# A Labor-Saving Container Handling System

**George E. Slagle and William L. Loucks**
*Forestry Seedling Technician and Extension Forester, State and Extension Forestry, Kansas State University, Manhattan*

*A tree seedling container handling system designed to handle the Tinus Rootrainer is described. The authors report a significant labor savings and the elimination of expensive and bulky trays to hold the Rootrainers.*

Large container tree seedling (CTS) nurseries must have container handling systems that will efficiently process large numbers of containers both to minimize production costs and to get an entire crop germinated over a relatively short period. Many CTS nurseries have developed sophisticated equipment to meet these requirements. Some nursery managers report filling and seeding as many as 500,000 cavities per day. However, small CTS nurseries, such as ours (Kansas State and Extension Forestry) with an annual production of 300,000 plants, have different requirements.

It is not as important for small nurseries to fill and seed 500,000 or even 100,000 cavities per day. But it is important to minimize the total labor used in producing and shipping a crop. With that in mind, we have designed and constructed a system which has greatly reduced our labor requirements.

Our system is designed around the Tinus Rootrainer (by Spencer-LeMaire, Ind., Edmonton, Alberta). This is because Dr. Richard W. Tinus, USDA Forest Service, found that large seedlings survive Great Plains climatic conditions better than small seedlings and large containers produce larger trees than small containers *(1)*. The 22-cubic-inch volume of the Tinus Rootrainer is a reasonable volume compromise between a container for the largest possible trees and the higher costs of handling large containers and trees. Another reason for using the Tinus Rootrainer is that the seedlings can easily be removed from the container. Since our average order is about 60 seedlings and the customer expects every seedling to be "plantable," we remove each seedling from the container, grade it, and place the select seedlings back in the container.

Since the Tinus Rootrainer is a "book" of four cavities, it is necessary to have a tray to support individual "books" in a larger unit. We experimented with several homemade trays. We tried constructing trays with wood, ¼-inch cold round iron rods, and concrete reinforced wire. All of them seemed to be too expensive, and required too much labor and too much storage space. Finally, we designed a system that allows us to move large units by forklift rather than smaller units by hand. The basic unit is a bunker made of 1¼-inch angle iron with outside dimensions of 44 by 120 inches (fig. 1). It holds four rows of books for a total of 1,120 cavities. From filling with medium to preparation for shipping, the containers are moved as a unit on the bunkers.

When outdoors, the bunkers are moved by a forklift. In the more constricted greenhouse, however, a special bunker carrier is used. Pictured in figure 2, the bunker carrier is constructed of 2-inch pipe with four swivel wheels and two shafts with ratchets and

Figure 1—*Tinus Rootrainer containers are supported on an angle-iron bunker.*

Figure 2—*A bunker carrier is used to move bunkers from the headhouse to the greenhouse.*

cable for lifting the bunker. The lifting hooks are welded to 2½-inch pipe, which slides over the 2-inch pipe legs. The bunker carrier can lift and move any bunker from a row without disturbing any others.

The growing medium mixer is a 1-cubic-yard Davis feed mixer powered by a 3-horsepower motor. Six cubic feet of Canadian sphagnum peat moss and an equal amount of perlite are placed in the mixer. After the lid is closed (we installed a safety switch so that the mixer cannot operate with the lid open), a timer is set to 2 minutes and the switch is turned on. The timer and a solenoid control the amount of water that is injected as the mixer operates. This arrangement produces a very uniform growing medium. It is thoroughly mixed and every batch has the same moisture content. The mixer unloads through a controlled gate into a vertical 12-foot bucket elevator. The elevator moves the medium with a ½-horsepower motor to an 8- by 4- by 8-foot medium hopper. In the bottom of the hopper is a chain and slat system, which draws the medium through a chute into the containers on the bunker (fig. 3).

**Figure 3**—*A chain and slat system draws the medium from a hopper into the containers.*

**Figure 4**—*A shaker table shakes the containers as they are being filled so that the medium is settled to a uniform density.*

Before being filled with medium, the bunker is set on a wheeled shaker table. As the shaker table (fig. 4) is pulled under the hopper chute, the cavities are filled with soil and the soil is settled to a uniform density. Like most of our equipment, the shaker table was constructed by the senior author. The support frame sits on four springs. The shaking action is provided by a ½-horsepower motor with the drive shaft offset ½ inch on an eccentric attached to the support frame. From the shaker table, the bunker is moved by hand to a cradle, which supports the bunker while the cavities are being seeded.

A self-propelled vacuum drum seeder (fig. 5) straddles the bunker as it moves the full length of the bunker in 2 ½ minutes. The seeder can operate in either direction. The vacuum drum and the wheels are powered by a ¼-horsepower motor and a system of drive chains. The vacuum is provided by a home shop vacuum cleaner. The drum is 48 inches long and has three rows of holes so that three seeds are dropped with each revolution of

**Figure 5**—*Seeding is done by a self-propelled vacuum drum seeder.*

the drum. The spacing of holes within each row is adjusted to match the cavities as they are arranged on the bunker. The holes were drilled with a no. 52 wire gauge bit.

Each hole in the drum might pick up from 1 to 6 seeds. To get an acceptable degree of accuracy, we directed a small column of air at each row of holes after they passed over the seed hopper. The air brush removes the extra seed. The gearing arrangement is designed so that each cavity receives three seeds.

Unlike some nurseries, we have found no benefit in covering the seed. A 10:00 a.m., 12:00 noon, and 3:00 p.m. light irrigation is adequate to keep the seed moist. We have not experienced any problem with root orientation on our four primary species: Austrian pine, Scotch pine, ponderosa pine, and eastern redcedar. After being seeded, the bunker is moved to the greenhouse by bunker carrier.

The seedlings are graded just before being shipped. The grading trailer (fig. 6) is a four-wheel flatbed trailer with a conveyor belt running lengthwise down the

**Figure 6**—*A trailer with a conveyor belt is used to grade the seedlings.*

center of the trailer. The grading trailer is located so that there are bunkers with ungraded seedlings on both sides. Three graders work on each side of the trailer. Each grader places an armful of Rootrainers on the flatbed and then opens each book and removes the culls and fills the blanks with good seedlings. The graded books, as well as the culls, are placed on the conveyor belt. At the discharge end of the conveyor belt, the culls are allowed to drop into a bin. The graded books are lifted off the conveyor belt and taped into a unit of eight books or 32 seedlings, which is our sales unit. The tape machine operator controls the movement of the conveyor belt.

Eight books of graded seedlings are placed on the taping machine (fig. 7). With a hand lever, the books are slightly compressed. Two rolls of reinforced filament tape, which are mounted on a frame, are pivoted around the unit of books so that two rows of tape secure the unit. A short reversal of the tape frame causes a cutting edge to swivel out and cut the two tapes. As shown in figure 8, the taped unit is secure and easily handled.

In conclusion, we have found that this container handling system has significantly reduced our labor requirements. An additional benefit is that we no longer need expensive and awkward trays to hold the Rootrainers.

Two future innovations are planned to increase the efficiency

**Figure 7**—*A taping machine secures the Tinus Rootrainers in units of 32 seedlings.*

**Figure 8**—*A taped unit of 32 seedlings is secure and easily handled.*

of the system. Currently, as the bunker is drawn under the hopper chute, a person using a floor broom levels the medium, ensuring that all cavities are filled. Final brushing leaves the cavity with a slight depression to receive the seeds. We plan to add a powered brush to do this task mechanically.

Secondly, we plan to place the hopper, brush, and seeder on line, and gear their operation so that we will have a continuous flow of bunkers entering the greenhouse.

## Literature Cited

1. Tinus, Richard W. Large Trees for the Rockies and Plains. In: North American Containerized Forest Tree Seedling Symposium. Great Plains Agricultural Council Publication No. 68: 112-118. 1974.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# Storage Technique Affects White Oak Acorn Viability

**George Rink and Robert D. Williams**
*Research Geneticist, USDA Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, Carbondale, Ill.; and Research Forester, USDA Forest Service, North Central Forest Experiment Station, Bedford, Ind.*

*Viability of acorns stored in 1.75-mil polyethylene and cloth bags did not change with increased storage time, while viability of acorns stored in 4-mil bags declined rapidly. If 4-mil polyethylene bags are to be used for moist white oak acorn storage, the bags should be kept open.*

The best way to maximize germination of white oak (*Quercus alba* L.) acorns is to sow them in the fall immediately after collection. Prompt sowing is not always possible, and often the acorns must be stored for short periods. For example, when acorns are collected for provenance tests, acorns from northern sources, which mature 30 to 60 days earlier than those from southern sources, must be stored until collection is complete. To facilitate such storage, we compared the suitability of three different containers for short-term fall storage of white oak acorns.

## Methods

Acorns from several trees in the vicinity of Carbondale, Ill., were collected in early October 1982. Within hours after collection, the acorns were in cold storage at 2 to 3° C in a walk-in cooler. On the following day, the acorns were bulked, floated to remove defective acorns, and equally divided among four each of 4-mil and 1.75-mil wall thickness, zip-lock polyethylene bags and four muslin cloth bags. These bags had a capacity of 1 quart (0.95 l), and each contained approximately 400 acorns. Each of the four bags of each type corresponded to a storage interval. The bags were sealed until the designated date. This was done to prevent opening and closing of bags, which would allow gas exchange and could negate the effect of bag type on acorn viability.

Thirteen days after collection and at three 2-week intervals thereafter, one bag of each type was taken out of storage and a sample of 100 acorns from each bag type (4 groups of 25 acorns each) was tested for viability in a germinator. Each group consisted of a tray with 25 acorns in moist vermiculite covered with a damp tissue and a sheet of plastic. Germination counts were made daily except for weekends for 30 days. Acorns were scored as germinated when shoots (epicotyls) emerged.

The experiment was considered as a randomized complete block design with a factorial arrangement of treatments (containers and storage intervals) in which all treatments were fixed while blocks were assumed to be random. Analyses were performed on actual germination counts and not percentages.

In a further attempt to explain the relation between storage time and viability, acorns from Minnesota, southern Illinois, and Mississippi were stored in 4-mil polyethylene bags and sown in the germinator on the same four dates as in the container portion of the study. (Acorns from Mississippi matured later and were subject to only three storage periods.) Analysis of variance of these data was by State in a simple two-way ANOVA with blocks and storage intervals considered as treatments.

## Results and Discussion

Results from analysis of variance showed the effects of bag type, time in storage, and their interaction to be statistically significant ($p > 0.001$) for both number of acorns with emerging roots and those with emerging shoots. There were no differences among blocks. Storage in cloth bags provided the same germination as storage in 1.75-mil polyethylene bags, while substantially lower viability was obtained from storage in 4-mil bags (table 1).

Time in storage affected acorn viability only in the 4-mil bags (table 1). In both the cloth and the 1.75-mil polyethylene bags, approximately the same number of radicles and shoots were present after 54 days as after 13 days of storage. By contrast, with one exception, the number of germinating acorns decreased rapidly with

**Table 1** —*Average number and percentage of acorns with emerging shoots and radicles after storage in three bag types for four intervals*[1]

| Bag type | Storage interval | Acorns with emerging radicles | | Acorns with emerging shoots | |
|---|---|---|---|---|---|
| | *Days* | | % | | % |
| Cloth | 13 | 25 | 98 | 19 | 75 |
| | 26 | 25 | 99 | 21 | 85 |
| | 41 | 23 | 93 | 21 | 84 |
| | 54 | 24 | 97 | 19 | 77 |
| Mean | | 24 | 96a | 20 | 80a |
| 1.75-mil polyethylene | 13 | 24 | 94 | 20 | 79 |
| | 26 | 23 | 93 | 20 | 80 |
| | 41 | 25 | 98 | 22 | 86 |
| | 54 | 25 | 99 | 19 | 77 |
| Mean | | 24 | 96a | 20 | 80a |
| 4-mil polyethylene | 13 | 22 | 89 | 20 | 78 |
| | 26 | 16 | 64 | 8 | 32 |
| | 41 | 24 | 97 | 20 | 78 |
| | 54 | 6 | 23 | 1 | 0 |
| Mean | | 17 | 68b | 12 | 47b |

[1]Means followed by the same letter are not significantly different from each other (0.05 probability level).

increased storage time in 4-mil bags (table 1). The 41-day storage treatment was the anomaly in this trend; we surmise that the 4-mil bag corresponding to the 41-day storage treatment had not been tightly sealed.

This trend of decreasing germination is also evident among acorns from the three other provenances, all of which were stored in 4-mil bags (table 2). In every case, the number of acorns with emerging shoots declined rapidly with increased storage time.

Another striking feature of the data in table 2 is the difference between the number of acorns with emerging roots and those with emerging shoots. We can only speculate about the cause for this difference. Generally, this difference was much less among acorns from cloth and 1.75-mil bags (table 1) than among acorns from 4-mil bags. It may be that there is a buildup of volatile toxic metabolic byproducts in the 4-mil bags caused by the greater wall thickness; 1.75-mil and cloth bags allow greater gas exchange and therefore less accumulation. The aroma of ethanol was common when 4mil bags were opened. Furthermore, a preliminary chromatography analysis of gas in bags containing white oak acorns showed extraordinarily high $CO_2$ concentrations. These gaseous metabolic byproducts may reduce the viability of shoot meristems.

**Table 2** —*Average number and percentage of acorns from three provenances with emerging shoots and radicles after different storage intervals*[1]

| Provenance | Storage interval | Acorns with emerging radicles | | Acorns with emerging shoots | |
|---|---|---|---|---|---|
| | *Days* | | % | | % |
| Minnesota | 13 | 21 | 82a | 15 | 59a |
| | 26 | 25 | 98a | 17 | 69a |
| | 41 | 23 | 90a | 5 | 19b |
| | 54 | 23 | 90a | 1 | 2b |
| Illinois | 13 | 18 | 72a | 12 | 48a |
| | 26 | 20 | 81a | 9 | 37ab |
| | 41 | 13 | 50ab | 3 | 12bc |
| | 54 | 5 | 20b | 0 | 0c |
| Mississippi | 13 | 24 | 97a | 22 | 89a |
| | 26 | 24 | 96a | 16 | 63b |
| | 41 | 19 | 76b | 10 | 39c |

[1]Means followed by the same letter are not significantly different from each other (0.05 probability level).

