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# Controlled Pollination Techniques for Fraser Fir

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*Several methods of pollen forcing and different isolation bags were tested to develop controlled pollination procedures for Fraser fir. Depending on date of pollen shedding, different methods of forcing are recommended. Standard sausage casing was a good, inexpensive isolation bag.*

Fraser fir (*Abies fraseri (*Pursh) Poir.) is a small-to-medium-sized tree native to several high-mountain locations in Virginia, North Carolina, and Tennessee (*6*). It is closely related to balsam fir (*A. balsamea* (L.) Mill.), differing mainly in the length of the ovuliferous bracts. In balsam fir, the bracts are completely enclosed within the scales; whereas in Fraser fir, the bracts are longer than the scales and strongly reflexed (*4*).

Natural stands of Fraser fir are most commonly found at elevations of 4,500 feet and higher in climax association with red spruce (*Picea rubens* Sarg.) and yellow birch (*Betula lutea* Michx. f.). As elevation increases, spruce and birch become less frequent; and on the highest peaks, Fraser fir forms pure stands (*1, 5, 12*).

The climate occurring where Fraser fir grows naturally is cool and humid. The mean July temperature is 15.1° C and annual precipitation averages between 200 and 250 centimeters (*1, 2, 8*). The soil is relatively acidic (pH 3.5 to 5.5) with a substantial amount of organic matter (*10*).

### Economic Importance

In the southern Appalachian Mountain region, Fraser fir is the most important Christmas tree. It has a natural Christmas tree shape, strong branches to support ornaments, a pleasant aroma, glossy dark-green foliage, and good needle retention (fig. 1). Vigorous 4- to 5-year-old transplants require 7 to 12 years to grow to a market height of 7 to 8 feet (*11*). Fraser fir commands the highest price and is the most preferred commercial Christmas tree in the region. In 1978, the Fraser fir Christmas tree industry in the western counties of North Carolina produced 660,000 cut trees and generated $6,600,000 of gross revenue.[2]

**Figure 1.**—*An excellent Fraser fir phenotype.*

### Purpose of Study

Responding to the needs of a growing commercial Christmas tree industry, the North Carolina Forest Service established a Fraser fir seedling seed orchard at the Linville Nursery in Crossnore, N.C., during the mid-1960's. The trees were selected from cooperating commercial plantations solely on the basis of phenotype. Today, the trees are 12 to 20 feet tall and many are producing cones. The orchard is intensively managed including such practices as mowing, fertilization, subsoiling, and insect control. However, very little is known about pollen collection, pollen handling, and controlled pollination techniques. With these concerns in mind, a study was designed to evaluate and develop methods of controlled pollination in Fraser fir.

### Materials and Methods

Fraser fir in natural stands at high elevations normally begins to flower in mid-May and continues

[1]The author was a graduate student at North Carolina State University when the research for this article was conducted.

[2]Huxster, W. Extension Forester, North Carolina State University. Personal communication.

into early June (*7*). However, the seed -orchard at Linville River is located at a much lower elevation, and flowering is somewhat earlier. Two years of observations in the seed orchard indicate that the reproductive buds start to swell in early April and break around the end of the same month.

Studies of controlled pollination in balsam fir and the eastern spruces indicate that the sausage casing isolation bags commonly used in pine pollination may not be satisfactory, mainly because of the heat buildup within the bag[3] (*3*). These investigators recommend either a nonwoven, white fiber bag with a plastic window or a wet-strength Kraft bag. These isolation bags are impervious to pollen; allow the passage of water vapor; are not subject to overheating; and are strong enough to withstand periods of wet, windy weather.

Three isolation bag types were evaluated. The standard sausage casing bag was tested to determine its performance with Fraser fir. A nonwoven, white fiber bag with a plastic window was also used. Third, the Advance 20 "Rain in the Face" 100-percent Kraft bag was tested. In order to follow female flower development, windows were created in the Kraft bags with sausage casing and sealed with duct tape. All seams and corners of the Kraft bags were reinforced with duct tape. The three bags were supported internally with coils of heavy-gage aluminum wire and were placed on branches bearing female cone buds a few days before bud break.

In combination with the three isolation bags, seven methods of pollen collection were devised and tested. The pollen collection methods used were:

1. Sausage casing bags placed on catkin-bearing branches 4 to 5 weeks before expected anthesis.
2. Sausage casing bags with the desiccant Drierite placed on catkin-bearing branches 4 to 5 weeks before anthesis.
3. Polyethylene bags placed on catkin-bearing branches 4 to 5 weeks before anthesis.
4. Polyethylene bags with the desiccant Drierite placed on catkin-bearing branches 4 to 5 weeks before anthesis.
5. Swollen catkins picked off trees, brought indoors, and placed in paper bags with the desiccant Drierite 1 to 2 weeks before anthesis.
6. Catkin-bearing branches cut from trees, brought indoors, and placed in buckets of water under incandescent light, 1 to 1½ weeks before anthesis.
7. Catkins shedding pollen picked and placed in paper bags in a warm, sunny location.

As pollen was collected by methods 1 through 6, it was dried in the pollen room at the School of Forestry on the North Carolina State University campus at Raleigh. Pollen ready for use was sealed in bottles and refrigerated until needed. Pollen collected by method 7 was used on the same day it was obtained and was applied with a camel's hair brush. Pollen collected by methods 1 through 6 was applied with a bulb syringe developed by Dr. Thomas Perry of North Carolina State University. In all, there were 21 treatment combinations. Because the seed orchard at Crossnore is not clonal, it was impossible to have true replications. Also, there were not enough female cones on any one tree to include all treatment combinations on a single tree. Therefore, all treatment combinations of a single pollination method were placed on the same tree, four trees being used in the study. Each treatment combination was repeated three times.

The female conelets of Fraser fir elongate rapidly, and isolation bags were removed approximately 1 week after pollination to prevent the conelets from pushing up against the bags. Conelet development was checked periodically throughout the summer.

The cones were harvested during the first week of September and

[3]McCormack, M.L., Jr. Extension Forester, University of Maine,. Personal communication.

returned to Raleigh for processing. Paper bags containing cones were placed in a control room under warm, dry conditions. In approximately 2 weeks, the cones had disintegrated and seeds were extracted. A sample of 100 seeds was taken from each seedlot and x-rayed to determine the percentage of viability. The appropriate fixed-effects model is:

$$Y_{ijk} = P_i + I_j + (PI)_{ij} + E_{ijk}$$

where $i = 1...7$; $j = 1...3$; $k = 1...3$

$P$ = pollen collection method

$I$ = isolation bag

$(PI)$ = pollen-by-bag interaction

$E$ = error

and the analysis of variance is summarized in table 1.

**Results**

The mean performance of each treatment combination is summarized in table 2. Analysis of variance reveals that there were no significant differences among 21 treatment combinations. However, the method of pollen collection does show a significant effect (table 3). Discounting sausage casing without desiccant (method 1), the other six methods of pollen collection perform similarly (table 4); and pollen collection effects were not significant. The three isolation bags performed similarly with regard to foreign pollen contamination. But the sausage casing and white fiber bags were able to withstand wet, windy conditions and did not tear at the corners as did some of the Kraft bags.

Because flowering is protogynous in Fraser fir, pollen forcing is necessary. The pollen collection method chosen depends on the time of flowering, cost of materials, and ease of method. Bringing cut branches indoors in buckets under incandescent light works well for the trees that shed pollen early. Despite the poor performance of forcing with sausage casing, this collection method will produce pollen if bags are placed only on the north and east sides of late-flowering trees. Pollen is best applied with a bulb syringe after air drying. Isolation bags should be removed as soon as there is danger of the conelets growing against the sides of the bag.

**Discussion**

Unlike the pines, the true firs produce mature cones in 1 year. Cone initials are laid down in the late summer of the first year, starting to swell in late March to early April of the following spring. Female cones are usually concentrated in the uppermost part of the crown, while males are usually located in the middle one-half. Rarely do males and females occur on the same branch. Female cone buds emerge from the tops of branches of the previous year's growth, while males are clustered on the undersides of branches.

Bisporangiate cones do occur in Fraser fir, although rarely. In these reproductive structures, the male

**Table 1.**—*Analysis of variance for 21 controlled pollination procedures of Fraser fir*

| Source | Degrees of freedom | Error (mean square) |
|---|---|---|
| Pollen collection method | $p$-1 | $\sigma^2_e + ki\,\Sigma_i\, p^2_j \;/\; (p-1)$ |
| Isolation bag | $i$-1 | $\sigma^2_e + kp\,\Sigma_j\, I^2_j \;/\; (i-1)$ |
| $P$ x 1 | $(p$-1$)$ $(i$-1$)$ | $\sigma^2_e + k\,\Sigma_i\,\Sigma_j\,(PI)\,2_{ij} \;/\; (p-1)\,(i-1)$ |
| Error | $pi(k$-1$)$ | $\sigma^2_e$ |
| Total | $pik$ - 1 | |

**Table 2.**—*Percentage of filled seed per treatment combination in test of controlled pollination methods in seed orchard Fraser fir*

| Pollen collection[1] method | Isolation bag: Sausage casing | White fiber | Wet-strength Kraft | Mean |
|---|---|---|---|---|
| 1 | 1.33 | 2.00 | 0.00 | 1.11 |
| 2 | 7.33 | 15.33 | 18.00 | 13.55 |
| 3 | 39.33 | 13.00 | 13.00 | 21.78 |
| 4 | 17.33 | 7.00 | 5.00 | 9.78 |
| 5 | 23.33 | 17.00 | 28.33 | 22.89 |
| 6 | 23.33 | 6.33 | 15.00 | 14.89 |
| 7 | 28.33 | 17.00 | 16.33 | 20.55 |
| Mean | 20.04 | 11.09 | 13.66 | |

[1] 1 = forced on tree with sausage casing; 2 = forced on tree with sausage casing plus desiccant; 3 = forced on tree with polyethylene; 4 = forced on tree with polyethylene plus desiccant; 5 = forced indoors in paper bag with desiccant; 6 = forced indoors under incandescent light; and 7 = wet pollen applied with a brush.

**Table 3.**—*Analysis of variance for controlled pollination study in seed orchard Fraser fir*

| Source | Degrees of freedom | Mean square | F-value [1] |
|---|---|---|---|
| Replication | 2 | 0.0069516 | 0.26n.s. |
| Pollen collection method | 6 | .1624108 | 6.19** |
| Isolation bag | 2 | .0805635 | 3.07n.s. |
| Pollen x bag | 12 | .0262013 | 1.00n.s. |
| Error | 40 | .0262391 | |

[1] ** = significant at 0.01 level; n.s. = not significant.

cone is located on top of the female cone. A cone of this type is capable of producing sound seeds.

Based on 2 years of observation in the Linville River Fraser fir seed orchard, female flowers break bud between mid- and late April.

Reproductive bud break appears to be dependent on temperature. Warm, sunny days at this time seem to speed the onset of bud break. Following bud break, maximum receptivity is reached within 1 week. The sequence of reproductive structure development in this orchard is protogynous, with the period of maximum pollen flight occurring after the period of maximum receptivity.

After pollination, conelet growth is rapid with cones reaching full size by mid-summer. As maturation proceeds, the scales harden and become woody. Seed dispersal occurs in early September as the cones disintegrate, leaving the central axes on the trees.

Using this background information on the reproductive cycle of Fraser fir, methods of controlled pollination were tested. Analysis of variance revealed that, while there were no significant treatment combination effects, the effect of the pollen collection method was significant (table 3). Discounting the use of sausage casing without a dessicant from the analysis, the other six methods were about equal in producing viable pollen. In this particular crossing study, all bags of a given pollination treatment were placed on a single tree. It is possible that the tree used to test forcing with sausage casing does not produce a high percentage of filled seeds. It is also possible that placement of sausage casing on the south and west sides of trees caused the death of pollen. Forcing with sausage casing plus desiccant did result in successful pollinations.

**Table 4.**—*Analysis of variance for controlled pollination study, discounting forcing with sausage casing*

| Source | Degrees of freedom | Mean square | F-value[1] |
|---|---|---|---|
| Replication | 2 | 0.013561 | 0.46n.s. |
| Pollen collection method | 5 | .061736 | 2.09n.s. |
| Bag | 2 | .094133 | 3.18n.s. |
| Pollen x bag | 10 | .028335 | .96n.s. |
| Error | 34 | .029599 | |

[1] n.s. = not significant.

### Recommendations

Based on the reproductive cycle, time of flowering, cost of materials, and ease of methods, the following guidelines are offered for the controlled pollination of Fraser fir.

