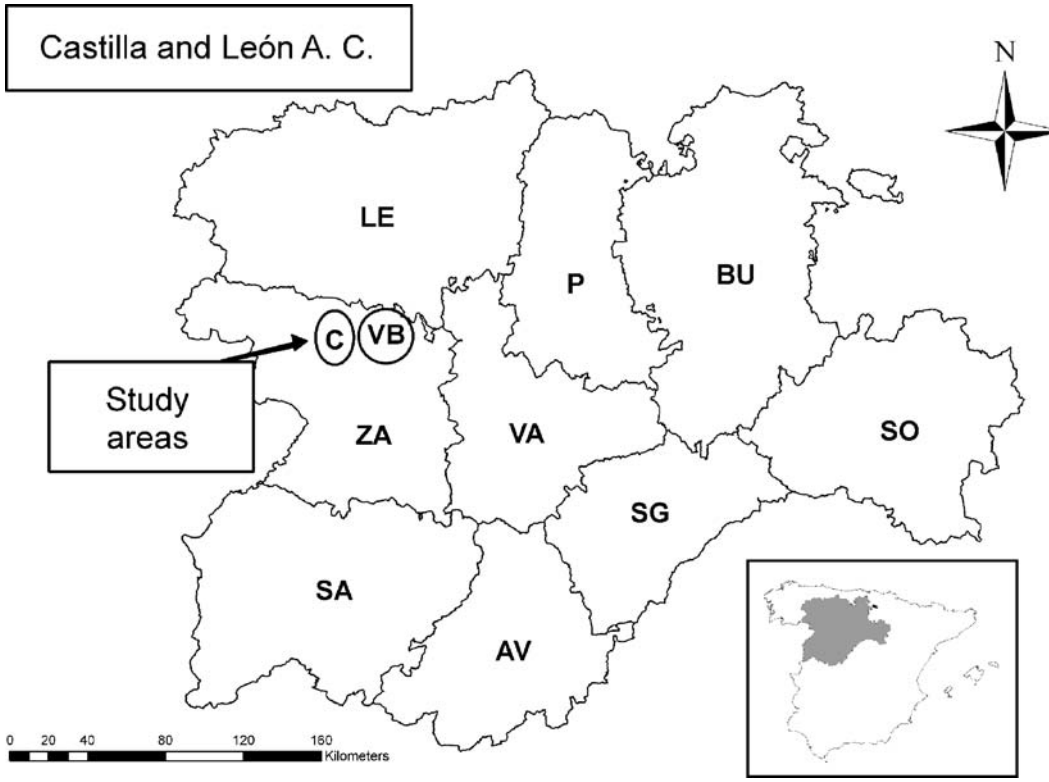


**Fig. 1.** The approximate location of the two study sites (C=Carballeda; VB=Valle de Benavente) in Zamora province of Castilla and León Autonomous Community: AV, Avila; BU, Burgos; LE, León; P, Palencia; SA, Salamanca; SG, Segovia; SO, Soria; VA, Valladolid; ZA, Zamora.

This region has a sub-Mediterranean climate with a three-month summer dry season and mean annual rainfall of 750 mm and 450 mm for the Carballeda and Valle de Benavente areas, respectively, and mean temperatures of 10 and 12°C. The soil is classified as an Inceptisol.

## Sampling Methods

Twelve permanent sampling plots were randomly selected and then analyzed from 2001 to 2004. Three in each location were dominated by *Cistus ladanifer* and three by *Halimium lasianthum*. The 2 m × 50 m plots were established in accordance with previous studies (Dahlberg and Stenlid 1994). As a decline in mushroom production has not been observed when mushrooms are repeatedly harvested (Egli et al. 2006), the plots were harvested once a week during the fruiting season (October–December of each year) (see Dahlberg 1991). The harvesting was always done on a Friday in order to reduce error due to mushroom removal by weekend collectors. On each sampling date, all of the observed mushrooms were harvested and transported to the laboratory, where they were stored at 4°C, and then weighed and identified within 24 hours of collection.

## Results

In the Carballeda plots dominated by *Cistus ladanifer*, mean annual yield was 37.8 kg per ha (fresh weight) for *B. edulis* and 22.5 kg per ha for *B. aereus* (see Table 1). The high production for *B. edulis* was consistent with observations by Martín-Pinto et al. (2006) made during their one-year study of fire and fungal communities. In the Carballeda plots dominated by *Halimium lasianthum*, mean annual yield was 15.15 kg per ha (fresh weight) for *B. edulis* and 5.4 kg per ha for *B. aereus* (see Table 1).

The Valle de Benavente plots were characterized by lower rainfall and higher temperature than the Carballeda plots, and only *B. aereus* was found in these sites. Mean annual production was 47 kg per ha (fresh weight) in the three plots dominated by *C. ladanifer*, and 38.9 kg per ha in the three plots dominated by *H. lasianthum* (see Table 1).

