United States
Department of
Agriculture

Forest Service

Southern Research Station

General Technical
Report SRS-25

National Proceedings: Forest and Conservation Nursery Associations— 1998

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April 1999
Southern Research Station
P.O. Box 2680
Asheville, NC 28802

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Southern Forest Nursery Association Conference

Lafayette, Louisiana
July 13-17, 1998

Host:
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ONSET HOBO® TEMP RECORDER[1]

Dean McCraw[2]

Most all Southern Nursery Managers use computers in the day to day operation of their nurseries. The HOBO® temperature recorder used in conjunction with the computer now gives nursery managers a cost effective and reliable tool for managing their cooling operations.

Manufactured by Onset Computer Corp., the HOBO® has a temperature operating range of 20°C to +70°C (-4°F to +158°F). Weighing in at less than one oz., its small size adds to its versatility (fig. 1). Battery life of the unit is rated at 1.5 years in continuous use. Our experience has shown that the battery should be changed once a year, which we usually do at the start of our lifting season.

The unit is capable of recording 1800 data points. These points can be set for various interval periods. The shortest interval period is 15 minutes with a data point collected every 0.5 seconds. The longest interval period is 675 days with a data point collected every 9 hours.

The HOBO® has a red light that blinks while it is recording. The light blinks brightly at every measurement and weakly every two seconds if the interval between measurements is longer than two seconds.

The unit can be set to record temperature in either Fahrenheit or Celsius. This is not critical as the recorded data can be converted between Fahrenheit and Celsius when the unit is downloaded.

Figure 1—The Onset HOBO® Temp Recorder.

As noted initially, this unit does not function without the aid of a personal computer. The HOBO connects to the computer using a special cable, which is attached to the Com (Serial) port of the computer. When you purchase the download software, the cable is included. The software is appropriately named BoxCar (as every HOBO® needs a Boxcar), and allows you to launch the unit or download the data points.

List price for the HOBO® is $49.95 each and the BoxCar software package, including the cable, is $14.00. Units can be purchased directly from Onset Computer Corp at (508) 563-9000 or at their web site at www.onsetcomp.com and can also be purchased through Forestry Suppliers. The HOBO® is warranted to be free from defects for a period of one year from the date of purchase.

Our main use of these units has been for tracking cooling temperatures in our cooler and refrigerated vans. We have used the units for the past two lifting seasons with very good success. When used in seedling vans the units are contained inside a watertight hard plastic case. These cases are mounted to the underside of the seedling racks to avoid damage (fig. 2). The unit must be mounted far enough away from the door of the seedling van to avoid the sunlight that may affect the readings.

The biggest problem our field people encountered was their inability to read the recorder in the field. We solved this by

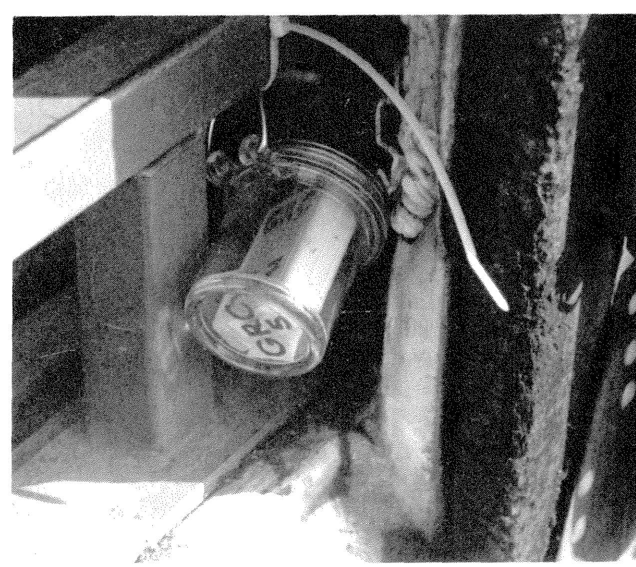
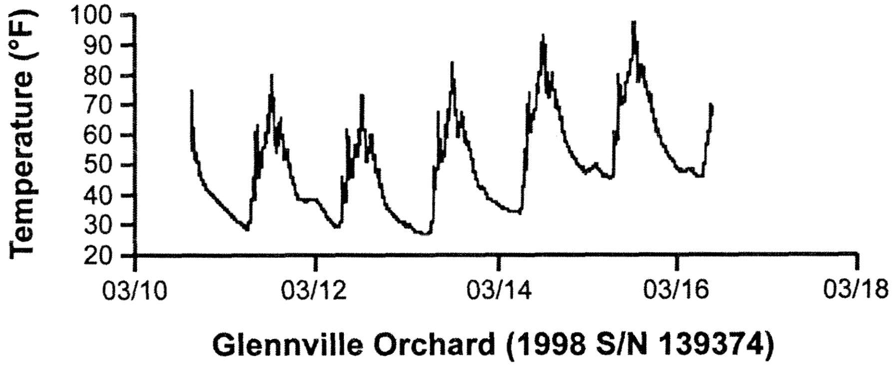


Figure 2—The mounting of the Onset HOBO® Recorder in the rear of a refrigerated van.

[1]McCraw, D. 1999. Onset HOBO® temp recorder. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 3-4.
[2]Rayonier, Rt 2 Box 1975, Glennville, GA 30427.

(a)



(b)

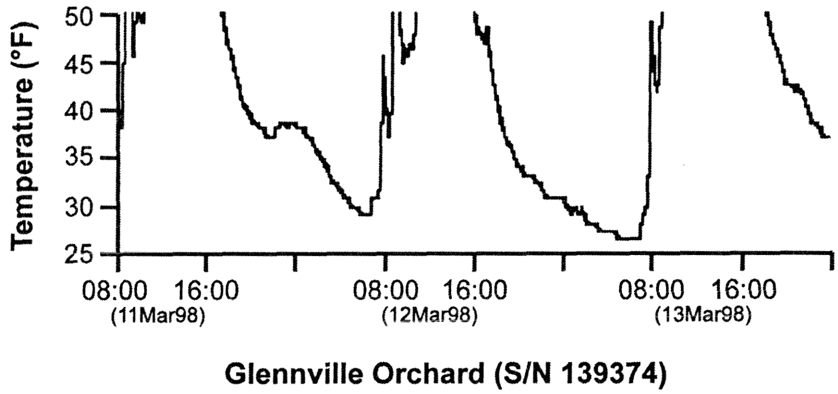


Figure 3—Temperature graph from Hobo® sensor for the Glennville seed orchard (a) and a zoom view of the same graph (b).

purchasing a $9.99 digital min/max thermometer. This allows the field personnel to check temperature ranges as long as they reset the max/min temperatures on the thermometer.

The HOBO® unit has a temperature sensor that can be placed outside the case. The sensor has a greater range outside the case but we have not found a use for this to date.

The output of the data points with the BoxCar software is presented in a line graph (see example). The software allows you to zoom into a small area of the graph so the data points can be seen in more detail (see example). If the graph does not give you the detail you need, then you can export the data points to a spreadsheet. The latest version of BoxCar has an icon for both Excel and Lotus 123.

In recap the advantages of the HOBO® temperature recorder are:

- Small size.
- Low initial price.
- Easy to download.
- More durable than other data loggers used.

CURRENT REFORESTATION DEMANDS ON SOUTHERN NURSERIES[1]

Robert P. Karrfalt[2] and Clark W. Lantz[3]

ABSTRACT—Forest nurseries in the southern U.S. are experiencing changing demands from several and widely varied sources. Government incentives for tree planting are decreasing but free market forces, disaster relief, and environmental tree planting might push seedling demand up. High turnover in nursery work forces, and a changing reforestation community present new challenges that nurseries must adapt to.

INTRODUCTION

Present demands on southern nurseries have risen from several sources. There are more hardwoods, longleaf pine, shrubs and container seedlings. There have been changes in government incentive programs and very significant shifts in free market forces. More changes are likely. Tree planting for carbon sequestration came to the fore again following the Kyoto conference on green house gases. In Washington D.C., there is growing awareness of the importance of non-industrial private forest land for timber production as one way to compensate for the loss of timber harvest from public lands. Additionally, there are changes in the reforestation community. Reforestation activity was once focused on well established agencies and companies. Now there are more seed collectors, more small private nurseries, continual turnover in nursery personnel, and many groups, such as the Arbor Day Foundation and the National Tree Trust, that are oriented toward the layperson. Southern nurseries will be challenged to find ways to educate and partner with this changing reforestation community.

CHANGING SPECIES COMPOSITION AND STOCKTYPES

Over the last decade forest tree nurseries throughout the U.S. have initiated the production of many more diverse species than in past decades. In 1993, about 25,000 acres in the south were reforested with hardwoods. By 1997 that acreage had grown to 90,000 (Southern Group of State Foresters 1997). The interest in longleaf pine has increased dramatically as witnessed by the organization of the Longleaf Alliance. Southern state nurseries of course were effected by both of these changes with hardwood and longleaf pine production going up sharply. The number of species of hardwoods and shrubs produced increases every year for many nurseries. Longleaf container seedlings are very popular because of their higher survival and better initial growth under certain planting conditions. Despite a cost that is often double or more than that of bare root seedlings, the market for container longleaf seedlings continues to increase. Growing more species and containers has helped support nursery operations by keeping revenues up, but has created new demands for the nursery manager. Because hardwoods, shrubs, and longleaf pine often have seed dormancy or low seed quality problems, managers have problems predicting inventories, using bed space efficiently, and maintaining cost-effective operations. Figure 1 illustrates the relationship between seed and nursery management effectiveness. Even with high quality seed and uniform germination, these species are challenging to the manager because they require more growing space and unique cultural practices. Growing larger pine seedlings is another recent trend affecting nursery capacity and costs.

CHANGING INCENTIVES

With political pressures to reduce government spending, the money available for government cost share programs to encourage reforestation has been decreasing (fig. 2). This tends to lower the demand for seedlings. However, there are clearly some free market forces which are compensating for this loss of government incentive. Figure 3 shows how planting continues to increase on non-industrial private lands. Not only has the total number of seedlings planted on this category of ownership increased, but also

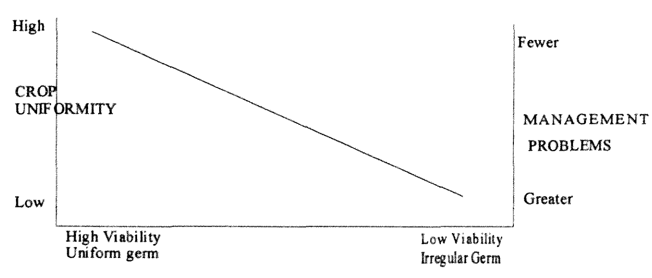


Figure 1—Seedling crop uniformity decreases and management problems increase as seed quality and seed dormancy problems increase.

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[1]Karrfalt, R.P.; Lantz, C.W. 1999. Current reforestation demands on southern nurseries. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 5-7.
[2]Laboratory Director, National Tree Seed Laboratory, USDA Forest Service, Dry Branch, GA 31020; Tel: 912/751-3552.
[3]Nursery/Tree Improvement Specialist - Retired, USDA Forest Service, Atlanta, GA 30367.

annually it accounts for an increasing percentage of all seedlings planted (fig. 4). A likely explanation for the increases on small properties is the loss of timber harvest on public lands and the current housing boom with low interest rates. These two factors have kept stumpage prices high, making reforestation for timber an attractive investment. The shortage in seedlings experienced over the last several years is additional proof that interest in planting trees is strong in the South. This shortage is likely to continue because the number of acres planted is currently less than half the number of acres harvested (Southern Group of State Foresters 1997). Furthermore, many of these unplanted acres possibly will revert to over stocked stands of low quality hardwoods and brush if not replanted within one to two years following harvest.

What events might occur that would change the incentive picture? Environmental crises and concerns might well have a major impact. The Kyoto conference on controlling greenhouse gases opened a discussion on carbon credits. Carbon credits would be the right to generate a certain level of CO2 if compensating steps were taken to reduce CO2 by another activity. At least some of these credits could translate into more tree planting. Such credits would bring new players into the picture such as power utilities who would pay for tree planting on private land instead of government. Large destructive wildfires have occurred in the last year in Florida and Texas. Reforesting parts of this burned area could have a major impact on seedling supplies. There is at least a slight chance that governmental disaster relief funds could pay for tree planting. Finally, there appears to be a growing concern that if timber production will not take place on public lands, then non-industrial private lands need to be a focus of the production of wood products. If free market forces do not make a full correction for the loss of public timber, then, government incentives to encourage reforestation and timber production could receive renewed attention.

CHANGING REFORESTATION COMMUNITY

Changes in the makeup of the reforestation community are certainly placing new demands on southern nurseries. A need for many small seed lots of shrubs and other native species has encouraged more new seed collectors. More small private nurseries have begun to produce tree seedlings. Longleaf container seedling production has been especially attractive to this group of growers. Larger horticultural growers have also taken on container seedling production. There are also more groups than ever promoting the planting of trees. Is there a need to educate the new players in reforestation? Furthermore, what is the best way to educate the public on the importance of quality seedlings, species choice and seed source selection. Such problems were more manageable when reforestation activities were focused more within established agencies and companies. Almost everyone knew everyone who worked a nursery, seed orchard or seed plant. Information and expectations moved effectively in a more informal manner. Now that changes are taking place, the need to protect the consumer and the conscientious experienced provider of seed and seedlings is growing. Accreditation of nurseries and seedling certification are programs that could serve nurseries well by providing the layperson assurance

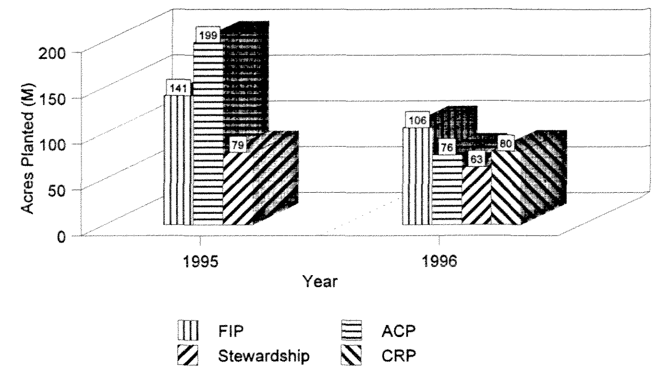

Figure 2—Federal cost share incentives have decreased in recent years. (Note: CRP figures not available for 1995) (USDA 1995, 1996).

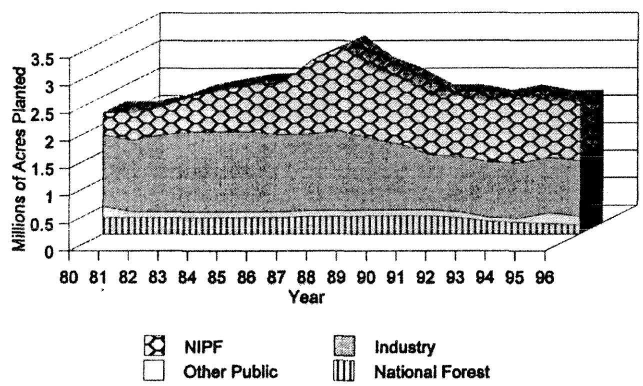

Figure 3—Tree planting by ownership has changed over the years (USDA 1997).

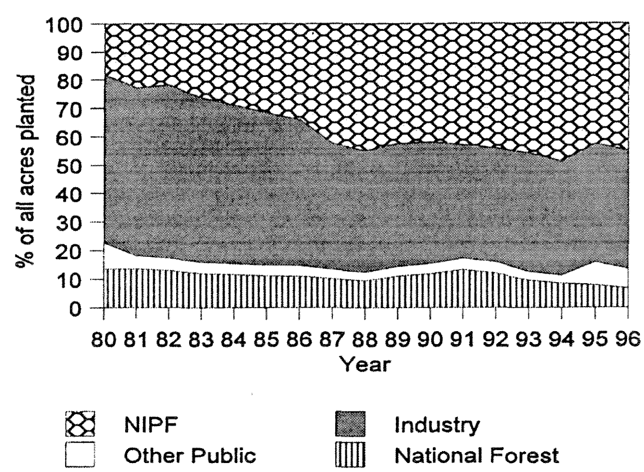

Figure 4—The largest percent (about 45 percent) of all tree planting now occurs on non-industrial private forest lands (USDA 1997).

that the seedlings they are receiving are quality trees and well suited to their needs. Additionally, such programs would demonstrate to the general public that reforestation efforts are conducted in the most environmentally responsible manner.

Regular turnover in nursery staffs appears to be part of the current employment picture, placing significant stress on nursery managers. These new personnel must be given training that quickly brings them up to competence without negative impacts on quality seedling supplies. Here again, a quality management program for nurseries will help meet this demand. In a quality management program, all important production steps are written down in operation manuals, with records kept to verify what was done, when it was done, and what to do if errors occur.

An additional educational challenge relates to the inappropriate transport of seedlings from one planting zone to another. Improper movement of seedlings may occur with absentee land owners who are not aware of the importance of planting zones. They might buy trees in their home state and innocently, but incorrectly, transport them to their land in another state where the seedlings are not adapted. In other cases, seedlings are transported for resale into planting zones where they are not adapted. The need for education is strongest when seedlings are in short supply. Faced with the choice of no trees or maybe the wrong trees, the temptation is to use whatever is available. This may result in reduced growth, poor form, or even failed plantations.

REFERENCES

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USDA Forest Service. 1995. Tree planting in the United States - 1995. Washington, DC: Forest Service, Cooperative Forestry. 18 p.

USDA Forest Service. 1996. Tree planting in the United States - 1995. Washington, DC: Forest Service, Cooperative Forestry. 17 p.

REFUGE CONTRIBUTIONS TO REFORESTATION[1]

Ray Aycock[2]

The National Wildlife Refuge system of the U. S. Fish and Wildlife Service, consisting of some 504 units scattered throughout the country, contains several thousand acres of bottomland forests in the Lower Mississippi River Valley. Many of these refuges contain extensive stands of forests that have historically contributed acorns to nurseries for seedling production. Since the heavy commercialization of hardwood seedlings brought on by the Wetlands Reserve Program and Conservation Reserve Program of USDA in the mid-1980s, there has been a restriction on commercial pick up of acorns on national wildlife refuges.

Prior to this restriction, there was significant private interest in collecting acorns on national wildlife refuges in the White River and Ouachita River systems in Arkansas. Restrictions were imposed by refuge managers for a number of reasons, but primarily because collecting became a heavy commercial interest that often conflicted with refuge public uses, particularly deer hunting. Refuge managers could issue collecting permits to private citizens, but they were then faced with an additional paper work responsibility that meant little to that refuge, but additional complaints from the public. Bow hunters which constitute a large user group were usually the primary group that complained.

Public complaints were usually the result of disturbance from collectors. In addition the public often perceived collectors as causing a hardship on wildlife by taking their food supply. We know that the later is an erroneous assumption because the target species, Nuttall, fell over a long period of time and often in very wet sites. Private collections were probably biologically insignificant, but public perception is still real. There were problems with littering, cheating, disturbance, and time spent on administering the program.

During the mid-1990s the Fish and Wildlife Service reorganized on an ecosystem basis. One of our administrative units within Region 4 (Southeast Region) is the Lower Mississippi Valley Ecosystem. One of the features of ecosystem management is empowerment by field stations. The LMR has a number on functioning committees that provide direction and funding to field stations. Probably the 3 most important committees are Reforestation, Migratory Birds, and Private Lands. All 3 committees strongly support reforestation, an ecosystem goal, both on private and public land.

The Reforestation Committee which is composed primarily of foresters and biologists recognized the potential contributions of refuges to nursery production of hardwood seedlings in the southeast. This situation is particularly true for Nuttall oaks because a significant acreage of this species is on refuge lands or state wildlife management areas. This particular species has been the single most desired species on both public and private lands because of its high wildlife and commercial value. It also does really well on fairly wet sites and is the best survivor of all oak species used in reforestation attempts.

The Reforestation Committee is charged with coordinating the procurement and planting of hardwoods on refuge lands and private lands enrolled in the Services Partners for Wildlife Program. Partners is a program where the Service furnishes seedlings and usually pays for planting hardwood seedling under a 30-year agreement with private landowners. During the last few years we have been faced with trying to obtain both seedlings and acorns so we were aware of what both the private and public nurseries were facing from an acorn shortage standpoint. In addition many of us had been working with NRCS and recognized the tremendous potential impact of reforestation on lands enrolled in USDA programs.

We attempted to encourage refuge managers to liberalize their attitudes toward private acorn pickup on refuge lands. This was done both to benefit our own needs and those of nurseries within the LMV that supply seedlings to the private sector. We also hoped that it would encourage an expansion of the nursery industry that would be able to meet the demand for hardwood seedlings.

The Refuge Manager at White River NWR, Larry Mallard, and particularly his forester Jeff Dedmon, decided to initiate an acorn collection program utilizing a new special use permit system on a trial basis. In years past, special use permits were utilized on an individual basis, but there was heavy speculation that the government never received anywhere close to its share, generally around 10 percent of the acorns or the value of the acorns. Closer scrutiny of collection required additional manpower refuges did not have, so the operation usually took place on an honor system. This same situation often existed on other public lands. Due to these problems most of our refuge managers did not allow private acorn collecting on their refuges.

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[1]Aycock, R. 1999. Refuge contributions to reforestation. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 8-9.
[2]U.S. Fish and Wildlife Service, 6578 Dogwood View Parkway, Ste B, Jackson, MS 39213; TEL: 601/965.4903.

White River decided to utilize one collector on a bid basis that would have exclusive rights to approximately 70,000 acres in Monroe and Prairie Counties in Arkansas. A bid solicitation was issued in November of 1997 for the privilege of collecting up to 500,000 pounds of acorns and pecans. The successful bidder had to meet the following conditions of his special use permit if they were the successful bidder:

(1) Bids were received on the basis of the number of pounds of Nuttall oak acorns the bidder will furnish and deliver to the refuges for the first 50,000 pounds of Nuttall oak acorns collected from the refuge.

(2) For any amount collected beyond that first 50,000 pounds of Nuttall oak acorns, the successful bidder will furnish and deliver to the refuge 10 percent of that excess volume in Nuttall oak acorns.

(3) If the bidden amount of acorns was not provided, the permittee forfeited the performance deposit of $5000.

(4) All bids were subject to the special conditions of the permit which set certain parameters for acorn condition, delivery to the refuge, storage, sub-permittees, treatment of trees, littering, indemnity issues, and other legal issues.

Mr. Larry Crosby of Clarendon, Arkansas was awarded the bid based on his willingness to post the performance bond and his bid of 7,600 pounds of Nuttall acorns. In addition he agreed to furnish 10 percent of Nuttall acorns in excess of that first amount, along with 10 percent of all other acorns and pecans collected.

Mr. Crosby furnished a total of 8,030 pounds of Nuttall acorns including 430 pounds of additional acorns. These acorns are being used for us to contract grow seedlings for planting on Service and private lands. A total of 54,304 total pounds was picked up by Mr. Crosby's subpermittees. This new supply of Nuttall oak acorns provided a significant infusion to the nursery industry. Continuation of this project and possible expansion could significantly affect the supply of this species for nurseries in future years.

White River did experience some problems including subpermittees selling acorns to competitors, reporting less than they actually picked up and not having a valid permit. Close supervision by the refuge enabled us to obtain a fair return for our needs and to provide acorns for the private sector. Weather conditions, particularly flooding, shortened the collection period.

We believe that this activity is compatible with the goals and objectives of the refuge system and contribute significantly to the reforestation goals of the ecosystem. Hopefully it will be used for years to come.

SEED ORCHARD PRODUCTION: ITS POTENTIAL AND ITS LIMITATIONS[1]

T. D. Byram and W. J. Lowe[2]

ABSTRACT—Over 8,000 acres of improved pine seed orchards in the South support annual regeneration programs of approximately 1.2 billion seedlings. These orchards are sufficient to meet the demand for improved seedlings if they are correctly allocated to the appropriate species and seed sources. However, because better clones are identified in the breeding and progeny testing programs of the tree improvement cooperatives every year, the most desirable seed will always be in short supply. Customer needs may also change rapidly, making it difficult to meet short-term demands.

