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# Survival and Growth of Planted Douglas-Fir *(Pseudotsuga menziesii* (Mirb.) Franco) and Ponderosa Pine *(Pinus ponderosa* Dougl. ex Laws.) on a Hot, Dry Site in Southwest Oregon[1]

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*After two growing seasons on a hot, dry site at low elevations in southwest Oregon, survival rates were 88 percent for 1 +0 plug Douglas-fir (*Pseudotsuga menziesii *(Mirb.) Franco), 99 percent for 2+0 bareroot Douglas-fir, 91 percent for 1 +0 plug ponderosa pine (*Pinus ponderosa *Dougl. ex Laws.), and 98 percent for 2+0 bareroot ponderosa pine. Survival of the bareroots was significantly greater than that of the plugs (P = 0.05). Stress testing ranked all four stock types as excellent. Relative volume growth was greatest for the pine. The initially smaller 1 +0 plug pine nearly equaled the size of the 2+0 bareroot Douglas-fir after 2 years. (Tree Planters' Notes 36(4):3-6; 1985)*

Foresters in southwest Oregon have debated whether Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) or ponderosa pine (*Pinus ponderosa* Laws.) is the better suited for planting on lower elevation sites where both species occur naturally. These sites are typically located below 1,000 meters (3,300 feet) of elevation and receive less than 1,000 millimeters (40 inches) of precipitation annually. These sites are typical of the interior valley zone and lower elevation portions of the mixed evergreen zone (5). At least 10,000 hectares (49,000 acres) of public land and many small, private woodlands share these characteristics.

Both conifer species are available as 1-year-old container-grown seedlings (plugs) and as 2-year-old nursery-grown bareroot seedlings. The container-grown seedlings are of smaller diameter and cost more, but their roots have been better protected and they are often easier to plant (1, 10).

This study was conducted to compare survival and growth of Douglas-fir and ponderosa pine 1 +0 plug and 2+0 bareroot seedlings on a low-elevation, low-rainfall site. Interim results will help to determine which species and stock types offer the greatest chances for reforestation success on such sites, as well as their relative cost effectiveness. This is part of a larger study addressing the potential for reforestation on difficult-to-reforest lands withdrawn from the allowable-cut land base.

## Study Area

The study area is located on a 35-percent slope facing west on Tin Pan Peak near Rogue River, OR (lat. 123°10' W., long. 42°25' N.). The soil is classified as a loamy-skeletal, mixed, mesic Typic Haploxeralf (Beekman series), 60 to 90 centimeters (24 to 36 inches) deep (3). The site receives less than 760 millimeters (30 inches) of precipitation annually and less than 130 millimeters (5.1 inches) between May 1 and September 30 (6, 8). Potential direct-beam insolation was estimated at approximately 245,500 gram-calories/square centimeter annually and at 137,100 gram-calories/square centimeter from May 1 to September 30 (4).

The study site and environs supported Pacific madrone (*Arbutus menziesii* Pursh), California black oak (*Quercus kelloggii* Newb.), greenleaf manzanita (*Arctostaphylos patula* Greene), wedgeleaf ceanothus (*Ceanothus cuneatus* (Hook.) Nutt.), western poison-oak (*Toxicodendron diversilobum* (Torr. & Gray) Greene and occasional large overstory ponderosa pine. This land, on Bureau of Land Management holdings, had been withdrawn from the allowable-cut base because of reforestation problems.

On September 15, 1981, the Tin Pan Peak area burned in a wildfire. The burn was seeded with a grass-legume forage mix in October 1982. A large portion of the burn, including the study area, was operationally planted in January 1982 with 2+0 bareroot ponderosa pine.

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### Methods

The four combinations of species and stock type used in this study were planted on February 3, 1982. The Douglas-fir plugs were grown in 164-cubic-centimeter (10-cubic-inch) Ray-Leach tubes and the pine plugs in 66-cubic-centimeter (4-cubic-inch) Ray-Leach tubes. Random samples from all four seedling lots were stress tested (7).

Fifty seedlings of each stock type were planted in 0.02-hectare (0.05-acre) plots in a 4-by-4 Latin square design. Planting started at 9:00 a.m. in fog (97 percent relative humidity) and ended in sunshine at 1:00 p.m. (85 percent relative humidity). Each row of the Latin square was planted by a different planter. The planters were experienced and conscientious. Before planting, standing dead hardwoods were felled and removed from the study site.

Weeds were controlled with herbicides applied before and after planting. During the winter before planting, atrazine was aerially applied for grass control at 4.5 kilogram/hectare (4 pounds/acre). Because of spotty application, glyphosate was applied with a backpack sprayer at 0.89 kilogram/ hectare (1 .0 pounds/acre) on May 5, 1982. The test seedlings were protected with paper bags, but the ponderosa pine seedlings that had been planted operationally in January were not protected. The Pacific madrone and California black oak stumps produced sprouts ranging from 100 to 150 centimeters (40 to 60 inches) in height by August. The basal 30 centimeters (12 inches) of all hardwood sprouts within the study area were sprayed with 2 percent triclopyr ester in diesel oil. Flat fan nozzles and 0.1-megaPascal pressure settings were used. The nozzles were held within 30 centimeters (12 inches) of the sprouts with the spray directed away from adjacent conifer seedlings, which were not covered. In 1982, the study plots were baited twice with strychnine-treated oats in order to control pocket gophers (*Thomomys* spp.).

Seedling heights and diameters (2 centimeters above the soil) were measured after planting, and along with survival, at the end of the first two growing seasons. The data were analyzed as a Latin square design; analysis of variance and the Ryan-Einot-Gabriel-Welsch multiple Ftest (9) were used. Survival data were corrected with the arcsine transformation (2). Values were calculated for individual seedlings as diameter squared times height ($D^2H$). Relative growth (RG) was calculated for individual seedlings by determining the difference between the current and previous year's sizes and dividing by the previous year's size.

### Results and Discussion

The atrazine and glyphosate kept herb cover below 5 percent through the second growing season. All of the unprotected, operationally planted ponderosa pine were damaged by glyphosate, but more than 50 percent were alive at the end of the second growing season. The glyphosate did not detectably damage the covered test seedlings. The triclopyr killed all hardwood sprouts and prevented resprouting in 1983. Two Douglas-fir seedlings were probably killed by triclopyr. Both seedlings were within 20 centimeters (8 inches) of a sprayed clump. No seedlings were destroyed by pocket gophers. Stress testing rated the four seedling lots as "excellent." No seedlings died during stress testing.

Survival in the field after 2 years was excellent. It averaged 94 percent across all four combinations of species and stock type. For both growing seasons, survival was nearly identical for the two species but differed significantly by stock type. After two growing seasons, the 2+0 bareroot seedlings averaged 98 percent survival, which was significantly greater than the 89 percent survival of the plugs (table 1).

The cost of surviving seedlings can be calculated for each stock type by dividing the initial purchase price by the survival rate. In 1984, 2+0 bareroot seedlings typically cost $120 per thousand, 166-cubic-centimeter (10-cubic-inch) plugs cost $210 per thousand, and 66-cubic-centimeter (4-cubic-inch) plugs cost $110 per thousand. When divided by survival after 2 years, the cost of surviving 1 +0 plug Douglas-fir ($238 per thousand) is nearly twice that of bareroot Douglas-fir ($121 per thou

**Table 1**—*Percentage survival of the planted seedlings at the end of the first (1982) and second (1983) growing seasons*[1]

| | Douglas-fir | | Ponderosa pine | |
|---|---|---|---|---|
| Year | 1+0 plugs | 2+0 bareroots | 1+0 plugs | 2+0 bareroots |
| 1982 | 90a | 99b | 92a | 98b |
| 1983 | 88a | 99b | 91a | 98b |

[1]Means within a row followed by the same letter do not differ at $p = 0.05$.

sand). The costs of surviving pine are nearly equal for the two stock types (plugs, $121 per thousand; bareroots, $122 per thousand) and are nearly the same as the cost of bareroot 2+0 Douglas-fir.

At planting, the 1 +0 plugs were significantly smaller in diameter, height, and volume than were the 2+0 bareroots (table 2). But the seedlings with the smallest starting size-the 1 +0 plug pines-grew the most in volume and tended to increase the fastest in diameter and height as well. These seedlings increased in volume 13.76 times by the end of the first year (table 3). After 2 years, they reached a volume nearly equal to that of the 2+0 bareroot Douglas-fir.

**Table 2**—*Diameters, heights, and volumes ($D^2H$) of the seedlings at planting and at the end of the first (1982) and second (1983) growing seasons*[1]

| | Douglas-fir | | Ponderosa pine | |
|---|---|---|---|---|
| Measurement | 1+0 plugs | 2+0 bareroots | 1+0 plugs | 2+0 bareroots |
| Diameter (mm) | | | | |
| Planting | 2.6a | 5.5b | 2.3a | 5.1b |
| 1982 | 4.5a | 7.2b | 6.2c | 8.4d |
| 1983 | 8.8a | 12.3b | 13.6b | 16.3c |
| Height (mm) | | | | |
| Planting | 215a | 274b | 151c | 155c |
| 1982 | 301a | 359b | 226c | 250c |
| 1983 | 427a | 489b | 357c | 395a |
| Volume (cu mm) | | | | |
| Planting | 1,521a | 9,197b | 899a | 4,225c |
| 1982 | 6,095a | 18,611b | 8,687a | 17,640b |
| 1983 | 36,745a | 79,023b | 72,604b | 114,629c |

[1]Means within a row followed by the same letter do not differ at $p = 0.05$.

Overall, the pine outgrew the Douglas-fir. After 2 years, the 2+0 bareroot pine were significantly larger in volume than the 2+0 bareroot Douglas-fir despite a smaller starting size. Their relative growth was greater than that of the Douglas-fir stock types in diameter, height, and volume for 1982 and 1983. Similarly, the 1 +0 plug pine tended to grow faster than the 1 +0 plug Douglas-fir in diameter and volume, but this trend did not hold true for height. At the end of 2 years, 1 +0 plug pine had almost twice as much volume as did 1 +0 plug Douglas-fir.

If relative growth rates continue, the pine stock types will clearly be larger than the Douglas-fir in all growth variables after one more year. In an operational plantation, this superiority could give pine an advantage in withstanding competition from weeds, which often encroach after the second growing season.

