Mechanizing Site Preparation -- Spot Scarification

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Because so many areas are targeted for planting, mechanizing the site preparation operation can achieve more efficient, faster reforestation. Two scarifier implements mounted on crawler-tractors proved feasible for preparing planting sites in a variety of vegetative covers. Production rates ranged from 1½ to 2½ acres per hour.
Tree Planters' Notes 38(1) : 3-5 ; 1987

Site preparation is vital for rapid reforestation and often can mean the difference between success or failure of a plantation. Because site preparation is so important and the areas involved are often rough and obstacle-filled, the Missoula Equipment Development Center (MEDC) has been investigating ways to mechanize the site preparation process. Part of this effort involved locating site preparation implements that could be mounted on crawler-tractors.

The challenge was twofold: produce quality spots and produce them efficiently. A quality spot was defined as one that reduces vegetative competition for moisture, nutrients, and sunlight to help ensure seedling establishment and survival.

Two Scalper Concepts Chosen

The MEDC investigated many concepts for crawler-tractor-mounted scalpers. Two proved effective in making planting spots in extensive testing. One method mounts a scalper on both the right and left side of the tractor blade; the other mounts two scalpers on the tractor's tool bar.

The blade-mounted system was developed by Lowell Birch. The MEDC used Birch's prototype to build a final version of the Birch "Quik-Tach" Scalper for testing (fig. 1).

The tool-bar-mounted scalper was designed and built at MEDC and is called the Rocky Mountain Scalper (fig. 2).

Testing and Results

To determine the effectiveness of these implements, both were extensively tested in a variety of ground covers, ranging from pine grass and beargrass to heavy brush and moderate slash. Testing took place on the Bitterroot National Forest in Montana and the Clearwater National Forest in Idaho. Approximately 600 acres received site preparation

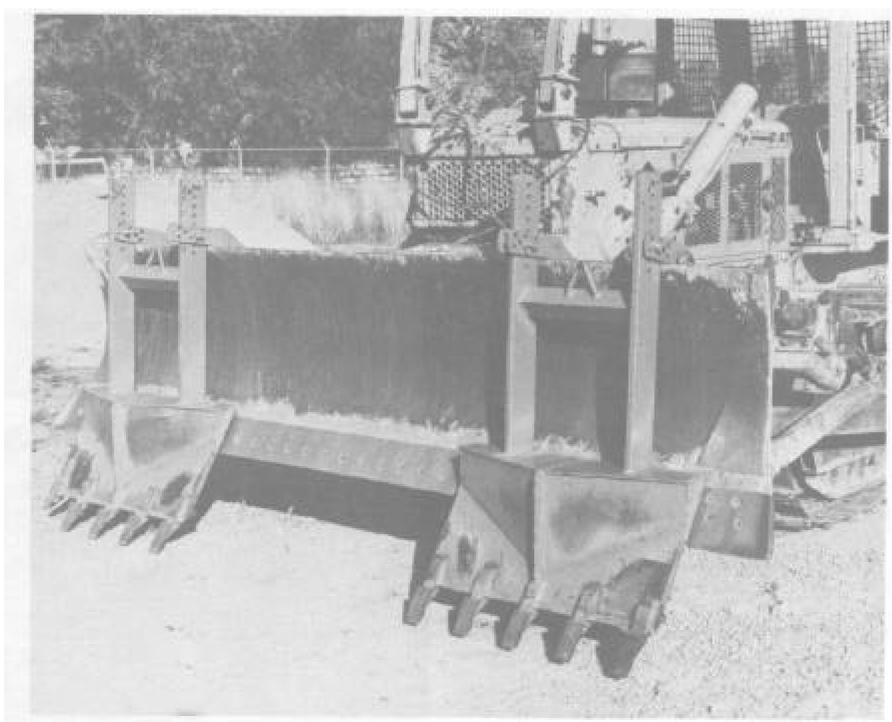

Figure 1—*Birch Quik-Tach Scalper.*

with these implements during testing.

Both the Birch Quik-Tach Scalper and the Rocky Mountain Scalper proved successful in preparing quality spots in the different ground cover types found at the test sites (fig. 3). Also, both prepared spots on slopes as steep as crawler-tractors can safely operate.

Both prepared about 600 planting sites per acre. Production rates for both implements ranged from 2½ acres per hour in grass cover to 11½ acres per hour in the heavy brush and moderate logging slash. The cost per acre treated ranged from $18 to $30, based on $45 per hour for machine costs with operator. The recommended machine size for these implements is in the 70 to 150 horsepower range.

Based on test results and implement design, both types of scalpers have advantages and disadvantages. The Birch Quik-Tach Scalper appears to be the superior implement for most conditions and was highly praised by those testing it.

Birch Quik-Tach Scalper

Advantages:

1. Each Quik-Tach Scalper implement can be attached or removed from a crawler-tractor blade in about 5 minutes.
2. Crawler-tractor requires no modification. The scalpers can be attached directly to the blade of any leased crawler-tractor.
3. The operator has an excellent view of both scalpers.
4. Initial cost is low: $1,500 to $2,500 per set.
5. Good depth control for spot scarification.
6. Because most machines have tilt blades, the operator can position the blade for even scalp depth on the right and left scalpers.
7. Up to 1,500 spots per hour can be prepared.
8. Operator can easily control spot depth and length.

Disadvantages:

1. Operator must raise and lower blade to create spots.
2. Operator must be skilled at blade control to ensure quality spots.
3. Crawler tracks run over scalped sites and can compact soil on sensitive sites.

Figure 2—*Rocky Mountain Scalper.*

Rocky Mountain Scalper

Advantages: This implement has one major advantage--it is better suited to site preparation in areas sensitive to soil compaction. Because the scalp is made behind the machine, that is, after the machine has passed over the site, the duff and litter layer is still in place to help support the crawler-tractor and minimize soil compaction before the tool-bar mounted scalpers scoop out spots. The Rocky Mountain Scalper also can prepare up to 1,500 spots per hour.

Disadvantages:

1. Because it is mounted at the rear, the scalper is not as visible to the operator, so scalp depth is more difficult to control.
2. The scalper must be used on a tool bar and modifications to the tool bar are necessary.
3. The winch must be removed when using the tool bar.
4. The tool bar cannot be tilted sideways to level the scalpers to the terrain.
5. A skilled operator is required to create good scalps.
6. Attaching and removing the tool bar is time consuming.
7. The operator must raise and lower the tool bar to create spots.

Recommendations for Scalper Use

Based on our testing, the Birch Quik-Tach Scalper is recommended, unless the area to be treated is extremely sensitive to soil compaction. In sensitive areas, the Rocky Mountain Scalper may be a better choice.

Plans are available from MEDC for building these scalpers. Request drawing MEDC-751 for the Birch Quik-Tach Scalper and drawing MEDC-686 for the Rocky Mountain Scalper. Fabrication costs for both implements range from $1,500 to $2,500. The tool bar for the Rocky Mountain Scalper can cost up to $10,000.

For further information on these implements, write or call the Missoula Equipment Development Center, Building 1, Fort Missoula, Missoula, MT 59801; (406) 329-3958 or FTS 585-3958.

Figure 3—*Typical spot prepared by crawler-tractor-mounted scalper, measuring 3 feet by 3 feet.*

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Cable-Scarification-A Site Preparation Alternative

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A cable-yarder scarification implement offers land managers an alternative to preparing planting sites on steep slopes when fire or chemicals cannot be used. The scarifier, powered by a lightweight yarder, works well in lighter slash (smaller than 9-inch dbh) where loads do not exceed 40 tons per acre and brush cover is less than 10 feet tall. Tree Planters' Notes 38(1):6-10; 1987

Preparing sites for planting on steep slopes often presents land managers with a difficult challenge, particularly if the slopes are covered with slash and brush.

What are the alternatives? Crawler tractors are restricted on steep slopes, and hand piling and hand scalping are slow and expensive. The method of choice more often than not has been prescribed burning. It can be an economical and practical way to rid a site of slash and prepare it for seedling planting.

However, air quality regulations and weather can restrict fire as a site preparation tool, and not all areas on steep slopes are suitable for burning. Chemical treatment may prove the best alternative in the long run.

In the meantime, mechanical methods can offer some of the best site preparation alternatives.

Figure 1—Scarifier implement rides skyline cable downslope to begin digging planting spots.

The Cable Scarifier

As part of its efforts to improve site preparation methods, the Missoula Equipment Development Center (MEDC) designed, built, and tested a cable scarification implement.

Cable scarification is not new, of course. It was introduced in the Pacific Northwest in the late 1960's. A high-lead cable yarder was used to drag two concrete-filled steel drums over an area to be planted. These drums weighed about 5,000 pounds. As they moved at line speeds of 500 to 1,000 feet per minute, they scattered the slash and created areas where seedlings could be planted without having to burn first.

MEDC's scarifying implement is much lighter, and with it, the yarder operator can dig out planting spots of various lengths as it moves up a slope.

The implement is approximately 10 feet wide by 4½ feet high and weighs 1,000 pounds (fig. 1). Scarifiers on either side of the implement's frame create planting spots about 24 inches wide. Teeth along the bottom of each scarifier penetrate surface litter and duff to help scoop out planting spots. The teeth are two-part replaceable backhoe teeth. Skids directly behind the scarifiers ensure that the teeth bite into the surface at the most efficient angle. These skids are adjustable to accommodate slopes of different steepness.