It is interesting to note that in the studied areas, *B. edulis* was harvested only in locations where mean annual rainfall is higher than 700 mm, and typically at altitudes of 1,000 m or more. *B. aereus*, on the other hand, was frequently harvested where mean annual rainfall is less than 500 mm. Though our study was not specifically designed to test for rainfall and temperature differences, the absence of *B. edulis* in the warmer, drier valley plots was not surprising, as many years of field observation by the authors suggest that *B. aereus* is a more xerophilous and thermophilous species than *B. edulis*.

We also found that the *B. edulis* fruiting bodies collected from the Carballeda *Cistus* plots were small for the species: 4–14 cm in cap diameter with a mean of 10 cm. In contrast, *B. edulis* collected from local forest stands can reach 30 cm in diameter (Sánchez and García 2006). As previously noted, the scrubland boletes (*zamoranitos*) are prized for their uniformly small size. Tejedor and Basso (2004) noted that cap diameter of *Lactarius deliciosus* was smaller when associated with *Cistus ladanifer* than with *Pinus pinaster* Aiton. A similar host-dependent size difference appears to occur with *B. edulis*. (*B. aereus* collected from the scrubland plots were also observed to be smaller than B. *aereus* from forests, but the mushrooms were not measured.)

Our most dramatic finding, however, was that high yields of both *B. edulis* and *B. aereus* were

TABLE 1. PRODUCTION OF *BOLETUS EDULIS* AND *B. AEREUS* (KG PER HA FRESH WEIGHT) ASSOCIATED WITH *CISTUS LADANIFER* AND *HALIMIUM LASIANTHUM* AT THE TWO STUDY SITES.

| | | *Boletus edulis* | | | | | *Boletus aereus* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2001 | 2002 | 2003 | 2004 | Mean | 2001 | 2002 | 2003 | 2004 | Mean |
| Carballeda | *Cistus ladanifer* | 65.0 | 32.2 | 26.4 | 27.6 | 37.8 | 8.9 | 36.3 | 42.7 | 2.1 | 22.5 |
| | *Halimium lasianthum* | 27 | 18.1 | 12.3 | 3.2 | 15.1 | 5.3 | 5.1 | 3.2 | 8.1 | 5.4 |
| Valle de Benavente | *Cistus ladanifer* | 0 | 0 | 0 | 0 | 0 | 12.9 | 26.2 | 137.0 | 12.0 | 47.0 |
| | *Halimium lasianthum* | 0 | 0 | 0 | 0 | 0 | 86.2 | 4.3 | 65.0 | 0 | 38.9 |

