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ORIGINAL PAPER

Performance and nutrient dynamics of holm oak (*Quercus ilex* L.) seedlings in relation to nursery nutrient loading and post-transplant fertility

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Abstract Holm oak (*Quercus ilex* L.) seedlings were exponentially (E) nutrient loaded using incremental increases in fertilizer addition or conventionally (C) fertilized using a constant fertilizer rate during nursery culture. The fertility treatments (mg N plant^{-1}) were control (0), 25E, 100E, and 100C. Subsequently, 1-year-old plants were transplanted under simulated soil fertility gradients in a greenhouse to evaluate effects of nutrient loading and post-transplant fertility on seedling performance. Post-transplant fertility consisted of fertilizing plants at two rates (0 vs. 200 mg N plant^{-1}). A water-soluble fertilizer 20-20-20 was supplied in both nursery and post-transplant experiments. Nutrient loading increased plant N content by 73% in 100E and by 75% in 100C relative to controls, although no significant differences were detected between constant and exponential fertilization regimes at the 100 mg N plant^{-1} rate. When transplanted, nutrient loading promoted post-transplant root growth relative to shoot, implicating potential to confer competitive advantage to loaded holm oak seedlings after trans-planting. In contrast, post-transplant fertility increased new shoot dry mass by 140% as well as N, P and K content relative to controls. Results suggest that holm oak seedlings can be successfully nutrient loaded in the nursery at higher fertility rates, improving its potential to extend new roots, but alternative fertilization regimes and schedules that better fit nutrient availability to the growth rhythm and conservative strategy of this species must be tested.

Keywords Exponential fertilization · Forest restoration · Nitrogen · Mineral nutrition · Remobilization

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Introduction

Holm oak (*Quercus ilex* L.) is an important evergreen tree species widely used for forest restoration in Mediterranean ecosystems (Rodà et al. 1999; Rey Benayas and Camacho-Cruz 2004). Holm oak survives and grows from warm and arid areas to dry and cold highlands and mountains in Spain and the western Mediterranean basin (Ruiz de la Torre 2006). This is mainly due to its ability to cope with summer drought by different water stress avoidance and tolerance mechanisms (Hinckley et al. 1983; Romane and Terradas 1992; Terradas and Savè 1992). However, seedlings are vulnerable to transplanting stress and to summer drought, exhibiting high mortality and slow growth compared with other Mediterranean species (Rodà et al. 1999). Water deficits (Gakis et al. 2004; Villar-Salvador et al. 2004a, b), low site fertility (Pardos et al. 2005; Valdecantos et al. 2006; Sanz-Perez et al. 2007), and poor seedling quality (Villar-Salvador et al. 2004a) are key factors that could explain poor survival and growth of holm oak seedlings in restoration plantings in Mediterranean ecosystems.

Field fertilization has the potential to ameliorate nutrient limitations on low-fertility soils and enhance seedling growth (Vilà and Terradas 1995; Jacobs et al. 2005;