The use of 4-mil polyethylene zip-lock bags is commonly recommended for red oak acorn storage (2, 3). However, based on past experience and on these results, 4-mil bags should be used for white oak acorn storage even for short periods of time only if the bags are to be opened at least once a week to allow gas exchange and aeration. This stipulation was pointed out by Bonner (1) and cannot be stressed enough. According to our data, 1.75-mil polyethylene and cloth bags should allow enough gas exchange for short-term storage of moist acorns without opening and are preferable to 4-mil bags.

## Literature Cited


1. Bonner, F. T. Hardwood seed collection and handling. In: Silviculture and management of southern hardwoods. Louisiana State University Annual Forestry Symposium Pro(. 19:53-63: 1970.
2. Bonner, F. T. Storage of acorns ,and other large hardwood seeds-problems and possibilities. In: Proceedings of the southeastern nurserymen's conference. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry; 1971.
3. Bonner, F. T. Storing red oak acorns. Tree Planters' Notes 24(3):12-13;1973.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# Geese, Grass, and Trees

**Edward A. Hansen and Daniel A. Netzer**
*USDA Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, Rhinelander, Wis.*

*Hybrid Populus trees grew only half as tall when weeded by geese as did those in herbicide-treated plots. Although geese may be useful for controlling weeds in some hardwood plantations, soil type may limit their use in some situations. Geese did not eat the leaves of young hybrid Populus, but they did damage 6 percent of the small shoots by stepping on them.*

Hardwood plantations are often established on cleared forest land, marginal farmland, or pasture. The latter two usually have fair soil, but unfortunately, often have dense stands of grass. Despite numerous attempts to control grass competition by good site preparation, cultivation, and herbicides, the problem still remains.

For generations, geese have been used by farmers for various weeding chores. Presently they are used to control grass and many weeds in a large variety of crops such as cotton, flowers, strawberries, and mint and among many species of trees and shrubs grown in nurseries. *(1, 2, 3)*.

Six-week-old goslings are the best weeders. Grazing should be started as soon as weeds appear, and water should be placed at the far ends of the rows to encourage geese to work the entire field. A limited amount of growing pellets should be fed in the evening to supplement their diet. Fencing, such as 0.6-meter-high poultry netting, is sufficient to contain the geese.

Geese have several advantages for weed control: (1) They are selective feeders and eat only grasses and weeds; (2) They leave behind well-distributed, nutrient-enriched fertilizer; and (3) No pesticide use approval is required. Consequently, we tried geese for weed control in an intensively cultured hybrid *Populus* plantation is Wisconsin.

## Methods

A complete block design with four replications was used. Each replication contained two 6- by 30-meter plots, one fenced and weeded with geese, and the other with the herbicide linuron applied for weed control. The treatments were allocated systematically within each block so as to reduce the effects of the communal nature of the geese.

Site preparation consisted of spraying Roundup herbicide October 29 followed by plowing and disking. On May 21, the area was disked again and then harrowed. Linuron was applied at a rate of 1.6 kilograms active ingredients per hectare to four of the plots. The other four plots were fenced with 0.6-meter-high poultry fence.

The plots were planted on May 25 with 20-centimeter unrooted hardwood cuttings of clone NC-9922. The parentage of this clone is not known, but it appears morphologically identical to NC-5334 (NE-252) *Populus deltoides* var. *angulate P. trichocarpa.* The cuttings were planted at 1- by 1-meter spacing.

Day-old white ender goslings were purchased May 10 and raised on starter mash. On June 10, the geese were placed in the pens to graze. Initially, the geese were separated three to a pen and allowed to graze 3 days per week. Beginning in late July, all 12 geese were placed in each pen 1 day a week. Grazing was halted August 13.

On days the geese grazed in the pens, they were fed 1/8 kilogram of growing pellets per bird in the evening. On other days, they were allowed to forage elsewhere.

Tree height, survival, and damage from grazing were measured in October following the weeding test. All 30 trees in each of the interior four rows on each plot were measured.

## Results

Trees in the plots weeded with geese were significantly shorter, averaging less than half the height of the trees in the plots treated with linuron (table 1).

Survival was also less in the goose-weeded plots, averaging 63 percent versus 85 percent in

**Table 1**—*Height of trees in plots with weed control by geese or herbicide.*

| | Height of trees | |
|---|---|---|
| Replication | Geese plots | Linuron plots |
| | ---M--- | |
| 1 | 0.50 | 1.13 |
| 2 | .49 | 1.17 |
| 3 | .48 | 1.20 |
| 4 | .47 | 1.11 |
| Average | .48 | 1.15 |

the plots treated with linuron (table 2).

Observations showed that the geese did not eat *Populus* leaves except for occasional, probably inadvertent, pieces while feeding near trees. Less than 2 percent of the trees were chewed on. Six percent of the trees were damaged by geese stepping on them. But only shoots less than 30 centimeters tall were so damaged.

**Table 2**—*Survival of trees in plots with weed control by geese or herbicide*

| | Survival | |
|---|---|---|
| Replication | Geese plots | Linuron plots |
| | ---%--- | |
| 1 | 50 | 88 |
| 2 | 65 | 84 |
| 3 | 72 | 82 |
| 4 | 64 | 85 |
| Average | 63 | 85 |

The geese did a thorough job of controlling grasses and some broad-leaved weeds. However, other broad-leaved weeds (predominantly white cockle and lambsquarters) were not controlled and created a low, but rather dense, groundcover.

We are not certain why the plots with geese had much poorer tree growth and survival. Possibilities are that: (1) The reinvading broad-leaved weeds were worse competitors than the grasses, or (2) The goose traffic produced soil sealing on the silt-loam soils. We believe the latter to be more likely. Areas of high mortality observed in nearby plantations may have been caused by soil sealing inasmuch as they occurred in areas with the highest irrigation and nitrate fertilization rates. Therefore, root aeration and soil sealing may be problems in some instances on these silt-loam soils.

Others have found geese to be very effective as weeders. A study comparing geese with hoeing and an herbicide (dalapon) for controlling weeds in cotton showed that cotton yields were highest with geese and lowest with the herbicide (2). Net returns were 35 percent greater with the geese than with the other methods. Although this did not include the cost of management and care of the geese, it also did not include salable value of the geese at the end of the season.

Geese have also proven successful as weeders in a forest nursery.[1] However, our experience indicates that using geese may not always work, and we speculate that soil type may be a factor.

Use of geese for controlling weeds in hardwood plantations warrants more investigation. Geese may bean alternative weed control method to expensive mechanical cultivation or to the use of increasingly restricted herbicides on some sites.

[1] Dave Dutton, Wind River Nursery, Carson, Wash. Personal communication. 1981.

## Literature Cited


1. Geiger, Glenn; Biellier, Harold. Weeding with geese. Sci. and Tech. Guide 8922. Columbia, MO: University of Missouri; 1976. 2 p.
2. Goddard, R. J. Weeding cotton with geese on Ames plantation. Tennessee Farm and Home Science. Prog. Rep. 44. Knoxville, TN: University of Tennessee, Agricultural Experiment Station; 1962 October-December: 23-24.
3. Orr, H. L. Duck and goose raising. Pub. 532. Ottawa, ON: Canadian Ministry of Agriculture and Food; [no date]. 55 p.

# Mesurol 75% Seed Treater as a Bird Repellent Seedcoat Treatment

**Randy Fuller,[1] Tom Landis, John Cummings, and Joseph Guarino**
*Plant Pathologist and Westwide Nursery Specialist, USDA Forest Service. Region 2, Lakewood, Colo.; and Research Biologists, USDI Fish and Wildlife Service, Denver Wildlife Research Center, Lakewood, Colo.*

*Bird damage to planted ponderosa pine seeds was significantly reduced in alternate-treated versus control nursery plots with Mesurol 75% Seed Treater (1 percent methiocarb active ingredient). Coating with Mesurol at levels up to 4 percent active ingredient did not effect germination of ponderosa or lodgepole pine or Engelmann spruce seeds.*

Bird predation of newly planted conifer seed is a serious problem in bare-root nurseries, especially with the larger conifer seeds. Many seed protection methods have been tested to control this problem. Protection generally falls into four categories: (1) Physical barriers, (2) frightening devices, (3) poisonous chemicals, and (4) repellent chemicals. Most methods have some drawback that precludes their wide acceptance as an effective control agent.

Physical barriers constructed of polyethylene netting properly supported over seedbeds after sowing can virtually eliminate bird depredation, but are expensive both in materials and labor *(1)*. Frightening devices such as exploding shotgun shells and noise bombs *(8)*, scarecrows, and predator calls initially have some success, but birds often become accustomed to them. Also, noisemaking devices may be impractical when a nursery is located near residential areas. Avicides may be effective, but are usually nonselective and can often result in killing of nontarget birds. Furthermore, the use of poisonous chemicals is restricted by pesticide regulations and many nursery managers are reluctant to use them in their seedbeds. Repellent chemicals, however, have obvious benefits over other seed protection methods.

Because of the high cost of researching, developing, manufacturing, and registering pesticides, relatively few nontoxic chemicals are available as bird repellent seedcoat treatments. Arasan 42-5 (42 percent tetramethylthiuram disulfide) and anthraquinone are currently the only two nontoxic chemical seed treatments being widely used on conifer seed *(1)*. Although Arasan and anthraquinone are currently registered for forest tree seed treatments, there is some question about their effectiveness as bird repellants *(14)*. Many nursery managers are also concerned about possible phytotoxic effects on succulent young seedlings. Because of these concerns about effectiveness and chemical phytotoxicity, many nurseries are not currently using any bird repellants and are consequently suffering considerable seed losses.

Past tests indicate that certain carbamate insecticides show some effects in reducing bird damage to agricultural crops *(4, 5, 12, 15)*. Mesurol (3,5-dimethyl-4-[methylthio]phenol methylcarbamate) has shown bird repellent properties on several agricultural crops *(6)* and is currently registered for use on corn seed and in cherry orchards *(13)*. While Mesurol may be toxic to birds if enough treated seeds are ingested, birds are apparently repelled through a learned aversion (i.e., A bird consumes a treated seed and then feels sick. On the next encounter with treated seed, the bird associates the initial sickness with the taste of the chemical) *(9)*.

The purpose of this investigation was to test the practicality of Mesurol 75% Seed Treater as a conifer seed treatment against bird predation. The investigation evaluated possible phytotoxic effects of Mesurol Seed Treater on the laboratory germination of three Rocky Mountain conifer species; and a field trial was conducted on ponderosa pine *(Pinus ponderosa* Laws.) seeds to test its effectiveness under actual nursery conditions.

## Materials and Methods

***Laboratory test.*** Potential phytotoxic properties of Mesurol Seed Treater were tested on three conifer species commonly grown at nurseries in the Rocky Mountain

[1] The author thanks David Otis for his assistance in statistical analysis of these data.

Region. The seed was provided by Mt. Sopris Tree Nursery, Carbondale, Colo, and consisted of: (1) Ponderosa pine lot no. PIPO-04-05-000-075-65; (2) lodgepole pine *(Pinus contorta* Engelm.) lot no. PICO-12-01-496-105-64A; and (3) Engelmann spruce *(Picea engelmannii* Engelm.) lot no. PIEN-02-03-432-095-74. The seeds were taken directly from long-term storage to Lakewood, Colo., and stored at 2°C ± 1°C until used. The methods of pesticide evaluation employed are those recommended by the American Phytopathological Society (2).

The formulation of Mesurol used was 1254-1 (batch 1030216) provided by Mobay Chemical Corp. Before treatment, seeds were soaked for 24 hours in tap water to aid in germination *(3)*. The chemical was applied to about equal numbers of seeds as a slurry at 0.25, 0.5, 1.0, 2.0, and 4.0 per cent active ingredient with a water control with no active ingredient. After chemical application, seeds were spread out on filter paper and air-dried for 24 hours to dry the seed surface and prevent seed clumping.

Approximately 500 seeds per treatment for all three species were germinated on moistened filter paper in petri plates. The experimental design consisted of three replications for each species. Plates were placed inside a growth chamber and incubated for 8 hours of light at 30° C and 16 hours of darkness at 20°C per day for 4 weeks. Starting on day 7, seeds were observed at 2- to 3-day intervals to monitor germination. Seeds with radicles twice the seed length and with all essential structures intact were considered germinated. Germinated seeds were tallied and removed from the petri plates. After a 4-week germination period, all remaining seeds were examined, both externally and internally, to determine cause for germination failure.

Data analysis utilized an analysis of variance coupled with Tukeys' honestly significant difference *(10)*. Statistical tests were completed using both the percentage of seeds germinated and emergence index *(11)*. Phytotoxicity would have been indicated by a significant reduction in the percentage of seeds germinated or by a significant increase in the mean number of days required for seedling emergence (emergence index) of 1 to 1½ days (7).

***Field test.*** A field trial to test the effectiveness of Mesurol Seed Treater for repelling birds from ponderosa pine seed was conducted at Mt. Sopris Tree Nursery, Carbondale, Colo. Ponderosa pine seed from the same lot used in the phytotoxicity test was used in the field trials.

After a 24-hour water soak, the seed was coated in a 1 percent active ingredient Mesurol Seed Treater slurry and air dried for 24 hours. A control batch was soaked, but untreated. Study plot layout (fig. 1) consisted of four beds, each 76.2 meters (250 ft) long by 1.21 meters (4 ft) wide, which were established within unit 13 of block 2. Five 9.2-meter (30 ft) subplots were selected in each bed, with each subplot separated by a 6.1-meter (20 ft) fallow area. The treated plots and 10 control plots were assigned locations within the seedbeds at random. Seed was sown in six rows per bed to generate a growing density of 269 seedlings per square meter (25 per ft²). Control seeds were sown first to eliminate hopper-contamination with Mesurol. Seedbeds were mulched with 0.63 centimeter (¼ in) sawdust and irrigated according to normal nursery procedures. Wire bird exclusion cages (106.6 by 45.7 by 7.6 cm) (42 by 18 by 3 in) were placed across every subplot at systematic intervals of 2.1 meters (7 ft) and 4.26 meters (14 ft) (fig. 2). After 4 weeks, a measurement of seedbed density was obtained by counting the seedlings in two randomly selected 20.3-centimeter by 2.1-meter (8 in by 4 ft) quadrats outside of exclusion cages and one quadrat inside each caged area. A one-tailed, unpaired T-test was used to test for differences between treatments.

