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# Tree Improvement Comes of Age in the Pacific Northwest—Implications for the Nursery Manager

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*Tree improvement programs in the Pacific Northwest have reached the stage of supplying limited, but ever increasing, quantities of genetically improved seed to nurseries for regional regeneration programs. With this seed come opportunities as well as responsibilities for the nursery manager. The nursery manager plays an important role in "capturing," packaging, and transferring the potential for genetic gain in the integrated forest management system.* Tree Planters' Notes 38(3): 3-8; 1987.

The status of tree improvement today in the Pacific Northwest can be likened to a relay race. The tree improvement worker is nearing the end of the first lap and is about to pass the baton onto the nursery manager. The handoff is critical, as is the race strategy. We need to give thought to both these elements and to better understand how our concerted efforts will make our investment in tree improvement a winner.

In keeping with this theme, the objectives of this paper are threefold:

1. To briefly review the status of tree improvement in the region and its impact on regeneration programs.
2. To develop the concept of genetic gain, and its "capture," packaging, and transfer into an integrated forest management system.
3. To explore the role of nursery managers in this system and their opportunities to maintain or even enhance the potential of genetically improved planting stock.

## The Development and Status of Tree Improvement in the Region

Tree improvement programs, as we think of them today with selection, breeding, testing and seed production functions, started in the Pacific Northwest in the mid-1950's. By 1960, several Douglas-fir seed orchards had been established, representing both Federal and private organizations. During the 1960's, few new orchards were established.

However, with the 1970's came a surge of activity—by 1980 at least 82 orchards, representing more than a dozen species, had been established (3). There are about 90 orchards today, with about half of them growing Douglas-fir. Douglas-fir orchards cover about 1,700 acres, about 75% of the total orchard acres for all species.

To support this very large production activity, much effort has been placed on selection of parents from natural stands. In the "Douglas-fir region" alone, close to 30,000 "parent" or "plustree" selections have been made, with about 26,000 of them Douglas-fir. More than 700 genetic tests have been established, with the primary purposes of evaluating these selections as parent trees and/or providing advanced-generation selections.

Participation in tree improvement in the Douglas-fir region is broad-based, involving at least 40 private landowners, 1 Canadian federal and 3 U.S. Federal agencies, 3 State agencies, 1 Canadian province, and 3 universities. Although a few programs are independent, the majority are involved in IFA-PNW cooperatives (4).

The programs vary widely in their approaches, with different selection intensities, different approaches to seed production, and different levels of management and support. These differences in themselves have an impact on nursery practices and the management of improved seed, and will be discussed later in this paper.

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### The Impact of Tree Improvement on Regeneration Programs

In western Oregon and Washington, more than 11 million acres are covered by a tree improvement program (1); in coastal British Columbia, more than 2 million acres (2). Each year, out of this 13 million total, about 263,000 acres are replanted.

The impacts of genetically improved seed on this annual planting stock requirement for some major programs are given in table 1. The situations of other programs not listed range from having no improved seed yet available to fully meeting their current planting stock requirements.

As shown in table 1, nursery managers will be having a progressively higher proportion of genetically improved seed coming through their nurseries in the near future.

**Table 1**—*Impact of improved seed on regeneration programs for several representative organizations in the Douglas-fir region*[a]

| | Current levels | | Future projections | | |
|---|---|---|---|---|---|
| Programs | Acres | % PSR | Acres | % PSR | Year |
| IFA-PNW co-ops | 18,000 | 12[b] | 120,000 | 75 | 1995 |
| (gov't. & private) | 80,000 | 50[c] | 160,000 | 100 | 2000 |
| British Columbia | | | | | |
| (gov't. & private) | 9,900 | 29 | 30,000 | 85 | 1995 |
| Weyerhaeuser | 19,000 | 62 | 40,000 | 100 | 1992 |

[a]Acres regenerated with improved stock and percent of total annual planting stock requirements (PSR).
[b]Five-year average through 1984.
[c]Projected 1986 sowing only. Reflects expectations of an exceptional cone crop for 1985.

### Genetic Gain: Its Integration into a Forest Management System

To better understand what "improved" seed means to nursery managers, we need to understand the concept of genetic gain and its integration into a forest management system. Because genetic gain is integral to tree improvement, the goals of tree improvement must be defined. We can think of these goals as three interrelated functions:

1. To realize potential for genetic gain.
2. To "package and transfer" this potential into a regeneration system.
3. To optimize the benefits of this potential in terms of product value, throughout the nursery, stand culture, harvest and utilization phases.

Two points need to be stressed here. First, we are dealing with potential for gain. We may capture it at one stage, only to lose it at another. Thus, the onus of maintaining the potential for gain transfers from the tree improvement worker to the nursery manager, to the silviculturist and to the forest land manager, much like the example of the relay race cited in the introduction. Secondly, we use the word "optimize" rather than "maximize." Implicit in this distinction is the knowledge that economic constraints should and will play a role in seeking tree improvement benefits, a point that will be further developed later in this paper.

We have many key leverage points at which we can capture, maintain, and enhance potential for genetic gain, from the time a tree improvement program is planned to the time the end product is utilized (fig. 1).

The first four leverage points—tree improvement program development through seed production and harvest—largely determine the amount of potential that can be captured. The last five-seed production and harvest through stand harvest and utilization—determine largely how much potential is maintained.

The seedling production (nursery) phase can also effectively enhance the potential, because the

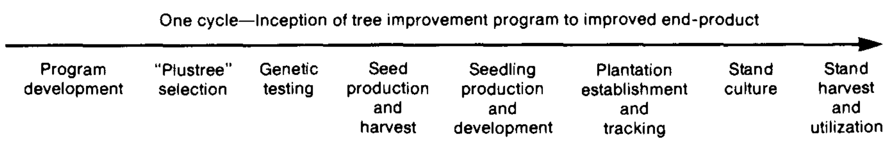


**Figure 1**—*Key leverage points to realizing, maintaining, or enhancing the potential genetic gain.*

nursery manager manages populations of seeds and seedlings, and as such, can manipulate gene frequencies in a directed way. For today, we will restrict our discussions to those leverage points most directly affecting nursery management, that is, seed production and development, and plantation establishment and tracking.

### Impact of Seed Production System on Nursery Management

Both potential for gain and seed availability will affect the management of improved seed in the tree improvement program followed. Seed derived from a "parent tree" program (that is, selected trees in natural stands used for seed supply) will probably become available sooner, have less potential for gain, and be less dependable in supply year-to-year than seed derived from a seed orchard program.

A clonal orchard typically will produce sooner, and with a higher potential for gain, than a seedling seed orchard. A rogued orchard will have a higher potential for gain than an unrogued orchard but at the expense of total seed production at various times during the production period.

It is important to recognize here that a seed orchard is not simply a seed orchard, nor is the objective of an orchard simply to provide genetically improved seed. Rather, the orchard should strive to strike a balance between maximizing potential for genetic gain and meeting planting stock requirements. The seed orchard and the seed it produces represent a very dynamic system. As the quantity of seed produced increases, so should the potential for gain, due to the increasing ability to rogue inferior parents or selectively harvest from the best.

Perhaps the key leverage point at the seed orchard affecting the nursery system is seed harvest strategy. The strategy adopted for harvest sets the stage for the development strategy and directly affects nursery management practices. Some of the harvest options available to the orchardist include:

1. Whole orchard bulk mixes.
2. Specific mixes based on: seed zone/evaluation, tested versus untested status, elite versus average.
3. Family-level collections (that is, seed from individual clones).

Whole-orchard bulk mixes will result in the largest seedlot size possible, but will also have the lowest potential for gain. As we progress down through the options we tend to decrease lot size (fewer parents or trees contributing per seedlot), but we also increase our ability to maximize potential for gain. The orchard harvest strategy therefore will affect nursery management by determining seedlot size and potential for gain, which in turn will affect nursery costs and practices.

### Role of the Nursery Manager in Maximizing Gain Potential

Within the nursery system there are several key leverage points for maintaining or enhancing potential for genetic gain. Among these include:

1. Ability to manage small lots.
2. Potential to sow by family.
3. Optimum utilization of improved seed.
4. Cost control.
5. Tracking and follow-up.

**Small lot management.** The ability to deal with small lots is essential to maximizing potential for gain. As discussed earlier, there is a general inverse relationship between potential for

**Table 2**—*Changes in height performance rank of the fastest and slowest growing families (total = 45) of Douglas-fir seedlings in the Weyerhaeuser Twin Harbors progeny test*

| | Performance rank | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | After 1 yr | After indicated years in test | | | | | | | |
| Family | in greenhouse | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| A | 27 | 14 | 9 | 8 | 3 | 2 | 2 | 1 | 1 |
| B | 40 | 40 | 22 | 6 | 4 | 3 | 1 | 2 | 2 |
| C | 39 | 20 | 5 | 7 | 7 | 7 | 8 | 3 | 3 |
| D | 29 | 7 | 2 | 1 | 1 | 1 | 3 | 4 | 4 |
| E | 5 | 2 | 4 | 2 | 2 | 4 | 4 | 5 | 5 |
| W | 45 | 45 | 45 | 44 | 43 | 43 | 43 | 42 | 41 |
| X | 37 | 38 | 38 | 40 | 41 | 41 | 41 | 41 | 42 |
| Y | 35 | 39 | 41 | 42 | 42 | 42 | 42 | 43 | 43 |
| Check | 44 | 44 | 44 | 43 | 44 | 44 | 44 | 44 | 44 |
| Z | 42 | 41 | 43 | 45 | 45 | 45 | 45 | 45 | 45 |

The check value is the mean of two field check seedlots.

gain and lot size. Thus, smaller lots can be considered opportunities rather than liabilities, as is generally the case.

Two questions the nursery manager must address are: a) What constitutes the minimum size lost that can be efficiently managed operationally? and b) What changes in nursery technology might be possible to change this? Answers to these questions will bear on the orchard harvest strategy chosen.

**Family sowing.** Sowing by individual family represents the probable extreme case of small lot management with its associated high potential for gain. In addition to this attribute, there are several other benefits from family sowings. By sowing "pure" families rather than mix-tures of families, the chance for disproportionate culling could be avoided. Progeny test data have shown that some families, although excellent performers over time, start very slowly in the nursery. For example, families B and C in table 2 ranked 40 and 39, respectively, of 45 in height at the end of the first year in the greenhouse. However, by year 8 of the field test, they had risen to rank 2 and 3. Both would have been largely culled from a mixed lot after 1 year in the nursery, even though both proved superior performers in the field.

Thus, differential culling standards may be appropriate, particularly in those cases where subsequent potential for good field performance has been demonstrated. Differential culling standards here translates into improved yields, which means an increased contribution by superior families to the regeneration program.

Traits other than growth response, for example, frost tolerance, susceptibility to herbicides, etc., also may be more observable when seeds are sown as families rather than mixes. Thus, family sowings become the key to identifying and managing unique opportunities or problems at the nursery stage.

Another benefit of family sowing is that it allows for the development option of family block plantations. While this option is little used in the Pacific Northwest, it is the main deployment strategy on large forest ownerships in the southeast United

States. Limiting its use at present in the Pacific Northwest are the unknowns relative to opportunity and risk.