### Conclusions

These results indicate that sites similar to Tin Pan have the potential to be quickly reforested with Douglas-fir or ponderosa pine. The key elements appear to be planting stock of good quality, good planting practices, and vigorous control of weeds and rodents. Given the equal survival of the two species, selection of species for planting can be based more confidently on such considerations as long-term productivity. For the short run, the greater initial growth rates of the pine sug-

**Table 3**—*Relative growth[1] of the planted seedlings in diameter, height, and volume at the end of the first (1982) and second (1983) growing seasons[2] (based on means of seedling ratios)*

| | Douglas-fir | | Ponderosa pine | |
|---|---|---|---|---|
| Measurement | 1+0 plugs | 2+0 bareroots | 1+0 plugs | 2+0 bareroots |
| Diameter | | | | |
| 1982 | 0.78a | 0.33a | 1.91b | 0.69a |
| 1983 | 1.00ab | .72c | 1.20a | .94b |
| Height | | | | |
| 1982 | .42ab | .32a | .50b | .69c |
| 1983 | .43ab | .37a | .58bc | .60c |
| Volume | | | | |
| 1982 | 3.88a | 1.40a | 13.76b | 4.04a |
| 1983 | 5.07a | 3.21b | 6.91c | 5.17a |

[1]RG = $X_{n+1} - X_n$ where X = size and n = measurement year.
[2]Means within a row followed by the same letter do not differ at $p = 0.05$.

gest that it may be able to withstand subsequent competition better than will Douglas-fir.

The stock types tested, all of which were high quality, have almost equally good potential for high survival on hot, dry sites on which competing vegetation has been controlled for the first 2 years. The greater cost and somewhat lower survival of the Douglas-fir 1 +0 plugs make them the least cost-effective after 2 years. But their very good survival makes them a feasible choice for reforestation when stock types of lower cost are unavailable. The differences in survival among stock types corresponded to characteristic differences in initial size. This pattern suggests that on hot, dry sites, size and stock type are better indicators of initial seedling survival than species.

## Literature Cited


1. Cleary, B.D.; Greaves, R.D.; Hermann, R.K. Regenerating Oregon's forests. Corvallis: Oregon State University Extension Service; 1978. 286 p.
2. Cochran, W.G.; Cox, G.M. Experimental designs. 2nd ed. New York: John Wiley and Sons; 1957. 611 p.
3. DeMoulin, L.A.; Pomerening, J.A.; Thomas, B.R. Soil inventory of the Medford District. Portland, OR: U.S. Department of the Interior, Bureau of Land Management; 1975. 250 p.
4. Frank, E.C.; Lee, R. Potential solar beam irradiation on slopes: tables for 30° to 50° latitude. Res. Pap. RM-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1966. 116 p.
5. Franklin, J.F.; Dryness, C.T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.
6. Froehlich, H.A.; McNabb, D.H.; Gaweda, F. Average annual precipitation in southwest Oregon, 1960-1980. EM 8220. Corvallis, OR: Oregon State University Extension Service; 1982. 8 p.
7. Hermann, R.K.; Lavender, D.P. Testing the vigor of coniferous planting stock. Res. Note 63. Corvallis: Oregon State University, Forest Research Laboratory; 1979. 3 p.
8. McNabb, D.H.; Froehlich, H.A.; Gaweda, F. Average dry season precipitation in southwest Oregon, May through September. EM 8226. Corvallis: Oregon State University Extension Service; 1982. 9 p.
9. SAS Institute, Inc. SAS user's guide: statistics. Ray, Alice Allan, ed. Raleigh, NC: SAS Institute, Inc.; 1982. 584 p.
10. Stein, W.I.; Owston, PW. Why use container grown seedlings? In: Proceedings, Western Reforestation Coordinating Committee. Portland, OR: Western Forestry and Conservation Association; 1975: 119-122.

# Alternate Types of Artificial Shade Increase Survival of Douglas-Fir *(Pseudotsuga menziesii* (Mirb.) Franco) Seedlings in Clearcuts[1]

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*Survival of Douglas-fir (*Pseudotsuga menziesii *(Mirb.) Franco) seedlings on two sites facing south was increased by three artificial shading devices: shadecards to the south of the seedlings, shadecards to the east of the seedlings, and Styrofoam cups inverted around seedling bases. Shadecards placed to the south of the seedlings increased survival the most, but the cups also increased survival and were cheaper. On one site, deer did not browse the seedlings; but on the other site, seedlings with shadecards were browsed less than either the controls or the seedlings with cups.* (Tree Planters' Notes 36(4):7-12; 1985)

In southwest Oregon and northern California, excessive heat has killed many Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) germinants and nursery-grown seedlings on slopes facing south. Heat can be moderated by shelter-wood regeneration (8) but still may be great enough to kill natural germinants (5). Shelterwoods, however, usually cost more than clearcutting and complicate weed control. Also, logging the overstory may kill many established seedlings. Some sites in southwest Oregon may require additional preparation and planting after final overstory removal.

Artificial shade boosts survival of nursery-grown conifers planted on clearcuts facing south. Shade from hand-piled rocks and woody debris increased survival of Douglas-fir and white fir *(Abies concolor* (cord. & Glend.) Lindl. ex Hilde br.) in California (13) and Douglas-fir in Oregon (11), but many seedlings were killed by toppling debris. In northern California, shade from lath fencing increased survival of Douglas-fir germinants, but nursery-grown stock survived well regardless of shade (16). Shade from cedar shingles boosted survival of Douglas-fir and white fir in northern California (1) and of Douglas-fir in southwest Oregon (9).

Large shingles are expensive. Shadecards, a cheaper alternative, have been widely used to protect seedlings on slopes facing south in southwest Oregon. Shadecards are 216- by 280-millimeters (8- by 10-inch) pieces of heavy waxed cardboard stapled to lath stakes, which are then driven into the soil about 7 centimeters (3 inches) south of the seedling (fig. 1).

Hobbs (7) reported that shadecards increase survival of 1+0 Douglas-fir seedlings on slopes facing south, but not on those facing north, east, or west. Shadecards are also effective on flat sites (1). Although shadecards apparently have not decreased survival, data showing increased survival with

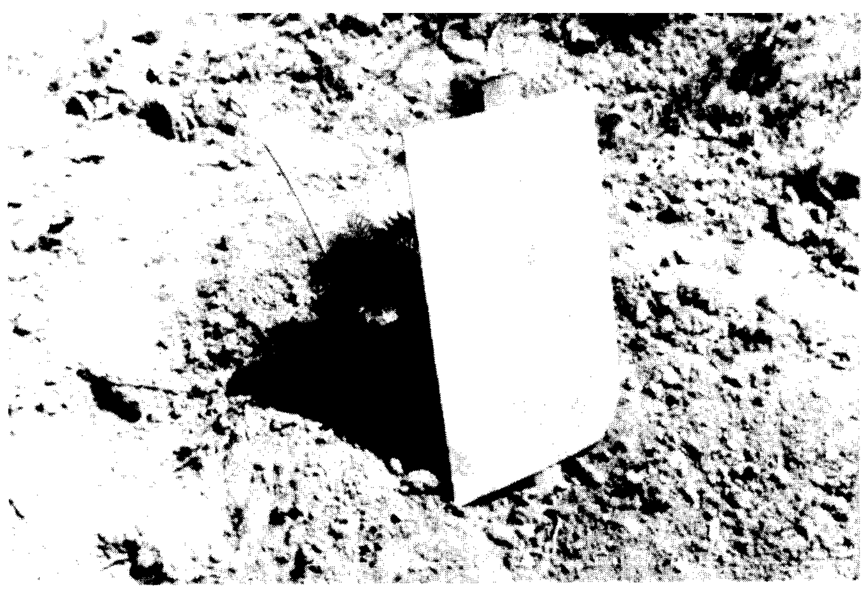

**Figure 1**—*Seedling with shadecard.*

[1] Paper 1949 of the Forest Research Laboratory, Oregon State University. This study is a cooperative effort of the Oregon State University's Southwest Oregon Forestry Intensified Research Program (FIR) and the USDI Bureau of Land Management, Medford District.

[2] The authors thank Dr. Susan Stafford for advice on the statistics and Rod Slagle for helping with computer-based analyses.

shadecards vary considerably (9, 12, 15). Soil characteristics may contribute to this variation, because shade effectiveness apparently increases with coarseness of soil texture (9, 12). Annual and seasonal weather changes may also be important.

Although clearcutting and planting with shadecards can be a cheaper reforestation method than shelterwood harvesting (9), the shadecards are still expensive. They cost 30 to 40 cents per seedling for materials and installation.

This study was done to determine if shading with Styrofoam cups (fig. 2) would lower costs and increase survival rates compared to shadecards. Another objective was to test whether shadecards placed to the east would, because of additional morning shade, increase survival despite greater afternoon heat. A third objective was to explore the effects of shade on Douglas-fir planted under different conditions on two different sites.

**Figure 2**—*Seedling with Styrofoam cup.*

**Methods**

Bareroot 2+0 Douglas-fir seedlings at two sites were shaded in the following ways: a) with shadecards to the south, b) with shadecards to the east, and c) with 187-millimeter ($6^1/_3$ -ounce) Styrofoam coffee cups inverted around seedling bases. Some seedlings were left unshaded for controls. The shades were installed in a randomized, complete-block design (2), with three replications at the two sites.

Before the cups were installed, the bottom of each was removed and the sides were slit. After installation, the rim of each cup was fastened to the soil with three U-shaped pins made from paper clips. Whereas a shadecard shades most of the seedling and a diurnally changing area of soil behind it, an inverted cup continuously shades about 60 millimeters (2.3 inches) of the seedling's base and a much smaller soil area (fig. 1).

***Lick Ridge Site.*** The Lick Ridge site (T. 39 S., R. 2 W., S. 34, Willamette Meridian) is on a south-facing 30-40 percent slope at 883 meters, (2,900 feet) elevation. The soil has characteristics of both a loamy, skeletal Typic Haploxeralf and a fine-loamy, mixed, mesic Typic Haploxeralf. Gravel particles ( > 2 millimeters) average 13 percent (SE, 1.33; N = 3) by weight of the surface 80 millimeters. Annual rainfall is about 890 millimeters (35 inches) (4), one-seventh of which (127 millimeters, or 5 inches) falls between May 1 and September 30 (10). Potential direct-beam solar radiation is about 144,000 gram calories per square centimeter between May 1 and September 30 (3).

The site, on Bureau of Land Management holdings, had been withdrawn from the allowable-cut land base because of reforestation problems. A manzanita *(Arctostaphylos patula* Greene) brushfield with scattered ponderosa pine *(Pinus ponderosa* Laws.) dominated the site. The brush was piled with a bulldozer and burned in 1980. The site had been planted as part of a land reclamation effort in 1981 and received 2.25 kilograms/hectare (2 pounds/acre) of atrazine for grass control.

Study seedlings at Lick Ridge were planted February 19, 1982, in cold, clear weather. Each treatment plot held 50 seedlings planted by an experienced crew. Shade cards and cups were installed within 2 weeks of planting. In 1983, germinant brush plants were controlled by hand-pulling within the plots and by application of 2.25 kilograms/hectare (2 pounds/acre) of 2,4-D on the rest of the unit.

