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Germination and Growth of Douglas-Fir and Incense-Cedar Seedlings on Two Southwestern Oregon Soils

Don Minore

Plant Ecologist, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oreg.

Douglas-fir and incense-cedar seeds were germinated and grown for 18 months with and without grass competition on soils derived from pillow basalt and marine sandstone. Grass reduced Douglas-fir germination on the basalt soil. Douglas-fir seedlings were heavier than incense-cedar seedlings on basalt soil where grass was absent, but incense-cedars were heavier than Douglas-firs on all other soil-grass combinations.

Clearcut stands of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) growing on soils derived from pillow basalt east of Sutherlin, Oregon, are often replaced by dense stands of grass and poison oak (*Rhus diversiloba* T. & G.). Survival of planted Douglas-fir seedlings is poor on many soils derived from basalt. There is less vegetative competition and better seedling survival in nearby clearcuts located on soils derived from marine sandstone. The clearcuts on basalt parent material and on sandstone are of similar age, with similar elevations, aspects, and slopes. They are less than 1-0 kilometers apart and have similar climates. Differences in vegetative competition and seedling survival appear to be associated with soil differences.

Parent material is only one factor in soil development, and soil is only one of the factors affecting plant growth. One can, however, compare the effects that different soils have on plant growth when other edaphic and environmental factors are equal (2). This study describes the growth of two native conifer species and a native grass on sandstone and basalt soils in a growth chamber. The two objectives were: (1) to compare the effects that soils developed from basalt and sandstone have on conifer germination and growth, and (2) to compare the responses of Douglas-fir and incense-cedar (*Libocedrus decurrens* Torr.) seedlings to grass competition on both soil types.

Materials and Methods

Three separate areas were sampled to obtain the basalt and sandstone soils used in this study. Sub-samples of equal size were collected 20 to 30 centimeters below the surface in the seedling root zone of three randomly located pits in each area. The nine sub-samples of each parent material were combined and mixed thoroughly. The blended soils were used to fill 14 x 14 x 14-centimeter pots to a depth of 12 centimeters.

Twelve pots of each soil type were sown with 7 Douglas-fir seeds, and 12 were sown with 7 incense-cedar seeds. The seeds, from sources near Sutherlin, were moistened and stratified at 1 ° C for 6 weeks before sowing. In six pots of each soil-tree combination, 28 blue wild rye (*Elymus glaucus* Buckl.) seeds collected near Sutherlin were also sown. Thus, four combinations were replicated six times on each soil: (1) Douglas-fir alone, (2) Douglas-fir + grass, (3) incense-cedar alone, and (4) incense-cedar + grass. The 48 pots were randomly arranged in a growth chamber set at 16-hour, 21° C days and 8 hour, 16° C nights. Average growth-chamber illumination (550 nm) at the soil surface was 30,000 lux. The pots were given equal amounts of water, but no nutrients were added.

Seed germination was monitored every other day for the first month. Seedlings were then thinned to the largest conifer and the 12 largest grass plants per pot. When the seedlings were 7 months old, growth chamber photoperiod and temperatures were reduced to 6-hour, 4° C and 18-hour, 2° C nights to induce dormancy. After 4 months, photoperiod and temperatures were increased to 14-hour, 21° C days and 10-hour, 16° C nights. These conditions were maintained until the plants were harvested 7 months later, 18 months after sowing.

Harvested conifer plants were washed free of soil, oven-dried at 65° C for 72 hours, and weighed to obtain oven-dry shoot and root weights. The weights were analyzed using a completely randomized design with a factorial arrangement of treatments. Germination percentages were analyzed in the same way after arc sin transformation.

Results and Discussion

Douglas-fir and incense-cedar seedlings are morphologically and physiologically different (1, 3), so differences in seed germination and seedling growth are to be expected. Species differences were not consistent under various soil and competition regimes used in this study, however, and these inconsistencies are of interest.

Douglas-fir germination was greater than incense-cedar germination on both soils. Grass did not reduce the germination of incense-cedar on either soil, but it did reduce Douglas-fir germination of basalt soil (table 1).

Field comparisons of juvenile conifer growth in southwestern Oregon (4) indicated that incense-cedar seedlings grew larger than Douglas-fir seedlings during the first 2 years in soils developed from pumice, rhyolitic tuff, and breccia parent materials. Similarly, early incense-cedar grew larger than Douglas-fir when grown without grass in soil developed from marine sandstone but not in soil developed from pillow basalt.

Douglas-fir seedlings grown in basalt soil were heavier than those in sandstone soil-with or without grass. In contrast, average incense-cedar weights did not differ for the two soils when the seedlings were grown without grass. With grass, the incense-cedar in basalt soil were about twice as heavy as those in sandstone soil. Grass competition reduced the average dry weights of both species by 70 percent in sandstone soil. In basalt soil, grass reduced the average seedling weight of Douglas-fir by 78 percent, but it reduced the average weight of incense-cedar by only 40 percent.

Table 1—*Average germination and weight of conifers grown in various soil-grass combinations*[1]

Conifer and treatment	Germination	Shoot weight	Root weight	Total weight	Shoot/root ratio
	%	g	g	g	
Basalt soil					
Douglas-fir alone	90.7	5.49	6.39	11.88	0.86
Douglas-fir + grass	66.7	1.32	1.31	2.63	0.88
Incense-cedar alone	19.0	3.25	6.97	10.22	0.47
Incense-cedar + grass	19.0	2.38	3.71	6.09	0.66
Sandstone soil					
Douglas-fir alone	83.3	2.90	3.46	6.36	0.83
Douglas-fir + grass	90.5	0.80	1.10	1.90	0.79
Incense-cedar alone	18.8	3.61	6.66	10.27	0.54
Incense-cedar + grass	21.5	1.25	1.84	3.09	0.68

[1]Means are based on six replicates. Differences were evaluated by analysis of variance.

Incense-cedar roots were heavier than Douglas-fir roots in all soil-grass combinations (fig. 1). Roots of both species were heavier on basalt soil than on sandstone soil and heavier without grass than with grass. Soil x grass x species interactions were significant ($p = 0.01$) however. Grass competition reduced Douglas-fir root weights more than incense-cedar root weights in basalt soil but not in sandstone soil.

Grass had a similar effect on the shoots of both conifers in sandstone soil, but restricted the shoot growth of Douglas-fir more than that of incense-cedar in the basalt soil. Without grass, Douglas-fir shoots were heaviest in basalt soil and incense-cedar shoots were heaviest in sandstone soil.

Seedling shoot/root ratios were similar on both soils, but larger overall for Douglas-fir than for incense-cedar. Grass competition increased the incense-cedar shoot/root ratios on both soils, but did not affect Douglas-fir ratios.

The growth chamber conditions used in this experiment were not the same as field conditions. In fact, the germination and seedling weight information obtained in limited amounts of homogeneous potted soil under artificial light, temperature, and moisture conditions may not be applicable in the field. Neverthe-

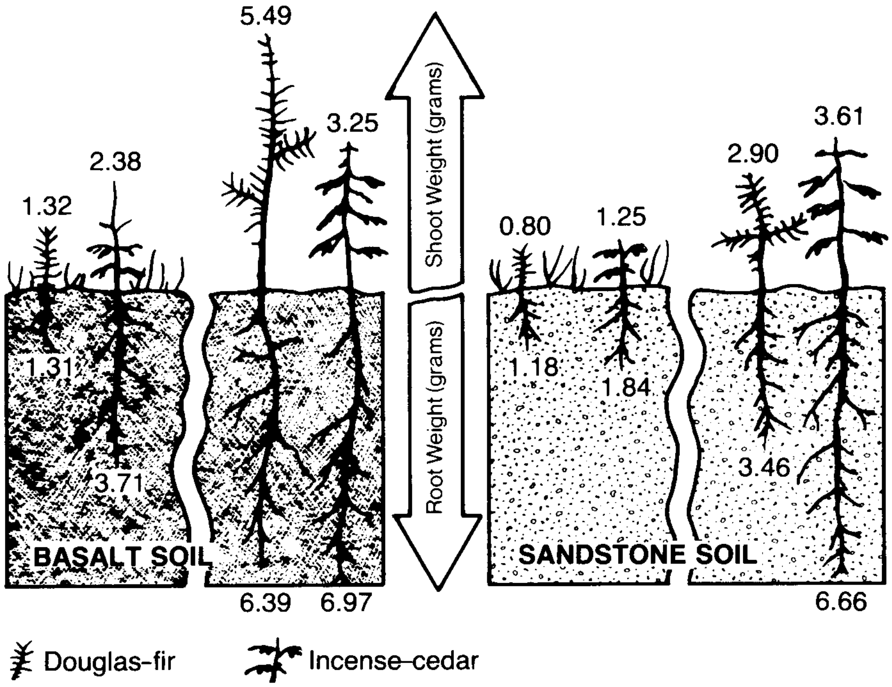

Figure 1—*Average shoot and root weights of Douglas-fir and incense-cedar seedlings grown in soils developed from basalt and sandstone parent materials, with and without grass.*

less, artificial conditions made it possible to compare soils and conifer species response without having to account for unmeasured variation in other factors. Explaining the differences in species response was difficult, however, because the factors causing the differences were not apparent.