Seed orchards supply seed to nursery programs very cheaply: seed costs generally range from $5 to $7 per thousand seedlings. Seed orchards are also the only technology that can currently supply the huge number of propagules needed for the large regeneration programs in the South. However, open-pollinated seed orchards have a number of limitations. Genetic potential is lost through pollen contamination and year to year variation in seed yields is highly unpredictable. In addition, the eight to ten-year delay between grafting a new orchard and the onset of commercial seed production makes it very difficult to respond to rapid increases in seed requirements. Sowing by open-pollinated families has provided an incentive to design seed orchards only with heavy cone producers. Because there is no correlation between a family's cone production capability under orchard culture and the performance of its seedlings, clones with high genetic gains should not be automatically excluded from seed orchards because of low seed production. Their contribution to the overall genetic quality of the orchard through pollen production may be significant.

Short-term strategies for meeting increased demands using existing seed orchards include putting mothballed orchards back into production, substituting one seed source (or species) for another, and maintaining larger seed inventories. Each of these options has an associated cost, generally incurred by sowing lower genetic quality seed. Short-term strategies for increasing genetic gain from existing seed orchards include roguing, collecting by open-pollinated families, and controlled-mass pollination. Long-term strategies for increasing yields and improving the genetic quality of seed require regular establishment of new seed orchard blocks. Designing orchards with excess capacity provides increased flexibility to meet rapid increases in short-term seed demands and allows additional genetic gain to be captured by high-grading the seed crop in years with surplus production. Probability distributions for seed yields can assist in planning seed orchard expansion programs.

INTRODUCTION

One of the largest reforestation efforts in the world occurs each year in the Southeastern United States where approximately 1.2 billion pine seedlings are planted. This program is supported by over 8,000 acres of seed orchards supplying 120,000 pounds of seed. Orchard acreage in the South is currently less than the 9,600 acres reported six years ago (White 1992) because of the closure of 1,400 acres of orchard by the US Forest Service (T. Tibbs, personal communication). Seed orchard acreage managed by industry and the states appears to be steady as first-generation orchards are replaced with advanced-generation orchards (G. Powell and R. Weir, personal communication; Byram and others 1997).

Loblolly and slash pine seed orchards are sufficient to supply all the seed required for these species from genetically improved sources. Seed supply for some minor species, such as longleaf pine in the Western Gulf region, still rely on natural stand collections. However, seed orchards have been established for most of these species and genetically improved seed will soon be available. This does not mean that orchard establishment has been completed and that seed supplies are adequate. Because better families are identified in breeding and progeny testing programs annually, older seed orchards continually become genetically obsolete. The result is that the best seed sources will always be in short supply. This situation is aggravated when management makes rapid changes in favored seed sources, rotation ages, or planting densities.

While vegetative propagation techniques such as rooted cuttings or artificial seed will likely supplant some demand for seed in the near future, the large majority of the planting material in the South will continue to come from seed orchards. This is true because of scale and economics. Seed orchards are the only technology now available that can supply the large numbers of propagules needed and they do this very inexpensively. Seed costs generally range from 25 percent to 33 percent of total nursery production costs, or roughly less than $0.01 per seedling. Unfortunately, seed orchards have a number of drawbacks that affect the regeneration manager's ability to make long range plans. Major disadvantages are the inability of seed orchard managers to respond rapidly to increased seed requirements and the large year to year variation in seed yields. Genetic potential is also lost by dependence on open-pollinated seed.

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[1]Byram, T.D.; Lowe, W.J. 1999. Seed orchard production: its potential and its limitations. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 10-13.
[2]Western Gulf Forest Tree Improvement Program, Texas Forest Service, Forest Science Dept., Texas A&M University, Forest Science Laboratory, College Station, TX 77843-2585; Tel: 334/365-2488.

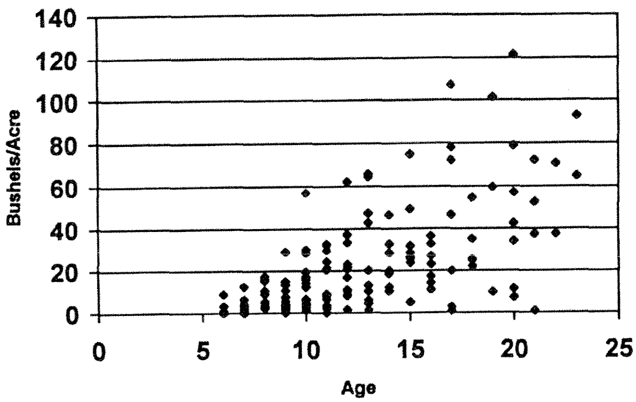

Figure 1—Yield for WGFTIP loblolly pine seed orchards collected between 1976 and 1985.

SEED ORCHARD PRODUCTION

Seed Orchards Take Many Years to bring into Production

Designing a seed orchard program requires an extremely long planning horizon. Generally, a two-year period is required to prepare an orchard site, establish rootstock, and graft a new seed orchard. After grafting, there is an eight to ten-year delay before the production of seed in commercial quantities. At this point, seed production potential increases quite rapidly; however, annual production can still be extremely variable (fig.1). Top grafting for seed orchard conversion may shorten this period, but it is uncertain if this technique will be widely adopted.

There is very little that seed orchard managers can do to reduce large and unpredictable year-to-year variation in seed crops.

Factors that affect annual seed production include the amount of flowering and damage from weather and insects. Orchard managers practice fertilization and drought stressing to promote flowering, but there is very little that can be done to offset the effects of weather. For example, nearly all of the entire loblolly and slash pine flower crop was lost to a series of spring freezes in 1996 and some orchards in the Western Gulf Region experienced 30 percent losses again in 1998.

Crop losses to cone and seed insects can also be severe, exceeding 90 percent without insect protection. While these losses can currently be controlled, possible changes in pesticide regulations make for an uncertain future. Seed orchard mangers now depend on a limited number of products in only two classes of chemicals (organophosphates and synthetic pyretheroids), both of which are under review by the Environmental Protection Agency. Most chemical companies have only minimal interest in maintaining registration for seed orchard pesticides because such small amounts used. For the same reason, it is unlikely that any new chemicals will be introduced. If the industry looses a chemical or class of chemicals for cone and seed protection, average seed harvests could decline drastically and annual variations in seed crops will certainly increase.

The Best Genetic Quality Seed Will Always be in Short Supply

Older orchards become genetically obsolete as better families are identified in breeding and testing programs. For example, the average orchard currently in production in the Western Gulf Forest Tree Improvement Program (WGFTIP) produces seed with a 17 percent improvement in mean annual increment at age 20 (MAI20) over unimproved sources (Byram and others 1997, p. 10). However, the newest orchards (which will begin production in about eight years) have a 30 percent improvement in MAI20. In fact, new loblolly orchards have been increasing in gain at an annual rate of 1.4 percent genetic improvement for the last five years (Byram and others 1997, p. 7).

Short-Term Strategies to Supply More Seed Incur a Cost by Reducing Genetic Quality

Seed can be in short supply when managers change preferences for seed sources faster than the demand can be met by orchard establishment programs. For example, in the last eight years, one organization in the WGFTIP increased demand for one seed source by 400 percent while cutting demand for their previously preferred source by 90 percent. When shifts in demand occur, several short-term strategies can be used to address the resulting shortfalls. Unfortunately, all of these measures result in using seed with less genetic improvement.

Older, genetically obsolete seed orchards can be put back into production. There will be increased costs incurred due to managing additional orchard acres. Most importantly, lead-time is necessary to implement this option. Fertilization for flower stimulation must be done in the summer to affect the following spring's flower crop. The cone and seed insect control program should also be in place for at least two years to be fully effective. However, the biggest cost incurred is in using genetically inferior seed. This cost can be offset somewhat by collecting only the best families, but the poorer families in the orchard will still contribute to the genetic quality of the seed by their contribution to the pollen cloud.

Larger seed supplies can be stored in inventory by collecting more of the crop in years with surplus seed production. This is equivalent to collecting more genetically obsolete seed orchards, because this seed would not otherwise be used. Again, foresight is required and seed costs reflect additional collection and storage expenses.

One seed source (or species) can be substituted for another at an opportunity cost that depends on how closely the substitution meets the needs of the customer. This option can be justified only if it is better than other alternatives that might include waiting a year or substituting genetically unimproved seed.

Short-Term Strategies for Improving Genetic Gain can Reduce Seed Production

Short-term strategies for improving genetic gain from existing orchards include roguing, collecting by family or gain groups, and controlled-mass pollination (CMP). All of these options lower seed production potential, at least

temporarily, and may raise seed costs. Whether or not these options are economically desirable, depend upon the availability of surplus seed and on the value of genetic gain. According to Bridgwater and others (1998), 1 percent improvement in MAI20 has a present value of $0.01375 per seedling ($13.75 per thousand seedlings). Assuming 80 percent nursery efficiency, this value translates to $0.011 per seed.

Roguing reduces the number of trees per acre and has a short-term affect on seed yields. Long-term affects are negligible as expanding crowns on the remaining trees increase production. In fact, thinning is an integral component in maintaining the health and seed production potential of seed orchards.

Controlled-Mass Pollination has Implications for Nursery Production Systems

CMP seed is produced by isolating the female flowers before they are receptive and using selected male parents to perform controlled pollination. This technique captures genetic gain by avoiding pollen contamination. As little as 30 percent pollen contamination will result in losses averaging 2.5 percent in MAI20 for the current production orchards in the WGFTIP (Bridgwater and others 1998). Pollen contamination rates may be much higher (Lowe and Wheeler 1993) and the losses in absolute value will increase in higher gain, advanced-generation orchards. Gain is also captured by using selected male parents. Using the best six parents in a breeding region will provide an average improvement of 13.8 percent gain in MAI20 in addition to the 2.5 percent improvement achieved by preventing pollen contamination. Therefore, CMP seedlings with 16.3 percent gain in MAI20 over average orchard seed have a marginal present value of $224.12 per thousand ignoring the cost of seed production.

Unfortunately, CMP seed is expensive to produce. Current estimates from pilot scale projects indicate that isolation bags, pollination, labor, equipment rental, and processing will cost approximately $0.05 per seed, or assuming an 80 percent nursery efficiency, $62.50 per thousand seedlings. This expensive seed may justify an extra effort to improve nursery efficiency. Furthermore, to maximize the benefits of these additional genetic gains, these seedlings may need to be used in intensive silvicultural systems that include growing larger seedlings at lower nursery bed densities.

Long-Term Strategies for Improving Seed Yields and Genetic Gains Require Regular Orchard Establishment

The potential to capture more genetic gain than is available from using seed makes vegetative propagation attractive. However, to be economical, vegetative propagules must have a marginal value sufficient to offset production costs when compared to alternative sources. Except for high value products in specialty markets or the development of transgenic plants with novel attributes, this is not likely to occur for southern pines in the near future. In the meantime, we will continue to depend on orchard seed and the only way to ensure continued genetic improvement is the regular establishment of new seed orchard blocks. Orchard establishment should be timed to coincide with the identification of better genetic material in the tree improvement program. In the WGFTIP, as well as in many other regional tree improvement programs, the breeding and progeny testing program is distributed across members and generations are indistinct. This results in new and better families being identified almost every year.

One strategy for rapidly incorporating new clones into the production population is the advancing-front orchard. The advancing-front orchard is a fully regulated seed orchard complex where new orchard blocks are established at regular intervals with the best available genetic material. At any given time, there are multiple orchard blocks of different ages, different genetic gains, different seed production capacities, and under different management regimes. Because some of these orchards are too young to produce seed, they add to management costs without adding to seed production capabilities. However, these blocks contain the best genetic material and the overall quality of the collected seed improves as they mature and contribute a larger portion of the harvest.

Genetic Gain is Evaluated by Progeny Testing not Generation Number

Generation refers to the number of breeding and selection cycles that separate an individual from the base population. More advanced generations are expected to be better than previous generations. However, it is important to realize that there are exceptions. Some excellent parents in one generation may be better than their progeny in the next generation simply because they were crossed with inferior partners. Furthermore, selections from a cross between two good parents may have disappointing performances (table 1). This occurs because a tremendous amount of genetic variation exists within families and selection between siblings is inexact. The only way to accurately evaluate the genetic quality of a seed orchard is to field test progeny from the parents.

Poor Cone Producers Should not be Automatically Excluded from Orchards

The strategy of sowing open-pollinated families is an incentive to design seed orchards with many ramets of a few clones and to ensure that all of these clones are abundant cone producers. There is no correlation between seed production capability of a clone managed for cone production in an orchard and its progeny's performance in

Table 1—Predicted performance based on parental mid-parent values for two sets of half-sib second-generation selections compared to actual progeny test performance

Selection	Predicted perfomance	Actual perfomance
Family one		
A	104	99
B	104	130
Family two		
A	106	92
B	106	116

growth tests (Byram and others 1986). Some clones with poor cone production have very high genetic values and should not be automatically excluded from orchard designs. These clones contribute significantly to the overall quality of the orchard through their pollen production. They may also be good candidates for use in CMP programs.

Over Capacity is not a Mistake, it's a Strategy

Deliberately designing seed orchard programs with surplus seed production capacity permits increased flexibility to meet rapid increases in short-term demands. This flexibility is extremely important as seed demands can change much more rapidly than seed orchard managers can respond with orchard establishment programs. Excess capacity also allows additional genetic gain to be captured by high-grading the seed crop in years with surplus production. Unfortunately, these benefits come at the cost of managing more orchard acres than strictly needed in most years. This extra cost is an insurance premium against unexpected disasters or rapid changes in demands.

Determining the size of a seed orchard program requires knowledge of average seed production and the variation around this value. Cumulative probabilities for seed production developed for specific management scenarios can be used to plan seed orchard expansions with known levels of risk. For example, under the production parameters represented in figure 2, average seed production for an advancing-front orchard is 20.2 pounds per acre over a twenty-year life span. In other words, 50 percent of the orchards will meet or exceed this production level and 50 percent of the orchards will not. However, there is an expectation that 80 percent of the orchards will exceed seed yields of 17.2 pounds per acre over a twenty-year life span. A regeneration program requiring a 1,000 pounds of seed per year could on average, be supported by an orchard complex of approximately 50 acres (1,000 pounds/20.2= 49.5 acres). However, increasing the overall size of the orchard by only 8 acres (1,000 pounds/17.2=58.1 acres) improves the likelihood that seed demands will be met or exceeded to 80 percent.

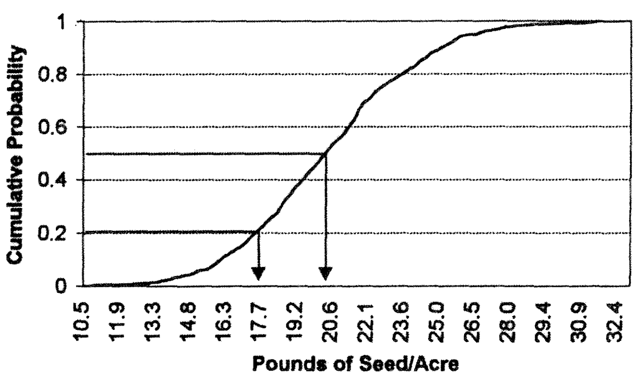

Figure 2—Cumulative probability curve for pounds of seed per acre averaged over a twenty-year life span of a hypothetical loblolly pine seed orchard.The probability on the y-axis is the likelihood that production will be less than the seed production value on the X-axis.

SUMMARY

Regeneration programs in the South will continue to depend on seed orchards for the foreseeable future. Seed orchards have the advantage of being able to inexpensively supply the large numbers of propagules needed for southern regeneration programs. However, seed orchards require many years to reach full production, year to year variation in seed yield is large and unpredictable, and genetic gain is lost to pollen contamination and the dependence on sexually reproduced seed. Furthermore, seed demands can change much more rapidly than seed orchard expansion programs can respond to them. Continued improvement from the tree breeding programs also ensures that desirable seed sources will always be in short supply. Unfortunately, short-term strategies for increasing seed supply reduce genetic quality; conversely, all short-term strategies to improve genetic quality lower seed production capability, at least in the short-term.

Controlled-mass pollinated seed offers one of the best options for capturing substantial quantities of additional genetic gain for use in operational regeneration programs. This seed will be much more expensive than the seed currently grown by nursery managers. Maximizing the return on CMP seedlings may require that their use be incorporated into intensive silvicultural systems that include growing larger seedlings at lower nursery bed densities. Attempts to improve nursery efficiency for these seed lots will certainly be warranted.

Long-term strategies for improving genetic quality while ensuring adequate seed supplies require regular establishment of new seed orchard blocks. Designing these blocks with excess production capacity provides important flexibility to meet changing demands and allows additional gain to be captured by high-grading the seed crop in years with surplus production.

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THE DECEMBER DIP OF LOBLOLLY PINE[1]

David B. South[2]

ABSTRACT— Several planting date studies with loblolly pine (*Pinus taeda*) have shown a decline in survival during the month of December. The term "December dip" was coined to describe this phenomenon. The "dip" in survival occurs just before the prime planting season (January and February) and just after the fall planting season (October and November). The exact reason for a decline in survival is unknown but it appears to result from a decline in root growth potential. Some half-sib genotypes of loblolly pine may be more sensitive to the December dip than other genotypes.

INTRODUCTION

Throughout the world, the "optimal" time for outplanting loblolly is determined by adequate soil moisture. For example, in the summer rainfall area of South Africa, bare-root and container-grown loblolly pines are transplanted during the summer months when rainfall is highest. In contrast, the rainy season for much of the southern United States is during the winter months. Rainfall usually exceeds the potential evapotranspiration in December, January and February (fig. 1). It is during this period when most loblolly pine seedlings are outplanted in the South.

In the southern U.S., seedling morphology changes during the fall and winter and these changes can affect outplanting survival. Typically height growth ceases in the nurserybed by October but diameter growth and root weights continue to increase (fig. 2). Therefore, depending on the environment, seedlings lifted in February will have larger root-collar diameters and higher root/weight ratios (root dry weight/seedling dry weight) than seedlings lifted in October (Mexal and South 1991). As a result, one might expect a gradual increase in outplanting survival over the planting season. For example, during the 1950's, survival in North Mississippi (Ursic 1963) increased from 68 percent (December) to 73 percent (January) to 76 percent (February). Based on increases in root mass and diameter (fig. 2), one would expect this increasing trend in survival. Occasionally, researchers have observed an unexpected decline in survival when planting in December. This phenomenon has been given the name "December dip" (Stumpff and South 1991). This "dip" in survival cannot be easily explained since seedlings lifted in November have received less chilling and are slightly smaller in diameter than seedlings lifted in December. It is believed the effect is caused by changes in seedling physiology. This paper reviews some planting date studies that have shown a December dip. It also updates a planting date/survival curve by South and Mexal (1984).

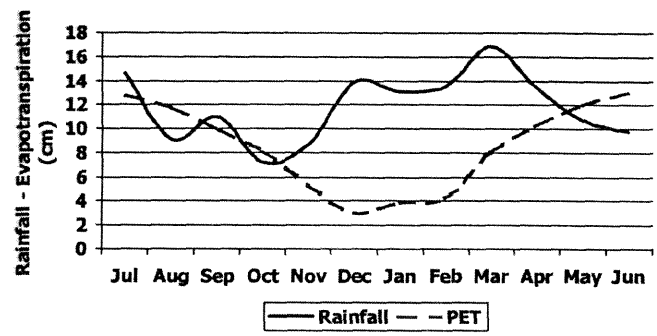

Figure 1—Average monthly rainfall and average potential evapotranspiration at Auburn, Alabama.

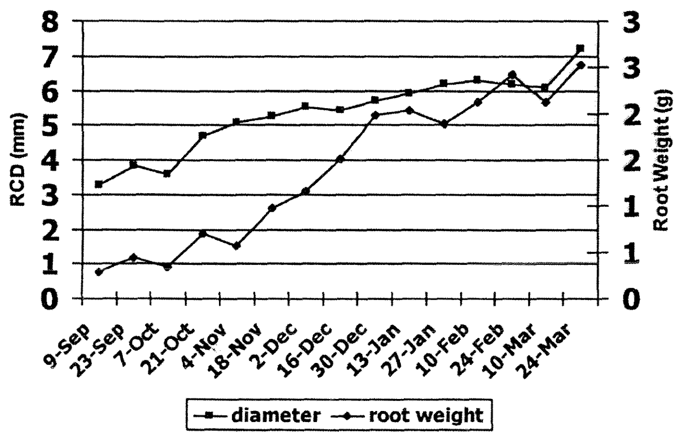

Figure 2—Changes in root-collar diameter and dry weight of roots of loblolly pine seedlings in the nursery (unpublished data provided by James Boyer).

WAKELEY

Philip Wakeley may have been the first to document a December dip in a 1937 study (Wakeley 1954). Seedling survival in Louisiana was greater than 90 percent when planting in October (27th) or November but survival

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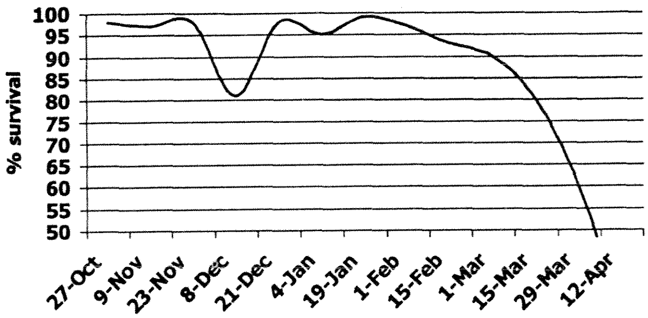

Figure 3—Survival of loblolly pine seedlings planted in Louisiana in 1937-38 (adapted from Wakeley 1954).

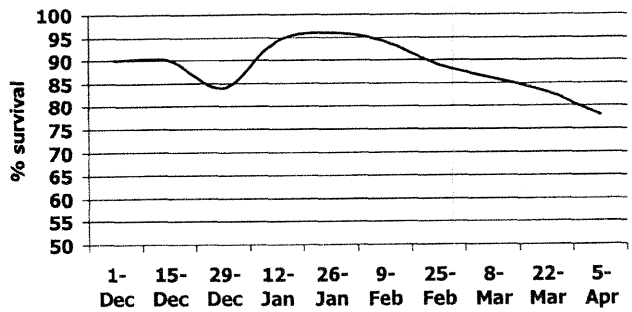

Figure 4—Average survival of loblolly pine seedlings planted in Mississippi over a three-year period from 1959-62 (adapted from Switzer 1969).

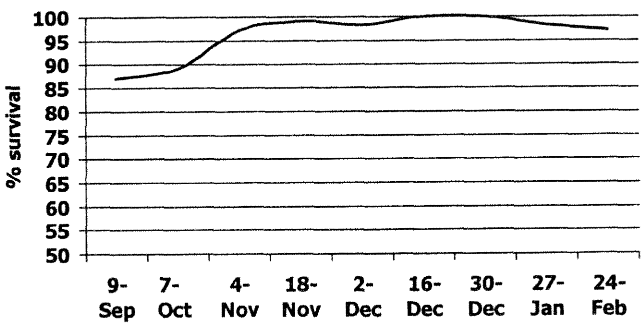

Figure 5—Survival of loblolly pine seedlings planted in Alabama in 1986-87.

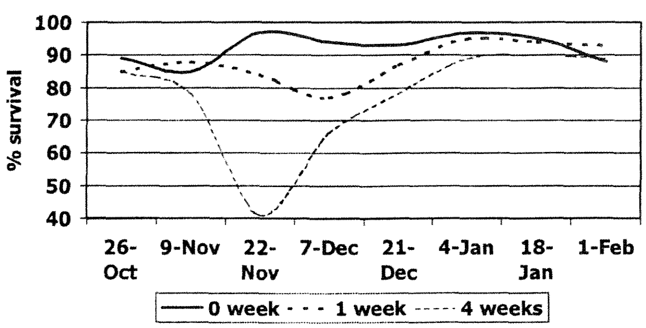

Figure 6—Survival of loblolly pine seedlings planted in Alabama in 1988-89 (adapted from Stumpff and South 1991).

declined to 81 percent around the 7-9th of December (fig. 3). This dip in survival was not deemed important and, in general, Wakeley stated that in most of the lower south, the optimum planting season extends from about December 1 to March 1 (Wakeley 1954).