***Julie Creek site.*** The Julie Creek site (T. 34 S., R. 9 W., S. 35, Willamette Meridian) faces south with slopes between 40 and 60 percent at an elevation of 944 meters (3100 feet). The soil is a fine-loamy, mixed mesic Ultic Haploxeralf. Gravel particles make up an average of 14 percent (SE = 3.38, N = 3) by weight of the surface 80 millimeters. Average annual rainfall is about 2,032 millimeters (80 inches) (4), one-tenth of which (203 millimeters or 8 inches) falls between May 1 and September 30 (10). During this period, potential directbeam insolation is about 142,000 gram calories/square centimeter (3). Old-growth Douglas-fir with understory tanoak *(Lithocarpus densiflorus* (Hook & Arn.) Rehd.) and Pacific madrone *(Arbutus menziesii* Pursh) occupied the site. The Douglas-fir was harvested, the brush slashed, and the site burned in 1981. In 1983, tanoak and madrone sprouts in the study plots were controlled with a broadcast application of 1.09 kilograms/ hectare (1.5 pounds/acre) of triclopyr ester.

At Julie Creek, seedlings were planted in warmer weather (May 4-6, 1982) because access roads were previously blocked by snow. Each treatment plot held 40 seedlings planted by an inexperienced crew. Shadecards and cups were installed within 4 weeks of planting.

The 2+0 bareroot seedlings planted at both sites were grown at the USDA Forest Service J. H. Stone Nursery near Medford, Oregon. The Lick Ridge seedlings were lifted January 19, 1982, and the Julie Creek seedlings were lifted January 4 and 5, 1982. The vigor of seedlings from each lot was measured by stress-testing (6). Seedling heights and root collar diameters were measured after planting and at the end of the first two growing seasons. Treatment differences were tested with analyses of variance and the Ryan-Einot-Gabriel-Welsch multiple F-test (14). Survival and browsing means were transformed with the arc-sin conversion (2). The means for each location were compared by analysis of variance, according to the place-by-treatment interaction.

## Results and Discussion

***Effects on Survival.*** At Lick Ridge, survival of the shaded seedlings was near 100 percent for the first and second year. Survival of the control seedlings was significantly lower within each year ($P<0.05$) and dropped from 94 percent in 1982 to 89 percent in 1983. At Julie Creek, overall seedling survival was lower than at Lick Ridge, but the difference between shaded seedlings and the controls was greater, differing significantly in 1982 and 1983. At both sites, seedlings with south-placed shadecards survived best, and most of the mortality occurred in the first growing season (table 1).

On both sites, the survival of seedlings shaded with cups was about the same as those shaded with south-placed shadecards. This result suggests that shading the base of seedlings is as effective as shading a larger area on the seedlings. Some cups blew away and had to be reinstalled; otherwise, more seedlings shaded with cups might have survived. All shadecards stayed in place. In general, shadecards placed on the east side increased survival on both sites, but not as much as shadecards placed on the south side or cups. Unshaded control seedlings that died showed no heat lesions.

In stress tests, Lick Ridge seedlings ranked "excellent" (3 percent mortality of stressed seedlings), and Julie Creek seedlings ranked "good" (10 percent mortality of stressed seedlings). The Lick Ridge

**Table 1**—*Percentage survival of seedlings, planted at Lick Ridge and Julie Creek sites, during their first (1982) and second (1983) growing seasons*[1]

| Site | Control | Shade card East | Shade card South | Styrofoam Cup |
|---|---|---|---|---|
| Lick Ridge | | | | |
| 1982 | 94a | 99b | 100b | 99ab |
| 1983 | 89a | 97ab | 100b | 99ab |
| Julie Creek | | | | |
| 1982 | 72a | 85b | 94b | 89b |
| 1983 | 69a | 82b | 89b | 85b |

[1]Means within a row followed by the same letter do not differ at p = 0.05.

was 4.58 millimeters (SE = 0.31) and that of live seedlings was 4.95 millimeters (SE = 0.08). At Julie Creek, the average diameter of dead seedlings was 4.20 millimeters (SE = 0.19) and that of live seedlings was 4.11 millimeters (SE = 0.13). After 2 years, some live seedlings in control plots at Julie Creek had planting diameters under 3 millimeters, and some dead seedlings had planting diameters over 7 millimeters.

seedlings broke bud quickly and uniformly in the spring; the Julie Creek seedlings broke bud more slowly, some not until late June. Results from Julie Creek showed a higher mortality rate for control seedlings and a relatively higher survival rate for shaded seedlings. Because soil gravel content was almost the same at the two sites, probable causes for the increased mortality were poorer quality seedlings (longer in storage), hotter planting conditions, and inexperienced planters. This theory supports Strothman's (16) suggestion that high survival is partly due to excellent planting stock and careful planting, regardless of shading intensity.

Some foresters suggest that small-diameter seedlings may be more susceptible to heat damage than large-diameter seedlings. In this study, however, live and dead seedlings in the control plots within each study area did not vary greatly in size at the end of the first year. In the first year, the average diameter of dead seedlings at Lick Ridge

**Table 2**—*Seedling sizes at Lick Ridge (all live seedlings) and Julie Creek (all live unbrowsed seedlings)*[1]

| Site, seedling size, and year | Control | Shadecard East | Shadecard South | Styrofoam cup |
|---|---|---|---|---|
| Lick Ridge | | | | |
| Diameter (mm) | | | | |
| Planting | 4.9 | 4.8 | 4.9 | 4.9 |
| 1982 | 7.9 | 6.8 | 6.9 | 6.9 |
| 1983 | 13.6a | 11.4b | 12.4ab | 12.2ab |
| Height (mm) | | | | |
| Planting | 246 | 237 | 243 | 246 |
| 1982 | 334 | 303 | 312 | 309 |
| 1983 | 512 | 464 | 484 | 489 |
| Volume ($mm^3$) | | | | |
| Planting[2] | 6,387 | 6,185 | 6,296 | 6,165 |
| 1982 | 24,896 | 15,849 | 16,965 | 16,851 |
| 1983 | 117,719a | 72,356b | 86,647b | 88,138ab |
| Julie Creek | | | | |
| Diameter (mm) | | | | |
| Planting | 4.0 | 3.7 | 4.1 | 4.4 |
| 1982 | 5.3 | 5.5 | 5.5 | 5.8 |
| 1983 | 7.6 | 8.0 | 7.1 | 8.2 |
| Height (mm) | | | | |
| Planting | 271 | 260 | 256 | 286 |
| 1982 | 294 | 282 | 283 | 313 |
| 1983 | 329 | 321 | 299 | 354 |
| Volume ($mm^3$) | | | | |
| Planting[2] | 5,228 | 4,215 | 5,109 | 6,396 |
| 1982 | 8,823 | 9,437 | 9,575 | 11,692 |
| 1983 | 21,636 | 25,499 | 17,724 | 30,707 |

[1]Treatment means in a row with different letters differ at $P < 0.05$, as indicated by ANOVA with previous size as a covariate when appropriate.
[2]Volume = $D^2H$.

***Effects on Growth.*** After 2 years, the unshaded seedlings at Lick Ridge had the largest diameters and volumes, and the seedlings in the east shade were the smallest. Tests of statistical significance indicated overlap between the treatments (table 2). The greater growth of the unshaded seedlings concurs with results in Strothman's (16) study.

Overall, seedling growth was greater at Lick Ridge. Tests of location means show that the Lick Ridge seedlings were larger ($P<0.05$) than the Julie Creek seedlings in diameter and height at planting. After 2 years, the Lick Ridge seedlings were larger than the unbrowsed Julie Creek seedlings in diameter, height, and volume. The ratio of growth to planting size was greater ($P<0.05$) at Lick Ridge than at Julie Creek.

Probably the larger size of Lick Ridge seedlings at planting did not affect their overall greater survival. Findings in this study showed that the size of live and dead seedlings did not vary greatly.

***Effects on Deer Browsing.*** Lick Ridge seedlings showed no evidence of deer browsing, but shadecards apparently reduced deer browsing at Julie Creek. Most browsing occurred during the first growing season. Shadecards may therefore increase survival by reducing deer browsing (table 3). The only significant relationship between browsing and survival was in the controls at Julie Creek (table 4).

**Table 3**—*Percentage unbrowsed seedlings at Julie Creek*[1]

| Growing season | Unshaded control | Shadecard East | Shadecard South | Styrofoam cup |
|---|---|---|---|---|
| 1982 | 69a | 92b | 93b | 75b |
| 1983 | 68a | 90b | 92b | 71a |

[1]Values in a row followed by different letters differ significantly ($P = 0.05$).

**Table 4**—*Effect of browsing on mortality of seedlings at Julie Creek*

| Seedling treatment | No. of seedlings Unbrowsed | No. of seedlings Browsed |
|---|---|---|
| Controls | | |
| Dead | 28 | 5 |
| Alive | 55 | 32 |
| Shaded seedlings | | |
| Dead | 66 | 8 |
| Alive | 327 | 79 |

Note that about half of the unbrowsed, unshaded controls died, compared to only 5 of the 32 browsed, unshaded controls. Browsing probably does not increase survival; a more plausible explanation is that the unbrowsed seedlings were less healthy or less palatable. Shade may increase survival of poorer-quality seedlings most. The unbrowsed, unshaded seedlings at Julie Creek had the lowest survival rate, whereas the unbrowsed, shaded seedlings had a high survival rate.

***Cost-Effectiveness.*** Cardboard and lath shadecards weigh about 200 grams (0.44 pound) and cost about 20 cents each. Cost of installation is about 20 cents. Styrofoam coffee cups weigh about 2.2 grams (0.005 pounds) each and cost about 2 cents. Estimated installation cost is 5 to 10 cents each. Subsequent observations indicate that installing the cups over the seedlings by punching out the bottoms but not slitting the sides will prevent their blowing away and thus will eliminate the need for pins. Although south-placed shadecards are slightly more effective in boosting survival, cups are less expensive. Although the three shading methods increased survival at Lick Ridge significantly, they are not cost-effective, given the 89-percent survival rate of the unshaded controls.

## Conclusions

Initial survival and growth of Douglas-fir may depend more on seedling quality, planting conditions, or both, than on shade treatment or expected rainfall. This theory is supported by the better survival, growth, and stress test results of seedlings planted at the drier site, Lick Ridge. Artificial shade had greater effects on the survival rate of poorer quality seedlings and seedlings planted under adverse conditions than on better quality seedlings and those planted under optimal conditions. If shade is necessary, inverted Styrofoam cups are nearly as effective as shadecards and are much less expensive. Shadecards may reduce deer browsing during the first 2 years of seedling growth.