Nutrient and moisture differences probably caused the observed differences in conifer growth. Basalt soil had a higher cation exchange capacity and more available nitrogen, calcium, and magnesium than sandstone soil (table 2). Because Douglas-fir seedlings may have been able to utilize the additional nutrients in basalt soil more efficiently, they grew larger than incense-cedar seedlings when supplied with abundant water in grass-free pots.

In pots where severe grass competition caused soil to dry out, moisture may have been the limiting factor for conifer growth. Although incense-cedar is more drought tolerant than Douglas-fir, the two species reacted similarly to grass competition in sandstone soil. When grown with grass in basalt soil, incense-cedar grew better than Douglas-fir, but not necessarily because of drought tolerance. The Douglas-fir seedlings may have shown poor growth because they could not use nutrients in dry basalt soil as efficiently as they could in wet soil.

Table 2—*Properties of soils developed from pillow basalt and marine sandstone parent materials*

Soil property	Pillow basalt	Marine sandstone
Sand (%)	39	55
Silt (%)	37	28
Clay (%)	24	17
pH[1]	6.4	5.6
C.E.C. (Meq/100 g at pH 7.0)	39.48	8.64
Total N (%)[2]	0.140	0.062
NO_3-N (mg/kg)[3]	2.00	0.28
NH_4-N (mg/kg)[3]	6.60	4.82
P (%)[4]	0.000	0.001
K (%)[5]	0.247	0.475
Ca (%)[5]	1.349	0.463
Mg (%)[5]	1.839	0.484
S (%)[6]	0.044	0.063

[1]Soil-water paste.
[2]Kjeldahl.
[3]Water extractable.
[4]Acid extractable (Bray method).
[5]Extractable (NH_4OAc at pH 7.0).
[6]Sulfate S.

Literature Cited

1. Franklin, J. F. A guide to seedling identification for 25 conifers of the Pacific Northwest. PNW-Misc. Pub. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1961. 65 p.
2. Kruckeberg, A. R. Soil diversity and the distribution of plants, with examples from western North America. Madrono 20: 129-154; 1969.
3. Minore, D. Comparative autecological characteristics of northwestern tree species-a literature review. Gen. Tech. Rep. PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 72 p.
4. Stein, W. I. Comparative juvenile growth of five western conifers. New Haven, CT: Yale University; 1963. 194 p. Ph.D. dissertation.

Effects of Site Preparation on Survival and Moisture Stress of Interior Douglas-Fir Seedlings Planted in Grass

Hollis W. Barber, Jr.

Eastern Washington Silviculturist, Washington Department of Natural Resources Ellensburg, Wash.

Survival of planted Douglas-fir seedlings, *Pseudotsuga menziesii* (Mirb.) Franco, was improved by several types of site preparation, especially herbicide treatment. Survival patterns closely followed levels of internal moisture stress. The results demonstrate the effect of grass on survival and internal moisture stress of planted Douglas-fir seedlings, as well as the benefits of grass controlling by spot treating with an herbicide.

Twenty years of research and field observations have established the connection between competition and improved survival and growth of tree seedlings. Where soil moisture is severely limiting, even minor amounts of competing vegetation are important. Grasses are especially strong competitors because their often massive root systems rapidly occupy the soil and deplete soil moisture. At best this shortens the effective growing season and reduces the growth of tree seedlings; at worst it leads to their death (1, 2, 4, 5, 7, 8, 9).

One objective of this study was to compare two site preparation methods: scalping and spot treating with atrazine. Selected treatments were compared on the basis of predrawn moisture stress (PMS) and survival of 2-0 Douglas-fir seedlings. A second objective of the study was to test the possibility of applying a mixture of paint and atrazine in autumn to provide on overwintering marker that would help planting crews relocate treated spots at planting time-6 months later. If planting crews can identify spots treated the previous fall, they will be able to plant seedlings directly in the centers of the spots, where minimum competition occurs.

Methods

The study site is located near Cle Elum, Washington, on a gentle northerly slope at 880 meters (2900 ft) elevation. The soil, formed in old alluvium, is a moderately well-drained inclusion in the Quicksell series. Surrounding forest vegetation is dominated by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Douglas-fir, but the site itself is a grassy meadow measuring approximately 6 hectares (15 ac).

Locations at which trees would be planted were staked in the summer of 1981 to insure relocation and ready identification of treatments. Treatments were assigned at random, in four blocks. One-meter squares were sprayed around each stake in September 1981, using either AAtrex 4-L in water or AAtrex 80-W in diesel, and paint as indicated in table 1. Each load was mixed individually and applied from a backpack sprayer.

Two-year-old Douglas-fir seedlings were planted in the centers of the treated spots in April 1982, using a planting hoe or auger. Where a hoe was used, a slight scalp removed surface litter, but not topsoil or roots, except as noted for treatment 1 B. Scalps were approximately 35 to 40 centimeters (15 in) square.

Planting weather was cool, with some snow. Seedlings were small, but appeared to be in good condition. PMS at the time of planting averaged 2.5 bars, well below the limit of 5 bars recommended for planting stock by Cleary and Zaerr (3). Buds were dormant and tops had a healthy green color.

Survivors were counted in mid-August 1982. A pressure bomb (11) was used to determine predawn (4 a.m. Pacific Standard Time) PMS for a random sample of survivors from treatments representing a range of site preparation treatments (table 1). PMS was determined according to general recommendations given by Ritchie and Hinckley (10). The whole top of each seedling was removed because seedlings were too small to take branch samples. Each top was cut off with a razor and placed in a plastic bag to retard transpiration; no more than 10 minutes elapsed between cutting and stress determination. Rate of pressure increase was standardized at 10 psi/sec. Since the limit of safe operation for the instrument used was 40 bars, any sample exceeding a PMS of 40 bars was arbitrarily recorded as 41 bars.

***Table 1**—Summary of treatments, indicating (x) those on which PMS were determined*

Treatment	Seedlings per treatment	PMS
1. Unsprayed controls		
A. No scalp; auger-planted	30	x
B. Thorough scalp with hoe, removing vegetation, roots, and about 1 cm of topsoil; hoe-planted	30	x
C. Slight scalp with hoe, removing surface litter only; hoe-planted	30	x
2. Atrazine in water, with red latex paint, at the rate of 23.5 ml paint/liter of water (3 oz/gal)		
A. Auger-planted	30	x
B. Hoe-planted	30	
3. Atrazine in water, without paint		
A. Auger-planted	30	
B. Hoe-planted	30	
4. Atrazine in diesel, with orange tree-marking paint, at the rate of 125 ml paint/liter diesel (16 oz/gal); hoe-planted	60	

Differences in survival were analyzed by chi-square; PMS differences between treatments were analyzed by analysis of variance.

Results and Discussion

The highly visible red latex paint showed where coverage had been insufficient, allowing crews to immediately re-treat skips. By contrast, the orange tree-marking paint in diesel carrier was not much more visible than atrazine in water. Because this treatment was four times as expensive as treatments employing latex paint, it was considered uneconomical to increase its concentration to improve visibility. Besides, the combination of treemarking paint and atrazine-diesel mixture formed a precipitate that clogged the sprayers, making them unusable within 15 minutes.

Neither paint survived the winter. The site was inspected several times in early spring 1982, before planting, and before any grass had turned green. Neither of the paints were visible. Increasing the concentration of latex paint to 94 milliliters/liter (12 oz/gal) produced a spot that overwintered well, but was again prohibitively expensive. Fortunately, since treated spots were also marked by stakes, seedlings were still planted at the centers of the spots.

Both formulations of atrazine controlled grasses well. There appeared to be no benefit to using expensive diesel instead of water as a carrier. There was no indication that the latex paint had formed a "skin" around atrazine granules, or inhibited herbicidal action in any way.

Some reinvasion of treated spots was evident in all treatments by August 1982, and was most serious in treatment 1C. Percent coverage was not estimated, but reinvasion seemed to be greatest in treatments where a hoe had been used. This might be due to soil and litter disturbance caused by the minimal scalp of the hoe-planting technique. In contrast, auger-planting left the surface soil and dead thatch undisturbed, presenting invaders with an unfavorable seedbed.