SWITZER

Georgia Switzer (1969) was likely the first researcher to detect a consistent decline in survival in December. Over three planting seasons (1959, 1960, 1961), seedlings were lifted from the nursery at two-week intervals from December 1st till April 5th. When averaged over the three years, a decline of about 6 percent in survival was noted for December 29th (fig. 4). Switzer did not know the reason for the dip but speculated the decline might be due to onset of cool temperatures (below 8° C). Based on a consistent pattern of survival, he suggested planting be delayed until late January.

AUBURN STUDIES

The Auburn University Forest Nursery Management Cooperative installed several date of planting studies during the 1980's. James Boyer lifted seedlings by hand periodically from September 9th (1986) till February 24th (1987) from a nursery at Union Springs, Alabama. When half-sib seedlings were planted the same day of lifting, survival was typically high (fig. 5). However, seedlings lifted prior to November 18th did not store well. Seedlings lifted on November 18th and stored for 12 weeks had 91 percent survival. In this and other studies, no December dip was observed. However, in a subsequent study, a December dip was observed for seedlings stored for one or four weeks (Stumpff and South 1991). Seedlings from an orchard-mix were grown at a nursery in Opelika, Alabama. Seedlings were hand-lifted every two weeks from October 27, 1988 till February 1, 1989. Seedlings were planted the next day, or were planted after storage (one or four weeks). Survival of seedlings planted soon after lifting was high and there were no signs of a December dip. However, seedlings stored for a week or more exhibited a dramatic decline in survival (fig. 6). A physiological reason for the December dip is unknown but it may be related to a decline in root growth potential. This appears to be the case for the 1988 study since the RGP of stored seedlings declined about the same time as the reduction in survival (fig. 7). Slight declines in RGP from November to December have also been reported for loblolly pine in Virginia (DeWald and Feret 1987), Alabama (Nursery Coop Newsletter - Fall 1987) and in both Florida and Alabama (Page and Oehler 1991).

FAMILY BY DECEMBER DIP INTERACTION

In the 1960s and 1970s, many tree improvement programs collected seed in bulk-lots from their seed orchards. As a result, differences in outplanting survival among genotypes were masked. It seems plausible that poor survival from several half-sib families was lowering the overall survival. This might explain why no December dip was observed from the half-sib source used by James Boyer but one was observed when using a mixed-lot (Stumpff and South 1991). It is known that an interaction exists between planting date and survival for half-sib lots of slash pine (Beineke and Perry 1965). Some half-sib progenies do well when lifted in

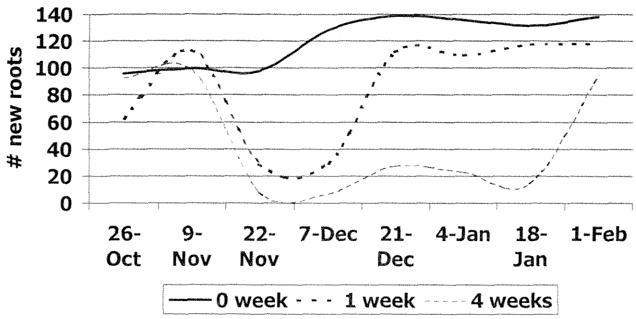

Figure 7—Root growth potential of loblolly pine seedlings in Alabama in 1988-89.

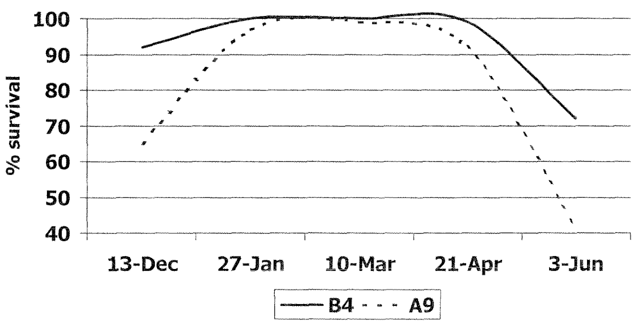

Figure 8—Survival of two half-sib slash pine families planted in North Carolina in 1963-64 (adapted from Beineke and Perry 1965).

mid-December while others do not (fig. 8). Since more organizations are now reaping the advantages of planting certain half-sib families, the chance of observing a December dip (for sensitive genotypes) could be greater now than in the past. For example, average December survival was 78 percent for 30 progenies in the slash pine study but two (A13 and C11) exhibited 62 percent and 61 percent survival, respectively. The same two families performed well (100 percent survival) when planted in January.

AN UPDATED PLANTING WINDOW MODEL

Historically, most southern foresters consider the optimum planting season to be from December 1st to March 1st (Wakeley 1954, Shultz 1997) or from mid-December to mid-March (South and Mexal 1984). During this period, loblolly pine seedlings are often stored for a week or more prior to planting. Some mixed-lots and some half-sib progenies will likely perform well when lifted throughout the month of December. However, some genotypes may exhibit a 6 percent to 40 percent drop in survival when planted or placed in cool storage in December. Since 1937, data from "hot" planting trials (where time between lifting and planting is two days or less) have shown that loblolly pine can be successfully planted in moist soil in October and November. Although seedlings lifted during this time are sometimes more succulent and are not as storable as seedlings lifted in January, proper handling can be provided at an

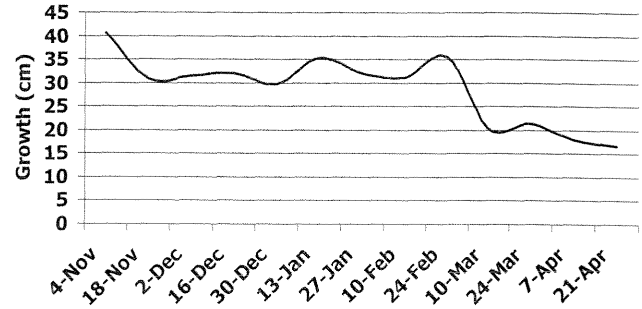

Figure 9—Early growth of loblolly pine seedlings planted in Texas in 1959-60 (unpublished data supplied by Bilan 1961).

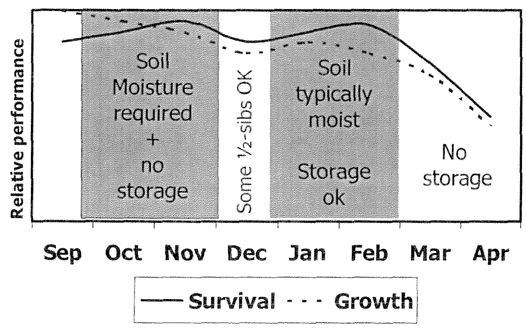

Figure 10—Relative performance of bare-root loblolly pine seedlings when "hot" planted during the fall planting season (October and November) and in the traditional planting season (January and February) in the southern United States. Some genotypes may perform well when planted soon after lifting during the month of December.

operational level. Several companies have successfully machine planted thousands of hectares of wet sites in October (mostly in Georgia and Florida). One advantage of planting into moist soil in October or November is that trees can become well established before winter freezes occur. In the lower South, roots will grow throughout the winter months and therefore the early-planted seedlings will grow more in height than March-planted seedlings (fig. 9). If the trend towards a 15-year rotation for loblolly pine continues, the economic incentives to plant in October and November will increase. For this reason, two planting windows have been designated for bare-root seedlings (fig. 10). The October-November window is for large-diameter seedlings that are "hot" planted into moist soil. To increase the probability of survival, seedlings should be machine-planted (where possible) and the root-collar should be planted about 8 cm (or more) below the groundline. Seedlings lifted during this period should be kept cool during transit to the planting site. If refrigeration is not available, seedlings should be loosely packed into boxes or in open-ended bails to avoid a buildup of heat. When transplanting seedlings in the fall, it is advised to use "morphologically improved" seedlings grown at low seedbed densities (South 1993). This will result in large-diameter seedlings that are more tolerant to rough handling.

By mid-November, succulent bare-root seedlings that have been grown at a seedbed density of 270/m² might have a small RCD of only 3 mm. The chance of survival of such small seedlings would not be high when planted in October or November. However, assuming soil moisture is adequate, these months would be an ideal time to plant container-grown stock with RCD of 3 mm or greater. December is a month of transition between the fall-planting window and the traditional winter-planting window (fig. 10). During this transition, loblolly pine seedlings are experiencing the longest nights of the year and the terminal buds are reaching their deepest endodormancy (Boyer and South 1989). Lavander (1985) suggested that a seedling's resistance to stress is low when the terminal buds (when present) are in deep endodormancy. Lifting seedlings at this time may be a problem for some genotypes. Seedlings from some half-sib families may exhibit a decline in RGP and might not store well. To increase the chance of survival, these genotypes should be kept in the seedbed and lifted in January. If they are lifted in December, they should be planted within a day or two of lifting in order to minimize stress. The main challenge now is to identify the half-sib families that are particularly susceptible to the December dip.

ACKNOWLEDGEMENT
Some of the information present in this paper is from unpublished work by Victor Bilan, James Boyer and Nancy Stumpff. The author would like to recognize these individuals for their contributions.

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QUALITY HARDWOOD SEED PRODUCTION[1]

John Eric Delaney[2]

ABSTRACT—The current market demand has brought about an increase in the number of hardwood tree and shrub seedlings that are being grown by the forest nurserymanager. High quality seed is a necessary element for the nursery manager who wishes to efficiently produce quality hardwood tree and shrub seedlings. First-hand experience recommendations are given in regards to collection, cleaning, and upgrading of hardwood tree and shrub seed, to produce quality seed, necessary for propagation of quality seedlings.

INTRODUCTION

As the demand for hardwood seedlings continues, so does the demand for seed. Although different outlets for seed are available, proper collection, cleaning, and storage are necessary for the procurement of quality seed. As nursery managers continue to grow larger amounts of hardwood seedlings, one would expect a demand for increased hardwood seed quality. Improved collection and storage techniques by the industry has provided improved benefits to seed quality, but is the industry capable of a higher level of seed quality in which the value added is greater than the added cost? Many nurserymanagers have shown a complacent view to current seed quality. Are they satisfied with current industry standards? Do they believe that upgrading is cost prohibitive, or will provide little or no benefit? For whatever reason, there has been very little push for increasing seed quality from the forest nursery industry.

This presentation is divided into two categories of oaks and other hardwood tree and shrub seed. Each category provides information on collection, cleaning, storage, and upgrading. Information given is based on current practices at Louisiana Forest Seed Company, Inc. (LFS) applied from internal and external research.

OAKS

Collection of acorns begin in the fall, which is when the acorns have reached maturity. From experience, the first ten percent of acorns falling from a tree are unsound or of low quality. The float test method still proves to be the most reliable and cost efficient method for removal of unsound acorns, leaves, and other trash. A blower cleaner is useful in removing initial amounts of trash material and insect damaged acorns, although the float test is still necessary. It is recommended that acorns be floated on the day of collection, which not only removes unsound acorns, but also provides moisture for sound acorns (Bonner 1992) Maintaining moisture of collected acorns is important, and

Table 1—Sizing data on selected species of acorns

Species	Screen size/seed per lb.[a]								Weighted average seed per lb.
	8	9	10	12	14	16	18	18+	
Quercus acutissima				107	**71**	48			76
Quercus alba			115	**80**	62	80			81
Quercus falcata v. pagodaefolia	305	**232**	169						261
Quercus laurifolia	**380**	235							366
Quercus lyrata				202	**118**	78	51		120
Quercus macrocarpa					75	56	**39**	23	32
Quercus michauxii					62	**47**	34		45
Quercus nigra	364	**319**	208						328
Quercus nuttallii			158	**104**	79	53			97
Quercus palustris	340	**268**	208	165					243
Quercus phellos	438	**345**	263						384
Quercus rubra				111	**87**	58			90
Quercus shumardii			158	**106**	75	59			97
Quercus virginiana	308		**206**	114					225

Bold numbers for each respective species indicates the most common size for that species.
[a] Seed per pound will vary based on moisture content of acorns, origin of the species, and year to year crop production.

[1] Delaney, J.E. 1999. Quality hardwood seed production. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 18-21.
[2] Vice-President of Louisiana Forest Seed Company, Inc., 303 Forestry Road, Lecompte, LA 71346; Tel: 318/443-5026.

common sense is the best tool for preventing desiccation. Do not collect acorns from a sidewalk or parking lot, keep collected acorns out of direct sunlight, and place them in proper packaging and storage as soon as possible.

Although storage is generally the next step taken in the procurement of acorns, LFS adds an additional step to the process. All acorns are sized prior to placement in cold storage. Each size is designated by a number such as "12," rather than termed "small," "medium," or "large." A number "12" size for one species will be roughly the same size for a different species, but a "medium" size designation is a generic term which may not have any size correlation between two different species, much less across many species. With a number designation, the nursery manager is able to correlate a certain size plate for the planter with a specific number size across several different species of acorns. Other benefits to sizing of acorns for the nursery manager include a more accurate seed per pound count (table 1), a more uniform spacing and bed density, and more consistent seed development has been noted for some species.

After sizing, acorns are bagged for storage in fifty and ten-pound bags. Bags are a polyweave construction with a 4 mil polyethylene liner inside the polyweave bag for red oak species, and a 2 mil polyethylene bag for white oak species. A 4 mil polyethylene liner is recommended for red oak species because it allows gas exchange while preventing desiccation (Bonner 1992) The use of 2 mil polyethylene liners is recommended for white oaks because evidence suggests the need for greater aeration. Most red oak species can be successfully stored for several years with the right moisture content, packaging, and storage facilities.

LFS believes quality cold storage facilities play an integral part in the storage of acorns and other hardwood seed. A good quality cold storage facility will have a small range in temperature fluctuation. Acorns will be more prone to sprout the higher the rise in temperature from the suggested storage temperature of 1 to 3 °C (34 to 37 °F) (Bonner 1992). Temperature fluctuation on large coolers can be further negated with two compressor units. With two units, while one is in a defrost mode, the other unit may be cooling. It is also important to incorporate shelving in the cold storage facility that will allow air circulation. Open weave shelving provides greater air circulation than a fully closed bottom shelving.

The nursery manager should be aware that availability of acorns will vary from year to year, and therefore consider the option of planting stored acorns. An avenue for the nurserymanager is to plant red oaks in the fall as one would plant white oaks. This technique may be a viable option for water oak (*Quercus nigra*), which is difficult to germinate after spring sowing.

OTHER HARDWOODTREE AND SHRUB SEEDS

Obtaining quality seed for nursery use begins with the collection stage. One must remember that seedsmen are not magicians. They can not take immature collected seed, pass it through a cleaner, and produce seed with 99 percent germination and purity. Care must be taken to collect seed at its fullest point of maturity. One case in point at LFS is collection of american sycamore (*Platanus occidentalis*). In the past collection took place not long after the fruit turned brown in color, which Handbook 450 (Schopmeyer 1974) regards as the stage in which collection may take place. Germination of seed collected at this stage is typically 10-30 percent. What Handbook 450 (Schopmeyer 1974) fails to mention, which Miscellaneous Publication 434 (Engstrom and Stoeckeler 1941) acknowledges is that germination can be enhanced by delaying collection as long as possible for seeds which hang on the tree for a considerable time after apparent ripening (Engstrom and Stoeckeler 1941) Therefore, LFS is able to increase germination from 10-30 percent to 60-80 percent by delaying collection of American sycamore until the point in time when the seed ball is about to shatter and disperse.

Only in a few circumstances can one break the rules and collect seed prior to maturity and reap some benefit. From personal experience, the *Crataegus* and *Viburnum* species can be collected while the fruit is still green, just slightly prior to maturity before the seed coat hardens, to provide speeder germination and reduce the stratification time period. The drawback to this procedure is that storability of the seed is sacrificed.

Is fresh collected seed better than stored seed? If there is not an upcoming crop, evidently the stored seed is better. Just because the seed is fresh does not make it any better than stored seed. Seed stored properly will maintain its viability with time. One should compare laboratory tests between the different collection years if possible. Ask questions, and if possible inspect the seed. There have been situations in which nurserymanagers have passed up better quality seed because it was not the current crop year's seed. One should not make a hasty decision in regards to stored seed as a planting option.

Most all of the hardwood and shrub seed discussed in this section can be stored long term (beyond three years) in freezers (10°F/-12°C.) Seed stored under these conditions by LFS are packaged in 4 or 6 mil polyethylene liners within corrugated boxes. Moisture content of seed at time of storage is under 10 percent.

Many times short-term storage (one to 2.5 years) is adequate. In this situation storage in a cooler will be satisfactory. Containers used for storage will vary depending on the species. Species such as sweetgum (*Liquidambar styraciflua*), American sycamore (*Platanus occidentalis*), and yellow-poplar (*Liriondendron tulipifera*) can be either stored in a polyethylene liner within a corrugated box, or a plastic container with a lid. Flowering dogwood (*Cornus florida*), common persimmon (*Diospyros virginiana*), blackgum (*Nyssa sylvatica*) (pulp removed on each), and elms (*Ulmus*) can be stored in a plastic container with a lid, or a polyweave sack without a polyethylene liner. Plastic ventilated trays or grass sacks are used to store ginkgo (*Ginko biloba*), redbay (*Persea borbonia*), cherry laurel (*Prunus caroliniana*), and cleyera (*Cleyera japonica*). Hickory species are stored in

Table 2—*Liriondendron tulipifera* (yellow-poplar)

Lot	Full seed	Live seed	Purity	Seed per pound	Live seed per pound	Price/lb	Price/seed	Pounds required for 100,000 viable seeds
	- - - - - - - - -	%	- - - - - - - - -			- - - - -	$ - - - - -	
Winged	10	08	80	14,600	934	10.00	0.0107	107.0
Upgraded	93	91	98	21,500	19,076	200.00	0.0105	5.2

polyweave sacks without polyethylene liners. Low moisture content for storage is beneficial in reducing mold.

Upgrading allows LFS to not only provide higher quality seed but to also reduce the amount of material the nurseryman must handle and store. Two of the species that LFS has had great success with are yellow-poplar (*Liriondendron tulipifera*) and bald cypress (*Taxodium distichum*).

For yellow-poplar, upgrading begins with removal of the wing material from the seed. This is accomplished with a brush machine. Once the wing of the seed is removed, it is much easier to remove empty seed and other trash material whether by an aspirator or gravity table. At LFS, the dewinged yellow-poplar seed is screen cleaned after being dewinged to remove sticks, wing material, some empty seed, and other trash material. Clean seed is then upgraded on a gravity table to further reduce the number of empty seed within the lot. One pass across the gravity table will not produce two distinctive lots of low and high quality seed. Several passes, each resulting in two to three different lots of varying seed quality, is necessary to produce a desirable end product. The end product will generally consist of two to three lots.

LFS is capable of procuring yellow-poplar with a full seed percentage of greater than 90 percent. Approximately 21 pounds of winged yellow-poplar is required to procure a pound of yellow-poplar with greater than 90 percent full seed. The resources required to produce a high quality lot of yellow-poplar pushes the cost up considerably. The vast majority of nurserymanagers will quickly say no to a price tag of $200.00 per pound for yellow-poplar with 90 percent plus full seed. Many, though, fail to look at the numbers before making their hasty decision (table 2). The cost per full live seed is almost the same for the winged yellow-poplar as compared to the high-graded yellow-poplar. Also, high-graded, dewinged yellow-poplar reduces the amount of volume which the nursery must handle, there is greater control of bed density, and the seed is able to be planted in drills. High-grade yellow-poplar seed also opens a window for containerized planting.

LFS has worked extensively with bald cypress to procure seed with germination and purity greater than 90 percent. Seed is collected from trees in the water rather than on dry land. LFS's experience is that seed from trees over the water will generally be of a higher quality relative to seed on dry land. An initial cut test is made on seed prior to collection in an area to insure the seed to be collected is of good quality. One must remember that cleaners and gravity tables are not miracle workers. It is very difficult, if not impossible, to start with low quality material and produce a high quality product. To produce a high quality product one must seek out high quality material to work with.

Collected bald cypress seed is then dried down so that it may be screen cleaned. The screen cleaner removes large, trash material such as sticks and small, lighter material such as needles. The bald cypress is also sized into three sizes with the screen cleaner. The sizing serves two purposes. A more accurate seed per pound count is available, which helps the manager plant a more precise bed density. Also, sizing is beneficial in the upgrading step on the gravity table. As with the yellow-poplar, more than one pass on the gravity table is necessary for procuring high quality bald cypress. Three sizes, with two grades making up each size, were procured during the 1997 season. This process was successful in procuring bald cypress with greater than 90 percent germination and purity (table 3).

A few other activities with other hardwood seed at LFS that are worth mentioning include dewinging green ash (*Fraxinus pennsylvanica*), Arizona ash (*Fraxinus velutina*), white ash (*Fraxinus americana*), and silverbell (*Halesia diptera*) to reduce the volume the nursery must handle and to allow upgrading. Sizing of flowering dogwood (*Cornus florida*) provides a more accurate seed per pound count

Table 3—*Taxodium distichum* (bald cypress)

Lot	Germ	Purity	Seed per pound	Live seed per pound	Price/lb	Price/ pound	Pounds required for 100,00 viable seeds
	- - - %	- - -			- - - - -	$ - - - - -	
Regular	40	50	6,500	1,300	5.00	0.0038	77.9
Upgraded	85	93	6,500	5,138	20.00	0.0039	19.5

and separates the large seeds, which may contain two embryos (this situation may result in a germination test result greater than 100 percent). Due to the volume of drupes and other fruits which LFS processes a specific cooler is used to store these prior to cleaning. Also, certain species such as *Ilex*, which require maceration, foam considerably during cleaning. This problem can be alleviated with the use of an antifoaming agent (the same additive that is used in spray tanks for chemicals that foam) without harm to the seed.

SUMMARY

External factors play a big role in seed quality, and mother nature will have a different affect on each species seed quality from one year to the next. But with technology we are able to improve on the seed quality available to us. Improved seed quality should not be viewed as an additional cost only, but as an avenue for increased nursery efficiency and quality seedling production. As with any operation, a quality product requires quality materials, and the same is true for a seedling nursery.

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HARDWOOD SEEDLING PRODUCTION[1]

Randy Rentz[2]

ABSTRACT—Columbia Nursery is a part of the Louisiana Department of Agriculture and Forestry. We grow between 5 and 6 million hardwood seedlings annually, along with 3 to 4 million loblolly pine. Growing hardwood seedlings can be quite challenging and is always interesting. For those lucky enough to be affiliated with an organization that makes the production of hardwood seedlings a priority, it can be quite fulfilling and sometimes quite a humbling job.

At Columbia Nursery the primary goal is to produce a seedling that meets the needs of the customer, be it in an urban forestry capacity, a reforestation effort or a wetlands restoration site. It is these many variable situations along with the number of different species that make it impossible to grow hardwood seedlings to one particular set of specifications. Impossible, meaning it would not be the proper way to handle these seedlings, not that it could not necessarily be done.

Hardwood seedling production has seen almost unbelievable growth over the past 8 years while research has lagged behind. Though research is a slow process under any circumstances it seems to be even slower in the area of hardwood seedling production. With the nurseries being pushed to their limits to supply the needs for programs such as WRP, CRP, and WHIP there seems to be a mind set to accept less quality as long as we can get the volume. This can be very harmful down the road in terms of survival and quality of our reforested hardwood stands. Why have we relived the same mistakes we made in reforesting our cut over upland forest and abandoned hill country farms years ago? Of course government programs are not going to wait on research to catch up and the economics of money in the hand now is not going to slam the brakes on hardwood reforestation. As long as the money is there it is going to be full steam ahead at all cost. It is therefore thrown back in the hands of the field foresters, planters, and nursery manager to provide the best quality with what resources are available.