## Literature Cited


1. Adams, R.S.; Ritchey, J; Gary, T. Artificial shade improves survival of planted Douglas-fir and white fir seedlings. State Forest Notes No. 28. Sacramento: California Division of Forestry; 1966. 11 p.
2. Cochran, WG.; Cox, G.M. Experimental designs. 2nd ed. New York: John Wiley and Sons; 1957. 611 p.
3. Frank, E.C.; Lee, R. Potential solar beam irradiation on slopes: tables for 30° to 50° latitude. Res. Pap. RM-18, Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station; 1966. 116 p.
4. Froehlich, H.A.; McNabb, D.H.; Gaweda, F. Average annual precipitation in southwest Oregon, 1960-1980; EM 8220. Corvallis: Oregon State University Extension Service; 1982. 8 p.
5. Helgerson, O.T.; Wearstler, K.A.; Bruckner, W.K. Survival of natural and planted seedlings under a shelterwood in southwest Oregon. Res. Note 69. Corvallis: Oregon State University, Forest Research Laboratory; 1982. 4 p.
6. Hermann, R.K.; Lavender, D.P. Testing the vigor of coniferous planting stock. Res. Note 63. Corvallis: Oregon State University, Forest Research Laboratory; 1979. 3 p.
7. Hobbs, S.D. Performance of artificially shaded container-grown Douglas-fir seedlings on skeletal soils. Res. Note 71. Corvallis: Oregon State University, Forest Research Laboratory; 1982. 5 p.
8. Holbo, H.R.; Childs, S.W.; McNabb, D.H. Solar radiation at seedling sites below partial canopies. Forest Ecology and Management *(in press).*
9. Lewis, R.; Ritter, C.J., II; Wert, S. Use of artificial shade to increase survival in the Roseburg area. Tech. Note TN-321. Denver: U.S. Department of Interior, Bureau of Land Management; 1978. 8 p.
10. McNabb, D.H.; Froehlich, H.A.; Gaweda, F. Average dry season precipitation in southwest Oregon, May through September. EM 8226. Corvallis: Oregon State University Extension Service; 1982. 9 p.
11. Minore, D. Shade benefits Douglas-fir on southwestern Oregon cutover areas. Tree Planters' Notes 22(1):22-23; 1971.
12. Petersen, C.J. The effects of artificial shade on seedling survival on western Cascade harsh sites. Tree Planters' Notes 33(1):20-23; 1982.
13. Roy, D.F. Don't plant close to unbarked logs! Forest Res. Note 101. California Forest and Range Experiment Station; 1955. 1 p.
14. SAS Institute, Inc. SAS user's guide: statistics. Ray, Alice Allan, ed. Raleigh, NC: SAS Institute, Inc.; 1982. 584 p.
15. Schoene, D.H.F. The valuation and use of site information for Douglas-fir reforestation in western Oregon: a decision analysis. Ph.D. Dissertation. Corvallis: Oregon State University; 1984. 337 p.
16. Strothman, R.D. Douglas-fir in northern California: effects of shade on germination, survival and growth. Res. Pap. PSW-84. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1972. 10 p.

# Performance of Outplanted Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.) Seedlings Inoculated With *Cenococcum geophilum*[1]

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*In the first of two experiments, container-grown seedlings of western hemlock (*Tsuga heterophylla *(Raf.) Sarg.) inoculated with* Cenococcum geophilum *Fr. had significantly (P = 0.05) better top growth 2 years after outplanting than did noninoculated controls. Seedling survival was unaffected by mycorrhizal inoculation.*

*In the second experiment, western hemlock seedlings inoculated with* Cenococcum*-bearing rotten wood and noninoculated western hemlock seedlings planted in either rotten wood or mineral soil on a clearcut in western Oregon survived and grew equally well during the first two growing seasons. Survival was not affected by mycorrhizal inoculation but significantly (P = 0.05) fewer seedlings survived in rotten wood than in mineral soil because of the higher second-season mortality in rotten wood.* (Tree Planters' Notes 36(4):13-16; 1985)

Seedling responses to mycorrhizal inoculation can vary with different combinations of site and fungi. For example, pines grew and survived better on coal spoils with *Pisolithus tinctorius* (Pers.) Coker & Couch than with other fungi (10). Increased growth and survival on less stressful sites are-sometimes obtained with other fungi; for example, pine seedlings inoculated with the mycorrhizal fungus *Paxillus involutus* (Batsch: Fr.) Fr. (7).

Inoculation with mycorrhizal fungi has occasionally decreased seedling growth. On certain soils, *Leccinum scabrum* (Bull.:Fr.) Gray decreases growth of birch (8). Shemakhanova (14) reports variable growth response of pine and oak seedlings to mycorrhizal inoculation. In some cases, the height of inoculated seedlings increased and in other cases it decreased when compared to that of noninoculated seedlings. Response varied with soil characteristics and with the fungus used.

Responses of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seedlings to inoculation with ectomycorrhizal fungi have been little studied. Trappe (16) reports that dry weight of container-grown western hemlock increased by inoculation with several mycorrhizal fungi. No data have been published on the performance of mycorrhizal versus nonmycorrhizal western hemlock seedlings after planting.

Along the Pacific coast, western hemlock commonly regenerates in mature forests with heavy to moderate shade, on rotten logs or stumps rather than on the forest floor (3, 11). This species also regenerates on rotten wood in clearcuts (1) and can colonize brushy sites by establishing on the relatively brush-free wood residue (13). MacBean (9) suggest that survival of germinants on rotten wood or thick humus requires a mild, moist summer climate.

Kropp (4) shows that nonmycorrhizal, container-grown western hemlock seedlings outplanted onto rotten wood or onto mineral soil survived equally well the first year. Some seedlings on rotten wood had less growth than did those on mineral soil, but all appeared vigorous and had formed mycorrhizae by the end of the first growing season. How western hemlock seedlings perform on rotten wood is important for foresters to learn, especially for sites on mineral soil where brush competition is severe.

Two experiments were designed to determine how mycorrhizal inoculation affects western hemlock survival and growth in plantations and whether inoculation affects seedling performance in mineral soil versus rotten wood.

### Materials and Methods

***Experiment 1***. *Cenococcum geophilum* (Isolate A-145) was isolated from surface-sterilized sclerotia (15), and vegetative inoculum was prepared as described by Molina (12).

Noninoculated, 1-year-old container-grown western hemlock seedlings were obtained from the Crown Zellerbach Corp. container nursery near Aurora, Oregon, in January 1978 and kept at 3 to 4 °C until inoculation in early March. The seedlings, originally grown in 98-cubic-centimeter plastic contain-

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ers, were transplanted during inoculation into 656-cubic-centimeter plastic containers filled with pasteurized peat and vermiculite (1:1). Seedlings were extracted from the original containers and placed (along with about 16 cubic centimeters of inoculum) into a hole pressed into the medium in the larger containers. Noninoculated controls were similarly transplanted but without inoculum.

Seedlings were grown in a lath house under natural light and temperature conditions until the following January, when they were placed in storage at 3 to 4 °C. In early April 1979, they were outplanted on six separate sites selected for a variety of aspect, slope, vegetation, and soil types. Three sites were in the moist coastal zone near Seaside, OR, at an elevation of 183 meters with an average annual precipitation of 200 to 250 centimeters. The remaining three sites were on Mary's Peak in the Siuslaw National Forest in western Oregon at an elevation of 183 meters with 178 centimeters of precipitation annually.

Three treatments of 30 seedlings each were planted in a completely randomized design within each plot. Treatments were a) noninoculated seedlings, b) well-colonized mycorrhizal seedlings (about 67 square centimeters of the plug surface was colonized), and c) moderately colonized mycorrhizal seedlings (about 32 square centimeters of the plug surface was colonized). After planting, each seedling was protected with plastic tubing to minimize animal damage.

At the end of the first and second years after outplanting, survival and current year's leader growth were measured for each seedling. An analysis of variance was done to test for treatment differences. Treatment means were separated by Tukey's test.

***Experiment 2.*** The site, at an elevation of 870 meters on Mary's Peak in the Siuslaw National Forest, was originally a Douglas-fir stand. The stand was clearcut in winter 1977, and the slash was burned in autumn 1978. It receives an average annual precipitation of 178 centimeters, with 13 centimeters falling from May to August. The soil is a deep, well-drained gravelly loam in the Slickrock series.

Seedlings were grown in 98-cubic-centimeter molded polyethylene containers, which were surface-disinfected by submersion for 5 minutes in a 10-percent bleach solution. Containers were filled with a 3:1 mixture of peat vermiculite and fragmented rotten wood inoculum (S). Control seedlings were grown in peat vermiculite medium alone.

Seedlings were grown for 10 months in 1978 at the Crown Zellerbach container nursery near Aurora, Oregon, and throughout 1979 in a lath house under natural light and temperature at Oregon State University, Corvallis. In the nursery, nutrients were applied twice weekly at operational rates (weeks 4 to 5, 10-52-16 fertilizer at 625 grams per 1,000 liters; weeks 6 to 16, 20-20-20 fertilizer at 500 grams per 1,000 liters; weeks 17 to 18, 0-52-34 fertilizer at 625 grams per 1,000 liters; weeks 19 to 26, 10-52-16 fertilizer at 625 grams per 1,000 liters; ferrous sulfate at 155 grams per 1,000 liters was added occasionally to all seedlings). In the lath house, fertilizer was applied once every 2 weeks at 11.34 grams, 20-20-20 (N-P-K) soluble fertilizer and 2.8 grams Fe iron chelate micronutrient per square meter of surface area. Seedlings were selected for uniformity of size and mycorrhizal colonization and outplanted in five blocks in mid-April 1980. Each block had two plots: mineral soil and well-decayed rotten wood. Each plot contained 20 seedlings: 10 mycorrhizal and 10 noninoculated controls.

Early in October 1980, seedling survival was recorded and five inoculated and five noninoculated seedlings were randomly selected and carefully excavated both from rotten wood and mineral soil. The current year's leader growth and the average length of the five longest roots growing from each excavated plug were measured in centimeters. General observations on types of mycorrhizae were recorded.

After the 1981 season, survival of remaining seedlings was recorded and all seedlings were excavated for measurements as in 1980. An analysis of variance was performed to test for treatment differences. Differences between treatment means were separated by Tukey's test at P = 0.05.

## Results and Discussion

Bartlett's test of homogeneity revealed no differences among the three sites at the Seaside area and also among the three sites on the Mary's Peak area, so data were pooled for further analyses. Moderately colonized and well-colonized seedlings did not differ significantly in leader growth after 2 years, so data from these two categories were pooled for further analyses. In experiment 1, inoculated seedlings had significantly more leader growth after the second growing season than did noninoculated seedlings. Leader growth of all seedlings, regardless of mycorrhizal status, was significantly greater at Seaside than at Mary's Peak after 2 years (table 1). No significant area x treatment interactions were found, so overall differences between inoculated and noninoculated seedlings on both areas were due to inoculation rather than to site differences.