**Optimum utilization of improved seed.** Perhaps the key leverage point in the nursery to maximizing potential for genetic gain in the acceptance and use of a system, including alternative stock types, that converts the most seed to plantable seedlings. Although 100% oversow factors are not unusual in a conventional nursery program, we should not be content to lose half of our high-cost seed with improved potential for gain to nursery fall-down and culling. Even though some level of culling will probably always be appropriate, other factors than potential genetic growth contribute to this fall-down. Also, as shown in table 2, genetic potential may not express itself yet in the nursery phase.

Economics of improved seed utilization. In weighing the alternatives for improved seed utilization, the economics of the system must be considered. Decisions to maximize seed utilization are not "justifiable at any cost." One approach to economic evaluation is the present value/cost ratio, an approach commonly used for long-term investment decisions in forestry. To determine a PV/cost ratio, several factors must be considered and quantified.

- Incremental yields, that is, how many more plantable trees per pound of seed are achievable.
- Incremental costs to produce this incremental yield.
- Estimated incremental gain of improved seed, which may vary by harvest strategy or level of improvement, and will be estimated by genetic test results. Estimated value, for example, dollars per acre of incremental gain, which may vary by site class and can be estimated from economic and growth and yield models.

Once these factors have been estimated, the PV/cost ratio can be calculated. A hypothetical example follows:

*Incremental cost per acre*
= (trees per acre/1000) x (incremental cost per 1000 trees) x (improved yield factor)
= $10.

*Incremental value per acres*
Case I (improved seedlot 1, site I) = $40.
Case II (improved seedlot 1, site II) = $30.
Case III (improved seedlot 2, site I) = $20.
Case IV (improved seedlot 2, site II) = $10.

PV/cost ratio
Case I = 4:1.
Case II = 3:1.
Case III = 2:1.
Case IV = 1:1.

The calculated PV/cost ratios must be then compared to values considered as investment decision thresholds by your organization. PV/cost ratios equal to or above these thresholds would suggest a sound economic decision within your organization to improve yields while accepting the increased associated costs.

**Cost control.** Although cost control is essential in any nursery operation, it has a special significance in maximizing potential for genetic gain as it pertains to improved seed utilization. The lower the cost to produce a given stock type, the more opportunity there is to increase yields within given economic constraints.

Reduced costs can directly impact the PV/cost ratio just described, thus potentially qualifying additional seedlots for the improved-yield system. For example, if the incremental cost per acre was reduced from $10 to $7, and the organization's threshold value for investment was 4:1, all site II land would now qualify for improved seedlot I being grown in the improved-yield system. Potential for genetic gain would be enhanced because a higher proportion of plantation acres would be impacted with improved seed.

**Tracking and follow-up.** This leverage point is certainly not restricted to the nursery phase, for the genetic components of any seedlot must be trackable from the orchard through the nursery to the plantation, as well as from the plantation back to the orchard. Nurseries and plantations should be considered as extensions of the genetic testing program. Both time and number of traits measured are limited in genetic tests, and little or no testing is possible for unique and infrequent climatic events.

The nursery manager's role in this "extended testing" is vital. Not only must opportunities or problems related to improved seed be identified, but also they must be reported and followed up. Without this continual awareness by all those involved with improved stock, achievement of the potential for genetic gain will most certainly be compromised.

## Conclusions

Seed from tree improvement programs are becoming a major component of nursery sowing programs in the Pacific Northwest and within the next decade will become the exclusive component for many programs. Nursery managers are a part of the tree improvement effort and have a vital role in maintaining or enhancing the potential for genetic gain of improved planting stock. Of the many opportunities for nursery managers to help capture potential for genetic gain, perhaps their greatest contributions will be in optimizing the yields of improved seedlings. In so doing, they will positively affect the gene frequencies of desired traits in the integrated forest management system.

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# Improving Seed-Use Efficiency and Seedling Quality Through the Use of History Plots

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*History plots are permanent plots established at the time of sowing that are monitored throughout the nursery rotation. In the recommended procedure, the actual seed sowing density is measured immediately, which supplies information on seed drill efficiency and permits accurate monitoring of seed and seedling losses during the entire nursery period. Information from history plots has many different applications in nursery management, such as monitoring seed-use efficiency, producing seedling growth curves, scheduling or modification of cultural practices, and nursery problem -solving.* Tree Planters' Notes 38(3): 9-15; 1987.

*One for the squirrel,*
*one for the crow,*
*one for the weather,*
*and one to grow*

Old Indian Proverb

This old saying reveals that Indian farmers observed the causes of seed losses in their cornfields and made allowances for them in the amount of seed that they sowed. Efficient tree nursery management involves producing the maximum number of high-quality seedlings with the least amount of seed. Often, however, seed and seedling losses are hard to identify and quantify in the nursery seedbed. Because the sown seed is buried, preemergence losses are hidden from view and even post-emergence mortality happens so quickly that it often goes unnoticed. With history plots, the nursery manager can measure these losses empirically and obtain objective data on their amount and timing.

History plots are seedling monitoring plots that are permanently established in seedbeds at the time of sowing. They are not a new concept, as many different aspects of the history plot procedure have been used in forest tree seedling nurseries for many years. Belcher (1) provided one of the first published procedures for monitoring tree seedlings with history plots. Johnson (3) used a series of "monitoring plots" to identify the major causes of seed loss in a Washington nursery, and Landis (4) used a similar procedure in a similar effort in a Rocky Mountain forest nursery. Steinfeld (6) describes a seedling monitoring procedure that includes "intensive monitoring" of plots in which growth, mortality, and soil characteristics are measured. This publication is the first attempt, however, to incorporate all the various aspects of seed and seedling monitoring practices into one comprehensive procedure.

The information from history plots has several uses in nursery management. One of the principal uses is to develop or refine nursery sowing rate factors which govern sowing density and seed-use efficiency. Many nursery managers use sowing factors that were developed through years of experience but are not based on any actual measurements. Monitoring history plots yields specific information on the fate of sown seed that can be used to adjust future sowing rates. The major sowing rate factors and the associated seed and seedling losses are illustrated in figure 1.

In addition to supplying data on seed-use efficiency, history plots also provide several other incidental benefits to nursery management. When the procedure includes excavating seed immediately after sowing, they provide a check of seed drill calibration and sowing depth. Measurements of seedling growth and observations of seedling phenology (table 1) can also be used to produce seedling growth curves that will help the manager properly time cultural practices.

### Installing History Plots

There is no standard procedure or sampling sequence for establishing and monitoring history plots because the specific procedures and timing will differ depending on the needs and

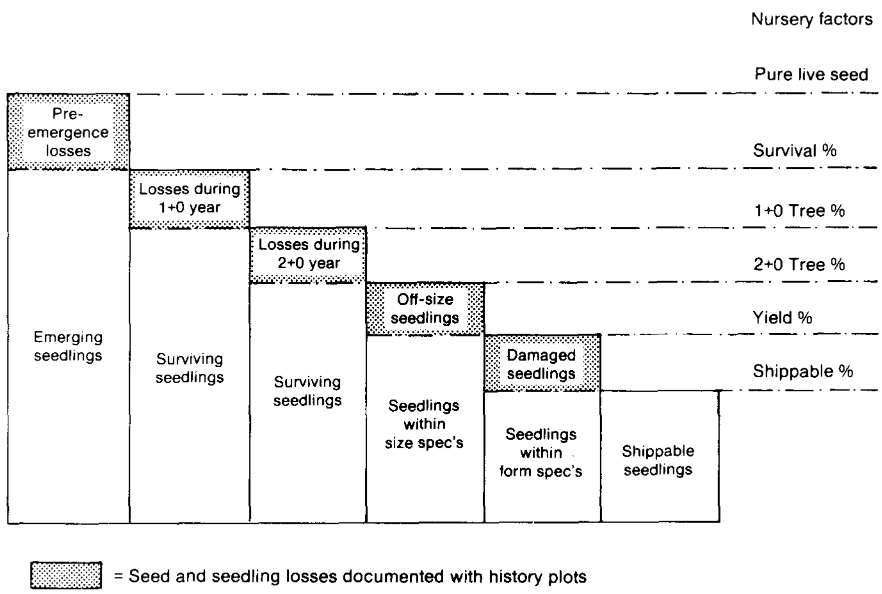


**Figure 1**—*History plots identify and quantify seed and seedling losses that can be used to establish or refine nursery factors for calculating sowing rates.*

**Table 1**—*Seedling growth and phenology events that can be measured with history plots*

| Measurement |
|---|
| Growth |
| Shoot height |
| Shoot caliper |
| Relative root growth |
| Seedling biomass (ovendry weight) |
| Shoot/root ratios |
| Phenology |
| Speed of emergence |
| Period of cotyledon formation |
| Period of primary needle formation |
| Period of secondary needle formation |
| Timing of shoot flushes, including lammas growth |
| Periods of root activity |

objectives of each nursery manager. A general, all-inclusive procedure is outlined here so that readers can adapt and modify this general model to their specific needs.

History plots are generally established at the time of sowing. The actual location of each plot is best chosen immediately before sowing, so that plots can be quickly marked out soon after the beds are sown. Plot locations should be chosen randomly, but the following areas should be avoided: ends of beds, locations where the seed drill had to stop or start, and any other areas that are not typical of normal seedbed conditions (1). History plots can be located near other nursery monitoring sites such as soil sampling pits or weather stations to exploit these other sources of valuable information.

The sampling population for history plots is the individual seedlot, and the number of plots is usually a function of available labor, although ideally the number of plots should be set using statistical procedures. The minimum number of history plots per seedlot should be at least 4, because this number of plots will supply the manager with useful information while providing some protection against plot loss. Johnson (3) recommends a sampling intensity of 6 plots per acre.

A crew of 2 or 3 should be used to install history plots, although later plot checks can be done by 1 person. The number of workers required will depend on the number of factors being monitored, but complete history plots can usually be established in a half hour with a crew of 3. Belcher (1) reports a yearly requirement of 2.3 person-hours per plot.

The identification and quantification of preemergence seed losses are the most difficult phase of the history plot procedure for two reasons. First, the exact number of seeds that were sown in the plot must be determined to provide a base against which all subsequent losses can be compared, and second, pre-emergence losses are naturally hidden and, therefore, hard to identify and quantify.

Determining the actual number of sown seeds in a history plot can be established in the following two ways.

**Estimates from sowing calculations or seed drill trials.** The approximate amount of seed that will be sown in the history plot can be estimated from sowing calculations and seed data. Dividing the seed requirement by the length of seedbed to be sown will provide the average amount of seed for the area of seedbed in the history plot. Another estimation procedure involves test runs with the seed drill. The drill can be run over the top of the soil or on a tarp, and the seed can be directly counted in an area that is equal in size to the history plot. These indirect techniques have the advantage of being quick, easy, and nondestructive, but they only provide approximations of the actual amount of seed that will be sown in the history plot because of the variable distribution patterns of all seed drills.