## Results and Discussion

***Laboratory test.*** The seed germination trials did not show any

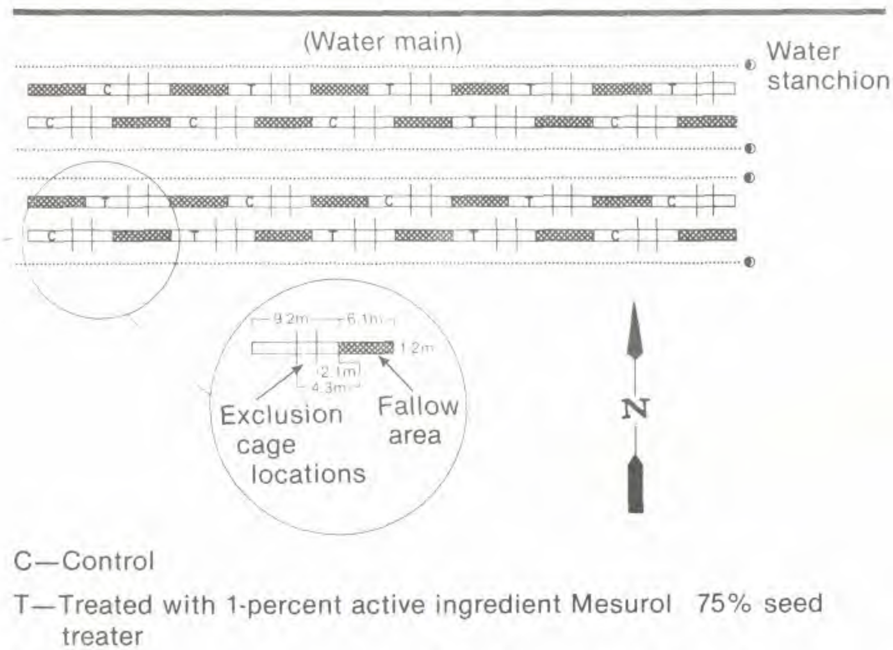


**Figure 1**—*Design layout for Mesurol Seed Treater field trials at Mt. Sopris Tree Nursery, Carbondale, Colo., block 2, unit 13.*

**Figure 2**—*Wire bird exclusion cages were randomly located in each plot.*

adverse effects of Mesurol at concentrations up to 4 percent active ingredient (fig. 3). Neither the germination rate nor the seedling emergence index differed significantly from the control at the 0.05 probability level. Considering that the label's application rate is between 0.5 and 1.0 percent active ingredient per 100 pounds of seed, the potential for phototoxicity appears to be slight.

***Field test.*** A pilot study was established in 1981 in block 1 at Mt. Sopris Nursery using the same design, but a different formulation (Mesurol 75% Wettable Powder) applied at 0.5 percent active ingredient. Birds consumed all treated and untreated seed that was outside the exclusion cages. It appears, however, that the poor results were caused by either one or a combination of the following factors: (1) The chemical had leached off the seed after it was sown in the beds because of the daily irrigation practices used at the nursery; (2) the low concentration of active ingredient (0.5 percent); and (3) the formulation. After the 1981 trials, Mobay Chemical Corp. indicated they realized a problem existed with the formulation; and in 1982, a new wetting agent was prepared.[3]

[2]Doyle Cohick, Manager of Insecticide Research, Agricultural Chemicals Division, Mobay Chemical Corp., Kansas City, Mo. Personal communication. 1982.

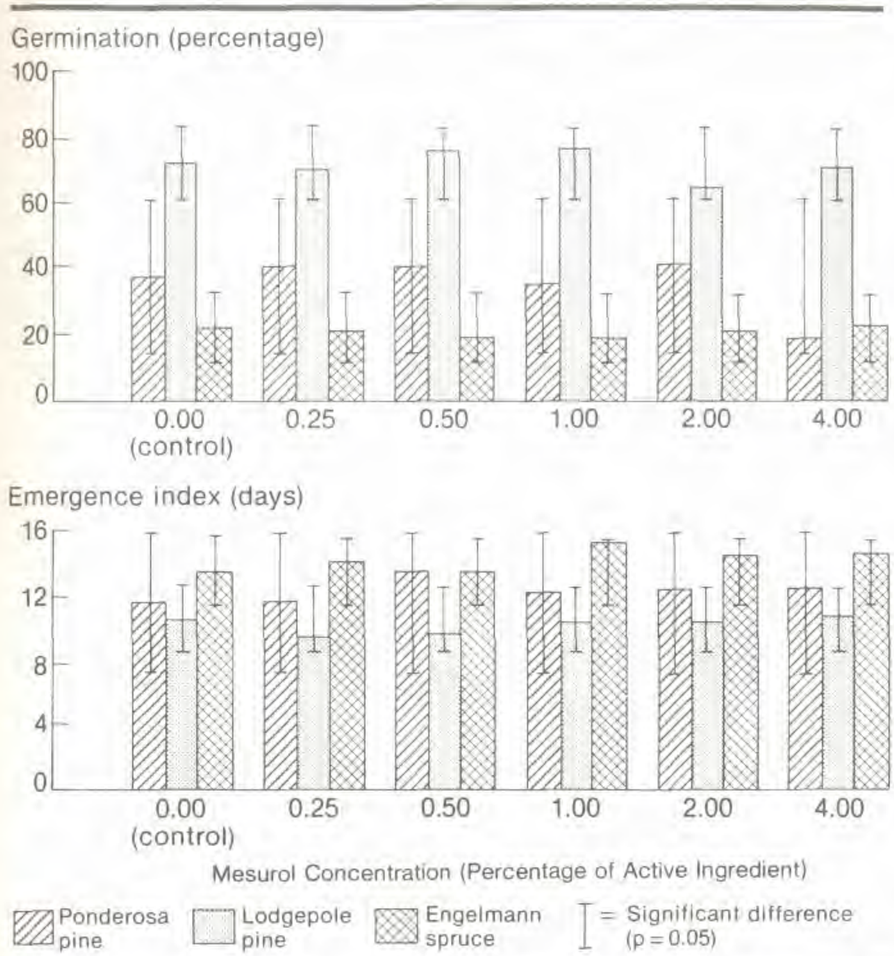


**Figure 3**—*Effects of Mesurol on seed germination and emergence rate of three Rocky Mountain conifers.*

The 1982 field trial used the formulation of Mesurol Seed Treater that was developed for rice seed. This new formulation apparently solved the leaching problems, and 1982 results were much improved over 1981. Therefore, nursery personnel should be advised to use Mesurol 75% Seed Treater only as used in rice seed application.

Seedbed density data from the field trials demonstrated that the Mesurol-treated seed suffered significantly less bird predation than the untreated seed. Statistical analysis also shows evidence ($t_{18} = 1.908$, $p = 0.036$) that the Mesurol treatments effectively reduced bird predation of seeds and seedlings (table 1). There were no statistically valid differences between the caged plots in the control beds and either the caged or uncaged plots in the seedbeds sown with Mesurol-treated seed, which indicates little consumption of the Mesurol-treated seed.

Even though the uncaged control plots contained significantly fewer seedlings than the other treatments, the overall bird damage was evidently low this season compared to 1981 when all plots were completely devastated by birds. This low bird pressure was supported by field observations of bird population levels.

The primary seed eater at Mt. Sopris Nursery was the mourning

**Table 1**—*Comparison of seedling densities between caged and uncaged plots in Mesurol-treated and control seedbeds*

| Treatments | Average seedling density | Average difference (standard deviation) |
|---|---|---|
| Mesurol—caged plots | 66.3 | −2.4 (15.79) |
| Mesurol—uncaged plots | 63.9 | |
| Control—caged plots | 62.4 | 19.6 (23.73) |
| Control—uncaged plots | 43.0 | |

dove *(Zenaidura macroura).* This species is also a problem with other agricultural crops where Mesurol has proven to be an effective deterrent. Because other conifer nurseries may have problems with other bird species, further field tests are warranted to test the effectiveness of this treatment against all types of seed-eating birds. On corn, rice, and soybeans, Mesurol has been proven to be a broad spectrum compound effective against red-winged blackbirds *(Agelaius phoeniceus*), ring-necked pheasants *(Phasianus colchicus),* common grackles (*Quiscalus quiscia),* brown-headed cowbirds (*Molothrus ater),* and common crows (*Corvus brachyrhynchos),* as well as doves *(6, 8, 12, 14, 15).*

Mesurol appears to be an economically feasible treatment for reducing bird predation in conifer seedling nurseries. Actual economic data were not collected in this study, but the cost-benefit ratio of this chemical should be quite high considering the per-acre value of conifer seedlings compared to agricultural crops.

**Conclusions**

It is clear that Mesurol 75% Seed Treater, as tested, is nonphytotoxic to the three conifer species evaluated. No adverse effects could be detected even when the Mesurol Seed Treater was applied at four times the recommended dosage rate.

The use of Mesurol Seed Treater as a 1 percent active ingredient seed dressing increased the number of surviving ponderosa pine trees in the first 4 weeks after sowing by 49 percent. This represents a significant increase over the number of surviving trees from untreated seeds.

Mesurol has proven to be a broad-spectrum repellant, which is effective for use on several different crops and against several species of birds. Mesurol 75% Seed Treater also appears to be able to protect the nursery's investment by reducing seed losses to bird depredation. The treatment has a potentially high cost-benefit ratio because conifer tree nursery crops, on an acre-per-acre basis, are worth far more than most agricultural crops. Nursery managers should be aware that Mesurol is currently being sold as an insecticide and not as a seed treatment; the seed treatment is still an experimental label. The possibility of registering Mesurol for use on a minor nonfood crop is being investigated.

## Literature Cited


1. Aldhous, J. R. Nursery Practice. Forestry Comm. Bull. No. 43. London: Her Majesty's Stationary Office. 1975:119.
2. American Phytopathological Society. Methods for evaluating plant fungicides, nematicides, and bactericides. St. Paul, MN: American Phytopathological Society; 1978. 141 p.
3. Bonner, F. T.; McLemore, B. F.; Barnett, J. P. Presowing treatment of seed to seed germination. In: Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture; 1974:126-135.
4. DeHaven, R. W.; Guarino, J. L.; Crase, F. T.; Schafer, E. W., Jr. Methiocarb for repelling blackbirds from ripening rice. Int. Rice Comm. Newsl. 29(4): 25-30; 1971.
5. DeHaven, R. W.; Mott, D. F.; Guarino, J. L.; Besser, J. F.; Knittle, C. E.; Schafer, E. W., Jr. Methiocarb for repelling birds from ripening sweet cherries. Inter. Pest Control. Slough, Great Britain: Chiltern Printers, Ltd.; 1979; 21 (1):12-14.
6. Guarino, J. L. Methiocarb, a chemical repellent: A review of its effectiveness on crops. Proc. Vertebr. Pest Conf. 5: 108-111; 1972.
7. Hansing, E. D. Techniques for evaluating seed-treatment fungicides. In: Methods for evaluating plant fungicides, nematicides, and bactericides. St. Paul, MN: American Phytopathological Society; 1978: 88-92.
8. Mott, D. F. Dispersing blackbirds and starlings from objectionable roost sites. Proc. Vertebr. Pest Conf. 9: 38-42; 1980.
9. Rogers, J. G., Jr. Responses of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage. 38(3): 481-423. 1974.
10. Sokal, R. R.; Rohlf, F. J. Biometry. San Francisco: W. H. Freeman and Co.; 1981: 245, 253.
11. Sonoda, R. M. Screening fungicides for seed and seedling disease control in plug mix plantings. In: Methods for evaluating plant fungicides, nematicides, and bactericides. St. Paul, MN: American Phytopathological Society; 1978: 92-95.
12. Stickley, A. R., Jr.; Ingram, C. R. Two tests of the avian repellent methiocarb in Michigan sweet cherry orchards. In: Proceedings, bird control seminar; 1973 October 30-November 1; Bowling Green, OH. Bowling Green, OH: Bowling Green State University; 1973; 6: 41-46.
13. Thomson, W. T. Agricultural Chemicals-Book I-Insecticides. Fresno, CA: Thomson Publications; 1980: 23-24.
14. West, R. R. Repelling boat-tailed grackles from sprouting corn with a carbamate compound. Texas J. of Sci. 21(2): 231-233; 1969.
15. West, R. R.; Brunton, R. B.; Cunningham, D. J. Repelling pheasants from sprouting corn with a carbamate insecticide. J. Wildl. Manage. 33(1): 216-219; 1969.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# The Fungus That Causes Scleroderris Canker Survives Field Exposure in Plastic Bags

**C. N. Davis and C. E. Dorworth**[1]

*Technician and Research Scientist, Department of the Environment, Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario*

*A currently used method for disposing of branches infected with* Gremmeniella abietina *in green garbage bags was tested. Contrary to original beliefs, the fungus was found to survive in the bags. The hazards associated with this method are noted.*

The fungus *Gremmeniella abietina* (Lagerb.) Morelet, which incites the disease of pines known as Scleroderris canker, causes enough damage that active control or eradication programs are in progress in critical areas. In Canada, pine plantations in settled areas and those involving provincial-private owner cooperation (6) are open to frequent public observation. Public objection to the damage caused by the disease justifies the use of available labor intensive sanitation methods (4), and managers accept the cost involved in order to get a return on their investment. The only method of control known at present involves sanitation removal and the disposal of infected plants and plant parts. In Austria, Donaubauer (2) indicated that large quantities of spores are formed in piles of slash that remain on the ground. Dorworth (3) and Magasi (5) found that one spore stage (ascospore) was formed on infected tissue left on the ground. These mainly wind-dispersed spores would pose a real threat of reinfection to surrounding trees if left in the plantation or disposed of near other host trees. Bergdahl (1) reported that the water-splash-dispersed spores from the second spore stage (conidial) did not present a danger of reinfection under similar circumstances in North America. At one time, we recommended disposing of slash in green garbage bags. Laboratory studies and fungal characteristics indicated that leaving the bags in sunlight would quickly generage enough internal heat to kill the fungus and render the contents harmless. Weevil disposal is another type of pest control in which plastic bags are used in this way. However, the bags are somewhat fragile under working conditions and loss of some slash is inevitable, either in transport or when bags are subjected to the elements. This test was designed to evaluate the safety of this method of treatment with respect to *G. abietina.* The possibility of release and/or dissemination of *G. abietina* was tested in the spring of 1982.

