Use of Shrubs as Nurse Plants: A New Technique for Reforestation in Mediterranean Mountains

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Abstract

Common techniques currently used for afforestation in the Mediterranean basin consider the pre-existing vegetation (mainly shrubs) as a source of competition for trees, and consequently it is generally eliminated before planting. Nevertheless, it has been demonstrated that woody plants can facilitate the establishment of understory seedlings in environments that, like the Mediterranean area, are characterized by a pronounced dry season. In this study, we experimentally analyze the usefulness of shrubs as nurse plants for afforestation of two native conifers, *Pinus sylvestris* L. (Scots pine) and *Pinus nigra* Arnold (black pine). Two-year-old seedlings were planted in four microhabitats: (1) open interspaces without vegetation (which is the usual method used in afforestation programs), (2) under individuals of *Salvia lavandulifolia*, (3) under the north side of spiny shrubs, and (4) under the south side of spiny shrubs. Pine survival was remarkably higher when planted under individuals of the shrub *S. lavandulifolia* (54.8% for Scots pine, 81.9% for black pine) compared with open areas (21.5% for Scots pine, 56.8% for black pine; chi square, $p < 0.05$). The survival of both pines was also higher when planted on the north side of spiny shrubs, although the survival on the south side was similar to that found in open areas. In addition, pine growth was not inhibited when planted in association with shrubs. This pattern appears to result from the combination of abiotic conditions imposed by the presence of a nurse shrub, which leads to improvement in seedling water status and therefore reduced summer mortality by drought. The results show that the use of shrubs as nurse plants is a technique that offers both economic and ecological advantages, in terms of savings in labor and plant material and reduced and even negligible impact on the pre-existing vegetation.

Key words: facilitation, Mediterranean ecosystems, nurse plant, *Pinus*, reforestation.

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Introduction

The Mediterranean basin has seen the development of some of the world's oldest civilizations, spreading agriculture and livestock while using trees for building and fuel. Therefore, forests in these areas have long been exploited (Bauer 1980; Le Houérou 1981; Thirgood 1981; Trabaud 1981; Blondel & Aronson 1999), and as a result the tree cover is drastically reduced in Mediterranean countries.

The transformation of the landscape by humans, together with a climate characterized by extreme summer dryness, makes afforestation one the most direct methods of regenerating the lost tree cover. However, reforestation in the Mediterranean basin often suffers heavy plant losses due to summer drought (Mesón & Montoya 1993; García-Salmerón 1995). Several techniques are used to alleviate this problem, such as construction of a water-catchment basin around each plant, planting seedlings having rootballs, applying water-retention gels in the root zone, mycorrhizal inoculation, and providing individual tree shelters (Honrubia et al. 1992; García-Salmerón 1995; Martínez de Azagra 1996). Nevertheless, the use of any of these techniques is restricted because they considerably raise the cost of reforestation.

The prevalent reforestation techniques consider the pre-existing shrubby vegetation to be a source of competition for the newly planted young trees (Mesón & Montoya 1993; García-Salmerón 1995; Savill et al. 1997). Thus, traditionally, before reforestation shrubs are cleared by burning, cutting, scraping, and so on or trees are planted far from shrubs. Nevertheless, the interactions between plant species can vary from negative (competition and interference) to positive (facilitation and mutualism), depending on the species involved and prevailing environmental conditions (Bertness & Callaway 1994; Callaway 1995; Holmgren et al. 1997; Brooker & Callaghan 1998). In temperate environments, the spatial proximity between plant species frequently results in a net negative effect as a consequence of competition for resources. On the contrary, in Mediterranean or semiarid environments the combination of high temperatures and low rainfall during summer can stress plants, converting water availability into the primary factor limiting plant growth. In such circumstances, changes in microenvironment characteristics provided by nurse plants may benefit survival and growth of understory species, and seedling recruitment is usually higher under the protection of these nurse plants (McAuliffe 1988; Keeley 1992; Cody 1993; Fisher & Gardner 1995; Sans et al. 1998; Chambers et al. 1999).