**Actual recovery of sown seed.** The only way to really know how many seeds have been sown in a history plot is to count them directly. This is relatively easy for nurseries that sow seed on the surface of the seedbed and cover the seed with a mulch, as the sown seed can be counted before the mulch is applied. Nurseries that drill their seed into the soil, however, must somehow recover and count the sown seed. Because many conifer seeds are small and dark, they are extremely difficult to distinguish from soil particles. One technique to overcome this problem is to color the seed with a material such as aluminum powder or an organic dye (2); seed that is treated with a fungicide or bird repellent prior to sowing will be easier to locate than untreated seed. The seed must still be excavated from the history plot with spatulas or screens and then resown after the counts are completed. Johnson (3) excavated each seed row to a depth of 3.8 cm (1.5 in.) and a width of 5.1 cm (2 in.), and used a screen with 1.98-mm (0.08-in.) openings to recover the seed. These excavations introduce another source of variation, however, because the seed can never be resown in exactly the same manner as an undisturbed plot.

One possible technique to deal with this problem, and the one recommended by the authors, is to use a paired-plot design (fig. 2). The total history plot includes

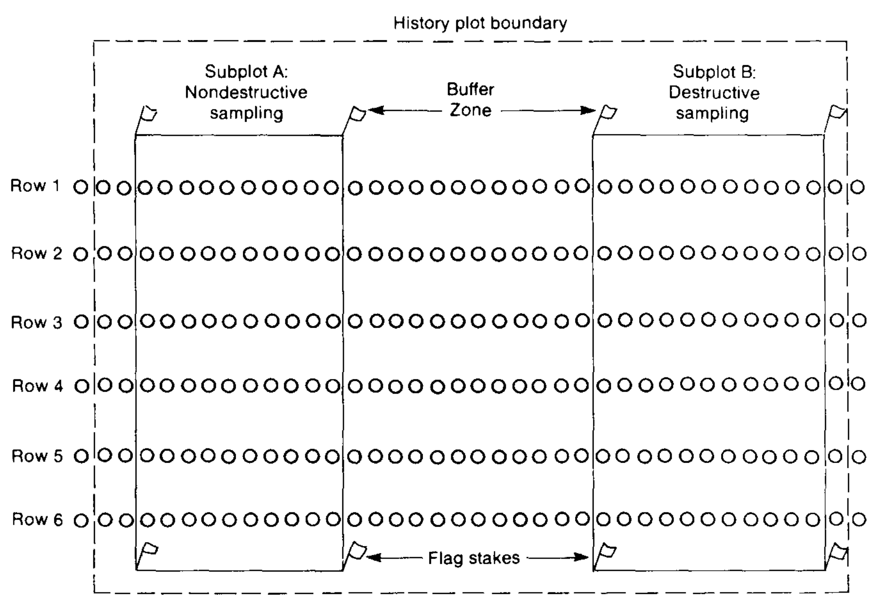


**Figure 2**—*A paired-plot sampling design is suggested for history plots so that destructive sampling can occur immediately adjacent to, but not disturb, the nondestructive sampling subplot. This example is for a nursery seedbed with 6 seed rows.*

two subplots that are separated by a buffer zone: subplot A for nondestructive sampling, and subplot B for destructive sampling. Nondestructive, repetitive measurements such as live seedling counts and shoot measurements can be made throughout the crop cycle in subplot A, whereas one-time destructive measurements involving seed and seedling excavation can be made in subplot B. The basic premise of this plot design is that the sown seed density will be similar between the two adjacent subplots; this assumption has been verified by actual nursery testing. Subplot B is generally excavated immediately after sowing to determine actual sowing density, and the seed resown to provide seedlings for later destructive sampling.

The subplots are generally 30.5 cm (12 in.) wide and rectangular in shape and extend completely across the seedbed. Plot corners should be marked with flag stakes or slats at all four corners (fig. 2) and referenced to some permanent feature such as an irrigation riser so that they can be precisely relocated at any time during the rotation, should the corner markers be accidentally removed. Flexible markers, such as flag stakes, are preferred because they are less likely to be damaged or pulled out during tractor operations.

The history plots should be revisited at regular intervals to monitor the fate of seed and seedlings and determine the causes of loss. Dead seedlings should be recorded and then removed during each visit to avoid possible confusion as to when the loss occurred (3). Request the assistance of a nursery pathologist during these first visits, particularly during the seed excavation procedure, to help determine the exact cause of mortality. If this is not possible, collect samples of dead seed and seedlings and store them under refrigeration until they can be examined by a trained pathologist.

While the history plots are read during the seedling emergence period, a string can be permanently run around the corner stakes to establish the plot perimeter. Seed located exactly on the boundary line should be alternately placed in or out of the plot to avoid bias and to make a

**Table 2**—*Specific measurements taken on history plots during a crop rotation*

| Measurement | Application to nursery management |
|---|---|
| Subplot A (nondestructive sampling) | |
| Standard | |
| A-1 Live seedling count | Used to compute field germination and seedbed density |
| A-2 Dead seedling count | Causes, timing, and quantity of seedling losses |
| A-3 Shippable seedling yield | Determine actual shippable seedling yield |
| Optional | |
| A-4 Seedling height and caliper | Develop seedling growth curves |
| A-5 Shoot phenology observations | Develop seedling growth curves |
| A-6 Soil pathogen analysis | Determine if regular fumigation is necessary and establish the relationship between pathogen levels and seedling losses |
| Subplot B (destructive sampling) | |
| Standard | |
| B-1 Seed density | Seed drill calibration and performance; needed for computing survival percentage |
| B-2 Sowing depth | Seed drill performance and adjustment |
| B-3 Ungerminated seed examination | Causes of preemergence mortality |
| Optional | |
| B-4 Relative root growth measurements | Development of seedling growth curves |
| B-5 Root phenology observations | Development of seedling growth curves |
| B-6 Ovendry seedling weight | Determining shoot/root ratios |
| B-7 Soil nutrient analysis | Determines mineral nutrient availability |
| B-8 Seedling nutrient analysis | Determines mineral nutrient uptake |
| B-9 Root growth capacity | Measures seedling performance potential |
| B-10 Frost hardiness | Measures ability to tolerate frost and storability |

clear decision about which seeds are in the plot and which are not (1). Once the seedlings have become established, rods or a counting frame can be placed across the seedbed to mark the across-bed sides of the plot.

### Monitoring History Plots

Standard and optional measurements that can be made with history plots are listed in table 2. Standard measurements are those needed to determine nursery sowing factors, whereas optional measurements provided other information about seedling growth and phenology that can be used in many phases of nursery management. Table 3 is a time schedule for taking the measurements listed in table 2.

History plots can be incorporated into other nursery sampling processes, such as seedbed inventory (1), because history plot data provide an intensive look at seedling growth and development. If the history plots are excavated at the end of the crop cycle, the seedlings can be measured and graded to provide information on seedling grading specifications, cull rates, and net seedling yield per area of seedbed.

**Table 3**—*Time schedule for specific measurements on history plots*[1]

| Sampling event | Sampling interval | Time after sowing (wks) | Specific measurements taken | |
|---|---|---|---|---|
| | | | Subplot A | Subplot B |
| 1. Prefumigation | Once | — | A-6 | — |
| 2. Postfumigation | Once | — | A-6 | — |
| 3. Postsowing | Once | 0 | — | B-1, B-2 |
| 4. During emergence | Weekly | 1 to 6 | A-1, A-2, A-5 | — |
| 5. Postemergence | Once | 6 | A-6 | B-3 |
| 6. During 1 + 0 season | Twice/mon. | 6 to end | A-1, A-2, A-4, A-5 | B-4, B-5 |
| 7. End of 1 + 0 season | Once | — | A-1 | B-6, B-7, B-8 |
| 8. During 2 + 0 season | Twice/mon. | — | A-1, A-2, A-4, A-5 | B-4, B-5 |
| 9. End of 2 + 0 season | Once | — | A-1 | B-6, B-7, B-8, B-9, B-10 |
| 10. Prelifting | Once | — | A-1, A-2 | B-9, B-10 |
| 11. Lifting, grading, and packing | Once | — | A-3 | — |

[1]Plot designations are those listed in table 2.

### Using History Plot Data in Nursery Management

**Seed-use efficiency.** The numerical data on seed and seedling losses have obvious applications in the determination and refining of nursery factors (fig. 1) that can be used in sowing rate calculations. As the specific causes of the losses are identified, corrective actions can be taken to reduce or eliminate them completely. Although not often recognized, improving seed-use efficiency can have significant economic impacts, particularly for genetically improved seed. South (5) estimates that a southern forest nursery with an annual production of 30 million seedlings could realize a yearly savings of $15,000 by increasing seed-use efficiency from 50 to 55 %.

**Scheduling and evaluating cultural practices.** The effort of nursery cultural operations, such as seedbed fumigation, can also be critically examined through history plots. When history plot data from Mt. Sopris Nursery were analyzed, it was obvious that the greatest seed and seedling loss occurred during the germination and emergence period (fig. 3). Direct observations during checks of the history plots and associated soil testing for pathogenic fungi identified the cause of the losses as damping-off and seed predation by birds. Consequently, regular seedbed fumigation was prescribed to reduce damping-off fungal populations, and early morning bird patrols were established to discourage bird predation.

Other cultural practices, like root pruning or top mowing, have extremely narrow operational windows that must be carefully scheduled. Many nursery managers try to prune the roots of pine seedlings in the fall of the 1 + 0 year to sever the dominant tap root and stimulate a more fibrous root system. The timing of this operation is critical, however. If it is done too early, it may reduce shoot growth, but if it is done too late, the seedlings will not have time to reestablish a good root system and may undergo frost-heaving during the winter. The best time for root pruning, as determined from the history plot data, is a narrow time period after budset but before the fall root growth period (fig. 4).