THE IDEAL SEEDLING

Quality in the nurseries means producing a seedling that has the best chance at survival when out planted. This quality is essential to be genetically compatible with the area in which it is to be planted, and ultimately providing a quality product whether it be for wildlife, watershed, recreation, or wood product.

What is the ideal hardwood seedling? Nuttall oak needs to be 3/8" at root collar and 22" tall. Willow oak can be 1/4" at root collar and 18" tall. Pecan needs a 3/8" root collar, but it doesn't have to be but 12" tall. Of course, these are all minimum standards because I've got some Nuttall that's 36" tall and some sycamore that's ready for the chipper. "Old Joe" likes the big ones, so I'm saving them for him. While "Sam" over there would just as soon them to be smaller, so he gets these we didn't get in the ground until the end of May and just couldn't seem to get the growth out of them like the others.

The ideal hardwood seedling for all practical purposes is at the very least quite debatable. Outside of answering this question individually through trial and error; there are no true guidelines for growing hardwood seedlings. It may well be that there is no optimum standard for hardwood seedlings. When considering sites where 6" in elevation can mean the difference between planting one species or the other, we can't expect to grow seedlings that meet one particular group of standards and say this is the way they should all be grown. This is not a practical way to think.

This being said, it would not be practical for us to suggest the best way to grow hardwood seedlings. Instead we will concentrate on what works at Columbia Nursery and hopefully these practices can be of benefit to others.

NURSERY PRACTICES

Soils

Columbia Nursery has a very fertile silt loam soil. A pH of 5.4- 5.9 is maintained primarily by the addition of cotton gin trash and other organic amendments to the soil. Internal drainage is maintained through subsoiling in the fall preceding fumigation and planting deep-rooted cover crops such as winter wheat (every little bit helps). Just as important as internal drainage is external drainage. Fields are land planned prior to fumigation and subsoiling to eliminate any low areas which would tend to hold water. All ditches are maintained regularly to eliminate any areas that would restrict water flow. Maintaining proper internal and external drainage is very important not only during the growing season but for overall soil structure.

Probably the primary overall objective of a nursery is maintaining good soil structure. The best way to assure good soil structure is through proper rotation, and the addition of organic amendments. These amendments should be in the form of both cover crops and organic matter from outside sources. It is usually very easy to find a local source of organic matter. At Columbia Nursery we get clippings from the town, materials from a local horse farm, sawdust from a small local mill and gin trash from a nearby cotton gin. Without this added organic matter, it would be

[1]Rentz, R. 1999. Hardwood seedling production. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 22-24.

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impossible to maintain proper levels of soil organic matter and provide a good soil structure.

The cover crops used are primarily sudex, corn, and winter wheat. Sudex is planted in the spring, when it reaches a height of 4-5' it is cut down. This can usually be done three times before August. In August, it is cut and turned under in preparation for fall fumigation. Corn and winter wheat are used on ground which will lay out for two years and the spring before fall fumigation sudex is planted.

Prior to fumigation, any additional organic matter should be incorporated along with the cover crop to assure proper decomposition and control of any outside sources of weeds. Rotation in the hardwood seedlings have normally been one year in seedlings and one year in cover crops followed by fall fumigation. This rotation has been interrupted somewhat in that we are now planting about 20 acres on a 2-1 rotation (2 years in seedlings and 1 year in a cover crop). The ground this has been practiced on seems to be holding up very well at this point with no loss of seedling quality the second year. The remaining ground is on a 2-2 rotation.

Weed Control

Weed control is another very important area in hardwood production. There has not been enough research in hardwood nurseries. Much of the work has been trial and error, but a fairly effective weed control program has been established. This program is primarily a zero tolerance weed control program, which consists of a combination of pre-emergence herbicides, post emergence drill spraying, hand weeding, and spot spraying. While it is impossible to maintain 100 percent weed control, it is very important to at least try.

It is just as critical to carry a weed control program over into the cover crop rotation. There are times when it is better, and will save money down the road to cut under a cover crop and replant, rather than carry one through with poor weed control.

Planting

After fall fumigation, all the ground, both fumigated and non-fumigated, which is to be planted is hipped up. Since this is a silt-loam soil, hipping allows quicker field access after a period of wet weather. Before planting, fertilize is added and it is then harrowed in preparation to pulling beds. Once the beds have been pulled, it is ready to plant.

Careful consideration should be given to species placement in the field. Growth patterns of individual species should be taken into consideration when determining placement in the nursery. Species such as green ash, sycamore, Nuttall, etcetera, that exhibit extremely fast initial growth patterns should not be placed adjacent to slower growing species such as water oak and pecan.

Timing of planting is also a factor. Fall planting is done as much as possible. All our white oak species, along with black walnut, water oak , and a couple of others are fall planted.

The majority of our crop, however, is planted in the spring from the middle of March through the end of May. We plant the slower germinating species such as pecan and water oak first and the faster species such green ash and sycamore last. This allows for a more uniform stand during the growing season.

Planting is done on a four foot wide bed with four drills per bed. Most species are planted at 6 to 8 seedlings per square foot. There are a few species which can withstand higher bed densities and still produce quality seedlings. Planting depth is determined by species, ranging from 1/4" for green ash to 1 ½ to 2" for pecan.

Immediately following planting, the beds are rolled and a soil stabilizer along with pre-emergence herbicide, and fungicide is applied. Once the soil stabilizer has cured , it is watered throughly and kept moist to assure uniform germination. The fall planted crop is handled somewhat differently, in that rye grass is broadcast over the beds following planting. In late winter the rye grass is killed and lays downs to provide mulch.

Growing Season

Germination can be erratic in most hardwood species. Sufficient moisture during germination must be maintained or germination will be extended or shut down all together. Again the germination characteristics of species must be taken into consideration. Species such as green ash, cypress, and pecan must be kept relatively moist during the entire germination process, while species such as cherrybark oak and Shumard oak, tend to germinate more readily with minimal moisture.

Once the seedlings have germinated and reached a height of 8-10" a shielded sprayer may be used to control any emerging weeds. This, used in conjunction with 2 or 3 hand weeders, can keep the crop relatively free of weeds.

After germination is complete 15 units of nitrogen along with 2.5 gallons of crop boaster is sprayed and watered in every 2 weeks until seedlings reach a height of 12-14". This usually takes 4 to 6 weeks depending on species. When the seedlings reach a height of 18 to 20" they are pruned back to 12 to 14". This is done to release the slower germinating seedlings and provide a more uniform stand.

Though it is not quite as critical to produce a uniform stand in hardwood it does make them easier to pack and ship. This can be accomplished in a number of ways, through top-pruning, regulating irrigation, fertilization, and undercutting or root pruning.

At Columbia Nursery top-pruning is used more that any other method of height control. As mentioned earlier when seedlings reach a height of 18-20" they are pruned back to 12-14". They are then top-pruned again when they reach a height of around 22" to about 18-20". If another top-pruning is needed they are pruned to 22-24". This will be the last top-pruning and usually occurs toward the end of August. Horizontal root pruning serves two purposes; it stimulates lateral root growth and shuts down top growth.

This method is used primarily on green ash and black walnut. Water and fertilize, when used properly can stimulate or inhibit seedling growth. Care must be taken when using this method not to shut the seedlings down completely. There is a fine line between just enough moisture and not enough moisture. This method when used properly works quite well.

CONCLUSION

Hardwood seedling production must not be categorized into one group. Just as we distinguish between upland hardwoods and bottomland hardwoods we must also distinguish between individual hardwoods. Anyone growing hardwood seedlings knows they each exhibit individual characteristics in the nursery bed just as they do in the field. There should be some form of criteria for hardwood seedling production, but it needs to be backed by research.

Good solid research in the area needs to be expanded and the genetics work which has begun again, needs to continue on past the point where economics may say it is feasible. The nurseries need to be more involved in the seedlings from the seedbed to the field. It is not enough to just grow a quality seedling and say that's where our job ends. Everyone knows that when a planting job fails it is not that the seedlings were planted off site, that they were mishandled, there was drought, flood, or any other act of God; it is because they weren't any good when they got them from the nursery.

USDA-FOREST SERVICE'S APPALACHIAN OAK PROGRAM[1]

Tom Tibbs[2]

INTRODUCTION

As the USDA-Forest Service moves forward into the 21st century, the agency is operating under a new natural resource agenda recently outlined by Chief Mike Dombeck. The primary thrust of the new agenda is restoring and maintaining forest health to provide for sustainability of ecosystems to meet the long term needs of the American public. To support this agenda, the Region 8 Genetic Resource Management Program will initiate an artificial regeneration program for northern red oak and white oak in the Southern Appalachian Mountains.

One of the major issues recently identified in the Southern Appalachian Assessment is the loss of oaks from the Southern Appalachian ecosystems and the gene conservation questions associated with this loss. Oaks are being lost and natural oak regeneration is not adequate in the following situations.

High-Quality Cove Hardwood Sites

In this situation, it is extremely rare to find any advanced oak regeneration on the forest floor when sites are logged or when stands succumb to natural disaster. These are very productive sites and the competition from shade tolerant species or faster growing intolerant species overwhelms slow growing oak regeneration. Generally the oaks in the cove hardwood sites are old and very large which contributes to low levels of stump sprouts. Disturbance on the cove sites generally results in fast growing fully stocked stands of yellow-poplar (Loftis 1993).

Gypsy Moth Impacted Sites

The gypsy moth is having a major impact on existing oak forests (Gottschalk 1989). Oak-dominated forests are subject to nearly complete destruction by the gypsy moth. The moth is not selective as to site quality. Oaks on the poorest sites, as well as the high-quality sites, are impacted. This is especially destructive even on the lower quality sites as it nearly eliminates all regeneration potential of oaks. Repeated defoliation of the trees weakens them so much that stump sprouting is reduced or totally absent. In addition, the defoliation reduces the stored food reserves and weakens the acorns to the point that they will not germinate or do not have vigor enough to survive. It is predicted that the gypsy moth will continue to increase and spread over the Southern Appalachians in the next 30 to 50 years.

Oak Decline Complex

The oak decline complex results from insects and disease impacts being magnified in low vigor over-aged stands of susceptible oaks. Oak decline increases have recently been attributed to the significant regional droughts of the 1980's (Oak and others 1989). Whatever the cause, the resulting stands grow very slowly, produce very little mast for wildlife and are being replaced by other species of lower economic and wildlife habitat values.

Because of the economic importance and the importance of the oak species for wildlife habitat, biologic diversity, and ecosystem sustainability, we project that there will be a significant need for artificial oak regeneration in the future. This need will involve high and low quality sites. For example, there is one contiguous 200,000-acre block in the Lee Ranger District on the George Washington National Forest where virtually every oak tree and seedling was killed by the gypsy moth. This occurred on both high and low quality sites and has a tremendous impact on wildlife and other resources. Since there is no natural regeneration potential available, the only alternative, if we are to restore oak forests in these situations, will be planting the oak species that we want. Many of these same impacts have been identified in the Ozarks. If the Southern Appalachian initiative is successful, a similar program will be developed for the Ozarks.

A 1992 symposium on oak regeneration documented the past failures of both natural and artificial oak regeneration attempts (Loftis and McGee 1993). There are very few success stories. In most cases of artificial regeneration, initial survival is good, however, subsequent growth of the seedlings is extremely slow and they are lost to deer browse, dieback, and competing vegetation. There are many practical problems to overcome in order for artificial regeneration to be successful.

CURRENT NEEDS

Before any significant intermediate or large-scale artificial regeneration program can be initiated with the oaks, there are some basic issues which must be addressed for practical reasons. First, adequate sources of seed of known source of origin that are adapted to the regenerated sites must be secured. A consistent planned regeneration program will be extremely difficult to develop without more uniform consistent sources and supplies of seed. In some instances, the period between acceptable seed crops in natural stands may be several years in any particular geographic area. This leads to the movement of seedlings to areas in which they may not be adapted to the environment. It may also lead to the planting of species that are ecologically inappropriate simply because they are the

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[1]Tibbs, T. 1999. USDA-Forest Service's Appalachian oak program. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 25-28.
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only hardwood seedlings available in a particular year. In either case, it is extremely important that we be able to develop and manage the source of hardwood seed if we expect a hardwood planting program to be successful.

Second, we must develop the knowledge of seed zones or seed provenances for the oaks. If we have knowledge of provenances and geographic sources, the seed and seedlings can be moved with greater confidence of long term performance. Seed orchards can also be developed to cover the hardwood areas without excessive overlap or gaps.

HOW WE WILL PROCEED

Our current plans are reasonably straight forward and simple. We will arbitrarily divide the Southern Appalachian hardwood region into geographic sources and select parent trees in each geographic source area. Both northern red oak and white oak will be included. We will make open pollinated collections of acorns from timber quality trees and grow seedlings from each family. The resulting seedlings will be graded at the nursery for specific characteristics and will be outplanted into seedling seed orchards. When we accumulate enough families in the seedling orchards and they begin to produce seed in reasonable quantities, we will have a source of seed with which provenance studies can be initiated. Please be aware that this is a long-term undertaking and we do not expect results over night. Keep in mind the ancient proverb that the longest journey begins with the first step.

Present plans are to divide the Southern Appalachian hardwood region into three areas based on latitude. In the small number of geographic provenance studies that have been completed, latitude has surfaced as a significant variable (Kriebel and others 1988). Our latitude lines will follow the State lines of Kentucky and Virginia for the northern source. Due to the wide east-west range of the Daniel Boone, Jefferson, and George Washington National Forests, this northern zone will be subdivided into an east zone and a west zone in southwestern Virginia. The Clinch Ranger District in far southwest Virginia will go with the Daniel Boone National Forest.

The central zone will include the national forests in east Tennessee and western North Carolina. Due to the narrow east-west orientation, this zone will not be subdivided.

The southern zone will include the national forests from the Bankhead in the west to the Uwharrie in the east and all of the Chattahoochee-Oconee National Forests in Georgia. The Bankhead and Uwharrie will be handled as seperate geographic sources.

Elevation may be an important factor with the oaks (McGee 1973). The amount of real information is very scarce. We will take elevation into account by selecting trees from across the elevations that are most important to us. Our selections will be grouped so that in effect, it will be possible to test for the effects of elevation between sources in the outplantings. Consultations are underway with research geneticists at the Southern Research Station at Saucier, MS, and with Dr. Scott Schlarbaum of the University of Tennnessee on the optimum sampling procedures that will allow us to meet our long-term goals for this effort.

Selection criteria will also be straight forward and simple. For a tree to qualify, it must be of timber quality and it must have a collectible acorn crop on the tree at the time of selection. We know from several sources (Beck 1993, Cecich 1993) that acorn production is genetically controlled and since mast production for wildlife is a major goal, this is an important criterion.

The seedlings will be grown under the nursery protocol developed by Dr. Paul Kormanik (Kormanik and Sung 1993, Kormanik and others 1993). At time of lifting, seedlings will be graded for size and number of first-order lateral roots. Seedlings not meeting the FOLR criteria will be culled. If, as we have observed in the past, a family produces an inherently high number of the seedlings that do not meet the FOLR criteria, the family may be eliminated altogether at the nursery production stage. At the seedling seed orchard, seedlings will be planted at a relatively close spacing, and non-performing seedlings will be eliminated as the planting develops. The orchard will be managed to produce seed at an early age and when enough families begin production, genetic provenance tests will be initiated. Seed, as available, will be used for reforestation plantings.

THE BASIS FOR THIS INITIATIVE

Many of you are probably familiar with the current research literature and actual field performance of planted northern red oak and white oak. You are probably asking why we think this initiative will work. We think this will work because there is an example of a producing seedling orchard and some established plantations of red oak and white oak that show excellent performance.

First, Region 8 has a producing northern red oak seedling seed orchard located on the Watauga Ranger District of the Cherokee National Forest. This orchard was originally established as a progeny test by the TVA in 1973. It was converted into a seed orchard by the Forest Service in 1987. It has been producing variable quantities of seed since 1991. The Forest Service also has a small number of white oak selections grafted into the Beech Creek Genetic Resource Management Area at Murphy, NC. The white oaks are about the same age as the red oaks and have produced several crops of acorns. These variable quantities of seed from known parent trees have been enough to generate considerable interest and research on orchard management, seed production, insect damage, seed quality, nursery seedling culture, and outplanting performance (Schlarbaum and others 1998). The research findings, while not conclusive in all cases, give us hope that an artifical regeneration program with northern red oak and white oak is currently feasible.

With seed produced in the two orchards we have been able to supply Dr. Paul Kormanik of the Southern Research Station and Dr. Scott Schlarbaum of the University of Tennessee with seed for research projects. From this we have established several outplantings of high-quality

graded oak seedlings. In 1994, seventeen northern red oak plantations were planted with seedlings in which family identities have been maintained. Some of the plantations have been lost due to combinations of drought, poor site selecton, insect damage, fire, and deer browse. However, of the plantations that remain, several are performing beyond our expectations for survival and growth. These plantations will yield much valuable data in future years. We now have several existing plantations in which seedlings are showing the ability to survive well and initiate height growth. As with other artifically regenerated species, either pine or hardwood, additional release is necessary, however, these plantations are better than any other oak plantings that have been attempted on the national forests.

In the winter of 1998 in collaboration with Kormanik, we established the first white oak field planting with family identified, graded seedlings on the Brasstown Ranger District. This planting was established with 25 open pollinated families with 5 tree row plots replicated 8 times. Seedlings were graded based on height, caliper, and meeting the minimum number of first-order lateral roots. So far, survival looks promising. Early examination indicates very high survival and an excellent first flush of growth. So far the deer have entirely avoided the white oak seedlings. This plantation has the potential to provide us with much more specific performance information as each seedling was individually measured, lateral roots counted and recorded prior to planting and each seedling will be followed as an individual thoughout its development.

WHAT WE HAVE LEARNED SO FAR

Comparison of the orchard types has been very rewarding. Seedling seed orchards are the way to go. The oaks are very difficult to graft due to rootstock compatibility problems. When the grafts are successful, the resulting trees do not grow and develop as rapidly as the seedlings. The acorn bearing surfaces on the trees in the seedling orchard are several times larger than for the grafted trees at similar age. In the seedling orchard, acorn production is strongly genetically controlled. Some trees bear crops or have potential every year and others have never produced anything.

We have also learned that the oaks seem to be as plagued by insect problems as the pine orchards. Chemical control of insects will be necessary if oak orchards are to produce on a consistent basis.

Seed size is important and very variable in the orchards. There seems to be a much wider range of seed sizes and the small ones can be eliminated by mechanical screening prior to planting.

Many species of wildlife become problems in oak orchards. When the acorns start to fall, the deer, turkey, bear, and squirrels show up, sometimes in massive numbers. They can fully destroy a crop in a short period of time.

Proper acorn handling is critical to success (Bonner and Vozzo 1987). It appears that white oak acorns are considerably more sensitive than red oak acorns to storage and handling practices.

To obtain high-quality seedlings, the nursery protocol developed by Paul Kormanik produces very high-quality seedlings. The protocol provides for balanced seedling nutrition, irrigation schedules determined by measurement of soil moisture, seedlings grown at a low density, and small applications of nitrogen based on the growth of the seedlings and target seedling sizes. Seedlings are graded on the development of a minimum number of first-order lateral roots. Based on the observations in the nursery in 1995, there appears to be significant differences in families in first-order lateral root production.

Even with the best quality seedlings, good site preparation, excellent storage and handling practices, these seedlings will still require release from the competing vegetation, primarily yellow-poplar.

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THE EFFECTS OF SEEDLING STOCK-TYPE AND DIRECT-SEEDING ON THE EARLY FIELD SURVIVAL OF NUTTALL OAK PLANTED ON AGRICULTURAL LAND[1]

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ABSTRACT—First-year results are presented for two studies designed to compare the effects of seedling stock-type and direct seeding on survival and stem height of Nuttall oak (*Quercus texana*) planted on former agricultural land. Bareroot and container seedlings were observed to have good survival when flooding or long-term soil saturation was not present. Container seedlings appear to survive flooding better than bareroot seedlings. Also, container seedlings were successfully established in the late spring after the floodwaters receded. The bareroot seedlings, which had to remain in cold storage while the site was flooded, had poor survival when planted in late spring. Direct seeding does not appear to be a viable reforestation option on sites which flood frequently. The bareroot and container seedlings were observed to have a notable amount of stem dieback during the first year after planting.

INTRODUCTION

Federal programs and regulations such as the Wetlands Reserve Program (WRP), the 1985 Food Security Act, and Section 404 of the Clean Water Act have been the driving forces for the recent increase in the hardwood reforestation of flood-prone agricultural lands. Unfortunately, the flooding which made farming difficult also hampers reforestation efforts. Seedlings of flood tolerant species are generally more sensitive to long durations of flooding than mature trees (Kozlowski and others 1991). When complete inundation occurs after bud break, significant amounts of stem dieback and lower survival can occur (Baker 1977, Whitlow and Harris 1979). As one might expect, the negative impacts of spring flooding appears to be most severe on seedlings of moderately flood tolerant and flood intolerant bottomland hardwood species. Day and others (1998) reported that spring flooding greatly reduced first-year survival of willow oak (*Quercus phellos*) bareroot seedlings planted in December. First-year survival of cherrybark oak (*Ouercus pagoda*) bareroot seedlings dropped from 90 percent on a nonhydric soil to about 50 percent on a hydric soil that was saturated during the late-winter and early spring (Williams and others 1993).

At locations where flooding is minimal, research results indicate that seedling establishment can be successful. Allen (1990) observed adequate bottomland hardwood oak stocking for five planted seedling stands (266 trees/ac) and five direct seeded stands (293 trees/ac) about 6 years after establishment. Miwa (1995) observed first-year seedling survival greater than 70 percent for four bottomland hardwood species planted on hydric and non-hydric soils which no longer experience significant flooding. Five years after planting, seedling survival was still greater than 60 percent (Ozalp and others 1998). Stanturf and Kennedy (1996) observed survival exceeding 60 percent after 5 years for 2-0 cherrybark oak seedlings planted in a floodplain clearcut.

The use of container-grown hardwood seedlings instead of bareroot seedlings may be a potential option for the reforestation of flood-prone sites. White and others (1970) presented the possible advantages of using container hardwood planting stock. Advantages that may be especially important to a wetland reforestation planner are the ability to extend the planting season and the higher survival usually observed on adverse sites. For example, container seedlings could be planted after the flood waters recede in early summer. While bareroot seedlings that are typically lifted from the nursery during the winter must spend an extended period of time in cold storage prior to planting. Since hardwood seedlings are sometimes packed in bundles or bags which cannot be completely sealed, there is a risk of seedling dessication during unplanned, long-term cold storage. Results are presented from two studies that compared the early field survival and growth between 1-0 bareroot seedlings and container Nuttall oak seedlings. Study A also included a direct seeding treatment.

METHODS

Study A

Container seedlings were grown in 164 cm^3 plastic cone containers filled with a 1:1 mix of peat moss and commercial grade vermiculite. The seed used were from a Mississippi Delta seed source. The seed were artificially stratified prior to sowing (Olson 1974). Seed were sown in the containers on May 26, 1992. The containers were placed at a density of 24 seedlings/ft^2. The container seedlings were grown in a shadehouse covered with a 50 percent shade cloth. The shadehouse was located at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. The seedlings were watered and fertilized as needed. The container seedlings remained outdoors until transported to the study site. The bareroot seedlings were obtained from a commercial forest tree nursery in early January 1993. The seedlings were packed in kraft storage bags, transported to

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Waterways Experiment Station and placed in cold storage until planted. While the seed for the bareroot seedlings were from a Mississippi Delta seed source, they were not from the same seed lot as the seed used for the container seedlings. The seed used for the direct seeding treatment were from the same seed lot as the seed for the container seedlings. Prior to sowing at the study site, the seed were artificially stratified.

