Chapter 12

Field Techniques to Improve Cork Oak Establishment

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Chapter 11 detailed best practices in germplasm selection and nursery techniques for active restoration of cork oak woodlands. In this chapter we focus on field techniques. In parts of its range in the western Mediterranean, the surface area covered by cork oak woodlands has been declining (Natividade 1950), and this decline probably is not as recent as it sometimes appears (Parsons 1962), nor is it unique; other Mediterranean oaklands show similar, equally worrisome trends (Pulido 2002). However, concern for the future of cork oak woodlands has fostered vast revegetation and restoration programs in recent years (e.g., Andrade 2003; Berrahmouni et al. 2005). Unfortunately, in addition to a progressive reduction in woodland area, cork oak often shows poor recruitment, the technical term for spontaneous regeneration via seedlings, regardless of the technique used for afforestation and restoration. This endangers the persistence of existing forests and limits the tree's potential to colonize new areas, as noted in Chapter 10. The reasons for low regeneration are numerous and may be site specific. Acorn predation, harvesting and herbivory on seedlings by various animals, unfavorable climatic conditions for seedling establishment, pests, competition, changes in fire frequency, and human-induced changes in forest composition are the main constraints to cork oak recruitment (Natividade 1950; Cabezudo et al. 1995).

Caution is warranted before we can draw any conclusions, however. The aforementioned studies were based primarily on observations rather than controlled experiments, and current knowledge on the driving factors and obstacles to cork oak recruitment is scarce (see Chapter 10). This limits our ability to prescribe successful field techniques for the establishment of cork oak seedlings. In addition, the costs of site preparation, seedling planting, and aftercare may amount to two thirds of overall plantation expenditures. Therefore, technical improvements are needed to help reduce the costs of planting and replanting for afforestation and restoration. In this chapter we review available field techniques to improve cork oak establishment and discuss the ecological bases for selection of available techniques. We focus on afforestation and *active restoration*, via acorn seeding and seedling plantings, because spontaneous regeneration (passive restoration) was discussed in Chapter 10.

Direct Seeding

Direct seeding was the preferred technique for reintroducing cork oak in the past, and it is still frequently used in some areas (Mesón and Montoya 1993). The main benefits, as compared to planting out of nursery stock, are the low cost and the advantage that an acorn sown in situ develops a normal taproot, whereas that of nursery seedlings often must be cut or pruned before being transferred to the field. An unpruned taproot may confer an advantage to cork oak, as for other trees that grow in areas with seasonal drought and that rely on an early exploration of deep soil horizons to ensure establishment (Rambal 1984; Pulido 2002). Acorn predation can be substantially reduced by wrapping individual acorns with a metal screen or hard cloth before seeding or covering the acorn, once seeded, with a small piece of metal screen (Schmidt and Timm 2000; J. Pons, personal communication, 2004). Protecting seeded acorns with tree shelters inserted a few centimeters into the soil may also work (Vilagrosa et al. 1997), provided that tree shelters do not attract large predators, which is sometimes the case.

Direct seeding can be an effective, rapid, and inexpensive forestation technique. However, planting of seedlings is still preferred in most cork oak planting programs, and many people mistrust direct seeding. However, most recorded failures in the use of this technique are probably the result of improper implementation, including poor selection of sites and seeding season, inadequate site preparation, low seeding density, and the use of poor-quality or unprotected seeds.

Seedling Planting

Given all the problems with direct seeding, planting nursery-grown seedlings probably is the best way to ensure cork oak regeneration (see Color Plate 13). However, there are drawbacks with this approach as well. In this section we review major field constraints for the establishment of nursery-grown seed-

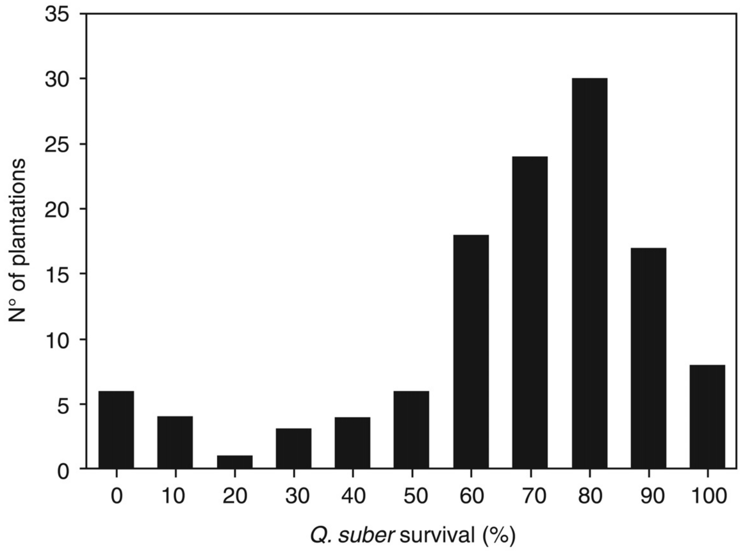

FIGURE 12.1. Frequency of experimental cork oak plantations ranked according to the survival rate of this species after the first summer in the field. Most of the plantings were performed after intense site preparation. (Data from Varela 2000; Oliet et al. 2003; Messaoudène unpublished data; Pérez-Devesa unpublished data)