**Seedling growth and phenology.** The seedling measure

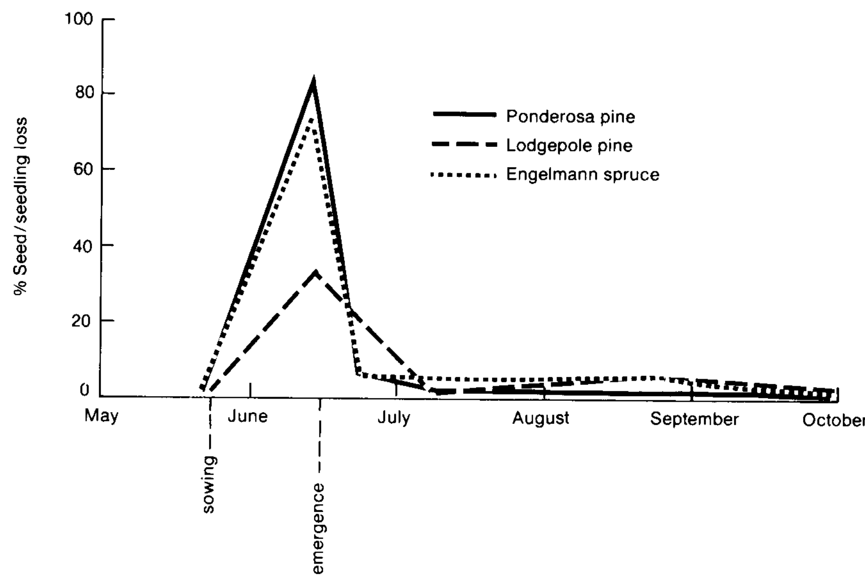


**Figure 3**—*History plots at Mt. Sopris Nursery, CO, revealed that the majority of seed and seedling losses were occurring during the germination and emergence period (4).*

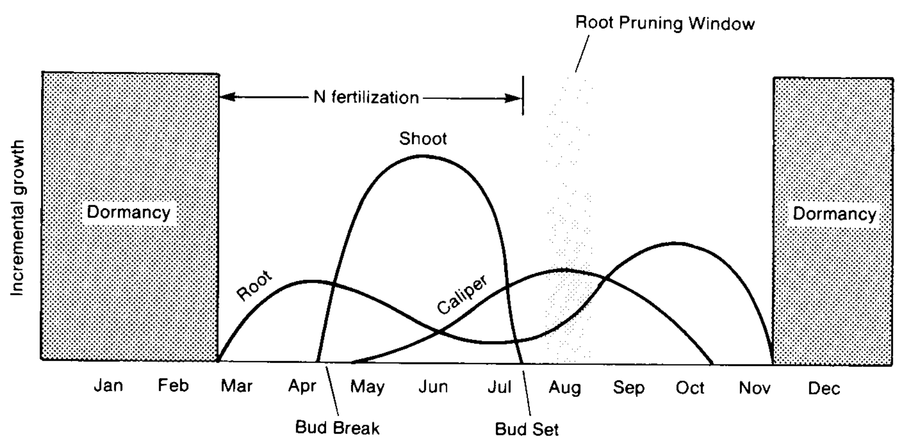


**Figure 4**—*Seedling growth curves from history plot data can be used to schedule nursery cultural practices such as fertilization and root pruning. This graph represents the second year of a 2 + 0 seedling production cycle.*

ments made in history plots can be used to generate seedling growth curves that illustrate the annual cycle of seedling growth (fig. 4). Not only do these growth curves provide an excellent visual representation of the timing of significant events such as budbreak and budset, but they can be used to help schedule cultural practices such as fertilizer applications. Nitrogen (N) fertilizer should be applied early in the growing season, so that sufficient N is available during the rapid shoot growth period, but not so late that it could interfere with the onset of dormancy (fig. 4).

**Problem solving.** One of the most useful applications of the history plot procedure is for nursery problem-solving. Installations of history plots in seedbeds of a particularly troublesome species or seed lot can provide invaluable information on the fate of the seed and seedlings during the crop cycle. Without the focused perspective provided by history plots, nursery managers often are unable to determine the specific causes of seed and seedling losses.

## Conclusions and Recommendations

History plots offer the nursery manager a technique to accurately monitor the fate of seed and seedlings throughout the nursery crop cycle. One of the principal uses of history plot information is to establish or refine nursery sowing factors. The causes of seed and seedling losses can be identified during the regularly scheduled plot visits, and this information can then be used to schedule or modify nursery cultural practices to reduce or eliminate these losses. Information on seedling growth and phenology can be used to generate seedling growth curves that give the nursery manager a valuable tool for timing cultural practices. The history plot procedure is also useful as a nursery problem-solving technique.

In summary, the history plot procedure brings the nursery manager into close contact with the growing seedlings at regular intervals throughout the crop cycle, providing the indepth understanding necessary to scientifically manage a forest tree seedling nursery.

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# Seedling Size Influences Early Growth of Longleaf Pine

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*Survival was not affected by seedling size in this study of longleaf pine (*Pinus palustris *Mill.) grown in northeast Florida. Planting seedlings with root collar diameters greater than $^{7}/_{16}$ inches resulted in improved tree height, percentage of trees out of the grass stage, and brown spot resistance.* Tree Planters' Notes 38(3):16-17; 1987.

Successful regeneration of longleaf pine (*Pinus palustris* Mill.) depends both on first-year survival and the length of time trees remain in the grass stage after outplanting. Past studies have shown that survival and early growth are influenced by seedling size (1-3).

This test was established to determine if the root collar diameter of longleaf pine seedlings at the time of planting affects early growth and survival. Survival, height, and the level of brown spot infection are reported through the end of the third growing season.

## Methods

Longleaf seedlings were hand-lifted from the nursery bed at the ITT Rayonier nursery located in Glennville, GA, in January 1983. Their roots were immediately dipped in a clay slurry. After dipping, the seedlings were separated into size classes based on root collar diameter. There were six $^{1}/_{8}$-in. size classes starting with a root collar diameter of $^{3}/_{16}$ in. and ending with the largest size class that consisted of seedlings with root collar diameters greater than $^{3}/_{16}$ in. The seedlings were placed in seedling storage bags and stored in a seedling storage shed for 11 days before they were outplanted on January 24, 1983.

The test site is located in Nassau County, FL, on a somewhat poorly drained Ridgewood fine sand. The Ridgewood series consists of somewhat poorly drained, rapidly permeable soils on slightly elevated ridges in the flatwoods that formed on thick beds of sandy marine deposits. 11 is a thermic uncoated Aquic Quartzipsamment. Competition from hardwoods is minimal, and they consist predominantly of oaks.

A randomized complete block design was used in which the seedling size-class was randomly assigned to each planting space within a given block. Twenty longleaf seedlings were handplanted for each size class in each of three blocks. Each of the blocks was planted by a different person and the order of planting for different size classes was randomly assigned by block. Soil moisture was high at the time of planting since 5 in. of rain had fallen in the 4 preceding days.

The trees were measured for height and survival at the end of the second and third growing seasons. Brown spot infection, which is caused by *Scirrhia acicola* (Dearn.) Siggers, was noted at the end of the second growing season. Since the level of infection seemed to be related to tree size and tree size was related to treatment, trees were classified at the end of the third growing season by the degree of brown spot infection. This was done by classifying each tree into one of five classes based on the percentage of needles damaged by brown spot disease. These classes were reduced during the analysis of the data into two classes that consisted of trees with less than 25% of their needles damaged by brown spot or trees with more than 25% of their needles damaged. Longleaf seedlings were considered to be in the grass stage if they were less than 0.5 ft. in height.

## Results

Seedling size did not have any significant effect on survival although there was a trend for lower survival in both the smallest and the largest seedling classes. Poor vigor was noted for the smallest class, and large, difficult to plant root systems for the largest seedling class. Seedling size had a significant effect on the height (average of all trees) and the percentage of seedlings out of the grass stage at the end of both the second and third years (table 1).

The percentage of trees that had greater than 25% of their needles damaged by brown spot

The author thanks Frank Watts, USDA Soil Conservation Service, for describing and classifying the soil.

**Table 1**—*Average survival and growth of longleaf pine seedlings by seedling size-class after 2 and 3 years*

| Seedling size class (in.) | After 2 years | | | After 3 years | | |
|---|---|---|---|---|---|---|
| | Height (ft) | Percent out of grass | Percent survival | Height (ft) | Percent out of grass | Percent survival |
| 3/16 to 5/16 | 0.2 a | 15 a | 82 a | 0.9 a | 55 a | 82 a |
| 6/16 to 7/16 | 0.4 a | 30 a | 87 a | 1.5 ab | 71 ab | 87 a |
| 8/16 to 9/16 | 0.6 ab | 61 b | 88 a | 2.2 b | 87 b | 88 a |
| 10/16 to 11/16 | 1.1 bc | 76 b | 93 a | 3.2 c | 98 c | 92 a |
| 12/16 to 13/16 | 1.6 c | 95 c | 92 a | 4.0 c | 98 c | 90 a |
| >13/16 | 2.2 d | 94 c | 83 a | 5.1 d | 96 c | 83 a |

Means in columns with the same letter in common do not differ significantly at the 0.05 level of probability. Comparisons of percentages used the arcsine $\sqrt{\%}$ transformation but actual percentages are reported.

**Table 2**—*Percentage of longleaf pine seedlings with more than 25% of their needles damaged by brown spot disease*

| Seedling size class (in.) | Percent |
|---|---|
| 3/16 to 5/16 | 20 ab |
| 6/16 to 7/16 | 31 a |
| 8/16 to 9/16 | 9 abc |
| 10/16 to 11/16 | 9 abc |
| 12/16 to 13/16 | 6 bc |
| >13/16 | 2 c |

Means in columns with the same letter in common do not differ significantly at the 0.10% level of probability. Comparisons of percentages used the arcsine $\sqrt{\%}$ transformation but actual percentages are reported.

differed significantly by seedling size at the 10% level. These percentages are summarized in table 2.

The high survival, which was over 80% for all six seedling size-classes, may not have occurred during a year with less favorable weather conditions or on more severe sites. Nonetheless, seedlings with root collar diameters less than 7/16 in. were slow to initiate height growth and a high percentage were damaged by brown spot disease.

Trees with initial root collar diameters greater than 7/16 in. had acceptable growth with at least 87% out of the grass stage after 3 years and future stunting by brown spot disease expected to be minimal. Tree height increased with seedling size, but nursery, handling, and planting considerations also need to be evaluated to determine the size desired for production seedlings.

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# Germination of Conifer Seeds Surface-Sterilized With Bleach[1]

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*Surface-sterilizing conifer seeds with 40% laundry bleach often significantly enhanced, rather than reduced, cumulative germination percentages.* Tree Planters' Notes 38(3):18-21; 1987.

Damping-off has long been a problem in forest tree nurseries. Common fungi associated with damping-off include *Pythium, Rhizoctonia, Phytophthora,* and *Fusarium*. Only tender germinants are affected, since disease incidence declines as soon as the stems begin to lignify, generally in 3 to 4 weeks (11).

Spores of damping-off fungi can be either soilbome or seedborne. Soilborne damping-off can be controlled by using sterile media and proper cultural techniques during the germination phase. Many techniques for reducing damping-off have been formulated, including lowering pH of the medium, improving its aeration, lowering relative humidity, maintaining proper moisture of the medium, delaying nitrogen fertilization until germination is complete, and drenching the growing medium with fungicide (2,7,11).

Seedborne inoculum may cause damping-off or be the source for later root disease by *Fusarium* species. The incidence of *Fusarium* root disease may vary dramatically among seedlots (3), and different levels of infection may be due to seedlot collection sources (4). James (5) found that most seedlots of Douglas-fir and ponderosa pine had less than 10% seed infection with *Fusarium*. Although infection levels seem low, they may be sufficient to cause widespread disease, particularly if secondary spread is extensive and not reduced by cultural methods (5).

Methods for controlling seedborne diseases have also been evaluated (1,2,7,8,11,12). One simple method involves rinsing seed in clear, running water for 24 hrs to wash off fungal spores (6). Applying fungicides to the seed coat is another method. Captan, ETMT, and thiram are commonly used fungicides, but their adverse effects on germination and inconsistent results in controlling fungi have reduced their usage (2,7,8,11). The third method involves soaking in chlorine bleach or hydrogen peroxide to disinfect the seed coat (1,2,7,12). Problems with solution concentration and soaking rates have produced poor fungal control or reduced germination.