The study site is located at the U.S. Army Engineer Lake George Wildlife/Wetland Restoration Project, Yazoo County, Missisippi. The soil type is a Sharkey clay (very fine, montmorillonitic, nonacidic, thermic, Vertic Haplaquept). The study site was farmed for soybeans during the growing season prior to initiating the study. The specific location was chosen because, based on observations, the site received backwater flooding from the Yazoo and Big Sunflower Rivers during the late winter and early spring almost every year. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on four dates: January 22, 1993, February 16, 1993, March 18, 1993, and June 8, 1993. Prior to each planting date, 40 bareroot and container seedlings were randomly sampled to measure stem height, root collar diameter, shoot oven-dry weight, and root oven-dry weight. For the direct seeding treatment, two seed were sown for each position on each date. Seed positions were on a 1.5 m by 1.5 m spacing and the seed were sown at a depth of about 5 cm. The experimental design is a randomized complete block split plot design with four replications. The whole plots are the planting dates. The bareroot seedlings, container seedlings, and the direct seeding are the sub-plots. T-tests were used to test for biomass differences. Analysis of variance was used to test for treatment differences regarding first-year survival, stem height and growth. As anticipated, the study site flooded for a period beginning in late March and ending in late May. The seedlings planted and the seed sown in January, February and March were completely inundated for almost eight weeks.

Study B

Container seedlings were grown in 164 cm^3 plastic cone containers filled with a 1:1 mix of peat moss and commercial grade vermiculite. Seed were from a Mississippi Delta seed source. The seed were artificially stratified prior to sowing (Olson 1974). Seed were sown on May 26, 1994 and seedlings grown at a shadehouse facility (50 percent shade) located at the Arthur Temple College of Forestry, Stephen F. Austin State University. Container density was 24 seedlings/ ft^2. Seedlings were irrigated and fertilized as needed. An additional treatment imposed on the container seedlings was a mycorrhizal inoculation conducted on July 6, August 30, and December 21. The inoculum used was from a commercially available kit of *Pisolithus tinctorus* mycelium. The same one-half of the container seedling population received a drench of the fungus solution, prepared according to manufacturers recommendations, on each date. Bareroot seedlings were purchased from a commercial hardwood nursery. The seed source and seed lot were the same for both the container and bareroot seedlings. Only bareroot seedlings taller than 46 cm were used in this study.

Seedling morphology was compared by randomly selecting 50 seedlings from each stocktype. Stem height, root collar diameter, stem oven-dry weight, root oven-dry weight, root volume, and the number of primary lateral roots were measured for each seedling. A one-way analysis of variance was used to test for differences in morphology between bareroot, container, and container-inoculated seedlings.

The bareroot and container Nuttall oak seedlings were planted on three former agricultural sites located in Mississippi, Louisiana and Texas. In Mississippi, the study site is located on the Yazoo National Wildlife Refuge, Sharkey County. The soil type at this site is a Sharkey clay. The seedlings were planted at three different elevations representing three different levels of flooding. Precise elevations were determined by using standard surveying techniques. At the lowest elevation, flooding should be deeper and of longer duration than at the highest elevation which should receive no flooding. The bareroot seedlings were lifted from the nursery beds on January 9, packed in kraft storage bags and transported to the study site on January 10. The container seedlings remained outdoors until transported to the study site on January 10. The bareroot and container seedlings were hand-planted on a 1.5 m by 1.5 m spacing. The experimental design is a randomized complete block split-plot design with 4 replications. The whole plots are the elevations while the subplots are the stock-types. Analysis of variance was used to test for treatment differences for percent survival and stem height.

In Louisiana, the study site is located on the Bayou Macon Wildlife Management Area, East Carroll Parish. The soil type is a Sharkey clay. For this site, only the stock-type treatment effects on percent survival and stem height were tested. The study design is a 3 X 3 Latin Square. While the planting location appeared to be flat, the Latin Square design was chosen to account for subtle changes in elevation which could have led to differences in soil moisture levels. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on February 14, l995. The bareroot seedlings were a subset of a general population obtained from the nursery on January 3 and placed in cold storage at Stephen F. Austin State University until planted. The container seedlings remained outdoors until transported to the planting site.

In Texas, the study site was located on the Alazan Bayou Wildlife Management Area, Nacogdoches County. The soil type is a Mantachie sandy loam (fine-loamy, silicious, acid thermic Aeric Fluvaquent). The study design and analysis were similar to that used for the Bayou Macon site. The seedlings were hand-planted on a 1.5 m by 1.5 m spacing on February 9, 1995. The bareroot seedlings were a subset of the general population obtained from the commercial nursery on January 3 and placed in cold storage at Stephen F. Austin State University until planted. The container seedlings remained outdoors until transported to the planting site.

RESULTS AND DISCUSSION

Seedling Biomass

For both studies, the container seedlings were smaller than the bareroot seedlings (tables 1 and 3). The minimum size recommendations for bottomland oak bareroot planting stock are a stem height of 46 cm, root collar diameter of 10 mm, and a tap root length of 20 cm (Kennedy 1992). For study A, the average root collar diameters for both bareroot and container seedlings were smaller than recommended. The average root collar diameter for bareroot seedlings used in study B exceeded the recommendation. Several early studies with hardwood species other than oaks suggested that the minimum root collar diameter for planting stock should be at least 6 mm (Belanger and McAlpine 1975, Klawitter 1961, Rodenback and Olson 1960, Williams 1965). Equal or greater survival was observed for planting stock with root collar diameters larger than 6 mm. McKevlin (1992) also recommends that the

Table 1—Average morphological characteristics (N=40) of Nuttall oak seedlings planted for study A

Variables	1993 Planting date							
	January		February		March		June	
	BR	CO	BR	CO	BR	CO	BR	CO[1]
Height (cm)	63	47*[2]	52	46*	53	39	56	54
Root collar diameter (mm)	7.4	6.1*	7.0	6.6	6.3	5.5	7.3	6.5
Shoot dry weight (g)	9.2	4.9*	5.4	6.1	5.7	3.5*	6.5	5.0*
Root dry weight (g)	6.7	4.5*	5.9	4.1	5.1	3.3*	5.3	3.2*

[1]BR = 1-0 bareroot seedlings; CO = seedlings grown in 164cm^3 plastic cone containers.
[2] For each planting date, means in a row followed by an asterisk are significantly different at the P=0.05.

Table 2—Average first-year height, height growth, and percent survival for the Nuttall oak seedlings planted in 1993 for study A. Values are determined by averaging the values from four subplots. There are 25 samples in each subplot

Planting date and stock-type[1]	Height	Height growth	Survival
	cm	cm	%
January			
Bareroot	35	-12	59
Container	44	4	84
Direct seedling	14	14	44
February			
Bareroot	39	-14	56
Container	46	3	80
Direct seeding	14	14	39
March			
Bareroot	37	-21	32
Container	48	4	75
Direct seeding	16	16	28
June			
Bareroot	22	-31	4
Container	48	3	95
Direct seeding	17	17	9
Root MSE[2]	5	7	14

[1]The interaction between planting date and stock-type is statisically significant at the P=0.05.
[2]Root MSE = Root Mean Square Error.

minimum root collar diameter for bottomland hardwood planting stock should be at least 6 mm. For both studies, an important distinction between the stocktypes may be in their root characteristics. The bareroot seedling roots consisted primarily of a large tap root and a few primary and secondary laterals. The container seedling roots were fibrous consisting of a tap root and many higher order lateral roots. Container seedling production typically promotes fibrous root system development and protects these roots until planting (Landis and others 1990). For study B, the container seedlings had a significantly higher number of primary lateral roots than the bareroot seedlings (table 3). Mycorrhizal inoculation appeared to have little effect on container seedling morphology.

Survival and Stem Height

For study A, survival was highest when the seedlings and seed were planted in January and February (table 2). Survival was reduced significantly if the planting occurred in March or June. Overall, container seedlings had the best first-year survival while direct seeding had the worst. Direct-seeding bottomland oak species can be a low-cost and effective means of reforesting agricultural lands (Bullard and others 1992, Stanturf and Kennedy 1996, Wittwer 1991), however, adequate stocking by direct-seeding may not be achieved because of seed predation, flooding, or drought (Johnson and Krinard 1987). Since two seeds were placed at each position, actual stocking by direct seeding is one-half what is presented in table 2. Seedling stocking could have been higher. Many of the acorns sown prior to the flood were found on the soil surface or exposed in the soil cracks in June. The high shrink characteristic of the Sharkey clay soil during rapid drying may have caused the seed exposure. Sowing seed deeper than 5 cm may be necessary for clay soils (Johnson and Krinard 1987). For reforestation projects initiated by Federal programs or regulation, adequate seedling survival usually must be guaranteed. The required seedling survival can range from 50-90 percent. Consequently, direct-seeding, although relatively inexpensive, may be too risky for many bottomland hardwood wetland restoration projects.

Excellent survival can be achieved by planting bareroot seedlings, especially when environmental conditions are

Table 3 —Average (N=50) morphological characteristics of the Nuttall oak seedlings planted in Study B

Variable	Bareroot	Container	Container w/ inoculation
Height (cm)	70.0a	60.0b	66.0b
Root collar diameter (mm)	13.0a	9.0b	9.0b
Stem dry weight (g)	13.0a	4.5b	4.6b
Root dry weight (g)	11.3a	7.5b	7.4b
Root volume (ml)	11.6a	3.5b	3.7b
No. primary lateral Roots > 0.5 mm	16.0c	30.0b	35.0a

Means within a row followed by the same letter are not significantly different at the P=0.05.

Table 4—Average height and survival for the Nuttall oak seedlings planted on three different sites for study B for the Sharkey Site averages were determined by averaging the values from 4 subplots, 30 seedlings in each subplot. For Alazan Bayou and Bayou Macon, the averages were determined by averaging the values from 3 plots, 30 seedlings in each plot

Stock-type	Sharkey Site, MS[1]		Alazan Bayou WMA, TX		Bayou Macon WMA, LA	
	Survival					
	Not flooded	Flooded	Height	Survival	Height	Survival
	- - - - - % - - - - -		- - cm - -	- - % - -	- - cm - -	- - % - -
Bareroot	20	36	57b	94	33c	79b[2]
Container	7	43	72a	97	49b	88b
Container with inoculation	3	28	66ab	97	59a	97a

[1] For the Sharkey Site, the numbers represent second-year survival. For Alazan Bayou and Bayou Macon, the numbers represent first-year survival and height.

[2] For each site, numbers in a column followed by the same letter are not significantly different at the P=0.05.

optimum (Allen 1990, Miwa 1995). For study A, the reduced survival for bareroot seedlings planted in March and June may partially be explained by the reduction in seedling viability during long-term cold storage (table 2). The original experimental design called for plantings to occur in January, February, March, April and May. The unplanned delay in planting was necessary because of the flooding which occurred in March, April and May. For study B, bareroot and container seedlings planted at Alazan Bayou and Bayou Macon had first-year survival greater than 80 percent (table 4). These sites did not experience long-term flooding or soil saturation. Survival was difficult to ascertain at the Sharkey Site. First-year survival and height was impossible to measure because of severe stem dieback and rodent hervibory. Flooding did occur following planting during the late winter and early spring at the lowest elevations. Second-year survival was observed to be highter at the lowest elevations. This observation is difficult to explain, in part, because of the high amounts of herbivory occuring at the Sharkey Site.

For study A, flooding appeared to have less adverse effect of container seedling survival. Container seedling survival was higher than bareroot seedling survival when the planting occurred in January or February. In addition, the high June survival for container seedlings suggests that they can be kept in the containers and successfully established after the flood waters recede. The successful establishment of the June-planted container seedlings was achieved even though the buds were not dormant and evapo-transpirational demand on the site was high. Graber (1978) reported the successful establishment of container seedlings of several northern hardwood species that were planted during the summer.

For study A, it was anticipated that the direct-seeded seedlings would be smaller than container or bareroot seedlings. However, for study A and B the amount of stem dieback observed for the container and bareroot seedlings was great. Bareroot seedlings were shorter after the first year in the field than when planted. Container seedlings were about as tall as when they were planted. Adequate survival is usually more important than rapid height and diameter growth for most bottomland hardwood wetland restoration projects. However, the detrimental effects of complete inundation on seedling survival suggests that rapid height growth after planting on flood-prone sites is desirable.

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COMMERCIAL CONTAINERIZED HARDWOOD SEEDLING PRODUCTION IN THE SOUTHERN USA[1]

John McRae[2]

ABSTRACT—This paper will discuss the production activity and the history of containerized hardwood seedling production in the southeastern United States. Containerized hardwood seedling production began in the mid 1980's. Since the early 1980's production capacity expanded from approximately 50,000 to about 500,000 seedlings per year. Through 1998 the estimated total annual production is nearly 600,000 seedlings. Most of the containerized hardwood seedling production is in Mississippi, where the USDA Forest Ashe Nursery is producing seedlings in containers. But, production also occurs in Florida, Alabama, and Georgia. Production activities from site selection through packaging for shipment are discussed.

INTRODUCTION

Commercial containerized hardwood seedling production dates probably to the mid 1980's in Odenville, Alabama. International Forest Company began growing *Quercus* spp. in containers in response to requests by the U.S. Corps of Engineers. Successful bareroot seedling establishment of *Quercus* spp. was difficult in areas of the Mississippi Delta. Frequent flooding and extremely elastic soils hindered bottomland restoration efforts. It is a widely known fact among foresters that a substantial risk is taken to transport, handle, and plant usually large bareroot *Quercus* seedlings.

Such seedlings normally contain large root systems requiring extra effort to plant properly, and the planting window was limited to the cold months of fall and winter. Many sites are naturally flooded or will flood during this period making planting and subsequent survival risky. Container hardwood seedlings offered a larger planting window since they do not necessarily have to be shipped during the dormant season. They were also easier to handle, being extremely uniform, with root plugs the same shape and size and shoot heights within manageable limits across all species. As with container longleaf pine, survival was all but guaranteed.

The success of plantations established by the Corps, using container hardwood seedlings, resulted in continued use and preference to this alternative to bareroot seedlings, especially in areas flooded for long duration.

PRODUCTION CONSIDERATIONS

Nursery Location

Selecting a site to grow containerized seedlings requires thoughtful consideration. The first consideration must be water quality. It is of course the water that will eventually lead to success or failure over time when growing tree seedlings, whether container or bareroot. The source of water is very critical and usually determines whether or not you would like to grow on a particular site. The pH of the water is probably the most important factor. A range of 5.5 to 6.5 is ideal. Also, consider the amount of other minerals and elements in the water. The recommendations of Dr. Charles B. Davey of Zobel Forestry Associates Inc. is an excellent source to use in establishing water quality thresholds.

When choosing a site, consider the climate in which you plan to grow. Seasonal changes are preferred to help produce quality seedlings. The cool weather in the fall is needed to help push seedlings into dormancy and the cold weather in the winter is needed to maintain dormancy. Of course, a cool spring (temperatures below 85° F) facilities excellent germination. Most hardwoods native to the southeastern USA do not require full sunlight to live. However, growing in full sunlight usually promotes rapid growth. Establish the nursery within the natural range of the species you plan to grow, but choose an area where the plants can be exposed to seasonal changes.

Containerized seedling production is a labor intensive process. The third most important factor when considering your location is to make sure that you have the infrastructure to support the nursery production. Obtaining labor to grow the crops is an important consideration. In this modern of times having "just in time" suppliers, a responsive distribution system is usually not a problem anywhere throughout the South. However, remember it is the biological deadlines of growing a crop that must steer your budgeting and planning.

Product and Service Objectives

The container in which you grow is without a doubt the most important decision to be made. The demands of customer requirements and the biological needs to establish a successful plantation drive this decision. A variety of cavity sizes and multi-pots are available. Experience has shown that the larger the cavity the larger the hardwood will grow. Only water and poor nutrition will limit them it seems. Successful plants, 14 to 24 inches tall with RCD of 5 to 7mm can be grown in 5.7 cubic inch cavity with a 3.5 inch depth. Multi-pots tend to cost less per cavity and are easier and less costly to manage when growing large quantities of seedlings. Removable cells provide extra flexibility if sorting is necessary but, in general add to production, packaging, and shipping costs. The grower usually finds, however, that

[1]McRae, J. 1999. Commercial containerized hardwood seedling production in the Southern USA. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 35-38.

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when producing hardwoods, the option of sorting by height growth yields more shippable seedlings, and sorting is much easier completed when using removable cells. The seedling quality (the product) and customer service is directly effected by the container used.

Seed

Quercus spp. seed germination still appears to be an enigma to just about all nurserymen. Germination vigor varies considerably within and among species. It is best to use uniform acorns, sized in groups varying only 50 to 100 seed per pound. Usually, large seeds germinate and grow best. Methods are in place, however costly, to consistently produce clean seed with germination of 85 percent and better. Once again, experience has shown that any improvements to seed quality that can be made, should be made, considering the additional costs involved in seedling production.

Choose seed with good vigor. That is, seed which germinates fully and quickly. Purities should be higher than 98 percent since debris slows sowing operations. Float off the empty seed and stratify the "sinkers" 0 to 30 days at 33° F depending on the species to enhance total germination and vigor. It is also advisable to sterilize the seed coat before sowing to remove or kill any pathogens that can inhibit germination.

The sowing strategy involves seed use management and how you plan to manage the crop. Total estimated germination usually drives the decision as to the number of seeds to sow in each cavity. But when considering *Quercus* spp., usually only one seed will fit to a cavity. Multiple seeds can be sown to a single cavity when species such as *Fraxinus* are grown. Considering labor costs to sow seed and to thin unneeded germinates from the cavity, the minimum germination for single sowing (one seed per cavity) is 90 percent. Less than 90 percent usually involves sowing more seed per cavity. Germination less than 60 percent are rarely cost effective. So choose your seed wisely.

Media

Don't use dirt! Use a soilless media. Commonly equal proportions of peatmoss, coarse vermiculite and perlite are used as a growing media. They must be well blended, but care needs to be taken to avoid destroying the material structure. Equal pore space of air:water:media is desirable for proper drainage. The target cation exchange rate should be 25-35 MEQ/L. Often, a few to several amendments are incorporated into the media during blending. Controlled release fertilizers and micronutrients are usually incorporated by most growers. The intent is to optimize growth throughout the seedling life cycle, even into the first few months after outplanting. Considerable investigation is recommended before deciding upon products and rates.

Wetting agents added to the media greatly improve the water distribution in the cavity. This affects drainage, which in turn greatly influences root and shoot growth. In general, any management activity that can optimize the drainage properties of the growing media will result in more plantable seedlings.

PRODUCTION ACTIVITIES

Media Filling and Germination Management

Filling the containers properly after the media is thoroughly blended is a critical operation that should not be taken lightly. First, the containers must be cleaned well enough to prevent weed seeds and/or diseases from significantly affecting seedling growth and development. During filling, careful tamping of the media is extremely important, as subsequent drainage and root growth are greatly influenced by this operation. Tamp each cavity precisely and uniformly. Do not destroy the media structure with "over tamping." Leave a depression on the top in which to place the seed. Mulching the seed is usually not necessary.

Once the filled containers are placed in the production area, immediate action is necessary to protect your investment from any environmental damage. Cover the crop with shade cloth. This will protect the seed and germinating seedlings from predators, heavy rains, hail storms and wind damage. The cloth should stay in place during the first 4 to 5 weeks after sowing or until about 90 percent of the seeds have germinated.

Irrigation should be frequent enough during the entire germination phase to maintain seed moisture levels that promote germination, but minimize pathogen development. Over watering, as well as under watering, can cause severe variation in filled cavity percentages. It is at this point in time of the operation that has the greatest influence on the success or failure of the crop. Be sure to have plant development goals in place before your operation begins, against which you can measure your progress.

To prevent disease development during the germination phase, regular fungicide applications are recommended. The "preventive" applications are used to manage against aggressive and undetected pathogens that can very quickly destroy a crop.

Water Management

Water management is the single most important activity the nursery manager must command. Earlier mention of pH and media drainage alluded to the fact that these factors are the two critical elements of water management. The pH of the irrigation water and the leachate should be between 5.5 and 6.5. The various fertilizers and chemicals applied throughout the growing season function best in this range. The drainage characteristics of the media also greatly influence water management decisions. Plant/water relations are continually monitored by the nursery manager. By maintaining a consistently drained media, accurate water schedules are easier to establish. A well-drained media also aides in fertility and pest management.

Fertility Management

The goal that a nursery manager should aim for is to produce a seedling with a good rootball first and good shoot growth second. It takes relatively little effort to produce a nice looking top, however, more effort is required to get a good rootball with abundant secondary and tertiary roots.

Resist the temptation for apply high levels of nitrogen early in the season. Instead, emphasize the phosphorus and potassium.

If you could roughly break down the season in thirds, apply low levels of nitrogen, and high levels of phosphorus and potassium during the first third of the season. During the second third of the season, apply more nitrogen in the approximate ratio of 20-10-20 or even a balanced fertilizer.

As shipping season approaches during the last third of the growing season, back off the nitrogen once again by applying a low nitrogen fertilizer with medium levels of phosphorus and potassium.

Pest Management

The keys to successful control of all pests are daily observations, monitoring and action. Every nursery manager should live by the saying "Don't expect what you don't inspect". All pests, whether they be disease, insects or weeds have the potential to explosively develop in the nursery environment. It is only through frequent inspection that problems can be diverted.

Just as daily inspection of the nursery crop is imperative, knowledge for all nursery workers of what a healthy tree looks like is just as important. A person can never identify the abnormal until they are familiar with what is normal. Bank tellers are trained to identify counterfeit money not by learning what the abnormal looks like but rather by having a thorough knowledge of the genuine.

Weed Control

Weeds are the perpetual nemesis of all nursery managers. The question we must answer each year is not "if we have a weed problem" but rather "when the weeds start developing."

Although our "bareroot" nursery counterparts may not agree, weeds are more difficult to control in a container nursery than in a bareroot nursery.

The small cavities used to grow container trees necessitate that any herbicides used must be very target specific and few exist for most the hardwoods grown. A container nursery manager can not afford to use a herbicide that may potentially cause any root inhibition to the container seedling. Such a chemical may control the weed, but may reduce the growth of the seedling due to root damage.

The nursery manager must consider the use of pre-emergent herbicides as the first choice in controlling the weed problem. To rely exclusively on post emergent control can be potentially damaging to the tree crop. First, a nursery manager may not find a post-emergent herbicide that will control the weed pest without doing damage to the trees. Of course, while the nursery manager is looking and experimenting with other post-emergent herbicides, the weeds are lushly growing at the direct benefit of tree that shares the cavity.

Unfortunately, many container nursery managers have relied too heavily upon hand weeding. Every manager knows that this labor intensive activity is a "budget killer." It is costly due to the amount of time required to "climb" in and around the container sets to hand weed. It is also costly due to the time it takes to separate a weed from the tree growing in an individual container cavity.

We as nursery managers owe it to our customers to be continually looking for not only new chemicals but experimenting with different rates of current herbicides to achieve an economic level of control. We can reduce the cost of container seedlings once we find a method of better controlling weeds in the nursery.

Insect Control

Until recently, insect control has not been an activity in which nursery managers have spent a great deal of their time. Their main focus has been on diseases, weeds or an occasional raccoon or opossum that decides to run across the top of the container sets. For years, International Forest Company has applied relatively few insecticides during the growth of the tree crop.

Nursery managers need to pay closer attention to the control of insects that directly attack trees and those that have a role in the spread of plant pathogens as insect vectors. Again, the key to successful insect management is monitoring and inspection.

Most container grown trees are grown in a soilless, high organic media. Under wet conditions this high organic media can support and propagate incredibly large populations of fungus gnats. Their exact role, as to whether they can directly attack and kill young trees or only act as a vector of other plant pathogens, is still being defined. All nursery managers should view this particular insect a potentially serious problem. Control of the moisture in and around the container sets is essential to controlling fungal gnats.

Other more "traditional" insect problems can be controlled fairly easily only if they are detected early. Again, daily inspection and monitoring is the key to successful pest management.

Disease Control

Water management is the primary factor in control of plant diseases in container nurseries. All nursery managers have noted that in dry years much less fungicides are used than in wetter years. Tied to water management is control of the water pH.