Analysis of PMS data revealed a progression of stress levels which corresponded to the intensity of site preparation (table 2). The values in table 2 probably underestimate the stresses for entire treatments, since they are derived from survivors only. The underestimation would be most pronounced on treatments with the greatest mortalities.

Table 2—*Predawn moisture stress in selected treatments*

Treatment	PMS (bars)
1A. Control, no scalp	41.0a[1]
1B. Control, thorough scalp	29.9b
1C. Control, minimal scalp	26.5b
2A. Atrazine in water, with red latex	9.1c

[1]PMS's followed by the same letter are not significantly different from each other (p = .05).

Atrazine reduced moisture stress of planted stock better than manual control of competing vegetation. The greatest stresses occurred in seedlings that received no site preparation. There was no significant difference between effects of deep and shallow scalps, and seedlings on sprayed spots experienced minimal predawn stress.

Lopushinsky (6) has shown that stomates of interior Douglas-fir seedlings are virtually closed at 20 to 22 bars. Thus, stomates of the seedlings in the control treatments remained closed all day during the later part of the growing season. This conserves plant moisture but also reduces gas exchange needed for photosynthesis. A decrease in photosynthesis lowers vigor and lessens a seedling's ability to grow and compete with surrounding vegetation. By contrast, seedlings on herbicide-treated spots would be able to photosynthesize for at least part of the day.

Analysis of survival data confirmed the obvious and significant (.01 level) benefit of some form of site preparation (fig. 1). Trees planted in grass (treatment 1A) suffered 87 percent mortality because of competition for soil moisture. This mortality rate corresponds to the high PMS values obtained on these seedlings (table 2).

Relative effectiveness of the two site preparation methods on first-year survival was also evaluated. Seedlings planted on sites prepared with atrazine survived at approximately the same rate as those on scalped sites. However, seedlings planted on deep scalps tended to be chlorotic, which might be a result of topsoil removal and consequent nutrient deficiency. If this is true, an atrazine treatment would be preferable from the standpoint of nutrition, if not survival, especially since atrazine also minimized moisture stress and reinvasion of competing vegetation. Herbicides are also preferable to manual treatments from the standpoint of ease of application and operator safety.

Conclusions

1. Some form of site preparation is essential to survival of

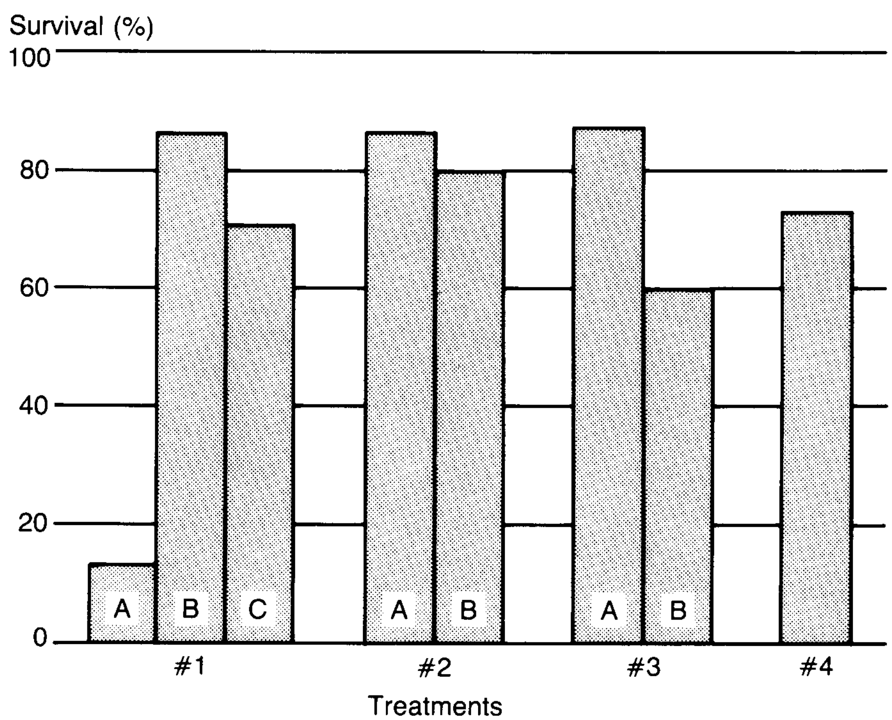

Figure 1—*Seedling survival after first growing season. Treatments are described in more detail in table 1.*

Douglas-fir planted in an established stand of grass.

2. Herbicide treatment is preferable to scalping because it minimizes reinvasion of competing species and improves water relations of seedlings. It may also improve seedling nutrition, insofar as nutrients are not displaced by scalping.

3. Neither latex nor tree-marking paint offers an economical solution to the problem of identifying herbicide-treated planting spots. An alternative is to mark each treated spot with a paint gun, but this requires a separate operation and usually involves an increase in workers needed.

Literature Cited

1. Baron, F.J. Effects of different grasses on ponderosa pine seedling establishment. Research Note PSW-199. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1962. 8 p.
2. Cleary, B.D. Vegetation management and its importance to reforestation. Research Note 60. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1978. 4 p.
3. Cleary, B.D.; Zaerr, J.B. Pressure chamber techniques for monitoring and evaluating seedling water status. New Zealand Journal of Forest Science 10(1): 133-141; 1980.
4. Eckert, R.E. Jr. Establishment of pine (*Pinus*, sp.) transplants in perennial grass stands with atrazine. Weed Science 27: 253-257; 1979.
5. Larson, M.M.; Schubert, G.H. Root competition between ponderosa pine seedlings and grass. Res. Pap. RM-54. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1969. 12 p.
6. Lopushinsky, W. Stomata] closure in conifer seedlings in response to leaf moisture stress. Botanical Gazette 130: 258-263;1969.
7. Newton, M. The influence of herbaceous vegetation on coniferous seedling habitat in old field plantations. Corvallis, OR: Oregon State University; 1964. 114 p. Ph.D. dissertation.
8. Newton, M. Seedling survival and vegetative competition. Western Reforestation: 39-41; 1964.
9. Phipps, H. M. Growth response of some shelterbelt species following sod removal-preliminary results. Research Note LS-21. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest and Range Experiment Station; 1963. 3 p.
10. Ritchie, G.A.; Hinckley, T.M. The pressure chamber as an instrument for ecological research. Advances in Ecological Research 9: 165-254; 1975.
11. Scholander, P.F.; Hammel, H.T.; Bradstreet, E.D.; Hemmingson, E.A. Sap pressure in vascular plants. Science 148: 339-346; 1965.

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Suppression of Sugar Pine by Douglas-Fir in a Northern California Plantation

Roy A. Woodward and Henry Land

Graduate Student, Botany Department, University of California, Davis, Calif., and Chief Sales Officer, Jackson Demonstration State Forest, Fort Bragg, Calif.

Competition from naturally invading Douglas-fir severely suppressed a 56-year-old sugar pine plantation in northern California. Only 19 percent of the planted 3-0 stock remained. The average tree was only 38.1 centimeters (15 in) in diameter and 23.8 meters (78 ft) tall. Unless weeded of native conifers, sugar pine is not a suitable plantation species in this area.

Sugar pine (*Pinus lambertiana* Dougl.) is an important species in the mixed conifer forests of California. It occurs on higher mountains of the Coast Ranges and is very common in the central and northern Sierras at elevations between 1200 and 1600 meters (1). It is occasionally found near the Pacific coast of northern California, but does not occur mixed with the dominant coastal redwood (*Sequoia sempervirens* (D. Don) Endl.) or Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

Near the turn of the century, when much of the coastal redwood forest was clearcut, it was common practice to burn the brush and slash shortly after logging in order to "open" the country. After several such harvest operations, William H. Gibbs, a forward-looking forester with the Caspar Lumber Company, established several plantations to test the feasibility of introducing "exotic" species into the central coast redwood region. California nutmeg (*Torreya californica* Torr.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and sugar pine were planted during the winter of 1926-27. We believe the results of these trials are best represented by the outcome of the sugar pine planting.

The sugar pine was 3-0 stock apparently from a Sierran seed source. About 0.1 hectare on a 5 percent south-facing slope was originally planted at a 2.4-by-2.4-meter spacing (fig. 1). The area had been cleared of old growth redwood-Douglas-fir forest and burned with a hot ground fire 6 months before planting.

In 1947 the State of California acquired the timberland holdings of the Caspar Lumber Company (approximately 20,000 hectares), which included the sugar pine plantation. The plantation site is currently managed by the California Department of Forestry as part of Jackson Demonstration State Forest (JDSF).