The facilitative effect of nurse plants during the growing season in dry environments may be caused by different interrelated mechanisms. First, the shade provided may protect understory species against high irradiance and temperatures (Franco & Nobel 1988, 1989; Valiente-Banuet & Ezcurra 1991; Vetaas 1992; Callaway 1992; Suzán et al. 1996). Second, as a consequence of lower radiation and temperature, soil moisture under nurse plants is usually higher and plant transpiration lower, improving the water status of the understory species (Soriano & Sala 1986; Aguiar & Sala 1994; Pugnaire et al. 1996a; Wied & Galen 1998); in addition, nurse plants may also enhance water availability actively via hydraulic lift (Richards & Caldwell 1987; Caldwell & Richards 1989; Dawson 1993). Third, nurse plants can increase available nutrients in the rhizosphere both because of an accumulation of litterfall (Franco & Nobel 1989; Callaway et al. 1991; Belsky 1994; Schlesinger 1996; Moro et al. 1997; Bisigato & Bertiller 1999) and because of higher moisture, which accelerates nutrient cycling (Mazzarino et al. 1991). Finally, all these processes improve physical and chemical soil properties (Hirose & Tateno 1984; Joffre & Rambal 1988; Pugnaire et al. 1996b).

Mediterranean mountains are also characterized by cold winters, where snow and especially freezes can be frequent. Nurse shrubs may also protect understory seedlings from winter frost and desiccating winds (Carlsson & Callaghan 1991), and positive interactions have also been found in environments with extreme low temperatures (Carlsson & Callaghan 1991; Shevtsova et al. 1995; Kikvidze & Nakhutsrishvili 1998; Núñez et al. 1999). Thus, the establishment of seedlings and saplings in Mediterranean mountains could also be favored under the protection of shrub species during winter, compared with open areas.

In the present study, we experimentally tested the usefulness of shrubs as nurse plants for reforesting two tree species of the Mediterranean high mountains, *Pinus sylvestris* (Scots pine) and *Pinus nigra* (black pine). For this purpose, the survival and growth rates of pine seedlings planted in open interspaces following the traditional method were compared with rates found for seedlings planted in association with nurse plants.

Materials and Methods

Study Area

Experimental reforestation was carried out at 1,800 to 1,850 m above sea level on the northwestern side of Loma de los Panaderos (Trevenque area, Sierra Nevada, SE Spain, 37° 5′ N, 3° 28′ W), where Salzmanniis black pine (*Pinus nigra* Arnold ssp. *salzmannii* [Dunal] Franco) and Sierra Nevada Scots pine (*Pinus sylvestris* L. var. *nevadensis*) dominate natural forests. The bedrock is calcareous, and the predominant soils are regosols and cambisols (Delgado et al. 1989), with slopes ranging between 5 and 15 degrees. The climate is subhumid Mediterranean, with rainfall (825 mm yearly average; 1990–1998) heaviest in autumn and spring, alternating with hot dry summers and cold winters. Mean temperature of the coldest month (January) is 3.7°C, and mean temperature of the hottest month (August) is 21.6°C (1990–1998). Snow is common during winter, persisting up to 2 months, and frost occurs from November to April. The study years were especially rainy, with precipitation rising to 1,252 and 1,273 mm in 1997 and 1998, respectively, although precipitation registered during July and August was as low as usual (11 and 4 mm in 1997 and 1998, respectively, for both months together).

In 1983, a fire in the study area burned around 8 ha of the original pine forest. Today the area has been recolonized by different early successional species of shrubs intermingled with interspaces of bare ground. The most abundant species are the shrubby *Salvia lavandulifolia* Vahl (Lamiaceae), an evergreen reaching a maximum of 50 cm high and 2 m in diameter, and several species of deciduous spiny shrubs, mainly *Prunus ramburii* Boiss., *Crataegus granatensis* Boiss. (Rosaceae), and *Berberis hispanica* Boiss. & Reuter (Berberidaceae), all able to reach at least 1.5 m high (Table 1).

Experimental Design

Experimental afforestation was conducted as part of a broader reforestation program supported by the Consejería de Medio Ambiente, Junta de Andalucía, covering the 8 burned ha of the study site. This reforestation used the usual procedure followed in the region, consisting of planting pines in open interspaces to avoid proximity to shrub species (hereafter referred to as "open" microhabitat). The planting holes were dug 40 cm deep with a mechanical augur having a bit size of 30 cm in diameter. This is the augur traditionally used in this type of reforestations in the region, because it provides the greatest hole without hampering its manipu-

Table 1. Habitat structure (percentage of cover of different plant species) in the study area, determined by means of 10 linear 50-m transects arbitrarily sited to cover a representative area of the stand