The cumulative difference in height growth between inoculated and noninoculated seedlings became greater from year 1 to year 2 (table 1). If differences in height growth between the two treatments continue to increase over time, growth benefits from inoculation could be more obvious much later after outplanting than soon after. This type of continued stimulation in height growth would be particularly relevant where brush competition or animal browsing impede establishment of plantations.

**Table 1**—*Leader growth and survival for inoculated and noninoculated western hemlock seedlings in the first 2 years after outplanting (experiment 1)*[1]

| Location | First year: Noninoculated mean | First year: Inoculated mean | Second year (cumulative): Noninoculated mean | Second year (cumulative): Inoculated mean |
|---|---|---|---|---|
| Leader growth (cm) | | | | |
| Mary's Peak | 12.55a | 14.23a | 24.46a | 26.86a |
| Seaside | 23.16b | 23.67b | 52.46b | 56.77b |
| Pooled mean | 17.86A | 18.95A | 38.47A | 41.82B |
| Survival (%) | | | | |
| Mary's Peak | 100.0a | 98.3a | 77.8a | 80.7a |
| Seaside | 100.0a | 100.0a | 96.6b | 95.0b |
| Pooled mean | 100.0A | 99.2A | 87.2A | 87.9A |

[1]Treatment means within sample years not sharing a common letter differ significantly by Tukey's test (P = 0.05).

Seedling survival in the first experiment was not affected by mycorrhizal inoculation but was significantly higher at Seaside than at Mary's Peak (table 1).

In experiment 2, leader and root growth did not differ significantly among treatments. Mycorrhizal inoculation did not improve survival on either rotten wood or mineral soil either year. Seedlings on rotten wood appeared more chlorotic and generally less vigorous at the end of the first season than did those on mineral soil, although neither growth nor survival differed significantly (P = 0.05). During the second growing season, mortality of seedlings on the rotten wood was significantly lower than that of seedlings on mineral soil (84 vs. 55 percent, respectively). Seedlings on rotten wood remained chlorotic except for those with occasional roots growing into underlying mineral soil; these were green and more vigorous than seedlings with roots confined to rotten wood.

Earlier work on western hemlock (4) indicated that nonmycorrhizal, container-grown seedlings planted in rotten wood survived as well as did those in mineral soil. Seedling root growth did not differ significantly between mineral soil or rotten wood; on one clearcut, however, seedling leader growth was significantly lower on rotten wood than on mineral soil. Berntsen (2) concluded that planting Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) or Sitka spruce *(Picea sitchensis* (Bong.) Carr.) on rotten wood in high rainfall areas is a sound practice. Results of our study, however, indicated that planting hemlock in rotten wood on open sites cannot be recommended.

Our observations of mycorrhizae on roots of excavated seedlings in experiment 2 showed that *Cenococcum geophilum* colonized many new roots growing out from inoculated seedlings in both rotten wood and mineral soil. Numerous fungi shown to be mycorrhizal with western hemlock (6) need to be compared with *C. geophilum* to determine whether they can improve seedling survival or more strikingly stimulate height growth.

## Literature Cited


1. Berntsen, C.M. Seedling distribution on a spruce-hemlock clearcut. Res. Note PNW-119. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1955. 7 p.
2. Berntsen, C.M. Planting Sitka spruce and Douglas-fir on decayed wood in coastal Oregon. Res. Note PNW-197. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1960.5 p.
3. Christy, E.J.; Sollins, P; Trappe, J.M. First-year survival of *Tsuga heterophylla* without mycorrhizae and subsequent ectomycorrhizal development on decaying logs and mineral soil. Canadian Journal of Botany 60:1601-1605; 1982.
4. Kropp, B.R. Formation of mycorrhizae on nonmycorrhizal western hemlock outplanted on rotten wood and mineral soil. Forest Science 28:706-710; 1982.
5. Kropp, B.R. Rotten wood as mycorrhizal inoculum for containerized western hemlock. Canadian Journal of Forest Research 12:428-431; 1982.
6. Kropp, B.R.; Trappe, J.M. Ectomycorrhizal fungi of *Tsuga heterophylla.* Mycologia 74:479-488; 1982.
7. Laiho, O. *Paxillus involutus* as a mycorrhizal symbiont of forest trees. Acta Forestalia Fennica 106:1-72; 1970.
8. Levisohn, I. Researches on mycorrhiza. Great Britain Forestry Commission Report on Forest Research. London; 89-91; 1957.
9. MacBean, A.P. A study of the factors affecting the reproduction of western hemlock and its associates in the Quatsino region, Vancouver Island. Tech. Publ. 25. Victoria: British Columbia Forest Service; 1941.
10. Marx, D.H. Mycorrhizae and establishment of trees on strip-mined land. Ohio Journal of Science 75:288-297; 1975.
11. Minore, D. Germination and early growth of coastal tree species on organic seed beds. Gen. Tech. Rep. PNW-135. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1972. 18 p.
12. Molina, R. Ectomycorrhizal inoculation of containerized Douglas-fir and lodgepole pine seedlings with six isolates of *Pisolithus tinctorius*. Forest Science 25:585-590; 1979.
13. Ruth, R.H.; Harris, A.S. Management of western hemlock-Sitka spruce forests for timber production. Gen. Tech. Rep. PNW-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 197 p.
14. Shemakhanova, N.M. Mycotrophy of woody plants. Washington, DC: U.S. Department of Agriculture; National Science Foundation; 1962. 129 p. translated by the Israel Program for Scientific Translations.
15. Trappe, J.M. Studies on *Cenococcum graniforme*. I. An efficient method for isolation from sclerotia. Canadian Journal of Botany 47:1389-1390; 1969.
16. Trappe, J.M. Selection of fungi for ectomycorrhizal inoculation in nurseries. Annual Review of Phytopathology 15:203-222; 1977.

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# Survival of Shortleaf Pine (*Pinus echinata* Mill.) Seedlings as Influenced by Nursery Handling and Storage

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*Shortleaf pine (*Pinus echinata *Mill) seedlings were successfully established in the Ouachita Mountains when planted promptly after lifting. Five different handling and storage treatments were tested on December 10, 1980, January 10, 1981, and February 10, 1981. Survival rates of seedlings that were hand lined carefully were not significantly higher than those of seedlings that were liked operationally if the seedlings were planted with 48 hours of lifting. Second-year survival rates of seedlings planted within 48 hours of liking averaged 87 percent; the rates of seedlings stored for 30 days averaged 51 percent. The results show that seedlings liked in January and February should be planted as soon as possible after liking. Seedlings lifted in December survived adequately after 30 days of storage.* (Tree Planters' Notes 36 (4):17-19; 1985)

Shortleaf pine seedlings generally survive poorly when planted on the rocky, drier slopes of the Ouachita Mountains, and loss of 2-year-old seedlings to drought is not uncommon. Because of the rocky terrain, slope, and soil, machine planting shortleaf pine seedlings is difficult. Most of the trees are planted by hand with the use of a dibble bar. Because of the high costs of site preparation and planting in the Ouachita Mountains, it is critical to establish successful plantings on the first effort.

Field survival alone does not necessarily reflect the full capability of seedlings to become established and initiate vigorous growth (1). In addition to survival, rapid initiation of shoot and root growth increases the ability of seedlings to quickly overcome weed competition. Lifting, packing, transportation, storage, and planting techniques all influence seedling quality and the seedlings' subsequent capability to develop a strong root system.

Year-to-year variation in plantation survival is common. The most critical environmental factor affecting survival after outplanting is soil moisture. Seedling quality is the single most important biological factor for survival.

The objective of this study was to test whether extra care in nursery lifting and handling, time of lifting, length of seedling storage, and planting techniques affected survival of shortleaf pine seedlings planted in the Ouachita Mountains.

## Materials and Methods

On December 10, 1980, shortleaf pine seedlings of morphological grades 1 and 2 (based upon Wakeley's 1954 classification) were carefully handlifted from the Weyerhaeuser Company Nursery in Magnolia, AK.

The seedlings were assigned to one of the following study treatments:

A. Controls-hand lifting and handling, with planting within 48 hours.

B. Normal operational handling, with planting within 48 hours.

C. Four hours' storage in tubs at ambient (45 + 10 °F) packing shed temperatures followed by normal handling, planting within 48 hours.

D. Normal handling plus 30 days' cold storage (36 °F).

E. Four hours' storage in tubs at the nursery followed by normal handling and 30 days' cold storage (36 °F).

For treatment A, root-zone soil was gently washed away to minimize root loss and every precaution was taken to handle the seedlings as gently as possible, with minimal exposure of roots to drying conditions. Immediately after lifting, seedlings were carefully packed for transport in sphagnum moss within bags. These seedlings were hand planted with dibbles on the Ouachita National Forest within 48 hours after lifting. This treatment served as the control for the treatments B, C, D, and E. These treatments were located on two sites near Mt. Ida and two sites near Mena, AK.

Seedlings were lifted on December 10, 1980, January 10, 1981, and February 10, 1981. Those kept in cold storage for 30 days were planted at the same time as those newly lifted the following month. Storage temperature was 36 °F throughout the study.

The four planting sites had been logged within the past 3 years. Burning the previous fall reduced weed and brush competition. Six 50-seedling rows were planted for each of six replications in a completely randomized design. Spacing within and between rows was 2 feet.

## Results

Second-year survival of all seedlings lifted in December and planted within 48 hours was uniformly high, averaging 90 percent (table 1). Storage for 30 days resulted in lower survival rates. Seedlings of treatment D (Normal handling plus storage) averaged 80 percent, while those of treatment E (4 hours in tubs plus storage) averaged 65, indicating that the additional exposure is detrimental.)

All seedlings lifted in January and planted without storage had a uniformly high survival rate, averaging 87 percent (table 1). There were no significant differences in survival among treatments A, B, and C. Seedlings stored for 30 days prior to planting (D and E) had an average survival rate of 55 percent. Storage was clearly detrimental to successful establishment of seedlings lifted in January.

Greater differences in survival appeared among treatments in the February planting than in the earlier two outplantings. Treatments A, B, and C had survival rates equal to those of comparable treatments in December and January. The survival rates for seedlings stored for 30 days (D and E) averaged 26 percent, a great reduction.