Our objective was to examine the effects of bleach sterilization on the seed germination energy and capacity of several western conifers.

**Table 1**—*Treatment of conifer seeds after surface sterilization with a solution of 2 parts laundry bleach and 3 parts water*

| Species | Length of rinse (days) | Length of stratification (days) |
|---|---|---|
| Western white pine[1] (*Pinus monticola* Dougl. ex D. Don) | 5 | 90-120 |
| Ponderosa pine (*P. ponderosa* Dougl. ex Laws.) | 2 | 40 |
| Shore pine[1] (*P. contorta* Dougl. ex Loud. var. *contorta*) | 2 | 40 |
| Scotch pine (*P. sylvestris* L.) | 2 | 40 |
| Austrian pine *(P. nigra)* Arnold | 2 | 40 |
| Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn, Franco) | 2 | 21 |

[1]Species routinely sterilized at the research nursery but not included in this study.

## Methods and Materials

Seeds were treated in a sodium hypochlorite solution consisting of 2 parts common laundry bleach (5.25% sodium hypochlorite) to 3 parts clear water. Seeds were soaked in the bleach solution for 10 min. with constant hand agitation. (Hands were protected with rubber gloves to avoid skin reactions.) Agitation is important to obtain uniform cleaning and sterilization (9). After treatment, the seed were thoroughly rinsed, with constant hand agitation, to remove all bleach that could damage the seed. The bleach solution was discarded after one use. Seed were then rinsed in clear-running tap water for 2 days to ensure full imbibition before stratification (table 1).

Four conifer species (three species had two seed lots each) were examined for the effects of bleach on seed germination. Both treated and untreated (controls) seed were stratified and each treatment was replicated four times with 100 seeds per replicate. Analysis of variance (10) was used to detect differences in cumulative germination percentage.

**Table 2**—*Cumulative percent germination at 7 to 28 days of conifer seed sterilized with a solution of 2 parts laundry bleach and 3 parts water*

| | Cumulative percent germination | | | |
|---|---|---|---|---|
| Species/treatment | 7 days | 14 days | 21 days | 28 days |
| Austrian pine | | | | |
| Bleach | 65.8* | 68.6* | 68.6* | 68.6* |
| Control | 53.8 | 59.2 | 62.3 | 62.3 |
| Douglas-fir | | | | |
| Lot 1 | | | | |
| Bleach | 54.3 | 80.5* | 81.5* | 82.0* |
| Control | 51.5 | 72.3 | 73.0 | 73.0 |
| Lot 2 | | | | |
| Bleach | 70.3 | 81.6 | 86.6 | 87.5 |
| Control | 72.5 | 84.3 | 89.0 | 89.6 |
| Ponderosa pine | | | | |
| Lot 1 | | | | |
| Bleach | 68.3* | 80.8** | 80.8** | 80.8** |
| Control | 58.0 | 62.3 | 62.8 | 62.8 |
| Lot 2 | | | | |
| Bleach | 98.0 | 99.0 | 99.0 | 99.0 |
| Control | 97.5 | 98.5 | 99.0 | 99.0 |
| Scotch pine | | | | |
| Lot 1 | | | | |
| Bleach | 72.5* | 80.3* | 80.3* | 81.0* |
| Control | 59.0 | 72.0 | 72.0 | 72.0 |
| Lot 2 | | | | |
| Bleach | 72.3** | 84.3** | 86.5** | 86.5** |
| Control | 52.3 | 58.3 | 59.0 | 59.0 |
| Average for all lots | | | | |
| Bleach | 71.6 | 82.2 | 83.3 | 83.6 |
| Control | 63.5 | 72.4 | 73.9 | 74.0 |

Values are means of four 100-seed replications.
*Significantly different from controls at $P < 0.05$.
**Significantly different from controls at $P < 0.01$.

**Results and Discussion**

Cumulative germination percentage was increased by sterilizing with bleach (table 2). This increase was probably due to reduced fungal propagules that would otherwise kill the germinants. Improved germination percentage may be more evident in seedlots heavily infected with pathogens and exhibiting poor germination due to fungal colonization on the seed coat. Each seedlot should have a sample tested with the bleach solution before the entire lot is treated.

This bleach seed treatment has been used routinely at the University of Idaho Forest Research Nursery as a disease preventative method. Although the bleach treatment does not eradicate all organisms on the seed coat (6,9), we believe that it helps reduce early seedling mortality when used with proper cultural methods, while not detrimentally affecting germination.

This treatment, used in combination with lower pH of the growing medium and low rates of applied nitrogen during the initial phase of seedling growth, has reduced early seedling mortality due to fungi associated with damping-off and appears to reduce later losses to *Fusarium* (fig. 1). This seems consistent with the findings of James and Genz (6), who found a significantly lower incidence of disease in hypocotyls of germinated ponderosa pine seeds treated with bleach then in controls. There is still early mortality from *Fusarium*

Figure 1—Fusarium cotyledon blight, from within the seedcoat, infecting the emerging cotyledons of ponderosa pine.

cotyledon blight due to fungal propagules borne within the seed coat (fig. 2). This technique has been effective only for thick-coated seeds such as pine and Douglas-fir, which can withstand the oxidizing effects of bleach. It should not be used on seed of true firs, larch, and spruces.

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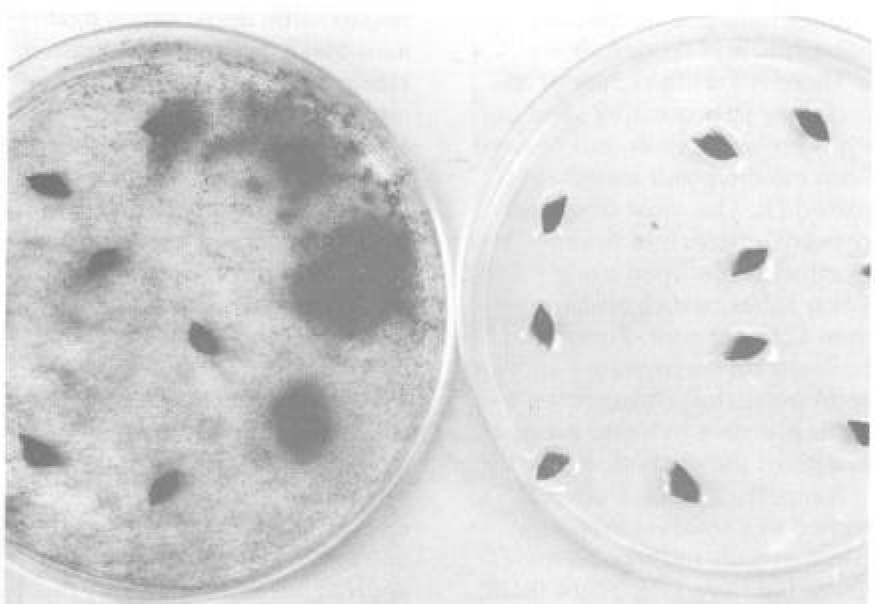

**Figure 2**—*Agar plates with fungal growth from unsterilized (left) and sterilized Douglas-fir seed.*


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# Effectiveness of New Formulations of Deer Repellants Tested in Douglas-Fir Plantations in the Pacific Northwest

**David DeYoe and Wieger Schaap**

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*Data were collected from 25 sites west of the crest of the Cascade Mountains in Washington and Oregon. Only 14% of Douglas-fir seedlings (*Pseudotsuga menziesii *(Mirb.) Franco, treated with a powder formulation of Deer Away (putrefied egg solids) revealed browse damage by deer or elk. Of control seedlings, and seedlings treated with Repelliff (a 1:1 mix of epi-dihydroandrosterone and androsterone), and Repelliff placebos, 42, 38, and 40%, respectively, were browsed.* Tree Planters' Notes 38(3):22-25; 1987.

Animal damage to conifer seedlings is the leading cause of plantation failures in Oregon (2). Deer have proven to be a major deterrent to reforestation because of their widespread occurrence, mobility, and freedom from natural predators. In Oregon, damage by deer currently costs the forest industry millions of dollars annually (1,2).

Deer inflict damage by browsing and occasionally trampling seedlings and stripping their bark off. They may do this at specific times of the year or continually throughout the year. However, in most areas of western Oregon, damage occurs only in the brief period following bud flush when conifer foliage is nutritious, palatable, and tender (4).

There is a wide variety of approaches to protecting seedlings from browsing deer, but few are both effective and reasonably priced (3). The most frequently chosen approach in the Pacific Northwest has been using staked Vexar tubes, which costs more than $225 per acre. Recently, budcaps (of waterproof paper or spun polyester) were shown to be as effective as Vexar tubes at one-third the cost (4).

A repellant made from putrefied egg solids is available commercially in three formulations. Big Game Repellant (BGR), which costs $20 to $40 to apply, is premixed by the distributor. It must be applied within 2 to 3 days of shipment to minimize deterioration of the active ingredient. Deer Away-L is storeable, can be mixed on site as weather conditions permit, and costs about $50 to $60 to apply. Both liquid formulations must be applied to dry tissue. A powdered formulation, Deer Away-P, was developed for use during wet weather conditions. The cost is $40 to $50 and application requires damp tissue.

All formulations are effective, but they last only 8 to 12 weeks. Plantations frequented by large populations of deer and elk throughout the year may require two to three applications to insure that browsing is prevented. However, in most areas, browsing damage is confined to a 3- to 4-week period following bud flush in the spring.

Seeding new plantations with alternative forage plants costs about $110 per acre but has only been quantitatively assessed on Northwest forest sites not limited by moisture or nutrients (7).

Exclusion fencing in forested areas is very costly and can only be justified for small, high-value operations such as local nurseries, seed orchards, and progeny test sites. The remaining approaches are either only marginally effective (hunting, planting larger seedlings, planting unpalatable seedlings, etc.), very costly (trapping), or impractical for most owners (clearcuts larger than several hundred acres) (3).

In this study, we compared a repellant currently being marketed in Norway, Repelliff (epi-dihydroandrosterone and androsterone in a 1:1 mix), with a powdered formulation of Deer Away. Our purpose was to test their efficacy and to develop general guidelines and specific criteria for their use. Repelliff was evaluated because of its reported efficacy (5,6) as a perimeter repellant of Norwegian red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), and because an effective perimeter repellant would greatly reduce material and labor costs.

## Materials and Methods

Six study regions were selected within the Pacific Northwest: the Oregon Coast Range, Northwest Oregon, Southwest Oregon, Eastern Oregon, the Cascade Range, and the Olympic Peninsula (fig. 1). The experimental design was a randomized complete block. In each region, clearcut units of 30 to 50 acres were chosen. Each unit contained four 5-acre plots separated by a 200-ft buffer. The treatment for each plot was either Repelliff, Repelliff placebo, Deer Away, or control.