The plantation is located in west central Mendocino County,

Figure 1—*Note stand density and amount of downed material in 56-year-old sugar pine plantation.*

California, in the center of the coast redwood region. The site is 18 kilometers from the Pacific Ocean at an elevation of about 230 meters. Annual rainfall averages 130 centimeters, falling almost exclusively as rain from November to April. Additional moisture is provided during much of the summer by coastal fog. Temperatures range from -4° C in winter to 27° C in summer. The deep (>1.2 meters) sandy loam soils are considered excellent for growing conifers.

Sampling

The plantation was sampled in the winter of 1982 when it was 56 years old. Using a numbering system set up in an earlier plantation check (2), all living trees were located and included in the sample. The plantation had been measured in 1927 (Caspar Lumber Company), 1957, 1962, and 1967 (JDSF staff).

Height was measured to the nearest 0.1 meter with a Spiegel-Relaskop. Diameter at breast height was recorded to the nearest centimeter with a steel diameter tape. Our field notes also contain information about regeneration, disease or insect damage, subjective ratings of crown position (dominant, co-dominant, intermediate, suppressed), and general condition of the stand.

Findings

Survival and growth statistics for the stand are shown in table 1 along with available data from previous samplings. In 1962, six Douglas-firs thought to have invaded the plantation shortly after planting were marked so that their growth could also be monitored. The performance of these six trees is also shown in table 1.

First year survival (42 percent) of the pine was quite low considering the use of 3-0 stock. It is possible that blacktailed deer (*Odocoileus heminous columbianus*) browsed the new trees in the burned-over harvest area, thus contributing to tree mortality. Current (1982) survival is 19 percent.

Although sugar pines have shown reasonable growth, they have been overtopped by native Douglas-firs for the past 20 years. The sparseness of sugar pine crowns is illustrated in figure 2. Similar results have been obtained in southwestern Oregon (3). We expect none of the pines to survive to the planned 80-year rotation age of this stand.

No evidence of mortality from insects or disease was found in the plantation. White pine blister rust (*Cronartium ribicola*), common in other parts of the sugar pine range, has not been found here.

Sugar pine cones are quite distinctive and normally easy to find in sugar pine forests. At this site, however, no regeneration

Table 1—*Survival and growth of a 56-year-old sugar pine plantation in northern California. Data for six Douglas-fir trees growing with the sugar pine are shown in brackets for comparison*

Plantation Characteristics	1927	1957	1962		1967		1982	
Survival (%)	42.3	32.7	3.2	[100]	30.3	[100]	19.2	[100]
Total basal area (m²/ha)	—	7.8	9.8	[2.0]	11.2	[2.4]	12.4	[3.9]
Mean diameter (cm)	—	24.1	25.1	[40.9]	27.7	[45.5]	38.4	[57.9]
Volume (m³)	—	21.4	35.7	—	—	—	36.4	—
Mean height (m)	—	—	—	—	—	—	25.5	[33.7]
Tallest (m)	—	—	—	—	—	—	35.1	[39.0]
Dominant or codominant (%)	—	—	43.3	—	39.7	—	12.5	—
Intermediate (%)	—	—	22.4	—	30.2	—	32.5	—
Suppressed (%)	—	—	34.3	—	30.2	—	55.0	—
Six Largest Sugar Pines								
Mean diameter (cm)	—	—	35.8	[40.9]	49.5	[49.8]	58.2	[57.9]
Mean height (m)	—	—	22.0	[28.2]	—	—	30.9	[33.7]

[1]From Malain et al. (1963).

Figure 2—*Sugar pines exhibit sparse crowns as a result of competition with Douglas-fir. Note the 2 trees in the lower left corner.*

occurred and there were no cones found. Other studies have shown that heavy cone crops occur every 4 years on the average and that small diameter trees like those in this plantation produce a very small percentage of a normal cone crop (3). As these characteristics indicate, sugar pine is not well adapted to unmanaged plantations in this area.

Conclusions

As results of this study indicate, introduced sugar pine is unable to compete with naturally seeded Douglas-fir. Therefore, landowners who want to establish sugar pine plantations in this area will have to weed out invading native conifers. Considering the inferior merchantibility of sugar pine compared to redwood in this area, a plantation requiring this sort of intensive management would seem to be unfeasible except for special purposes.

Literature Cited

1. Griffin, J. R.; Critchfield, W. B. The distribution of forest trees in California. PSW-82/1972. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1976. 114 p.
2. Malain, R. J.; Burns, D. M.; and Sindel, J. E. Sugar pine planting on Jackson State Forest. Calif. State For. Note 17. 4 p.
3. Fowells, H. A.; Schubert, G. H. Seed crops of forest trees in the pine region of California. Agric. Tech. Bull. 1150. Washington, DC: U.S. Department of Agriculture; 1956. 48 p.
4. Fowells, H. A. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; 1965. 762 p.

Growth Loss and Mortality of White Pine Nursery Stock Caused by Pine Bark Aphids After Field Planting

Don Rogers, Coleman Doggett, and Harvey Barron

Pest Control Forester, Sr. Staff Forester, and Pest Control Ranger, North Carolina Department of Natural Resources and Community Development, Division of Forest Resources, Raleigh, N. C.

Outplantings of 2-0 white pine seedlings heavily infested with pine bark aphids were compared with outplantings of uninfested seedlings in a 1980-81 study. After two growing seasons, there was no statistically significant difference in mortality between heavily infested and uninfested seedlings. There was a significant difference in growth, however, with the uninfected seedlings averaging 11 percent greater growth than the infested seedlings.

The pine bark aphid (*Pineus strobi* (Htg.)), a species accidentally introduced from Europe, is found in most areas of the United States wherever white pines grow. Aphid infestations are best recognized by the presence of white spots and patches of white cottony material on the smooth bark of the trunks and limbs, at the bases of needles, or on buds. During the growing season of 1979, a heavy infestation of the aphid occurred throughout the 2-0 white pine seedling nursery beds at Edwards Nursery in Morganton, North Carolina. The purpose of this study was to determine the effects of the pine bark aphid on the survival and growth of white pine nursery-grown seedlings after field planting.

Materials and Methods

White pine seedlings (2-0) were selected for the study in February 1980. All seedlings selected were 19 to 20 centimeters in height, measured from root collar to terminal bud. The seedlings were divided into two categories: (1) lightly infested, and (2) heavily infested. Microscopic examination of heavily infested seedlings revealed a mean aphid density of approximately 1,400 aphids per seedling, while lightly infested seedlings had a mean aphid density of approximately 100 aphids per seedling. To facilitate growth measurement, a yellow stripe of Nelspot tree-marking paint was applied to each seedling 8 centimeters below the terminal bud.

The two study areas were located in Avery County and Burke County, North Carolina. Six 20-tree rows of seedlings were planted in each area in late March and early April 1980. Seedlings were spaced at 4-foot intervals within rows, and rows in each treatment were 4 feet apart. Three of the rows in each study area were planted with heavily infested seedlings, and three rows were planted with lightly infested seedlings.

Rows with lightly infested trees were then treated to remove all aphids. Treatment consisted of hand removal of all visible aphids followed by a 1 percent Lindane spray.

To determine the effects of pine bark aphids, survival was determined and height growth was measured in November 1980 and in November 1981. Data on growth and mortality were statistically analyzed using an analysis of variance.

Results and Conclusions

Table 1 summarizes growth and mortality of study seedlings. There was no significant difference in survival between infested and uninfected seedlings when land 2-year data were analyzed at the 95 and 99 percent significance levels. There was no significant difference in growth after 1 year at the 95 and 99 percent significance levels. After 2 years, however, the difference in growth widens, and the growth of the uninfected seedlings is significantly better than the infested

Table 1—*Growth and Mortality of 2-0 White Pine Seedlings, 1980-81*

	1980		1981	
	Survival	Mean growth	Survival	Mean growth
	%	*cm*	%	*cm*
Infested	97.50	14.84	93.00	31.57
Uninfested	98.33	15.67	97.44	35.49

seedlings, both at the 95 and 99 percent levels.

Since the differences in growth during the first several years in the field tend to diminish with age, we feel that this growth difference will probably not be significant by the end of the rotation.

Seedlings were carefully examined for aphids after one and two seasons of growth. Few aphids were detectable on either the heavily infested or uninfested seedlings.

We speculate that aphids flourish in nursery beds because the dense foilage protects them against both predators and the elements. When trees are outplanted, the aphids become more exposed and vulnerable, and consequently, populations rapidly decrease.

Fungicide Trials to Control Botrytis Blight at Nurseries in Idaho and Montana[1]

R. L. James and J. Y. Woo

Plant Pathologist, USDA Forest Service, Cooperative Forestry and Pest Management, Missoula, Montana and Research Plant Pathologist, Intermountain Forest and Range Experiment Station, Moscow, Idaho.

