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The relationship between *Cerambyx* spp. damage and subsequent *Biscogniauxia mediterranum* infection on *Quercus suber* forests

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Abstract

In this paper we shall show the first data on the level of *Cerambyx* spp. beetle damage and the subsequent *Biscogniauxia mediterranum* (De Not) Kunze fungus infection in the Extremadura region (southwestern Spain). Our results indicate a strong correlation between damage, caused by bad cork removal and pruning practices (injuries that cannot heal and permit the attack of insects), and holes made by beetles ($r = 0.86$). The relationship between holes and subsequent *Biscogniauxia* infection was $r = 0.91$. Different regression models have been proposed in order to find mathematical equations applied to forest health monitoring of wide areas. Additionally, we show the evolution in infection after 14 years in the four different areas. The results indicate an increase in damage by *Cerambyx* and *Biscogniauxia* infection after this period. Significant differences were found when comparing the four areas suggesting that local factors can be affecting these pests. Finally, we discuss the possible influence of different sociological, economic and agricultural factors on the management and conservation of *Quercus suber* forests in southwestern Spain and we propose possible solutions to integrate biological conservation and economic benefits of a sustainable cork industry associated with these Mediterranean forests.

Keywords: *Quercus suber*; Spain; *Cerambyx*; *Biscogniauxia mediterranum*

1. Introduction

Quercus forests (*Quercus rotundifolia*, *Quercus suber*, *Q. faginea* and *Q. pyrenaica*) of the Extremadura region (southwestern Spain) are agroecological systems similar to savanna, and characterized by the presence of livestock and/or wild species. These forests are commonly named dehesa and cover approximately 5,800,000 ha in western and southwestern Spain where they represent 52% of useful agrarian surface (Díaz et al., 1997). The dehesa is one of the last examples of traditional rural agroecological systems in Europe (Fabbio et al., 2003; Joffre et al., 1999; Morillo and Gómez, 2000). Nevertheless, the survival of the dehesa is threatened by different environmental problems. One of them is overgrazing by livestock (Plieninger et al., 2004; Leiva and

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Fernández, 2003; Pulido et al., 2001, 2003). Together with livestock husbandry, the dehesa has been exploited for pruning in a clear model of multiple uses, thus, maintaining its ecological equilibrium and adaption to the sociological and economic framework of Mediterranean areas of Southern Europe (Scarascia-Mugnozza et al., 2000; Schmitz et al., 2003). From a methodological point of view, it has been demonstrated that this multi purpose management contributes to increasing plant and animal biodiversity in forests (Piussi and Farrell, 2000). These strategies of management are necessary in Mediterranean areas since *Quercus* species present a very low growth rate, a strong seasonality and they are not physiologically adapted to an intensive pruning (Baldocchi et al., 2004). In fact, the increase in the last decades of intensive management practices in Mediterranean forests, is producing a strong decrease in their regeneration and a parallel increase in their vulnerability to diseases (Piussi and Farrell, 2000). More specifically, *Q. suber* forest management in southwestern Spain, includes at least two treatments: pruning (Cañellas and Montero, 2002) and cork removal (Barberis et al., 2003; Borges et al., 1997). Nevertheless, cork removal is the main use of this tree species, mainly due to the low nutritive value, palatability and productivity of *Q. suber* acorns, in contrast to *Q. rotundifolia*, together with the high price of cork in the present European markets. Recently, different mathematical models have been developed to calculate the exact cork yield in the dehesa (Costa et al., 2001, 2003; Fonseca and Parresol, 2001). In the Extremadura region cork oak forests cover 252,140 and 600,000 ha mixed with other species. The cork related production in the last years varied from 18 500 Tm (1999) to 24 000 Tm (2003), this figure represents about a quarter of the Spanish production depending on the year. In 2003, the cork sector employed 1300 workers in the forest duties during 2 months with an average daily salary of 80€. In 2003 to the local cork production were added 18,000 Tm imported from other Spanish and Portuguese regions and 6500 Tm were exported without any transformation. The average non-manipulated cork price in 2003 was 2€/kg. After the first industrial treatment the cork price increased to 6€/kg and during this year 24,000 Tm were transformed. Secondary processes or cork for taps, agglomerates and similar products increase the prices per kg but these prices can vary according to the quality of the cork extracted in any particular year. These manufactured products were 24,000 Tm in 2003 for the Extremadura region.

Present costs of the cork removal process due to the high salary of specialized workers and the costs of chemical treatment in the industry has produced an important decrease in the profit margins of this traditional management (Benitez et al., 2003).

According to Fialho et al. (2001) cork removal does not affect the radial growth rate but has a slight effect on leaf abscission. Nevertheless, a bad cork removal process impedes the natural healing of injuries and facilitates the development of diseases (Montoya Oliver, 1988). A phenomenon with a high incidence in the cork oak forests of Sierra of Jerez is the attack of *Cerambyx* beetles. This environmental pest affects a large number of trees and forest areas. The life cycle of *Cerambyx cerdo* (El Antry, 1999) begins with larvae development that is produced 10 days after egg-laying. In the next 28 months this species has five larval instars. According to Montoya Oliver (1988) the larval stage increases in size up to approximately 70 mm in length and 16 mm wide. Adults remain inactive for a further 7 months until spring when they emerge to mate. The average longevity of the imago is 13 days and the maximum fecundity reaches approximately 305 eggs. Exit holes produced by *Cerambyx* larvae are one of the entryways of fungal infection by *Biscogniauxia mediterranum*. Under natural conditions, this fungus disease attacks decrepit *Quercus* trees or trees that suffer damage of a meteorological or biotic origin. In managed forests, the fungus spore are transported by pruning or cork removal forestry equipment infecting other trees. This fungus has a very slow growth and remains in the tree until the infection is very advanced. Then it produces the spore and the typical charcoal black surface in the branches and trunks then appears. In healthy trees with a low level of injuries a certain resistance can be shown and the progression of the disease stops. In other cases, charcoal disease can kill the tree (Montoya Oliver, 1988).

According to European Directives for the preservation of the natural environment (Habitat Directive, 1992, Annex I,) the oak and holm-oak forests are protected in Europe. Therefore, the pest control of *Cerambyx* spp. could be a desirable management strategy. Nevertheless, some species of the Cerambyx