

EFFECTS OF LATE-SEASON FERTILIZATION ON FIELD PERFORMANCE OF QUERCUS ROTUNDIFOLIA SEEDLINGS

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Abstract:

Restoration of degraded Mediterranean ecosystems frequently demands the re-introduction of plant species. Planting is often recommended when seeds are not available or post-seeding conditions are harsh. However, seedling morpho-functional traits allowing high survival probability and early growth are largely unknown. We hypothesized that seedling nutrient content positively affects seedling rooting capacity and performance. We tested this hypothesis by applying late-season fertilization to *Quercus rotundifolia* seedlings and evaluating their performance in lysimeter and field experiments. We found that autumn fertilization did not affect seedling size but greatly improved seedling nutritional status. In lysimeters, we found no effect of fertilization on early growth rate and rooting ability. In the field, growth rate was lower in unfertilized seedlings but transplant mortality was very low and similar to fertilized seedlings. Seedling performance during summer will help to assess the interest of late-season fertilization.

Keywords: *Quercus ilex*, Holm oak, seedling quality, nursery culture (9340)

Introduction

Mediterranean landscapes have been affected by human activity for millennia. Since the early 20th century, vast areas once covered by cropland and pastures are now reverting to forests and shrublands. But spontaneous recovery is not always possible or at least not at the speed that society demands.

The lack of propagules and the establishment of communities arresting further succession preclude the establishment of key components of Mediterranean woodlands. This problem has been recognised for centuries, prompting the development of large forestation projects. For various reasons, by the second half of the 20th century, the array of species used in these projects was reduced to a few conifers. Later, increased sensitivity towards restoring ecosystems and deeper knowledge on the dynamics of Mediterranean ecosystems and species fostered the use of a wider range of species. However, information on the best practices to establish them was largely lacking.

For the last decades, researchers and managers have improved silvicultural techniques, enhancing plantation success. One of the areas receiving more attention has been the production of nursery seedlings. Still, our knowledge on the traits defining optimum seedling quality is incomplete. Several studies have suggested that nutrient content could be directly related to field survival and growth (Villar et al., 2004). But the relation cannot be generalised. Our own results show that nutrient deficient seedlings of Mediterranean woody species may perform better than fully fertilised seedlings in semi-arid areas (Trubat et al., 2004; Trubat et al., 2007). In addition, studies relating nutritional status and seedling performance may be confounded by covariance in other seedling traits.

We have carried out a field and rhizotron experiment to assess the effect of nutrient status on the performance of *Quercus rotundifolia* Lam. seedlings. We avoided the

confounding effect of other seedling traits, particularly morphological and anatomical traits, by applying late season full fertilisation to nutrient deficient seedlings. Our hypothesis is that nutrient deficient seedlings would show lower ability to root and establish than well fertilized seedlings.

Materials and methods

Seedling production. In October 2006 we sowed *Quercus rotundifolia* acorns from local provenance in 305 cm³ containers filled with a buffered unfertilized peat. From late October 2007 to March 2008, half of the seedlings were fertilized by watering them once a week with a nutrient solution containing 100 µg L⁻¹ N, 43.5 µg L⁻¹ P and 83.3 µg L⁻¹ K. Then, we randomly sampled 10 unfertilized and 10 fertilized seedlings and measured root collar diameter, stem height and photosynthetic pigment content using a non-destructive chlorophyll meter (SPAD-502, Minolta Camera Co. Ltd., Japan).

Lysimeter experiment. We used a factorial design with nursery fertilization as fixed factor, and soil depth and rock content as random factors with 2 levels each and N=5-7 replicates, to evaluate the response of fertilized and unfertilized seedlings under contrasting soil conditions. In March 2008 we planted one seedling in each of forty-eight 40 x 40 cm wide and 70 cm depth lysimeters simulating a planting hole (CEAM Foundation, patent pending). The front wall of the lysimeters is covered by acrylic glass and slightly tilted, allowing for direct observations of fine roots. Lysimeters were filled with carbonated forest soil to a depth of 35 cm and 65 cm. In addition, 50% of the soil volume was filled with ca. 15 cm diameter limestone rocks in half of the lysimeters. We monitored root growth between March and July 2008, and measured stem height and pigment content on July 2008.

Field performance. In February 2008 we planted 40 fertilized and 40 unfertilized seedlings in each of 16 plots in Gallinera, Ebo and Alcalà Valleys (Alicante, E Spain) distributed over a 2,000 ha restoration project. Climate is dry subhumid and soils are shallow, carbonated and moderate to highly rocky. Seedlings were planted on 40 x 40 x 40 cm holes and were protected with plastic treeshelters. We measured seedling survival and growth between March and July 2008.

Results and discussion

Autumn fertilization did not affect seedling size by the end of the nursery period, but it substantially improved nutritional status, as reflected by the increase in pigment concentration (**Table 1**).