1. Because flowering is protogynous, pollen forcing is absolutely necessary. It appears that all of the forcing methods tested will deliver viable pollen. However, depending on the time of flowering, different methods should be used.
2. If a proposed pollen parent has a history of early or average pollen anthesis relative to the orchard, cut branches bearing swollen, but still-moist, catkins and place them in buckets of water under incandescent light. This method will start producing pollen in a few days.
3. If a proposed pollen parent has a history of late pollen anthesis relative to the orchard, forcing in place with sausage casing is recommended. Bags should be placed on catkin-bearing branches, preferably on the north and east sides of the tree, to prevent sun scorching. These bags should be in place at least 4 weeks before anthesis.
4. Once catkins start to open and pollen is visible, the pollen should be extracted by a forced-air system similar to the one used by the North Carolina State University-Tree Improvement Cooperative (9). This is a critical step in the process. Fraser fir pollen is highly susceptible to molding. If the moisture content is not reduced rapidly, mold starts to form and the pollen is useless.
5. Once pollen is extracted and dried to the 8- to 10-percent moisture content, it should be stored in a cool place until needed. The sooner pollen is used after extraction the better. In the field, pollen lots should be kept in an ice chest until needed.
6. Application of pollen to the female flowers is best accomplished with some type of bulb syringe system. A bulb syringe pollinator developed by Dr. Thomas Perry performed well in this study. Pollen should not be applied with a brush because the method is too time consuming and allows ample opportunity for foreign pollen contamination.
7. The sausage casing bag is suitable for use as an isolation bag. This bag is inexpensive, durable, and easy to make. The largest size available should be used because the flowers of Fraser fir elongate rapidly following pollination. For this same reason, bags should be removed as soon as there is danger of flowers pushing against the bag.

8. A durable tag bearing the identity of the particular cross should be placed loosely around the branch bearing the pollinated flowers. Any other flowers in the vicinity that might cause confusion at harvest should be removed.
9. Cones should be picked when they are woody but still firm. In the Linville River orchard, this occurs during the first week of September. Unnecessary delay may result in a loss of the seeds.

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# Failure of Grafted Douglas-Fir Planted at Monterey, Calif.

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*Grafted coastal Douglas-fir clones from Oregon were transplanted to the Monterey Peninsula of California. The grafts failed to grow properly. Winter temperature was not cool enough to satisfy bud dormancy requirements of the scion clones or of the rootstocks. Identical grafts grew normally at Monmouth, Oreg.*

In the Pacific Northwest, practically all coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) orchards have been established well within the indigenous range of the species. As a result, the orchards are subject to various degrees of pollen contamination from nearby native stands. It is often suggested that orchards be established in California where Douglas-fir is absent or just a very minor component of nearby stands. Such a move might reduce pollen contamination, enhance seed maturation, and stimulate earlier and more abundant seed production. The following brief report describes an attempt to establish a planting of grafted clones in an area considerably south of its place of origin.

In April 1979, Douglas-fir trees for this trial were grafted on established rootstocks at a field location near Monmouth, Oreg. Two types of rootstocks were used: Rooted cuttings of 13 highly graft-compatible clones from the Willamette Valley of Oregon and two seedling sources from the Sierra Mountains near Placerville, Calif. All rootstocks had been transplanted into the field two growing seasons before grafting. Scions were from 50-plus trees growing in the Cascade Mountains near Sweet Home, Oreg. (760 to 1,200-m elevational zone). Four grafts of each clone were made on the Oregon cuttings and another four grafts of each clone on seedlings of the two Sierra sources. Scion leader growth the year of grafting ranged from 20 to 40 centimeters; the trees were vigorous and capable of good growth following transplanting.

In December 1979, the grafts were dug at the Oregon grafting site and 109 grafts were transplanted to a site on the Monterey Peninsula in California. Another 200 grafts of the same scion clones and rootstock combinations were retained at the Oregon site; 30 grafts were transplanted to new positions at the site and 170 grafts were left in place. Of the 109 grafts at Monterey, 46 were on Oregon and 63 on California rootstocks. The Monterey site was located less than 100 meters above sea level on a large estate within 200 meters of the Pacific Ocean. It was rototilled, irrigated, and intensively cared for by a gardener from the estate. Other native conifers such as Monterey pine grew normally at the site.

Observations on scion survival and leader growth were made in July 1981. Grafts at the Oregon planting site were healthy and had 1 to 2 meters of accumulated growth in 1980 and 1981. Trees that had not been transplanted in 1979 were slightly larger than those whose roots were disturbed. Leader growth was nearly the same for both Oregon and California rootstocks. Only 2 percent of the Oregon rootstocks and 10 percent of the California rootstocks had died from early graft incompatibility.

The normal growth and high survival at Monmouth were not indicative of how the same scion clones and rootstocks did at Monterey. At Monterey, grafts of the same clones were either dead, dying, or had grown very little in 1980 and 1981. More than 30 percent of the scions had died of early graft incompatibility, and cumulative 1980 and 1981 leader growth of the surviving scions averaged a meager 12 centimeters (range 0 to 25 cm). Scion growth and survival were equally poor on both Oregon and California rootstocks. There was no possibility that a viable Douglas-fir orchard would develop. The Monterey planting was such an obvious failure that a decision was made in 1981 not to waste time and money on extensive measurements to prove the obvious.

An unusual pattern of shoot growth was observed in the survivors at Monterey; less growth occurred in 1981 than in 1980. The normal shoot growth pattern for Douglas-fir would have been reduced shoot growth immediately after transplanting in 1980 and then the growth of long leaders in 1981. Poor leader growth resulted from abnormal bud flush each spring. Buds on some trees failed to burst in either year; some burst in 1980, but not in 1981; and a few trees managed to burst both years. Shoot elongation was abnormally short even when buds burst both years. Often the buds that did flush in 1981 were lateral rather than terminal buds.

The hypothesized cause of the atypical bud flush and reduced leader growth at Monterey is thought to be winter temperatures that were not cool enough to satisfy the bud dormancy requirements of Douglas-fir trees from Oregon's Cascade Mountains. Data from the weather station at Santa Cruz (30 miles north of the planting site) indicated that the average monthly temperature had varied from 9.3° to 12.2° C from November to February, while average minimum monthly temperatures were only 3.4° to 5.6° C (1). With such a mild climate, it is probable that the Oregon clones received far less than the required 1,344 to 3,016 hours at 3° and 6° C (2). Little leader growth for Douglas-fir scions from Oregon's Cascade Mountains is likely to occur in future years. It is not possible to blame the problem on salt built up in the soil because no external symptoms of salt toxicity were evident. High salt content causes Douglas-fir scales to unfold rather than being tightly appressed; the loosening of the bud scales causes the buds to have a ragged or frayed appearance. That symptom was not seen.

Lack of adequate chilling also influenced bud burst and shoot growth of rootstocks from both Oregon and the Sierra Mountains of California. Oregon rootstocks showed the same pattern of inhibited bud flush as did the grafted scions, but they did not appear to be influenced as severely as the scions. Rootstocks from the Sierras had even less atypical bud flush than did Oregon rootstocks, but growth was abnormal enough to indicate that most seedlings would have difficulty growing normally at Monterey.

The important lesson learned from this small trial is that it is not possible to establish Douglas-fir seed orchards, at least those grafted with scion material from the Cascade Mountains of west-central Oregon, in areas where insufficient winter chilling occurs. Orchard placement must take into consideration more than just the absence of extraneous pollen or weather patterns that favor cone initiation or maturity; the climatic restraints of seed sources within a species with a large geographic range must be honored or results similar to those of this study may result.

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# Performance of Three Douglas-Fir Stocktypes on a Skeletal Soil

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*Two years after outplanting, survival of Douglas-fir 1-0 plug and plug—1 bare-root seedlings on a steep, skeletal soil in southwest Oregon exceeded that of 2-0 bare-root stock by 35 and 31 percent, respectively. Height and diameter growth did not differ despite large differences in the initial size of stocktypes.*

In southwest Oregon, reforestation of skeletal soils (soils with at least 35 percent rock fragements by volume) is difficult, particularly where precipitation is low and temperatures are high during summer months. The difficulty is further compounded where steep terrain limits the use of machines for site preparation and where competition from sclerophyll brush is severe. These problems have resulted in withdrawal of commercial forest land from the allowable-cut base *(11)*. Unfortunately, few specific regeneration guidelines are available for such areas where, historically, 2-0 bare-root seedlings have been used with disappointing results. The performances of different stocktypes on skeletal soils have not been compared, though seedling morphological characteristics and stocktypes are recognized as being associated with field performance *(1, 3, 6).*

The lack of information on reforesting droughty, skeletal soils prompted us to initiate a study in 1980 on a severe site in the Siskiyou Mountains of southwest Oregon to compare performance of three Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) stocktypes: the widely used *2-0* bare-root stock; 1-0 plugs, because it had been suggested that they may perform well in rocky soils *(9)*; and plug—1 seedlings, a newer stocktype whose field performance is relatively unknown.

### Methods

The study site is a nonstocked clearcut in the Mixed-Evergreen Forest Zone *(2)* of the Siskiyou Mountains on which previous reforestation attempts with 2-0 bare-root Douglas-fir seedlings and spot seeding with sugar pine *(Pinus lambertiana* Dougl.) have failed. Average annual precipitation is 229 centimeters, of which 22 centimeters occur between May and September.[1] Located at 1,067-meter elevation with a southeast exposure and a 75-percent slope, the area typifies many that are particularly difficult to reforest. The soil is a loamy skeletal Xerochrept with an unstable surface mantle of rock fragments (ravel) as much as 20 centimeters deep. Rock fragment content in the mineral soil is estimated to range from 50 to 60 percent of the total volume. Sclerophyll species on the site, tanoak *(Lithocarpus densiflorus (H.* & A.) Redh.), golden evergreen chinkapin *(Castanopsis chrysophylla* var. minor (Benth.) A. DC.), and canyon live oak (*Quercus chrysolepsis* Liebm.), were handslashed before planting.

A randomized complete-block experimental design with five blocks was used for field layout and subsequent statistical analysis. The stocktypes tested were 1-0 plug seedlings grown in 164-cubic-centimeter Leach cells, 2-0 bare-root seedlings, and plug—] bare-root seedlings initially grown in 66-cubic-centimeter Leach cells and then transplanted into the nurserybed for 1 year. Before outplanting, 30 seedlings of each stocktype were randomly selected for measurements of dry-weight biomass and shoot-root ratio. One hundred seedlings per stocktype *(20* per block), hoe-planted in March *1980* and protected from big-game browsing with flexible Vexar tubes, were used for survival and growth measurements. Seedling height and diameter were measured immediately after outplanting and in the fall of *1980* and *1981.* An additional 100 seedlings per stocktype were planted for measuring xylem pressure potential with the pressure chamber technique described by Waring and Cleary *(12).* Predawn xylem pressure potential levels

[1] McNabb, David H. Department of Forest Engineering, Oregon State University. Personal communication. May 14, 1982.

were determined every 3 weeks during summer 1980 on 10 seedlings randomly selected from each stocktype. We excavated seedlings that were destructively sampled for xylem pressure potential readings on the same morning to examine their root systems for root initiation and growth.

Total 2-year height and diameter growth were analyzed for treatment effects by covariance analysis *(5)*. Initial seedling height and diameter of stocktypes, which were dissimilar at outplanting, were used as covariates.

**Results and Discussion**

Measurements of dry-weight biomass of the three stocktypes at outplanting showed well-balanced shoot-root ratios. Only the 1-0 plug had more root than shoot biomass. Mean shoot-root ratios and corresponding standard errors were:

| | |
|---|---|
| 1–0 plug | 0.79±0.04 |
| 2–0 bare-root | 1.59±0.05 |
| Plug–1 bare-root | 1.66±0.06 |

Mean predawn xylem pressure potential was lowest in 1-0 plug seedlings throughout the measurement period, except on August 19 when 2-0 seedlings registered a dramatic drop, probably because of an unusually low air temperature (7.7° C) and the formation of heavy dew during predawn hours (fig. 1). Predawn xylem pressure potential levels of 2-0 stock varied most; that of the other two stocktypes increased more gradually with increasing drought as the summer progressed.

Differences in patterns of predawn xylem pressure potential may have been related to new root development. Although not quantified, differences in root initiation and growth were obvious among stocktypes. Development was greatest in 1-0 plug seedlings, followed by that of plug-1 stock. In 2-0 stock, it was sparse. In droughty environments, rapid root elongation is critical to seedling survival and growth as newly planted seedlings must maintain root contact with receding soil moisture *(8, 10)*. We believe that inadequate root growth in the 2-0 stock may have resulted in greater seedling water deficits.

Container-grown 1-0 seedlings had the best survival (91 percent) after 2 years, followed closely by the plug-1 seedlings (87 percent). Only 56 percent of the 2-0 stock

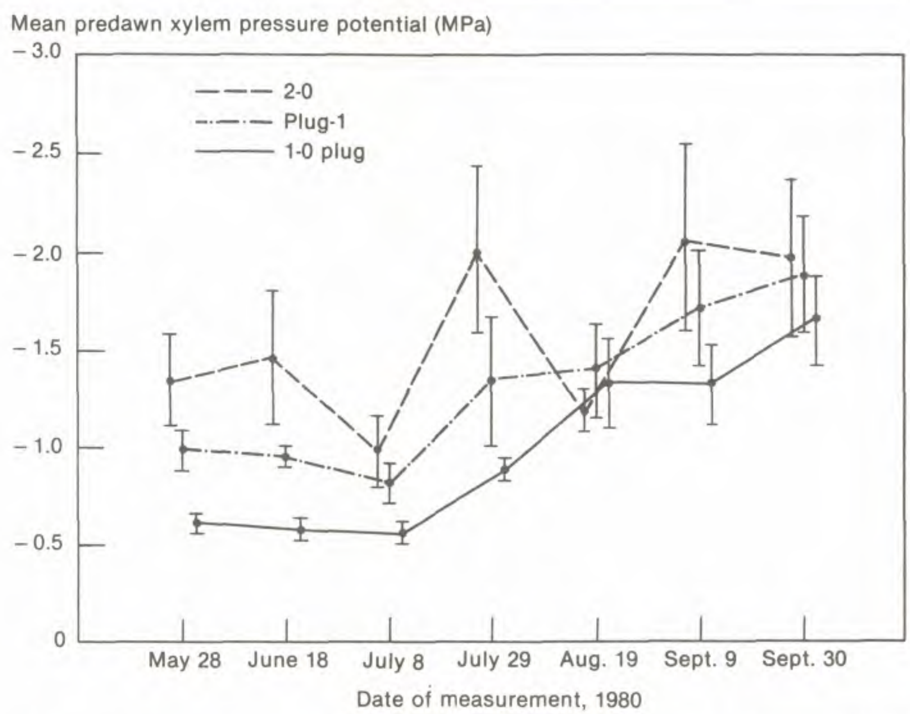


**Figure 1.**—*Mean predawn xylem pressure potential of three Douglas-fir stocktypes. (Vertical bars indicate one standard error.)*

remained alive (table 1). Regardless of stocktype, drought was the primary cause of mortality, most of which occurred during the first year. Population levels appeared to stabilize by the end of 1981. Survival rates corresponded inversely with the first-year xylem pressure potential levels, which may have been associated with differences in root development, as previously noted.