The implement travels up and down the yarder's skyline cable on two 10-inch sheaves mounted at the top of the frame. The mainline is attached to a swivel that in turn is hooked by cables to the implement.

We used a Clearwater cable yarder to test our scarifier implement. The Clearwater Yarder was designed by MEDC engineers a few years ago. It is a three-drum system mounted on a 5-ton Army truck (fig. 2). The yarder has a live skyline of 800 feet of ½-inch cable, with 7,500 pounds maximum line pull and a top line speed of 500 feet per minute. The mainline has 900 feet of $^3/_8$ - inch cable with 3,500 pounds maximum line pull and 1,000 feet per minute maximum line speed.

Test Procedures

To determine how well our scarifier worked, we tested it under a number of field conditions at sites in Idaho, Montana, and Oregon. Clearcut areas were selected in which the Clearwater Yarder could operate favorably, either first removing slash and then running the scarifier implement or operating the scarifier alone. We evaluated the slash loading on each test site. If it was too heavy, we yarded off enough material so that the scarifier could operate. A four-person crew yarded slash: two choker setters, one person on the deck, and the operator. A two-person crew operated the scarifier: an operator and a person at the mobile tailhold.

To begin the scarifying process, the skyline was tightened, lifting the implement off the ground. The mainline was then released, allowing the scarifier to travel down the skyline to the bottom of the slope. The scarifier was stopped by braking the mainline. Tension on the skyline was then released, lowering the scarifier to the ground. The mainline was then tightened. The scarifier bit into the soil, and as it was pulled back upslope it dug out a planting spot.

About every 10 feet, or when the scarifier hung up on a stump or other obstacle, tension on the skyline was tightened, lifting the implement over the obstacle or out of the scalp.

One trip up a slope was considered a pass and was repeated until adequate scarification was achieved, usually in two to four passes. Then the tailhold was moved and the procedure was repeated. All the passes from one tailhold position were considered a set.

For our tests, we used a D-5 crawler tractor with a 12-foot-high tower as a mobile tailhold.

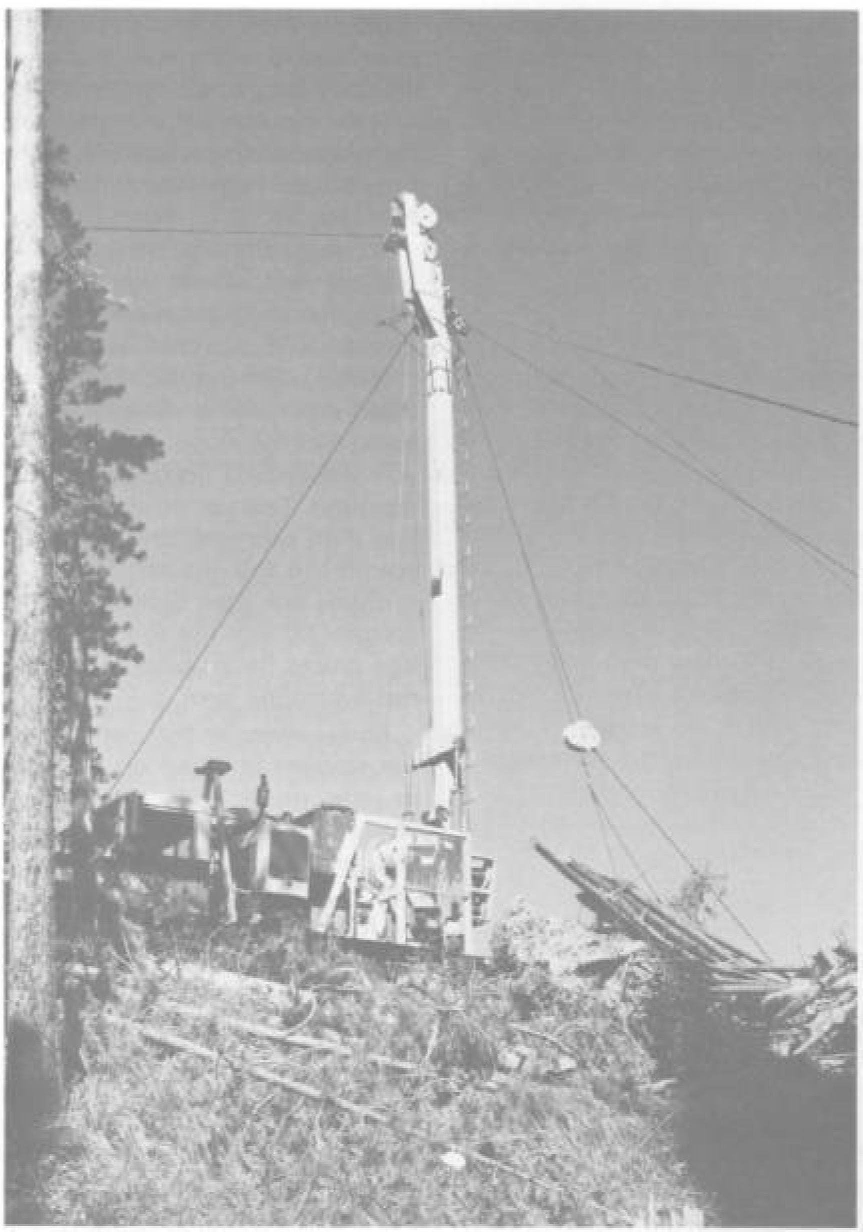

Figure 2—Clearwater Yarder reduces slash loading before operating scarifier implement.

Test Results

Initial shakedown testing was conducted on a clearcut on the Bitterroot National Forest in western Montana. The 20-acre test site contained heavy concentrations of lodgepole pine, ranging from 4 to 14 inches dbh. Slopes averaged 60 percent, with moderate grass and brush cover.

Before we could test the scarifier implement, much of this slash had to be removed. So 60 to 70 percent of the downed lodgepole was removed. Once yarding was completed, mostly fine slash and rotten logs remained in which to operate the scarifier.

Two to four passes of the scarifier per set provided adequate scarification. Some 500 to 600 planting sites were created per acre, with 3 to 4 acres prepared per operating day. Scalps were 2 to 4 inches deep, 18 to 20 inches wide, and 4 feet long (fig. 3). Needles and duff fell back over some of the scalps and would have to be cleared out before planting.

Another test site in western Montana, on the Flathead Indian Reservation, was in Douglas-fir/ninebark habitat type in the ninebark phase. Slopes were 45 to 50 percent. Vegetative cover consisted of a heavy cover of ninebark. After initial yarding of heavy slash and cull logs, 33 percent of the test site was plantable. After one or two passes with the cable scarifier, 61 percent was plantable.

Before this treatment, the site would have been difficult to plant, and heavy ground cover and slash limited crew access. After treatment, hand-planting crews had relatively easy access, and the area was immediately planted to ponderosa pine at a spacing of 11 by 11 feet --- 360 trees per acre. Tree planters did some hand scalping to achieve the desired spacing. A check 3 months later showed 96 percent of the seedlings were alive and growing.

Yarding costs for this operation totaled about $170 per acre and scarification costs about $90 per acre (assuming $80 per worker-day personnel costs). However, in areas where fuel loadings are higher and terrain rougher, these costs would go up.

A ceanothus brush field on the Clearwater National Forest in Idaho served as another test site. This area had a steep slope – 60 to 90 percent – and was covered with brush that was 4 to 12 feet tall.

Our scarifying implement did not work well in the area. Even five of six passes were not enough to create adequate planting spots. The brush proved too thick and limber. The implement simply skidded over much of the

Figure 3—*Typical spot dug out by cable scarifier.*

vegetation, seldom reaching the ground. When it did, the yarder did not have the power to tear the brush out by the roots. A heavier scarifying implement and more powerful yarder would be needed.

To determine capabilities on West Coast fuel and brush types, the yarder and cable scarifying implement were tested on five different Bureau of Land Management sites in western Oregon. All had heavy concentrations of light slash with medium to heavy brush cover. Brush commonly was vine maple (*Acer circinatum* Pursh), willow (*Salix* sp.), and bigleaf maple (*A. macrophyllum* Pursh) from 4 to 7 feet tall. Depending on the site, it required two to eight passes per set to prepare a site for planting adequately in the estimation of the silviculturist working with the evaluation team.

We also found that material over 24 inches dbh had to be removed before the scarifier could be effective. In addition, the Clearwater Yarder's mainline cable proved too short; West Coast yarder span capability was needed. In addition, convex slopes prevented complete access to some areas needing treatment.

In ideal terrain, where slopes are concave, slash is light, and brush is small, the Clearwater

Yarder and the scarifier worked well. But BLM personnel estimated that in the Eugene District where the tests were conducted, these conditions exist on only about 5 percent of the land needing treatment. Normal conditions on the West Coast would require a bigger yarder and heavier scarification implement.

Discussion and Conclusions

Our evaluation enabled us to identify those conditions in which the scarification implement is likely to work well, resulting in higher production rates and lower costs per acre. We also recognized that there are sites unsuited to this system -- particularly West Coast sites where slash tends to be bigger and the slash loading heavier. The combination of Clearwater Yarder and scarifying implement works well on steep slopes and with slash loadings under 40 tons per acre of fuels smaller than 9 inches dbh and where brush cover is less than 10 feet.

Scarifying costs for site preparation on our test sites ranged from $100 to $200 per acre, with production rates of 2 to 4 acres per 8-hour day (yarding costs were $200 to $400 per acre at 1 to 2 acres per day).