**Table 1**—*Survival of shortleaf pine seedlings 2 years after planting at four sites in the Ouachita National Forest*

| Lifting date & treatment[1] | Percent survival March 1983 | | | | Average[2] |
|---|---|---|---|---|---|
| | Mena A | Mena B | Mt. Ida A | Mt. Ida B | |
| December 10, 1980 | | | | | |
| A | 91 | 86 | 90 | 94 | 90 ± 3.3a |
| B | 92 | 82 | 94 | 94 | 91 ± 5.6a |
| C | 89 | 84 | 91 | 88 | 88 ± 3.2a |
| D | 86 | 76 | 72 | 85 | 80 ± 6.9ab |
| E | 81 | 74 | 50 | 54 | 65 ± 14.7bc |
| January 10, 1981 | | | | | |
| A | 89 | 87 | 90 | 91 | 89 ± 1.4a |
| B | 87 | 79 | 90 | 93 | 87 ± 6.0a |
| C | 85 | 85 | 85 | 90 | 86 ± 2.6ab |
| D | 62 | 54 | 61 | 58 | 59 ± 3.6c |
| E | 65 | 50 | 37 | 53 | 51 ± 11.2c |
| February 10, 1981 | | | | | |
| A | 84 | 82 | 94 | 93 | 88 ± 6.0a |
| B | 85 | 75 | 96 | 92 | 87 ± 9.1a |
| C | 78 | 67 | 91 | 89 | 81 ± 11.2ab |
| D | 32 | 18 | 20 | 24 | 24 ± 6.4d |
| E | 41 | 22 | 20 | 30 | 28 ± 9.5d |

[1]A = control (handlifting, planting within 48 hours); B = normal operational handling, planting within 48 hours; C = 4 hours' storage in tub (45 ± 10 °F), normal handling, planting within 48 hours; D = normal handling, 30 days' cold storage (36 °F); E = 4 hours' storage in tubs, normal handling, 30 days' cold storage (36 °F).
[2]Values followed by different letters are significantly different $P < 0.05$) according to Duncan's multiple range test.

## Discussion

The results summarized here illustrate that shortleaf pine seedlings can be successfully established on the stressful sites found in the Ouachita Mountains if they are planted shortly after lifting. Statistical analysis did not reveal any significant differences in survival rates of seedlings given special handling and those that were lifted and graded normally if the seedlings were planted within 48 hours of lifting.

Shortleaf pine seedlings apparently do not store as well as expected from data on loblolly pine. The data show that the survival of shortleaf pine seedlings in cold storage is highly sensitive to the date of lifting. The mean survival rate for seedlings in treatment D lifted in December 1980 was 80 percent and 59 and 24 percent for those lifted in January and February 1981. This difference may reflect the shorter period for establishment before the spring drought for seedlings planted at the later dates. Mean survival of treatment E seedlings was low for all dates.

The poor survival of stored seedlings indicates that the seedlings lifted in January and February were not physiologically capable of adjusting to storage following lifting or that the stored seedlings were not capable of initiating adequate root growth after storage. Drought following outplanting is always a serious problem in the Ouachita Mountains. Seedlings held in cold storage for 30 days after lifting have a greater ability to survive if outplanted early in the winter than if planted later in the planting season. Until additional studies establish optimum times for lifting and storing shortleaf pine seedlings, lengthy storage should be avoided. Lifting should be done immediately before planting.

## Literature Cited

1. Venator, Charles R. Is it possible to defect-cull trees within 1 year after planting? Tree Planters' Notes: 34(2):26-27; 1983.
2. Wakeley, Phillip C. Planting the southern pines. Agric. Monogr. 18. Washington, DC: U.S. Department of Agriculture; 1954.

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# A Simple Method for Determining a Partial Soil Water Retention Curve

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*Nursery managers can develop their own partial soil water retention curves. Developing these curves can provide nursery managers with a better understanding of the soil moisture relationships for the various soils at their nurseries.* (Tree Planters' Notes 36(4):20-23; 1985)

Soil water retention curves can help nursery managers make decisions about irrigating their nursery crops more objectively (1, 3). For various reasons (including the expense of developing the soil water retention curves) many nursery managers have chosen to forego this practice. However, by using a soil tensiometer, a large pot, a known volume of nursery soil, a graduated cylinder, and a scale, nursery managers can develop their own partial soil water retention curves.

## Materials and Methods

We developed this system with a tensiometer (Jet Fill Tensiometer, Soilmoisture Equipment Corp., Santa Barbara, CA), a single 3.8-liter plastic pot, and a sample of Norfolk loamy sand soil. The tensiometer was filled, according to the manufacturer's instructions, with a solution containing 1 gram of copper sulfate (an algae inhibitor) for each 3.8 liters of water and then weighed.

The filled tensiometer was held in the center of the pot, with the ceramic tip about 4 to 8 centimeters from the pot's bottom, and soil was poured in until it reached the 15-centimeter level on the tensiometer (figure 1). The soil was packed by gently dropping the pot

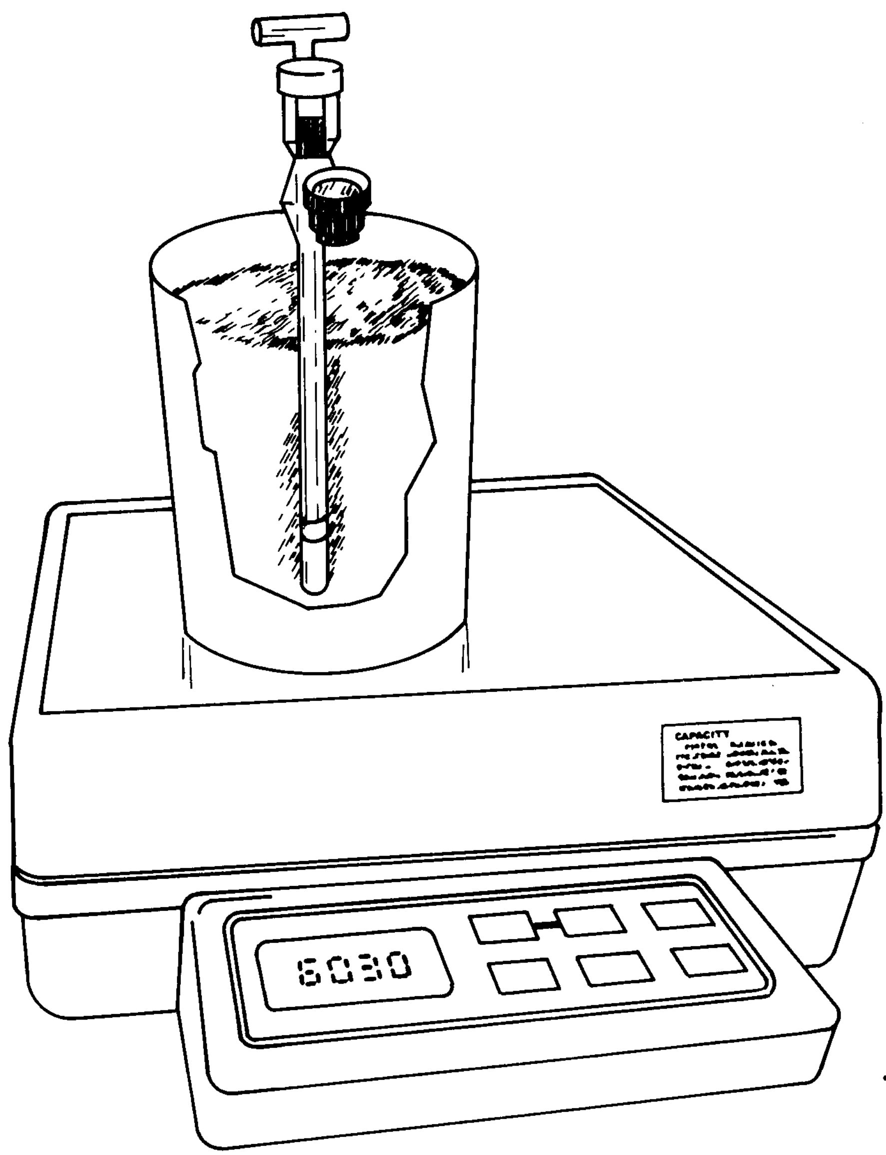

**Figure 1**—*Weighing the pot and tensiometer.*

several times from a height of about 5 centimeters. More soil was added and the packing and filling process repeated until the soil bulk density approximated that used in the nursery. It is important to ensure good contact between the ceramic tip on the tensiometer and the soil in the pot.

Then the soil in the pot was saturated with tap water; that is, it was filled until water ran freely through the drain holes in the pot bottom. The pot was let stand overnight so that the tensiometer could equilibrate with the soil.

On the following day, the weight of the pot with the tensiometer was recorded to the nearest 0.01 kilogram and the soil moisture tension to the nearest centibar (table 1). This weighing process was continued every day throughout the test period, until the tensiometer readings reached 70 to 80 centibars (1 centibar = 1 kilopascal). Then, the pot was rewatered and the tensiometer re-zeroed. At this time, the tensiometer was kept in place, and the fluid in the reservoir was replenished.

Each wet-to-dry cycle represented a replication in this experiment. The time required for each drying cycle depends upon several factors, including soil texture, relative humidity, and air temperature. The drying cycles in our study ranged from 10 to 12 days. A nursery manager can also develop a curve with one drying cycle using three or four pots and tensiometers. With one pot and tensiometer, three or four drying cycles are suggested to ensure repeatability. Because soil water retention curves change with different bulk densities and soil textures, a separate curve should be developed for each soil used at the nursery.

**Table 1**—*Calculations for the soil moisture tension curve*

| Day | Soil moisture tension (centibars) | (A) Weight of wet soil pot, and tensiometer (kg) | (B) Weight of dry soil pot, and tensiometer (kg) | (C*) Weight of water (kg) | (D) Weight of dry soil (kg) | (E) Soil bulk density (g/cm³) | (F†) Volumetric water content (%) |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 6.33 | 5.68 | 0.65 | 5.00 | 1.33 | 0.17 |
| 2 | 6 | 6.32 | 5.68 | 0.64 | 5.00 | 1.33 | 0.17 |
| 3 | 12 | 6.26 | 5.68 | 0.58 | 5.00 | 1.33 | 0.15 |
| 4 | 20 | 6.22 | 5.68 | 0.54 | 5.00 | 1.33 | 0.14 |
| 5 | 30 | 6.16 | 5.68 | 0.48 | 5.00 | 1.33 | 0.13 |
| 6 | 70 | 6.00 | 5.68 | 0.32 | 5.00 | 1.33 | 0.09 |
| 7 | 0 | 6.49 | 5.68 | 0.81 | 5.00 | 1.33 | 0.22 |
| 8 | 0 | 6.44 | 5.68 | 0.76 | 5.00 | 1.33 | 0.20 |
| 9 | 0 | 6.41 | 5.68 | 0.73 | 5.00 | 1.33 | 0.19 |
| 10 | 8 | 6.31 | 5.68 | 0.63 | 5.00 | 1.33 | 0.17 |
| 11 | 10 | 6.30 | 5.68 | 0.62 | 5.00 | 1.33 | 0.16 |
| 12 | 24 | 6.16 | 5.68 | 0.48 | 5.00 | 1.33 | 0.13 |
| 13 | 72 | 6.01 | 5.68 | 0.33 | 5.00 | 1.33 | 0.09 |
| 14 | 0 | 6.58 | 5.68 | 0.90 | 5.00 | 1.33 | 0.24 |
| 15 | 10 | 6.27 | 5.68 | 0.59 | 5.00 | 1.33 | 0.16 |
| 16 | 16 | 6.20 | 5.68 | 0.52 | 5.00 | 1.33 | 0.14 |
| 17 | 30 | 6.13 | 5.68 | 0.45 | 5.00 | 1.33 | 0.12 |
| 18 | 38 | 6.05 | 5.68 | 0.37 | 5.00 | 1.33 | 0.10 |
| 19 | 60 | 6.01 | 5.68 | 0.33 | 5.00 | 1.33 | 0.09 |

* C = A − B.
† F = (C/D) × E/(g/cm³).