lings in the field and the techniques developed to overcome those limitations. Seedling survival in the field shows varying results, as shown in Figure 12.1. This may be a consequence of various factors, including improper site preparation, and clearly there is much room for improvement.

Interactions between Extant Vegetation and Introduced Cork Oak

Studies of cork oak seedling density reveal that recruitment rates can be highly dependent on plant cover and community composition (Herrera 1995; Zaidi and Kerrouani 1998; Pons and Pausas 2006; Acácio et al. 2007; Chapter 10). Seedling establishment may be favored by clearing, particularly in *mesic* sites, because shrubs and herbaceous vegetation may compete with introduced seedlings for resources, mainly water and light (Montero and Cañellas 1999). Shrubland clearing may also incorporate organic matter and nutrients into the soil and change microclimatic conditions, temporarily increasing soil fertility.

However, plant–plant interactions are not always negative (Callaway 1995). Many studies have shown that standing vegetation may facilitate seedling performance under Mediterranean conditions (Pulido and Díaz 2005a).

Shading, improved soil fertility, defense against herbivores by spiny nurse plants, and protection from freezing may all play a beneficial role (Maestre et al. 2003; Castro et al. 2004a; Cortina and Maestre 2005). The shift from net positive to net negative plant–plant interactions cannot be easily defined for a particular set of interacting species, however, because the outcomes of the interactions vary spatially and temporally (Maestre and Cortina 2004). This is a major limitation for a straightforward application of scientific advances to restoration practices.

Shrubland clearing, sometimes including uprooting, has been a traditional technique to establish cork oak (Natividade 1950; Lepoutre 1965). Manipulative experiments carried out in Serra d'Espadà (eastern Spain) support the idea that shrubs have a negative effect on the short-term performance of cork oak seedlings (Figure 12.2). However, some studies have shown a negative effect of shrubland clearing on cork oak establishment (Santilli 1998), suggesting that we still lack a full understanding of the interplay between extant vegetation, environmental factors, and cork oak performance.

Other processes beyond plant–plant interactions must also be taken into account in planning for shrubland management (Table 12.1). Natividade (1950) suggested that competing vegetation should be controlled with caution, preserving as much as possible the protective cover of accompanying vegetation and slash. He recommended clearing the shrubland in strips perpendicular to the prevailing slope, preserving some herbaceous cover, a

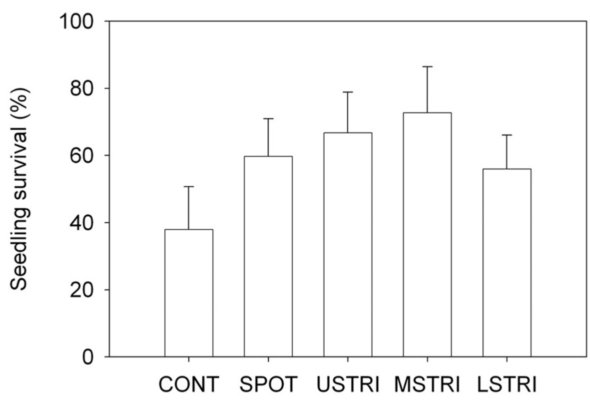

FIGURE 12.2. Effect of shrubland management on survival rates of cork oak seedlings 16 months after planting and after 2 summers in the field. Seedlings were planted in 40-cm^3 holes with minimum shrubland disturbance (CONT); in 2-m diameter circular clearings (SPOT); and in the upslope, middle, and downslope parts of a 5-m-wide cleared strip (USTRI, MTRI, LSTRI, respectively). Bars correspond to average and standard errors of 3 replicated sites.

TABLE 12.1.

Ecosystem-scale effects of shrubland clearing in cork oak plantations

Positive	Negative
Fire protection	Surface soil alteration
Biomass harvest	Erosion risk
Increased palatable vegetation (improved pasture quality)	Alien species invasion
Decreased competing vegetation	
Less habitat for harmful fauna	

Source: Natividade (1950).

suggestion that has been incorporated into the International Code of Good Practices (Proyecto SUBERNOVA 2005).