Analysis of covariance showed that treatment effects on growth were not significant. The lack of significant differences among stocktypes may be attributed, in part, to early elimination of individuals in poor physiological condition and in less favorable microsites. This is particularly true for 2-0 stock, which had growth equivalent to that of the other stocktypes after 2 years despite high mortality (table 1).

Performance of plug-1 seedlings was good after 2 years. Initially, they were as large as many 2-1 transplants, but had better developed root systems. Like the 1-0 plug stock, plug-1 seedlings used for xylem pressure potential measurements had good root initiation and growth during the 1980 growing season.

These results reinforce earlier reports of the performance of container-grown Douglas-fir in droughty environments (4, 7) and offer encouraging information on plug-1 Douglas-fir seedlings. Root growth during the first year after outplanting appears to have been important to seedling survival, as shown by decreased xylem pressure potential in 1-0 plug and plug-1 stocktypes. Reasons for the relatively poor survival of 2-0 stock, characteristic of its performance in other plantings in similar southwest Oregon environments, are not known; however, low root growth capacity may be a major factor.

**Table 1.**—*Performance of three Douglas-fir stocktypes after planting on a droughty, skeletal soil*

| Measurement | 1–0 plug | 2–0 bare-root | Plug–1 bare-root |
|---|---|---|---|
| Survival | | % | |
| August 1980 | 100 | 74 | 97 |
| November 1980 | 95 | 63 | 93 |
| May 1981 | 93 | 57 | 91 |
| October 1981 | 91 | 56 | 87 |
| Mean height (± s.e.[1]) | | *Cm* | |
| Initial | 14.32±0.30 | 19.22±0.51 | 32.88±0.65 |
| 2-year growth | 12.10± .66 | 12.61±1.00 | 11.39± .59 |
| Mean diameter (± s.e.) | | *Mm* | |
| Initial | 2.71±0.06 | 5.46±0.15 | 6.65±0.11 |
| 2-year growth | 1.91± .11 | 1.50± .15 | 1.49± .12 |

[1]S.e. = standard error.

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# Fungicide Trials on Sugar Pine at a Southern Oregon Nursery

**Sally J. Cooley**
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*Treatment of sugar pine seedbeds with the fungicides captan, benomyl, and Banrot did not consistently reduce losses from fusarium root rot.*

Fusarium root rot, caused by *Fusarium oxysporum* Schlect., is common in many bare-root conifer nurseries. Most conifer species are susceptible to some degree to infection by *F. oxysporum* during early seedling growth. Observations of nurserybeds at the J. Herbert Stone Nursery (U.S. Department of Agriculture, Forest Service) in southern Oregon show that severe fusarium root rot occurs in sugar pine (*Pinus lambertiana* Dougl.) seedlings. Resultant mortality or root decay leads to fewer seedlings and increased culling of surviving ones. Although all beds are fumigated in the fall before spring sowing, additional treatment is sometimes needed where fumigation was inadequate, fungal reinfestation has occurred, or highly susceptible species are sown. It was felt that fungicide treatment of seedbed soil, in addition to fumigation, might provide protection from fusarium root rot. Treatment of first-year sugar pine seedbeds with fungicides in 1980 and 1981 is described.

**Methods**

In April 1980, the fungicides benomyl (Benlate 50 WP, Dupont), captan (Orthocide 50 Wettable, Ortho), and Banrot (Banrot 40 WP, Mallinckrodt) were applied to one seedlot of sugar pine. These beds had been fumigated in the fall of 1979. Benomyl was tested at 20 pounds per acre (10 lb. a.i./acre) and captan at 13 pounds per acre (6.5 lb. a,i./acre), rates commonly used in Pacific Northwest forest nurseries. Two rates of Banrot, 61 pounds per acre (24.4 lb. a.i./acre) and 25 pounds per acre (10 lb. a.i./acre), were tested. These were the label-recommended rate and approximately one-half of the recommended rate, respectively. Captan was applied immediately before sowing; benomyl and Banrot were applied 14 days after emergence.

In April 1981, Banrot was applied to two sugar pine seedlots to determine an effective rate and time for a single application and an optimal number of applications (up to three) at a single rate. Seedlot 1 was treated with two rates of Banrot, 41 pounds per acre (16.4 lb. a.i./acre) and 61 pounds per acre (24.4 lb. a.i/acre), at three different times: sowing, 20 days after sowing, and 40 days after sowing. Seedlot 2 was treated with one, two, or three applications of Banrot at 41 pounds per acre at sowing, at sowing and 20 days later, at 20 days and 40 days after sowing, and at sowing and 20 days and 40 days later. In both 1980 and 1981 trials, fungicides were applied as drenches to 4-by 10-foot portions of nurserybeds. Four replications of each treatment (including checks) were laid out in a randomized block design over each seedlot. Four 1/2- by 4-foot sampling subplots were established in each 4- by 10-foot treatment plot.

The percentage of mortality was determined by making counts of living and dead seedlings within subplots at 1- or 2-week intervals. Mortality counts were made from June 2 to September 22, 1980, and from June 18 to August 27, 1981.

The data from each trial were subjected to analyses of variance and tests to compare treatment means.

**Results and Discussion**

***1980 trials.*** As shown in figure 1, treatment with the high rate of Banrot resulted in the best survival (82.2 percent) at the final measurement date. The poorest survival (69.7 percent) was seen with no treatment (check), followed by the low rate of Banrot (71.1 percent), benomyl (73.6 percent), and captan (75.0 percent). Significant differences ($P < 0.05$) were found between high rates of Banrot and no treatment and between high and low rates of Banrot. Significance was determined by the Newman-Keuls test of multiple means.

**1981 trials.** Only small differences in percentage of survival were found when Banrot was ap-

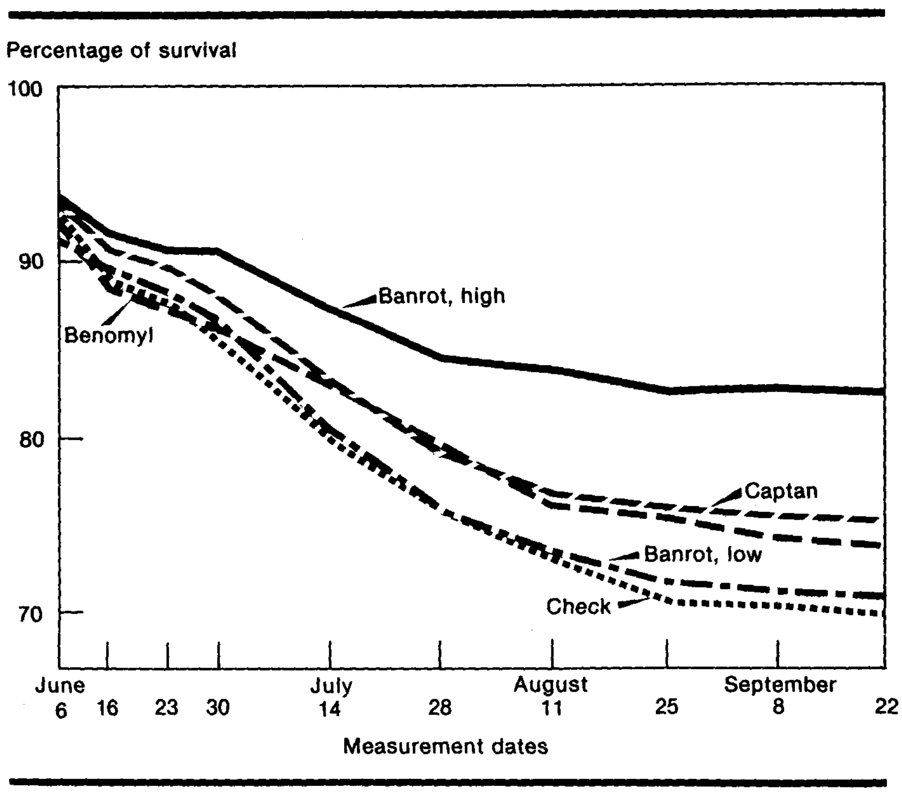


**Figure 1.**—*Percentage of survival of sugar pine seedlings after treatment with fungicides—1980.*

plied to seedlot 1 at 41 and 61 pounds per acre at sowing, 20 days after sowing, and 40 days after sowing (fig. 2). Although average survival was greatest with applications of 61 pounds per acre 20 days after sowing and 40 days after sowing, enough variation existed between replications in all treatments to make any differences statistically insignificant. Average survival over all treatments using 41 pounds per acre was 61.0 percent, over all treatments using 61 pounds per acre was 70.3 percent, and with no treatment was 63.1 percent.

Similarly, no significant differences in percentage of survival were found between one, two, and three applications applied at 41 pounds per acre to seedlot 2 (fig. 3). Survival was highest, 79.5 percent, in plots treated twice, at sowing and 20 days after sowing. Survival for all other treatments, including the check, was virtually identical, ranging from 68.0 to 70.2 percent.

Benomyl and captan are commonly used in forest nurseries as soil treatments for control of such soil-borne fungi as *Fusariurn* spp., *Pythium* spp., and *Rhizoctonia* spp. Reports of control success are varied (*1, 2, 3, 4, 5, 7*). Banrot has not been used widely in Pacific Northwest conifer nurseries, and reports of its performance have been sparse. Good fungicidal control of fusarium root rot in conifer nurseries has been achieved either with high rates of captan (52 to 65 lb. a.i/acre) applied two times after sowing (*1*) or when a systemic such as benomyl or thiophanate methyl (systemic ingredient in Banrot) is combined with a nonsystemic such as chloroneb or ethazole (e.g., Banrot, Benlate and Tersan, Benlate and Truban) and applied at sowing (*6*).

No adequate explanation can be found for differences in performance of Banrot in 1980 and 1981. Factors such as soil properties, inoculum load, rate of seedling development, or temperature may have adversely influenced the activity, persistence, and fungicidal properties of Banrot in 1981.

These data suggest that the fungicide treatments had little or no effect on growth of surviving seedlings at the end of the first growing season.

### Conclusions

Consistent control of fusarium root rot in sugar pine seedlings

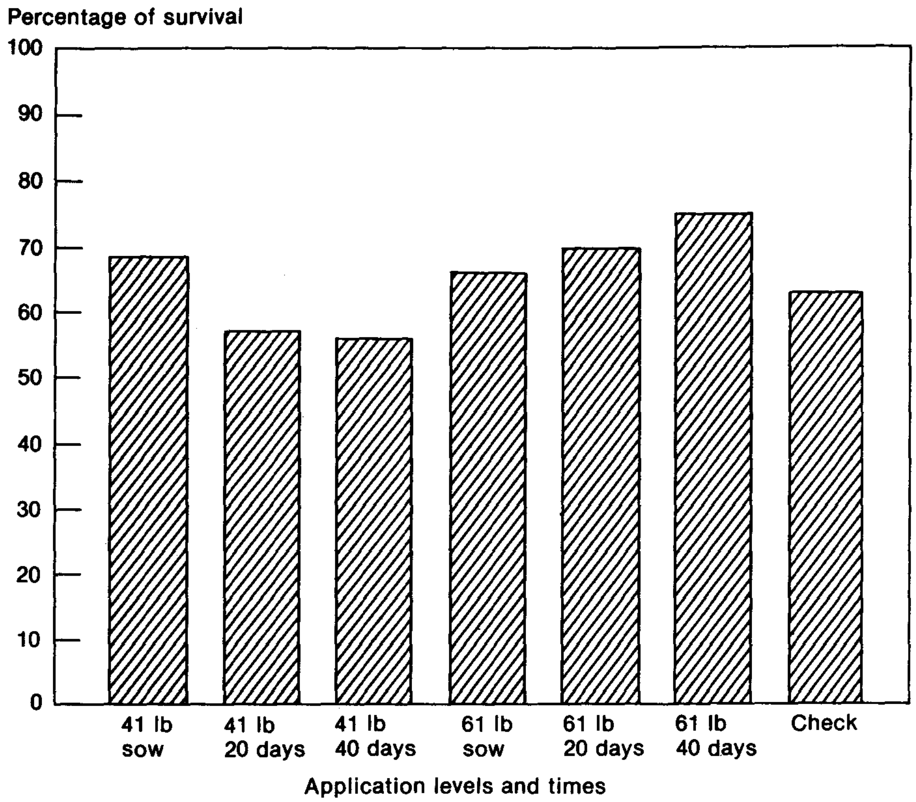


**Figure 2.**—*Percentage of survival for seedlot 1. Single application of Banrot at different times at 41 pounds per acre or 61 pounds per acre—1981.*

was not achieved with the fungicide Banrot during 1980 and 1981. The highest rate tested, 61 pounds per acre, applied 14 days after seedling emergence in 1980, resulted in superior survival. Improved seedling survival was not realized with earlier or multiple Banrot applications in 1981. The fungicides benomyl and captan gave poor disease control when applied at rates commonly used in Pacific Northwest nurseries. Until biological effectiveness is clearly established and cost-effectiveness is determined, operational use of these fungicides at the tested rates is not recommended for control of fusarium root rot in Pacific Northwest forest nurseries.

