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Artificial regeneration with *Quercus ilex* L. and *Quercus suber* L. by direct seeding and planting in southern Spain

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Abstract

• **Introduction** The limited ability of *Quercus* species to regenerate naturally in Mediterranean forests has led to the development of various artificial regeneration methods; however, there is no general consensus as to what specific method is the best one for this purpose.

• **Material and methods** In this work, we assessed morphology, growth and survival of two *Quercus* species (*Quercus ilex* ssp. *ballota* and *Quercus suber*) using two different methods of artificial regeneration (viz. direct seeding and planting) and two seedling ages (1-year-old seedlings and 3-year-old seedlings) in southern Spain.

• **Results and discussion** The 1-year-old seedlings of both species were found to exhibit the highest survival percentages and direct-seeded plants intermediate survival values. For direct-seeded plants, seed mass was found to have a significantly positive effect on the establishment success in both species. No clear-cut trend in survival was detected in the 3-year-old seedlings. The survival of the 3-year-old *Q. suber* seedlings and the direct-seeded plants was similar, but not in *Q. ilex*, where the survival of the 3-year-old seedlings was the

lowest. The latter result may have been a consequence of cultivation in smaller containers leading to root deformation and limiting plant access to water. Differences in survival could not be ascribed to morphological and growth variables or stomatal conductance.

• **Conclusion** Based on the results, all three artificial regeneration methods can be similarly effective provided appropriate nursery cultivation conditions are used and seeds are protected against predators, the best choice in each case being dictated by the particular restoration goals.

Keywords Artificial regeneration · Nursery · Oak · Seedling age · Sowing

1 Introduction

Holm oak [*Quercus ilex* L. ssp. *ballota* (Desf.)] and cork oak (*Quercus suber* L.) are two evergreen woody species widely represented in the wild and managed forests of the Iberian Peninsula. Also, they constitute two essential elements of the agro-sylvopastoral system known as “dehesa”. Ensuring sustainable use of natural resources in savanna-like ecosystems (dehesas) is of great economic importance for rural areas.

Oak tree mortality has increased considerably over the past 20 years due to the effect of the combined action of pathogens, xylophagous insects and adverse climate conditions (Brasier 1996). Poor regeneration (Smit et al. 2009) and high adult mortality (Brasier 1996) in many areas have led to the implementation of artificial regeneration programmes, mainly in areas where the tree population has declined or disappeared, or the land has been converted to agriculture.

Artificial regeneration with *Quercus* trees is limited by many factors including acorn predation, slow growth, and

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