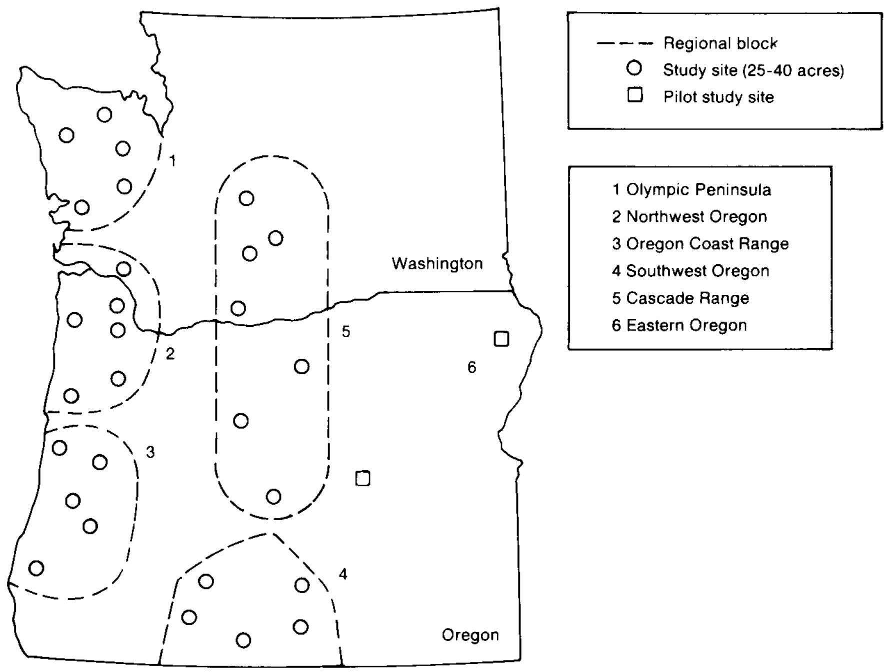


**Figure 1**—*Location of study regions and sites.*

The units were all in close proximity to preferred deer/elk habitat (water, food, temperature, and cover) to optimize the potential for browse damage. The 5-acre plots were established on existing 1-yr-old plantations or on units planted to Douglas-fir in the winter of 1983-84. All study plots were established before bud swell in the spring. However, Deer Away was not applied until after bud flush because it must be placed on new foliage to be effective. Data were collected in the late summer and fall of 1984.

The powdered formulation of Deer Away was tested. A small quantity was sprinkled on moistened (naturally or artificially) foliage of emerging terminal leaders. The powder has a hydrophobic (water-repellent) coating to make it adhere to the leaf cuticle. If overapplied, however, it will bind to itself following the first rainy period and form a slimy globule that slides off the terminal without providing protection.

Repelliff was tested as a perimeter repellant. Ten milligrams of each component sterol was incorporated into micropore plastic strips. The concentration of each sterol was 0.12% of the dry weight of the plastic strip. The plastic strips measured about 12 in. long and were consolidated into tassles of about 40 strips. Each tassle was affixed to a 4-ft-long bamboo stake; and the tassled stakes were distributed at 20-ft intervals around the perimeter of a 5-acre plot. The placebo tassles were prepared and installed in the same manner, but contained no sterol mix.

The incidence of browsing on seedlings within each of the treatments was randomly sampled using a sampling intensity of 25%. Seedlings treated with Deer Away were also evaluated for any visual indication of toxicity. Analysis of variance was performed for each region separately and for all regions together.

**Results**

Browse damage to seedlings protected by Deer Away was significantly lower than that observed for seedlings subjected to control, placebo, or Repelliff treatments (table 1). No visual signs of toxicity (needle discoloration or formation of stress needles) were observed on seedlings treated with the powder formulation of Deer Away. Powder granules were observed on needles 9 to 11 weeks after application, even though most of the regions experienced strong winds and heavy rain during this time. The Repelliff "fence" was unsuccessful in preventing deer or elk from entering the plots. Deer or elk signs (scat and tracks) were observed on all study sites, and on a few sites, Repelliff tassles actually showed signs of chewing.

All six regions showed similar results (table 1). Most of the sites in the Oregon Coast Range showed signs of both deer and elk. Plots in the Northwest Oregon region showed average browse damage; the 22% for Deer Away could be as low as 13% if missing data calculations are excluded from the analysis (table 1). Damage by elk appeared to be higher in this region, relative to the others, possibly due to the proximity of the sites to a large elk refuge.

**Table 1**—*Browse damage on 1-year-old Douglas-fir planted in winter 1983–84 and treated with various repellents*

| | Percent seedlings browsed | | | |
|---|---|---|---|---|
| Site & ownership | Repelliff | Placebo | Deer Away | Control |
| Oregon Coast Range | 40 ± 33 a | 45 ± 31 a | 10 ± 9 b | 48 ± 20 a |
| Philomath (WI) | 38 | 59 | 25 | 52 |
| Alsea (SF) | 97 | 88 | 12 | 78 |
| Alsea (FS) | 26 | 37 | 8 | 47 |
| Hebo (FS) | 29 | 39 | 5 | 38 |
| Coos Bay (BLM) | 11 | 3 | 0 | 24 |
| Northwest Oregon | 54 ± 19 a | 46 ± 31 a | 22 ± 14 b | 61 ± 17 a |
| Knappa (BC) | 25 | 15 | 2 | 36 |
| Knappa (OR) | 45 | 61 | 17 | 81 |
| Elsie (CZ) | 74 | 54 | 39* | 70 |
| Vernonia (CZ) | 67 | 42 | 31* | 62 |
| Cathlamet (CZ) | 58 | 60 | 19 | 58 |
| Southwest Oregon | 36 ± 29a | 38 ± 33a | 9 ± 9a | 29 ± 25 a |
| Medford (BLM) | 62 | 53 | 5 | 43 |
| Butte Falls (FS) | 5 | 0 | 0 | 0 |
| Galice (FS) | 40 | 60 | 21* | 43 |
| Eastern Oregon | | | | |
| Enterprise (BC) | 28 | 22 | 0 | 24 |
| Cascade Range | 36 ± 21 a | 37 ± 26 a | 19 ± 19 a | 34 ± 34 a |
| Mehama (BC) | 14 | 32* | 3 | 53 |
| Mehama (PP) | 67 | 80 | 45* | 67 |
| Mehama (LF) | 40 | 57 | 40 | 24 |
| Sweethome (FS) | 18 | 8 | 6 | 4 |
| Blue River (RL) | 24 | 22 | 4 | 50 |
| Wind River (FS) | 55 | 24 | 17 | 23 |
| Olympic Peninsula | 28 ± 22 a | 36 ± 30 a | 8 ± 8 b | 35 ± 15 a |
| Aberdeen (ITT) | 39 | 71 | 21 | 55 |
| Aberdeen (W) | 22 | 46 | 7 | 42 |
| Quinalt (FS) | 7 | 1 | 2 | 33 |
| Forks (ITT) | 61 | 53 | 8 | 33 |
| Hoodsport (FS) | 10 | 8 | 3 | 13 |
| Overall | 38 ± 24 a | 40 ± 25 a | 14 ± 13 b | 42 ± 21 a |

FS = USDA Forest Service, BLM = USDI Bureau of Land Management, OR = State of Oregon, BC = Boise Cascade, CZ = Crown Zellerbach, ITT = ITT Rayonier, LF = Longview Fiber, PP = Publishers Paper, RL = Roseburg Lumber, SF = Starker Forests, W = Weyerhaeuser, WI = Willamette Industries. Values (± standard deviation) in a row followed by different letters differ significantly at the 1% level.

*Some sites did not provide information on all treatments, although calculations incorporated estimations for missing data analyses (note the conservativeness of this technique). Other sites, however, did not provide enough valuable information to be included in the statistical analysis. Some of the reasons for this were a) no browsing encountered, b) Deer Away application too late or inappropriate, and c) Repelliff and/or placebo tassels were destroyed by animals or wind.

Elk also appeared responsible for a significant component of the damage occurring in the Olympic Peninsula. Although the Repelliff did maintain damage below the level for controls on two sites in this region, it was still not as effective as Deer Away. Six of the nine sites in the Cascade Range were browsed; the other three, all in Washington, showed no evidence of spring browsing. Only three of the six sites from the Southwest Oregon region provided reliable data; the 9% for Deer Away could be as low as 2.5% if missing data calculations are excluded from the analysis (table 1). One of the two pilot sites in Eastern Oregon yielded reliable data and showed no damage to seedlings treated with Deer Away.

## Discussion

The powder formulation of Deer Away was very effective in preventing browse damage by deer and elk unless applied improperly. The powder is easy to overapply. It is very hydrophobic to facilitate strong binding to the waxy leaf cuticle. When a lightly dusted leaf is moistened by rain or by water from a spray bottle (for applications during dry weather), the particles bind tightly to the leaf as the water film evaporates. However, if needles are too heavily dusted, subsequent rainy periods may induce formation of a powdery globule. The globule slips from the terminal, and protection is lost. This happened in all Deer Away plots experiencing browse damage greater than 20%.

The poor performance of the Repelliff, relative to that demonstrated in Norway, is puzzling. The concentration of the sterol mix and the spacing of tassles around the unit are identical to the conditions that were effective in Norway. The frequency of contact with humans and the behavior of the deer and elk towards humans appears similar to that observed in the Pacific Northwest. Feeding of deer and elk by humans occurs in the more populated areas of Norway just as it does in the Northwest. Hunting pressure in Norway appears similar for roe deer (1 month) but slightly more intensive for red deer (3 months).

It appears likely that there are behavioral or physiological differences between the deer and elk species in the two locations that account for the different response to Repelliff; these could be either qualitative (specific sterol mix) or quantitative (concentration). The low material and labor costs of Repelliff and its potential for success, based on product performance in Norway, provide strong incentive to attempt resolution of the problem, particularly if it is only a matter of increasing the concentration of the sterol mix or adjusting the mix ratio.

Regardless, the powder formulation of Deer Away is effective and can be considered a reliable treatment for browse protection.

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# Vexar Seedling Protectors Did Not Reduce Nutria Damage to Planted Baldcypress Seedlings

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*Vexar seedling protectors were tested for preventing nutria damage to baldcypress (Taxodium distichum* (L.) Rich) *seedlings planted in Louisiana swamp forests. Five areas were planted with 1-year-old baldcypress seedlings. Half the seedlings in each area were protected with Vexar seedling protectors. The protectors slowed down the rate of destruction in some areas, but after 3 months, 85% of the guarded seedlings and 87% of the unguarded seedlings were destroyed.* Tree Planters' Notes 38(3):26-29; 1987.

Recent articles by Sternitzke (15) and Williston et al. (16) indicate that there are large reserves of baldcypress (*Taxodium distichum* (L.) Rich. and pondcypress (T. *distichum* var. *nutans* (Ait.) Sweet) in the southeastern United States. With proper management, the swamplands of the south may once again supply the United States with this valuable wood product (15, 16).

Unfortunately, very little is known about the silvicultural practices best suited for cypress management. One area of particular concern is regeneration of this species in its natural environment. Baldcypress is very exacting in its requirements for successful germination and seedling establishment, including an abundant supply of moisture and overhead light. However, seedlings must reach sufficient height to stay above floodwater (13) because they will die after total submergence for even a short length of time during the growing season (9, 12). As a result of the erratic flooding patterns found in most swamp areas, natural regeneration of baldcypress is generally unreliable (8). One way to ensure the proper stocking of baldcypress is to plant seedlings that are already tall enough to be above floodwaters (5).