At the end of the test period, the tensiometer was removed and the pot and the soil were dried for 48 hours at 105 °C. The dry weight of the soil was recorded. Before the volumetric water contents (VWC) of the soil were calculated, we subtracted the weights of the filled tensiometer and the pot from all weights recorded during the drying cycles. Soil bulk density (BD) was then calculated according to the following formula:

Bulk density = (weight of ovendry soil)/(volume of soil).

To calculate the soil volume, we taped over the drain holes in the pot bottom and then filled the pot with water to the level previously occupied by the soil. The water was then poured into a graduated cylinder and its volume recorded. The volume of space occupied by the tensiometer must also be accounted for. To find this value, we placed the tensiometer (15 centimeters deep) into a graduated cylinder with a known volume of water and recorded the volume of the displaced water (70 milliliters in this case), which represents the volume occupied by the tensiometer. The volume of soil in the pot equals the volume of water in the pot minus the displacement volume of the tensiometer.

After these calculations, the following formula was used for calculating the soil volumetric water content (VWC) at the recorded soil moisture tension (1 gram/cubic centimeter = density of water at 20 °C):

VWC = [(weight of soil wet -- weight of soil dry)/weight of soil dry] x bulk density/ (1 g/cm$^3$)

Examples of these calculations are listed in table 1. The VWC values were then plotted against their corresponding soil water tensions and a regression line was fitted (figure 2). Although a statistically fitted regression line is recommended, a hand-fitted curve can also be used.

**Discussion**

Developing a soil moisture curve should provide the nursery manager with a better understanding of water retention in the upper soil

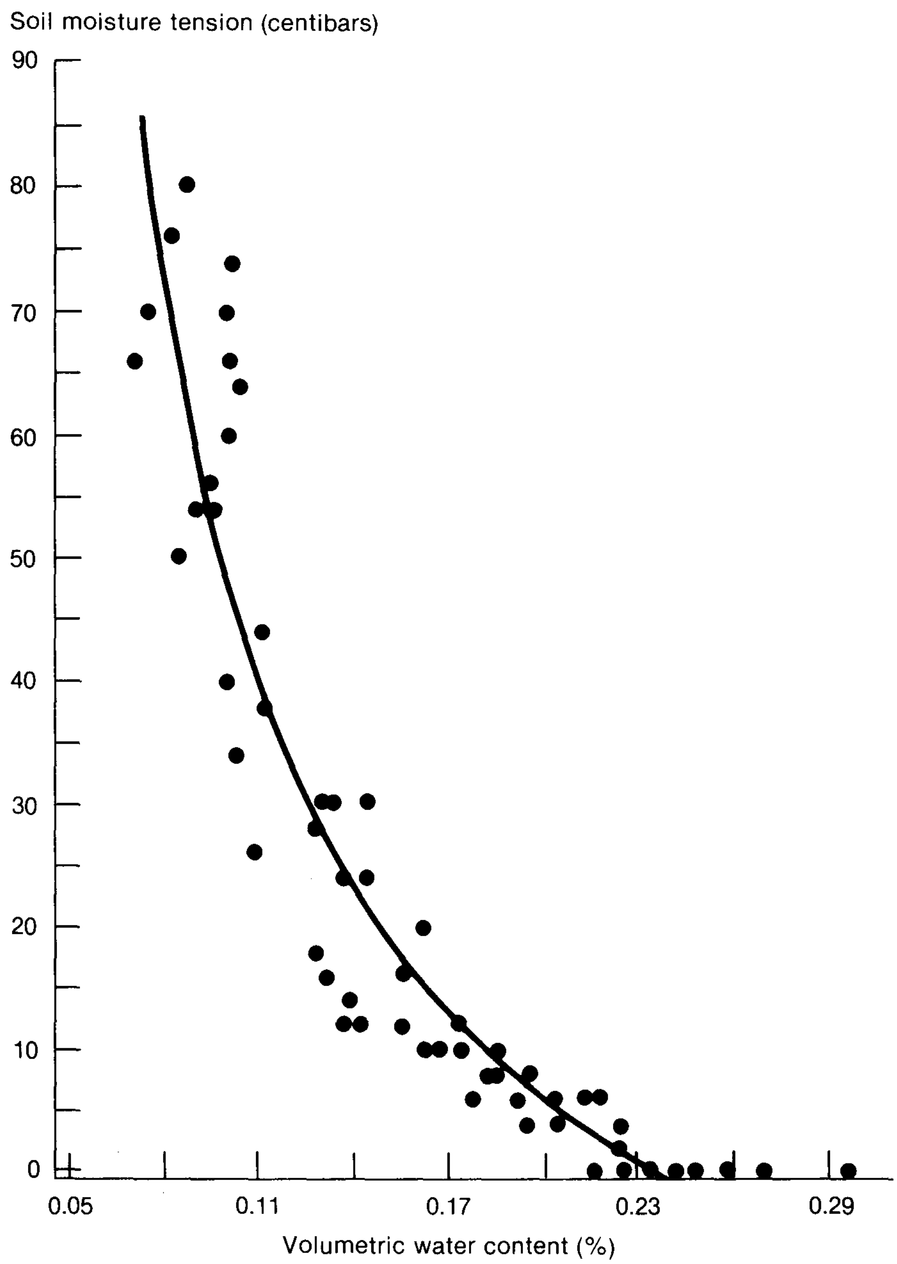


**Figure 2**—*A soil water retention curve; centibars = (33.5 + 7.9)/volumetric water content. $R^2$ = 0.86.*

profile of the nursery. Of particular interest is the point on the water retention curve where the soil tension begins to rise steeply. To promote seedling growth, irrigation should be applied to maintain the plow layer between field capacity and the point on the curve where the soil tension begins to rise steeply (2). For the curve represented in figure 2, this point is at about 40 centibars.

The curve can also be used to predict how much water should be applied in order to bring the soil tension back to field capacity (1,2). The following information is needed for making this prediction:

1) The average depth of the plow layer in centimeters (conventionally 18 centimeters).

2) The soil water retention curve, with values of VWC at field capacity (10 centibars) and an upper limit of dryness (normally between 30 to 75 centibars).

In the following example, the amount of irrigation water needed to change the soil tension in the top 18 centimeters of soil from 30 to 10 centibars is calculated with the soil water retention curve in figure 2.

a) At field capacity (10 centibars), the water value is 0.18 x 18 = 3.24 centimeters.

b) At the upper limit for irrigation (30 centibars), the water value is 0.13 x 18 = 2.34 centimeters.

c) The irrigation needed would be 3.24 -2.34 = 0.9 centimeters of water.

Although this method can be used to predict the amount of irrigation water needed to correct a soil moisture deficiency, it is not essential that nursery managers actually calculate the amount needed every day. By keeping a daily record of the soil moisture tension and how much irrigation is applied, the nursery manager can eventually learn by trial and error how much irrigation is needed. For example, if 1 centimeter of irrigation lowered the soil moisture tension from 40 centibars to 20 centibars, then the nursery manager would know that next time more irrigation would be needed to lower the tension from 40 centibars to 10 centibars. In time, the nursery manager will gain experience in determining how much irrigation is needed to change the soil tension from an upper limit for dryness back to field capacity. However, developing soil water retention curves provides the nursery manager with a better understanding of the moisture relationships for the nursery soil. Knowing whether to irrigate or not should help nursery managers improve their water use.

### Literature Cited

1. Day, R.J. Effective nursery irrigation depends on regulation of soil moisture and aeration. In: Proceedings, North American forest tree nursery soils work shop; Syracuse, NY; 1980 July 28. Syracuse: State University of New York, College of Environmental Science and Forestry; 1980: 52-71.
2. Day, R.J. Water management. In: Duryea, Mary L.; Landis, Thomas D., ed. Forest nursery manual: production of bareroot seedlings. The Hague: M. Nijhoff/Dr. W. Junk Publishers for Forest Research Laboratory, Oregon State University; 1984: 93-105.
3. McDonald, S.E. Irrigation in forest-tree nurseries: monitoring and effects on seedling growth. In: Duryea, Mary L.; Landis, Thomas D., ed. Forest nursery manual: production of bareroot seed lings. The Hague: M. Nijhoff/Dr. W. Junk Publishers for Forest Research Laboratory, Oregon State University; 1984: 107-121.

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# Effect of Preplant Spraying or Soaking on Growth and Water Relations of Jack Pine (*Pinus banksiana* Lamb.) Seedlings[1]

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*Spraying seedlings before bagging in the nursery and soaking them immediately before planting were each investigated for their effects on the water potential and root-to-shoot ratio of jack pine seedlings over the course of their first growing season. Neither treatment had any significant effect on the root-to-shoot ratio of the seedlings after one growing season. Reaction in terms of xylem pressure potential also suggested that neither treatment produced lasting effects on seedlings. Therefore, barring undue stress or damage due to improper storage or handling, jack pine seedlings will probably not benefit markedly from either treatment.* (Tree Planters' Notes 36(4):24-27, 1985)

The success of a conifer plantation may well rest on the survival and establishment of planted seedlings during the first growing season. One of the most important environmental factors affecting seedling survival is the availability of moisture. Consequently, knowledge of the effects of water stress on the physiology of conifer seedlings is desirable.

Past studies have shown that water stress both directly and indirectly affects a myriad of physiological processes. The level of water stress directly influences plant water potential (2,6) and stomatal closure (4). Water stress indirectly affects three major physiological processes: photosynthesis, transpiration, and respiration. Experiments with a wide variety of coniferous seedlings all show significant declines in photosynthesis as a result of increases in water stress (1,2,6). Similarly, transpiration rates diminish as stress increases. The rate at which transpiration decreases reflects stomatal sensitivity to water stress, which varies greatly with species (4,5). Respiration has also been demonstrated to be under the indirect influence of water stress (6).