After a thorough evaluation of the scarifying implement, we were able to reach some conclusions about its effectiveness as a site preparation tool:

* Treatment with this implement creates sufficient planting spots to achieve full stocking, and it can be considered a useful option in specific instances.
* The factors limiting cable scarification are terrain (adequate deflection), debris, vegetative cover, and, of course, costs.
* Site preparation with this implement is relatively slow and expensive compared to other current methods such as fire or chemicals.
* A larger yarder with a swing boom and heavier implement would improve production and be more effective in heavier slash and brush.
* Vegetative control is limited with this site preparation method.

Generally, the cable scarifier was effective in disturbing existing vegetation and scarifying soil for planting where conditions were ideal and brush was not large. In large, dense brush, the implement lacked the weight and the yarder lacked the power to be effective. No doubt, a larger yarder with a swing boom and a heavier implement would be more effective in heavier brush and more productive. In addition, the deflection and span capabilities of the Clearwater Yarder limited the areas that could receive site preparation in one set. The mobile tailhold was valuable. Estimates were that production was doubled using it versus using trees and stumps.

To sum up, this yarder-scarifier combination offers an effective alternative for site preparation on steep slopes under the specific conditions outlined and where normal treatment methods are not possible.

Construction drawings for the cable scarifier are available from MEDC; request drawing number MEDC-767. Building costs are estimated at $2,000 to $3,000.

For additional information, write or call the Missoula Equipment Development Center, Building 1, Fort Missoula, Missoula, MT 59801; (406) 329-3958 or FTS 585-3958.

Modification of Seed Covering Material Yields More and Larger Pine Seedlings

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Ponderosa pine (Pinus ponderosa Dougl. ex Laws.) seed, sown in a soil with a high composition of calcium carbonate that tends to crust, was covered with either soil, soil treated with phosphoric acid, light colored sand, or dark volcanic cinder. After two seasons, seedling density and size were greatest with cinder covering, second best with sand, and poorest with soil. Phosphoric acid was ineffective. Tree Planters' Notes 38(1):11-13; 1987

When dry, the soil in many places at the Albuquerque Tree Nursery, Albuquerque, NM, forms a strong crust that can impede seedling emergence (5, 7). One answer to the crusting problem is frequent, light irrigation to prevent the crust from forming; this is standard practice at the nursery. Two other methods were tested. Treatment of the soil immediately covering the seed with phosphoric acid would convert calcium carbonate, the main cause of the crust, to calcium phosphate, which forms a softer, more crumbly crust when it dries (5, 7). A second method, sometimes used in nurseries with heavy soil, is to cover the seed with a material that does not crust, such as sand. Using a grit or sand mulch is common nursery practice, but usually to reduce surface evaporation and frost heaving (1, 3, 6, 8). However, sand covering has been shown to increase seedling emergence of many species in hardwood nurseries with soil that crusts (9).

Such a covering can modify soil surface temperatures, depending on the material's albedo. Southwestern sources of ponderosa pine germinate poorly at cool temperatures (4); therefore, a dark-colored material that would warm up more than the surrounding soil might speed germination, especially for spring sowings.

Materials and Methods

On May 23, 1983, one bed on one of the poorer soils at the Albuquerque Tree Nursery, Albuquerque, NM, was marked off in 1.5-meter sections. It was then sown to ponderosa pine with an Øyjord drill, which was lifted by the front end so that the discs and rear roller did not cover the seed. The seed in each 1.5-meter plot was covered by hand to a 20-millimeter depth with one of the following:

1. Soil, simulating standard nursery practice.
2. Soil, followed by application of 100 milliliters of 7.5 per cent H_3PO_4 per 1.5 meters of drill row.
3. Sand, 0.5- to 2-millimeter particles, light tan in color, mostly quartz and granite.
4. Volcanic cinder, 1- to 4-millimeter particles, almost black.

The four treatments were randomized within each of eight blocks within the one bed. (Confining research plots to a small portion of the nursery is not statistically optimum, but is often a practical necessity. In this case, soil analyses indicated sufficient calcium carbonate throughout the nursery to cause crusting, and I have observed crusting in many parts of the nursery.)

The seedlings were grown to full size in two growing seasons using the same practices of irrigation, fertilization, weeding, etc., as used routinely throughout the nursery. At the end of the first and second growing seasons, a 30-centimeter strip across the bed was selected at random near the middle of each plot. All of the seedlings in the strip were lifted and the following observations were made per plot:

1. Number of seedlings, from which seedling bed density was calculated.
2. Mean fresh weight per seedling.
3. Mean epicotyl height.
4. Median foliage color.

Foliage color varied from dark green to yellow, and was measured by an index keyed to the following Munsell standard colors *(2):*

Index/color	*Munsell code*
4/dark green	7.5G 4/4 to 2/4
3/light green	7.5GY 5/6 to 5/8
2/yellow green	5.0GY 6/6
1/yellow	2.5GY 7/6 to 7/8

Data were analyzed by one-way analysis of variance. Significant differences in treatrnent means were determined by Duncan's multiple range test. Median color per plot was treated as a continuous variable.

Results and Discussion

The soil was observed to form a crust whenever the surface was dry. The sand and cinder did not. The sand was nearly the same color as the soil, and therefore, soil and sand surface temperature of the dark cinder was undoubtedly warmer that either soil or sand. Thus, although there are some other factors that cannot be ruled out, differences in seedling performance between soil and sand covering are probably attributable to presence or absence of a crust, and differences between sand and cinder are probably attributable to difference in surface daytime temperatures.

Compared to the soil covering, covering seed with sand or dark cinder increased 1-0 seedling fresh weight an average of 36 percent, epicotyl height and aver-

Table 1—*Effect of seed covering on stand establishment and seedling characteristics*

		Seed covering[1]			
Parameter	Growing season	Soil (control)	Soil plus phosphoric acid	Sand	Black cinder
Density (no./m²)	2-0	181 b	162 b	308 a	273 a
	1-0	222 b	194 b	295 a	224 b
Fresh weight (g)	2-0	2.56 c	2.55 c	4.07 b	6.68 a
	1-0	0.78 b	0.78 b	1.05 a	1.06 a
Epicotyl height (mm)	2-0	41.6 c	42.0 c	60.0 b	75.2 a
	1-0	23.2 b	22.9 b	33.0 a	32.7 a
Color index	2-0	2.43 c	2.51 c	2.99 b	3.38 a
	1-0	2.85 b	2.70 c	3.32 a	3.33 a

[1]Within rows, numbers followed by the same letter are not significantly different at $P = 0.05$.

age of 42 percent, and foliage color was significantly greener (table 1). Seedling bed density was 33 percent greater with the sand covering.

At the end of the 2-0 year, the superiority of the sand or cinder seed covering was even more apparent, and the cinder covering was significantly better than the sand. Compared to soil covering 2-0 bed density was 70 percent and 51 percent greater with sand or cinder covering, respectively; fresh weight was 59 percent and 161 percent greater, respectively; epicotyl height was 44 percent and 81 percent greater, respectively; and foliage color was greener with cinder than sand, which, in turn, was greener than with soil covering (table 1).

By the end of the second season, the surface of the sand-covered plots was almost indistinguishable visibly from soil-only plots. Cinder-covered plots were distinguishable by surface color, although the cinder was by then mixed with the surface soil. Second-year differences in growth probably are a carryover effect from the first growing season.

The prolonged beneficial effects of the sand and cinder may have included better percolation of the irrigation water into the soil. Volcanic cinder tend to be highly fertile and may have contributed some nutrients, particularly potassium and sulfur, to the soil. However, because nursery nutrient levels were adequate, it is unlikely that mineral nutrition could account for the observed differences between the plots.

treated with sand and with cinder. More likely, the dark cinder raised soil surface temperatures in the spring and fall enough to prolong the effective growing season.

The favorable effect of the dark cinder compared to light-colored sand is at variance with usual nursery recommendations where the objective is to minimize daily fluctuation in soil surface temperatures (1.3). However, these recommendations apply more to nurseries in cool, humid climates, which are very different from the hot, dry climate at Albuquerque.

Depth of recommended seed covering also varies between nurseries in different climates. May (6) recommended 0 to 3 millimeters of soil covering over southern pine seed. Armson and Sadreika (3) recommended 3 to 6 millimeters over boreal conifer seed in Ontario. Stoeckeler and Slabaugh (8) recommended 6 to 12 millimeters over ponderosa pine seed in the Great Plains and commented that more covering is needed in drier climates. Fore the dry climate at Albuquerque Tree Nursery, a target sowing depth of 20 millimeters for ponderosa pine seems reasonable.

Soil covering treated with phosphoric acid failed to increase seedling numbers or growth, or to improve foliage color (table 1). However, the soil Was very dry when the phosphoric acid was applied. It effervesced and rolled off the drill rows, which may explain lack of positive results. The day after the seedbeds had been irrigated, a simple unreplicated plot was treated with phosphoric acid. Growth response was similar to sand covering, but there was no increase in number of seedlings.

Conclusions and Recommendations

1. Sand or cinder seed coverings were used effectively to increase stand establishment and growth in soils were crusting can be a problem.
2. Because of variation in soils, climate, and the different reactions of species to soil crusting, nurseries considering such mulching should test it on a small scale on their problem soils first. Over an entire nursery, the cost of applying substantial volumes of sand or cinder might outweigh any gain. In addition, if the composition and color of materials available locally is different from the ones used in this experiment, their use may give quite different results.