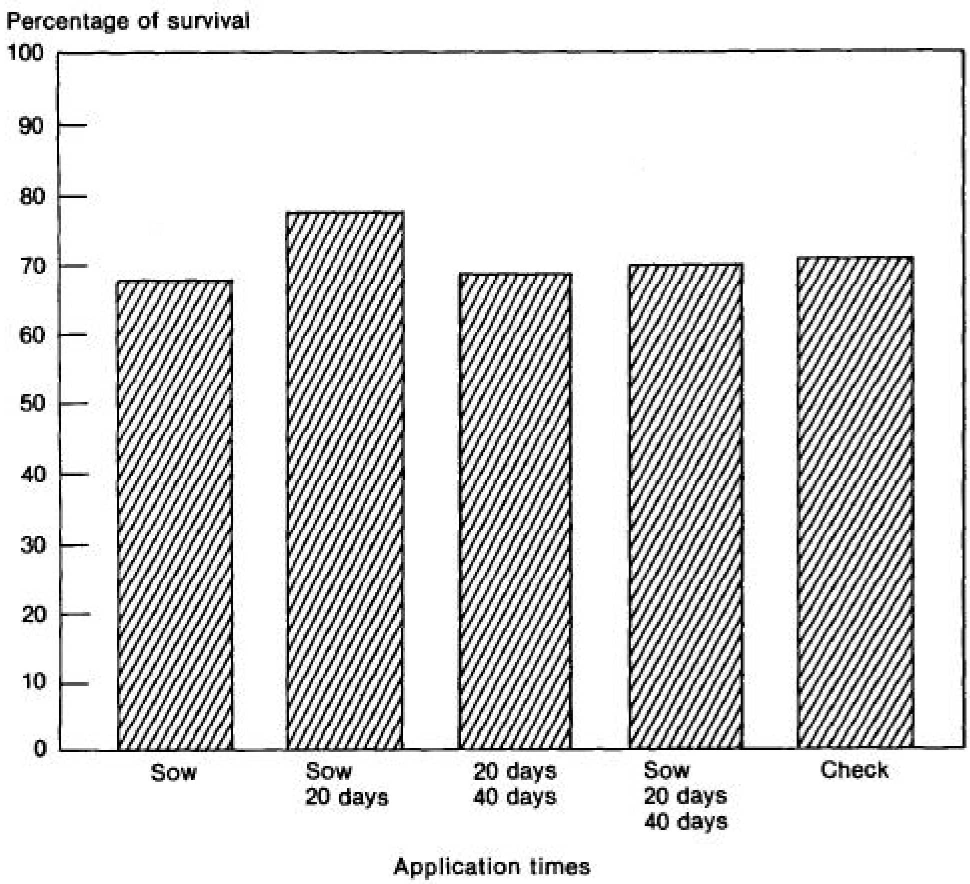


**Figure 3.—***Percentage of survival for seedlot 2. Single and multiple applications of Banrot at 41 pounds per acre—1982.*

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# Efficacy of 18 Adjuvants in Combination With Bayleton for Control of Fusiform Rust on Pine Seedlings

**S. J. Rowan**

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*Eighteen adjuvants tested in formulations with Bayleton were essentially equal in enhancing the effectiveness of the fungicide for control of fusiform rust on southern pine seedlings.*

The protective and systemic fungicide Bayleton[1] (triadimefon; 1-(4-chlorophenoxy)-3,3-dimethyl-1 (1 H-1,2,4-triazol-1-yl)-2-butanone) will effectively control fusiform rust caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* in pine nurseries with as few as three or four foliar sprays (1, 3). The fungicide has 24-C registration in several Southern States for use in pine tree nurseries as foliar sprays for control of fusiform rust. Mobay Chemical Corp. (Kansas City, Mo.) distributes this fungicide in the United States and has suggested sprays be formulated with Agri-Dex (Helena Chemical Co., Memphis, Tenn.) adjuvant. Their reason for suggesting this adjuvant was based on chemical compatibility tests made in the laboratory rather than biological tests comparing a number of adjuvants.

The efficacy of a pesticide formulation is measured by its ability to eradicate or prevent crop losses to the target pest. An adjuvant is used in formulations to improve the efficacy of the pesticide. Formulations may be improved by increased wetting of foliage, greater tenacity of spray residues, improved solubility or suspendibility of the pesticide, less drift, less foam, less phytotoxicity, and less inactivation of the active pesticide ingredient. Reported here are results of testing 18 spray adjuvants in formulations with Bayleton for control of fusiform rust on loblolly pine (*Pinus taeda* L.) seedlings.

## Methods

***Efficacy tests of adjuvants.*** Twenty 2 to 4-day-old loblolly pine seedlings were transplanted into each of 200 flats (33 by 13 by 11 centimeters) containing a sandy loam, sand, and vermiculite soil mix (2:1:1 ratio by volume). All seedlings were fertilized 2 weeks, 4 weeks, 2 months, 4 months, and 6 months after transplanting with Miracle-Gro, a commercially available liquid fertilizer. Bayleton sprays were formulated to contain 600 milligrams of active ingredient and the adjuvant at the distributor's recommended rate per liter (table 1).

Each Bayleton formulation was vigorously agitated and applied at the rate of 1.87 kiloliters per hectare to 10 replicate flats of each treatment. After 48 hours, five flats of each treatment were placed in a rain chamber and exposed to 5 centimeters of rain. The rain chamber was equipped with a cone Raindrop nozzle that delivered 2.5 centimeters of rain each 63 minutes. The other five replicate flats of each spray treatment were not put in the rain chamber. Two hours after seedlings were removed from the rain chamber and when their foliage was dry, all test seedlings were artificially inoculated with basidiospores (75,000 spores/ml) of *C. quercuum* f. sp. *fusiforme*. Controls were nonsprayed seedlings and seedlings sprayed with Bayleton alone.

The experimental design was a randomized complete block with five replications. Seedlings were sprayed and inoculated 6 weeks after emergence when their growth rate was near maximum. Inoculum derived from aeciospores collected from loblolly pine galls in Clarke County, Ga. (source 2-74), was used to produce basidiospores on northern red oak (Quercus rubra L. seedlings. The percentage of seedlings infected (galled) was determined 9 months after inoculation.

**Compatibility tests of selected adjuvants.** All Bayleton-adjuvant formulations rated by the distributor of Bayleton as inferior for control of fusiform rust were tested for incompatibility reactions between adjuvant and pesticide. Replicate water agar plates were seeded with basidiospores of *C. quercuum* f. sp. *fusiforme* and then atomized with nonagitated, 24-hour-old suspensions of Bayleton (600 mg/1) alone and Bayleton in formulations with Agri-Dex (the recommended adjuvant), Agway Target NL (because of suspected incompatibility), and all adjuvants judged

[1]Bayleton is a registered trademark of Farbenfabriken Bayer GmbH, Leverkusen, West Germany.

**Table 1.**—*Efficacy of 18 adjuvants in Bayleton sprays for control of fusiform rust of loblolly pine seedlings when applied 2 days before seedlings were exposed to 0 and 5 centimeters of artificial rain*

| Treatment | Application rate | Galled seedlings[1] 0 cm | Galled seedlings[1] 5 cm |
|---|---|---|---|
| | *Ml/l* | - - - - - - - - - - - % | - - - - - - - - - - |
| Agri-Dex | 2.5 | 0.0a[2] | 0.0a |
| Agway Target NL | .63 | .0a | .0a |
| Atlas Sur-Fac | 5.0 | .0a | .0a |
| Bio-88 | .63 | .0a | .0a |
| Bio-film | .47 | .0a | .0a |
| Bond Spreader-Sticker | 2.5 | .0a | 1.2b |
| Dupont Spreader-Sticker | .31 | .0a | .0a |
| Exhalt-800 | 1.25 | .0a | .0a |
| Nu-film-17 | 1.25 | .0a | .0a |
| Olds Worlde | 1.25 | .0a | .0a |
| Ortho-Chevron Spray-Sticker | .63 | .0a | .0a |
| Ortho X-77 | .47 | .0a | 1.1 b |
| Plantgard | 200.0 | .0a | .0a |
| Plyac | 1.25 | .0a | .0a |
| Security Spreader-Sticker | .63 | .0a | .0a |
| Triton x-45 | 1.25 | .0a | .0a |
| Triton x-100 | 1.25 | .0a | .0a |
| Wex | .78 | .0a | .0a |
| No adjuvant | —[3] | 1.2b | 1.2b |
| No Bayleton | — | 56.0c | 69.8c |

[1]Infection percentages are the average of five 20-tree replicates determined 9 months after inoculation. Sprays contained 600 miligrams active Bayleton ingredient per litter.

[2] Means in a column followed by the same letter do not differ significantly at the 95-percent probability level. Duncan's new multiple range test was used to compare column means, and Student's t-test was used to compare rainfall effects. Zero percentages were excluded from these analyses.

[3]— = not applicable.

inferior for control of the disease. Germination percentages were determined after 24 hours' incubation at 20° C by counting a minimum of 200 spores per plate. Spores were counted as germinants only when the germ tube exceeded spore diameter by threefold.

## Results and Discussion

Without simulated rain, all Bayleton-adjuvant spray formulations controlled the disease, but Bayleton alone did not, indicating the need for adjuvants (table 1). After 5 centimeters of simulated rain, only 16 formulations containing adjuvants were superior to Bayleton alone; Ortho X-77 and Bond Spreader-Sticker failed to improve the efficacy of Bayleton.

In compatibility tests, germination percentages after 24 hours' incubation at 20° C indicated that Bayleton precipitated from suspension when formulated alone or with Ortho X-77, Bond SpreaderSticker, and Agway Target NL adjuvants (table 2). Basidiospore germination percentages were not significantly different among the untreated, Bayleton, and Ortho X-77 plates. Formulations with Bond Spreader-Sticker and Agway Target NL adjuvants, however, significantly reduced germination, but Agri-Dex-treated plates reduced

**Table 2.**—*Efficacy of selected adjuvants in nonagitated formulations with 8ayleton to inhibit Cronartium quercuum f. sp fusiforme basidiospore germination on seeded water agar plates*

| Adjuvant | Application rate | Spore germination |
|---|---|---|
| | *Ml/l* | *%* |
| No Bayleton (control) | —[1] | 83.2a[2] |
| No adjuvant | — | 82.6a |
| Ortho X-77 | 0.47 | 82.0a |
| Bond Spreader-Sticker | 2.5 | 40.0b |
| Agway Target NL | .63 | 35.9b |
| Agri-Dex | 2.5 | .0c |

[1]— = not applicable.
[2] Means followed by the same letter do not differ significantly at the 95-percent probability level according to Duncan's new multiple range test.

spore germination to zero. Thus, Bayleton formulated without adjuvant results in a precipitated product with poor wetting and residue tenacity features. Control obtained after treatment with Bayleton formulations depends upon the ability of the fungicide to act systemically. Bond Spreader-Sticker and Agway Target NL adjuvants keep Bayleton in suspension better than does Ortho X-77, but. not as well as does Agri-Dex. Bond Spreader-Sticker and Ortho X-77 adjuvants, although inferior in these tests, are nearly as effective as any adjuvant tested in formulations with Bayleton for control of fusiform rust. The rapidity with which Bayleton formulations are absorbed by pine seedling tissues (*2*) probably explains why the adjuvants tested varied so little. These test results appear to confirm the Mobay Chemical Corp.'s results that Bayleton and Agri-Dex are compatible. However, proper agitation of the spray mix in spray tanks should make most, if not all, adjuvants tested of equal value when used with Bayleton. Economics, therefore, should be an important factor in choosing adjuvants to be used in Bayleton formulations. No phytotoxicity was noted in any of the formulations tested in this study.

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Tree Planter's Notes, Vol. 34, No. 3 (1983)



# Low-Cost Shields Used for Handspraying Herbicides

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*The shields described are used to minimize spray-drift when a chemical weed control is applied with low-pressure handsprayers. They can be used by foresters to spray around young trees during the establishment phase. Nursery personnel, grounds maintenance personnel, and gardeners can use the shields wherever weed control is needed around young trees or shrubs.*

Spray-drift onto sensitive trees is a primary concern when hand-sprayer application of a nonselective herbicide is essential to control weeds in nursery tree plots with varied spacings, in nurserybed aisles, and alongside irrigation pipelines. To prevent spray-drift damage, workers are needed to hold shielding panels or cover the trees with stovepipes while applying the herbicide. Two simple shields can be constructed to eliminate the need for this additional personnel and still spray without fear of damaging trees.