Iprodione, chlorothalonil, and captan adequately controlled Botrytis blight of containerized western larch and lodgepole pine seedlings. Less satisfactory results were obtained with benomyl and dicloran. Vinclozolin caused severe phytotoxicity to young containerized western larch seedlings but not to 2-0 bareroot seedlings. All fungicides tested reduced height growth of conifer seedlings.

Botrytis cinerea (Fr.) Pers. is an important pathogen in conifer nurseries where it causes foliage blight of seedlings. The disease is especially severe on containerized seedlings grown in greenhouses, where conditions are often ideal for infection (10). Although the disease is most destructive in greenhouses, losses have also been reported on bareroot stock (4). Botrytis blight occurs on many conifer hosts in Idaho and Montana nurseries, but most damage occurs on western larch (*Larix occidentalis* Nutt.), lodgepole pine (*Pinus contorta* Dougl.), Engelmann spruce (*Picea engelmanni* Parry), and ponderosa pine (*Pinus ponderosa* Laws).

Botrytis blight has been traditionally controlled by using cultural methods to reduce chances of infection and applying fungicide during periods of when seedlings are highly susceptible (7, 10). Fungicides are usually applied through overhead irrigation systems in green-houses and after irrigation or rain on bareroot seedlings. Unfortunately, frequent applications and high dosage rates have often led to development of *Botrytis* strains that are tolerant to many commonly used fungicides (2, 3, 8).

Because of recurring problems with fungicide tolerance at several nurseries in Idaho and Montana (1, S), tests were conducted to determine how effective different fungicides are in controlling Botrytis blight in greenhouses and bareroot beds. These tests provided the basis for recommendations of specific fungicides to reduce future losses from this disease.

Materials and Methods

Tests to control Botrytis blight with fungicides were conducted on containerized western larch and lodgepole pine seedlings in greenhouses and on western larch seedlings in outdoor bareroot beds at the USDA Forest Service Nursery in Coeur d'Alene, Idaho, and on containerized western larch in greenhouses at the Champion Timberlands Nursery in Plains, Montana. Fungicides tested (table 1) included four chemicals previously used at these nurseries (benomyl, chlorothalonil, captan, and dicloran) and two never used (iprodione and vinclozolin).

Five replications of 200 seedlings each (Coeur d'Alene) or 160 seedlings each (Plains) were used for each of the greenhouse treatments and the distilled water check. Fungicides were applied at label rates (table 1) with a standard garden sprayer until they began to run off the seedling foliage. This was repeated eight times at biweekly intervals, starting when seedlings were 2 to 2 $^1/_2$ months old. Treated seedlings were randomly placed in greenhouses among nontreated seedlings. To ensure uniform exposure to *Botrytis* inoculum, all test seedlings were inoculated with a spore suspension of the fungus after applying fungicide twice. Each container tray of 200 or 160 seedlings was inoculated with 10 milliliters of the spore suspension (1.15 to 1.5 x 10^6 spores/ml) using a fine-mist atomizer. *Botrytis* isolates used in all inoculations were local fungal strains obtained from western larch seedlings.

A randomized block design was used for the bareroot tests. Each treatment block consisted of 0.9 linear meters of seedbed containing western larch seedlings in their second growing season. A 0.3-meter, untreated buffer strip separated each treatment block.

[1] We wish to acknowledge the assistance of J. F. Myers and P. L. Malone of the USDA Forest Service Nursery in Coeur d'Alene and D. Genz of the Champion Timberlands Nursery in Plains.

Table 1—*Fungicides tested to control Botrytis blight on western larch and lodgepole pine*

Fungicide	Trade name	Chemical name	Application rate per 100 gallons water	Manu-facturer	Test location
Benomyl	Tersan 1991	Methyl 1-(butylcar-bamoyl)-2-benzimida-zolecarbamate	1 lb	Dupont	CDA-G CDA-B
Dicloran	Botran	2,6-Dichloro-4-nitroaniline	1-1/3 lb	Tuco	CDA-G P-G CDA-B
Chloro-thalonil	Bravo 500	Tetrachloroisophthalo-nitrile	2-3/4 pt	Diamond Shamrock	CDA-G P-G CDA-B
Chloro-thalonil	Daconil 2787	Tetrachloroisophthalo-nitrile	1-1/2 lb	Diamond Shamrock	CDA-G CDA-B
Captan	Captan	*N*-[(trichloromethyl) thio]-4 cyclohexene-1, 2-dicarboximide	2 lb	Stauffer	CDA-G P-G CDA-B
Iprodione	Chipco 26019	3-(3,5-dicholophenyl)-*N*-(1-methylethyl)-2,4-dioxo-1-imidazolidine carboximide	1 lb	Rhone-Poulence	CDA-G P-G CDA-B
Vinclozolin	Ornalin	3-(3,5-dichlorophenyl) -5-ethenyl-5-methyl-2,4-oxazolidinedione	1 lb	Mallinc-krodt	P-G

[1]CDA-G = Forest Service Nursery, Coeur d'Alene—greenhouse.
CDA-B = USDA Forest Service Nursery, Coeur d'Alene, Idaho—bareroot beds.
P-G = Champion Timberlands Nursery, Plains, Montana—greenhouse.

Each treatment and a distilled water check was replicated five times. Treatment blocks were clearly delineated at each end by string that was tied to wooden stakes placed at each corner so that the number of test seedlings in each block at the beginning and end of the test could be accurately compared. Seedlings were treated with the fungicides or distilled water six times at biweekly intervals starting in the spring. The seedlings in each block were thoroughly drenched with approximately 9.5 liters of fungicide, solution, or water. Seedlings in each block were inoculated with 20 milliliters (2.6×10^6 spores/ml) of a *Botrytis* spore suspension twice during the test-once after two fungicide or distilled water applications had been made and again about $1\frac{1}{2}$ months later. The second inoculation was considered necessary because of dry, windy weather during and shortly after the first inoculation, resulting in little apparent infection.

At the end of the trials, the number of seedlings killed by *Botrytis* infection and heights of all treated seedlings were compared using Duncan's multiple-range comparison test.

Results

All fungicides reduced *Botrytis* infection and improved survival of western larch seedlings in the greenhouse test at Coeur d'Alene (table 2). Heights of both western larch and lodgepole pine seedlings were reduced as a result of fungicide application, but the reduction did not cause seedlings to be below acceptance standards. Chlorothalonil, iprodione, and captan provided best protection against *Botrytis* infection. Benomyl did not effectively reduce infection of either western larch or lodgepole pine. Dicloran reduced infection of lodgepole pine but was less effective on western larch.

The greenhouse test conducted at Plains did not produce conclusive results because of the infection. Vinclozolin was not the only fungicide in this test that significantly reduced seedling survival, even though label seedlings were used (table 3). We believe this was due to phytotoxic

Table 2—*Effects of fungicides on survival and height of containerized western larch and lodgepole pine seedlings inoculated with* Botrytis cinerea *(Coeur d'Alene, Idaho)*[1]

	Western larch			Lodgepole pine		
Fungicide	Seedling infection	Seedling survival	Average seedling height	Seedling infection	Seedling survival	Average seedling height
	%	%	*mm*	%	%	*mm*
Water (check)	96.2a	86.9d	165.4a	27.6a	100.0a	125.6a
Dicloran	58.5b	94.0c	159.7c	0.5c	99.9a	121.4b
Benomyl	54.8c	87.1d	166.6a	12.8b	99.6b	119.1bc
Captan	29.7d	97.6a	153.3d	0.1c	100.0a	121.3b
Chlorothalonil (Daconil 2787)	8.4e	95.8abc	160.8bc	1.7c	100.0a	118.6cd
Iprodione	6.8e	96.8ab	163.8ab	0.2c	100.0a	120.9bc
Chlorothalonil (Bravo 500)	5.9e	95.1bc	152.3d	0.2c	100.0a	116.7d

[1]Within each column, means followed by the same letter are not significantly different (p=0.05) using Duncan's multiple range comparison test.

Table 3—*Effects of fungicides on survival and height of containerized western larch seedlings inoculated with* Botrytus cinerea *(Plains, Montana)*

Fungicide	Seedling survival	Average Seedling height
	%	*mm*
Water (check)	98.8a[1]	152.6a
Dicloran	98.4a	137.4b
Captan	99.2a	116.8c
Chlorothalonil	99.1a	118.9c
Iprodione	99.9a	150.0a
Vinclozolin	78.0b	141.2b

[1]Means followed by the same letter are not significantly different (p=0.05) using Duncan's multiple range comparison test. Percentages were converted to arc sin for statistical analysis.

response of larch seedlings rather than to *Botrytis* infection. As with the Coeur d'Alene greenhouse test, all fungicides reduced seedling height, especially captan and chlorothalonil.