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Stratification and Temperature Requirements for Germination of Autumn Olive (*Elaeagnus umbellata*) Seed

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*Optimum seed germination requirements were determined for autumn olive (*Elaeagnus umbellata*), an exotic low-growing shrub planted widely on coal surface-mined lands and wildlife management areas in the United States to provide food and cover for wildlife. Study results indicated that optimum germination of autumn olive seed is achieved with a minimum cold stratification period of 16 weeks and a subsequent night/day germination temperature of 10/20 °C.* Tree Planters' Notes 380) :14-17; 1987

Autumn olive (*Elaeagnus umbellata*), a shrub originally introduced into the United States from Asia in 1830 *(1),* grows to heights of 3 to 5 meters and produces red berries (4 millimeters in diameter) in 3 to 5 years *(3).* The seed of autumn olive has been characterized as having a hard seed coat and an embryo dormancy that can be overcome by cold stratification at 1 to 10 °C for 10 to 90 days *(6).*

The berries stay on the shrub until late winter, when they are consumed by a variety of wildlife species because other foods are scarce *(2, 4).* This shrub is planted extensively on surface mines, wildlife management areas, and disturbed lands in the eastern United States to provide food and cover for wildlife. Autumn olive is particularly useful in reclamation of both abandoned and active coal surface mines because of its adaptability to the wide range of pH conditions found in these sites *(3)*. For example, during spring 1985, reclamation specialists with the Tennessee Valley Authority planted over 122,000 autumn olive shrubs on abandoned coal mine sites in North Carolina, Alabama, and Tennessee *(5).*

Because of the demand for these shrubs, many State and private nurseries are growing autumn olive seedlings. However, little is known about the conditions for optimum germination of these seeds. This information is needed for cost-efficient production of autumn olive seedlings in nurseries. Consequently, this study was designed to determine optimum germination temperatures and cold stratification requirements of autumn olive.

Methods

On 30 November 1979, berries were collected in large plastic storage bags from 25 autumn olive shrubs located on the Ollis Creek Surface Mine, Campbell County, TN. The samples were combined in the laboratory, and the fruit pulp was separated from the hard, inner seed in a Waring Blendor filled with approximately 150 milliliters of water. To avoid damage to the seed coats, the blender was turned on for only short periods of time (about 5 seconds). The resultant mixture was screened through a wiremesh sieve to separate the seeds from the pulp. Seed were then air-dried at room temperature.

The seed were divided into equal lots and placed into naked cold stratification for 8, 12, 16, and 20 weeks at 5 °C. After removal from cold stratification, 600 seeds were randomly selected from each treatment, separated into lots of 50 seeds, and placed in petri dishes lined with moistened filter paper. Filter paper was replaced as necessary to prevent mold growth. Six replications of 50 seeds from each cold stratification treatment and from a nonstratified control seed lot were placed in three germination chambers set at night/day temperatures of 5/15 °C, 10/20 °C, and 20/30 °C. All replications were left in the chambers for 10 weeks and checked three times weekly for germination. At each inspection, germinated seeds (radicle 1 millimeter) were counted and removed from the dishes.

Results and Discussion

After removal from cold stratification, only seed subjected to the 20-week stratification treatment showed signs of mold development. judging by the high germination percentage, mold was not an inhibitory factor at this length of stratification, except possibly at the 20/30 °C night/day germination temperatures. Because there were no significant differences in percentage germination between replications within stratification treatments (Chi-square test), these data were pooled during analysis.

In general, longer lengths of cold stratification resulted in faster germination of a higher percentage of seeds (fig. 1). For example, after 1 week at 10/20 °C night/day germination temperatures, seeds cold stratified at 8, 12, 16, and 20 weeks germinated at 13, 40, 80, and 88 percentages, respectively. Seed germination at all three night/day temperatures for the nonstratified control seeds was significantly lower ($P < 0.05$) with the highest percent germination (51 percent) being achieved at 10/20 °C night/day temperatures.

At 5/15 °C night/day temperatures, the percentage germination after 8 weeks of cold stratification (75 percent) was significantly lower ($P < 0.05$) than at longer stratification periods

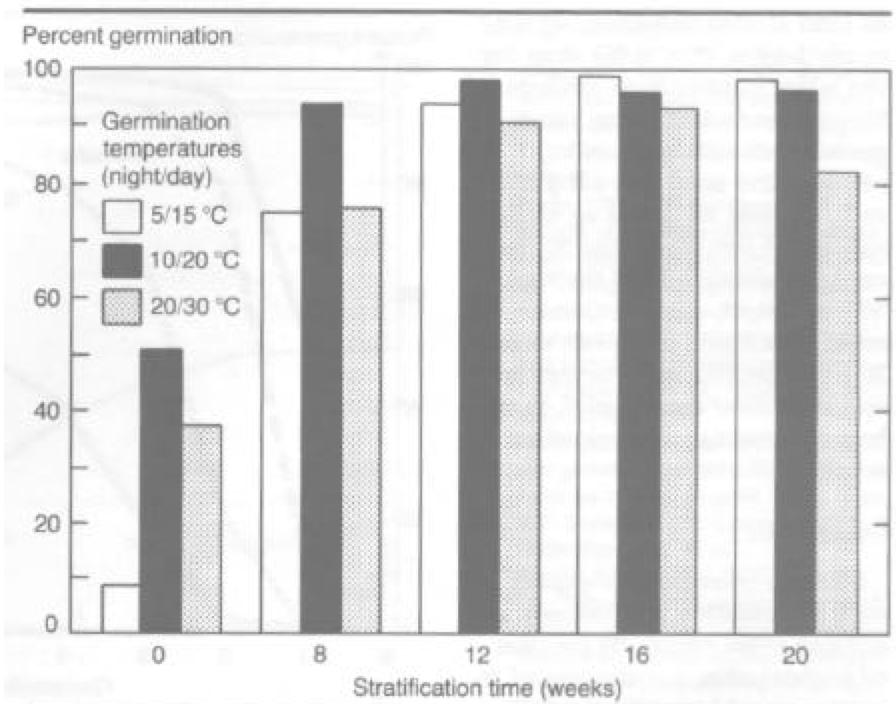


Figure 1—*Percentage germination of autumn olive* (Elaeagnus umbellata) *seed treated with varying lengths of cold stratification and germinated at different night/day temperatures.*

(fig. 2). Seeds cold-stratified at 12 and 16 weeks achieved a total germination percentage of 90 percent or greater after 3 and 8 weeks in the germination chambers, respectively. However, after 20 weeks of cold stratification, 96 percent of the seeds germinated within 2 weeks at the 5/15 °C night/day temperatures.

At 10/20 °C night/day temperatures, there was no significant difference in percent germination ($P < 0.05$) between seed lots subjected to different lengths of cold stratification. However, it took 4 and 2 weeks for seeds at 8 and 12 weeks of cold stratification to exceed 90 percent germination, respectively. By contrast, the seeds stratified for 16 and 20 weeks achieved 95 percent germination within 2 weeks.

At 20/30 °C night/day germination temperatures, percent germination of seeds after 16 weeks

Results and Discussion

of cold stratification was significantly higher ($P<0.05$) than for the other stratification periods. Ninety percent of these seeds germinated within 2 weeks, whereas the seed lots subjected to 8, 12, and 20 weeks of stratification did not reach the 90 percent germination level during the 10-week study period. Some mold developed on seeds in the 20-week stratification treatment and may have contributed to the lower percentage germination results.

Conclusions

Nursery growers can expect high germination percentages of autumn olive seeds (90 percent or higher) after a minimum of 16 weeks of cold stratification. Our data suggest that the optimum night/day germination temperature for cold stratified autumn olive seed in 10/20 °C. At this temperature, high percentages of seeds stratified for 16 or more weeks will germinate within 2 weeks after placement into germination chambers. Because of possible contamination from cold harmful molds, periods of cold stratification longer than 16 weeks are not recommended unless the seeds are treated with mold preventive chemicals before they are placed in the germination chambers.