[1]The authors are grateful to Mr. Gary Pelton and Mr. Doug Renwick, Ontario Ministry of Natural Resources, Parry Sound, Ontario, for assistance during the course of this work and Miss Toni D'Ettorre, a student at Ryerson Polytechnical Institute, Toronto, for technical assistance.

## Materials and Methods

Red pine (*Pinus resinosa* Ait.) branches infected with *Gremmeniella abietina were* collected in late spring and early summer when sanitation work is normally done. These were handled as in a typical sanitation pruning operation and placed in 90-by 65-centimeter, green plastic garbage bags, the tops of which were then sealed. For purposes of this experiment, care was taken not to puncture the bags. A Taylor maximum-minimum thermometer was placed in each bag and a Feuss recording hygrothermograph was placed in one bag per replication. All bags but one (control) were set in an open area exposed to the elements. One bag was removed after 1, 2, 4, 6, 7, and 14 days of exposure and was immediately placed in a freezer at -4° C. The entire experiment was replicated twice in green bags and once in 45-kilogram clear polyethylene bags.

Branches were subsequently thawed and removed from bags and examined for the presence of active perfect and imperfect fruiting structures. Portions of diseased tissue were then sectioned and surface-disinfected in Javex diluted 50 percent with water supplemented with 1 drop of Tween 20 per 250 milliliters. These tissue portions were placed in petri plates on a medium consisting of 200 milliliters of Campbell V-8 juice to

800 milliliters of distilled water to 20 grams of Difco Bacto Agar. The fungus was incubated at 20° C. for 20 days and checked daily for the presence of *G. abietina.* Spores, when found, were germinated on media to determine their viability.

Additional branches were sealed in green garbage bags and placed in a Fisher Isotemp oven at 45° C ±2° C for 2-, 4-, 6-, 16-, 18-, and 24-hour periods. Infected tissue was then sectioned and cultured as previously described.

## Results and Discussions

The fungus remained viable to some extent in all bags exposed to sunlight. *G. abietina* was isolated from 33 to 70 percent of all the branches checked. By comparison, *G. abietina was* isolated from 98 percent of the branches not exposed to sunlight, an indication that the exposure treatment killed the fungus in some cases. Temperatures inside the green bags went as high as 45° C during the 4 hottest midday hours. Temperatures varied with such factors as cloud cover. Temperatures inside the clear bags tended to be as much as 8° C higher than those in the green bags. Large numbers of viable spore-producing pycnidia (conidia) (fig. 1) and apothecia (ascospores) (fig. 2) were found in all bags, encouraged by wet, humid conditions that resulted from alternate heating and cooling.

The fungus survived in bags exposed to constant heat in the oven

**Figure 1**—*Apothecia of* G. Abietina *unopened (left) and opened (right) (10X).*

**Figure 2**—*Pycnidium of* G. abietina *with spore tendril (12X).*

at a rate comparable with that of survival after sunlight exposure, and this further suggests that temperatures in the field are not sufficiently high to kill *G. abietina* within infected branches.

Under operational-conditions, holes accidentally punched in bags could reduce the effectiveness of the system by providing exit holes for released spores and would reduce maximum inside temperatures. Where this method is used, special care must be taken to remove all bags from the sanitation site daily and not to lose any while transporting them. They must then be disposed of in such a way as to offer no further threat to plantations that maybe near the disposal site; that is, they should be buried or burned.

## Literature Cited


1. Bergdahl, D. R.; Ward, T. M. Selective pruning of *Pinus resinosa* results in reduced rates of inoculum production and infection by *Gremmeniella abietina.* Phytopathol. 71(5): 5581981. Abstract.
2. Donaubauer, E. Die Kieferntriebsterben-Kalami6t 1959/1960. Allgemeine Forstzeitung 71: 9-10; 1960.
3. Dorworth, C. E. Longevity of *Scleroderris lagerbergii* Gremmen in pine slash. Bi-mon. Res. Notes. Ottawa, ON: Department of the Environment, Canadian Forestry Service; 1972; 28:5.
4. Dorworth, C. E. Reducing damage to red pine by *Gremmeniella abietina in* the Great Lakes-St. Lawrence forest region of Ontario. Inf. Rep. O-X-252. Sault Ste. Marie, ON: Department of the Environment, Canadian Forestry Service; 1976.
5. Magasi, L.; Manley, M. Survival of *Gremmeniella abietina (Scleroderris lagerbergii*) in marketed Christmas trees. Plant Dis. Rep.58(10):892-894; 1974.
6. Staley, R. N. Agreement forests. Ont. For. Toronto, ON: Ontario Forestry Association; 1979 Spring and Summer: 4-7.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# Presowing Treatments and Storage for Green Ash Seeds

**W. H. Cram**
*Tree Nursery PFRA, Indian Head, Saskatchewan*

*Stratification for 90 days at 41 ° F was superior to soaking and warm plus-cold stratification for greenhouse sowing to test the viability of green ash seeds. Germination after 8 years of storage at 0° F was 80 percent.*

Several presowing treatments have been reported to overcome seed dormancy for germination tests of green ash (*Fraxinus pennsylvanica* Marsh.) by the U.S. Department of Agriculture, Forest Service *(4, 5).* However, Bonner and Gammage (2) discovered no reliable viability test. Barton (1) reported 63-percent germination for green ash after storage at 41 ° F. for 7 years. This article reports on the germination of fresh green ash seeds after 10 presowing treatments and after storage at three temperatures for 1 to 8 years.

## Materials and Methods

***Presowing treatments.*** Bulkseed samples were harvested on October 6 from three trees. These were air-dried for 24 hours to 7.3 percent moisture content and then divided into 10 lots. Seeds from each lot and tree were surface sterilized by dipping in a 0.5-percent mercuric chloride solution. The seeds were then subjected to 10 presowing treatments. All seeds were then sown in a greenhouse in a sterilized medium (two parts sand to one part soil), and the observed germination was recorded each day for 30 days.

***Seed storage.*** Seed samples were harvested from three trees in October 16, then bulked and air-dried for 72 hours in the greenhouse to 6.3 percent moisture content. Each bulked sample was divided into 12 lots, which were sealed in individual 2-mil polyethylene bags. Four of each of the bagged lots were sealed in large poly bags; and these were stored at 0°, 24°, and 35° F. Viability of these seedlots was evaluated by greenhouse sowings after 90 days of stratification at 41 ° F and after 0, 1, 6, and 8 years of cold storage.

Moisture content of all seedlots was determined at harvest (after drying) and after 1 to 8 years of storage, by ovendrying five samples of 10 seeds at 212° F for 24 hours.

## Results and Discussion

***Presowing treatments.*** Germination of seeds from all three trees (table 1) was increased significantly by the soaking treatments, but to a greater and more uniform degree by the stratification treatments. Mean germination was highest (88 to 90 percent) after warm plus cold stratifications for up to 90 days, although not significantly more than after cold stratification for 30 to 90 days.

In addition, the germination rate was fastest after stratifications for 90 days. However, the germination

**Table 1**—*Germination[1] of green ash seeds from three trees following 10 presowing treatments*

| Presowing treatments | | | Seed trees and germination of seeds | | | Treatment means |
|---|---|---|---|---|---|---|
| Type | Temp. | Time | #1 | #2 | #3 | |
| | *°F* | *Days* | % | | | |
| Dry | 70 | Check | 5e[2] | 12d | 11d | 9e |
| Soak | 70 | 10 | 22d | 38c | 76c | 45d |
| Soak | 70 | 20 | 59c | 47c | 83bc | 60cd |
| Soak | 70 | 30 | 61c | 81ab | 83bc | 75bc |
| Strat. | 41 | 30 | 80b | 69b | 91ab | 80ab |
| Strat. | 41 | 60 | 84ab | 82ab | 89abc | 84ab |
| Strat. | 41 | 90 | 92a | 85ab | 90ab | 89ab |
| Strat. | 70 & 41 | 30+60[3] | 89a | 87ab | 89ab | 88ab |
| Strat. | 70 & 41 | 20+70 | 85ab | 93a | 90ab | 89ab |
| Strat. | 70 & 41 | 10+80 | 91a | 85ab | 94a | 90a |

[1]Germination as a percentage of the 25 seeds sown for six replications.
[2]Values within a column followed by a common letter are not significantly different at the 1-percent level.
[3]Stratified alternatively at the warm and cold temperatures for the days indicated.

rate after cold stratification was faster for seeds from two trees than after any warm plus cold stratification for 90 days.

These results demonstrated the superiority of stratification as a presowing treatment for green ash seeds. Stratification for 90 days at 41 ° F would provide the most practical nursery method for seed viability testing. However, somewhat different results may occur with other than freshly harvested seeds.

***Seed storage.*** Germination capacity of the seeds remained high after 1 year of storage at 0° to 35° F, but only for the 0° F storage after 6 and 8 years (table 2). Viability of seeds stored at 24° and 35° F decreased to 15 percent after 6 years and to zero after 8 years.

**Table 2**—*Germination[1] of green ash seeds following stratification for 90 days after 1 to 8 years of storage at three temperatures*

| Storage temperatures | Years of storage and germination | | | |
|---|---|---|---|---|
| | 0 | 1 | 6 | 8 |
| °F | % | | | |
| 0 | 86 | 86a[2] | 71a | 80 |
| 24 | 86 | 81a | 15b | 0 |
| 35 | 86 | 83a | 15b | 0 |

[1]Germination capacity as a percentage of 25 seeds sown with six replications.
[2]Means within a column followed by a common letter are not significantly different at the 1-percent level.

These levels of seed viability after storage were inversely related to the seed moisture levels. Germination was 86 percent after harvest when the seed moisture was 6.3 percent and 86 percent after 1 year of storage at 0° F when the seed moisture was 6.4 percent. However, the germination decreased to 71 and 80 percent after 6 and 8 years of storage at 0° F when the seed moisture increased to 8.8 and 9.8 percent, respectively. Germination of seeds stored at 24° and 35° F for 1 year was 81 and 83 percent, respectively, when the corresponding moisture contents increased to 8.0 and 7.1 percent. Then, the germination after 6 years of storage at both 24° and 35° F decreased to 15 percent when seed moisture increased to 13.8 percent. Finally, the seed viability was zero for storage at both 24° and 35° F, when the seed moisture increased to 18.6 percent after 8 years of storage. Barton (1) reported 83 percent germination for ash seeds with 7.6 percent moisture after sealed storage for 1 year at 41 ° F, 51 percent after 5 years of storage, 63 percent after 7 years, and 39 percent after 8 years; but no seed moisture levels were reported after 5 to 8 years of storage.

In the present study, seed moisture increases during storage to the ambient moisture levels of the storage rooms were attributed to permeability of the 2-mil polyethylene bags. This was previously reported by Owen (3).

Thus, heavier poly bags or other nonpermeable containers are required to prevent absorption or loss of moisture for long-term storage of ash seeds.

### Literature Cited


1. Barton, L. V. Viability of seeds of *Fraxinus* after storage. Contrib. Boyce Thompson Inst. (Yonkers, NY). 13: 427-432; 1945.
2. Bonner, F. T.; Gammage, J. L. Comparison of germination and viability tests for southern hardwood seeds. Tree Plant. Notes. 18(3): 21-23; 1967.
3. Owen, E. G. The storage of seeds for maintenance of viability. Bull. 43. Farnham, Bershire, England: Commonwealth Bureau of Pastures and Field Crops, Commonwealth Agricultural Bureau; 1956.
4. Schopmeyer, C. S., tech. coord. *Fraxinus.* In: Seeds of woody plants in the United States. Agric. Handb.450. Washington, DC: U.S. Department of Agriculture; 1974: 411-416.
5. U.S. Department of Agriculture. *Fraxinus.* In: Woody plant seed manual. Misc. Pub. 654. Washington, DC: U.S. Department of Agriculture; 1948: 178-183.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# Effect of Selected Insecticides and Fungicides on Germination of Douglas Fir and White Spruce Pollen

**Jack R. Sutherland, T. A. D. Woods, and G. E. Miller**
*Research Scientist, Research Technician, and Research Officer, Environment Canada, Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia*

*Germination of two lots each of Douglas-fir and white spruce pollen was determined in vitro on a pesticide-amended medium. In general, all the pesticides (two insecticides and two fungicides) reduced pollen germination of both tree species; an exception was ferbam which sometimes increased Douglas-fir pollen germination slightly. Additional tests are needed to determine if pesticides affect pollen germination in vivo.*

Various seed and cone insects and inland spruce cone rust (*Chrysomyxa pirolata* Wint.) are major impediments to seed production in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and spruce (e.g., white spruce (*Picea glauca* (Moench) Voss.)) seed orchards in British Columbia (5, 6). Until alternative strategies or integrated approaches are developed, orchard managers must rely solely upon pesticides for controlling these pests. The efficacy and possible phytotoxicity to trees and cones of several pesticides have been (or are being) determined, but information is also needed on their possible detrimental effects on pollen germination.

## Methods

The pesticides tested were the insecticides dimethoate 25 EC (at 10,000, 1,000, and 100 p/m a.i.) and oxdemeton-methyl 25 EC (at 10,000, 1,000, and 100 p/m a.i.) and the fungicides ferbam 76 WP (at 1,520, 821, and 152 p/m a.i.) and potassium coconate 11-percent (at 20,000, 10,000, and 5,000 p/m a.i.). The highest of these concentrations corresponds to the manufacturers' recommended field application. The pollen germination medium (3), with 2-percent agar added, was autoclaved and cooled to 50° C. The pesticides were added before it was poured into petri dishes. A pH meter was used to determine the pH of the medium for each treatment. Two lots each of Douglas-fir (34-percent and 31-percent germination capacity) and white spruce (18-percent and 50-percent germination capacity) pollen were dusted with a dry paint brush onto the various media. After incubation in the dark at 26° C for 24 hours and 48 hours, the percentage of germination (8, p. 74-75) was determined. The data were subjected to analysis of variance and the significance of mean differences determined using the Student- Newman-Keuls' test (9). Each treatment and the control were replicated three times and the number of pollen grains (200300) counted per replicate was based on the germination capacity of each lot at the 0.95 confidence level (8, p. 76).