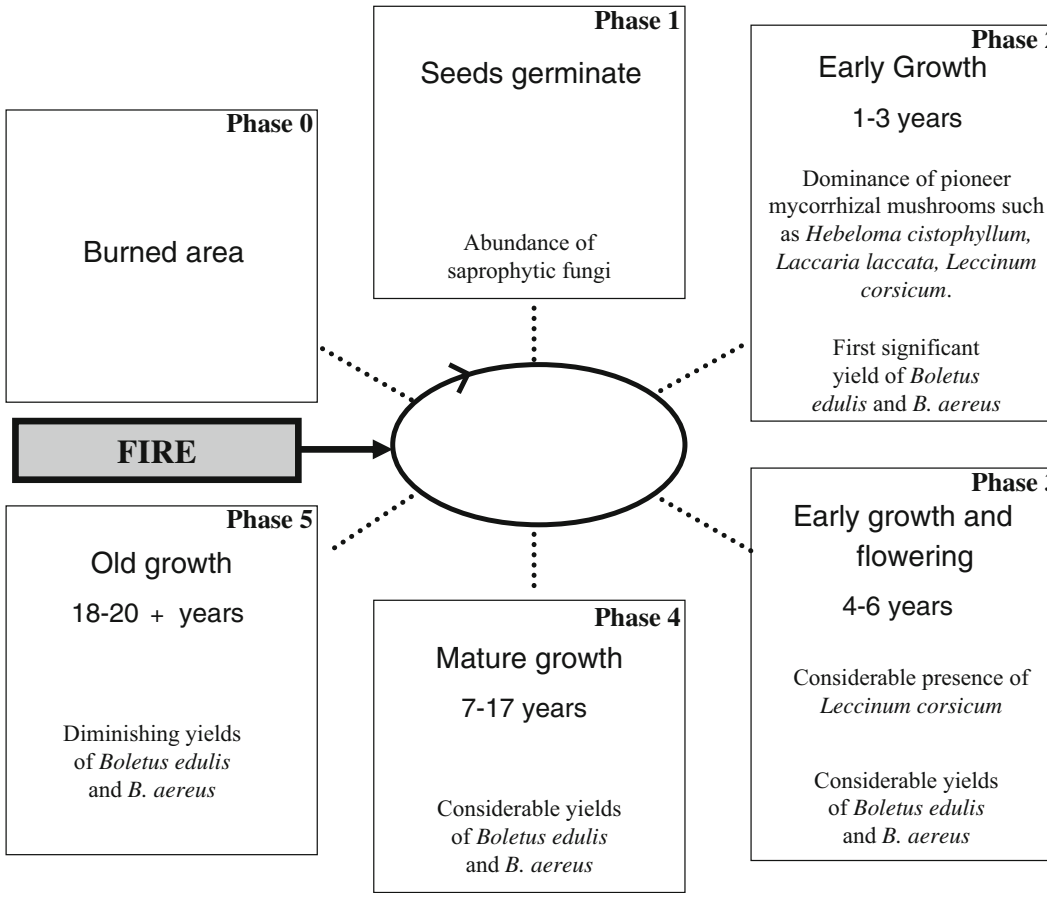


**Fig. 2.** Phases in the lifespan of *Cistus ladanifer* and its associated, commercially valuable boletes.

associated with cistaceous shrubs as young as three years. In contrast, Diaz-Baleiro et al. (2003) found that in *Pinus* and *Quercus* stands the same boletes are typically associated with trees which are more than 40 years old (Díaz-Balteiro et al. 2003), while Martinez (2003) found that *B. edulis* associated with *Pinus sylvestris* was absent in young (15-year-old) stands, present in medium-aged stands (47 kg per ha annually from trees 31–50 years old), and most prevalent in mature stands (71 kg per ha annually in stands 51–70 years old).

## Management Considerations

In the study area, as well as in other parts of Europe, the commercial value of forests can be increased through well-planned timber removals that may improve the habitat for commercially valuable edible mushrooms and provide wood and employment at the same time (Bonet et al. 2004; Pilz et al. 1999; Pilz et al. 2003; Wang and Hall 2004).

Fire is a dominant factor in the evolution and ecology of these Mediterranean ecosystems (Trabaud 1990; Ne'eman et al. 1995). *Cistus* and *Halimium* species are important pioneers after fire, when, stimulated by a temperature increase, they germinate rapidly from a persistent seed bank in the soil (Calvo et al. 2003) (see Fig. 2). *Cistus* and *Halimium* also colonize abandoned (formerly cultivated) grounds after 1–3 years, providing adequate conditions for the presence of *Boletus edulis* and *B. aereus*.

In both burned and abandoned ground, cistaceous shrubs can dramatically alter surface soil characteristics and erosion rates (Amaranthus 1989) and can act as a bridge for ectomycorrhizal mushrooms, favoring the eventual establishment of mature tree stands (Milne 2002). Their function as an ectomycorrhizal bridge is highlighted by our study, which shows that boletes fruit in 3-year-old stands (and may establish their

mycorrhizae earlier). But cistaceous shrubs are short-lived, and in the last stage of succession, when they are 18–20 years old, humidity and environmental conditions are optimal for the ignition and spread of fire. Management should be focused on avoiding uncontrolled or catastrophic fires. Destroying dead plants by mechanical tools or by prescribed and controlled fire in local areas could avoid serious ecological and economic losses. The resulting mosaic landscape has at least two additional advantages: first, it provides income from the harvest of highly esteemed mushrooms; and second, it provides the food and cover necessary for popular game species such as red-legged partridge (*Alectoris rufa* L.), European rabbit (*Oryctolagus cuniculus* L.), and brown hare (*Lepus granatensis* L.).

In scarcely productive, poor, and dry agricultural soils, plantations of cistaceous shrubs inoculated with boletes could be developed as a crop. In young forests, the establishment of an understory of inoculated *Cistus* and *Halimium* shrubs could also lead to an early and more reliable mushroom yield, since the shrubs produce boletes at a much earlier age than the trees. Inoculation procedures are currently being investigated in our laboratory as per Rincón et al. (2001).

## Conclusion

Although members of the Cistaceae frequently grow after fire, and some highly esteemed mushrooms decrease significantly in numbers following fire (Martín-Pinto et al. 2006), our study shows that scrublands dominated by *Cistus ladanifer* and *Halimium lasianthum* can provide considerable yields of the commercially valuable mushrooms *Boletus edulis* and *B. aereus*. In other words, these scrublands are not "unproductive" as characterized by Ruiz-de-la-Torre (1981).

Yields of both species were smaller than the optimum yields of forest stands (Martinez 2003), but the mushroom production is initiated much earlier (on 3–4-year-old plants) than it is with pine trees (30–40 years or more). Therefore, there is income potential not only in scrublands but also in forests with young (preproductive) trees and a cistaceous understory.

While additional, more rigorous studies are desirable before generalizing our productivity figures to other regions, our results do demonstrate that scrubland boletes should be an important consideration for land managers around the Mediterranean, especially given the preponderance of cistaceous scrublands (up to 10,000 ha in the study area alone). If attention is given to promoting and expanding the scrubland bolete crop, it could be a valuable stimulant to local rural economies, especially since a high percentage of rural families are already involved in the commercial harvesting and processing of boletes and other wild mushrooms.

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