Microhabitat	*Cover (%)*
Salvia lavandulifolia	28.3
Other shrubs < 50 cm high[a]	3.1
Prunus ramburii	4.8
Crataegus granatensis	1.8
Berberis hispanica	3.1
Other shrubs > 50 cm high[b]	2.7
Forbs and grasses	16.3
Bare ground	36.4
Rock	3.6

At each meter the presence or absence and the identity of vegetation covering the ground were recorded at two points, 1 m from both sides of the transect (n = 100 sampling points per transect, 1,000 points in all).
[a]Mainly *Erinacea anthyllis* Link, *Ononis aragonensis* Asso, and *Genista versicolor* Boiss.
[b]Mainly *Amelanchier ovalis* Medik, *Cotoneaster granatensis* Boiss, and *Rosa* spp.

lation by workers due to excessive weight. After planting, the soil was manually worked in an area of 0.5 m^2 around the plant, which improves soil structure and increases water retention (Mesón & Montoya 1993; García-Salmerón 1995; Savill et al. 1997).

To test this traditional method against an alternative technique using shrubs as nurse plants, a set of pines was specifically planted for this experiment in association with nurse shrubs (Fig. 1). For this, we chose three planting microhabitats according to the availability of shrub species in the area (see Table 1 for habitat structure determination): (1) *Salvia*, seedlings planted under the canopy of individuals of *Salvia oxyodon*; (2) *shrub N*, seedlings planted just below the northern edge of the canopy of spiny shrubs (mainly *P. ramburii*, *C. granatensis*, and *B. hispanica*); and (3) *shrub S*, seedlings planted just below the southern edge of the canopy of spiny shrubs. In this case, the augur bit used was smaller (12 cm in diameter) to minimize damage to the shrub roots, and no further cultivation was done around the plants, implying that the initial conditions for establishment and growth were poorer compared with the open microhabitat (García-Salmerón 1995; Savill et al. 1997). In all cases, the soil was returned to the holes and firmed around the root collar of the seedling. Several nurse species were grouped into shrub N and shrub S microhabitats because of the low availability of specimens (Table 1). The *Salvia* plants chosen were between 20 and 35 cm high; for shrub N and shrub S, we chose nurse plants from 90 to 200 cm high.

The experimental pine seedlings, planted from 14 to 21 March 1997, were distributed in three 3,000-m^2 plots separated by approximately 200 m and protected from sheep and goats with a 1.5-m high fence. In each plot, we planted 50 seedlings per pine species in each of the four microhabitats (open, *Salvia*, shrub N and shrub S), representing 200 individuals of each species per plot and 600 experimental pines per species as a whole (randomized-block design). In June 1997, before the beginning of the summer drought, we examined the planted pines, excluding from the experiment those that had died (4.6%), presumably for not having survived transplanting. As a result, the final number of seedlings per plot and microhabitat can differ from 50, causing the design to be unbalanced.

The pine seedlings used in the experiment came from a nursery located at 1,600 m a.s.l. in the Sierra Nevada (Soportújar, Granada), were grown from seeds collected from local populations of the two species, and were 2 years old. The black pine seedlings were grown

Figure 1. Workers digging holes for planting under the canopy of *Salvia oxyodon* (microhabitat *Salvia* in the text).

in small plastic bags (10 cm in diameter, 25 cm in depth) filled with a substrate of native soil mixed with organic material. Scots pine seedlings were grown in beds and were undercut at about 10 cm in depth 1 year before transplanting. At the time of reforestation, they were bare-root transplanted, the roots being previously dipped into mud made from screened forest soil.

Abiotic Characteristics of the Microhabitats used for Planting

We measured several abiotic variables putatively influencing seedling establishment and survival. Total radiation at 10 cm from the soil was measured using a Li-Cor LI-200 sz pyranometer sensor connected to a LI-1000 data logger (Li-Cor Inc., Lincoln, NE, U.S.A.); air humidity was also quantified at 10 cm aboveground using a Rotronic YA-100 (Rotronic AG, Zürich, Switzerland) humidity sensor connected to the same data logger. Samples were collected on 6 August 1997, a clear day with no clouds, at 1-hr intervals from 10:00 to 16:00 hr solar time in the four microhabitats (six sample stations per microhabitat, seven cycles completed). Soil moisture was recorded at a depth between 10 and 15 cm on 6 August 1997; samples ($n = 10$ per microhabitat) were collected with a 5-cm-diameter core, and moisture was determined gravimetrically (samples oven-dried 48 hr at 110°C). Finally, soil temperature at 5-cm depth was recorded every hour from 19 August to 4 September 1997 with thermistors connected to a Hobo XT temperature logger (Onset Computer Corporation, Pocasset, MA, U.S.A.). We used one thermistor in the microhabitats open and *Salvia* and two in the other microhabitats. All abiotic variables were measured in the same randomly chosen plot.