Special attention needs to be focused on the role of the nutria (*Myocastor coypu*), an aquatic rodent, in preventing baldcypress regeneration. Nutria often clip or uproot newly planted cypress seedlings before the root systems are fully established, thus destroying the whole seedling. In the 1960's, the Soil Conservation Service found that as much as 90% of their planted baldcypress seedlings were damaged, prompting them to recommend the cessation of baldcypress planting until better nutria control measures were found (4).

Several alternatives have been proposed to prevent nutria from eating newly planted baldcypress seedlings. Eradicating nutria is one alternative to the problem, but this method is expensive and requires constant vigilance to keep the animal population in an area under control. In pilot studies conducted by the authors, fencing kept nutria out of planted areas; but workers in other parts of the country have shown fencing to be costly and esthetically displeasing (11, 14). It is often easier to protect seedlings by using a repellant rather than controlling the animal itself (3, 4). However, chemical repellants are usually limited by their short-term persistence (1), and research into nutria repellents is non-existent.

Vexar plastic seedling protectors have provided excellent protection for conifer specifies from predation by animals in the northwestern United States. These relatively inexpensive, lightweight, photodegradable polypropylene plastic tubes (fig. 1) have been tested and used to prevent damage by deer, rabbits, elk, and pocket gophers (1, 2, 6, 10). Anthony et al. (2) reported that even though pocket gophers could easily chew through the Vexar plastic mesh, the protectors nevertheless were highly effective in reducing seedling losses.

The objective of this study was to test the effectiveness of Vexar tubes in protecting planted baldcypress seedlings from nutria.

**Table 1**—*Characteristics of the baldcypress-tupelo stands and survival of baldcypress seedlings 3 months after underplanting*

| Site | Overstory No. trees/ha | Overstory Basal area (m²/ha) | No. seedlings planted | % Survival Guarded[1] | % Survival Unguarded |
|---|---|---|---|---|---|
| 1 | 397 | 20.4 | 600 | 8 | 10 |
| 2 | 442 | 26.6 | 400 | 16 | 5 |
| 3 | 442 | 44.2 | 300 | 96 | 87 |
| 4 | 542 | 25.4 | 150 | 0 | 0 |
| 5 | 385 | 23.1 | 150 | 0 | 0 |

[1]Guarded by Vexar plastic mesh seedling protector.

## Methods

Baldcypress seedlings were underplanted in five flooded stands typical of baldcypress-tupelo stands in southeastern Louisiana. Characteristics of the overstory trees are listed in table 1. Sites 1 to 4 had been logged 1 year before planting and are normally free of standing water only during the late summer months. Site 5 has been permanently flooded for nearly 30 years. It has not been logged but much of the overstory has died (7). All test sites had standing water on them at the time of planting in February-early March 1985 (average water level 45 ± 10 cm). One-year-old barerooted baldcypress seedlings with their tap roots pruned to 20 cm and their lateral roots pruned to 3 cm were planted by holding the seedling at the root collar and inserting it into the soft swamp sediment. The seedlings averaged 70 ± 5 cm in height and 10 ± 1 mm in diameter at the root collar. Fifty to 100 seedlings were planted in each of three to six 0.1-ha plots established on each of the five sites.

Because nutria were known to exist in the study areas, half the seedlings were enclosed in 3.8-cm diameter by 24-strand Vexar photodegradable seedling protectors. The protectors were wired to the ground with two 45-cm wire stakes. Seedling survival was monitored monthly for 3 consecutive months and at the end of the ninth month.

## Results and Discussion

Nutria damage to the seedlings was quick and severe in most cases. After 3 months, 86% of the seedlings had been clipped, uprooted, and destroyed (table 1). Nutria seemed to have very little trouble getting into the Vexar tubes. It appeared that they chewed a hole through the plastic netting at water level, clipped the seedling, and then pulled the tap root through the hole (fig. 1). In nearly every case, the stem of the seedling was left in the tube or adjacent to the tube. Rarely was anything except the bark of the tap root and root collar eaten.

In site 1, four plots were planted on March 2. Three days later when we returned to finish planting two additional plots, 88% of the previously planted seedlings had been destroyed. All seedlings planted on this site were destroyed by the end of the month. In site 2, all of the unguarded seedlings were destroyed during the first month after planting, and the guarded seedlings were destroyed during the second month of the study. In sites 4 and 5, nutria destroyed all of the seedlings within 2 months.

In site 3, the pattern was different from the other plots. Of the 6 plots planted in this area, 2 were destroyed except for 3 unguarded seedlings. In the other 4 plots, only 4 guarded seedlings and 12 unguarded seedlings were eaten after 9 months. The only observed difference among the sites was that there were fewer resting and feeding mounds in the relatively untouched plots (only one mound in the four plots) than in the heavily damaged sites (eight mounds per plot). Assuming that mounds are an indication of the nutria popu-

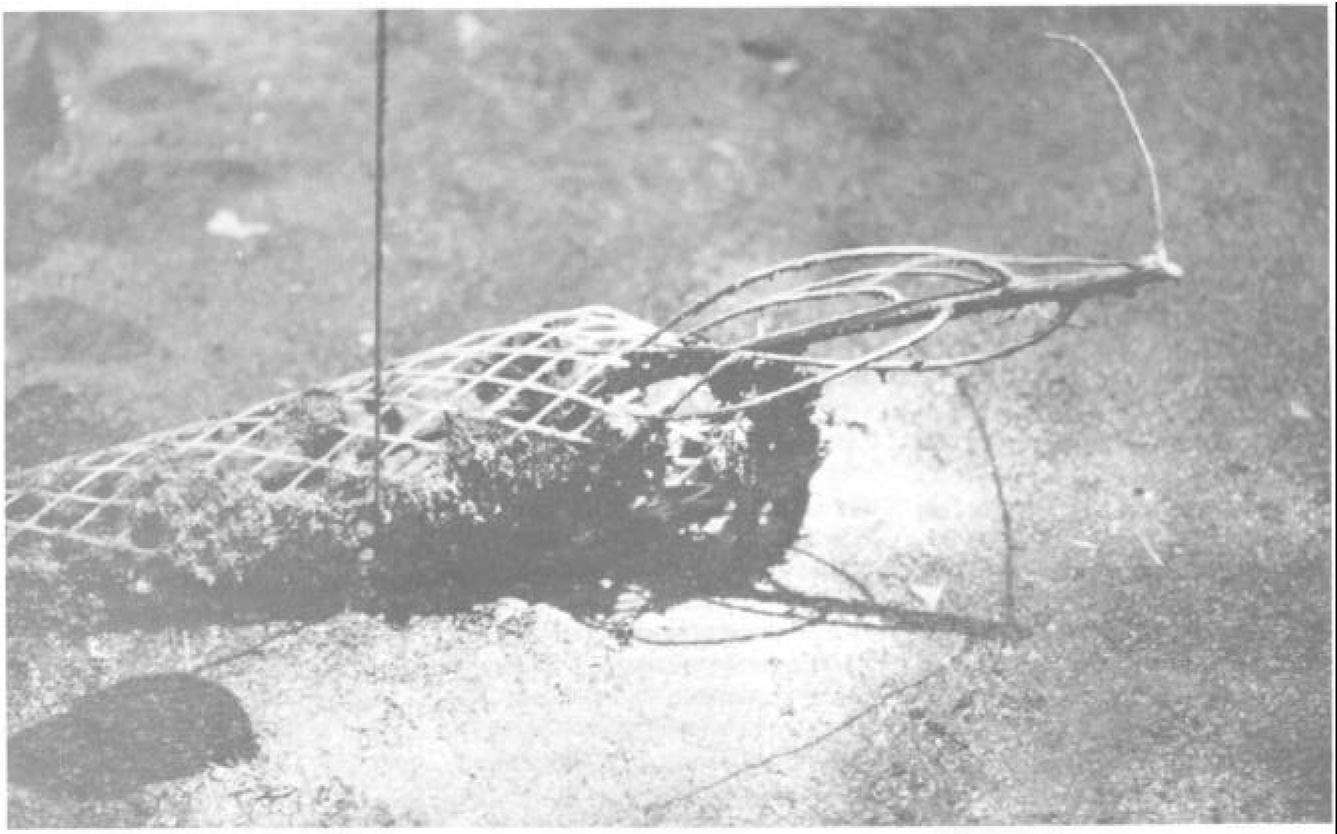

Figure 1—Nutria-damaged baldcypress seedling enclosed in a Vexar plastic protector.

lation in a given area, it appears that adequate seedling survival is dependent on the number of nutria in close proximity to the planted areas. However, Vexar seedling protectors provided little protection against nutria. If artificial regeneration of baldcypress is expected to succeed in areas densely populated with nutria, some other method of protection needs to be devised.

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# Drastic Temperature Fluctuation-The Key to Efficient Germination of Pin Cherry

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*The germination rate of pin cherry (*Prunus pensylvanica *L.) was greatly improved by drastic temperature fluctuation treatment. The optimum treatment regimen was a 24-hour soak followed by 30 days of stratification with 5 days at 5 °C alternating with 5 days at 30 °C, followed by 60 to 90 days of stratification at 5 °C, followed by a 10-day germination period with 12 hours at 5 °C alternating with 12 hours at 30 °C. The germination rate with this treatment was over 75%.* Tree Planters' Notes 38(3):30-32; 1987.

Efficient production of containerized seedlings of pin cherry (*Prunus pensylvanica* L.) has proven to be a problem because of the apparent deep dormancy of the seed. Stratification treatments that give good results with other Prunus species (30 days of stratification at 20 °C followed by 60 to 120 days of stratification at 5 °C followed by a 10to 20-day germination period at 20 °C) result, in the author's experience, in germination rates for pin cherry of less than 10% when seed viability is near 100%.

The USDA Agriculture Handbook No. 450 (5) records a germination rate of 62% with 60 days of warm stratification followed by 90 days of cold stratification followed by a 60-day germination period with day/night temperature fluctuation from 25 to 10 °C. Although this germination rate approaches an acceptable level, the germination period is too long for efficient production of containerized seedlings.

Marks (4), working in the northeastern hardwoods forest of the Unites States, found that pin cherry exhibits a "buried seed strategy" for maintaining itself in the forest landscape. The species is only moderately shade tolerant and eventually dies out beneath a canopy of trees. While reproductively active, however, the shrub produces heavy crops of seed that fall to the forest floor and become buried in the duff. The seed maintain their viability for many years. Germination beneath a closed forest canopy is rare. However, when the canopy is removed by disturbance, germination is extensive, and the stand is reestablished. Marks (4) tested a variety of seed treatments to promote germination; the only treatment that gave good results was removal of the endocarp, which raised germination from 0 to 45%.

Auchmoody (1) found that fertilization of closed canopy northeastern hardwood forest with urea, ammonium, and nitrate resulted in heavy germination of buried pin cherry seed.