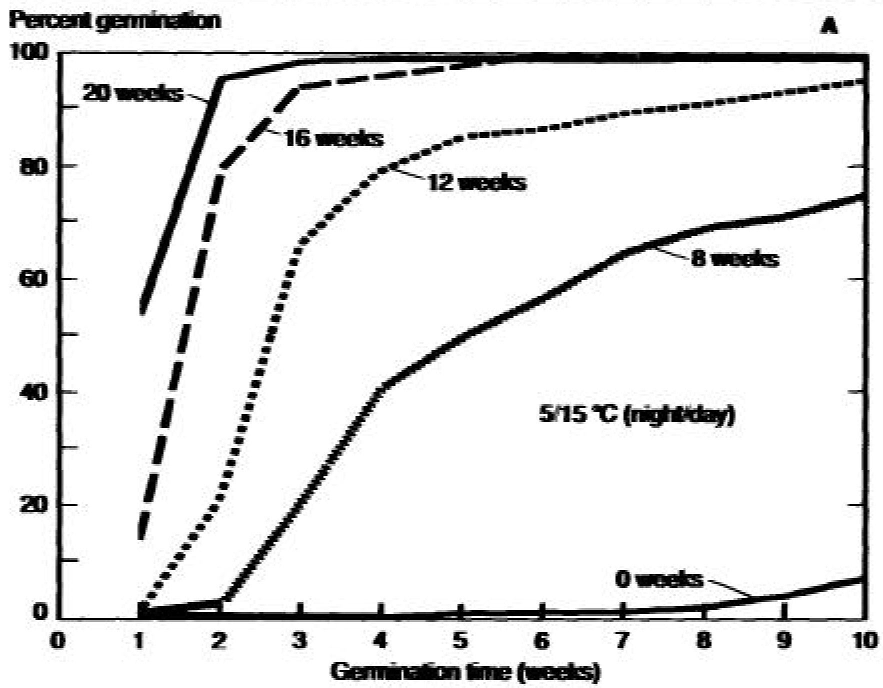
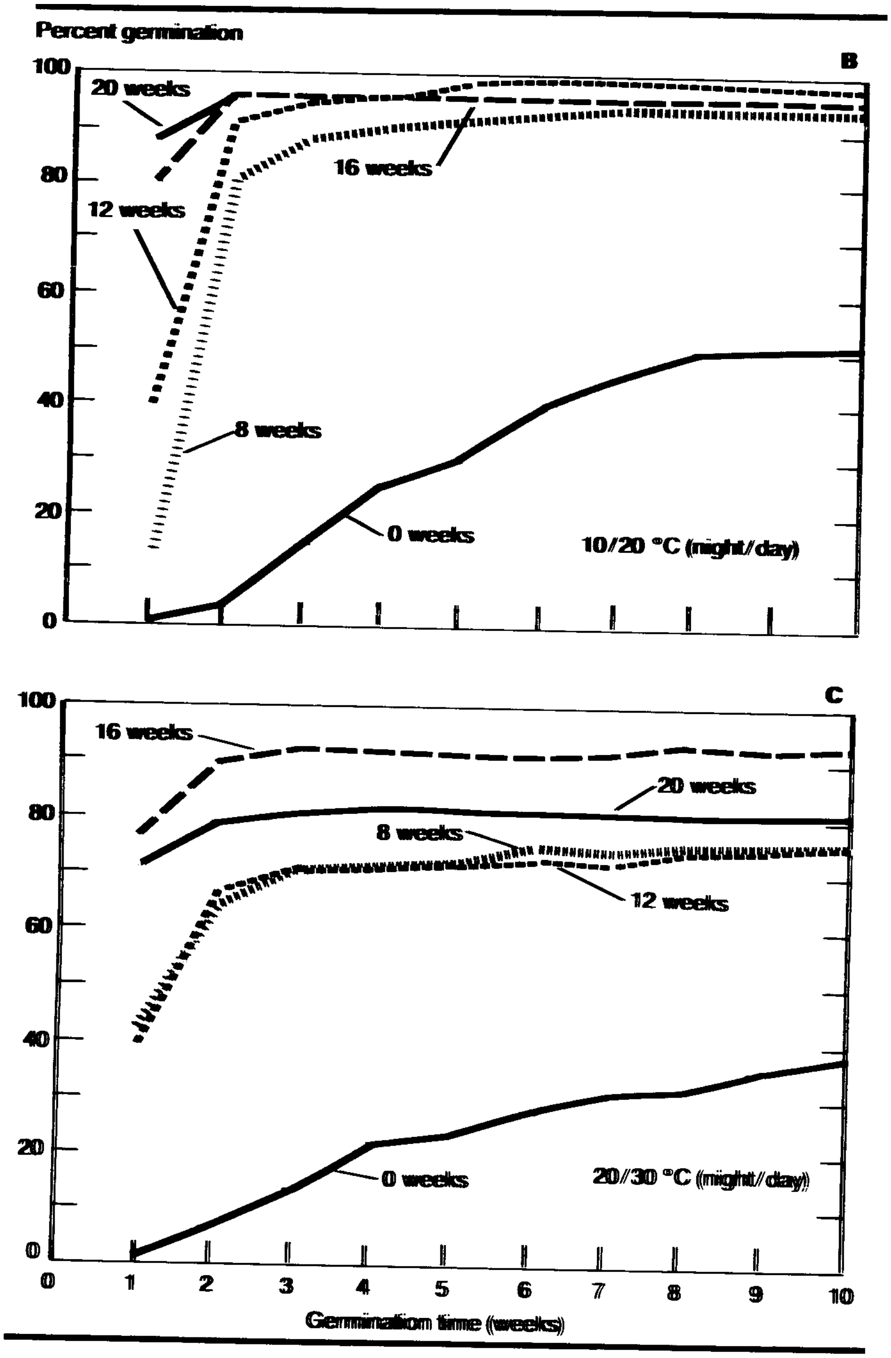


Figure 2—Germination time and percentages for autumn olive (Elaeagnus umbellata) seed treated with 8 to 20 weeks of cold stratification and germinated at 5/15 °C (A), 10/20 °C (B), and 20/30 °C (C) night/day temperatures.



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Growth Response of Five Rocky Mountain Conifers to Different Ectomycorrhizal Inocula

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Artificial inoculation with the mycorrhizal fungus Pisolithus tinctorius *(Pers.) Coker & Couch significantly increased the growth of Engelmann spruce (*Picea engelmannii *Parry ex. Engelm.) and Douglas-fir (*Pseudotsuga menziesii *(Mirb.) Franco) containerized seedling stock. No significant differences in height, diameter, and weight of limber pine (*Pinus flexilis *James), lodgepole pine (*Pinus contorta *var*. latifolia *Engelm.), and ponderosa pine* (Pinus ponderosa *Dougl. ex Laws.) were noted when artificial and natural inoculation were compared. Root/ shoot ratios were greater with artificial inoculation for lodgepole and ponderosa pines. Pine species readily form* P. tinctorius *mycorrhizae; Englemann spruce and Douglas-fir do not.* Tree Planters' Notes 38(1):18-21; 1987

Successful reforestation of land requires proper site preparation, a quality planting job, proper seedling handling, and high-quality planting stock. Good quality seedlings must be physiologically and morphologically able to withstand transplant shock and the rigors of the planting site environment. Seedling quality is especially important in the reforestation of the central Rocky Mountains, where seedling size, planting time constraints, and environmental and climatic extremes are critical elements to success.

Mycorrhizae have been shown to play a significant role in successful reforestation with a variety of conifers in many parts of North America. A sufficient amount of the proper mycorrhizal symbiont on seedling root system aids in seedling survival and early tree growth. Mycorrhizae provide the seedling with more root surface to absorb soil nutrients and water, better physiological balance, and therefore, a better chance of seedling establishment. Thus, mycorrhizae are a significant component of the quality seedling.

Over the last few years, emphasis has been placed on the commercial development of vegetative mycelial inoculum of *Pisolithus tinctorius* (Pers.) Coker & Couch, a mycorrhizal symbiont. *P. tinctorius* has been reported to form mycorrhizae with many coniferous and hardwood tree species throughout the world *(4)*. Marx and others *(1, 5)* have shown *P. tinctorius* to improve the survival and growth of many southern pine species on a diverse range of reforestation sites.

The purpose of this study was to compare the growth response and mycorrhiza-forming ability of five Rocky Mountain conifers that were inoculated "artificially" with *P. tinctorius* or "naturally" with screened duff.

Methods and Materials

Artificial inoculation. Mycelial cultures of *P. tinctorius* (isolate 166, D.H. Marx) were grown on modified Melin-Norkrans liquid nutrient medium for 30 days. For inoculation, mycelial mats were leached of excess nutrients with distilled water and macerated in distilled water in a Waring Blendor. A 30-milliliter suspension of mycelium was injected into a growth medium of vermiculite and peat moss (1 :1 mixture) in 1-quart paperboard containers.

Natural inoculation. Indigenous mycorrhizal fungi were obtained from localized forest duff samples collected underneath pure stands of the conifer species tested. The duff was screened to remove cone fragments and undecayed pine needles, then mixed with vermiculite (1:1) and placed in the paperboard containers. Growth medium for both inoculation treatments was rinsed with water several times before seed planting.

Seedling management. Seeds of Englemann spruce (*Picea engelmannii* Parry), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), limber pine (P. flexilis James), ponderosa pine (P. ponderosa Dougl. ex Laws.), and Douglas-fir (*Pseudotsuga* *menziesii* (Mirb.) Franco) were germinated in containers of one of the two inoculation treatments. Sixty seedlings per inoculation treatment per tree species were grown in a greenhouse for 6 months. Seedlings were fertilized with full-strength Hoagland's nutrient solution every 30 days; they were watered every 2 days to minimize differential water availability because of drying.

Data collection and statistical analysis. After 6 months, 30 seedlings for each inoculation treatment for each tree species were randomly selected for destructive sampling. Seedlings were removed from the containers and cleaned in tap water. Shoot height, root collar diameter, and shoot and root dry weights were measured for each seedling. Mycorrhizal infection was determined by the counting procedure on fresh root systems *(2).*

Statistical comparisons (one-way analysis of variance) were made between inoculation treatments for each seedling parameter. All testing was performed at P = 0.05.