The positive or negative outcomes and the magnitude of plant–plant interactions may change depending on the identity of the species and their stage of development (Castro et al. 2004a; Gómez-Aparicio et al. 2004). Some studies have shown that cork oak establishment can be facilitated by the presence of native shrubs and trees, such as mastic, strawberry tree, hawthorn, laurustinus, Butcher's broom (*Ruscus aculeatus*), Mediterranean fan palm, tree heath, *Prunus* spp., and *Phillyrea* spp., and hampered by others, such as rockroses, black wattle (*Acacia mollissima*), and various *Eucalyptus* species that are planted in the region (Natividade 1950; Beaucorps et al. 1956; Santilli 1998; Acácio et al. 2007; Figure 12.3). Most of these studies are based entirely on observation; manipulative experiments considering a range of species and environmental conditions are clearly needed.

A completely different situation arises in open cork oak woodlands (e.g., *dehesas* and *montados*), where isolated trees are surrounded by an herbaceous understory. *Canopy* cover reduces high summer temperatures and thermal amplitude, improving plant water relations and seedling survival (Nogueira 2006). But herbaceous vegetation may outcompete oak seedlings (Pulido and Díaz 2005a), and mowing or seasonal grazing can be necessary, as is the case also for holm oak (Plieninger et al. 2004). In addition, herbivore pressure is commonly high in these ecosystems, representing an additional risk for oak seedlings (see Chapter 3). In well-stocked *dehesas* and other cork oak woodlands, temporary suppression of grazing and cropping may be enough to ensure successful recruitment, as for holm oak (Plieninger et al. 2003, 2004). Planting shrub patches to create safe sites for oak seedlings and using other types of shelters may also be advisable to protect seedlings against herbivory (Pulido 2002). Careful soil preparation may be needed when cork oak establishment is main priority, as will be discussed next.

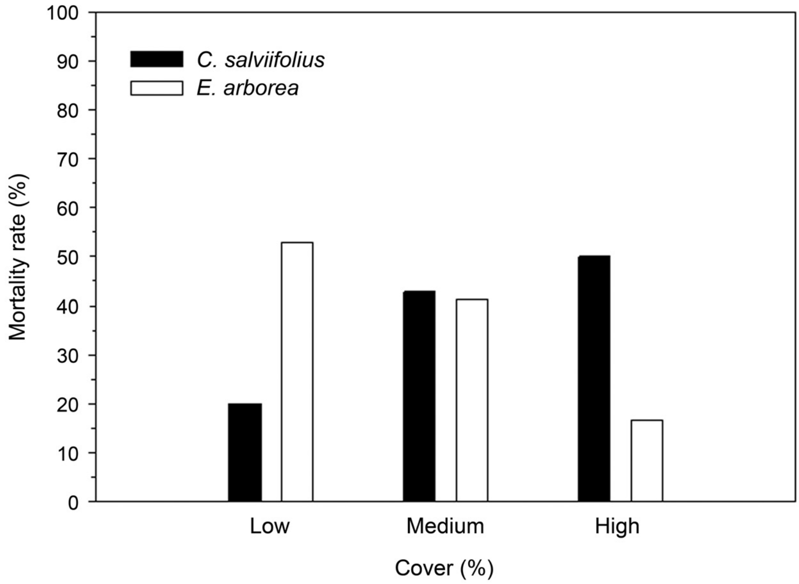

FIGURE 12.3. Effect of shrub species (*Cistus salviifolius* and *Erica arborea*) cover on cork oak seedling mortality 1 year after planting in a shrubland site in Serra d'Espadà (eastern Spain). Shrub cover was estimated on a 2-m-diameter circle around each 40-cm^3 planting hole. Low, medium, and high cover classes correspond to 0–10%, 10–20%, and >20% cover for *C. salviifolius* and 0–10%, 10–25%, and >25% cover for *E. arborea*.

Soil Preparation and Cultural Treatment

The interaction between unfavorable soil conditions and climatic constraints has been identified as one of the major factors limiting seedling establishment, and the improvement of soil properties has high priority in afforestation programs in environmentally degraded areas in the western Mediterranean (Navarro Garnica 1977). It is not surprising that manipulation of soil conditions has commonly focused on improving soil water availability because water is the most limiting resource for seedlings. Watering has been recommended when feasible (Anonymous 2000). Watering may be more efficient when applied copiously on each cork oak seedling immediately after planting and, if possible, two or three more times during the first two years (M. H. Almeida, personal observation, 2006). *Mulching* with cereal straw or other suitable materials may help reduce direct evaporation and decrease transpiration by hampering the establishment of herbaceous vegetation. This technique may improve seedling survival (Abourouh and Bakry unpublished data) and growth (Favrel and Priol 1998). Runoff concentration may be a suitable alternative to increase water availability in dry sites. Microcatchments (e.g., two ridges, 1 to 1.5 meters long and 0.15 to 0.20 meter high, forming an oblique angle upslope from the planting hole) can be an affordable technique, but its success depends on the quantities of runoff water during the critical period after plantation (Whisenant et al. 1995; Saquete et al. 2006).