Pine Measurements

For each experimental pine, we recorded survival, which was sampled three times: (1) after the first summer, once the autumn rains arrived (October 1997); (2) after the first winter, before the beginning of the summer drought (May 1998); and (3) once the second summer had ended and autumn rains arrived (October 1998). We also recorded the most likely cause of mortality and the growth rate, quantified as the length of the leader shoot in the summer.

Data Analysis

Seedling survival was analyzed for every sampling period by using contingency tests (Zar 1996). For the first summer and cumulative survival after two growing seasons, we used multivariate contingency tests, examining simultaneously the effect of plot and microhabitat. For winter and second summer periods, however, some cells had less than 5% or even zero data (0% mortality in some cases in microhabitats *Salvia* and shrub N); therefore, we pooled data from plots to analyze differences among microhabitats. Finally, among-microhabitat differences for cumulative survival after two growing seasons were identified for each plot and species by subdividing chi-square analyses (Zar 1996). Growth of the leader shoot was analyzed for surviving pines after two growing seasons by using a mixed repeated analysis of variance, with plot as a random factor, microhabitat as a fixed factor, and shoot length as the dependent variable.

Analyses, performed using JMP 3.1.5 software (SAS Institute 1995), were initially run with full models; however, when interactions were not significant ($p > 0.05$), we used a pooling procedure (Zar 1996). For performing the repeated analyses of variance on seedling growth, we log transformed the dependent variable to obtain normality and homoscedasticity and then used type III sum of squares due to the unbalanced nature of data (Shaw & Mitchell-Olds 1993). Means ± SE are shown.

Results

Abiotic Conditions

The four microhabitats differed markedly in mean irradiance received: Open and shrub S had the highest values, whereas shrub N and *Salvia* had the lowest (Table 2). Air relative humidity was the lowest in open, whereas *Salvia* had the highest value (although not significantly different from shrub N; Table 2). Values of soil moisture in *Salvia* and shrub N were significantly higher than those found in Open (Table 2). By contrast, soil temperature followed the opposite trend, with Open having the highest and most contrasted values compared with *Salvia* and shrub N (Table 2).

Survival and Growth of Seedlings

The highest mortality occurred during the first summer, when 47.1% of the initially established Scots pine seedlings and 28.1% of the black pines died. Throughout the winter, the mortality reached 14.2 and 5.9% of the Scots and black pines, respectively, and 17.0 and 9.0% for the second summer, respectively. Drought was the cause of mortality during summers, whereas mortality during winter was attributable to frost. Only the death of one seedling was attributed to other causes (vole tunnels).

The microhabitat had a significant effect both during summer and winter (Table 3). The patterns of variation among microhabitats were quite similar in the different seasons, with *Salvia* generally registering the highest survival rate, followed by shrub N (Fig. 2). Among-microhabitat differences also appeared for cumulative survival after two growing seasons (Table 3), which, in

Table 2. Abiotic conditions measured in the four microhabitats used for planting.

	Microhabitats			
Abiotic conditions	*Salvia*	*Shrub N*	*Shrub S*	*Open*
Irradiance (W/m^2)	473.1 ± 61.1[a]	340.2 ± 40.4[a]	895.7 ± 26.2[b]	916.9 ± 3.2[b]
Air relative humidity (%)	26.5 ± 0.8[a]	26.4 ± 0.3[ab]	24.3 ± 0.3[b]	22.3 ± 0.4[c]
Soil moisture (%)	11.7 ± 0.3[a]	11.1 ± 0.5[a]	10.6 ± 0.3[ab]	8.6 ± 0.9[b]
Soil temperature* (C°)	15.0 (13.7–16.3)	14.7 (10.8–20.0)	16.7 (11.0–27.1)	18.5 (10.6–32.9)