Table 1—*Seedling growth of five Rocky Mountain conifers in response to natural (duff) and artificial* (Pisolithus tinctorius) *inoculation*[1]

Inoculation treatment	Shoot height (cm)	Root collar diameter (mm)	Total dry weight (g)	Root/ shoot (g/g)	Ectomycorrhizal infection (%)
Picea engelmannii (Engelmann spruce)					
Artificial	10.9 a	2.2 a	0.68 a	0.51 a	1 a
Natural	7.2 b	1.4 b	0.20 b	0.47 a	0 b
Pinus contorta (lodgepole pine)					
Artificial	11.0 a	2.5 a	1.20 a	0.73 a	59 a
Natural	11.0 a	2.4 a	1.07 a	0.47 b	11 b
Pinus flexilis (limber pine)					
Artificial	5.6 a	1.9 a	0.58 a	0.51 a	31 a
Natural	5.8 a	1.9 a	0.58 a	0.50 a	18 b
Pinus ponderosa (ponderosa pine)					
Artificial	10.0 a	2.9 a	1.99 a	0.72 a	35 a
Natural	9.3 a	2.6 a	1.78 a	0.55 b	17 b
Pseudotsuga menziesii (Douglas-fir)					
Artificial	15.8 a	1.7 a	0.63 a	0.56 a	<1 a
Natural	12.4 b	1.4 b	0.38 b	0.52 a	<1 a

[1]Mean values within a species and between inoculation treatments, followed by the same letter are not significantly different at $P \geq 0.05$.

Results and Discussion

Engelmann Spruce. Shoot height, root collar diameter, and seedling dry weight of Englemann spruce seedlings were significantly greater with artificial inoculation with *P. tinctorius* (table 1). Seedling dry weight was more than three times greater in the *P. tinctorius* inoculation treatment, even though mycorrhizal infection was low (1 percent). No mycorrhizae formed with natural inoculum sources. Root/shoot ratio was not significantly different between treatments.

Lodgepole pine. No significant differences occurred between inoculation treatments for shoot height, root collar diameter, or dry weight for lodgepole pine (table 1). However, dry weight was 12 percent greater with artificial inoculation. This differential was further expressed in a significant treatment difference in the root/shoot ratio. The greater ratio with artificial inoculation is partly attributable to the high degree of *P. tinctorius* mycorrhizae formation. Over five times more mycorrhizae formed with artificial inoculation. Lodgepole pine formed the greatest amount of *P. tinctorius* mycorrhizae of all species. Natural mycorrhizae were of two types; one with white hyphae, the other with brown. The brown hyphae are distinctive from the golden brown *P. tinctorius* mycorrhizae.

Limber Pine. Limber pine seedlings were almost identical in all seedling characteristics except mycorrhizal infection between inoculation treatments (table 1). Mycorrhizal infection was significantly greater with artificial inoculation. Natural fungi were white.

Ponderosa pine. As with lodgepole pine, inoculation of ponderosa pine did not result in significant differences in shoot height, root collar diameter, or seedling dry weights (table 1). However, the root/shoot ratio was significantly greater with artificial inoculation. *P. tinctorius* mycorrhizal infection was twice as great as formation with natural white symbionts.

Douglas-fir. Shoot height, root collar diameter, and seedling dry weight were significantly greater for Douglas-fir with artificial inoculation, even though no *P. tinctorius* mycorrhizae were formed (table 1). Root/shoot ratios were not significantly different. Only 7 percent of the seedlings inoculated with forest duff formed mycorrhizae, but the mean value showed less than 1 percent infection. These white mycorrhizae were monopodial, which was unique to Douglas-fir among the five conifer species tested.

Growth response and mycorrhizal infection charateristics of these conifer species can be used to separate species into two groups. Englemann spruce and Douglas-fir showed significant treatment differences in morphological characteristics and little or no mycorrhizal infection. The three pine species showed no significant treatment differences in growth; there were high levels of mycorrhizal infection, with artificial inoculation producing significantly higher levels of infection than did natural inoculation.

Lodgepole pine (7,9), ponderosa pine (6,9), and Douglas-fir (6,9) have previously been shown to form mycorrhizae with *P. tinctorius* in containerized systems. Engelmann spruce and limber pine have not been previously reported to form *P. tinctorius* mycorrhizae.

Improvements in seedling growth due to *P. tinctorius* inoculation have been shown by Marx and others (6). In their 1977 tests, ponderosa pine shoot height was not significantly great in *P. tinctorius* seedlings (3-, 6-, and 12- percent inoculation rates) compared to control seedlings. Higher inoculation rates (6 and 12 percent) resulted in greater shoot height and weight of ponderosa pine seedlings and in greater weight of Douglas-fir seedlings compared to inoculated seedlings.

The results of this study suggest that seedling growth and development are influenced by factors other than inoculation treatment. These factors include differential water-holding capacity of the two growth media, a greater micro-flora population available for competition for nutrient and water absorption, and different nutrient adsorption properties of the growth media. These factors and their interactions may have contributed to treatment differences.

Summary

Artificial inoculation with *P. tinctorius* significantly increase shoot height, root collar diameter, and dry weight of Engelmann spruce and Douglas-fir seedlings. However, little or no mycorrhizae formed in either treatment.

No significant differences occurred in height, diameter, and seedling weight due to inoculation treatment for limber, lodgepole, and ponderosa pines. The root to shoot ratio of lodgepole and ponderosa pines was significantly greater when seedlings were inoculated with *P. tinctorius* than with duff. The three pine species readily form *P. tinctorius* mycorrhizae, and at levels two to five times greater than natural inoculum sources, depending on the pine species.

Care should be taken in the selection of sources of natural mycorrhizal inoculum. Seedling growth and quality returns as a result of application of natural inoculum sources may not be worth the investment.

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Stunting of White Spruce (Picea glauca (Moench) Voss) Associated With Ectomycorrhizal Deficiency

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*Stunting of 1-0 white spruce (*Picea glauca *(Moench) Voss) was associated with poor mycorrhizal development.* Tree Planters' Notes 38(1):22-23;1987

Stunting of 1-0 white spruce (*Picea glauca* (Moench) Voss) in Lake States nurseries has been considered a serious problem for the last decade *(1,2,4).* Although this condition has little effect on growth and survival when third-year stock is outplanted, the cull at nurseries due to small seedlings results in substantial dollar losses *(2).* The early cessation of growth in the first growing season, purple discoloration of foliage, low foliage phosphorus (P) concentration without a soil P deficiency *(3,4),* and scatter pattern of stunting within the nursery beds strongly suggest that stunting of white spruce in Lake States nurseries results from a mycorrhizal deficiency.

Mycorrhizal deficiency on hardwood and conifer seedlings in forest tree nurseries is common in nurseries on prairie soils or after soil fumigation *(7,8,12).* In addition to killing harmful pests, fumigants kill beneficial organisms such as mycorrhizae. To verify our theory, we designed a study to find out if stunted white spruce seedlings did indeed have fewer ectomycorrhizae than nonstunted seedlings from fumigated nursery soils.

Samples of fall-sown first-year seedlings were taken on August 12, 1984, at the Hayward State Nursery, Hayward, WI, and the J.W. Tourney Nursery, Watersmeet, MI, from beds that were fumigated the previous year with dazomet (Mylone 50D, 400 pounds per acre) and methyl bromide + chloropicrin (Dowfume MC-33, 350 pounds per acre) respectively. Five stunted and 5 nonstunted white spruce seedlings were collected at 10 randomly selected positions in affected seedling beds. Seedlings that demonstrated the extremes of stunted and nonstunted conditions were selected-that is, seedlings with purple foliage, small shoots, and bud set and seedlings with deep green foliage, long shoots, and active shoot elongation. Samples were frozen for later evaluation.

The percent ectomycorrihizal infection was calculated for each seedling. The entire root system was cleared and stained for Hartig net demonstration according to methods reported by Nylund and others *(9).* Each growing point on an individual squash-mounted root system was examined with 200 x conventional light microscopy. The root tip was considered ectomycorrhizal if a Hartig net was present. A nonpooled Student's *t*-test was used to compare percent root tip infection of the stunted and nonstunted seedlings.

Results

The percent mycorrhizal root tips of stunted seedlings was significantly less than that found on nonstunted seedlings at both nurseries (table 1). Many stunted seedlings were nonmycorrhizal.

Discussion

Stunting of 1-0 white spruce seedlings at both nurseries was associated with low ectomycorrhizal colonization of growing tips. This poor development of mycorrhizae explains the foliage P deficiency that occurs in the absence of soil P deficiency previously observed in stunted white spruce seedlings *(3-5),* because mycorrhizae aid in the uptake of P *(6).*

We thank John Borkenhagen, manager of the Hayward state Nursery, and Thomas Emerson, assistant nursery manager of the J.W. Tourney Nursery, for their assistance and cooperation.

Table 1—*Percent ectomycorrhizal root tips on 25 stunted and 25 nonstunted 1–0 white spruce seedlings at the Hayward State Nursery, Hayward, WI, and the J.W. Toumey Nursery, Watersmeet, MI*

	Percent ectomycorrhizal root tips	
	Stunted	Nonstunted
Hayward Nursery	7	44*
Toumey Nursery	2	79**

*Significantly different at $P = 0.05$ (Student's *t*-test).
**Significantly different at $P = 0.01$ (Student's *t*-test).