## Results and Discussion

Table 1 show that, at the recommended label concentrations, dimethoate, oxydemeton-methyl, and potassium coconate prevented germination of Douglas-fir and white spruce pollen, as did ferbam for white spruce. In general, even lower concentrations of these materials lowered germination, especially of spruce pollen. These reductions in germination occurred regardless of the initial germination capacity of the pollen. One anomaly was the increased germination of both lots of Douglas-fir pollen at the intermediate levels (821 and 1 52 p/m) of ferbam. Matthews and McLintock (4) found that ferbam could increase germination of slash (*Pinus elliotti* Engelm. var. *elliottii*) and longleaf (*P. palustris* Mill.) pine pollen. Observations made both before and after the 48 hours for Douglas-fir and 24 hours for the white spruce (table 1) confirmed that the chemicals affected germination capacity rather than rate.

The pollen lots of each species responded similarly. Overall, reduced germination, particularly of white spruce pollen, appeared to be related to changes in acidity of the medium (table 1) resulting from the added pesticides (e.g., the lower pH of the oxydemeton-methyl-amended medium and the higher pH values when potassium coconate was added). Correlation coefficient or *r* values (9)

**Table 1**—*Effect of dimethoate and oxydemeton-methyl insecticides and ferbam and potassium coconate fungicides on germination* in vitro *of Douglas-fir and white spruce pollen*

| Pesticides and concentration (p/m) | Medium pH | Kind of pollen and percentage of germination | | | |
|---|---|---|---|---|---|
| | | Douglas-fir | | White spruce | |
| | | Lot 1 | Lot 2 | Lot 1 | Lot 2 |
| Dimethoate | | | | | |
| 10,000 | 5.3 | 0a[1] | 0a | 0a | 0a |
| 1,000 | 5.7 | 3.4ab | 3.7b | 0a | 0a |
| 100 | 5.7 | 5.4b | 9.1c | 2a | 4.8a |
| 0 (control) | 5.9 | 9.0c | 11.2c | 24.1b | 56.5b |
| Oxydemeton-methyl | | | | | |
| 10,000 | 4.2 | 0a | 0a | 0a | 0a |
| 1,000 | 5.2 | 7.5b | 9.5b | 0a | 0a |
| 100 | 5.7 | 9.0c | 9.9b | 14.0b | 42.7b |
| 0 (control) | 5.9 | 9.0c | 11.2b | 24.1c | 56.5c |
| Ferbam | | | | | |
| 1,520 | 6.0 | 11.3a | 12.1a | 0a | 0a |
| 821 | 6.3 | 14.7b | 16.8b | 0a | 0a |
| 152 | 5.9 | 14.7b | 10.3a | 0a | 0a |
| 0 (control) | 5.9 | 9.0a | 11.2a | 24.1b | 56.5b |
| Potassium coconate | | | | | |
| 20,000 | 9.6 | 0a | 0a | 0a | 0a |
| 10,000 | 9.3 | 0a | 0a | 0a | 0a |
| 5,000 | 8.4 | 0a | 0a | 0a | 0a |
| 0 (control) | 5.9 | 9.0b | 11.2b | 24.1b | 56.5b |

[1]The four treatment means for each pollen lot and pesticide are significantly different ($p = 0.05$) if followed by a different letter. Germination after 48 hours for Douglas-fir and 24 hours for white spruce.

of 0.59, 0.61 (significant at p = 0.05), and 0.11 (nonsignificant) were obtained when germination percentages of both Douglas-fir and spruce pollen were regressed against the pH of the media containing dimethoate, oxydemeton-methyl, and ferbam, respectively. No such analysis was possible for the potassium coconate data because no pollen germination occurred at any dosage rate. Stanley (7) lists pH as one of the principal exogenous factors affecting *in vitro* germination of conifer pollen. However, it is not possible to state whether the pesticide effects were caused by changes in pH or by the pesticides themselves because these two factors are very closely connected. Moreover, pollen germination varied among chemicals at the same pH, which suggests a true pesticide effect.

The results of this study suggest a potential harmful effect of pesticides on pollen germination and subsequent seed yield. Additional research is planned to determine if these harmful effects also occur *in vivo*. Other studies (1, 2) suggest that this seldom occurs or that the harmful *in vitro* effects may be nullified by using other formulations of the pesticide or by varying application timing or equipment.

## Literature Cited


1. Bristow, P. R. Effect of triforme on pollen germination and fruit set in highbush blueberry. Plant Dis. 65: 350-353;1981.
2. Gentile, A. G.; Vaughn, A. W.; Richman, S. M.; Eaton, A. T. Corn pollen germination and tube elongation inhibited or reduced by commercial and experimental formulations of pesticides and adjuvants. Environ. Entomol. 2: 473476; 1973.
3. Ho, R.; Sziklai, O. Germination of Douglas-fir pollen. Silvae Genetica. 21: 48-51; 1972.
4. Matthews, F. R.; McLintock, T. F. Effects of fungicides on pollen germination of slash and longleaf pine. Res. Note 122. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1958. 2 p.
5. Ruth, D. S. A guide to insect pests in Douglas-fir seed orchards. BC-X-204. Victoria, BC: Department of the Environment, Canadian Forestry Service; 1980.19 p.
6. Ruth, D. S.; Miller, G. E.; Sutherland,J. R. A guide to common insect pests and diseases in spruce seed orchards in British Columbia. BC-X-231. Victoria, BC: Department of the Environment, Canadian Forestry Service; 1982. 28 p.
7. Stanley, R. G. Factors affecting germination of the pollen grain. XIV IUFRO Congress, Munich, Sec. 22: 39-59; 1967.
8. Stanley, R. G.; Linskens, H. F. Pollen biology biochemistry management. New York: Springer-Verlag; 1974.
9. Steel, R. G. D.; Torrie, J. H. Principles and procedures of statistics. New York: McGraw-Hill; 1960.

# Second-Field-Year Growth of Eastern White Pine Progenies From Seed Orchards[1]

**John E. Kuser and Brian K. Hobbs**[2]
*Assistant Professor of Forestry and Undergraduate Honors Scholar, Department of Horticulture and Forestry, Cook College, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N.J.*

*In the second year after field planting at New Brunswick, N.J., about 1,100 white pine seedlings from 60 different seed sources showed highly significant differences in current year's growth and in dates of beginning and ending growth. Seedlings from Maryland, Pennsylvania, and Vermont seed orchards performed best; overall, growth was negatively correlated with latitude of origin, but there were marked exceptions. Progeny of selected clones in seed orchards performed an average of 7 percent better than seedlings from wild-collected seed; the best half-sib family was 57 percent better.*

Eastern white pine (*Pinus strobus* L.) is the most planted tree species in New Jersey. More than 600,000 a year are planted for timber, windbreak, Christmas tree, and landscape use. Provenance variation in growth rate has been reported, with performance of trees from the best seed sources exceeding that of those from the poorest by 40 to 80 percent (2, 4). At most test plantations except those farthest north, Southern Appalachian sources have performed best up to age 10 (1, 3).

Seed orchards of locally selected, superior white pine clones have been established in several States. It would be advantageous for New Jersey nursery personnel and growers to identify orchards and clones that produce progeny best suited for use here and to quantify genetic gain over trees grown from wild-collected seed. Correlations between juvenile and mature trees are useful in predicting growth and allow early selection for timber trees. Moreover, isolation of clones having vigorous juvenile growth is highly important for Christmas tree, windbreak, and landscape use.

## Materials and Methods

In March 1981, we obtained about 1,200 2-year-old seedlings representing 60 different sources of white pine (table 1) from the U.S. Department of Agriculture Forest Service. Of the 60 lots, 49 were half-sib families of open-pollinated seedlings from ramets of selected clones grown in seed orchards. Nos. 1 and 20 were mixed seed orchard progeny from New York; no. 43 came from an Ohio plantation of unknown seed source; and the remaining eight were progeny of wild trees in native stands. All the seedlings were grown for their first two seasons at Buckingham State Nursery, Harmans, Md.

Seedlings were planted in four randomized blocks on a uniform Nixon loam site at Cook College horticulture farm no. 1, New Brunswick, N.J. Each source was represented by one five-tree plot in each block. No fertilizer was applied. Simazine was used to control weeds in a 0.3-meter-diameter circle around each seedling in 1981, and a Simazine-Enicle mixture was used in 1982.

During the 1982 growing season, three responses were measured:

1. Date of beginning of growth, defined as the date on which the first new shoot exceeded 2 centimeters in length (because no budburst occurs in white pine).
2. Date of ending of growth, defined as the date after which further shoot elongation was less than 1 centimeter.
3. Length of leading shoot after the date of ending of growth.

Data were subjected to analysis of variance to determine whether the seed source was a significant cause of variation in responses. After significance had been determined, responses were regressed against latitude of genetic

---

[1] This work was performed as apart of the NJAES Project 12384, supported by the New Jersey Agricultural Experiment Station and McIntire-Stennis Act funds.

[2] We thank Peter Garrett, Henry Gerhold, John Genys, and Clyde Hunt for their contributions to our study.

**Table 1**—*Second-year growth of open-pollinated white pine seedlings from 60 seed sources, at New Brunswick, N.J.*

| | Female parent | | | | Number | 1982 season's growth | | |
|---|---|---|---|---|---|---|---|---|
| No. | Clone | Origin | Latitude | Source[1] | living | Began | Ended | Length |
| 13 | --[2] | Pickett County, Tenn. | 36°35′ | 1 | 15 | 4/29 | 5/20 | 11.97 |
| 41 | PA 104 | Ashton, Md. (plantation) | 39°00′ | 6 | 15 | 4/30 | 5/23 | 13.70 |
| 52 | MD 3 | Harmans, Md. (plantation) | 39°07′ | 4 | 18 | 4/28 | 5/21 | 14.12 |
| 62 | MD 8 | Harmans, Md. (plantation) | 39°07′ | 4 | 16 | 4/23 | 5/23 | 18.19 |
| 66 | PA 53 | Harford County, Md. | 39°30′ | 6 | 16 | 4/28 | 5/24 | 14.24 |
| 32 | MD 7(PA93) | Swallow Falls St. Pk., Md. | 39°30′ | 6 | 17 | 5/1 | 5/21 | 10.91 |
| 54 | MD 7 | Swallow Falls St. Pk., Md. | 39°30′ | 5 | 18 | 4/30 | 5/20 | 10.97 |
| 60 | MD 19 | Potomac St. For., Md. | 39°30′ | 4 | 16 | 4/30 | 5/19 | 9.48 |
| 39 | PA 111 | Mont Alto, Pa. | 39°45′ | 6 | 20 | 4/29 | 5/21 | 12.70 |
| 3 | PA 90 | Hagerty's Crossing, Pa. | 40°45′ | 6 | 18 | 4/28 | 5/25 | 13.65 |
| 17 | PA 18 | Pottersdale, Pa. | 40°45′ | 6 | 17 | 4/27 | 5/20 | 11.27 |
| 45 | PA 26 | Rush Twp., Clearfield Co., Pa. | 41°00′ | 6 | 20 | 4/27 | 5/21 | 12.22 |
| 31 | PA 19 | Stroudsburg, Pa. | 41°00′ | 6 | 18 | 4/26 | 5/20 | 12.92 |
| 36 | PA 78 | Mifflinburg, Pa. | 41°00′ | 6 | 18 | 4/27 | 5/22 | 15.54 |
| 30 | PA 12 | Cook Forest, Clarion, Pa. | 41°20′ | 6 | 20 | 4/27 | 5/22 | 13.72 |
| 33 | PA 8 | Cook Forest, Clarion, Pa. | 41°20′ | 6 | 19 | 4/29 | 5/19 | 12.09 |
| 44 | PA 9 | Cook Forest, Clarion, Pa. | 41°20′ | 6 | 19 | 4/28 | 5/23 | 14.06 |
| 50 | PA 15 | Cook Forest, Clarion, Pa. | 41°20′ | 6 | 18 | 4/28 | 5/22 | 13.43 |
| 43 | -- | Findley St. Pk., Ohio (plantation) | 41°08′ | 3 | 18 | 4/27 | 5/21 | 13.78 |
| 26 | -- | New London, Conn. | 41°30′ | 1 | 18 | 4/29 | 5/25 | 11.44 |
| 46 | -- | New London, Conn. | 41°30′ | 1 | 16 | 4/24 | 5/21 | 13.19 |
| 20 | Mixed | Southern N.Y., northern Pa. aver. | 42°00′ | 7 | 17 | 4/26 | 5/21 | 13.68 |
| 16 | PA 77 | Oxford, N.Y. | 42°30′ | 6 | 18 | 4/28 | 5/21 | 11.57 |
| 1 | Mixed | Warren & Saratoga Co.'s, N.Y. aver. | 43°00′ | 8 | 16 | 4/28 | 5/27 | 11.59 |
| 34 | PA 79 | Oneonta, N.Y. | 42°30′ | 6 | 15 | 4/29 | 5/21 | 11.92 |
| 27 | PA 61 | Saratoga Spring, N.Y. (plantation) | 43°00′ | 6 | 17 | 4/27 | 5/21 | 12.19 |
| 12 | -- | Adirondacks near Jay, N.Y. | 44°30′ | 1 | 17 | 4/28 | 5/18 | 9.96 |
| 42 | VT 9-1 | Brattleboro, Vt. | 42°52′ | 9 | 20 | 4/28 | 5/21 | 13.09 |
| 9 | VT 7-2 | Shaftsbury, Vt. | 43°00′ | 9 | 17 | 4/29 | 5/23 | 13.22 |
| 18 | VT 6-1 | Shaftsbury, Vt. | 43°00′ | 9 | 18 | 4/26 | 5/21 | 12.79 |
| 24 | VT 7-1 | Shaftsbury, Vt. | 43°00′ | 9 | 20 | 4/27 | 5/20 | 13.68 |
| 10 | VT 3-2 | West Rutland, Vt. | 43°35′ | 9 | 18 | 4/27 | 5/21 | 12.87 |
| 51 | VT 15-1 | West Rutland St. For., Vt. | 43°38′ | 9 | 16 | 4/27 | 5/23 | 15.63 |
| 29 | VT 2-1 | Moretown, Vt. | 44°15′ | 9 | 18 | 4/30 | 5/21 | 12.68 |
| 40 | VT 2-1 | Moretown, Vt. | 44°15′ | 9 | 14 | 4/26 | 5/21 | 13.26 |
| 7 | ERL-1 | Rindge, N.H. | 42°44′ | 10 | 18 | 4/29 | 5/25 | 15.82 |
| 28 | ERI | Rindge, N.H. | 42°44′ | 10 | 17 | 4/29 | 5/19 | 9.92 |
| 5 | HLY-1 | Lyndeboro, N.H. | 42°52′ | 10 | 19 | 4/25 | 5/21 | 12.95 |

origin of female parent to determine whether there was a significant association.