Values are means ± SE. Statistical comparisons were performed with analysis of variance. For solar radiation and air relative humidity we used as a dependent variable the mean values recorded per sample station throughout the day. The results of the tests are the following: Irradiance: $F = 23.33$, $df = 3, 20$, $p < 0.0001$; Air relative humidity: $F = 17.57$, $df = 3, 20$, $p < 0.0001$; Soil moisture: $F = 5.42$, $df = 3, 36$, $p = 0.0035$ (data log or arcsin-transformed). Means followed by different superscript letters are significantly different at $p < 0.05$ by Scheffe's t-test.
*Data of soil temperature could not be analyzed due to lack of replicates; in brackets, mean minimum and mean maximum values.

general, was the highest under *Salvia* for both pine species, followed by shrub N (Fig. 3). Thus, the overall plant survival after two growing seasons was 54.8% under *Salvia* for the Scots pine and 81.9% for the black pine, values that are much higher than those found in open interspaces (21.5% for Scots pine and 56.8% for black pine). Shrub S produced results similar to those of Open for both pine species (Fig. 3).

Growth of the leader shoot differed between years for the two pine species (Table 4), being lower during the second year (4.4 ± 0.1 vs. 4.2 ± 0.2 cm for Scots pine; 8.2 ± 0.2 vs. 6.8 ± 0.2 cm for black pine). The growth of the Scots pine was similar in all microhabitats (Table 4; 8.7 ± 0.3 cm on average after two growing seasons). For the black pine, however, growth was affected both by plot and microhabitat (Table 4), with significant interactions between the two factors, indicating that the effect of the microhabitat was dependent on the plot. In any case, among-microhabitat differences in growth after two growing seasons for this species were very low, the highest being in *Salvia* (15.4 ± 0.5 cm) and the lowest in Open (14.7 ± 0.5 cm).

Table 3. Summary of contingency analyses of survival for *Pinus sylvestris* and *Pirus nigra* seedlings in different seasons and overall after two growing seasons (cumulative).

		Pinus sylvestris		*Pinus nigra*	
Source	df	χ^2	p	χ^2	p
Summer 1997					
Model	11	50.90	<0.0001	161.24	<0.0001
Plot (P)	2	10.64	0.0049	90.98	0.0000
Microhabitat (M)	3	21.86	0.0001	21.66	0.0001
P × M	6	14.29	0.0266	12.81	0.0461
Winter					
Microhabitat	3	29.03	<0.0001	12.04	0.0073
Summer 1998					
Microhabitat	3	9.03	0.0288	9.12	0.0288
Cumulative					
Model	11	69.34	<0.0001	186.78	<0.0001
Plot (P)	2	6.91	0.0316	92.77	0.0000
Microhabitat (M)	3	45.68	0.0000	27.02	0.0000
P × M	6	13.20	0.0399	26.73	0.0028

For winter and summer 1998, we analyzed only among-microhabitat differences due to lack of data. Microhabitats are *Salvia*, shrub N, shrub S, and open.

Discussion

Our results show that survival of planted pines can be promoted (whereas shoot growth was not reduced) un-

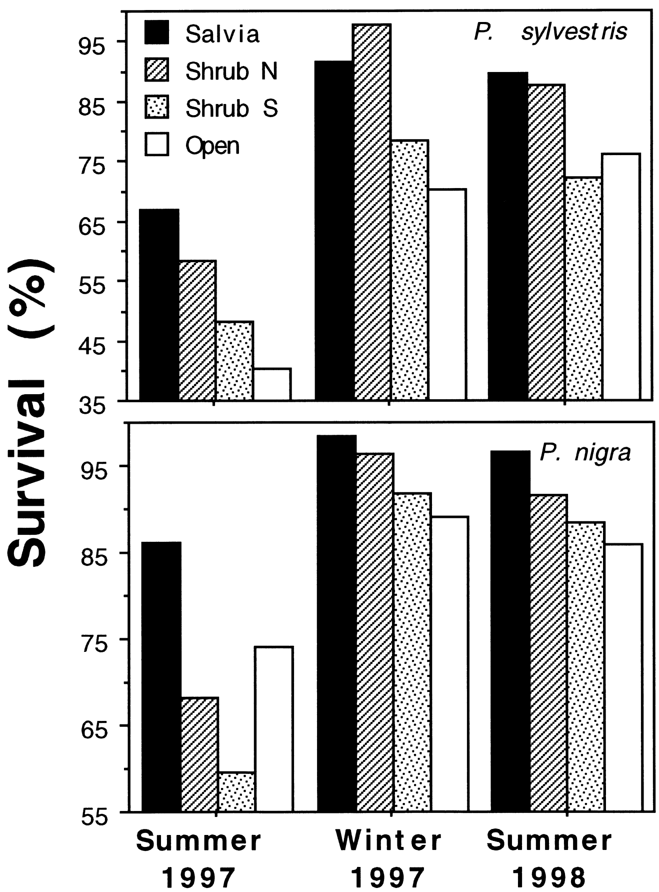

Figure 2. Survival of *Pinus sylvestris* and *Pinus nigra* seedlings in the planting microhabitats for each season. Data from different plots were pooled for simplicity.