The author conducted a preliminary study and a series of formal experiments on germination of pin cherry, described in detail in two reports *(2,3).* The overall objective of the study was to achieve over 75% germination during a 10-day germination period that follows a stratification period of less than 6 months.

**Temperature Regime Within the First 30 Days of Stratification.** One experiment examined the impact on rate of endocarp splitting and germination of seven temperature regimes (assume ± 2 °C for all temperatures) applied over the first 30 days of stratification:

1. Continuous 5 °C.
2. Continuous 20 °C.
3. Continuous 30 °C.
4. Five days at 5 °C alternating with 5 days at 20 °C.
5. Five days at 5 °C alternating with 5 days at 30 °C.
6. One day at 5 °C alternating with 1 day at 20 °C.
7. One day at 5 °C alternating with 1 day at 30 °C.

Air-dried seeds were given a 48-hour soak in distilled water, then placed in moist peat in polyethylene bags. The 30 days of stratification was followed by 120 days of stratification at 5 °C. At 60, 90, 120, and 150 total days of stratification, the percentage of seeds having split endocarps was determined. Stratification was followed by a 10-day germination test at steady 30 °C.

The author thanks Nova, An Alberta Corporation, of Calgary, for its financial support

The progression of endocarp splitting and the results of the germination test are shown in figure 1. The figure shows the benefit of drastic temperature fluctuation (from 5 to 30 °C) in the early part of stratification. The test results were attained with treatments 5 and 7. Treatment 5, involving fewer temperature shifts, is the more convenient and gave good results in all later experiments.

### The Germination Period

The preliminary study showed that germination was more rapid and reached higher levels if the test was run at steady 30 °C rather than steady 20 °C. Steady 30 °C was still not satisfactory, however, as shown in figure 1. In treatments 5 and 7, only 42% and 44%, respectively, of the seeds having split endocarps actually germinated. It was initially thought that in seeds with split endocarps that did not germinate, the endocarp had split relatively late and the seeds required additional cold stratification.

However, a subsequent experiment showed that application of temperature fluctuation (5 °C/ 30 °C) on a 12-hour/12-hour cycle over the 10-day germination period resulted in near 100% germination of seeds with split endocarps and 34% germination of seeds having intact endocarps at the beginning of the germination period.

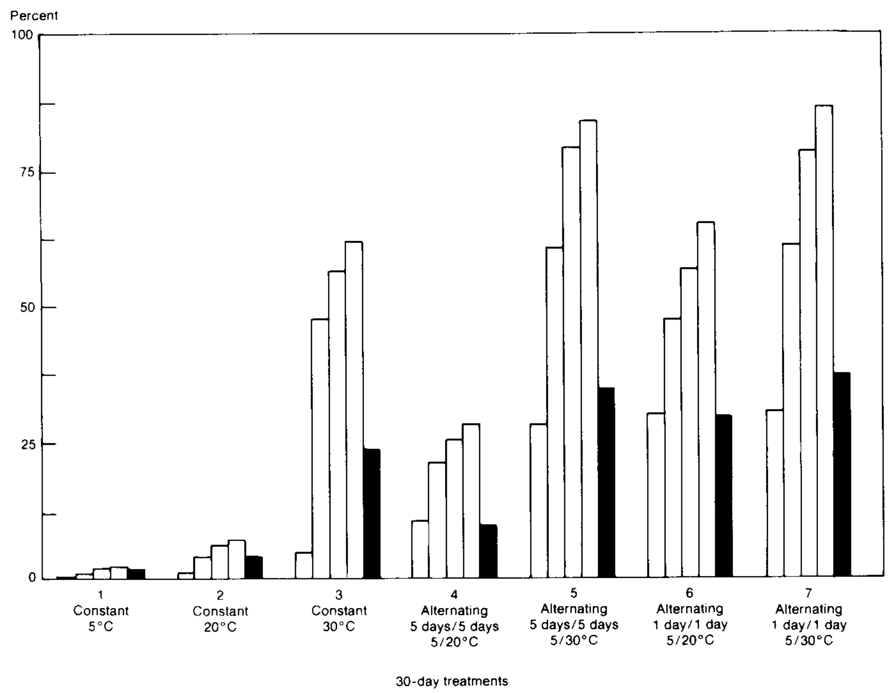


**Figure 1**—*Mean percentage of seeds with split endocarps at 60, 90, 120, and 150 days of stratification (open columns, left to right, respectively) and mean percentage of germination (solid columns).*

**Minimizing Uncontrolled Germination.** It is desirable to minimize uncontrolled germination, that is, germination during stratification, for such germinants are usually discarded and represent a loss of seed. Pin cherry seed with split endocarps will germinate if exposed to drastic temperature fluctuation. Some endocarp splitting and uncontrolled germination can occur in the latter part of the 30-day period of temperature fluctuation, but in the author's experience, it is negligible. A portion of the seed will germinate at 5 °C if kept long enough at this temperature. The author found that extending cold stratification beyond 90 days added little to the percentage of seeds having split endocarps and markedly increased uncontrolled germination.

### Other Seed Treatments

In the preliminary study, the endocarp of some seeds were punctured by clipping off the radicle end before stratification.

The technique was tedious, required great care to avoid obvious damage to the embryo, and even with such care, resulted in disease and deformation of many germinants. Although puncturing or removing the endocarp is not recommended for routine mass production of seedlings, it may have application where a small number of seedlings is required in the shortest possible time. The removal of the endocarp would be followed by 5°C/30°C temperature fluctuation on a 12-hour/12-hour cycle.

The preliminary study found that a 24-hour soak of air-dried seed in 0.02 M calcium nitrate markedly increased the rate of endocarp splitting over a distilled water soak. Later experiments showed no benefit from a nitrate soak, but many details of stratification differed from the preliminary study. Urea, nitrite, ammonium, and hydroxylammonium were also tested; the only form of nitrogen that consistently increased the rate of endocarp splitting (slightly but significantly) was hydroxylammonium chloride at 0.05 to 0.5 M. Further work on the impact of nitrogen is planned.

## Conclusions

The recommended treatment for pin cherry seed is a 24-hour soak in 0.5 M hydroxylammonium chloride followed by 30 days stratification with 5 days at 5 °C alternating with 5 days at 30 °C, followed by 60 to 90 days of stratification at 5 °C, followed by a 10-day germination period with 12 hours at 5 °C alternating with 12 hours at 30 °C.

It would appear that the factor that triggers heavy germination of buried pin cherry seed following forest disturbance is the more extreme temperature fluctuation within the clearing.

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*Available on a loan basis from Environ mental Affairs, Nova, An Alberta Corpora tion, Box 2535, Postal Station M, Calgary, Alberta T2P 2N6.

# Wire Girdles Increase Male Flower Production on Young Loblolly Pine Grafts

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*Wire girdles applied near the branch base of 4-year-old loblolly pine* (Pinus taeda *L.) grafts increased by fourfold the yield of male flower clusters over an equal number of ungirdled branches. Wire girdling is now being used as a routine operation to increase pollen production for accelerated breeding in industrial breeding orchards.* Tree Planters' Notes 38(3):33-35; 1987.

The Alabama Timberlands of Champion International Corporation has selected 105 phenotypically superior loblolly pines (*Pinus taeda* L.) from old-field plantations in northern Alabama, south-central Tennessee, and north-central Mississippi. These selections, along with 3,000 additional selections by other members of the North Carolina State University--Industry Tree Improvement Cooperative, will make up 84% of the Cooperative's future genetic base for loblolly pine in the southern United States (5).

Members of the Cooperative are committed to an ambitious, but realistic, goal of breeding these plantation selections by 1992 (6). The best individual trees of the best families from this breeding effort, as determined by progeny tests, will then be incorporated into second- and third-generation operational seed orchards and breeding clone banks for the fourth generation production orchards.

The operational plantings from this tree improvement effort are estimated to produce 50% or more volume per acre over a 30-year rotation than plantations established with unimproved seed. The total process is expensive and any technique that can shorten this breeding and testing cycle will pay handsome dividends.

Breeding requires that pollen be available from the correct male parent at the time the selected female parent is receptive, and breeding cannot be completed until each male and female parent produce flowers in sufficient quantities to systematically breed the target population. Male flower development and pollen production usually lag behind the female flower development, although this can vary considerably from clone to clone. Therefore, the lack of sufficient pollen from a designated male parent to pollinate a particular female parent can delay the breeding process and greatly lengthen the time required to complete the necessary crosses, test the progeny, and incorporate the material into production orchards.

One method demonstrated to hasten male flower development and production of pollen in pines is to apply a wire girdle near the base of potential pollen-bearing branches (2). Bark-girdling techniques have been used for many years to stimulate early flowering in the horticultural trade. Partial girdling of pines has also been tried in attempts to achieve similar results, but the success has been variable and often poor (4).

Treatment of 7-year-old loblolly pine with branch girdles, gibberellic acid, and naphthaleltic acid resulted in an eightfold increase in male flowering (3). The girdle was made by removing strips of bark, each strip covering three-fourths of the branch circumference. This method of girdling resulted in nearly 50% mortality of the branches treated. A simple wire girdle applied in February has been used to promote male flowering on loblolly pine grafts the year following the application of the girdles (1,2).

## Methods

In February 1982, three clones were selected in a breeding orchard that had been grafted in 1979 and 1980. In the lower third of the crown of each selected graft, four branches were chosen on two ramets of the three clones. Two branches were selected as controls and were not girdled, the other two branches were girdled. An 8-in. segment of 17-gauge electric wire was snugly fastened near the base of the branches (fig. 1). The following

Figure 1—*Wire girdle on loblolly pine branch to promote male flower production. Additional wire loops with flagging used to support girdled branch.*

spring all branches were inventoried for male flowers. The results were sufficiently encouraging to increase the number of girdles in 1983.

In February 1983, branches on two ramets of 40 clones, three ramets of one clone, and one ramet of three clones were girdled. A total of 251 girdles were attached to these 4-year-old grafts. Branches were selected in the same manner as in the initial trial in 1982. These were inventoried in the spring of 1984.

**Results and Discussion**

There were 71 branches lost to mechanical or natural causes, leaving 180 girdled branches. Each girdled branch was inventoried for male flower clusters and an equal number of ungirdled branches on the same tree were also inventoried for male flower clusters (table 1). Pollen production varied by clone, but clone by girdling interactions were not analyzed. Girdled branches remaining from the 1982 trial continued to produce pollen in two subsequent years. Tests on 2-year-old field grafts did not produce pollen.

This test girdling of 4-year-old field grafts increased male flower production when branches in the lower third of the crown of grafts receiving intensive cultural treatment were stressed with wire girdles. The current technique uses

**Table 1**—*Results of branch girdling of 4-year-old loblolly pine grafts*

| Treatment | No. of branches | No. of branches with male flower clusters (No.) | No. of branches with male flower clusters (%) | Total No. of male flower clusters |
|---|---|---|---|---|
| Girdled | 180 | 131 | 73 | 452 |
| Ungirdled | 180 | 10 | 6 | 113 |

preformed 7-in. black 18-gauge wire and a twister used in the construction trade to fasten reinforcing rod prior to the pouring of cement.

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