For shield no. 1, use a discarded, clear-plastic, 67.6-ounce bottle placed over the hose nozzle of a low-pressure handsprayer. This shield can be used for spot-spraying a sparse weed cover and can be used close to the trees or shrubs (figs. 1 and 2).

For shield no. 2, use 2- by 2-lumber and corrugated fiberglass panels. The shield is adjustable for width. It is light and can be pulled along while spraying between the panels. If desired, small wheels can be added on one end to hold the shield slightly off the ground. This shield is recommended for use in a dense weed cover (figs. 3 and 4).

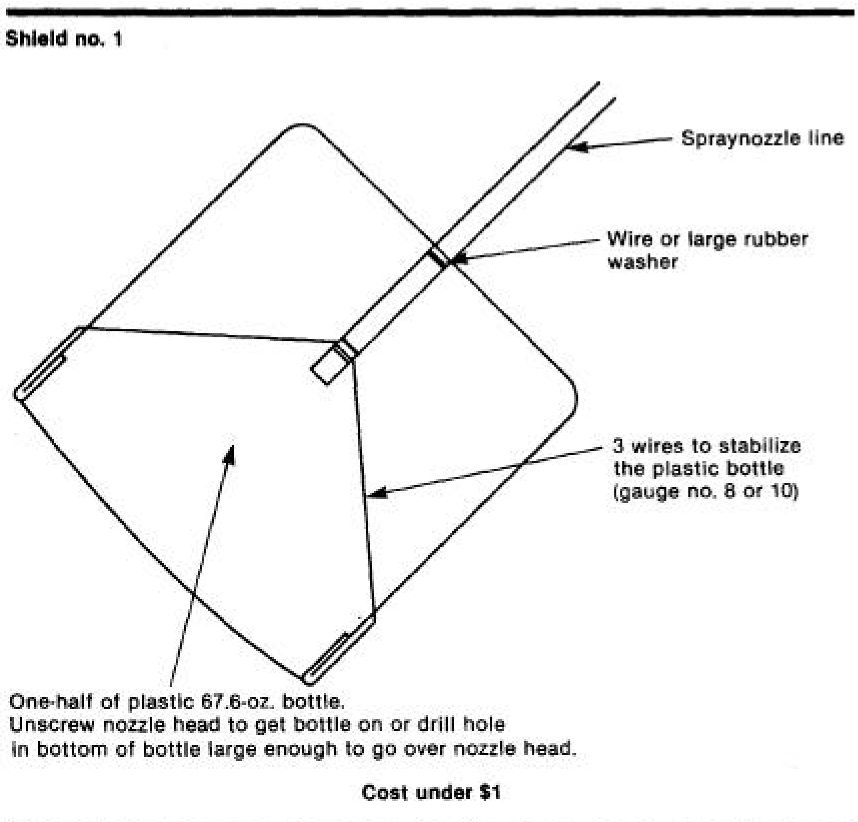



**Figure 1.**—*Illustration, list of materials required, and cost for construction of shield no. 1.*

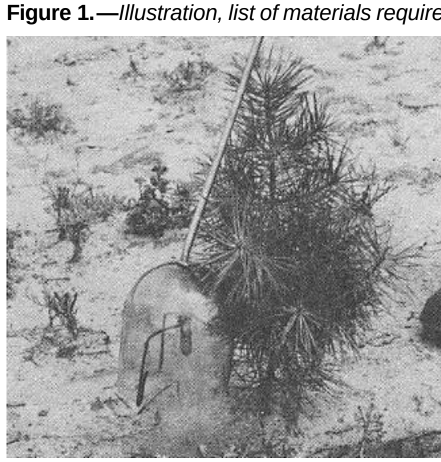
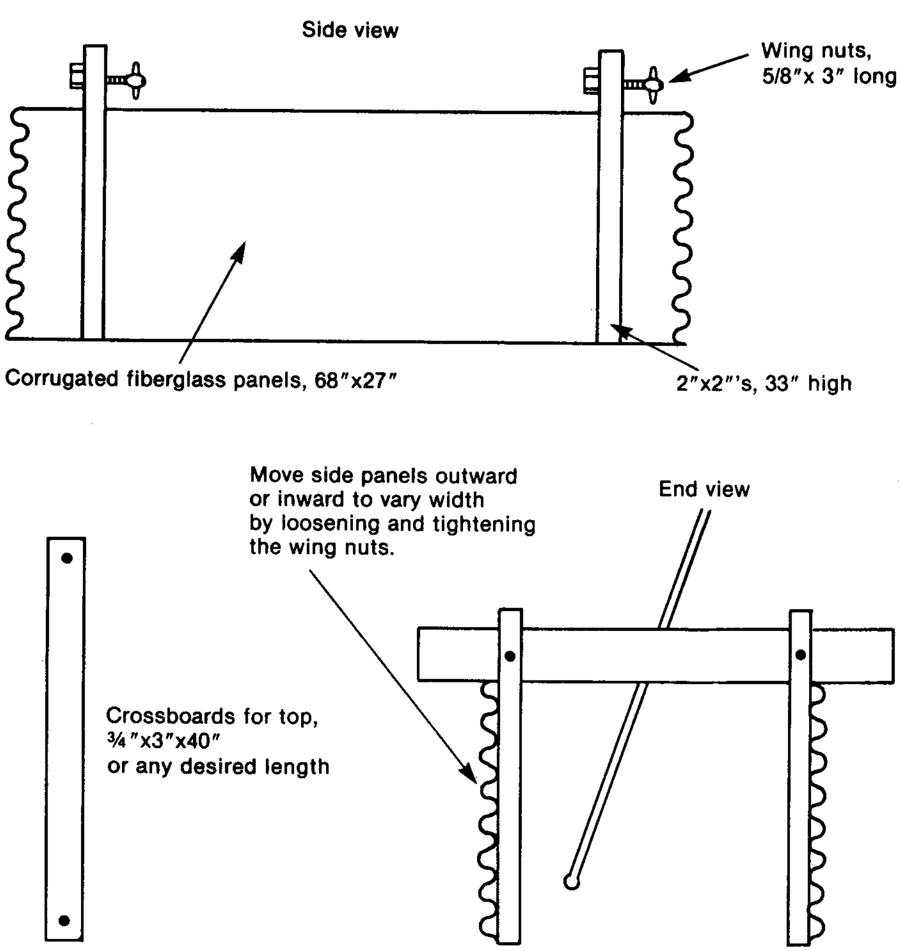


**Figure 2.**—*Shield no. 1 close to the tree while a nonselective herbicide is sprayed under low pressure with a handsprayer.*

Shield no. 2




**Cost: $15**

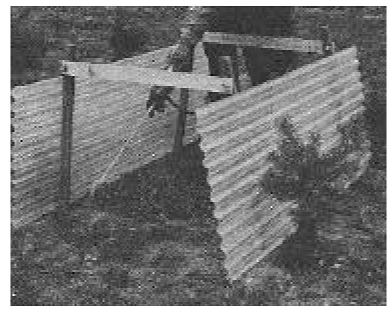


**Figure 4.**—*Shield no. 2 in position for spraying a dense weed cover between rows of trees.*

Tree Planter's Notes, Vol. 34, No. 3 (1983)


# Preemergent Herbicides for Direct Seeding Kentucky Coffeetree, Honeylocust, and Black Locust

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*Graduate Research Assistant and Professor, Department* of *Forestry, and Professor, Department* of *Horticulture, Kansas State University, Manhattan*

*Alachlor, DCPA, and oryzalin herbicides applied 1 day after sowing tree seeds provided good weed control and did not adversely affect Kentucky coffeetree or honeylocust growth.*

Direct seeding of pine has been successful in the Southern United States (*6*), but broad-leaved species are seldom seeded in the field. One exception is black locust, which has been seeded extensively on surface-mined lands in the Southeast (*3, 5*). Weed competition is one major obstacle to successful direct seeding. Tree nurseries usually overcome this problem with handweeding and scant use of herbicides. If adequate silviculture techniques could be developed for field operations, direct seeding might be a feasible way of establishing high-density, short-rotation plantations for energy forests (*4*).

Labor costs for handweeding can be as high as 90 percent of the total production costs in some tree nurseries (1). Labor-intensive weeding may be reduced with the use of selective herbicides on nursery crops. Previous weed control research on woody plants has focused on preemergent herbicides used on established seedlings, while only a few reports have been made on the effects of herbicides on seed germination and early seedling growth (*2, 7, 8*). Understanding the tolerance of germinating broadleaf species to preemergent herbicides is important in developing a successful silviculture technique for direct seeding.

This study evaluated resultant seedling survival and growth of Kentucky coffeetree (*Gymnocladus dioicus* (L.) K. Koch), honeylocust (*Gleditsia triancanthos* LJ, and black locust (*Robinia pseudoacacia* L.) when treated with preemergent herbicide 1 day after seed sowing in the field.

### Methods and Materials

All seeds were scarified with concentrated sulfuric acid ($H_2S0_4$). Kentucky coffeetree seeds were acid treated for 120 minutes and honeylocust and black locust for 60 minutes. A preliminary growth-chamber study was conducted with all three species and herbicides. Acid-scarified seeds of each species were placed on filter paper in glass petri dishes. Chemical stock solutions of 1 milliliter of herbicide mixed with 5 milliliters of water were applied at field rates as subsequently described. Another sheet of filter paper was placed on top of seeds to retain moisture. Petri dishes were placed in a Mangeldorf germinator at 23° C, and paper was routinely moistened with distilled water until germination.

A weed-free seedbed was prepared at the Rocky Ford experimental field located near Manhattan, Kans. Scarified Kentucky coffeetree, honeylocust, and black locust seeds were then planted in the phase silty-loam soils at depths of 2.5, 1.3, and 0.6 centimeters, respectively. Plots consisted of 40 seeds sown at 10-centimeter intervals in a 1.1- by 3.8-meter area with three replications arranged in a randomized design.

The herbicide treatments, in kilograms per hectare, included DCPA (dimethyl tetrachloro-terephthalate) at 11.2, chloroxuron (3-[p-(p-chlorophenoxy) phenyl] -1, 1-dimethylurea) at 2.2, alachlor (2-chloro-2', 6'-diethyl-N-(methoxymethyp acentanilide) at 2.2, and profluralin (N-cyclopropylmethyl) -α,α,α-triflroro-2, 6 dinitro-N-propyl-p-toluidine) at 0.6 for all three species. Other herbicide treatments for Kentucky coffeetree and honeylocust plots, in kilograms per hectare, included napropamide (2-(α-napthoxy)-N, N-diethyl-2, 2-diphenylacetamide) at 2.2, diphenamid (N,-N-dimethyl-2, 2-diphenylacetamide) at 4.5, and oryazlin (3,5-dinitro-$N^4$,$N^4$-dipropyl sulfanilamide) at 2.2. EPTC (5-ethyl dipropylthiocarbamate) at 4.5, napropamide at 1.1, and oxadiazon 2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-$\Delta^2$-1,3,4-oxadiazolin-5-one) at 4.5 kilograms per hectare were the additional herbicides for black locust treatments. Selected rates were based on previous seedling survival and growth studies conducted in the greenhouse with these tree species (*7*).

A $CO_2$ constant-pressure plot sprayer was used for liquid applications and a drop spreader was used for the granular herbicide. Treatments were applied in May 1979 at 23° C with a wind velocity of less than 8 kilometers per hour. Plots were irrigated immediately following application and periodically throughout the summer to supply supplemental moisture.

Seedling survival data and weed control evaluations were recorded 60 days after treatment. One year after herbicide application, survival and plant heights were measured.

**Table 1.**—*Seed germination of Kentucky coffeetree, honeylocust, and black locust in growth chamber tests*

| Chemical | Treatment rate | Germination | | |
|---|---|---|---|---|
| | | Kentucky coffeetree | Honeylocust | Black locust |
| | *Kg a.i./ha* | % | | |
| Alachlor | 2.25 | 100 | 95 | 90 |
| Chloroxuron | 2.25 | 100 | 90 | 100 |
| DCPA | 11.23 | 100 | 90 | 95 |
| Diphenamid | 4.49 | 100 | 85 | —[1] |
| EPTC | 4.49 | — | — | 85 |
| Napropamide | 1.12 | — | — | 85 |
| Napropamide | 2.25 | 100 | 95 | — |
| Oryzalin | 2.25 | 100 | 90 | — |
| Oxadiazon | 4.49 | — | — | 95 |
| Profluralin | .56 | 95 | 85 | 100 |
| Control | — | 95 | 85 | 85 |

[1]— = not applied to these species.

## Results and Discussion

Herbicide treatments did not seriously affect germination of any of the three species during the preliminary growth chamber study. Seed germination was 95 to 100 percent for Kentucky coffeetree in 16-day trials, 85 to 100 percent for honeylocust in 5-day trials, and 85 to 100 percent for black locust in 8-day trials (table 1). Germination in the control treatments was 85 to 95 percent, thus indicating that, under controlled conditions, the herbicides were not toxic to the tree seeds.

Field herbicide treatments differed in effectiveness of weed control because of variations in weed populations (table 2). Weeds in Kentucky coffeetree and black locust plots were predominately grasses such as yellow foxtail (*Setaria lutescens* (Weigel) Hubb.) and large crabgrass (*Digitaria sanguinalis* (L.) Scop.), while honeylocust plots had mostly redroot pigweed (*Amaranthus retroflexus* L.), velvet-leaf (*Abutilon theophrasti* Medic.), and other broad-leaved weeds.