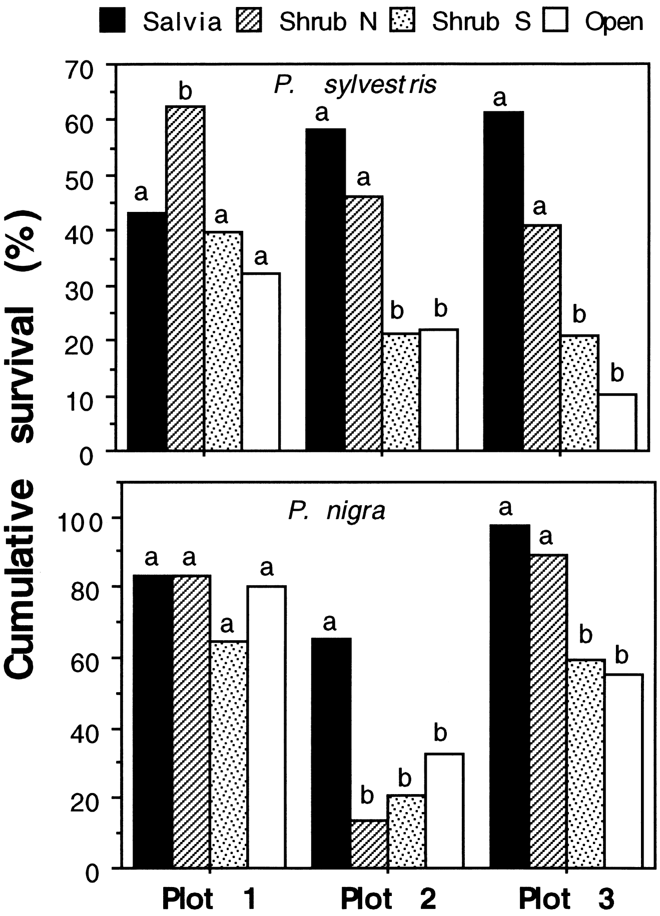

Figure 3. Cumulative survival of *Pinus sylvestris* and *Pinus nigra* seedlings in the planting microhabitats after two growing seasons, considering every plot independently. Different letters indicate among-microhabitat differences, located for each plot at an α level of 0.05 by subdividing the χ^2 test.

der shrubs in comparison with open areas, the places generally used in traditional reforestation programs. This happens despite the planting conditions being a priori more favorable for those pines planted in the open areas for several reasons. First, planting holes were larger in the open sites (30 cm width), providing a larger volume of loosened soil for easier root establishment (García-Salmerón 1995; Savill et al. 1997). In fact, the holes in the shrub treatments (12 cm width) provided only 16% the volume of loosened soil compared with the open-area holes. Second, seedlings planted in open areas received additional working of the soil, whereas the seedlings of the other treatments received no such cultivation. Despite these differences in planting conditions, even the worst position within the shrub treatments (shrub S) had results comparable with those of the traditional technique.

Differences in survival among microhabitats could be detected both during summers and winters, suggesting that the possible beneficial effects of shrubs are multiple. During summers, high radiation and low precipitation may restrict the survival of planted pines (García-Salmerón 1995; Pemán & Navarro 1998). In this case, shrubs may have a facilitative effect directly related to the shade they provide by reducing soil-water evaporation and transpiration of the seedlings (Larcher 1995; Lambers et al. 1998). In fact, Open and shrub S were the microhabitats that presented the highest values of solar radiation, the lowest values of air humidity, the highest fluctuations and most extreme values of soil temperature, and the lowest values of soil moisture. As a result, water stress must have been the highest in these microhabitats, which may be responsible for the generally lowest pine survival. In contrast, shrub N and *Salvia* presented lower radiation and soil temperature, whereas relative humidity of air and soil moisture were higher. This may reduce the water stress of seedlings, thereby increasing pine survival during the summer period.