Container design also plays an important role in controlling plant diseases. Some containers used today can potentially harbor plant pathogens by allowing them to "overwinter" either inside the walls of the container or on the wall surface in organic matter left over after the trees were extracted. Each nursery manager must address the problem of set sanitation before the container sets are reused.

All containers used in the industry today have water drainage holes in the bottom of the container. The size and location of these holes or hole can play a part in control of plant pathogens that cause root problems. In general a well designed container set will allow free water to rapidly drain out of the cavity.

Allowing the tree foliage to dry down as rapidly as possible each morning after an evening rain or dew is extremely important in controlling foliar pathogens. Most foliar plant pathogens require free moisture to develop. Limiting the amount of time the foliage stays wet following irrigation, rainfall or dew can significantly reduce losses due to plant pathogens.

A review of approved chemicals for container trees indicates a broad choice of available options. However, an informal survey of the most frequently used chemicals indicates a much smaller list. The most popular chemicals of choice are Banrot (or it's components used individually), Captan, Cleary 3336. Most nursery managers sincerely regret that we have lost the use of Benlate.

The chemicals listed above are not a "recommended list." Each manager must make their own choice dependent upon the results in their own nursery and the species of trees grown.

Use of chemicals should be rotated in order to prevent any resistance buildup in the pathogen population. Be sure that the chemical rotation includes chemicals which are not in the same group or similar chemical structure.

Regardless of the chemicals chosen, control of the water pH is imperative. All chemicals have an optimum pH range at which the chemical remains active in the water. This information is not readily available for chemical labels. However if you are using water with a pH much outside the recommended range around 6.0, you should check with the manufacturer to determine if the chemical remains active for as long as you require at your pH.

Shipping

Shipping season is not necessarily the end of the headaches, for many managers, it is only the beginning. Decisions as to how to ship the seedlings, how to store them and weather concerns permeate the shipping season.

Perhaps the most common way to ship seedlings is to extract them from the container and ship in a box to the customer. Extraction of all the seedlings allows for better quality control than shipping the seedlings to the customer in the container sets. Culls are easily removed before they are shipped to the customer.

Weather conditions are an important consideration during the extraction of seedlings. A wet rootball is more difficult to extract than a rootball that is dry. A seedling that is difficult to extract or has a marginally good rootball may end up as a cull if it must be extracted when very wet. However, the root plugs of hardwoods are usually very well formed leaving only the obvious culls as problem seedlings.

Container trees are also shipped in the container sets. This is not a preferred method for the nursery manager for several reasons. First, good seedlings and culls that could have been detected by extraction are shipped together. The tree planters seldom remove any culls unless well trained. Second, container sets sent to the customer are frequently not returned or returned damaged. A deposit can be required, however, it significantly increases the amount of administrative bookkeeping to track them. Thirdly, shipping the trees in the sets is more costly than extracted. More extracted trees can be shipped in the same cubic foot area than can trees shipped in the sets.

Although shipping trees in the containers has many disadvantages for the nursery manager, some customers prefer this method. Difficulty in lining up planting crews is not as much of a problem since the customer can easily water and maintain their trees in the containers.

Container trees do not need to be shipped in refrigerated vans unless they are traveling to a much hotter location. A tree with a rootball of about 80 percent moisture would have no problem being shipped in non-refrigerated vans.

We feel that one of the greatest advantages to container seedlings is that they can be planted anytime of the year as long as adequate soil moisture exists. Nursery managers need to encourage customers to accept shipment as early as possible in the fall. We have had customer plant container trees in late July when good summer rains occur.

The other advantage to early planting is the ability to avoid freezing temperatures that are common after mid December in the Southeastern United States. We at International Forest Company are very strong proponents of fall or late summer planting of container trees.

EFFECT OF CHLOROPICRIN, VAPAM, AND HERBICIDES FOR THE CONTROL OF PURPLE NUTSEDGE IN SOUTHERN PINE SEEDBEDS[1]

William A. Carey[2] and David B. South[3]

INDRODUCTION

Methyl bromide (MBr) controls purple and yellow nutsedge (*Cyperus rotundus L.* and *C. esculentus L.*) better than other soil fumigants. Chloropicrin is a good alternative to MBr for enhancing seedling growth but is inferior as a herbicide (South and others 1997). Nutsedge control with chloropicrin has been increased by adding Vapam® (metham) or selective herbicides such as Eptam® (Carey 1997). In this trial, loblolly (*Pinus taeda*) and slash pine (*Pinus elliottii*) production and growth, were measured and the number of nutsedge tubers were counted. Fumigated plots (chloropicrin or chloropicrin plus Vapam) were treated with either Tillam® (pebulate), Eptam® (EPTC) or Manage® (halosulfuron).

METHODS

The trial was at the Georgia Forestry Commission's Flint River Nursery in Macon County, Georgia. The study area was divided into three equal blocks each with five pre-sow treatments and a control. All treated plots contained 300 lbs. per acre chloropicrin. One treatment received Tillam and one EPTC (both at 6 lbs ai/ac) incorporated to a six inch depth with a rototiller before being fumigated with chloropicrin. Two treatments contained Vapam (80 gal/ac), one of these with and one without 6 lbs ai/ac EPTC.

Five beds of loblolly and one bed of slash pine were sown across all treatments on May 5, 1997. Two beds of loblolly and the slash pine seedlings were selected for treatment with Manage. These treatments were applied over the fumigation study plots on June 15. Each of the three beds in each pre-sow-herbicide by fumigant plots were sprayed with a different rates of Manage (0, 0.5, or 1 oz ai/ac) applied over the seedlings. On November 5, 1997, seedbed densities were assessed at the center of each treatment plot. Seedlings (25 per plot) from the center six drills of each density plot were harvested to determine heights, rcd's and dry weights. Nutsedge tubers were collected from each harvested plot. Treatment effects were analyzed as a randomized complete block design.

RESULTS

Table 1 presents the means for plots in the three Manage treated beds. The trends among plots with and without Manage treatments were similar. However, there was less separation between means when both species were combined (and the Manage treatments included). In plots not treated with Manage, chloropicrin fumigation reduced the production of nutsedge tubers and increased seedling height and plantable seedlings. The addition of Tillam had no benefit. However, the addition of EPTC or Vapam improved at least one measured variable (a=0.05).

Table 1—Effects of fumigants and pre-sow-herbicides on loblolly and slash pine seedlings and numbers of nutsedge tubers in beds treated with Manage

Fumigant[a]	Herbicide[b] pre-sow	Seedlings parameters			Stems/ft^2			Nutsedge tubers
		Height	RCD	Weight	All	>2.8	>4.7	
		cm	mm	gms		mm	mm	
None	None	26 b	3.7 b	2.9 b	26 b	19 a	2.2 b	12 a
Chloropicrin	None	28 ab	3.8 ab	3.3 ab	26 b	21 a	3.3 ab	1 b
Chloropicrin	Tillam	28 ab	3.8 ab	3.1 ab	28 ab	21 a	3.7 ab	1 b
Chloropicrin	EPTC	30 a	4.0 a	3.5 a	27 ab	22 a	4.6 a	1 b
Chloropicrin + Vapam	None	30 a	3.8 a	3.4 ab	29 a	22 a	4.4 ab	4 b
Chloropicrin + Vapam	EPTC	31 a	4.0 a	3.4 ab	28 ab	22 a	4.9 a	1 b
lsd		*2.6*	*0.2*	*0.44*	*2.5*	*03*	*2.1*	*4*

[a] chloropicrin (300 lb/ac) treatments plastic tarped except those with Vapam (80 gal/ac) which were power-rolled.
[b] Tillam and EPTC at 6 lbs ai/ac and rotovated in to 6 inch depth.

[1]Carey, W.A.; South, D.B. 1999. Effect of chloropicrin, Vapam, and herbicides for the control of purple nutsedge in southern pine seedbeds. In: Landis,T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 39-40.

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Table 2—Effects of Manage treatment at 41 days after sowing on loblolly and slash pine seedling development and numbers of nutsedge tubers

Pine species	Manage rate	Seedling parameters			Stems/ft²			Nutsedge tubers
		Height	RCD	Weight	All	>2.8	>4.7	
	Oz ai/ac	cm	mm	gms		mm	mm	
Slash	0.0	32 a	4.1 a	4.0 a	28 a	22 a	7.7 a	4 a
Slash	0.5	24 b	4.1 a	3.2 ab	22 b	19 a	3.6 a	1 a
Slash	1.0	25 b	3.8 a	2.9 b	26 a	20 a	3.6 a	2 a
	lsd	*3*	*0.5*	*0.8*	*3.7*	*6*	*4.5*	*5*
Loblolly	0.0	31 a	3.8 a	3.2 a	30 a	23 a	2.8 a	2 a
Loblolly	0.5	29 ab	3.7 a	3.0 a	28 ab	21 ab	2.9 a	5 a
Loblolly	1.0	28 b	3.8 a	3.0 a	26 b	20 b	2.6 a	2 a
	lsd	*2*	*0.2*	*0.3*	*2.2*	*1.5*	*1.5*	*4*

Although we expected chloropicrin to increase seed efficiency and seedling growth (South and others 1997), the reduction in nutsedge was unexpected. Tillam was less effective than the chemically similar EPTC (which is already registered for use in pine seedbeds). The other three treatment combinations (EPTC, Vapam, and EPTC plus Vapam) performed similarly and are being tested at additional sites. It will be less expensive to treat with 6 lbs ai of EPTC than to treat with 80 gallons of Vapam to control nutsedge.

Table 2 presents means by Manage treatment for the plots summarized in table 1. Manage at the high rate reduced seedling growth for all measured variables without effecting the number of tubers. It did reduce seedling height more than diameter so might be useful when managers are not allowed to top-prune seedlings. At 1 oz/ac, seedlings taller than 14 inches were reduced from 36 percent to 1 percent for slash pine and from 36 percent to 14 percent for loblolly pine. However, plantable seedlings were also reduced 10 percent (from 22 to 20/ft²), so top-pruning would be a better choice if nursery revenue is important.

In this and other studies, chloropicrin has been an effective alternative to MBr for enhancing the nursery development of pine seedlings. Adding EPTC or Vapam to the chloropicrin as pre-sow treatments enhanced most of the measured variables. In this trial, applying Manage did not increase nutsedge control.

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CONTAMINATION OF PINE SEEDS BY THE PITCH CANKER FUNGUS[1]

L. D. Dwinell and S. W. Fraedrich[2]

The pitch canker fungus, *Fusarium subglutinans* f. sp. *pini*, has been identified as a significant problem in many pine seed orchards and nurseries in the South. The fungus causes strobilus mortality, seed deterioration, and cankers on the main stem, branches, and shoots of pines (Dwinell and others 1985). The pitch canker fungus causes damping-off (Blakeslee 1980) and stem cankers on seedlings in southern pine nurseries (Barnard and Blakeslee 1980). Contaminated seeds may be a source of inoculum for diseases in nurseries caused by *F. subglutinans* f. sp. *pini*.

CONES

In 1979, Miller and Bramlett established that the pitch canker fungus was pathogenic to both first- and second-year female strobili of slash and loblolly cones inoculated with *F. subglutinans* f. sp. *pini*. Inoculated cones became necrotic, and the pitch canker fungus could be isolated from the cone scales, the axis, and the seeds.

We have studied the natural infection of shortleaf pine cones by the pitch canker fungus at a Federal seed orchard in North Carolina (Dwinell and Fraedrich 1997b). It was isolated from the surface and interior of immature cones. There was no apparent correlation between necrotic cones with external wounds caused primarily by insects and the isolation of the fungus from internal tissues (fig. 1). We found no external symptoms indicative of fungal infection. Barrows-Broaddus (1987) reported that infected loblolly pine cones tend to be misshapen and smaller than normal, and some cones have a necrotic tip characterized by internal resin pockets. Mycelium of the causal fungus has been observed on the outer surfaces of badly deteriorated cones of slash and loblolly pines. The mode of entry of *F. subglutinans* f. sp. *pini*, a wound parasite (Dwinell and others 1985), is currently unknown.

SEEDS

Miller and Bramlett (1979) isolated the pitch canker fungus from gametophyte and embryo tissue of slash and loblolly pine seeds. They reported that isolation of the pathogen appeared considerably less in loblolly than slash pine seeds. Radiographs of seeds in advance stages of disease may show deterioration of the embryo and that the gametophyte has shrunken away from the seed coat. Microscopic examination may reveal the presences of hyphae throughout these seed (Barrows-Broaddus 1987). Often, however, evidence of internal infection is not apparent in radiographs of seeds from which the fungus is isolated. This may be due to its confinement to the outer seed coat, or because the disease is in its initial stages of development.

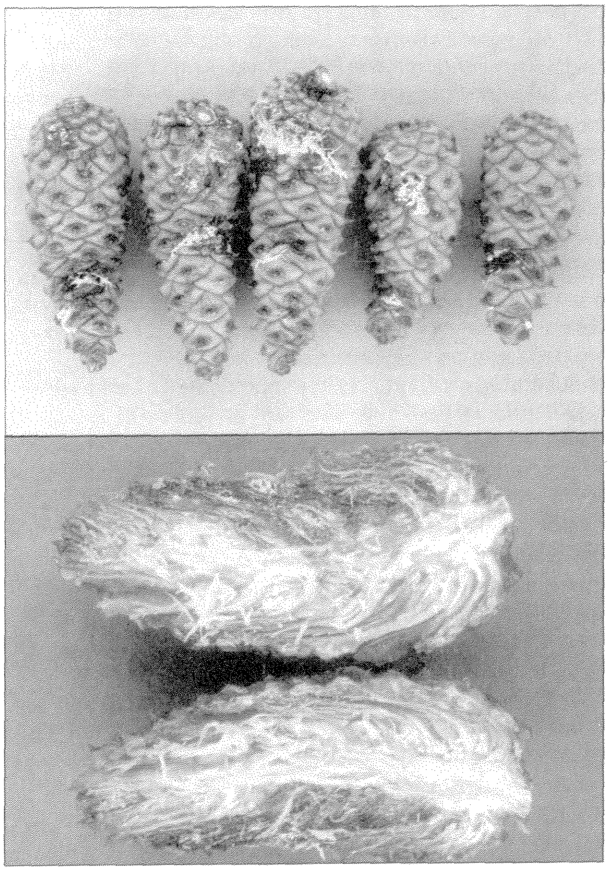

Figure 1—Shortleaf pine cones. (Top) These cones illustrate the extent of external wounds caused primarily by insects in a Federal seed orchard in 1995. The pitch canker fungus was often isolated from the surface of the cones and from the external necrotic tissue. (Bottom) The pitch canker fungus was isolated from internal tissue of asymptomatic cones, as well as cones with internal necrosis. Shown here, cross section of a shortleaf pine cone with necrotic tissue (Dwinell and Fraedrich 1997b).

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Seed contamination may be largely restricted to the seed coat in some pine species. *Fusarium subglutinans* f. sp. *pini* was isolated from an average of 61 percent of the freshly extracted shortleaf pine seeds; but only 1.6 percent of the seeds were infested internally (Dwinell and Fraedrich 1997b). Research on longleaf pine seeds also suggests that the pitch canker fungus may be primarily associated with the seed coat, and infection of the endosperm and embryos is rare (Dwinell and Fraedrich 1997a).

The external contamination of pine seeds by fungal pathogens can be eradicated by appropriate seed treatments. Hydrogen peroxide, for example, shows promise as a seed disinfectant (Barnett 1976). We have found that longleaf pine seeds can be decontaminated by treatment with a 30-percent hydrogen peroxide solution for 55 minutes (Dwinell and Fraedrich 1997a). In 1997, we operationally treated 3.63 kilograms of shortleaf pine seeds with a 30-percent hydrogen peroxide for 15 minutes and, after stratification, sowed them in a Georgia nursery. When the seedlings were lifted in the fall, there was no evidence of pitch canker in the treated or control plots. We concluded that the seed treatment was not detrimental. We are currently focusing on biological control, e.g., *Burkholderia cepacia*, and other seed treatment agents, such as benomyl (Dwinell and Fraedrich 1987b).

NURSERIES

There is little empirical data linking seed contamination by *F. subglutinans* f. sp. *pini* with seedling canker that occurs in nursery beds and on outplanted sites. In a current greenhouse study, we artificially contaminated Monterey, slash, and longleaf pine seed lots with an isolate of *F. subglutinans* f. sp. *pini*. Of the total container-sown seeds, 57 and 30 percent, respectively, of the Monterey and slash pine seedlings had damped-off and 22 percent of the Monterey pine seeds had damped-off prior to emergence. The longleaf pine seed lot was poor and the data were non-conclusive. Preliminary data suggests that the major result of seed contamination by the pitch canker fungus is pre- and post emergence damping-off. Understanding possible linkages between seed contamination and pitch canker in the nursery is a major area of our current research. Such understanding will help nurseries develop control strategies to pine seed contamination and diseases.

CONCLUSIONS

There is little information about the contamination of pine seeds and cones by *F. subglutinans* f. sp. *pini* and other fungal pathogens. Factors affecting the contamination of pine seeds need to be identified. The extent of internal and/ or external contamination appears to vary by species, but the external contamination of longleaf and shortleaf pine seeds by fungal pathogens can be eradicated by appropriate seed treatments.

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LONGLEAF PINE SEED PRESOWING TREATMENTS: EFFECTS ON GERMINATION AND NURSERY ESTABLISHMENT[1]

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ABSTRACT—Longleaf pine (*Pinus palustris* Mill.) seeds are sensitive to damage during collection, processing, and storage. High-quality seeds are essential for successful production of nursery crops that meet management goals and perform well in the field. A series of tests was conducted to evaluate the effect of a number of presowing treatments, e.g., soaking, stratification, and coat sterilization on performance of longleaf pine seeds in the laboratory and nursery. The results of these tests that were installed to determine if presowing treatments improved seed performance are reported here.

INTRODUCTION

Interest in restoring many sites in the South to longleaf pine (*Pinus palustris* Mill.) has increased dramatically in the last 10 years. One of the limitations in producing the quantities of seedlings needed for this reforestation effort is the lack of high-quality seeds. The quality of longleaf pine seeds has been a problem across the South since the quantities collected and produced have markedly increased. Part of the problem of low quality relates to level of maturity at time of collection and to difficulties in cone storage and processing (Barnett and Pesacreta 1993). Handling of large amounts of cones and seeds results in loss of seed quality because all of the recommended criteria for maintaining high quality cannot be met. Nursery managers have looked for seed treatments that may improve performance of such longleaf pine seeds. Treatments in use vary from stratification to soaks in hydrogen peroxide or a fungicide and specific use recommendations vary. At the suggestion of Selby Hawk of the North Carolina Forest Service, a cooperative study among personnel of the Claridge Nursery at Goldsboro, NC, the National Tree Seed Laboratory (NTSL) at Dry Branch, GA, and the Seed Testing Facility (STF) of the Southern Research Station at Pineville, LA, was initiated to evaluate some of the currently used treatments. The objective of the study was to develop recommendations for presowing treatments that will improve performance of longleaf pine seeds.

METHODS

Treatments were applied to the seeds in late April of two separate years—1997 and 1998. Germination tests were conducted at the NTSL, the STF at Pineville, and at the Claridge Nursery.

1997 Tests

The presowing treatments were: (1) control, (2) 1-hour (hr) 30-percent hydrogen peroxide (HP) soak, (3) 1-hr HP soak plus 16-hr water soak (WS), (4) 1-hr HP soak plus 16-hr WS plus 14-day stratification (ST), (5) 16-hr WS plus 14-day stratification, and (6) 16-hr water mist plus 14-day stratification. The 1-hr soak in 30 percent HP was based on earlier research (Barnett 1976) and is labeled as a stratification treatment. It is used operationally at the Claridge Nursery (Barnett and McGilvray 1997). The 14-day stratification treatment is recommended for longleaf pine seeds by the NTSL (Barbour 1996, Karrfalt 1988). These responses to stratification are based on seed imbibition on the germination medium. Other tests of stratification at the Pineville Lab (STF) indicated that the 16-hr WS as conducted for operational stratification may reduce germination by 10 percentage points (Barnett and Pescreata 1993). So, a mist imbibition treatment (misting 1 of every 10 minutes) was included to compare this technique with the water imbibition soak commonly used at nurseries to prepare seeds for stratification. It was felt that the rapidity of water absorption of longleaf pine seeds might be adversely affecting resulting performance (Barnett 1981) and that an intermitten mist might slow imbibition and have a less negative affect on germination.

Three seedlots were selected for the study. One high viability lot was provided by the STF and the two other lots were selected as medium and low quality by Claridge Nursery personnel. Five dishes of 50 seeds each were used for testing in the laboratories; 10 trays of 96 cavities each were used for testing in the nursery. The NTSL applied the presowing treatments to the seeds tested at NTSL and Claridge Nursery. The STF personnel applied the treatments to the same seedlots that were tested at Pineville. Laboratory germination tests followed the Association of Official Seed Analysts (AOSA) guidelines. Germination counts were made at 2- to 3-day intervals at STF in order to determine peak day or the speed of germination. Counts at NSTL and Claridge Nursery were made at 7-day intervals. In all cases, germination was complete within 28 days.

A determination of seedling establishment or percent stocking was made at the Claridge Nursery 3 months after sowing. This evaluation was made to determine if some treatments were more effective than others in protecting seeds from damping-off diseases during germination and early seedling development.

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Table 1—Germination and seedling stocking of longleaf pine seed treatments tested in 1997 under laboratory and nursery conditions[a]

Treatments	Peak day	Germination				Stocking	
		STF	NTSL	Nurs. 1	Nurs. 2	Nurs. 1	Nurs. 2
	No.	%					
Control	7.0ab	76b	71c	75bc	72c	66bc	64b
Hydrogen peroxide (HP)	7.2a	84a	84a	70d	81ab	70b	78a
HP + 16-hr water soak (WS)	6.0bc	71b	74c	84a	85a	81a	80a
HP + WS + 14-day strat.	4.4d	76b	78b	79abc	85a	77a	82a
WS + 14-day strat.	4.0d	85a	84a	79bc	77bc	54d	50c
Mist + 14-day strat.	5.0c	86a	82ab	80ab	76bc	62c	65b

[a]Germination 28 days after sowing in the Claridge Nursery (two separate tests of the same treatment applications sown 2 weeks apart) and Pineville (STF) and Dry Branch (NTSL) Laboratories. Peak day represents the time when maximum daily germination occurs and is a measurement of speed of germination. Seedling stocking is expressed as the percentage of seeds that become established 90 days after sowing. Averages within columns followed by the same letter are not significantly different at the 0.05 level.

1998 Tests

The study was essentially repeated in the second year. The treatments differed from the previous year by dropping the water mist-imbibition and stratification evaluation that did not germinate in the laboratory significantly different to the more conventional water soak-stratification treatment. Added in its place was a 10-minute benomyl drench (0.05 percent solution of benomyl 50WP or 227 grams per 12 gallons water). This treatment was based on research of Weyerhaeuser Company that demonstrated the efficiacy of the benomyl seed-dip treatment for controlling seedborne *Fusarium* and was the basis for registration in North Carolina (Littke and others 1997).

Three seedlots were again used in this study (high, medium, and low viability). A replication in time was a component of this test. All treatments were applied at the Pineville lab and shipped to the NTSL and Claridge Nursery for testing beginning in late April and were repeated again 2 weeks later. Germination counts were made at 7-day intervals at the three testing locations. The other aspects of the study were the same as in the 1997 test.

RESULTS AND DISCUSSION

Although essentially the same treatments were evaluated in the two separate years of testing, there are sufficient differences in procedures to discuss the results separately by year.

1997 Tests

The seedlots were selected to provide an evaluation of the treatments on different seed qualities; lots 1, 2, and 3 were selected to represent low, medium, and high qualities. All tests showed consistent differences among seedlots. For most analyses, there were statistically significant (0.05-percent level) interactions between seedlots and treatments. These interactions reflect that usually the lower quality lot responded more positively to the presowing treatments than the high-quality lot.