Results of the bareroot seedling test at Coeur d'Alene were similarly inconclusive because of low infection rates, despite two inoculations at different times. There were no significant differences in seedling survival among any of the treatments (table 4). With the exception of one chlorothalonil treatment (Bravo 6F), all fungicides reduced seedling heights.

Table 4—*Effects of fungicides on survival and height of bareroot western larch seedlings inoculated with* Botrytis cinerea *(Coeur d'Alene, Idaho)*

Fungicide	Seedling survival	Average seedling height
	%	*mm*
Water (check)	98.6a[1]	351.2c
Dicloran	96.8a	311.6a
Captan	97.9a	327.9b
Chlorothalonil (Daconil 2787)	97.2a	336.4b
Chlorothalonil (Bravo 6F)	98.3a	370.9d
Iprodione	99.3a	311.3a

[1]Means followed by the same letter are not significantly different (p=0.05) using Duncan's multiple range comparison test. Percentages were converted to arc sin for statistical analysis.

Discussion

Low infection levels obtained from inoculations in two of the three tests make it difficult to evaluate efficacy of tested fungicides to control Botrytis blight. Nevertheless, the greenhouse test at Coeur d'Alene provides some clues as to how well these chemicals control *Botrytis.*

Benomyl did not effectively control the disease on either western larch or lodgepole pine seedlings. We suspect that the *Botrytis* population at the Coeur d'Alene nursery may have developed tolerance to the chemical. Several isolates of the fungus from this nursery showed high levels of tolerance to benomyl in previous tests conducted by the Pacific Northwest Region (1). Tolerance of *Botrytis* to benomyl has also been reported at several other nurseries (3, 5, 7), and the fungicide often does not effectively control the disease at these places. As a result, many growers have stopped using benomyl to control *Botrytis.*

Dicloran was also not effective against Botrytis blight on containerized western larch at Coeur d'Alene, but provided satisfactory control in the lodgepole pine test. Previous tests of *Botrytis iso*lates from Coeur d'Alene did not show that they were tolerant to dicloran (1). However, according to Webster et al. *(11), Botrytis* can readily develop tolerance to dicloran. We believe that dicloran performs best when rotated or mixed with other fungicides.

The other fungicides gave satisfactory control of *Botrytis* on both containerized larch and lodgepole pine in the greenhouse test at Coeur d'Alene. Captan is widely used to control the disease (9) and should continue to provide adequate control, especially if rotated with other fungicides. Chlorothalonil is also usually effective against Botrytis blight, although tolerance to this fungicide may develop (1, 3, 5). Iprodione, a relatively new fungicide used for *Botrytis,* provided good control in our tests. This fungicide needs to be evaluated for tolerance development of the fungus and is not registered for use on conifers in many states.

All tested fungicides reduced seedling heights. Extensive phytotoxicity was evident only in the vinclozolin treatment of western larch in the greenhouse test at the Plains nursery. It is unclear why vinclozolin caused high seedling mortality in this test. Similar phytotoxic responses to this fungicide were not evident in the bareroot western larch test at Coeur d'Alene. However, bareroot seedlings in their second growing season were perhaps not as sensitive to this fungicide as young, container-grown seedlings.

Recommendations

We recommend that fungicides be rotated and applied at the lowest possible dosages consistent with adequate disease control. Otherwise, *Botrytis* may develop tolerance to them and become more damaging and difficult to control. Screening for fungicide-tolerant strains of *Botrytis* should be conducted periodically to determine if currently used fungicides are still effective. As new fungicides become available, they should also be evaluated for their effectiveness against Botrytis blight.

Literature Cited

1. Cooley, S. J. Fungicide tolerance of *Botrytis cinerea* isolates from conifer seedlings. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 13 p.
2. Dekker, J. Acquired resistance to fungicides. Annual Review of Phytopathology. 14: 405-428; 1976.
3. Gillman, L. S.; James, R. L. Fungicidal tolerance of Botrytis within Colorado greenhouses. Tree Planters' Notes 31(l) : 25-28; 1980.
4. James, R. L. Engelmann spruce needle blight at the Coeur d'Alene Nursery, Idaho. Rep. 80-21. Missoula, MT. U.S. Department of Agriculture, Forest Service, Northern Region; 1980. 5 p.
5. James, R. L.; Gilligan, C. J. Fungicide tolerance of *Botrytis cinerea* from the Flathead Indian Reservation Greenhouse, Ronan, Montana. Rept. 83-5. Missoula, MT. U.S. Department of Agriculture, Forest Service, Northern Region; 1983. 15 p.
6. McCain, A. H.; Smith, P. C. Evaluation of fungicide for control of Botrytis blight of container-grown redwood seedlings. Tree Planters' Notes 29(4): 12-13; 1978.
7. Miller, M. W.; Fletcher, J. T. Benomyl tolerance in *Botrytis cinerea* isolates from glasshouse crops. Transactions of the British Mycological Society 62: 99-103; 1974.
8. Ogawa, J. J.; Manjii, B. T.; Chastagner, G. A. Field problems due to chemical tolerance of plant pathogens. Proceedings of the American Phytopathology Society 3: 7-53; 1976.
9. Smith, R. S., Jr.; McCain, A. H.; Srago, M. D. Control of Botrytis storage rot of giant sequoia seedlings. Plant Disease Reporter 57: 67-69; 1973.
10. Webster, R. K.; Ogawa, J. M.; Bose, E. Tolerance of *Botrytis cinerea* to 2, 6-Dichloro-4 nitroaniline. Phytopathology 60: 1489-1492; 1970.

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Container Density Does Not Affect Baldcypress Growth[1]

Albert F. Stauder III and William J. Lowe

Silviculturist, Texas Forest Service, College Station, Tex., and Associate Geneticist, Texas Forest Service/ Assistant Professor, Texas Agricultural Experiment Station, College Station, Tex.

Baldcypress seedlings were grown in containers at densities of 10, 14, and 20 seedlings per square foot. Growth differences due to sowing density could not be detected after the first year in the field.

Baldcypress (*Taxodium distichum* (L.) Rich.) is a large tree that grows best on deep, fine sandy loam soils with good moisture and moderately good drainage. It is rarely found naturally in such areas, however, and more typically forms pure stands in swamps because of the absence of vegetative competition. Baldcypress grows in the Coastal Plain from southeastern Texas through southern Delaware. Its range extends northward up the Mississippi Valley to southern Illinois and southwestern Indiana (2).

Baldcypress, once highly prized for its lumber, is now processed in only a few mills. Natural and artificial regeneration is possible, and interest in managing cypress is increasing (3). Another important use of this species exists in the nursery and ornamental trade. More and more baldcypress is planted each year for use as street and shade trees. Its conical shape and fall coloration are prized by landowners.

State nurseries have been growing bareroot cypress seedlings for many years, but very few cypresses have been grown in containers. The Texas Forest Service in cooperation with the Urban Tree Improvement Program initiated this study to determine the effects of container planting density on the survival and growth of baldcypress seedlings.

Methods

Germinating seed from four Texas baldcypress selections were planted in "dee-pot" containers filled with a 1:1 peat-moss vermiculite media in the early spring, 1982. The containers were arranged in spacings of 10, 14, and 20 pots per square foot (fig. 1). The statistical design was a randomized complete block with six replications. Between 15 and 40 seedlings were grown at each density per replication. The seedlings were grown until fall in a lathhouse at College Station, Texas.

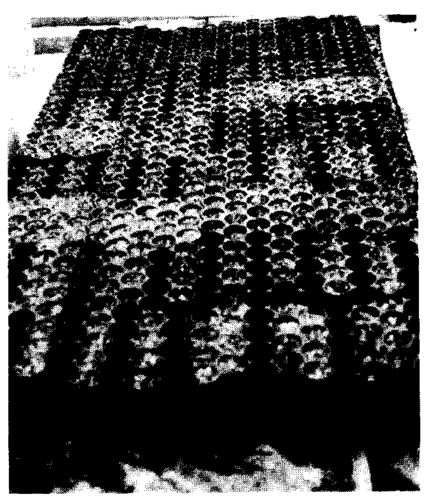

Figure 1—*Container design for the baldcypress container density study.*

When the seedlings were dormant, height and diameter at 2.5 centimeters above root collar were measured. Seedling from the outer edge of each treatment were not measured, since they did not represent the true container density.

After the initial growth measurements were obtained, seedlings were outplanted in the field at Storm Nursery, Premont, Texas, according to the experimental design from the lathhouse. The spacing for the planting was 6 by 4 feet. They were allowed to grow here as operational seedlings for one growing season (fig. 2). Height and diameter measurements at 15 centimeters were obtained during the following fall (1983). An analysis of variance using plot means (Procedure GLM) was used for the statistical analysis (1).