During winter months the results and field observations suggest that the beneficial effects of shrubs may derive from the protection against soil freezing. Expansion and contraction of soil caused by freezing may break seedling roots, causing plant death (Ellison 1949; Ryser 1993; Gobbi & Schlichter 1998). In fact, many of the pines dying during winter were partially uprooted and lifted above soil level. In the open microhabitat, lack of any protection from nurse plants may be responsible for such high values of plant mortality. On the contrary, inside and at the edge of shrubs (e.g., *Salvia* and shrub N), the buffering effect provided by the plant cover and the stabilizing effect of the soil provided by both the litter layer and the root system of the nurse plant may prevent frost heave, resulting in lower winter mortality of seedlings. Thus, nurse shrubs may promote survival of pine seedlings both in summer and winter.

Overall, the highest survival after two growing seasons occurred under *Salvia lavandulifolia*, an abundant shrub in the study area. This shrub not only provided the best microenvironmental conditions for establishment, but in addition presented some morphological characteristics that presumably benefit the development of pine seedlings over time. With a height of around 20 to 35 cm, *S. lavandulifolia* can be easily outgrown in some years by planted trees. This was, in fact, the case, and after two growing seasons some pine saplings (up to 20.7 cm for the Scots pine and 33.6 cm for the black pine) were as tall as *S. lavandulifolia* plants. Furthermore, this shrub has a shallow root system, which contrasts with the deeper root system of pines and most Mediterranean trees. After a few growing seasons, *S. lavandulifolia* will not interfere with the planted trees, either above- or belowground. Thus, this shrub serves as a nurse plant during the first years after plant-

Table 4. Summary of repeated-measures analysis of variance on *Pinus sylvestris* and *Pinus nigra* leader shoot length after two growing seasons.

	Source	df	*F*	p
P. sylvestris	Plot	2	3.39	0.0358
	Microhabitat	3	1.83	0.1427
	Error (between)	204		
	Year	1	9.07	0.0029
	Year × plot	2	1.52	0.2208
	Year × microhabitat	3	2.30	0.0783
	Error (within)	204		
P. nigra	Plot	2	7.87	0.0005
	Microhabitat	3	3.16	0.0247
	Plot × microhabitat	6	5.25	<0.0001
	Error (between)	350		
	Year	1	38.82	<0.0001
	Year × plot	2	5.57	0.0042
	Year × microhabitat	3	4.05	0.0075
	Year × plot × microhabitat	6	5.03	<0.0001
	Error (within)	350		

Non-significant interaction terms were pooled in error *df*. Microhabitats are *Salvia*, shrub N, shrub S, and open.

ing, the most critical period of tree establishment (García-Salmerón 1995; Savill et al. 1997).

Tree survival was, nevertheless, affected not only by the planting microhabitat but also by the plot, with significant interactions between the two factors (Table 3). This indicates that other factors, such as slight changes in soil quality or orientation among plots, may interact with the effect of the microhabitat. In any case, our results show that for both Scots and black pines this technique clearly comprises an improvement with respect to the use of the traditional technique.

Benefits of this Technique

The main conclusion from our experiment is that pine seedling survival can be enhanced by nurse plants, without hampering subsequent growth. These results therefore contradict generally held opinions about the negative effects of shrubs for reforestation programs in Mediterranean areas, such as southern Spain. Shrubs (mainly *S. lavandulifolia*) provided a microenvironment suitable for the establishment of other woody species, specifically providing regeneration niches (*sensu* Grubb 1977) for pine seedlings, and the resulting plant–plant interaction apparently corresponded to a mechanism of succession by facilitation (Connell & Slatyer 1977).

The advantages that nurse plants might provide for reforestation programs in Mediterranean mountains are multiple and especially relevant when considering that most areas to be reforested already have prior natural shrub cover. In economic terms, this technique provides considerable savings because it involves less labor in preparation of the soil for planting and less replacement due to seedling loss. Therefore, these savings could translate to a greater surface area reforested for the same cost. From an ecological standpoint, this technique also has important advantages in assisting regeneration of the original forest canopy with negligible impact on existing vegetation. Furthermore, retaining shrubs reduces the risk of erosion compared with more aggressive techniques such as shrub removal or more drastic manipulation of the soil. We therefore suggest the use of nurse plants for reforestation as an alternative technique that should be generalized in Mediterranean scenarios.

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