### Results

At the end of the first summer, overall survival was 91 percent and 1 year after planting, it was still 90 percent. Only seedlings of no. 63 from Minnesota had a markedly lower survival rate. Seed source differences in growth responses (table 1) were highly significant (table 2). Regressions showed negative correlation of height growth with latitude of origin of female parent and wider dispersion of actual values above and below predicted values at lower latitudes (fig. 1). In spite of the significance of seed source as a source of variation in dates of beginning and ending growth, regressions of these dates against latitude of origin of female parent were not significantly different from 0.

While mean growth of the 51 sets of seed orchard progeny was 7 percent better than mean growth of the 8 sets of progeny of wild trees in native stands, it was 25 percent better than that of no. 12 from an area in New York that has produced commercial white pine seed. Mean growth of seedlings from the best source, no. 62 (Maryland), was 46 percent more

**Table 1**—*Second-year growth of open-pollinated white pine seedlings from 60 seed sources, at New Brunswick, N.J.—continued*

| | Female parent | | | | Number | 1982 season's growth | | |
|---|---|---|---|---|---|---|---|---|
| No. | Clone | Origin | Latitude | Source[1] | living | Began | Ended | Length |
| 19 | HNBO-3 | New Boston, N.H. | 42°58′ | 10 | 20 | 4/26 | 5/22 | 13.66 |
| 49 | HNBO-1 | New Boston, N.H. | 42°58′ | 10 | 18 | 4/25 | 5/21 | 12.69 |
| 8 | MBO-1 | Gerrish, N.H. | 43°23′ | 10 | 20 | 4/28 | 5/22 | 12.44 |
| 25 | SCL-1 | Claremont, N.H. | 43°22′ | 10 | 16 | 4/29 | 5/20 | 10.11 |
| 65 | BSA-1 | Sanborton, N.H. | 43°30′ | 10 | 19 | 4/26 | 5/19 | 11.76 |
| 35 | ONOR-1 | Northumberland, N.H. | 44°30′ | 10 | 18 | 4/29 | 5/21 | 11.49 |
| 22 | ME 33 | Wells, Maine | 43°20′ | 11 | 18 | 4/30 | 5/25 | 12.53 |
| 23 | ME 32 | Wells, Maine | 43°20′ | 11 | 19 | 4/26 | 5/21 | 13.57 |
| 11 | ME 23 | Standish, Maine | 43°45′ | 11 | 18 | 4/25 | 5/19 | 11.08 |
| 64 | ME 10 | Durham, Maine | 43°55′ | 11 | 19 | 4/26 | 5/20 | 13.14 |
| 15 | ME 12 | Fryeburg, Maine | 44°00′ | 11 | 17 | 4/29 | 5/20 | 11.46 |
| 21 | ME 28 | Waldoboro, Maine | 44°05′ | 11 | 18 | 4/27 | 5/18 | 10.00 |
| 2 | -- | Searsmont, Maine | 44°30′ | 1 | 19 | 4/28 | 5/22 | 12.26 |
| 48 | ME 2 | Anson, Maine | 44°50′ | 11 | 16 | 4/29 | 5/22 | 12.59 |
| 47 | -- | Ile du Grand Calumet, P.Q. | 45°47′ | 2 | 18 | 4/28 | 5/23 | 12.97 |
| 4 | -- | Ile aux Allumettes, P.Q. | 45°54′ | 2 | 18 | 4/27 | 5/20 | 11.06 |
| 14 | -- | Deux Rivieres, P.Q. | 45°16′ | 2 | 20 | 4/28 | 5/19 | 9.92 |
| 53 | ONT 538 | Ontario | n.a. | 12 | 15 | 4/29 | 5/20 | 9.61 |
| 61 | WI 133 | Chequamegon N.F., Wis. | 45°55′ | 12 | 15 | 4/28 | 5/19 | 9.97 |
| 55 | U 113 | Ontonagon County, Mich. | 46°35′ | 12 | 18 | 4/30 | 5/20 | 9.40 |
| 58 | Patton 312 | Plantation at Duluth, Minn. | 46°45′ | 12 | 20 | 4/27 | 5/21 | 11.84 |
| 63 | MN 27 | Beltrami Co., Minn. | 47°38′ | 12 | 8 | 5/2 | 5/19 | 8.18 |
| | | Plantation mean | | | | | | 12.42 |

[1]Sources: native stand (bulk collection) = 1; native stand (single tree) = 2; plantation (bulk) = 3; seed orchards at Harmans, Md. #1 = 4; Harmans, Md. #2 = 5; Potters Mill, Pa. = 6; Chenango Co., N.Y. = 7; Chemung Co., N.Y. = 8; Moscow, Vt. = 9; Merrimac St. For., N.H. = 10; Veasie, Maine = 11; Oconto River, Wis. = 12.
Seed orchard means and dispersion from plantation mean:

| | |
|---|---|
| Native stands | 11.60 (+6% to −25%) |
| Ohio plantation | 13.87 (+12%) |
| Harmans, Md. #1 | 13.93 (+46% to −31%) |
| Harmans, Md. #2 | 10.97 (−13%) |
| Potters Mill, Pa. | 12.88 (+25% to −14%) |
| Chenango Co., N.Y. | 13.68 (+10%) |
| Chemung Co., N.Y. | 11.59 (−7%) |
| Moscow, Vt. | 13.40 (+26% to +2%) |
| Merrimac St. For., N.H. | 12.32 (+27% to −25%) |
| Veasie, Maine | 12.08 (+9% to −24%) |
| Oconto River, Wis. | 9.8 (−5% to −52%) |

[2]-- = no number assigned.

than the plantation mean, 57 percent more than the mean for the eight native-stand lots, and 122 percent more than mean growth of the poorest lot, no. 63 (Minnesota).

A block effect present in dates of beginning and ending growth, but absent in length of new shoot, appeared to be caused by earlier growth at the less windy end of the plot.

## Discussion

Great differences in performance between the best and worst seed orchard lots reflect genecological divergence between white pine strains from opposite ends of the tree's natural range. This and the effects of selection under domestication are the chief causes of seed source variation in performance.

As might be reasonably expected, seedlings from the northwestern edge of white pine's range were the poorest growers at New Brunswick, which lies along the southeastern border of its range in New Jersey. Seedlings of trees selected in nearby Maryland and Pennsylvania, where the climate is more like that in New Brunswick, performed best. Among the Maryland families tested, all four from seed parents native east of the

**Table 2**—*Results of analyses of variance for second-year growth of white pine at New Brunswick, N.J.*

| | df | SS | ms | F |
|---|---|---|---|---|
| | **Date new growth > 2 cm** | | | |
| Block | 3 | 3.16 | 1.05 | 3.00 ($p < 0.05$) |
| Provenance | 59 | 51.48 | .87 | 1.71 ($p < 0.0001$) |
| B × P | 174 | 88.45 | .51 | |
| Tree (B × P) | 800 | 281.75 | .35 | |
| Total | 1036 | 424.66 | | |
| | **Date further growth < 1 cm** | | | |
| Block | 3 | 3.49 | 1.16 | 4.64 ($p < 0.01$) |
| Provenance | 59 | 57.67 | .98 | 2.88 ($p < 0.0001$) |
| B × P | 174 | 59.47 | .34 | |
| Tree (B × P) | 799 | 199.03 | .25 | |
| Total | 1035 | 318.98 | | |
| | **Season's growth** | | | |
| Block | 3 | 20.28 | 6.76 | 0.49 n.s. |
| Provenance | 59 | 2970.86 | 50.35 | 2.18 ($p < 0.0001$) |
| B × P | 174 | 4027.89 | 23.15 | |
| Tree (B × P) | 799 | 11020.08 | 13.79 | |
| Total | 1035 | 18042.75 | | |

Appalachians were outstanding, while those from seed parents native in western Maryland (Garrett County) were poor. The strong showing of Vermont seedlings runs counter to the general latitude trend and may indicate either a local region of fast growth or high caliber of Vermont's white pine improvement program.

The inverse correlation of juvenile growth with latitude of origin of genetically improved white pine points to desirability of testing seed orchard progeny from the Southern Appalachians. Although the prediction equation does not indicate that an advantage will be gained by testing trees originating from this area, the increasing dispersion of actual seedlot performance above and below predicted values as one moves southward indicates that some southern lots might be extremely good. Further, the prediction equation is influenced by the presence of three subpar lots from Garrett County, Md., an area of short frost-free growing seasons comparable to those of higher latitude areas. In earlier provenance tests (2, 3), Southern Appalachian white pine performed exceptionally well at midrange-latitude test locations.

Our data represent only 1 year's growth at one test location in New Jersey. Our plantation is one of 10 roughly similar ones in New Jersey, Maryland (2), Michigan, Pennsylvania, New York (2), Connecticut, Vermont, and New Hampshire. After data from other plantations and other years become available, intelligent decisions on retention or roguing of parent clones in seed orchards can be made. We believe that our most significant finding is the large variability among families within seed orchards.

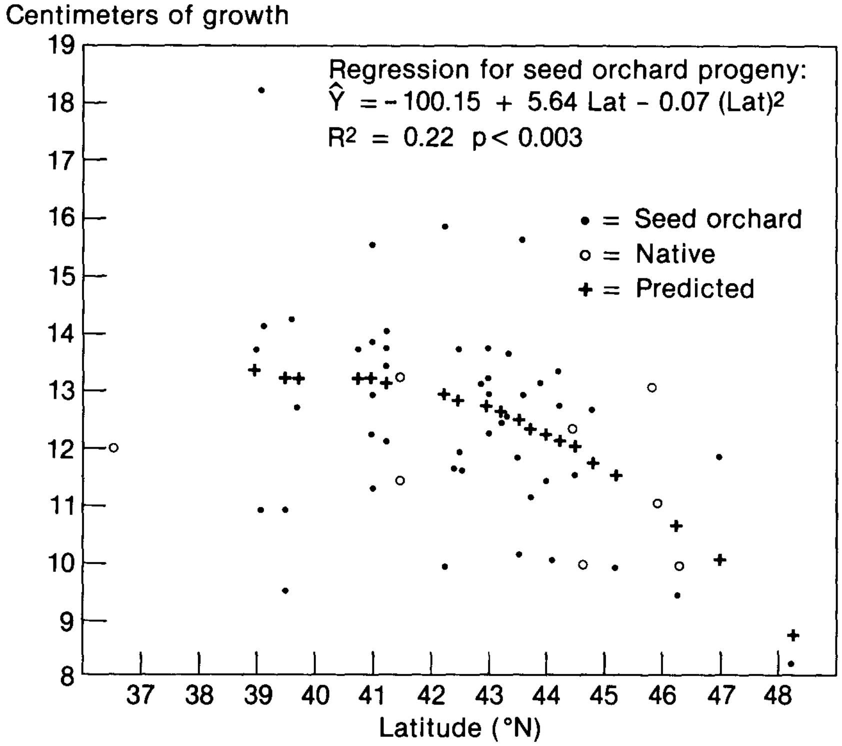


**Figure 1**—*Relation of second-field-year growth of white pine at New Brunswick, N.J., to latitude of origin of female parent.*

## Literature Cited


1. Garrett, P. W.; Schreiner, E. J.; Kettlewood, H. Geographic variation of eastern white pine in the Northeast Res. Pap. NE-274. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1973.
2. Williams, R. D.; Funk, D. T. Eighteen-year performance of an eastern white pine genetic test plantation in southern Indiana. Proc. Indiana Acad. Sci. 1977 87: 116-119; 1978.
3. Wright, J. W. Genetics of eastern white pine. Res. Pap. WO-9. Washington, DC: U.S. Department of Agriculture; 1970.
4. Wright, J. W.; Amiel, R. J.; Cech, F. C.; Kriebel, H. B.; Jokela, J. J.; Lemmien, W. A.; Matheson, A. C.; Meritt, C.; Read, R. A.; Roth, P.; Thor, P.; Thulin, I. J. Performance of eastern white pine from the Southern Appalachians in Eastern United States, New Zealand, and Australia. In: Proceedings, 25th Northeastern forest tree improvement conference; 1978 July 25-27; University Park, PA. Durham, NH: Northeastern Forest Experiment Station; 1978.

# Longleaf Pine Growth Following Storage and Benomyl Root-Dip Treatment

**A. G. Kais and J. P. Barnett**

*Principal Plant Pathologist, Southern Forest Experiment Station, USDA Forest Service, Gulfport, Miss., and Research Forester, Southern Forest Experiment Station, USDA Forest Service, Alexandria, La.*

*For longleaf pine seedlings, the length of cold storage before outplanting significantly affected survival and growth, while the benomyl root-dip treatment primarily affected incidence of brown-spot needle blight. Seedling response to both of these treatments was further affected by climatic conditions that existed during the first year after outplanting.*

Acceptable survival and subsequent growth of southern pine seedlings can depend upon critical storage factors (8). Longleaf pine *(Pinus palustris* Mill.) has been especially difficult to reproduce by natural or artificial methods. (3). The survival of longleaf pine is particularly influenced by seedling size and the length of storage (1, 4, 6). Drought conditions during the first growing season in the field also affect longleaf pine survival and growth (4, 5). More recently, longleaf pine survival and growth were increased following a benomyl root-dip treatment at outplanting (1, 2). The benomyl treatment also reduced brown-spot needle blight caused by *Scirrhia acicola* (Dearn.) Siggers.