Results and Discussion

After one growing season from seed, survival averaged 99 percent for the test with an average height and diameter of 49.8 centimeters and 3.7 millimeters respectively (table 1). Even though height measurements ranged from 52.4 to 46.3 centi-

[1]The authors wish to thank the members of the Urban Tree Improvement Program for their assistance; in particular we thank Storm Nursery for supplying the land and personnel for the field trial of this study.

Figure 2—*Baldcypress seedlings were grown for 1 year at densities of 10 per square foot (left), 14 per square foot (center), and 20 per square foot (right).*

Table 1—*Average survival and growth rates for different baldcypress container densities after 1 year from seed*

Seedlings per ft²	Survival	Height	Diameter
	%	*cm*	*mm*
10	100	52.4	4.1
14	100	50.8	3.5
20	98	46.3	3.5
Average	99	49.8	3.7

meters, this difference was not significant at the .05 probability level of significance. Also, there were no significant differences among the diameters of the seedlings. Although seedlings grown at the lower densities appeared to be larger, the differences were not statistically meaningful.

After 1 year in the field the baldcypress seedlings grew extremely well (fig. 2). Height and diameter of the trees averaged 1.3 meters and 2.7 centimeters respectively (table 2). An analysis of variance indicated that no significant differences (p=.05) were found for survival, height, or diameter among container densities. Furthermore, any visual differences that may have been noted after 1 year in containers could not be observed in the field.

Conclusions

Planting densities of 10, 14, and 20 seedlings per square foot had no effect on the survival and growth of the trees after one growing season in the field. Therefore, baldcypress seed can be container-grown at densities up to 20 seedlings per square foot with no expected loss in survival or growth. This enables nursery managers to grow quality seedlings in a smaller unit area.

Table 2—*Average survival and growth rates for different baldcypress container densities after 1 year in the field*

Seedlings per ft²	Survival	Height	Diameter
	%	*cm*	*mm*
10	98	1.3	2.9
14	88	1.3	2.7
20	92	1.2	2.6
Average	93	1.3	2.7

Literature Cited

1. Barr, A. J.; Goodnight, J. H.; Sall, J. P.; Blair, W. H.; Chilko, D. M. SAS user's guide. 1979 ed. Cary, NC: SAS Institute, Inc.; 1979. 494 p.
2. Harlow, W. M.; Harrar, E. S. Textbook of dendrology. New York: McGraw Hill; 1969. 512 p.
3. Williston, H. L.; Shropshire, F. W.; Balmer, W. E. Cypress management: a forgotten opportunity. For. Rep. SA-FR 8. Atlanta, GA: USDA Forest Service, Southeastern Area State and Private Forestry; 1980. 8 p.

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Effects of Seedbed Density and Fertilization on Root-Pruned 2-0 White Oak Nursery Stock

James R. Wichman and Mark V. Coggeshall

Nursery Forester and Tree Improvement Forester, Indiana Department of Natural Resources, Vallonia Nursery, Vallonia, Ind.

Average seedling caliper of white oak increased as seedbed density decreased and as fertilization increased. Seedling height increased with fertilization but was not affected by seedbed density. Percent of culls increased as density increased but was not affected by fertilization.

Nursery practices may affect the growth and survival of white oak seedlings after outplanting. Because larger seedlings appear to have a greater potential for good growth than smaller seedlings (1,2), Johnson (1) recommended a minimum size of 8 millimeters (10/32 in) in caliper at 2.54 centimeters (1 in) above the root collar and a shoot length of 50 centimeters (20 in). Under conditions at Vallonia Nursery, white oak (*Quercus alba*) seedlings take 2 years to reach this acceptable size. The purpose of this study was to measure the effects of seedbed density and fertilization on the growth of root-pruned 2-0 white oak seedlings.

Methods

The white oak acorns used in this study were collected from various sources in southeastern Indiana and thoroughly mixed before sowing so that the study results would represent the seed sources normally sown at Vallonia. The acorns were sown by hand in October 1981 in five 1-inch-deep drills spaced 8 inches apart on a standard 4-foot-wide nursery bed. The acorns were covered with $^1/_2$ to 1 inch of soil and mulched with hydromulch.

Treatments consisted of 3 seedbed densities of 4, 8, and 12 seedlings per square foot, and 3 top-dress fertilizer rates of 0, 400, and 800 pounds per acre of 12-12-12 fertilizer at each seedbed density. The study was a 3 by 3 factorial arranged in a randomized complete block design having 3 replications. The 9 treatment combinations were assigned randomly to each replication with 4-by-4-foot plots.

Except for root pruning, these seedlings were grown under the same conditions as described for 1-0 white oak by Wichman and Coggeshall (3). All fertilizer treatments were applied during June and July of the first growing season.

The seedlings were root-pruned in early April of 1983, just as they were beginning to grow new shoots. A standard horizontal root-pruner was used at a depth of 6 to 8 inches. The roots were pruned to limit tree size and also to increase root fibrosity, which has been shown to enhance field performance (2).

In December 1983, 3,867 seedlings were lifted and measured to determine height, caliper (diameter at 1 inch above the root collar) and percent cull. A cull was defined as a seedling with a caliper of 5 millimeters (6/32 in) or less. Height, caliper, and percent of cull were subjected to analyses of variance, and percent of cull data was transformed by using arc sin v (percentage) transformation.

Results and Discussion

Seedbed density and fertilizer significantly influenced seedling caliper (table 1). Seedling caliper increased from 6.0 millimeters at a seedbed density of 12 to 7.8 millimeters at a seedbed density of 4

Table 1—*Analysis of variance of caliper, height, and cull seedling percentage for 2-0 root-pruned white oak*

		Mean square for		
Source of variation	df	Caliper	Height	Seedlings culled
		mm	*cm*	*Arc sin* $\sqrt{\%}$
Blocks	2	1.1626*	26.9478	106.7811
Seedbed density (D)	2	7.7615**	20.6144	948.9811**
Fertilizer (F)	2	2.5848**	86.5433**	99.1033
D x F	4	0.0715	7.5994	14.1044
Error	16	0.2230	12.6149	33.1969

*Significant at p = .05 level

**Significant at p = .01 level

(table 2). Average caliper increased from 6.2 millimeters at 0 pounds per acre of top-dress fertilizer to 7.3 millimeters at 800 pounds per acre of 12-12-12 (table 2). For individual treatment combinations, caliper varied from 5.4 millimeters at a seedbed density of 12 and 0 fertilizer to 8.4 millimeters at a seedbed density of 4 and fertilizer of 800 pounds per acre. This combination of low seedbed density and high levels of fertilizer produced the largest caliper seedlings.

Wichman and Coggeshall (3) reported that fertilization did not significantly affect caliper of 1-0 white oak seedlings. The different response of 1-0 and 2-0 white oak to fertilization could be due to several factors. Because 2-0 seedlings were much larger than the 1-0 trees, they needed more soil nutrients. Also, the root-pruning cut many of the deep roots (more than 8 inches below the surface) established during the first growing season. The nutrients in deeper soil layers could therefore not be tapped for several weeks until deep roots were re-established.

Seedbed density had no effect on seedling height (table 1). Wichman and Coggeshall (3) reported that neither seedbed density nor fertilizer influenced the height of 1-0 white oak seedlings. For 2-0 white oak, seedling height was influenced by fertilization (table 1). Average height increased from 34.8 centimeters at 0 pounds per acre to 40.5 centimeters at 800 pounds per acre of 12-12-12 fertilizer (table 2). Nutrients apparently became a limiting site factor during the second growing season, because when fertilized, seedlings responded to the improved site conditions by growing taller.

Percent cull was influenced by seedbed density but not by fertilizer (table 1). Average cull percent increased from 16.1 at a seedbed density of 4 to 48.1 per-

Table 2—*Average caliper, height, and cull seedling percentages by seedbed density and fertilizer treatments for 2-0 root-pruned white oak*

Source of variation		Caliper	Height	Seedlings culled
		mm	*cm*	%
Seedbed density				
4 seedlings/ft²		7.8a[1]	39.6a	16.1a
8 seedlings/ft²		6.7b	38.8a	33.3b
12 seedlings/ft²		6.0c	36.7a	48.1c
Fertilizer				
0 lb/acre		6.2c	34.8c	37.6a
400 lb/acre		6.9b	39.8b	32.3a
800 lb/acre		7.3a	40.5a	27.5a
Seedbed density (D)x Fertilizer (F)				
D	F			
4	0	7.2	36.9	20.0
4	400	7.8	40.5	17.8
4	800	8.4	41.4	10.6
8	0	6.2	36.5	35.6
8	400	6.8	39.8	34.3
8	800	7.1	40.1	30.0
12	0	5.3	31.0	57.4
12	400	6.2	39.0	44.8
12	800	6.4	40.0	42.0

[1]Means within a column, within a treatment, not followed by a common letter are significantly different at the p = .05 level.

cent at a seedbed density of 12 (table 2). For individual treatments, percent cull varied from 10.6 percent at 4 seedlings per square foot and 800 pounds per acre of fertilizer, to 57.4 percent at 12 seedlings per square foot and 0 fertilizer (table 2). The former combination of density and fertilizer is therefore best for producing the greatest number of shippable seedlings.