Kentucky coffeetree seedling survival was not affected by any herbicide treatments. However, alachlor, DCPA, and oryzalin were the only herbicides that provided significant weed control. These three herbicides controlled 80 to 86.7 percent of the weeds in the plots.

There was no significant difference in survival among honeylocust seeds receiving chemical treatments. All herbicide-treated plots had fewer weeds than untreated plots. Alachlor, DCPA, and oryzalin were most effective in controlling 93.3 to 100 percent of the weeds, followed by diphenamid, which controlled 86.7 percent. Napropamide, chloroxuron, and profluralin all provided 71.7-percent control.

Overall germination of black locust was low. Only 4 percent of the seedlings survived in control plots, while 15 percent of the seedlings were present in DCPA-treated plots. Seedling survival in other treated plots was no different than the control. Profluralin, napropamide, and chloroxuron provided no better weed control than the untreated plots. EPTC controlled 66.7 percent of the weeds, and DCPA controlled 86.7 percent of the weeds. Alachlor plots were approximately 91.7 percent weed free. Oxadiazon-treated plots had 100-percent weed control, but also had no surviving seedlings.

There was only a 2-percent added seedling loss 1 year later with Kentucky coffeetree, and less

**Table 2.**—*Survival, weed control ratings, and plant height of Kentucky coffeetree, honeylocust, and black locust seedlings in field planting*

| Herbicide | Treatment rate | 60 days after treatment | | Plant height 365 days after treatment |
|---|---|---|---|---|
| | | Seedling survival | Weed control | |
| | *Kg a.i./ha* | - - - - - - - - - - - % | - - - - - - - - - - - | *Cm* |
| | | Kentucky coffeetree | | |
| Alachlor | 2.2 | 92.5a[1] | 85.0a | 38.1 ab |
| Chloroxuron | 2.2 | 95.8a | .0b | 30.1 be |
| DCPA | 11.2 | 92.5a | 86.7a | 38.5ab |
| Diphenamid | 4.5 | 92.5a | 20.0b | 36.0ab |
| Napropamide | 2.2 | 86.7a | 16.7b | 34.7abc |
| Oryzalin | 2.2 | 93.3a | 80.0a | 39.8a |
| Profluralin | 0.6 | 82.5a | .0b | 25.8c |
| Control | —[2] | 85.0a | .0b | 32.2abc |
| | | Honeylocust | | |
| Alachlor | 2.2 | 72.5a | 93.3ab | 74.5a |
| Chloroxuron | 2.2 | 69.2a | 71.7b | 61.8ab |
| DCPA | 11.2 | 65.0a | 100.0a | 79.6a |
| Diphenamid | 4.5 | 71.7a | 86.7ab | 62.6ab |
| Napropamide | 2.2 | 70.8a | 71.7b | 66.0ab |
| Oryzalin | 2.2 | 60.0a | 95.0ab | 71.3a |
| Profluralin | .6 | 71.7a | 71.7b | 50.0bc |
| Control | — | 63.3a | 67.0c | 37.2c |
| | | Black locust | | |
| Alachlor | 2.2 | 3.3bc | 91.7a | .0a |
| Chloroxuron | 2.2 | 8.3abc | 5.0c | .0a |
| DCPA | 11.2 | 15.0a | 86.7ab | .0a |
| EPTC | 4.5 | 4.2bc | 66.7b | .0a |
| Napropamide | 1.1 | 8.3abc | 16.7c | .0a |
| Oxadiazon | 4.5 | 0.0c | 100.0a | .0a |
| Profluralin | .6 | 11.7ab | 21.7c | .0a |
| Control | — | 4.2bc | .0c | .0a |

[1] Means within a column followed by the same letter do not differ significantly at the 5-percent level using Duncan's multiple range test.
[2]— = not applicable.

than a 5-percent added loss of honeylocust. None of the black locust survived.

The various herbicides affected honeylocust plant heights after 1 year. All treatments, except profluralin at 0.6 kilograms per hectare produced trees significantly taller than the control. Treatments did not cause Kentucky coffeetree plant heights to differ from the control.

In summary, results from black locust seedlings were inconclusive because of poor field germination. DCPA at 11.2, alachlor at 2.2, and oryzalin at 2.2 kilograms per hectare provided acceptable weed control with no decrease in survival of Kentucky coffeetree and honeylocust seedlings. These herbicides applied 1 day after planting can reduce costly handweeding in nursery seedbeds and lower plant establishment costs in the field. However, further research on subsequent growth and herbicide treatments is necessary before such a practice is recommended.

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Tree Planter's Notes, Vol. 34, No. 3 (1983)



# The Influence of Seed Scarification and Site Preparation on Establishment of Black Locust on Surface-Mined Sites[1]

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Controlled environment and field studies were conducted to determine the best scarification procedures for black locust seed. Results showed site preparation method must be matched to seed preparation method to obtain optimum results.

The establishment of black locust (*Robinia pseudoacacia* L.) on surface mine spoil for erosion control and soil development is a common practice in the Appalachians (*2*). Rapid germination is especially important when direct-seeding tree species to minimize competition from grass.

Prompt germination of black locust is hindered by the thick, impermeable seedcoat. The seedcoat weathers slowly so only a few seeds germinate at a time (*5*). Scarification of the seedcoat with sulfuric acid increases the percentage and rate of germination (*4*). However, while the scarification procedure increases germination, it also decreases the ability of seeds to survive unfavorable microclimatic conditions. Site preparation can decrease the severity of the environment and therefore allows a more intensive scarification.

In this study, the effects of scarification on black locust seeds were investigated, and treatments were designed to analyze the effects of field procedures on the germination potential. Controlled environment scarification tests were used to determine the best scarification procedure for seeds to be sown on mine spoils.

### Methods

**Controlled environment.** Black locust seeds were placed in concentrated sulfuric acid (two parts acid to one part seed). Subsamples were removed after 10, 30, 60, and 90 minutes. A control lot received no acid treatment. The seeds were rinsed thoroughly with tapwater upon removal from the acid. Four treatments were imposed on the seeds from each scarification period (fig. 1). Forty seeds from each treatment were placed in a convection oven at 34° C for 24 hours. Half these seeds (20) were watered immediately after planting. The remaining seeds were watered 72 hours after planting. Each treatment received 250 milliliters of distilled water daily, once watering commenced.

Spoil material in which to plant the seeds was collected from the same site that was to be used for field studies. A 4-centimeter-deep layer of subsurface spoil was placed in three seed flats, with another 1-centimeter-deep layer of surface spoil on top. The dark shale surface was covered with 2.5 centimeters of bark mulch similar to that described for the field test. Seeds were applied to the surface of the mulch and worked into it slightly to simulate raking as was done in field plots. Seeded flats were placed 0.3 meter below a light source providing $350\mu$ einsteins/$m^2$/sec incident light at the

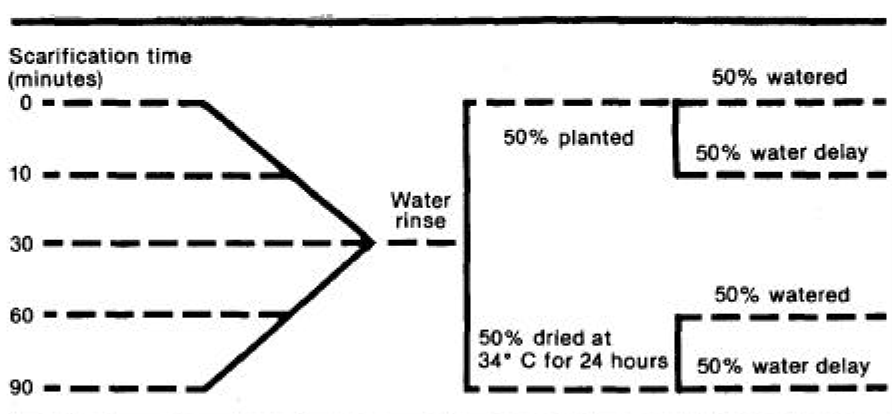


**Figure 1.**—*Scarification and preconditioning treatments performed on black locust seedlings for the controlled environment germination tests.*

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station. The research was supported in part by the Mt. Drive Coal Co., the Institute for Mining and Minerals Research, and the McIntire-Stennis Cooperative Forestry Research Program.

spoil surface. A 12-hour photoperiod was used during the 1-month germination trial.

***Field.*** Black locust seeds were scarified for 60 minutes, rinsed, dried in a convection oven at 34° C overnight, and then transported to the field. The seeds were sown in 14 plots 15 square meters in size at rates of 6 or 12 kilograms per hectare (5 and 10 Ib/acre). Seeds were applied, at each rate, to seven plots mulched with 2.4 centimeters of bark and to seven similar plots of bare mine spoil. The seeds were applied with a Panama seeder and then raked into the surface.

**Table 1.**—*Effect of scarification period (length of time in concentrated sulfuric acid) on germination of black locust seed after 1 month under controlled environmental conditions*

| Scarification time | Mean final germination[1] | Mean final germination percentage |
|---|---|---|
| *Min* | | |
| 0 | 3.3a[2] | 16.3 |
| 10 | 5.0a | 25.0 |
| 30 | 5.3a | 26.3 |
| 60 | 11.3b | 56.3 |
| 90 | 9.3b | 46.3 |

[1]Four replicates of each experiment with 20 seeds.
[2]Means followed by the same letter did not differ significantly at $P < 0.05$.

**Table 2.**—*Effects of postscarification treatments on germination of black locust seed after 1 month under controlled environmental conditions*

| Treatments | Mean final germination percentage[1] |
|---|---|
| Planted immediately, irrigated immediately | 36a[2] |
| Planted immediately, irrigated 3 days later | 42a |
| Dried at 34° C, irrigated immediately | 26a |
| Dried at 34° C, irrigated 3 days later | 32a |

[1]Mean germination of four scarification treatments.
[2]Means followed by the same letter did not differ significantly at $P < 0.05$.

**Table 3.**—*Survival of direct-seeded black locust seedlings on bare mine spoil and bark mulch plots after one growing season*

| | Number of seedlings per hectare given seeding rates of: | |
|---|---|---|
| Treatment | 6 kg/ha | 12 kg/ha |
| 2.4-cm bark mulch | 8,8751 | 23,750 |
| Control (bare mine spoil) | 0 | 0 |

[1]Average calculated from means of all treatments employing bark mulch.

## Results

***Controlled environment tests.*** Sulfuric acid scarification for 60 and 90 minutes was effective, increasing seed germination from 16 percent for nonscarified seed to 56 and 46 percent for the 60 and 90 minute treatments, respectively (table 1). Slight, but nonsignificant, increases in germination were observed after 10- and 30-minute scarifications. A 3-day irrigation delay did not significantly affect the total germination of black locust seeds (table 2). Drying the seeds at 34° C for 24 hours had no effect on total germination (table 2).

***Field Plots.*** None of the scarified seeds applied to the bare mine spoil plots survived the first growing season (table 3). Germination had occurred (radicles had penetrated the seedcoat), but the seeds had dried out before the radicles could penetrate the soil.

Seedling survival was greatly increased by site preparation with bark mulch (table 3). Survival was sparse in areas where soil was compacted or where the bark mulch had been washed away during the winter.

## Discussion

Scarification in sulfuric acid for 60 and 90 minutes increased the germination of black locust seeds in the controlled environment study. Black locust ground cover may be increased by as much as 100 to 200 percent through the use of seed scarification. The uniformity and rate of seedling establishment can also be increased by the scarification treatment (*6*). The percentage of germination of black locust seeds that is inhibited by the seedcoat can vary considerably between seedlots (*4*). It is of considerable importance for each seedlot to be tested for the optimum scarification time.

Rinsing the residual sulfuric acid from the seeds is a very important aspect of the scarification procedure. Drying the seeds at 34° C after rinsing removes excess moisture without decreasing germination (table 2). If the seeds are allowed to remain moist after rinsing, fungal growth and premature germination may occur before sowing.

Delaying irrigation for 72 hours after sowing did not result in decreased germination (table 2). This implies that, if improper germinating conditions exist at sowing time, the seeds will continue to survive for at least 72 hours.

The primary reasons for the poor seed survival on bare mine spoil were unfavorable moisture and temperature conditions when the seed began to germinate.

The 2.4-centimeter bark mulch treatment significantly increased seed survival on the field plots (table 3). Mulching with bark and straw increased soil moisture retention and decreased extremes of soil temperature (*1*). Areas washed free of bark mulch during the winter had sparse seedling survival.

Another strategy that can be used to increase black locust seedling establishment in unfavorable environments is decreased seed scarification. Less scarification results in a greater innate protection of the seed by the seedcoat.

Soil compaction is noticeably detrimental to seedling establishment and growth. Drastic effects of soil compaction on germination rate and survival in direct-seeded black locust were shown by Brown (*3*). Soil compaction from heavy vehicle use should be avoided on sites where black locust establishment is planned.

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# Effects of Age and Size of Sugar Maple Planting Stock on Early Survival and Growth

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*Age and size had little effect on the survival and height growth of bare-root seedlings and transplants. Survival and growth of containerized seedlings were significantly lower than those of bare-root stock.*

Sugar maple (*Acer saccharum* Marsh.) is planted only sparingly because most attempts to establish plantations have been unsuccessful (*1, 2, 6, 8*). However, recent experiments have shown that sugar maple can be planted successfully as long as the physiological requirements of the species are met (*3, 4, 5, 9*). To determine the effects of age and size of planting stock on survival and height growth during the first critical years after planting, sugar maple seedlings and transplants were planted in 1976, 1977, and 1978. This paper reports the 6-, 5-, and 4-year results of these studies.