Table 1. Morphological traits and pigment concentration in seedlings of *Quercus rotundifolia* unfertilized and subjected to autumn fertilization. Averages, standard errors, and results of analyses of variance are shown for N=10 seedlings per treatment.

Treatment	Root collar diameter (mm)	Stem height (cm)	SPAD (rel. units)
Control	3.1±0.2	7.6±0.5	34±2.2
Fertilized	3.3±0.2	7.7±0.4	42±1.0
F _{1,18} , p	0.054, 0.342	0.033, 0.858	9.853, 0.0

Differences in pigment concentration were still evident in lysimeter seedlings by July 2008 (**Table 2**). But the growth rate of seedlings planted in lysimeters, and indicators of rooting efficiency such as the time for the first root to be observed, and the time to reach the maximum observed rooting depth, showed no effect of fertilization.

Seedling transplant shock in the field was very low, as common in Mediterranean areas. Average survival rate by July 2008 was $98\pm 1\%$ (mean \pm SE) for both fertilized and unfertilized seedlings. Relative growth rate in the field between March and July 2008 was higher in seedlings receiving autumn fertilization than in control seedlings ($F_{1,279} = 42.2$, $p < 0.001$ and $F_{1,279} = 2.64$, $p < 0.001$, for factors Fertilization and Plot, respectively; **Fig. 1**).

Table 2. Pigment concentration and stem height in July 2008, time for the emergence of the first root and time to reach maximum rooting depth of seedlings of *Quercus rotundifolia* subjected to autumn fertilization (F+) and unfertilized (F-). D-/D+ correspond to soil depths of 35 and 65 cm, respectively. R-/R+ correspond to lysimeters without and with rocks, respectively. Note that rootable soil volume increases downwards for each fertilization treatment. Means and standard errors of N=5-7 seedlings per treatment are shown. Only Fertilization had a significant effect on SPAD ($p < 0.001$).

Treatment			SPAD	Stem height	Time for 1 st root	Time for max. rooting depth
			(rel. units)	(cm)	(days)	(days)
F-	D-	R+	32.9 \pm 1.8	10.0 \pm 1.9	25.8 \pm 5.3	46.4 \pm 4.1
F-	D-	R-	33.7 \pm 1.1	9.3 \pm 1.1	25.5 \pm 2.3	37.3 \pm 5.1
F-	D+	R+	30.3 \pm 3.8	7.7 \pm 0.7	27.4 \pm 3.0	56.0 \pm 8.7
F-	D+	R-	37.4 \pm 2.4	8.2 \pm 0.6	21.4 \pm 3.7	57.2 \pm 15.4
F+	D-	R+	36.3 \pm 1.8	7.7 \pm 0.5	25.6 \pm 6.1	61.8 \pm 12.7
F+	D-	R-	42.2 \pm 0.9	13.1 \pm 1.8	24.3 \pm 3.3	57.7 \pm 9.2
F+	D+	R+	41.4 \pm 1.2	11.5 \pm 1.3	25.3 \pm 5.0	61.2 \pm 9.4
F+	D+	R-	38.9 \pm 0.6	10.4 \pm 1.6	28.7 \pm 9.2	57.0 \pm 11.6

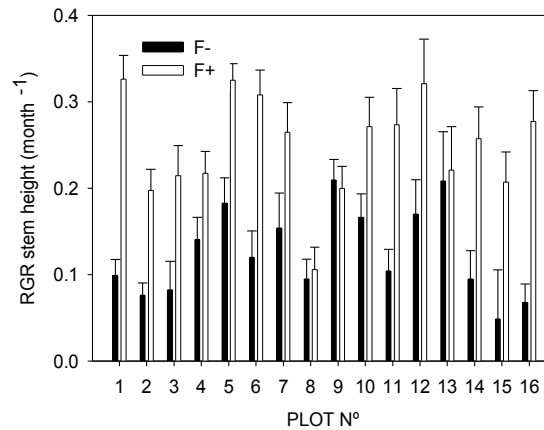


Figure 1. Relative growth rate in stem height of *Quercus rotundifolia* seedlings planted on 16 experimental plots in Alicante (E Spain), as affected by autumn fertilization. F-/F+ correspond to unfertilized and fertilized seedlings, respectively. Bars are averages and standard errors of N = 10 seedlings per treatment and plot.

Conclusions

We have shown that autumn fertilization is a suitable technique to improve seedling nutritional status while avoiding excessive aboveground growth in the nursery. Our results suggest that the ability of nutrient deficient seedlings to colonize the soil is not reduced. A decreased growth rate in the field, however, may indicate lower ability to access enough soil volume to ensure survival during maximum summer drought. As observed in other studies, transplant shock was negligible. Next months will be crucial to evaluate the effect of autumn fertilization and seedling nutritional status on seedling performance.

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