In this study, seedlings were not culled on the basis of height because nearly all seedlings were at least 20 centimenters tall. In fact, most of the seedlings approached 35 centimeters in height. At high seedbed densities, the seedlings apparently grew in height at the expense of diameter growth.

Studies with white oak and many other tree species have shown that large seedlings are more likely to grow at an acceptable rate after field planting (1, 2). If this criterion is applied to the trees in this study, a seedbed density of 4 with 800 pounds per acre of top-dress 12-12-12 fertilizer would be the best practice for producing large, high quality, 2-0 root-pruned white oak. This combination would also minimize the number of cull seedlings.

Seedlings from each treatment in this study will be outplanted and compared with the 1-0 seedlings described by Wichman and Coggeshall (3). Results from this outplanting phase will show how seedling age and nursery culture affect field performance of white oak seedlings in Indiana.

Literature Cited

1. Clausen, K. E. English oak grows better than white oak of comparable seedling size. Tree Planters' Notes: 34(4) 17-19; 1983.
2. Johnson, P. S. Nursery stock requirements for oak planting in upland forests. In: Proceedings, northeastern area nurserymen's conference; 1981 August 10-13; Springfield, MO. Columbia, MO: Missouri Department of Conservation; 1981: 2-19.
3. Wichman, J. R.; Coggeshall, M. V. The effects of seedbed density and fertilization on 1-0 white oak nursery stock. Tree Planters' Notes: 34(4): 13-16; 1983.

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Machine-Planting Seedlings with Near-Checkerboard Precision

David F. Van Haverbeke

Research Forester, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Laboratory, Lincoln, Nebr.

Trees machine-planted on cultivated sites can be aligned in checkerboard pattern by (1) setting several guide flags in each row to be planted, (2) setting three rows of baseline flags outside the plantation at within-row spacings parallel to the first row to be planted, and (3) advancing three rows of baseline flags across the plantation in leap-frog fashion every five rows as planting proceeds.

Plantation trees are more esthetic and easier to maintain and measure when "checkerboard" planted; that is, set so that an observer can sight along the rows, across the rows, and diagonally through the rows from any point inside or outside the plantation.

It is possible to hand-plant trees in a checkerboard configuration; however, hand-planting, especially in heavy-textured soils, is time consuming, laborious, and difficult to justify economically if the planting is large.

Machine-planting is faster, less laborious, and can achieve near-perfect row alignment; but it is more difficult to space trees accurately within rows. Devices commonly used to achieve within-row spacing, such as bells on planter wheels and trailing chains and ropes attached to planters; cannot usually achieve a perfect checkerboard effect. Alignment is especially difficult when planting on hilly or undulating sites.

Machine-planting perpendicular to previously identified rows, such as those set off in grass and sprayed with a herbicide, is a good way to achieve near-checkerboard precision. When planting on completely cultivated sites, however, this method is not feasible. This article describes a procedure to achieve near-checkerboard precision when machine-planting in a completely tilled and unmarked site.

Preparing to Plant

Before planting, the ends of each row to be planted are accurately identified with guide flags. Additional guide flags are set every 60 to 90 meters within each of these rows (fig. 1).

Three baseline rows are marked off outside the plantation boundary adjacent and parallel to the first row to be planted, at the designated between-row spacing. Flags are set accurately along the length of these three rows, marking individual seedling positions at the designated within-row spacing.

Planting

The driver centers the tractor over the first row to be planted and keeps the tractor and planting machine in line with and over the series of several guide flags in that row. The "planting" member of the crew sights across to the rows of baseline flags as the tractor proceeds along the row being planted, and sets a seedling each time three flags designating the same position in the rows come into alignment.

After completing the first plantation row, the tractor returns alongside the row just planted and packs the soil next to the seedlings with the weight of the rear wheel, eliminating any air pockets that may remain near the seedling roots. The tree planter is reloaded and the next row is planted. Beginning at the same end of the row each time enables the "planting" member of the crew to better maintain consistency of planting technique, and thus precision, by always sighting across to the flags from the same side of the planter without having to change position.

Realignment

Accurate alignment can be maintained with the original three rows of parallel baseline flags for about five rows, even over moderately uneven terrain, before plantings begin to drift off line, either behind or ahead of the true across-row alignment.

At this point, a new row of flags is set with a tape line at the correct within-row spacings in the last (5th) row planted-disregarding the positions of the just-planted seedlings (fig. 1). Planting is then resumed for another 5 rows, followed by the setting of additional rows of flags

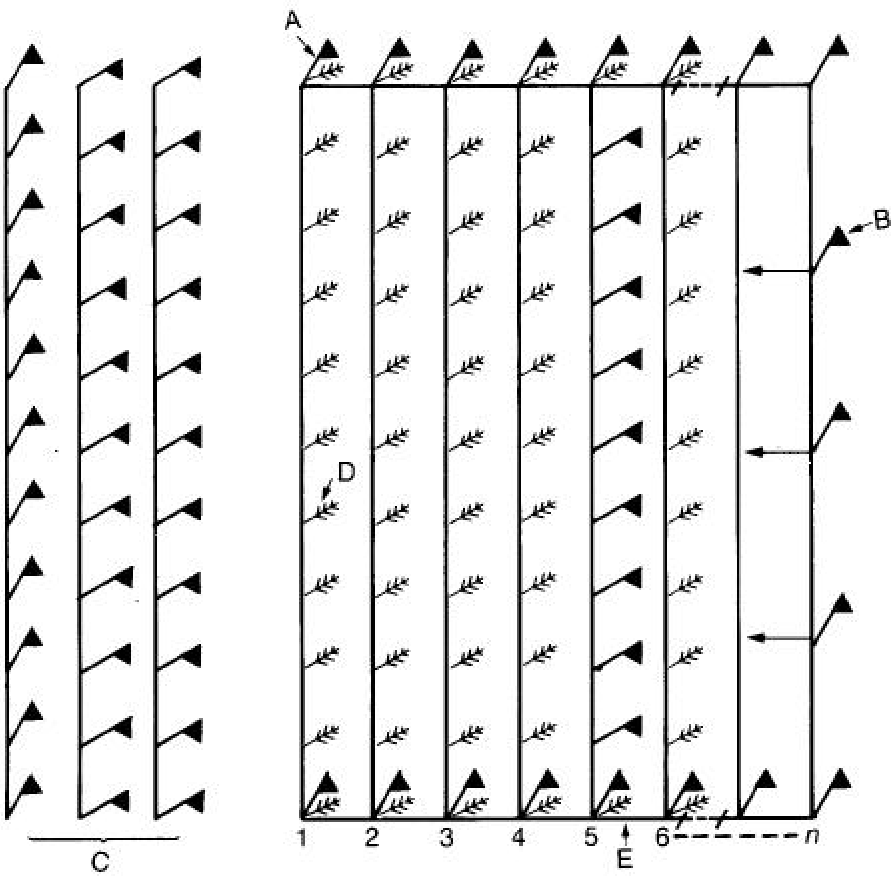

Figure 1—Diagrammatic sketch of procedure for checkerboard planting seedlings by machine. A. Identify the ends of each row to be planted. B. Set up tractor guide flags every 60 to 90 meters within each row. C. Mark three baseline rows outside the plantation boundary adjacent and parallel to the first row to be planted. D. From the tractor, sight across the planting row to the baseline flags and set seedlings when three baseline flags come into alignment. E. Set a new row of flags with a tape line using the baseline rows.

in the 10th, 15th, . . . nth row to the end of the plantation. To conserve flags, only the three rows of flags set at five-row intervals nearest the planting operation plus the first baseline row are needed to maintain proper alignment. All other intervening rows of marker flags can be pulled out and reused for rows yet to be planted.

The occasional out-of-line tree is readily detected by the person walking behind the planter straightening and tamping newly planted seedlings. These seedlings can then be replanted into better alignment. These out-of-line seedlings are most noticeable in the fifth of a set of five rows after the correct spacing distance has been reestablished.

This procedure was recently used to establish two progeny plantations, totaling 7 hectares, on freshly cultivated land. Seedlings were spaced 2.5 meters apart within rows 3.7 meters apart. In a short time, this technique periodically and systematically brought the across-row alignment within the plantation back into the desired checkerboard configuration.