A 1980 study investigated whether benomyl root-dip treatments could improve the survival and growth of longleaf pine seedlings held in cold storage for various periods following lifting. Unfortunately, high temperatures and drought conditions in the spring and summer of 1980 affected survival of newly established pine plantations throughout the South (7). Consequently, the effects of the benomyl dip treatment and storage time on survival, brown spot infection, and growth were evaluated in respect to climatic conditions at the specific planting sites.

**Materials and Methods**

Longleaf pine seedlings were lifted at the Ashe Nursery at Brooklyn, Miss., during the week of January 7 to 11, 1980. These seedlings were packed in kraft-polyethylene bags with moist sphagnum peat moss and stored at 35° F (2° C) until time of outplanting. A total of 210 bundles (6,300 seedlings) were lifted and prepared for storage at two locations. One planting location was the Harrison Experimental Forest (HEF) at Saucier, Miss., and the other was the Palustris Experimental Forest (PEF) near Alexandria, La.

A bundle of 375 seedlings was removed from storage and outplanted at each site atter 1, 14, 28, 42, 56, 70, and 84 days of storage. Seedlings were dip-treated with one of three mixtures just before outplanting: (1) Kaolinite clay, (2) a mixture of Kaolinite clay and 5-percent active ingredient (a.i.) benomyl, and (3) a mixture of Kaolinite clay and 10-percent a.i. benomyl. The root systems of 25 seedlings were moistened in water and then shaken in plastic bags containing one treatment, thus giving an even coating of the material. Treated seedlings were outplanted in each of five blocks at each site on each of seven planting dates. Twenty-one treatment combinations were randomly planted within each block at the two planting sites. Seedlings were planted by dibble bar at a 2-foot by 4-foot spacing on previously scalped 15-foot swaths at each site. The seven HEF planting dates were January 9 and 23, February 5 and 19, March 4 and 19, and April 2, 1980; the seven PEF planting dates were January 14 and 28, February 11 and 25, March 10 and 24, and April 7, 1980.

Notations and measurements of survival, the percentage of brown spot infection, and height growth were made on all seedlings during October 1981, the second year of growth in the field. Visual estimates were made of the percentage of needle tissue killed by brown-spot infection, and seedling heights were measured from soil line to terminal bud tip.

This study was designed and installed as a randomized complete block with five replicates. Each block consisted of 21 treatment rows. Data were analyzed independently at each location as a factorial consisting of three dip treatments and seven storage periods. Duncan's multiple range test (p = 0.05) was used to compare treatment means for the various parameters.

**Results**

***Survival.*** Seedling survival was much greater at the HEF-Mississippi site than at the PEF-Louisiana site after 2 years' growth in the field (table 1). The overall mean survival at the HEF site was 85.3 percent with a range from 75.2 to 99.2 percent. The PEF site had 26.9 percent mean survival with a range from 2.4 to 61 .6. For each site, significant differences in survival were attributed only to storage

**Table 1**—*Longleaf pine seedling survival, brown spot infection, and height growth following cold storage and benomyl root-dip treatment*

| Dip treatment and storage | Seedling survival | | Brown spot infection | | Height | Seedlings > 10 cm tall |
|---|---|---|---|---|---|---|
| | HEF | PEF | HEF | PEF | HEF | HEF |
| *Days* | % | | | | *Cm* | % |
| Clay dip | | | | | | |
| 1 | 99.2a | 47.2bc | 23.5a | 5.0a | 13.6abc | 66.2abc |
| 14 | 99.2a | 43.2c | 17.4ab | 3.4a | 12.4bcde | 58.2abcd |
| 28 | 84.8abc | 28.0d | 11.8bcd | 3.8a | 11.3cdef | 59.4abcd |
| 42 | 68.8c | 15.2efg | 6.9cdef | 3.3a | 10.1def | 44.0cde |
| 56 | 82.4abc | 23.2de | 12.6bc | 2.0a | 9.2ef | 42.8cde |
| 70 | 84.8abc | 16.0efg | 11.4bcde | 4.0a | 10.8cdef | 37.8de |
| 84 | 88.8abc | 2.4h | 7.1cdef | 3.0a | 10.1def | 39.4de |
| Mean | 86.9 | 25.0 | 13.0 | 3.5 | 11.1 | 49.7 |
| Benomyl 5% a.i. | | | | | | |
| 1 | 96.0ab | 61.6a | 5.3def | 4.6a | 14.7ab | 78.7a |
| 14 | 93.6ab | 48.0bc | 3.5f | 3.4a | 12.4bcde | 61.2abcd |
| 28 | 84.0abc | 24.0de | 4.9def | 3.8a | 13.2abcd | 67.8abc |
| 42 | 80.8abc | 24.8de | 4.7ef | 3.2a | 10.6cdef | 53.6abcde |
| 56 | 87.2abc | 18.4e | 4.3ef | 2.8a | 9.9def | 44.4cde |
| 70 | 75.2bc | 7.2gh | 3.7f | 3.0a | 11.0cdef | 56.0abcde |
| 84 | 85.6abc | 17.4ef | 4.6ef | 2.3a | 9.4ef | 53.0abcde |
| Mean | 86.1 | 28.8 | 4.3 | 3.3 | 11.6 | 59.3 |
| Benomyl 10% a.i. | | | | | | |
| 1 | 95.2ab | 57.6a | 3.2f | 5.4a | 15.6a | 77.0ab |
| 14 | 93.6ab | 54.4ab | 3.2f | 5.0a | 11.9bcde | 61.0abcd |
| 28 | 80.8abc | 24.8de | 3.5f | 3.8a | 11.8bcde | 59.6abcd |
| 42 | 76.8bc | 20.0de | 5.4def | 2.2a | 9.4ef | 39.2de |
| 56 | 80.8abc | 15.2efg | 3.4f | 3.0a | 9.9def | 51.6bcde |
| 70 | 78.4abc | 8.0gh | 2.6f | 4.0a | 11.6bcde | 56.8abcde |
| 84 | 75.2bc | 8.8fgh | 3.4f | 1.4a | 8.2f | 32.0e |
| Mean | 83.0 | 27.0 | 3.5 | 3.5 | 11.2 | 53.9 |

[1]For each column, values not followed by the same letter are significantly different ($p$ = 0.05).

time before outplanting. Survival generally decreased with storage increases, but the decreases were greater on the PEF site where environmental stresses were greater. The various dip treatments had no significant effect on seedlings survival at either site.

***Infection.*** Brown spot infection rates were comparatively low for the longleaf pine seedlings at both sites following the second year in the field (table 1). However, more fungal infection did occur on the longleaf seedlings at the HEF site than at the PEF site. Significant differences due to dip treatment were evident on the HEF seedlings, but treatment did not affect the PEF seedlings. Brown spot infection differences on the HEF seedlings were related to dip treatment, storage time, and the interaction of the two.

***Growth.*** Stem heights were determined only for the seedlings at the HEF site since stem elongation had not begun on the seedlings at the PEF site (table 1). Significant differences in height could be related only to storage time. The percentage of seedlings displaying rapid height growth (stem length > 10.0 cm) was determined only on the HEF site. Significant differences between these percentages are related only to differences in storage times (table 1).

## Discussion

Study results were confounded by the adverse climatic conditions during 1980, the first year of field growth. The extremely high temperatures and drought conditions during the late spring and summer of 1980 apparently had a significant effect on the survival, brown-spot infection, and height of the outplanted seedlings (tables 2 and 3). The Louisiana site experienced higher maximum daily temperatures from June through September and more days exceed-

**Table 2**—*Maximum daily temperatures at two outplanting sites from April through September 1980*

| Month | Maximum temperatures (°F) | | | | | | Mean (°F) |
|---|---|---|---|---|---|---|---|
| | <60 | 61-70 | 71-80 | 81-90 | 91-100 | >100 | |
| | *Frequency (days)* | | | | | | |
| April | 0; 1[1] | 3; 4 | 18; 14 | 9; 11 | 0; 0 | 0; 0 | 79.0; 77.1 |
| May | 0; 0 | 0; 0 | 9; 7 | 22; 21 | 0; 3 | 0; 0 | 83.6; 84.5 |
| June | 0; 0 | 0; 0 | 0; 0 | 6; 7 | 24; 22 | 0; 1 | 92.0; 92.7 |
| July | 0; 0 | 0; 0 | 1; 0 | 6; 3 | 19; 16 | 5; 12 | 94.0; 97.3 |
| August | 0; 0 | 0; 0 | 0; 0 | 5; 3 | 26; 19 | 0; 9 | 92.7; 96.6 |
| September | 0; 0 | 0; 0 | 0; 1 | 12; 6 | 18; 23 | 0; 0 | 91.4; 92.9 |
| Total | 0; 1 | 3; 4 | 28; 22 | 60; 51 | 87; 83 | 5; 22 | |

[1]First entry is HEF site in Mississippi; while second entry is PEF site in Louisiana.

**Table 3**—*Rainfall at two outplanting sites from April through September 1980*

| Month | Rainfall in inches | | | | | Total days | Total inches |
|---|---|---|---|---|---|---|---|
| | <0.2 | 0.2-0.6 | 0.6-1.0 | 1.0-2.0 | >2.0 | | |
| | *Frequency (days)* | | | | | | |
| April | 3; 1[1] | 3; 3 | 0; 1 | 1; 0 | 3; 1 | 10; 6 | 12.35; 5.54 |
| May | 5; 1 | 2; 0 | 2; 0 | 2; 0 | 1; 0 | 12; 1 | 11.36; .12 |
| June | 3; 1 | 3; 1 | 1; 0 | 0; 0 | 0; 0 | 7; 2 | 2.22; .51 |
| July | 1; 0 | 7; 0 | 1; 0 | 1; 1 | 0; 0 | 10; 1 | 5.25; 1.51 |
| August | 6; 1 | 2; 0 | 1; 1 | 0; 0 | 0; 0 | 9; 2 | 1.90; .88 |
| September | 6; 1 | 3; 2 | 0; 1 | 1; 0 | 0; 0 | 10; 4 | 3.29; 1.62 |
| Total | 24; 5 | 20; 6 | 5; 3 | 5; 1 | 4; 1 | 58; 16 | 36.37; 10.18 |

[1]First entry is HEF site in Mississippi; while second entry is PEF site in Louisiana.

ing 100° F than the site in Mississippi (table 2). The incidence and amount of precipitation from May through September were much less at the PEF site than at the HEF site (table 3). This combined effect of high temperatures and drought particularly inhibited seedling growth on the Louisiana site; it also somewhat affected seedling growth on the Mississippi site.

For the two seedling treatments, storage time apparently had the greatest effect on survival and height growth, while the two benomyl root-dip treatments had the greatest effect on brown spot infection. However, these treatment effects were also affected by the prevailing climatic conditions during the summer following planting. It is possible that results associated with length of storage were confounded by the climatic conditions that occurred during the 84-day planting period.

Survival was surprisingly high at the HEF site even for seedlings that had been stored for 84 days (75.2 percent). Maximum survival for PEF seedlings, however, was 61.6 percent for seedlings stored for only 1 day. These results suggest that climatic conditions following outplanting may be more important for longleaf pine survival than seedling storage time, assuming suitable storage and planting techniques. Longleaf seedlings apparently lose vigor and become more affected by adverse weather conditions as storage time is increased.

The prevailing drought had a significant effect on the amount of brown spot infection that developed, especially at the Louisiana site. The dissemination and germination of *S. acicola* conidia, which are dependent on rain splash and high humidity, were significantly restricted during the first year. Brown spot infection began to increase on the seedlings at the HEF site during the second year, but was still inhibited at the PEF site (table 1). Consequently, the effect of the benomyl root-dip treatment was observable only at the Mississippi site.

Total height growth and percentage of seedlings displaying rapid height growth were generally greater for the shorter storage regimes and the two benomyl root-dip treatments (table 1). None of the treatments had any significant effect on growth during unfavorable climatic conditions.

Maximum seedling survival, height growth, and minimal brown spot infection occurred when seedling storage time was reduced, when seedlings were treated with the benomyl root-dip treatment, and when favorable weather occurred. However, acceptable survival, height growth, and disease control should also be possible for seedlings held in extended cold storage and dip-treated with benomyl, as long as favorable weather conditions precede and follow planting.

## Literature Cited


1. Kais, A. G. Longleaf pine production-- A cooperative endeavor. In: Proceedings 1980 southern nursery conference; 1980 September 2-4; Lake Barkley, KY. Tech. Pub. SA-TP17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area State and Private Forestry: 1981: 73-85.
2. Kais, A. G.; Snow, G. A.; Marx, D. H. The effects of benomyl and *Pisolithus tinctorius* ectomycorrhiazae on survival and growth of longleaf pine seedlings. South. J. App. For. 5: 189-195; 1981.
3. Mann, W. F., Jr. At last-longleaf pine can be planted successfully. For. Farmer 28: 6-7, 18-19; 1969.
4. Shipman, R. D. Survival and growth of graded longleaf pine nursery stock. J. For. 58: 38, 39, 42; 1960.
5. Wakeley, P. C. Planting the southern pines. Agric. Monog. 18. Washington, DC: U.S. Department of Agriculture; 233 p. 1954.
6 White J. B. The influence of seedling size and length of storage on longleaf pine survival. Tree Plant. Notes. 32: 34; 1981.
7. Williston, H. L. Drought and fire result in heavy toll on southern forests. For. Farmer 40: 6-8; 1981.
8. Williston, H. L. Storage of southern pine seedlings; a review. Tree Plant. Notes. 25: 1-3; 1974.

Tree Planter's Notes, Vol. 35, No. 1 (1984)



# Seedling Size and Lifting Date Effects on Root Growth Potential of Loblolly Pine From Two Arkansas Nurseries

**John C. Brissette and Terrence C. Roberts**[1]
*Nursery and Tree Improvement Specialist, USDA Forest Service, Southern Region, Jackson, Miss.; and Nursery Supervisor, International Paper Co., Blenheim, S.C. (formerly Reforestation Manager, Arkansas Forestry Commission)*

*Loblolly pine seedlings lifted in March had greater new root growth than stock lifted in November or January, and large seedlings had more new root growth than medium or small seedlings for two of the lifting dates.*

The ability of newly outplanted seedlings to become established depends on their physiological readiness to produce new roots. Root growth potential (RGP) is a measure of new root growth determined after lifted seedlings are potted and grown for a specified time in a growth chamber or greenhouse. In the Western United States and in Canada, RGP has been used to evaluate physiological quality of seedlings in research tests and operational outplantings (1, 3). Relatively higher RGP generally indicates greater seedling quality than lower RGP.