A tabulation of responses to the seed treatments is shown in table 1. There were some major differences among testing locations in the results obtained, e.g., in Claridge Nursery test #1, the HP treatment performed consistently lower than in test #2 at the Nursery or at either the Pineville or Macon laboratories. This treatment, which did poorly in Nursery test #1, was equal to the best responding treatments in the other tests. The HP plus 16-hr soak treatment performed best in Claridge Nursery Test #1, but performed worst in the laboratory tests. One possible rationale for the differences in performance of the HP treatment in the nursery tests is that the treatment labels were switched during the test #1 seeding process. At any rate, it is fortunate that two evaluations were conducted at the nursery.

A flaw may have occurred in the Claridge test #1 study related to the HP treatment. In Nursery test #2, the HP treatments were superior to the control and equal to the stratification ones. The laboratory tests at Macon and Pineville showed that the HP soak and the 14-day stratification treatments (both soak and mist) performed best. So, there seems to be some differences between the nursery and the labs.

A determination of percent stocking in the nursery containers was done on July 15, 1997, about 3 months after sowing. In both nursery tests, the treatments that involved HP produced better stocking than the control or stratification treatments. Stocking resulting from the water soak-stratification treatment was significantly poorer that in the mist-stratification treatment. So, even though water imbibition occurred at comparable rates in the water soaking and misting treatments, there may be merit in evaluating misting approaches that would result in slower rates of absorption.

1998 Tests

The differences in germination due to seedlots, presowing treatments, and their interactions were statistically significant at the 0.05 level in each separate test (table 2). To make evaluations of the responses due to the measurement variables more straightforward, germination is presented by presowing and seedlot treatments and by presowing treatments and testing locations.

The effects of presowing treatments and seedlot quality indicate limited response to treatments in the seedlot of highest quality (table 3). Germination at 28 days ranged from 85 percent for the control to 93 percent for the benomyl drench. However, when the medium- and low-quality lots were evaluated, there were major differences in response among the presowing treatments. The HP and benomyl treatments resulted in increases in germination over that of the control with performance of the lower quality lot increasing by 20 percentage points with the HP treatment and 15 percentage points for the benomyl drench. Treatments that included a 16-hr water soak reduced overall germination from 10 to 30 percentage points.

The responses to treatments followed similar trends at each testing facility and between the two replications in time (table 4). As expected, germination in the nursery was somewhat lower than in the laboratories. However, the HP soak and benomyl drench consistently improved germination over that of the control in all situations.

The tests in both 1997 and 1998 indicate that a significant problem in longleaf pine seed performance results from the pathogens carried on the seedcoats. Fraedrich and Dwinell (1996) recently reported that the pitch canker fungus (*Fusarium subglutinans* [Wollenw. & Reinking] Nelson, Toussoun & Marasas f. sp. pini) is a cause of significant mortality of longleaf pine germinants. Our results show that the treatments that reduce microorganisms on the seedcoats improve germination of moderate and low-quality seedlots. The HP soak improved seedling establishment at 90 days in the nursery in the 1997 study by a significant amount (14 percentage points). In the 1998 tests, both the HP and benomyl treatments improved performance of lower quality seedlots. The high viability lot was largely unaffected by presowing treatments.

CONCLUSIONS

The results of both yearly tests indicate that the maximum improvement in longleaf pine seed performance can be obtained by using treatments that reduce seedcoat

Table 2—Germination of longleaf pine seed presowing treatments tested in 1998 under laboratory and nursery conditions[a]

		Test 1			Test 2		
Treatment	Seed quality	STF	NTSL	Nurs.	STF	NTSL	Nurs.
		— — — — — — % — — — — — —					
Control	H	91	84	83	82	85	80
	M	65	73	52	66	70	60
	L	56	52	49	58	49	58
Avg.		71	70	61	69	68	66
Hydrogen peroxide (HP)	H	92	92	76	90	92	86
	M	80	71	61	72	70	70
	L	76	75	60	81	72	63
Avg.		83	79	66	81	78	73
HP + water soak (soak)	H	84	86	88	74	85	88
	M	21	36	46	45	32	29
	L	46	21	44	42	30	21
Avg.		50	48	59	54	49	46
HP + soak + stratification	H	89	84	91	90	95	92
	M	25	40	33	49	27	52
	L	24	15	23	46	45	44
Avg.		46	46	49	62	56	63
Water soak + stratification	H	92	93	89	94	94	87
	M	56	50	34	61	57	60
	L	41	43	39	53	39	40
Avg.		63	62	54	69	63	62
Benomyl drench	H	92	93	91	92	95	92
	M	79	80	69	72	80	74
	L	70	65	71	64	70	64
Avg.		80	79	77	76	82	77

[a]Data are averages of the 5 replications of 50 seeds each. Highest germination in the nursery may have been at 7, 14, or 21 days: counts were lower on 13 of the 18 seedlot-treatment combinations due to damping-off losses before the final count at 28 days. Differences due to treatments, seedlots, and their interactions were statistically significant at the 0.05-percent level for each separate test.

Table 3—Germination of longleaf pine seeds tested in 1998 by presowing treatment and seed quality conditions

Treatment	Seed quality condition			
	High	Medium	Low	Average
	— — — % — — —			
Control	84	64	54	67
Hydrogen peroxide (HP)	88	71	71	77
HP + water soak (soak)	84	35	34	51
HP + soak + stratification	90	38	33	55
Soak + stratification	92	53	42	62
Benomyl drench	92	76	67	78

Table 4—Germination of longleaf pine seeds by presowing treatments and tested two times in 1998 in the laboratory and nursery

Treatment	Test 1			Test 2		
	STF	NTSL	Nurs.	STF	NTSL	Nurs.
	— — — — — — % — — — — — —					
Control	71	70	61	69	68	66
Hydrogen peroxide (HP)	83	79	66	81	78	73
HP + water soak (soak)	50	48	59	54	49	46
HP + soak + stratification	46	46	49	62	56	63
Soak + stratification	63	62	54	69	63	62
Benomyl drench	80	79	77	76	82	77

contamination. Both the 1-hr soak in 30-percent HP and the 10-minute benomyl drench were effective in increasing germination of medium- to low-quality seedlots. High-quality lots were little affected by any presowing treatment. Although operational stratification increases the speed of germination of many seedlots by about 3 days, total germination of less than high-quality seedlots is usually reduced by the treatment. The data confirm results of earlier tests that showed that the overnight soaking of longleaf seeds as done in operational stratification may reduce total germination (Barnett and Pesacreta 1993). Data from the 1997 test (the 1998 data are not yet available) that determined the effect of presowing treatments on nursery stocking show that use of treatments that reduce seedcoat contaminants can markedly improve establishment of germinants in the nursery. So, an additional gain in the nursery can be obtained from the use of treatments that control the seedcoat pathogens that are common on longleaf pine seeds. The 10-minute benomyl drench was equally effective as the 30-percent HP soak and it presents a less expensive and safer treatment for nursery managers. We should seek additional labeling of this benomyl treatment because it provides an excellent opportunity to improve performance of longleaf pine seedlots of typical quality.

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EFFECTS OF SPRING VERSUS FALL SOWING OF LONGLEAF PINE SEEDS IN THE NURSERY ON FIELD PERFORMANCE[1]

Chuck Fore[2] and James P. Barnett[3]

ABSTRACT—Despite advances in the production and planting of bare-root longleaf pine seedlings, problems continue to persist with first-year survival. Survival surveys conducted in 1988 and 1989 by the Georgia Forestry Commission showed survival rates of 35 and 47 percent, respectively, for longleaf pine seedlings planted in those years. In this paper, we look at the influence of season of seed sowing in the nursery on seedling survival in the field. In March and December of 1995, five sites were planted with bare-root longleaf pine seedlings, which were grown from fall- and spring-sown seed. Seedlings planted in March 1995 grown from spring-sown seeds had an average survival of 71 percent compared to 51 percent for seedlings grown from fall-sown seeds. Seedlings in the December 1995 planting grown from spring-sown seeds averaged 68 percent survival compared to 54 percent for seedlings from fall sowing. These results suggest that spring sowing of seeds in the nursery may improve field survival of longleaf pine seedlings over those sown in the fall.

INTRODUCTION

Prior to European settlement and until the early part of this century, longleaf pine (*Pinus palustris* Mill.) was the most prevalent yellow pine species in the southern Coastal Plain. Since then, large tracts of longleaf pine have been cut with very little replacement. Much of the longleaf acreage has been converted to slash and loblolly pine plantations due to the difficulty in regenerating longleaf pine (Landers and others 1995). The two major reasons why industrial companies and nonindustrial private landowners have favored other species over longleaf pine are the higher initial survival rates and the resulting lower establishment costs of the other species.

In recent years, there has been a renewed interest in planting of longleaf pine. However, adequate seedling survival is still problematic with longleaf pine. Survival has improved with the use of container-growing stock, but the cost of container longleaf seedlings is at least double that of bare-root stock (Barnett and McGilvray 1997). Survival surveys conducted by the Georgia Forestry Commission (GFC) for their seedlings in the late 1980's demonstrate significant differences in seedling survival between bare-root longleaf pine planting stock and that of other southern pine species (tables 1 and 2).

Even with improvements in longleaf pine seedling handling and planting methods (Barnett and Dennington 1992), survival of bare-root seedlings continues to be marginal or highly variable. One factor, which may contribute to lower survival rates for bare-root planting stock, is the season in which the seed is sown in the nursery. All or nearly all tree

Table 1—GFC Statewide seedling survival survey—1988

Pine species	Seedlings shipped	Orders sampled	Seedlings sampled	Percent sampled	Percent survival
Improved lob.	89,664,746	210	7,964,670	8.9	73.8
Liv. parish lob.	16,645,150	29	1,243,000	7.5	68.6
Improved slash	61,774,713	163	6,347,725	10.3	75.2
High gum slash	1,185,000	1	370,000	31.2	61.7
Longleaf	2,051,820	13	199,000	9.7	34.6

Table 2—GFC Statewide seedling survey—1989

Pine species	Seedlings shipped	Orders sampled	Seedlings sampled	Percent sampled	Percent survival
Improved lob.	48,080,386	122	4,209,536	8.8	79.8
Liv. parish lob.	3,336,100	12	299,000	9.0	77.6
Improved slash	69,707,960	200	5,482,835	7.9	77.4
High gum slash	3,000,000	2	105,000	3.5	93.9
Longleaf	2,500,000	4	85,000	3.4	46.8

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nurseries which produce bare-root longleaf planting stock sow the seeds in the fall. Fall sowing is based on the fact that longleaf seeds normally germinate in the fall immediately after seed fall. Also, fall sowing allows seedlings more time to attain a desired size before lifting (Huberman 1938, Shipman 1958). Numerous studies have shown that larger seedlings (root-collar diameters) perform better than smaller ones in the field (White 1981).

A case study, which is summarized in this paper, seeks to determine if the season of sowing of longleaf pine seeds in the nursery affects the survival rate of longleaf seedlings after outplanting.

METHODS

Longleaf pine seedlings from fall- and spring-sown seeds were planted on four sites in Dodge County, GA, and one site in Wheeler County, GA. The seed source was open pollinated or wild seed from southern Georgia and northern Florida. Seedlings produced from fall sowing were sown in November 1993 and 1994 at the GFC's Walker Nursery. Seedlings produced from spring sowing were sown in April of 1994 and 1995 at the same nursery. Seedlings grown from 1994 spring-sown seed came from a nursery bed that had been replanted due to a previous germination failure. This particular bed was fertilized and watered in an attempt to bring the seedlings up to an acceptable size to be sold the following winter. The seedlings produced from the spring sowing in 1995 were grown in a bed with loblolly pine and received the same cultural practices. The second spring sowing had a few problems with germination because of mulching problems. However, enough seeds germinated to supply the trees needed for the test plots.

Two sites were planted in March of 1995 and three sites were planted in December of 1995. In each planting season, both types of seedlings were lifted and planted at the same time. All seedlings were graded to meet a 1/2-inch minimum root-collar diameter prior to packing. Seedlings were planted within 6 days of lifting. At each site, half of the area was planted in fall-sown and half in spring-sown production. Each study area encompassed about 1.5 to 2.5 acres. In the spring following planting, the pines were sprayed with a herbicide in a 4-foot wide band over the top to control weed competition. Weeds included field broadleaf weeds along with Bermuda and Bahia grasses. The March 1995 plantings were sprayed with 24 ounces per acre of Velpar-L® in April 1995. The December 1995 plantings were sprayed with 24 ounces per acre of Velpar-L® and 1 ounce per acre of Oust® in May 1996. One site was a Bermuda grass pasture, which had been harvested for hay previously. That particular field was scalped prior to planting in addition to herbicide application to control grass competition (Shoulders 1958). However, half of the seedlings from the spring-sown treatment were planted in unscalped areas due to not properly anticipating the acreage needed for this particular site.

RESULTS AND DISCUSSION

In April 1996, a survival check was conducted on the first two sites, which were planted in March 1995. At each location, five 1/50-acre plots were installed and measured for the spring- and fall-sowing treatments. On each plot, the total dead and live seedlings were counted. Table 3 shows the results for these plantings. The results from these two sites show a 39-percent improvement in field survival resulting from spring sowing in the nursery.

In March 1996, twenty-five 1/50-acre plots were established on the remaining three sites, which were planted in December 1995. Plot centers were marked with flagging tape. The plots were established to determine the initial planting rate for seedlings from the two nursery treatments. These plots were measured in the fall to determine seedling survival. On two sites, nine plots were established and on one site, only seven plots were established. On one site, five of the plots could not be found during the fall due to the heavy grass development. However, since all plots were mapped when they were originally established, the survival checks were very close to the original plot centers. Table 4 presents the results from the December 1995 plantings.

The results of the December 1995 plantings show a 26-percent better survival rate of seedlings from spring-sowing over fall-sowing treatments. However, the Stuckey Tract showed comparable survival rates from fall- and spring-sown seeds. This is likely due to half of the seedlings from the spring-sown treatment being planted in heavy Bermuda grass which had not been scalped.

These test plots indicate that survival of bare-root longleaf pine seedlings may be improved by sowing the seeds in the nursery in the spring rather than the fall. Differences in survival may be due to differences in the physical characteristics of the seedlings produced in the two growing environments. From personal observations, the seedlings

Table 3—Field survival measurements for the March 1995 plantings

Site location	Season of sowing	Trees planted	Surviving trees	Survival
		Per acre	Per acre	Percent
Dodge County	Fall	750	420	56
Fordham Tract	Spring	680	500	74
Wheeler County	Fall	650	300	46
Johnson Tract	Spring	650	450	69
Weighted average	Fall	700	360	51
All plots	Spring	665	475	71

Table 4—Field survival measurements for the December 1995 plantings

Site location	Season of sowing	Trees planted	Surviving trees	Survival
		Per acre	Per acre	Percent
Dodge County	Fall	620	400	65
Stuckey Tract	Spring	788	538	68
Dodge County	Fall	763	363	48
Coffee Tract	Spring	800	550	69
Dodge County	Fall	813	400	49
O'Conner Tract	Spring	710	480	68
Weighted average	Fall	723	388	54
All plots	Spring	758	516	68

from the spring-sown seeds had noticeable physical differences (other than size, since comparable seedling grades were planted) from seedlings from the fall-sown seeds. Seedlings grown in the spring had shorter needles at lifting than those grown through the fall and winter. Earlier studies have shown that reduced needle length, and therefore, smaller transpirational surface area may result in improved seedling survival on adverse sites (Allen 1955, Allen and Maki 1951). Thus, shorter needles may result in less demand for water from stressed root systems.

Also, the spring-sown seedlings tended to have more lateral roots and these developed further down the taproot than fall-sown ones. Results from studies on the effect of soil temperature on root development of longleaf pine seedlings indicate that numbers of roots increase as soil warms from 55 to 74 °F. (Sword 1996). It may be, then, that because the soil temperature warms faster in the spring, this will favor the development of a more fibrous root system and would be advantageous to seedlings when outplanted onto adverse sites.

CONCLUSIONS

The results of this study indicate that spring sowing of longleaf pine seeds in the nursery should be further investigated as an alternative to fall sowing. Fall sowing is justified based on development of larger seedlings that will survive and grow better upon outplanting. However, there are some other data that indicate that seedlings from spring-sowings perform better than those sown in the fall if lifting is delayed until late in the season (Barnett 1991). The key to understanding these interacting responses is production of seedlings of equal size regardless of whether seeds are fall or spring sown. Quality longleaf pine seedlings can be produced from seeds sown in the spring, if appropriate seedbed densities and cultural practices are used. The possible improvement of field survival by 26 to 39 percent by shifting from fall to spring sowing should not be ignored.

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EVALUATING THE COLD HARDINESS OF CONTAINER-GROWN LONGLEAF PINE SEEDLINGS[1]

Mary A. Sword,[2] Richard W. Tinus,[3] and James P. Barnett[2]

ABSTRACT—Root systems of container-grown longleaf pine (*Pinus palustris* Mill.) seedlings stored outside in fall and winter can be severely damaged by low temperatures in the South. The freeze-induced electrolyte leakage (FIEL) test was used to evaluate the cold hardiness of container-grown longleaf pine. Results indicated that longleaf pine seedling roots should not be exposed to temperatures below 26.5 °F. Moreover after mid-January, the minimum temperature associated with permanent seedling damage may increase. One alternative to risking damage from low temperature in winter is planting seedlings in fall. If seedlings must be retained for winter and spring planting, the placement of black polyethlyene over seedlings can avoid damage from overnight freezing.

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) forests of the Southern United States have been reduced from approximately 92 million acres to less than 5 million acres within the last century (Landers and others 1995). During the first 90 years of this period, efforts to reestablish longleaf pine were unsuccessful (Landers and others 1995, Outcalt 1997), and alternative land management options led to natural and artificial regeneration of loblolly (*P. taeda* L.) and slash pine (*P. elliottii* Engelm. var. *elliottii*) on land that originally supported longleaf pine (Barnett and Dennington 1992, Landers and others 1995).

Recent research has defined desirable longleaf pine seedling characteristics and developed optimum cultural programs (Barnett and McGilvray 1997, Barnett and others 1990). This information has enabled the consistent establishment of container-grown longleaf pine throughout the South (Landers and others 1995, McRae and Starkey 1996). As a result, production and planting of container-grown longleaf pine has increased twelvefold within the last decade (McRae and Starkey 1997).

Although cultural improvements have made the large-scale planting of container-grown longleaf pine a reality, not all efforts have been met with success. Current cultural and planting practices often dictate that container-grown seedlings must be stored in a shade house environment during December and January. Without insulation, the root systems of container-grown seedlings are exposed to near ambient air temperature. Exposure to one or more days of cold weather has been associated with failed establishment of container-grown longleaf pine seedlings that appeared healthy at the time of planting. Knowledge of the minimum temperature tolerated by container-grown longleaf pine and methods to prevent damage from freezing are needed.

The whole-plant freeze test (WPFT) and freeze-induced electrolyte leakage (FIEL) test are commonly used in northern climates to determine the pattern of cold acclimation and deacclimation of nursery seedlings (Burr and others 1990, Rietveld and Tinus 1987). This information allows accurate prediction of optimum lifting windows (Burr and others 1990). Unlike the WPFT, which requires a 7- to 14-day incubation period prior to obtaining accurate results, the FIEL test can be completed within a 3-day period (Burr and others 1990). The FIEL test, therefore, provides the opportunity to quickly adapt cultural activities to the current seedling crop rather than rely on delayed information or predictive tools based on data from previous seedling crops.

Low temperatures that result in the mortality of bare-root nursery stock have not been encountered in the South. However, without insulation of the growth medium, the root systems of container-grown seedlings have been damaged by exposure to winter temperatures. The objectives of this study were to: (1) apply the FIEL test to determine the pattern of cold acclimation and deacclimation associated with the root system of container-grown longleaf pine, (2) evaluate the level of cold hardiness of longleaf pine during December through February, and (3) develop recommendations to reduce the risk of seedling damage due to cold temperature.

METHODS

Longleaf pine seedlings were sampled from the 1996-97 crop of container-grown seedlings produced at the U.S. Forest Service W.W. Ashe Nursery in Brooklyn, MS. The seed source was a 1992 bulk Mississippi orchard collection. In late March 1996, seeds were sown in Multipot 4/96 containers in peat-vermiculite (1:1) growth medium. Standard operational cultural practices were applied to

[1]Sword, M.A.; Tinus, R.W.; Barnett, J.P. 1999. Evaluating the cold hardiness of containerized grown longleaf pine seedlings. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 50-52.

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seedling production (Barnett and McGilvray 1997). The crop was grown and hardened in full sunlight on platforms elevated 10 cm above the ground, and remained outside in containers until packaging and immediate transport to planting locations.

Before packaging, 20 trays of seedlings were randomly identified and permanently marked. On 7 dates in December 1996 through February 1997 (December 1, 17, and 31, 1996; January 15 and 29, 1997; February 12 and 26, 1997), 30 seedlings were randomly extracted from the permanently marked trays, packaged, and shipped to the Southern Research Station laboratory in Pineville, LA, for cold hardiness testing.

The cold hardiness of seedling root systems was evaluated using a modification of the foliar FIEL test (Burr and others 1990). On the morning after seedlings were received in Pineville, the growth medium was washed from root systems, primary lateral roots were removed from the taproot, and the upper one-third of the taproot was excised. Excised taproot segments were kept submersed in distilled water until all seedlings were processed. A 1.2-cm section was excised from the upper portion of each taproot and placed in a capped test tube (12 X 125 mm) containing 2 g washed sand and 1 ml distilled water. Five test tubes were refrigerated (1.0 °C), and five subsets of five test tubes were grouped into glass beakers. Copper-constantan thermocouples were submersed in two test tubes per subset and wired to a data acquisition unit. The beakers of test tubes, enclosed in a styrofoam ice chest, were placed in the bottom of an upright freezer. Temperatures were recorded at 10-minute intervals. The speed of freezing was regulated by adjusting the lid of the styrofoam ice chest and freezer door so that solution temperatures did not decrease by more that 1.0 °C per 12 min. When temperatures reached -2 to -3 °C, the test tubes were shaken to induce freezing. One subset of test tubes was transferred from the freezer to the refrigerator when temperatures decreased to approximately -3.0, -4.5, -6.0, -7.5, and -9.0 °C (+/- 0.1-0.2 °C). Test tubes were thawed in the refrigerator (3 °C). Five ml of deionized water was added to each test tube after thawing and the tubes were agitated on a horizontal shaker for 24 h. The average solution temperature of the two test tubes with thermocouples at the time of removal from the freezer was calculated and applied to the three test tubes per subset that did not contain thermocouples.

After 24 h, electrical conductivities (EC) of solutions were recorded. Test tubes were boiled for 20 min, placed back on the shaker, and EC measurements were repeated 24 h later. The percentage of EC before, relative to that after boiling, was calculated for each solution, and data were expressed as indices of injury by the method of Flint and others (1967). Indices of injury and temperatures at which solutions were removed from the freezer were fit to both linear and Weibull sigmoid models. Lethal temperatures with 95-percent confidence intervals, were estimated by indices of injury equal to 10, 30, and 50 percent (LT10, LT30, and LT50) from the modeled data. Lethal temperatures predicted by the model, either linear or sigmoid, that yielded the smallest confidence interval were chosen for cold hardiness evaluations. Past research has shown a high degree of correlation between the electrolyte leakage of conifer seedling tissues and tissue viability, percent live root mass and seedling survival (Bigras 1997, Burr and others 1990). Based on this information, temperatures at which the seedling crop would not be significantly damaged were defined as LT10 values, and temperatures at which the seedling crop would be damaged beyond use and completely dead were defined as LT30 and LT50 values, respectively. Significant differences among LT10, LT30, or LT50 values associated with the seven sampling dates were determined by the test of nonoverlapping 95-percent confidence intervals (Jones 1984).