Soil fumigation reduces or eliminates mycorrhizal fungi *(11).* The scattered pattern of stunting within nursery beds reflects the pattern of reinoculation of mycorrhizal fungi following fall fumigation *(8).* Ectomycorrhizal fungi produce mushrooms in the areas surrounding the fumigated beds. The spores from these mushrooms are airborne and reinoculate the beds in a random pattern. Mycorrhizae form only on seedlings in inoculated areas of the bed. The volume of spores available for reinoculation of beds is reduced if there are extremely dry or wet periods in late summer and fall, when mushrooms are produced. The dry periods reduce the overall numbers of mushrooms produced, while excessive rains wash the spores from the air and prevent transport to the nursery beds *(10).*

In the Lake States we see stunting primarily in the northern nurseries. This is probably due to the rather short period between late summer fumigation and the first snows. Consequently, there is less time for mycorrhizal fungi to reinoculate fumigated areas.

Stunting occurs in both conifer and hardwood beds in many Lake State nurseries. Further work is underway to determine if mycorrhizal deficiencies exist on species other than white spruce and to study the effects of various cultural practices on mycorrhizal development.

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Commercial Produced Superabsorbent Material Increases Water-Holding Capacity of Soil Medium

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Four levels of a commercially available superabsorbent material (Terr-sorb, a starch-based polymer) were applied to a soil medium used in container seedling production. The superabsorbent treatments were very effective in increasing the water-holding capacity, which was directly related to the rate of application of the superabsorbent material. After watering was stopped, tomato (Lycopersicon esculentum var. pelican) seedlings in control medium (no superabsorbent) died rapidly, but seedlings planted in media with the superabsorbent remained viable for a longer period of time, which varied with the concentration of superabsorbent in the medium. Tree Planters' Notes 38(1):24-25; 1987.

The use of containers for growing plants has become commonplace in forest and horticultural industries. All types of plants, from trees to squash, are grown for the commercial market in container of various sizes, shapes, and materials *(2).* Plants are grown in media ranging from pine bark to commercially available materials. Regardless of the container and the medium used, the basic requirement for successful production of plants in container is water. Design of containers has helped reduce the problem of too much water of waterlogging, a common problem with some of the earlier container designs. *(1)*

However, the problem of maintaining adequate moisture in containers has been solved primarily by overwatering and allowing excess water to drain through the soil medium . This procedure is inefficient and leads to a greater likelihood of nutrients leaching out of the growth medium if liquid fertilizer is used.

In the past few years, a group of commercial products, known as "superabsorbents," have been advertised as having large water-holding capacities. These products are claimed to greatly increase water retention in an available from for plants without causing the problems associated with excess water. These claims by the producers of the materials are impressive, but little information that validates the perfomance of the materials has been published. We conducted the following experiment to determine if the use of a superabsorbent material (a starch-based polymer) can increase the water-holding capacity of a growth medium and increase the availability of the water to plants growing in the medium.

Materials and Methods

A growth medium consisting of peat moss, vermiculite, and perlite (1:1:1) was mixed thoroughly and divided into four portions. Superabsorbent (Terr-sorb, a starch-base polmer) was added to the portion sat the following rates: control, 0; low level, 1 pound per cubic yard; high level (recommended by the manufacturer), 2 pounds per cubic yard; double-high level, 4 pounds per cubic yard. The media were then each thoroughly mixed and put into planting containers that measures 3¼ by 3¼ by 3 inches and were lined with polyethylene. A total of 70 containers were filled for each medium.

Field capacity was determined for each growth medium, and the appropriate amount of water to bring the medium to field capacity was calculated. Seedlings of tomato (*Lycopersicon esculentum* var. *pelican*) were chosen to test the effectiveness of the media because of their rapid development and sensitivity to changes in moisture.

Plants were germinated in early May 1982 and allowed to grow 1 week to two-leaf stage in seed flats containing the same medium as the control. The water level in containers was brought to field capacity and one tomato seedling was planted in each. The containers were then placed on a greenhouse bench. The seedlings were watered three times after transplanting, bringing the soil to field capacity each time.

On May 24, 1982, the plants were watered for the last time. The seedlings were checked every day until wilting was observed. Thereafter, wilted seedlings were counted at 2-day intervals until the end of the study.

Results and Discussion

The superabsorbent added to the growth media improved the available water-holding capacities. After watering was stopped, seedlings wilted after 12 days in the control medium, after 16 days in the low and high treatments, and after 22 days in the double-high treatment. Sixteen days after watering was stopped, 46 percent of the controls, 13 percent of the low, and 1 percent of the high treatment seedlings were wilted. Eighteen days after watering was stopped, 100 percent of the controls, 30 percent of the low, and 13 percent of the high treatment seedlings were wilted. No double-high seedlings were wilted. Twenty days after watering was stopped, 77 percent of the high and 1 percent of the double-high treatment seedlings were wilted.

Table 1—*Number of wilted tomato seedlings grown in media with four levels of superabsorbent after watering ceased on 5/24/82*

Date	Control	Low level	High level	Double-high level
5/24/82	0	0	0	0
6/5/82	3	0	0	0
6/7/82	16	0	0	0
6/9/82	32	9	1	0
6/11/82	70	21	9	0
6/14/82	70	59	54	1
6/16/82	70	66	66	16
6/18/82	70	68	66	30

Low level = 1 lb/yd^3; high level = 2 lb/yd^3; double-high level = 4 lb/yd^3 of superabsorbent in peat moss/vermiculite/perlite (1:1:1).

The mortality patterns of the plants grown in the different levels of the superabsorbent were similar. After the first plants wilted, the majority of the plants would wilt within 6 days (table 1). The seedlings growing in the media with the superabsorbent lasted 4, 6, and 10 days longer than controls before wilting started. This indicated that the superabsorbent material, a starch-based polymer, was effective in retaining water, and that this water was available for the plants.

Superabsorbent materials added to growth media should alter timing and reduce the amount of water used, as well as reduce labor and the amount of fertilizer lost through leaching.

The superabsorbent materials are relatively inexpensive, but only if water consumption is reduced. If superabsorbent materials are used and the schedules for water applications are not adjusted, little will be gained by the use of such materials and the cost will be higher.

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Chemical Treatments Increase First-Year Height Growth and Reduce Dieback in Cold-Stored Sycamore (Platanus occidentalis L.) Seedlings

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*Chemical treatment of sycamore (*Platanus occidentalis *L.) seedlings before storage in refrigerated coolers produced significantly healthier seedlings. Seedlings were treated by dipping into Liqua Gel (a starch acrylate polymer that aids in moisture retention), Vapor Gard (an antitranspirant), and benomyl and propiconazol (systemic fungicides). Sixty-seven to eighty-five percent of seedlings treated chemically before cold storage showed no dieback 20 days after planting. Fifty-nine percent of untreated seedlings had dieback. Seedling height was significantly affected by chemical treatment.* Tree Planters' Notes 38(1):26-30; 1986.

One-year-old sycamore (*Platanus occidentalis* L.) seedlings used in forest regeneration in the South are grown in state forestry commission and private nurseries. The seedlings are lifted from nursery beds and packed barerooted in polyethylene-lined kraft bags. To prevent root drying, materials such as clay, peat moss, or absorbent paper are placed in the bags. For best root growth, hardwood seedlings should be stored at 0.5 to 5 °C and with a relative humidity of 70 to 85 percent *(1, 2).* There is some concern that first-year seedling survival is related to damage by microorganisms after the seedlings are lifted from nursery beds.

Our preliminary observations of the roots and tops of sycamore seedlings before cold storage showed an absence of disease symptoms. Sycamore seedlings were sampled for pathogenic fungi, but no root pathogens (such as *Fusarium* spp., *Pythium* spp., *Cylindrocladium* spp., or *Rhizoctonia*) were isolated. Also, gray mold (*Botrytis* sp.) was not isolated from samples made 24 to 48 hours after seedlings were removed from the nursery beds. In previous years, gray mold was observed on seedlings stored for 4 to 8 weeks in cold storage and thus was suspected as being the primary cause of seedling deterioration in cold storage.

A study was established in 1983 to test systemic fungicides, an antitranspirant, and a moisture retention chemical to determine whether survival and first-year height growth can be increased by various treatments and also to determine which organisms are associated with the roots and stems of sycamore.

Materials and Methods

Sycamore (*Platanus occidentalis* L.) seedlings were lifted, top-pruned, and treated chemically at the).P. Rhody Kentucky State Forest at Kentucky Dam. The seedlings were treated with various combinations (table 1) of a) Liqua Gel, a starch acrylate polymer, that when mixed with water forms a gel (3 pounds per 100 gallons of water); b) Vapor Gard (di-1-p-menthene), an antitranspirant concentrate (1 gallon per 125 gallons of water); c) the fungicide benomyl (Benlate; 2.0 pounds of active ingredient per 100 gallons of water); and d) the fungicide propiconazol (Tilt; 1.0 pound active ingredient per 100 gallons of water).

For application of Liqua Gel, only the roots of seedlings were dipped in the gel. For the other chemicals, roots and/or stems were dipped in solutions of the

Table 1—*Summary of treatments*

Treatment	Liqua Gel	Vapor Gard	Benomyl	Propiconazol
1	R	—	—	—
2	—	S	—	—
3	—	—	R/S	—
4	—	—	—	R/S
5	R	—	R/S	—
6	R	—	—	R/S
7	—	R/S	R/S	—
8	—	R/S	—	R/S
9	R	R/S	R/S	—
10	R	R/S	—	R/S
11	—	—	—	—

R = roots. S = stems.

chemicals (table 1). When several chemicals were applied, the seedlings were dipped in 1:1 solutions of the chemicals, except Liqua Gel, which was used last as a root dip.