In most species studied thus far, RGP is cyclic and appears related to the terminal bud dormancy cycle (3). Typically, RGP increases during the autumn and winter months, peaks in late winter or early spring, and declines rapidly just before bud burst. Because it is cyclic, RGP is affected by the timing of various nursery cultural treatments. Lifting date, for example, has major impact on RGP.

For the past several years, marked differences in average size and apparent vigor have been observed between loblolly pine (*Pines taeda* L.) seedlings grown at the two Arkansas Forestry Commission nurseries. This study was initiated to determine if differences in RGP existed between stock from the two nurseries and among seedlings from each nursery. A secondary objective was to investigate whether any differences measured in RGP related to differences in first-year field performance.

## Materials and Methods

Nursery A is located near the geographic center of Arkansas on a silt loam soil of alluvial origin from the Arkansas River. This nursery has been in operation since the mid-1950's. Established about 1940, nursery B is in the southwest part of the State on a sandy loam Coastal Plain soil.

Seedlings from the same seedlot were not available at both nurseries. At nursery A, seedlings were grown from open-pollinated seeds collected in an unrogued clonal seed orchard consisting of selections from the northern half of Arkansas. Stock at nursery B was grown from seeds collected in a similar seed orchard of southern Arkansas origin.

The seedlings used in this study received no special treatment while in the nursery. Stocks at each nursery were top pruned in late July. They were also undercut and laterally root pruned in October.

Seedlings for this study were hand-lifted in 8-week intervals from both nurseries on November 24, 1981, and January 19 and March 16, 1982. Because of the size differences, seedlings from each nursery were subdivided into three classes-large, medium, and small. These classes approximated the root collar diameter specifications of the morphological grades for loblolly pine seedlings described by Wakeley (4). They differed, however, because it was difficult to identify grade 3 seedlings at nursery A or grade 1 seedlings at nursery B.

After lifting, the seedlings were protected from heat and exposure and brought to the greenhouse at nursery A within 30 hours. Any new, white root growth was clipped off. The seedlings were potted in 1-gallon (4.5 liter) containers using a commercial 1 :1 :1 peat, vermiculite, and perlite medium. They were grown in the heated greenhouse, which varied from about 55° F (13° C) at night up to 80° F

[1]The authors wish to thank the Arkansas Forestry Commission for providing facilities and assistance for this study.

(26° C) on some days. The seedlings were grown under natural photoperiods for 28 days. They were watered as necessary to maintain the medium at near field capacity.

Among the seedlings lifted in November, each treatment (size class by nursery) was represented by five replicates of four trees. Because variability within treatments was high, the number of replicates was increased to 10 for the January- and March-lifted treatments.

After the 28-day growing period, the seedlings were removed from the pots and soil was carefully washed from the roots. All new root growth was measured and the total recorded to the nearest centimeter.

Seedlings lifted at the same time as those used for the RGP evaluation were outplanted in an unused portion of nursery A within 48 hours of lifting. Seedling size was not an experimental factor in the field plantings. Each treatment (nursery by lifting date) was represented by a 25-tree plot planted in four replications. Survival and total height were measured after the first growing season.

**Table 1**—*Root growth potential of graded loblolly pine seedlings from two Arkansas Forestry Commission nurseries, 1981–82*

| Lifting date | Seedling size | Average new root growth | | |
|---|---|---|---|---|
| | | Nursery A | Nursery B | Mean |
| | | Cm | | |
| Nov. 24 | L | 9.7 | 3.0 | 6.4 |
| | M | 5.1 | 4.5 | 4.8 |
| | S | 5.4 | 7.3 | 6.4 |
| | Mean | 6.7 | 4.9 | 5.8 |
| Jan. 19 | L | 96.7 | 44.9 | 70.8 |
| | M | 39.9 | 28.3 | 34.1 |
| | S | 36.3 | 11.4 | 23.8 |
| | Mean | 57.6 | 28.2 | 42.9 |
| Mar. 16 | L | 108.6 | 38.9 | 73.8 |
| | M | 54.9 | 54.5 | 54.7 |
| | S | 51.2 | 22.6 | 36.9 |
| | Mean | 71.6 | 38.7 | 55.1 |

## Results and Discussion

Root growth potential varied considerably among the various treatments (table 1). In each treatment, some seedlings did not exhibit any RGP. However, the new root growth of some seedlings was astonishing. One of the large seedlings lifted in March from nursery A had new root growth after 28 days totaling 23.7 feet (7.2 m) from approximately 360 growing points.

Among all the seedlings in the greenhouse study, mortality was 7.3 percent. The mortality occurred among seedlings from both nurseries and from each size class on at least one lifting date. The worst mortality in the greenhouse (22.5 percent) was among the small seedlings lifted in January from nursery B.

***Nursery effects.*** Seedlings from nursery A consistently had greater RGP than seedlings from nursery B (table 1). Although the November RGP difference between stock from the two nurseries was not significant ($p = 0.05$), those differences in January and March were highly significant ($p = 0.01$). However, these results do not indicate a clear contrast between nurseries because the same seedlots were not available from both nurseries. Therefore, it was not possible to separate RGP differences between nurseries from seed source effects. A subsequent experiment is now underway to determine those differences.

***Seedling size effects.*** Seedling size had a marked impact on RGP. In general, larger seedlings had greater RGP than smaller seedlings (table 1). Although this relationship did not occur among stock lifted in November, there were no significant (p = 0.05) differences in RGP for that lifting date. When averaged for both nurseries and all three lifting dates, the large seedlings had significantly (p = 0.05) more RGP than the small size class. Differences between large and medium seedlings, and between medium and small seedlings were not significant.

The positive relationship between seedling size and RGP was also reversed for medium and large seedlings lifted in March at nursery B (table 1). RGP declines rapidly just before bud break, which may explain why the large seedlings had lower RGP than the medium seedlings in that case. The buds of the large seedlings may have been more physiologically active than buds of the smaller size classes, thus accounting for the lower RGP. Such an anomaly to the general trend did not occur among March-lifted trees from nursery A but bud burst would be expected first at nursery B because it is farther south.

No attempt was made to measure root area, mass, or volume of the seedlings used in this study. From observations, however, the larger seedlings appeared to have bigger root systems and therefore more sites for new root growth RGP may also be related to food storage capacity; ial11gef seedlings have more stored. Carbohydrate reserves to use for producing new snots before the needles can supply sufficient photosynthate for rapid growth (2) .

Much of the contrast in RGP between the nurseries may be attributed to seedling size. From nursery A, medium and small seedlings respectively approximated the size of large and medium seedlings from nursery B. The similarities in RGP among these four size classes for the January and March lifting dates would indicate that seedling size had a more direct effect on RGP in this study than did nursery site. However, because larger seedlings were grown at nursery A, the effects of nursery site and culture on seedling size, and consequently on RGP, were important.

***Lifting date effects.*** The greatest differences in RGP were among the three lifting dates (table 1). The November-lifted seedlings had very low average RGP (5.8 cm). The January-lifted trees had over 700 percent more average new root growth (42.9 cm) than seedlings lifted earlier. The March-lifted seedlings averaged an additional 28 percent greater RGP (55.1 cm) compared to seedlings lifted in January. The differences in RGP between the November-lifted seedlings and the two later lifting dates were significant (p = 0.05) The RGP difference between January and March lifting was not significant.

We chose the three lifting dates to be what is generally considered early optimum and late. The RGP of seedlings lifted in midwinter (i.e., mid-December through mid-February) could typically be expected to be high and rather stable. However, before and after this period, RGP would be less predictable and vary considerable from year to year. RGP in this study averaged higher among March-lifted seedlings than January-lifted stock indicating that the seedlings had not yet initiated bud break. The date of bud burst varies greatly depending on the weather; and in another year, RGP of stock lifted in mid-March might be very low Possibly, RGP may have peaked sometime between the latter two lifting dates and was declining when the seedlings were lifted in March.

Together, lifting date and seedling size had a dramatic impact on RGP (fig. I). The greatest RGP was from urge seedlings from the last lifting date. in both January and March, the medium seedlings had RGP intermediate between large and small seedlings. In November, ail of the size classes had very low RGP.

***RGP and field performance.*** Those seedlings that were outplanted in an unused and nonirrigated portion of nursery A were left unattended. They encountered severe grass competition, but otherwise growing conditions were excellent. Over all first-year survival was 89 percent, with the highest survival from the January

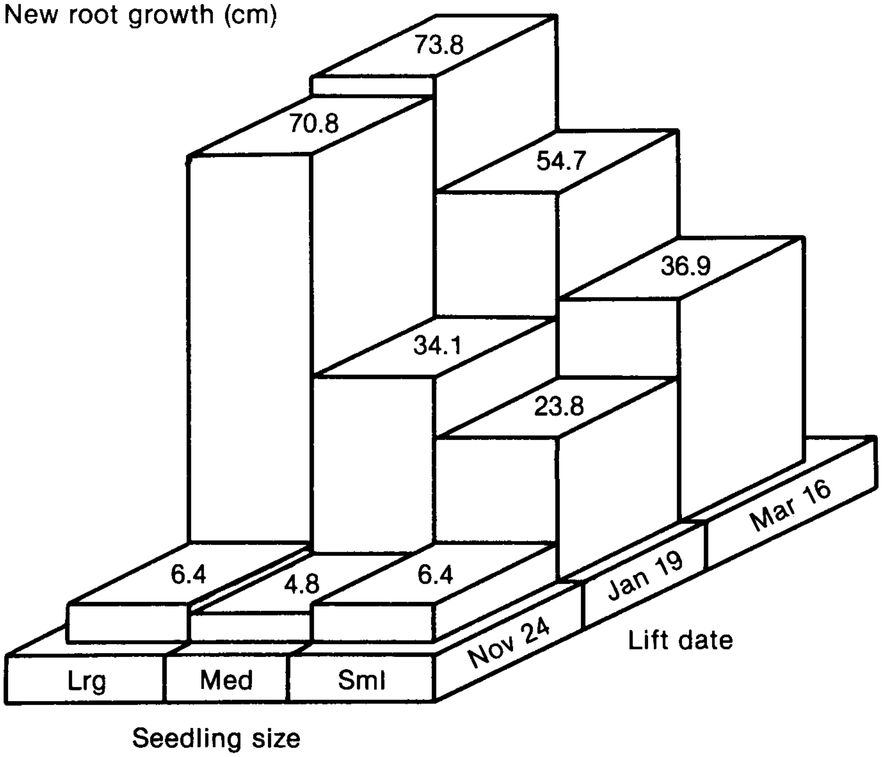


**Figure 1**—*Root growth potential (cm) of graded loblolly pine seedlings averaged for two Arkansas Forestry Commission nurseries for three lifting dates in 1981-82.*

planting date (table 2). Nursery A seedlings were taller than stock from nursery B when planted and retained that height advantage after one growing season. The tallest seedlings from both nurseries were those planted in November (table 2).

The correlation between average RGP and arc sine transformed survival was low (r = 0.14) and not significant (p = 0.05). The correlation between RGP and average seedling total height was somewhat better (r=0.26), but still not significant. These relationships may have been stronger if the seedlings had encountered more stressful conditions during the first growing season.

Although RGP did not correlate strongly with field performance in our study, it has proved to be a good predictor of field performance in other experiments. In their review, Ritchie and Dunlap (3) cite numerous studies with several species, including loblolly pine, in which RGP had positive, good-to-strong correlations with field survival. Only with three hardwood species did they cite no correlation or an inverse correlation.

**Table 2**—*First-year survival and total height of loblolly pine seedlings lifted on three dates from two Arkansas Forestry Commission nurseries*

| Lifting date | Nursery A | | Nursery B | | Mean | |
|---|---|---|---|---|---|---|
| | Survival | Total height | Survival | Total height | Survival | Total height |
| | % | Cm | % | Cm | % | Cm |
| Nov. 24 | 95 | 31.0 | 67 | 28.3 | 81 | 29.9 |
| Jan. 19 | 99 | 29.5 | 100 | 27.2 | 100 | 28.4 |
| Mar. 16 | 81 | 33.1 | 92 | 23.4 | 87 | 28.2 |
| Mean | 92 | 31.2 | 86 | 26.3 | 89 | 28.8 |

### Implications for Nursery Management

Evaluating RGP offers many benefits to nursery managers who have even a simple greenhouse available for growing seedlings.

The greatest benefit comes when RGP is evaluated for various dates over several lifting seasons. The optimum range of lifting dates, or the best "lifting window," can then be determined for a particular nursery. The technique can also be used to evaluate the effects of nursery site, seed source, and various cultural practices on new root growth.

In British Columbia, a modified version of the RG P test, taking only 7 days, is used to evaluate the quality of batches of nursery stock (1). More research is needed before the technique will have a real value in predicting field performance of southern pine seedlings because of the time now needed to conduct the test and the variability among seedlings. The greatest value of RGP testing is therefore in improving the quality of future crops by quantifying the effects of present nursery practice.

A side benefit we gained while conducting this study was a better understanding of pine seedling physiology. Observing and measuring the roots of many seedlings and analyzing the results provided the opportunity to study root growth in detail. The study has given us a better appreciation for seedling growth and the impacts that nursery management can have on seedling quality.

## Literature Cited


1. Burdett, A. N. New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. Can. J. For. Res. 9: 63-67; 1979.
2. Hay, Ronald L.; Woods, Frank W. Carbohydrate relationships in root systems of planted loblolly pine seedlings. In: Van Eerden, Evert; Kinghorn, James M. eds. Root form of planted trees: Proceedings of the symposium; 1978 May 16-19; Victoria, BC. Joint Report No. 8. Victoria, BC: British Columbia Ministry of Forests/Canadian Forestry Service; 1978: 73-84.
3. Ritchie, G. A.; Dunlap, J. R. Root growth potential: its development and expression in forest tree seedlings. New Zealand J. For. Sci. 10(1): 218-248; 1980.
4. Wakeley, Philip C. Planting the southern pines. Agric. Monog. No. 18. Washington, DC: U.S. Department of Agriculture, Forest Service; 1954. 233 p.