Unfortunately, very little can be done about optimizing the amount of water received by seedlings in the field during the growing season. On a commercial scale, irrigation is usually impractical for economic reasons. Growers can, however, easily regulate the period of time preceding planting during which seedlings are handled and subjected to stressful conditions. Stress encountered by bareroot stock due to lifting, packaging, and storage can be avoided or controlled by simply growing containerized stock, but in the Lake States species such as jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Ait.), and white spruce (*Picea glauca* (Moench) Voss) are still predominantly planted as bareroot seedlings. The level of water stress that such seedlings experience before and during the time of planting may have a significant effect on their establishment and survival. Therefore, it is surprising that relatively little research has been done to quantify the effects of water stress on coniferous seedlings. The following experiment was designed to measure the influence of two preplanting treatments on the water potential and root-to-shoot ratio of jack pine seedlings over the course of their initial growing season.

## Materials and Methods

Two hundred 2+0 jack pine seedlings were lifted by hand from the Southern Michigan State Forest Nursery on April 16, 1981, quickly sorted to assure uniformity, and placed in two standard plastic-lined paper seedling bags. For the *spray* treatment, 100 seedlings were placed in each bag. Before the bags were sealed, the seedlings were removed from one bag, sprayed, with water, and then replaced.

The bags were then stapled shut, taken to the Michigan State University Tree Research Center, and placed in cold storage. They remained in storage at 40 °F for 39 hours. Six seedlings were then chosen randomly from the sprayed and unsprayed bags. These twelve seedlings were tested with a Scholander pressure bomb to determine xylem pressure potentials ($\psi_X$). The procedures were standardized so that all seedlings were cut exactly 17 centimeters from the terminal

[1] Research supported by the Michigan Agricultural Experiment Station, Michigan State University, East Lansing, MI.

bud, and 3 centimeters of bark was stripped from the severed end of each seedling before testing.

The second preplanting treatment (soak) under investigation was soaking the roots of seedlings immediately before planting. Half of the sprayed and unsprayed seedlings were soaked for 30 minutes in tap water. The seedlings were planted in loamy sand soil in a cultivated nursery bed at the Michigan State University Tree Research Center on April 18.

Of the original 200 seedlings, 12 were sacrificed for presoak $\psi_X$ determinations and 144 were planted. From the remaining 44 seedlings, 24 were randomly chosen for an additional set of $\psi_X$ readings (6 for each factor level) to determine the overall effect of the soaking and spraying treatments on unplanted seedlings.

Because of the uniformity of the nursery bed, the seedlings were planted in a completely randomized design. The two treatments were regarded statistically as two factors, each at two levels. A total of 144 seedlings, 18 per factor level, were planted in two replications. During later $\psi_X$ readings, a group of three seedlings was considered a single experimental unit of three subsamples.

The planted seedlings were measured on three different days throughout the growing season to determine $\psi_X$. Each set of readings consisted of 24 seedlings, two replications of each experimental unit per factor level. Two separate sets of readings were taken on each date, one before dawn and one at noon. The dates chosen for $\psi_X$ determination were at the beginning (April 25), middle (July 20), and end (September 28) of the growing season. The seedlings used for the final two sets of readings on September 28 were lifted to provide root-to-shoot ratio data in addition to $\psi_X$ (table 1).

### Results and Discussion

Spraying seedlings before sealing them in seedling bags resulted in a markedly significant increase ($P = 0.005$), in $\psi_X$ (table 2). The subsequent preplant soaking treatment also resulted in a significant increase in $\psi_X$. When analyzed together, the soaking treatment produced a much greater effect on $\psi_X$ than did the spraying treatment (table 2). Although both treatments increased $\psi_X$, no interactive effects between soaking and spraying were evident.

The analysis of data gathered from planted seedlings over the course of the season was complicated by the loss of 10 seedlings to rodent damage. However, no other seedlings died. In addition to the spray and soak treatments, differences in $\psi_X$ were analyzed with regard to the time of day and the date on which pressure bomb readings were taken.

**Table 1**—*Chronology of treatments*

| Action/treatment | Date | Number of seedlings | | | |
|---|---|---|---|---|---|
| Lifted and sorted | 4/16 | 200 | | | |
| Treatment 1 | 4/16 | 100 (spray) | | 100 (no spray) | |
| $\psi_X$ measured[1] | 4/18 | 6 | | 6 | |
| Treatment 2 | 4/18 | 47 (soak) | 47 (no soak) | 47 (soak) | 47 (no soak) |
| $\psi_X$ measured[2] | 4/18 | 6 | 6 | 6 | 6 |
| no. of plants[3] | 4/18 | 36 | 36 | 36 | 36 |
| $\psi_X$ predawn | 4/25 | 6 | 6 | 6 | 6 |
| $\psi_X$ noon | 4/25 | 6 | 6 | 6 | 6 |
| $\psi_X$ predawn | 7/20 | 6 | 6 | 6 | 6 |
| $\psi_X$ noon | 7/20 | 6 | 6 | 6 | 6 |
| $\psi_X$ predawn[4] | 9/28 | 6 | 6 | 6 | 6 |
| $\psi_X$ noon[4] | 9/28 | 6 | 6 | 6 | 6 |

[1]Seedlings sacrificed for $psi_X$ measurement, total of 188 remain.
[2]Seedlings sacrificed for $psi_X$ measurement, total of 164 remain.
[3]Of 164 seedlings, only 144 were planted.
[4]Ratio of root/shoot dry weight determined from these seedlings.

**Table 2**—*Average xylem pressure potential of jack pine seedlings before planting, expressed in negative bars*[1]

| Treatment | Before soaking | After soaking |
|---|---|---|
| Sprayed seedlings | 4.6a | — |
| Soaked | — | 3.5a |
| Not soaked | — | 6.3b |
| Unsprayed seedlings | 8.3b | — |
| Soaked | — | 4.5a |
| Not soaked | — | 7.2b |

[1]Means in columns followed by different letters differ significantly ($P = 0.005$).

Interestingly, the time of day-predawn or noon-produced no significant change in $\psi_x$ on the days when readings were taken. The only important factor influenceing $\psi_x$ of the seedlings was the time of the season on which $\psi_x$ was measured (table 3). Although little change was apparent during the first half of the growing season, this factor showed significant differences ($P = 0.005$) over the whole growing season.

The final analysis concerned the effect of spraying and/or soaking on the root-to-shoot ratio of the seedlings. Analysis of the data collected at the end of the season (table 4) demonstrated that neither spraying, soaking, nor a combination of the two produced any significant difference ($P = 0.05$) in root-to-shoot ratio of the seedlings, although the ratio of soaked seedlings was higher.

The relatively dramatic effect of both spraying and soaking on $\psi_x$ of jack pine seedlings before planting proved to be merely temporary in duration. A lack of significant differ ence in $\psi_x$ after planting suggests the absence of permanent physiological change due to spray or soak treatments. This theory is supported by the insignificant root-to-shoot ratio differences at season's end. Either the untreated seedlings were not subject to sufficient stress to cause long-term damage, or the treatments themselves were unable to alleviate this damage for more than a short time. Because of the absence of mortality (other than from rodent damage) and the vigorous appearance of the seedlings over the entire season, the former explanation seems most plausible. Therefore, barring additional stress or damage due to improper storage or handling, it can be interred that jack pine seedlings will not benefit markedly from being sprayed before bagging or soaked before planting.

The curious result of $\psi_x$ varying with date, but not time of day, can be best explained as follows. Immediately before both the first and second sets of readings, precipitation was relatively high. Thus, it was unlikely that soil water poten-

**Table 3**—*Average xylem pressure potential of jack pine seedlings by time of day and date, expressed in negative bars*[1]

| Time of day | April 25 | July 20 | September 28 |
|---|---|---|---|
| Predawn | 2.3a | 2.3a | 3.9a |
| Noon | 2.6a | 2.5a | 4.2a |
| Pooled average | 2.5 | 2.4 | 4.0 |

[1]Means in columns followed by the same letter do not differ significantly ($P = 0.05$).

**Table 4**—*Average root-to-shoot ratios of treated seedlings after their initial growing season*

| | Average weight (g) | | |
|---|---|---|---|
| Treatment | Root | Shoot | Root/shoot[1] |
| Spray/soak | 10.5 | 14.8 | 0.71a |
| Spray/no soak | 11.2 | 19.0 | .59a |
| No spray/soak | 7.6 | 10.7 | .71a |
| No spray/no soak | 4.4 | 7.1 | .62a |

[1]Values in column followed by the same letter are not significantly different ($P = 0.05$).

tial within the test plot was low enough to cause appreciable stress during noon readings. Conversely, the third set of $\psi_x$ readings was preceded by relatively dry weather. The low water-holding capacity of the sandy soil placed a greater burden of water stress on the seedlings, so that $\psi_x$ values were significantly more negative than those obtained earlier in the season under wet conditions. Furthermore, jack pine, a drought-tolerant species, has been shown to quickly curtail transpiratory water loss by rapid stomatal closure (4,5). Stomates that normally closed before dawn may simply have stayed closed through the middle of the day. The end result was that $\psi_x$ varied only minutely from predawn to noon readings.

Further investigations into the quantitative effects of preplant treatments on the physiology of jack pine and other less drought-tolerant coniferous seedlings are needed. These studies should focus on simulating abusive treatment during storage and handling, rather than on developing treatments to alleviate stress, so that potentially injurious handling practices can be identified and eliminated.

## Literature Cited


1. Beadle, C.L.; Jarvis, P.G. The effects of shoot water status on some photosynthetic partial processes in Sitka spruce. Physiologia Plantarum 41:7-13; 1977.
2. Havranek, W.M.; Beneke, U. The influence of soil moisture on water potential, transpiration, and photosynthesis of conifer seedlings. Plant and Soil 49:91-103; 1978.
3. Kaufmann, M.R. Water relations of pine seedlings in relation to root and shoot growth. Plant Physiology 43:281-288; 1968.
4. Lopushinsky, W.M. Stomatal closure in conifer seedlings in response to leaf moisture stress. Botanical Gazette 130:258-263; 1969.
5. Lopushinsky, W.; Klock, G.O. Transpiration of conifer seedlings in relation to soil water potential. Forest Science 20:181-186; 1974.
6. Puritch, G.S. Effect of water stress on photosynthesis, respiration, and transpiration of four Abies species. Canadian Journal of Forest Research 3:293-298; 1973.


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**Erratum**

In "A Comparison of Nursery Sowers," by J. N. Boyer, D. B. South, C. A. Muller, and H. Vanderveer, in the Summer 1985 (Vol. 36, No. 3) issue of Tree Planters' Notes, two values in table 1 are incorrect. Please change the Singles value for Whitfield sowers to 27.8%b and the Coefficient of variation of seeds per row to 10.0.