The seedlings were then enclosed in polyethylene-lined kraft bags, with moist absorbent paper on the roots, and transported to the Westvaco facility at Wickliffe, KY, where they were kept in a refrigerated cooler at 34 to 36 °F. One hundred seedlings were taken randomly from each treatment group for weekly sampling of roots and stems for organisms growing during cold storage.

Ten root samples were combined and sterilized for 2 minutes with 50 percent laundry bleach (Clorox). Four root segments were randomly selected and placed on potato-dextrose agar plates. Ten plates with roots were prepared for each treatment and date. The same procedure was used for seedling stems. Plates were kept at 20 °C. Observations were made daily, and the microorganisms growing from the seedling parts were identified by light microscopy and tabulated.

Four bundles of 250 seedlings each, treated as described above (table 1), were refrigerated at 34 to 36 °F and relative humidity of 89 percent for 62 and 89 days. The seedlings were then outplanted at 11.5- by 11.5-foot spacing in 20-tree blocks, with 4 replications per treatment date. The percentage of healthy seedlings (those whose terminal buds produced leaves) and the seedling height were measured at 20 days after outplanting and at the end of the growing season. Analysis of variance was used together with Duncan's multiple range test to compare mean values.

Results

Microorganisms. Microorganisms isolated from roots and stems of sycamore seedlings kept in cold storage for 1 to 8 weeks showed that several genera were present (table 2). The chemical treatments appeared to reduce the number of isolates on the seedlings. The predominant fungus was *Rhizopus* sp. (tables 3 and 4), which could have caused deterioration of tissues. *Fusarium* spp. isolated from the seedlings also could have caused dieback. No lesions were evident on the roots and stems when the seedlings were placed in storage or after storage for 7 to 8 weeks.

Dead or missing seedlings. Chemical treatments did not significantly affect seedling survival. Over 98 percent of the seedlings stored for 62 days under proper conditions survived when planted in field plots. Survival decreased slightly when seedlings were stored for 89 days.

Healthy seedlings. There were significant differences in the percentage of healthy seedlings with no dieback as influenced by the chemical treatment (table 5). Benomyl, a systemic fungicide treatment, was significantly more effective than the check treatment (77 versus 41 percent) for seedlings stored 62 days (table 5). Liqua Gel applied to the roots before storage produced significantly more healthy seedlings as

Table 2—*Microorganisms isolated from sycamore roots and stems receiving no chemical treatment (controls) and stored in a refrigerated cooler for 1 to 8 weeks*[a]

Isolate	1 wk	2 wk	3 wk	4 wk	5 wk	6 wk	7 wk	8 wk
Alternaria sp.	S4	—	S3	S2	S4	S3/R1	S2/R2	S1/R1
Aspergillus sp.	—	S1	—	—	—	—	—	—
Bacterium sp.	—	S1	R1	—	—	—	—	—
Botrytis sp.	—	—	—	—	—	—	—	S1
Fusarium oxysporum	—	—	—	R1	—	—	—	—
F. roseum	S1/R1	—	—	—	R1	S1/R1	—	—
F. solani	R1	—	—	—	—	—	—	—
Mycelia sterilia	R1	—	R1	R2	R1	S2	R2	R1
Penicillum sp.	—	—	—	—	—	—	—	S1
Rhizopus sp.	R2	S4/R5	S5/R4	S5/R2	S2/R3	S3/R4	S5/R2	S3/R2
Tricoderma sp.	S1/R1	—	—	—	—	—	—	—

[a]S = number isolated from stem, R = number isolated from root.

Table 3—*Microorganisms isolated from sycamore roots and stems treated with benomyl and stored in a refrigerated cooler for 1 to 8 weeks*[a]

Isolate	1 wk	2 wk	3 wk	4 wk	5 wk	6 wk	7 wk	8 wk
Alternaria sp.	S1/R3	S4	S2	S2	S4	S3	S1	S4/R2
Aspergillus sp.	R1	—	—	—	—	R1	—	—
Bacterium sp.	—	S1/R4	—	—	R1	—	—	—
Botrytis sp.	S1	R1	—	—	S1/R2	S1	—	R1
Fusarium roseum	—	—	—	—	—	S1	—	S1
F. solani	—	—	—	R1	—	—	—	—
Mycelia sterilia	S1/R1	—	R4	S2/R2	R1	—	S2/R2	R2
Penicillum sp.	—	—	—	—	—	R1	—	—
Rhizopus sp.	S2/R2	S1/R1	S2/R1	S2/R3	—	S1/R4	S2/R3	S1/R1

[a]S = number isolated from stem, R = number isolated from root.

Table 4—*Microorganisms isolated from sycamore roots and stems treated with propiconazol and stored in a refrigerated cooler for 1 to 8 weeks*[a]

Isolate	1 wk	2 wk	3 wk	4 wk	5 wk	6 wk	7 wk	8 wk
Alternaria sp.	S2/R1	R3	S3	S4	S3	S2	S3	S1
Aspergillus sp.	—	—	S1	—	—	—	—	—
Bacterium sp.	—	R1	R1	—	—	—	R1	—
Botrytis sp.	—	—	S3	—	—	—	—	S2/R1
Fusarium roseum	S1	S1	—	—	R1	—	—	—
F. solani	S1	S1	—	—	—	—	—	—
Mycelia sterilia	—	—	R3	R3	R4	—	—	R1
Penicillum sp.	S1	—	—	—	—	S1	S1	S2
Pestalotia sp.	—	—	—	S1	—	S1	—	—
Rhizopus sp.	S1/R4	R2	S1	S1/R2	S1	S1/R2	S2/R3	S1/R2
Tricoderma sp.	—	—	S1	—	S1	S2	S1	R2
Tricothecium sp.	—	—	S3	S1	—	—	—	—

[a]S = number isolated from stem, R = number isolated from root.

compared to the check seedlings (83 versus 41 percent). Liqua Gel in combination with benomyl also produced significantly more healthy seedlings than the control treatment (81 versus 41 percent). Seedlings treated with Vapor Gard were significantly healthier than check seedlings (74 versus 41 percent).

Height of sycamores after first growing season. There was a significant difference in seedling height as influenced by chemical treatment (table 6). Seedlings treated with a combination of benomyl, Vapor Gard, and Liqua Gel before cold storage for 62 days and planted May 16, 1984, were significantly taller the first growing season than control seedlings.

The heights of seedlings stored in refrigerated coolers for 89 days and planted June 11, 1984, were significantly different due to treatments (table 6). Seedlings treated with benomyl + Liqua Gel were tallest, but their average height was not significantly different from that of seedlings treated with Vapor Gard + propiconazol. Seedlings treated with some chemical combinations were not significantly different from seedlings receiving no chemical treatment.

Table 5—*Percentage of healthy sycamore seedlings (terminal bud produced leaves), at 20 days after outplanting, that had been kept in cold storage for 62 or 89 days at 34 to 36 °F (N=80)*

Treatment	62 days of cold storage	89 days of cold storage
1. Liqua Gel	83.5 a	65.8 ab
2. Vapor Gard	74.4 ab	34.7 c
3. Benomyl	77.7 a	69.5 ab
4. Propiconazol	66.9 ab	58.3 b
5. Benomyl + Liqua Gel	80.8 a	66.5 ab
6. Propiconazol + Liqua Gel	79.7 a	58.3 b
7. Benomyl + Vapor Gard	44.3 c	20.9 d
8. Propiconazol + Vapor Gard	56.5 bc	69.5 ab
9. Benomyl + Vapor Gard + Liqua Gel	85.4 a	72.9 a
10. Propiconazol + Vapor Gard + Liqua Gel	71.8 ab	61.5 ab
11. None (controls)	41.3 c	33.4 c

Table 6—*Average height (feet) of first-year sycamore seedlings, stored at 34 to 36 °F for 62 or 89 days, at 20 days after outplanting (N = 80)*

Treatment	62 days cold storage[a]	89 days cold storage[b]
1. Liqua Gel	2.6 abc	3.2 cd
2. Vapor Gard	2.7 bc	2.6 abc
3. Benomyl	2.6 abc	3.1 bcd
4. Propiconazol	2.5 ab	2.8 abcd
5. Benomyl + Liqua Gel	2.4 ab	3.2 d
6. Propiconazol + Liqua Gel	2.5 ab	2.5 a
7. Benomyl + Vapor Gard	2.4 ab	2.5 a
8. Propiconazol + Vapor Gard	2.6 abc	3.2 d
9. Benomyl + Vapor Gard + Liqua Gel	2.9 c	3.1 bcd
10. Propiconazol + Vapor Gard + Liqua Gel	2.4 ab	2.5 a
11. None (controls)	2.3 a	2.6 ab

[a]planted May 16, 1984.
[b]planted June 11, 1984.

Discussion and Conclusions

Chemical treatment of sycamore seedlings before storage in a refrigerated cooler produced significantly healthier planting material in all but one treatment. Only 41 percent of the seedlings not chemically treated were considered healthy 20 days after planting (table 5); however, 44 to 85 percent of the seedlings treated chemically before cold storage were healthy.

Chemically treated sycamores that are not cultivated after establishment may have a higher survival rate than untreated seedlings. Seedlings that die back to the ground have greater competition from annual grasses and other weeds and are more subject to mechanical damage during cultivation.

On the average, seedlings planted in June were taller at the end of the growing season than the seedlings planted in May. This variation was probably due to site difference. The study results show that sycamore seedlings can be planted as late as June in western Kentucky and have good survival and good height growth.

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