Deep soil labor may also be used to improve water infiltration, facilitate plant rooting, improve water status, suppress competing vegetation, and thus improve seedling establishment (Pikul and Aase 2003; Patterson and Adams 2003; Alloza et al. 2004). The establishment of planted cork oak seedlings may be favored by deep soil preparation (more than 0.35 meter or even more than 0.9 meter; Anonymous 2000). Soil preparation can be particularly important for cork oak because this species is highly sensitive to soil properties, including waterlogging (see Chapter 8), and because of the importance of deep rooting in oak establishment. Cork oak is sensitive to excess water. Soil preparation may also help to reduce soil pest attacks (Zaidi and Kerrouani 1998). Harrowing associated with chemicals can effectively control damage from *Melolontha* sp. (Almeida unpublished data).

Protection against Adverse Microclimatic Conditions

Seedling performance can be impaired by excessive radiation and temperature. Reductions in direct radiation and thermal buffering may improve seedling performance. Many types of tree shelters are available for this purpose, and their effects on plant performance vary (Bellot et al. 2002; Oliet et al. 2003). Ventilation is needed to avoid excessive temperatures, allow transpiration, and keep CO_2 concentrations near atmospheric values (Bergez and Dupraz 2000; Jiménez et al. 2005). Cork oak tolerates high temperatures, even when water stressed (Ghouil et al. 2003; Aranda et al. 2005a), suggesting that this species may not be particularly sensitive to changes in maximum temperature inside tree shelters. However, cork oak is strongly limited by low temperatures, particularly in provenances from warm areas (Aranda et al. 2005a), and tree shelters may promote freezing because minimum winter temperatures can be slightly lower inside them (Oliet et al. 2003; Jiménez et al. 2005).

Acclimation to shade may reduce *photosynthetic capacity* in cork oak leaves (Aranda et al. 2005a) and the ability to tolerate drought through *osmotic adjustment* (Pardos et al. 2005). But shade provided by tree shelters may enhance *photoprotection* and reduce *photoinhibition* in summer (Werner and Correia 1996). As a result of improved microclimatic conditions, short-term growth of cork oak seedlings can be enhanced when they are protected with tree shelters (Oliet et al. 2003). Ventilated 60-centimeter-long polypropylene tree shelters, with translucent twin walls reducing as much as 70 percent of incoming photosynthetic radiation, may be the best choice for this species.

The use of tree shelters may have some disadvantages for cork oak establishment because seedlings tend to be slender and etiolated under light-limiting conditions (Quilhó et al. 2003). However, by using translucent tree shelters allowing the passage of high red:far-red ratios of irradiance—a type of irradiance controlling stem elongation—this problem can be alleviated (Sharew and Hairston-Strang 2005). In addition, tree shelters commonly favor aboveground rather than belowground biomass allocation (Dias et al. 1992; Bergez and Dupraz 2000; Jiménez et al. 2005), a trend that could compromise seedling capacity to withstand intense drought. Conversely, tree shelters may control excessive branching and promote straight stems, facilitating cork extraction and improving cork quality. Finally, tree shelters may hamper herbivory by rodents, rabbits, and hares, but they are not as effective against large grazers.

Livestock Management

Grazing on cork oak acorns and seedlings is responsible for low establishment success in many areas (Lepoutre 1965; Pulido 2002), which is why careful and closely supervised livestock management is essential to cork oak woodland health and sustainability. Grazing exclusion can be very effective in improving seedling establishment (Torres and Montero 1992; Montero and Cañellas 2003b). It has been suggested that protection from grazing should last more than ten years to be effective, or up to the age when grazers are no longer a threat (i.e., the age at which trees surpass the critical browsing height) (Marion 1951; Santilli 1998; Montero and Cañellas 2003b). Brush piles around planted seedlings, especially using spiny species, may also deter cattle and deer, as observed in other oaks (Wetkamp et al. 2001).

Conclusions

Many studies indicate clearly that success rates of plantings can be increased substantially by using suitable field techniques. Adequate grazing management, environmental friendly control of potentially competing vegetation, and low-cost techniques to improve soil conditions and increase water availability in the proximity of planted seedlings, such as microcatchments, appear to be the best options to promote cork oak establishment. Having completed the discussion of the ecological and horticultural bases for restoration, including nursery and field techniques, in Part III we discuss the economic aspects of the current predicament and future prospects of cork oak woodlands.

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