### Methods

All plantings were made on abandoned agricultural land in southwestern Ontario. The fields were plowed and disked in the summer prior to spring planting. All seedlings and transplants were raised in the Ontario Ministry of Natural Resources tree nursery at St. Williams, Ontario. Each experiment was laid out in a randomized block design with 16 seedlings or transplants per treatment. Each treatment was replicated 10 times for a total planting of 160 seedlings or transplants per age and size class. Spacing was 3 meters between rows and 1.5 meters within rows. During the first 3 years after planting, weed control was maintained by rototilling between the rows and spraying the unwanted vegetation within the rows with 2.1 kilograms per hectare of active glyphosate in 400 liters of water. In the fourth and fifth years, 4.5 kilograms per hectare of active simazine were broadcast over the total plantation area. Survival and height were recorded at the end of each growing season. Survival data were subjected to chi-square tests and height data to analyses of variance and Tukey's tests.

***Study 1.*** In April 1976, 2 +0, 3 +0, and 4 +0 seedlings and 2 + 1 and 2 +3 transplants were planted in a well-drained gravelly loam. All seedlings and the 2+1 transplants were machine planted, whereas the 2 + 3 transplants were planted in auger holes 30 centimeters in diameter.

***Study 2.*** In the autumn of 1976, 2+0, 3+0, and 4+0 seedlings and 2 + 1 and 2 + 2 transplants were lifted from nurserybeds, graded into size classes by root collar diameters, and coldstored over winter in polyethylene-lined Kraft bags at 1.0° C. Seedlings in paperpots (size 408) were grown for 12 weeks in a greenhouse and 4 weeks under shade frames and then overwintered in cold storage at 1° C. In April 1977, all seedlings and transplants were machine planted in a loam soil, while the containerized seedlings were planted by hand.

***Study 3.*** In the autumn of 1972, 2+0 and 3+0 seedlings and 2+2 transplants were lifted from nurserybeds, graded into size classes, and coldstored over winter at 1.0° C. Seedlings in paperpots were grown and overwintered by the same method outlined in study 2. In April 1978, all seedlings and transplants were machine planted, while the containerized seedlings were planted by hand. All trees in this study were planted in the same field as the trees in study 2.

### Results

Average survival of nursery-grown stock was 84 percent or better in all three studies (tables 1 through 3). Survival of containerized seedlings was significantly lower than that of the nursery-grown stock (tables 2 and 3).

In study 1, 6-year height growth of 2+3 transplants was significantly higher than that of 2 + 1 transplants and all seedlings (table 1).

In study 2, 5-year height growth of the large 3+0 seedlings was significantly higher than that of containerized, 2+0 , and all 4+0 seedlings (table 2).

In study 3, 4-year height growth of the 2+2 transplants was significantly higher than that of containerized and 2+0 seedlings (table 3).

Within age classes, trees with large shoot collar diameters always

**Table 1.**—*Sugar maple planting stock size at time of planting and survival, height growth, and total height 6 years after planting (study 1)*

| Stock age | Root collar diameter | Stem length | Oven-dry stem weight | Oven-dry root weight | Shoot: root ratio | Survival[1] | Height growth[1] | Total height |
|---|---|---|---|---|---|---|---|---|
| | *Mm* | *Cm* | *G* | *G* | | *%* | *Cm* | *Cm* |
| 2+0 | 5.6 | 44 | 3.4 | 3.9 | 0.87 | 95a | 278x | 322 |
| 3+0 | 8.4 | 60 | 9.7 | 10.3 | .94 | 95a | 284x | 344 |
| 4+0 | 9.7 | 64 | 13.7 | 18.3 | .75 | 97a | 295x | 359 |
| 2+1 | 6.2 | 42 | 4.4 | 7.6 | .58 | 96a | 291x | 333 |
| 2+3 | 19.5 | 109 | 108.0 | 97.0 | 1.11 | 96a | 352w | 461 |

[1]Common letters denote treatments without significant differences (P=0.05) in survival and height growth.

**Table 2.**—*Sugar maple planting stock size at time of planting and survival, height growth, and total height 5 years after planting (study 2)*

| Stock age | Root collar diameter | Stem length | Oven-dry stem weight | Oven-dry root weight | Shoot:root ratio | Survival[1] | Height growth[1] | Total height |
|---|---|---|---|---|---|---|---|---|
| | *Mm* | *Cm* | *G* | *G* | | *%* | *Cm* | *Cm* |
| Paperpots | _2 | 10 | — | — | — | 67c | 135yz | 145 |
| 2+0 | 4.5 | 28 | 2.3 | 5.1 | 0.45 | 97a | 149xyz | 177 |
| 3+0 small | 5.4 | 31 | 3.5 | 7.8 | .45 | 92ab | 169wx | 200 |
| 3+0 large | 10.3 | 63 | 18.7 | 27.1 | .69 | 87b | 182w | 245 |
| 4+0 small | 7.8 | 85 | 12.9 | 11.0 | 1.17 | 94a | 129z | 214 |
| 4+0 medium | 11.2 | 102 | 27.6 | 19.2 | 1.44 | 94a | 147xyz | 249 |
| 4+0 large | 12.7 | 103 | 35.6 | 30.3 | 1.18 | 96a | 151xyz | 254 |
| 2+1 small | 5.7 | 36 | 4.3 | 9.6 | .44 | 90ab | 165wx | 201 |
| 2+1 large | 8.8 | 48 | 11.4 | 22.0 | .52 | 84b | 173wx | 221 |
| 2+2 small | 8.0 | 55 | 11.3 | 23.9 | .47 | 90ab | 160wxy | 215 |
| 2+2 large | 11.0 | 71 | 21.3 | 35.5 | .60 | 92ab | 174wx | 245 |

[1]Common letters denote treatments without significant differences (P = 0.05) in survival and height growth.
[2]– = not applicable or not available.

**Table 3.**—*Sugar maple planting stock size at time of planting and survival, height growth, and total height 4 years after planting (study 3)*

| Stock age | Root collar diameter | Stem length | Oven-dry stem weight | Oven-dry root weight | Shoot:root ratio | Survival[1] | Height growth[1] | Total height |
|---|---|---|---|---|---|---|---|---|
| | *Mm* | *Cm* | *G* | *G* | | *%* | *Cm* | *Cm* |
| Paperpots | — | 10 | — | — | — | 12b | 36z | 46 |
| 2+0 small | 4.9 | 36 | 1.9 | 2.3 | 0.83 | 91a | 89y | 125 |
| 2+0 large | 8.2 | 52 | 6.5 | 8.1 | .80 | 94a | 119y | 171 |
| 3+0 | 6.5 | 39 | 3.4 | 5.9 | .58 | 97a | 120xy | 159 |
| 2+2 small | 14.0 | 85 | 30.3 | 35.6 | .85 | 96a | 138x | 223 |
| 2+2 large | 20.6 | 121 | 89.4 | 83.4 | 1.07 | 99a | 149x | 270 |

[1] Common letters denote treatments without significant differences (P = 0.05) in survival and height growth.
[2]– = not applicable or not available.

grew taller than trees with smaller diameters. However, none of these differences were statistically significant (tables 2 and 3).

## Discussion and Conclusions

Survival of all nursery-grown planting stock ranged from 84 to 99 percent, with neither age nor size having much effect. The significantly lower survival of the containerized seedlings was probably the combined result of the fact that the seedlings were small, that they were grown in unsuitable containers, and that improper production methods were used. Improved growing methods may overcome the problem (7); but until seedling quality has been improved, it is recommended that only bare-root seedlings or transplants be planted.

With few exceptions, little difference was found in height growth between seedlings and transplants. In study 1, the superior growth of the 2+3 transplants was probably greatly influenced by their being planted in auger holes. This allowed the planting of large root balls, while machine planting required severe root pruning to shape the roots to fit into the relatively narrow planting slit. In study 2, the significantly poorer growth of the small 4+0 seedlings was no doubt the result of the weakest 4+0 seedlings being represented in this size class. In study 3, the 2+2 transplants grew significantly better than the 2+0 seedlings, probably because they had much larger root collar diameters.

Within age classes, root collar diameter was a reliable indicator of relative growth potential. Trees with large root collar diameters always grew taller than trees with smaller root collar diameters. However, these differences were not statistically significant and this trend held true only for trees belonging to the same age class. For example, the large 3+0 seedlings planted in study 2 had an average root collar diameter of 10.3 millimeters and grew 182 centimeters in 5 years, while the large 4+0 seedlings with a root collar diameter of 12.7 millimeters grew 151 centimeters (table 2).

Other studies have shown that intensive weed control was one of the prerequisites of successful sugar maple establishment (*3, 5, 9*). Therefore, the excellent weed control maintained in these experiments no doubt contributed greatly to the good survival and growth of the nursery-grown stock.

The small number of sugar maple seedlings and transplants produced in the provincial nurseries makes it impossible to establish reliable production costs for the different age classes of stock. However, the average cost of production of 2+0 hardwood seedlings in the St. Williams nursery is $85 per thousand.[1] The additional seedbed costs to produce 3- and 4-year-old seedlings are rather minor, but lifting and shipping costs increase with seedling size. The production costs for transplants are estimated to be several times higher than those for seedlings because of transplanting, lifting, root pruning, and shipping of the larger trees with bulkier root systems. The cost of machine planting is very similar for all ages of stock, but spade and especially auger planting are much more expensive.

For the establishment of most plantations, machine planting of sturdy 2 or 3-year-old seedlings is recommended. For special plantations in which total height is of major importance, the planting of large transplants in auger holes may justify the higher establishment costs.

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Tree Planter's Notes, Vol. 34, No. 3 (1983)



# Continued Investigations in First-Year Survival of Long Cottonwood Cuttings

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One-year-old cottonwood stem cuttings, planted in December, February, and March, had over 90 percent first-year survival when soaked in water or when planting holes were filled with dry sand and flooding did not occur.

Cottonwood cuttings of 8 feet or more planted in 3-foot deep holes have apparent advantages over standard 20-inch cuttings. These advantages include less intensive site preparation requirements, reduced deer protection costs, and less critical weed control early in the growing season following outplanting. Two previous studies of long cuttings of five Stoneville clones showed better survival of rooted cuttings compared to unrooted cuttings (92 percent vs. 36 percent) (*6*) as well as unrooted cuttings soaked in water prior to planting compared to unsoaked cuttings (93 percent vs. 86 percent) (*4*). More than a 90-percent survival rate would permit wide planting spacing for sawlog production without requiring any pulpwood thinnings.

The two studies cited earlier differed in time of planting, method of planting, size of planting stock, and soil types. Therefore, three additional plantings in 1978, 1979, and 1980 were made to directly compare the effects of these various planting variables.

## Methods

For plantings in 1978 and 1980, long cuttings of four Stoneville clones (66, 67, 74, and 240 or 238) were planted in 3 months—December (9th to 22d), February (11th to 17th), and March (20th to 22d). Treatments used were: rooted and unrooted material that was soaked or not soaked in water with available soil or dry sand used as filler in the planting holes. In 1979, the March planting could not be included with plantings of the other two dates because of high water.

Cuttings were 1-year-old stems. Rooted cuttings had a foot of rooted material with lateral roots pruned, while unrooted cuttings were cut above ground. Length of soaking varied from 3 to 6 days the first year, 5 to 9 days the second year, and 2 to 5 days the third year.

A split-split-plot design was used, with months as whole plots, clones as subplots, and treatments as sub-subplots, each sub-subplot containing five cuttings. There were four replications or a total of 640 cuttings planted each month of each year. A 12- by 12-foot spacing was used.

By years, the three Mississippi Delta planting sites were: (1) 1978, cleared land in the Mississippi River batturel on clay-capped soils that graded from Tunica to Bowdre and approaching Commerce at the highest part; (*2*) 1979, a cleared clay-capped site near Steele Bayou; and (*3*) 1980, an old field of Commerce silt loam soil between the Little Sunflower and Yazoo Rivers. All areas are in Issaquena County, Miss.

Planting holes were punched to a 3-foot depth with a 1-1/2-inch iron bar (for unrooted cuttings) or a 2-1/2- or 2-7/8-inch iron bar (for rooted cuttings) driven by a hydraulic system on either a four-wheel pickup or tractor (*1*).

Heights at planting and after 1 year were measured for the first and third plantings. For the second planting, only heights of planted cuttings were obtained in July for the December and February planting dates.

## Results

***1978.*** At planting, the average above-ground height of the cuttings was 8.8 feet for unrooted material and 10.6 feet for rooted stock (table 1).

April flooding covered the lowest part of the study area for about 15 days to a maximum depth of about 2 feet. Two replications were completely covered, one partly covered, and the last was mainly free of any standing water.

A May examination showed the December planting had less mortality, but more dieback, than the other 2 months. The highest (driest) replication had the least dieback and mortality and the greatest leaf size, while the lowest (wettest)

[1] A batture is an elevated bed where the river is confined by natural levees above flood plain level.

**Table 1.**—*Above-ground planted height, first-year height growth, and survival by treatment and month and year of planting*

| Month | Treatment | | | 1978 | | | 1979 | | 1980 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Roots | Soak | Sand | Ht. | ΔHt. | Surv. | Ht. | Surv. | Ht. | ΔHt. | Surv. |
| | | | | - - *Ft* - - | | *%* | *Ft* | *%* | - - *Ft* - - | | *%* |
| December | 0 | 0 | 0[1] | 9.2 | -1.8 | 85 | 7.2 | 56 | 5.1 | 5.0 | 94 |
| | 0 | 0 | 1[1] | 9.2 | -1.4 | 71 | 7.2 | 61 | 5.0 | 4.9 | 91 |
| | 0 | 1 | 0 | 8.4 | 0.3 | 92 | 7.3 | 52 | 5.1 | 5.3 | 96 |
| | 0 | 1 | 1 | 8.4 | 0.8 | 93 | 7.2 | 69 | 5.0 | 5.5 | 99 |
| | 1 | 0 | 0 | 10.5 | -1.1 | 70 | 7.9 | 88 | 5.3 | 5.2 | 92 |
| | 1 | 0 | 1 | 10.5 | -2.0 | 64 | 7.8 | 90 | 5.3 | 5.7 | 91 |
| | 1 | 1 | 0 | 10.3 | -1.2 | 79 | 7.6 | 89 | 5.3 | 5.1 | 96 |
| | 1 | 1 | 1 | 10.2 | -0.7 | 77 | 7.6 | 93 | 5.2 | 5.5 | 99 |
| February | 0 | 0 | 0 | 9.5 | -0.3 | 45 | 6.0 | 19 | 6.0 | 4.2 | 82 |
| | 0 | 0 | 1 | 9.4 | -0.6 | 65 | 6.0 | 32 | 6.0 | 4.7 | 91 |
| | 0 | 1 | 0 | 9.1 | -0.7 | 76 | 5.9 | 15 | 6.2 | 4.5 | 98 |
| | 0 | 1 | 1 | 9.2 | 0.1 | 85 | 5.9 | 24 | 6.1 | 5.1 | 94 |
| | 1 | 0 | 0 | 10.8 | -1.0 | 66 | 7.8 | 45 | 6.5 | 4.5 | 92 |
| | 1 | 0 | 1 | 10.5 | -1.1 | 70 | 7.8 | 43 | 6.4 | 3.7 | 95 |
| | 1 | 1 | 0 | 11.2 | -1.3 | 69 | 8.0 | 45 | 6.4 | 3.7 | 95 |
| | 1 | 1 | 1 | 11.1 | -1.1 | 80 | 7.9 | 47 | 6.3 | 4.0 | 99 |
| March | 0 | 0 | 0 | 8.6 | 0 | 81 | —[2] | — | 6.1 | 2.9 | 95 |
| | 0 | 0 | 1 | 8.6 | -0.7 | 74 | — | — | 6.0 | 3.1 | 96 |
| | 0 | 1 | 0 | 8.0 | -0.6 | 83 | — | — | 6.2 | 2.7 | 94 |
| | 0 | 1 | 1 | 8.1 | 0.2 | 79 | — | — | 6.2 | 3.0 | 95 |
| | 1 | 0 | 0 | 10.2 | -1.5 | 44 | — | — | 6.0 | 3.1 | 96 |
| | 1 | 0 | 1 | 10.7 | -2.6 | 42 | — | — | 6.0 | 3.7 | 96 |
| | 1 | 1 | 0 | 10.8 | -2.6 | 60 | — | — | 6.0 | 2.8 | 90 |
| | 1 | 1 | 1 | 10.7 | -2.2 | 60 | — | — | 6.0 | 3.6 | 94 |

[1] 0 = without; 1= with.

[2] _ = not available

replication had the most dieback and mortality.

In July, eight trees (five from the next lowest replication and three from the highest) were dug up with a backhoe and the root systems examined. Roots went to the bottom of only one cutting, but root development was very poor. For the other cuttings, the bottom 2 to 15 inches were dead. The tree with the largest top had the largest root system. For comparison, a long cutting planted a year earlier in the same general area on an unflooded site was excavated. There was no dead stem at the bottom of the cutting and no taproot-only well-developed laterals to the 3-foot depth. The largest and longest roots were closest to the surface.

Neither first-year survival nor growth was satisfactory. Less than 90-percent survival and less than 3 feet of height growth were observed.

For rooted stock, only clone 66 with sand in December and clone 66 with sand and soak in February had satisfactory survival of 90 percent or better. For unrooted stock, several inconsistent combinations of clones and December and March planting treatments had 10-percent mortality or less. Statistically, several significant survival differences (at the 0.05 probability level) showed December survivals greater than those for March planting. Clone 66 survived better than clones 67 and 74 (table 2). Considering replications a fixed effect in spite of differences in evaluation and/or length of overflow, the site at the highest elevation provided higher survival rates than the two lower sites.

**Table 2.**—*First-year survival by clone and year of planting*

| Year | Clone 66 | Clone 67 | Clone 74 | Clone 240[1] |
|---|---|---|---|---|
| | - - - - - - - - - - - - % - - - - - - - - - - - - | | | |
| 1978 | 79 | 68 | 64 | 74 |
| 1979 | 53 | 71 | 41 | 55 |
| 1980 | 92 | 91 | 97 | 98 |

[1] Clone 238 in 1980.

Increases in mortality between the last of May and the end of the growing season were nearly twice as great for rooted as for unrooted stock in March planting compared to December planting and on the two lowest replications compared to the highest.

Fifty-four percent of the trees were within ±0.9 foot of their planted height at the end of the first year. A third of the trees lost a foot or more of their planted height, and 13 percent grew a foot or more in height. Of the 1,186 living trees, only 3 percent grew ≥ 3.0 feet in height.

***1979.*** Average above-ground heights at planting were 6.6 feet for unrooted cuttings and 7.8 feet for rooted cuttings.

The planting site varied about 4 feet in elevation. The lowest area was water covered from mid-March through May (2 ½ months), while the highest area was covered for 6 weeks. Maximum water depth ranged from 5.5 to 9.5 feet. At the July 5 measurement, none of the trees had leafed out adequately, and many only had a leaf or two. July survival was 90 percent for December-rooted cuttings and 59 percent for unrooted cuttings. The February planting survival was 45 and 22 percent, for rooted and unrooted cuttings.

***1980.*** Average above-ground planted heights were 5.8 feet for unrooted cuttings and 5.9 feet for rooted cuttings.

There was no flooding in this planting. Overall survival was 94 percent. There were no significant differences because of months or treatments. Clones 74 and 240 had significantly better survival than clones 66 and 67. There was a significant month by treatment interaction in that the unrooted, unsoaked, and soil-filler treatment planted in February had less survival than all other combinations.

Average height growth the first year was 5.2 feet for the December planting, 4.2 feet for February, and 3.1 feet for March.

**Discussion and Conclusion**

Flooding in 2 of the 3 years added another dimension to the survival aspect of planting large cottonwood cuttings. Where water covered the ground, survival was erratic. December planting of unrooted, soaked cuttings with or without sand filler gave satisfactory survival in 1978. In 1979, December-rooted cuttings had 90-percent survival at mid-growing season. No other month and treatment combination had greater than or equal to 90-percent survival. Furthermore, trees that survived did not have healthy leaves, either in quantity or size. The changes in survival in the 1978 planting between late May and the last of the growing season increased the differences already present. This indicates that variables that provided poorest survival conditions early in the growing season either continued to do so for the remainder of the season or weakened the trees sufficiently to produce greater mortality through the rest of the growth period. The main problem associated with first-year flooding appears to be improper root development. Spring flooding after the first year does not appear detrimental (*3*).

Thousands of acres have been planted with 20-inch unrooted cuttings, which are subject to the same problems as long cuttings. For sites where shallow flooding is likely to occur, 1-0 seedlings have been recommended instead of cuttings because of better survival (*5*). Extended flooding in 1973 virtually eliminated cottonwood cutting plantations, while about half of a similar seedling plantation survived (*3*).

A long-cutting planting treatment effectively producing 90-percent survival on sites subject to flooding is not apparent from these studies. However, if such sites are to be planted, early (December) planting is best, possibly because some roots develop prior to flooding. Kennedy (2) found that root initiation in planted cottonwood cuttings took place until temperatures dropped below 50° to 55° F, but that roots that had already started to grow continued growth. No distinction could be made between rooted and unrooted material even though seedlings survived better than unrooted smaller cuttings.

Where flooding is unlikely, time of planting and planting stock, with or without roots, appear unimportant although it would probably be inadvisable to plant during extended dry periods (*2*). Dry sand filler, which by its flowable nature should eliminate air pockets, provided no higher survival rates than soaking. However, sand backfill is a quicker method to close a punched planting hole (*1*). Water soaking is an easily applied treatment at the nursery. It also has the additional advantage of being an effective and safe method for storing cuttings for short periods of time. Both soaking and sand backfilling are feasible for commercial planting operations.

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# Root Rots on Shumard Oak in a Central Louisiana Nursery

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*Isolations from apparently diseased 1-0 Shumard oak seedlings grown at a small private nursery in Lecompte, La., yielded the root rot fungi Cylindrocladium scoparium Morgan and a Phytophthora sp. This is the first report of C. scoparium on Shumard oak and the first time it has been noted in Louisiana.*

In 1981, a high percentage of the Shumard oaks (*Quercus shumardii* Buckl.) in a plantation near Logansport, La., were evidently diseased. These seedlings had been transplanted from a small private nursery located in Lecompte, La. In the same plantation, seedlings of saw-toothed oak (*Quercus acutissima* Carruthers) and loblolly pine (*Pinus taeda* L.) obtained from a separate Louisiana nursery were apparently unaffected.

Foliar and root symptoms on the Shumard oak included leaves with brown irregular areas at the margins and taproots with extensive necrosis (fig. 1). Foliar symptoms were present both in the plantation and at the nursery (fig. 2); root symptoms were present only at the nursery.

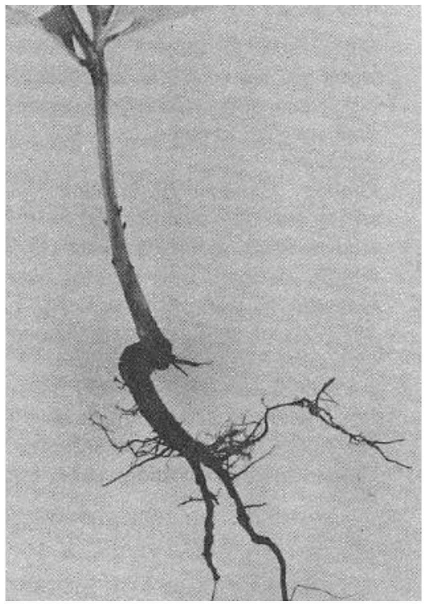

**Figure 1.**—Extensive root necrosis cause by Cylindrocladium scoparium on Shumard oak.

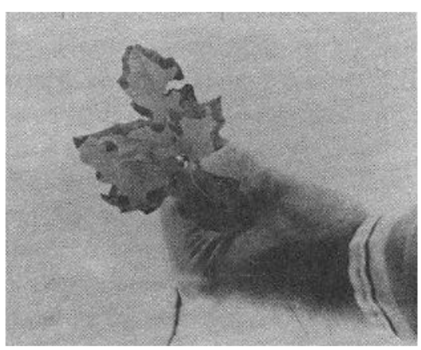

**Figure 2.**—Foliar symptoms associated with Cyclindrocladium root rot of Shumard oak.

### Methods

Isolations were attempted from nursery and plantation soil samples using Flowers and Hendrix medium for Phytophthora and from seedlings using potato dextrose agar (PDA) for other possible pathogens.

### Results

High propagule counts of *Phytophthora* sp. were obtained from soils collected from both the nursery and outplanting area. Counts of 16 and 62 propagules per gram of soil were obtained from the nursery samples. The outplanting sample yielded 7 propagules per gram.

Root tissue isolates from the nursery on PDA consistently yielded the fungus *Cylindrocladium scoparium* Morgan.

### Discussion

The two pathogenic soil fungi Phytophthora sp. and Cylindrocladium scoparium have diversified host ranges and cause severe seedling losses to a variety of hardwoods. The presence of *C. scoparium* in Louisiana was previously unknown (*1*). If these pathogens are transported to uninfested outplanting sites, subsequent root disease could pose problems for affected landowners in Louisiana.

In North and South Carolina and Kentucky, *Cylindrocladium* spp. destroyed all or most of walnut (*Juglans nigra* L.) (*2, 3*), yellow-poplar (*Liriodendron tulipifera* L.) (*1, 3*), and sweetgum (*Liquidambar styraciflua)* (*4*) crops at forest tree nurseries in the 1960's and early 1970's.

Preplant soil fumigation with MC-33 (67 percent methyl bromide and 33 percent chloropicrin) is currently recommended as the most effective prevention of these root rots. Once the disease appears, control of *Cylindrocladium* root rot can be achieved with soil drenches using benomyl (Benlate). Only Captan is registered and is effective against *Phytophthora root* rot once it appears. Local extension agents or foresters should be contacted for specific information about the use of these chemicals.

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### Correction

The Winter 1983 issue of Tree Planters' Notes (Vol. 34, No. 1) contains an error on page 11 in table 1 of the article "Evaluation of Six Weed Control Treatments in an Interior Spruce Seed Orchard" by Paul J. Birzins. The percentage of weed encroachment for the control should read "33.3bc."