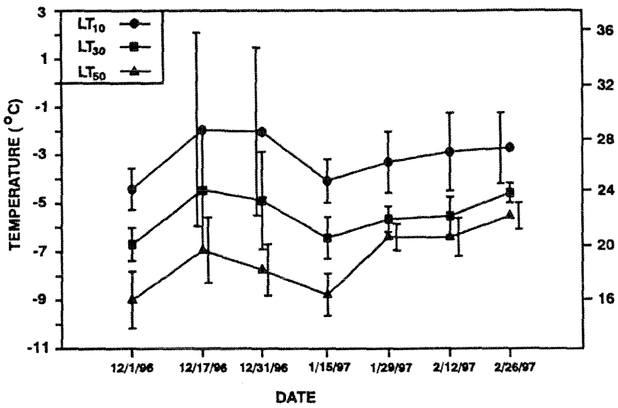

Figure 1—Root cold hardiness of container-grown longleaf pine seedlings grown at the U.S. Forest Service W.W. Ashe Nursery in Brooklyn, MS, during 1996. Lethal temperatures associated with an index of injury equal to 10 percent (LT10) are the threshold of minimum temperature that seedlings can be exposed to without significant damage. Lethal temperatures associated with indices of injury equal to 30 percent (LT30) and 50 percent (LT50) represent temperatures at which seedlings will be damaged beyond use.

RESULTS

Between December 1, 1996, and February 26, 1997, LT10 values averaged 26.5 °F. (-3.0 °C), and were not significantly different among sampling dates since the 95-percent confidence intervals overlapped (fig. 1). Between December 1, 1996, and January 15, 1997, LT30 values averaged 21.9 °F. (-5.6 °C) and were not significantly different. However, the LT30 on February 26, 1997, was significantly higher than that on December 1, 1996; January 15, 1997; and January 29, 1997. Similarly, LT50 values in December 1996 and January 15, 1997, averaged 17.4 °F. (-8.1 °C) and were not significantly different. As winter progressed, however, LT50 values on January 29, February 12, and February 26, 1997, were significantly higher than those on December 1, 1996, and January 15, 1997.

DISCUSSION

Temperatures that cause an index of injury equal to 10 percent represent the threshold of minimum temperature that seedlings can be exposed to without significant damage. Our results indicate that container-grown longleaf pine at the Ashe Nursery cannot withstand temperatures below 26.5 °F. Minimum temperatures reached 26.5 °F. or less on 11 nights at the Ashe Nursery in winter 1996-1997 (fig. 2). During periods of potentially damaging temperature, seedlings were covered with black polyethylene which

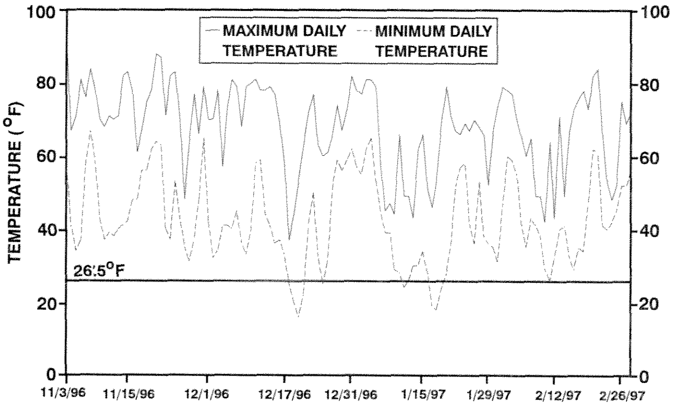

Figure 2—Daily maximum and minimum temperatures at the U.S. Forest Service W.W. Ashe Nursery in Brooklyn, MS, during November 1996 through February 1997. Note that on two occasions the exposed longleaf pine seedlings needed protection to prevent root damage by cold temperatures.

prevented damage. Air and growth medium temperatures were monitored during one period when seedlings were protected by polyethylene, which conserved the heat in the growth medium so that the temperature of the root system was 10 to 13 °F. warmer than the outside air temperature. This suggests that at the Ashe Nursery, container-grown longleaf pine seedlings covered with black polyethylene can withstand short periods of air temperature as low as 16.5 °F. before root damage occurs.

The degree of cold acclimation and deacclimation exhibited by tree species varies by the climate of their natural range. For example, Tinus (1996) used the FIEL test to compare the cold hardiness of Aleppo pine (*P. halepensis* Mill.), radiata pine (*P. radiata* D. Don), and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) roots. The roots of radiata pine, native to a cool Mediterranean climate, hardened 2 °C, and those of Aleppo pine, native to a warm Mediterranean climate, exhibited no cold hardiness; whereas, the roots of Douglas-fir, a species that naturally occurs in cold temperate climates, hardened 10 °C.

The natural range of longleaf pine is limited to the lower and middle Coastal Plain portion of the Southeastern United States (Loveless and others 1989), and is characterized by a warm temperate climate. Therefore, it is likely that LT10 values of container-grown longleaf pine from other origins in the South are similar to those observed at the Ashe Nursery. Although FIEL tests are required for validation, longleaf pine native to the northern range in southeastern Virginia, and montane longleaf pine in northern Alabama and Georgia, may exhibit more cold hardiness than longleaf pine seedlings from other portions of the species' natural range.

Significant seasonal differences among lethal temperatures were observed at indices of injury of 30 and 50 percent. For example, significantly different LT50 values indicate that longleaf pine seedlings lost approximately 4.6 °F. of cold hardiness between mid-January and late February. This information suggests that seedlings reached maximum cold hardiness in December and early January and lost cold hardiness in late January and February.

Our results indicate that longleaf pine seedling roots should not be exposed to temperatures less than 26.5 °F. Furthermore after mid-January, the minimum temperature associated with permanent seedling damage may increase. Longleaf pine is successfully established by fall planting (McRae and Starkey 1997). Therefore, one alternative to risking damage from suboptimum temperature in winter is planting seedlings in fall. If container-grown longleaf pine seedlings must be retained for winter and spring plantin methods to protect the seedings from low temperatures should be developed at nurseries where air temperatur reach 26.5 °F. or below. In the South, the placement of b polyethylene over container-grown longleaf pine seedli is one method to avoid short periods of damaging low temperatures. However, this method of seedling protec should be evaluated at each location before it is relied operationally.

ACKNOWLEDGMENTS

The authors thank Dan Andries, John McGilvray, and Ji Barner for their technical assistance.

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UTILIZATION OF JIFFY PELLETS IN THE PRODUCTION OF PINE AND EUCALYPT SEEDLINGS, PINE ROOTED CUTTINGS AND NATIVE SPECIES PROPAGATION: NURSERY AND FIELD COMPARISONS[1]

J.A. Wright, J. Escobar, and G. Henderson[2]

ABSTRACT—Smurfit Carton de Colombia began trials with Jiffy pellets in 1993. A number of pine and eucalypt species have been tested for seedling and clonal production. Field trials comparing root form and tree growth at one year of age show no height differences in seedlings grown in Jiffy pellets compared to those produced in containers. An advantage of the Jiffy pellets is reduced time in the nursery. Also there are further advantages to the Jiffy system since no further substrate needs to be obtained and this reduces labor costs in the nursery. Jiffy pellets are less costly to transport and are faster to plant when compared to seedlings in other container systems. Currently Smurfit Carton de Colombia is using Jiffy pellets on an operational basis for pine cuttings, eucalypt seedlings, pine seedlings and native tree species propagation.

INTRODUCTION

The two nurseries of Smurfit Carton de Colombia (SCC) have an annual capacity of twelve million plants. The species utilized include native and exotic species produced mainly for planting on land owned by the Company. In recent years much effort has been made to contract grow seedlings for other groups and to donate seedlings to certain government and non-governmental organizations. The systems presently used in the nurseries include bare root, plastic containers (tray) and plastic bag. Each system functions for certain species and has attached costs and benefits. Over the last 30 years, nursery systems have been matched to species, fertilizer regime, mycorhizae inoculation, irrigation system, seed and clonal propagation. As such the nursery manager is constantly evaluating methods to produce the required quality of plants in less time and at less cost. It is in this regard that Jiffy pellets were begun on a trial basis in 1993. Jiffy Products Ltd. was formed in Norway in the early 1950's to service the agriculture and horticulture industries in Europe and North America. The original products were peat pots. The Jiffy peat pellet was introduced in 1972 and provides both media and container in individual pellet form. The compressed peat is encapsulated in a biodegradable net. The Jiffy pellet is produced in New Brunswick, Canada where the Company has access to *Sphagnum* spp. peat. Worldwide the Company produces more than one billion peat pots and pellets and of this total one hundred million forestry pellets were produced and sold in 1996.

The Jiffy pellet has been utilized on a commercial scale in Europe, Canada (Henderson and others 1994), Colombia, Uruguay, Chile and Indonesia. The compressed, ready to use, pathogen-free and consistent forestry pellet system is easily transported in boxes. Once the pellet is placed on the ground or on a suitable platform, water is added, the compressed pellet (1 cm in height) expands to seven cm in height and a seed or cutting can be placed in the pre-formed cavity to provide an instant forest nursery.

Tree seedling root growth and development has been reported to be superior in Jiffy pellets (Balisky and others, 1995) and this was observed in the first trials conducted with the pellets at the SCC nursery. The objectives of the study were to evaluate nursery efficiencies and field growth of Jiffy pellets compared to normal nursery systems for pine and eucalypt seedlings and cuttings.

NURSERY AND FIELD TRIALS—ESTABLISHMENT

Jiffy Products Ltd. provided sufficient pellets for the nursery and field trials which were initiated in 1993. The traditional system consists of a plastic tray with a substrate of 50 percent sifted coal ash and 50 percent subsoil providing both an inert and a locally available product. The pellets and traditional systems were planted on the same day for a given species. This resulted in the Jiffy pellets being ready much earlier for trial planting than seedlings or cuttings produced in the traditional system. All seedlings and cuttings were planted on the same day in the field trials and it is likely that the Jiffy pellet material was planted later than would ideally be the standard.

Nursery management was slightly different for pellet and container grown seedlings and cuttings. Due to the smaller size of the pellet less total fertilizer was applied, though mycorhizae inoculation was the same between the two systems. The irrigation required for the Jiffy pellets was less than for container grown material due to greater water retention in the peat pellet. This implies that consideration to change a nursery to the Jiffy pellet system must be consistent with irrigation source and method of application.

Comparison of seedlings and cuttings produced in Jiffy pellets and the standard plastic tray were undertaken starting in 1995 in the nursery and in field plantings. The nursery evaluation was on the form and quantity of roots. Field evaluation was undertaken by establishing two replicated trials of single tree plot design to determine any differences in survival and growth due to the nursery production method.

[1]Wright, J.A.; Escobar, J.; Henderson, G. 1999. Utilization of Jiffy pellets in the production of pine and eucalypt seedlings, pine rooted cuttings and native species propagation: nursery and field comparisons. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 54-56.
[2]Wright Forest Management, 205 Bendan Choice, Cary, NC 27511; TEL: 919/468-1596.

Table 1—Root collar diameter (RCD) in mm and height (HT) in cm for pine seedlings grown in Jiffy pellets or plastic containers

Type	*P. patula*		*P. tecunumanii*		*P. maximinoi*	
	RCD	HT	RCD	HT	RCD	HT
			June 6, 1996			
Jiffy 28mm	3.9	11.1	4.7	23.2	4.2	19.0
Jiffy 30mm	3.8	11.9	4.0	20.0	3.8	16.3
Jiffy 36mm	4.0	13.5	4.5	25.1	4.2	19.3
Container	2.6	5.3	3.0	10.2	3.6	13.8
			October 23, 1996			
Jiffy 28mm	9.1	37.1	12.2	61.8	10.4	47.3
Jiffy 30mm	9.4	39.9	10.9	59.4	10.8	45.3
Jiffy 36mm	9.5	41.6	13.4	66.0	10.3	46.8
Container	6.8	30.3	11.3	59.6	9.6	40.7

Table 2—Root form evaluation for seedlings of *E. grandis* and *P. kesiya* and clones of *E. grandis* grown in Jiffy pellets or plastic containers

Type	*P. kesiya*	Seedling	MES0103	SUI2401	SUI4610
		E. grandis			
Jiffy 18mm	—	44.6	50.9	20.6	24.3
Jiffy 24mm	69.5	72.0	54.1	83.1	62.5
Jiffy 28mm	89.0	104.7	58.2	70.0	98.6
Jiffy 30mm	116.8	94.6	75.9	56.7	109.3
Jiffy 36mm	97.6	101.7	76.4	53.5	120.4
Container	93.4	92.9	134.3	186.4	119.3

NURSERY AND FIELD TRIAL—RESULTS

Root development in Jiffy pellets was generally superior to that of the standard nursery system. For pine cuttings from three species (patula, maximinoi and tecunumanii) the Jiffy pellets were superior for root collar diameter and total plant height (tables 1 and 3). However, for cuttings of *Eucalyptus grandis* the standard nursery container produced superior quality roots mainly because the Jiffy pellets were kept too humid in that first trial (table 2). Subsequent results have given better performance of Jiffy pellets with eucalypt cuttings. Root form scores for seedlings of *Pinus kesiya* and *Ecualyptus grandis* were also superior when produced in Jiffy pellets (table 2).

Survival of both nursery types was above 95 percent in the field trials. Height growth data at one year of age is presented in table 4. The Jiffy pellet-produced seedlings and clones were mostly equal to or taller than the standard nursery production system. In certain of the eucalypt clones the standard nursery system produced taller trees and this was again due to high humidity in the pellets during initial root formation, a problem corrected in subsequent use.

OPERATIONAL USE OF JIFFY PELLETS

Following acceptable root development along with adequate field growth a decision was taken in 1996 to increase the usage of Jiffy pellets. Trial results were also utilized to determine the appropriate Jiffy pellet size to maximize cost benefits of the Jiffy system. Since that time 100 percent of the pine cuttings have been produced in Jiffy pellets. This has resulted in an increase of 33 percent in rooting percentage and a 30 percent decrease in the length of time required for nursery production. Production of pine and eucalypt seedlings in Jiffy pellets will reach three million in 1998. Native tree species produced in Jiffy pellets include *Cordia aliadora, Alnus acuminata, Podocarpus* sp., *Quercus* sp. and others.

Use of Jiffy pellets has resulted in significant cost savings. Nursery space is reduced for Jiffy pellet production thus decreasing costs of water, fertilizer, pesticides and labor. Transport of the pellet-produced seedlings to the planting site has less than half the cost of transporting the standard nursery container. Planting productivity has increased since the Jiffy pellet material is smaller than conventional nursery production.

CONCLUSIONS

Significant cost reductions have taken place through the use of Jiffy pellets to produce pine and eucalypt seedlings and cuttings. Root form and initial height growth are as good as or better for Jiffy pellet produced material compared to standard nursery containers. Continued research and development of the Jiffy pellet system are likely to lead to future cost savings while resulting in superior root quality and growth of planted trees.

Table 3—Root form evaluation for rooted pine cuttings grown in Jiffy pellets or plastic containers

Type	*P. patula*	*P. tecunumanii*	*P. maximinoi*
Jiffy 28mm	58.0	47.0	71.0
Jiffy 30mm	74.3	28.2	63.2
Jiffy 36mm	61.6	68.8	50.9
Container	24.3	31.3	33.5

Table 4—First year height growth on two sites for seedlings and clones of *E. grandis* grown in Jiffy pellets or containers

LaSuiza					
		E. grandis			
Type	*P. kesiya*	Seedling	MES0103	SUI2401	SUI4610
Jiffy 18mm	—	4.3	3.3	4.5	4.5
Jiffy 24mm	1.2	4.2	3.5	5.3	5.1
Jiffy 28mm	1.1	4.0	3.8	5.0	5.1
Jiffy 30mm	1.2	4.4	3.5	4.9	4.8
Jiffy 36mm	1.2	4.6	3.7	4.8	4.9
Container	1.2	4.5	3.7	4.5	4.8

Emiliana				
	E. grandis			
Type	Seedling	MES0103	SUI2401	SUI4610
Jiffy 18mm	3.7	3.5	3.7	3.6
Jiffy 24mm	3.9	4.1	4.7	4.3
Jiffy 28mm	4.8	4.1	3.0	4.0
Jiffy 30mm	4.7	3.7	3.4	3.8
Jiffy 36mm	4.8	3.8	3.2	4.1
Container	4.8	4.7	5.3	4.6

Efforts began in the southern US in 1996 to begin the use of Jiffy pellets in forestry nurseries. Amongst the possible uses are for production of longleaf pine, hardwood seedlings and cuttings, pine cuttings and Christmas trees. Research is underway at universities, private companies as well as state owned nurseries.

ACKNOWLEDGEMENTS
The authors would like to thank Jiffy Products for supplying pellets in the establishment of the first trials. The authors also wish to thank Smurfit Carton de Colombia for permission to present these results.

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NITROGEN LEVELS, TOP PRUNING, AND LIFTING DATE AFFECT NURSERY DEVELOPMENT AND EARLY FIELD PERFORMANCE OF LOBLOLLY PINE SEEDLINGS[1]

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ABSTRACT—Loblolly pine seedling nursery development and 3-year field performance were contrasted between two nitrogen (N) application regimes and comparable top pruning regimes. Other initial soil nutritional elements were comparable, but high N seedlings received 150 lb/acre N (as NH_4NO_3) and low N seedlings received half this amount. Seedlings were either not top pruned, top pruned in August, or top pruned in August and September. The seedlings were outplanted during 12 equally spaced planting periods from mid-October to mid-March. The high N nursery seedlings were taller and had larger root-collar diameters as compared to the low N seedlings, but the latter survived and grew better after outplanting. Survival was 100 percent for the low N seedlings regardless of pruning treatment but did not reach acceptable levels for the high N seedlings until late December. The low N seedlings were consistently taller after three growing seasons and, depending on planting period, had consistently larger diameter at breast height (early planting periods) or had comparable diameter at breast height (later planting periods) compared to high N seedlings.

INTRODUCTION

Nursery technology has advanced considerably since the latter 1940's and early 1950's when extensive southern pine regeneration programs were rapidly developed to rectify regeneration shortfalls (Wakeley 1954). The most significant improvements have been those involving fertility practices. Today, a nursery is seldom faced with the problem of producing undersized seedlings. Current questions generally focus on ideal seedling size and the best nursery practice to achieve this size. There usually is not a consensus of which nursery procedures to follow. Forestry nurseries have come a long way since Boyer and South (1988) reported that 50 percent of the sampled nurseries in the South produced fewer than 5 percent grade 1 seedlings, based on Wakeley's (1954) morphological standard established at least 50 years earlier. These standards were developed when bed densities greatly exceeded those now recommended, and organic amendments instead of inorganic fertilizers were the rule. Effective irrigation systems had not yet been developed.

"Quality seedling" is a term difficult to define and is of limited value in describing the potential competitive ability of loblolly pine seedlings. Any number of nurseries have their own quality standards which serve their individual needs. Rose and others (1990) describe the attributes of loblolly pine target seedlings (i.e., quality seedlings) as those characteristics shown to affect survival and subsequent development after outplanting. When the target seedling size is exceeded, a root system may develop which can be too large to plant properly.

Our interest in nursery research was stimulated when we began intensive long-term research into the morphology and physiology of loblolly pine seedling root systems. It became apparent that a nursery fertility protocol was needed for statistically comparing results among and within loblolly pine half-sib seedlots for different years and locations. This protocol was to have a significant genetic component and thus, it was not prudent to use mechanical means to regulate or alter seedling development.

As the protocol was being developed, it became evident that commonly used nitrogen application rates and schedules made top pruning essential to maintain reasonable seedling sizes. This procedure made it difficult to obtain valid statistical comparisons when heritability estimates were calculated from specific morphological attributes from individual families' progeny. Eventually we dispensed with top pruning by development of a protocol involving significant alteration of our nitrogen application schedule. This nursery fertility protocol reported here was developed in cooperation with the Georgia Forestry Commission and many aspects of its development have been previously reported (Kormanik and Ruehle 1989; Kormanik and others 1989, 1990, 1992, 1998; Sung and others 1993a, 1993b, 1994, 1997). This protocol involved minimal mechanical manipulation of seedlings. Mechanical manipulation is used mainly to compensate for specific environmental occurrences such as frequent thunderstorms. For practical application of this new protocol, we felt it was essential to compare field performance of the seedlings grown under our nursery protocol with those produced by more traditional nursery management protocols (May 1984a, 1984b, 1984c).

Thus, the objective of this research was to compare survival and growth of seedlings in the nursery and after outplanting from a mixed loblolly pine seedlot when grown under the traditional or our nursery fertility protocols.

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METHODS

A single, mixed loblolly pine Piedmont seedlot obtained from the Georgia Forestry Commission was used in this study. The seedlings were sown in mid-April at the Institute for Tree/Root Biology (ITRB), USDA Forest Service's experimental nursery located on the University of Georgia's Whitehall Experimental Forest.

One phase of the study was designated as "Long-Term Study" (LTS) while the second phase was designated as "Dig Up study" (DUS). The LTS seedlings grown under the traditional nursery fertility protocol will be followed after outplanting until harvestable size. No designation was made as to the nature of the final crop or the rotation age specified. These seedlings were grown with nursery fertility levels comparable to that used in many nurseries during the 1980's. A seedling bed density of 24 to 26 per sq. ft. (260 to 280 per m^2) was established (May 1984c). These seedlings were irrigated as needed and total nitrogen levels of approximately 150 lb per acre N (168 kg per ha N) as NH_4NO_3 was used throughout the growing season. One-third of these seedlings were top pruned in early August and then again in mid-September, a normal procedure followed in many nurseries at that time. A like number of seedlings was pruned only once during the early August pruning. The remaining seedlings were not pruned but were permitted to grow without mechanical regulation.

The DUS seedling beds were given comparable preplant fertilizer applications but the irrigation schedule and nitrogen application rates approximated the amounts used in developing the nursery protocol employed by the Georgia Forestry Commission. In this particular growing season, approximately 75 lb per acre of N (84 kg per ha of N) (as NH_4NO_3) was applied. The amounts applied before mid-July were adjusted to obtain seedling heights of 6 to 8 inches (15 to 20 cm) at that time. Both the DUS and LTS seedlings were given an identical mid-September nitrogen top dressing of 20 lb per acre of N (22 kg per ha N)(as NH_4NO_3).

Adjacent plantation locations were prepared during the summer for DUS and LTS seedlings at the Savannah River Natural Resource Management and Research Institute maintained by the USDA Forest Service in conjunction with the Department of Energy, Aiken, SC. Thirty-six hundred planting positions were established for the LTS seedlings. This was to accommodate 12 planting dates of 100 seedlings from each of the 3 nursery treatments. Outplanting was to be undertaken to encompass the entire planting season from mid-October 1989 to mid-March 1990. The spacing was 10 by 10 feet (3.2 by 3.2 m) and the individual trees were shovel planted to maintain as much of the roots as possible. The specific planting position for each lifting date and nursery treatment was randomly assigned.

The DUS was concurrently outplanted in an adjacent area that had received identical summer site preparation. However, because these seedlings were initially designated to be excavated periodically from mid-June though the following winter for detailed root morphological and physiological evaluations, a different outplanting procedure was used to facilitate periodic seedling harvest. Fifty seedlings from each treatment were established in rows with 2 feet by 4 feet (0.61 by 1.21 m) spacing for each of 12 lifting periods. A total of 1,800 DUS seedlings were outplanted simultaneously with the LTS seedlings.

All seedling root-collar diameters (mm) and heights (cm) were recorded when seedlings were lifted and root systems were evaluated. Seedlings that were damaged in lifting or which had mainly primary needles were culled before outplanting. This closely approximated characteristics of seedlings being shipped from commercial nurseries and removed only 5 to 10 percent of the seedlings.

Statistical Methods

The LTS phase was a statistically designed study consisting of a factorial treatment combination of 3 pruning and 12 planting periods. Replication consists of 100 trees per treatment with each tree arranged in a completely randomized design over the 3,600 planting positions. Thus, traditional analysis of variance and mean separation tests are planned for future analyses. The DUS was installed as a demonstration study since field logistics prevented a valid statistical design. Each of the three nursery pruning treatments at a given planting period was arranged systematically down a length of planting row. Each planting period and pruning treatment combination had 50 trees. No statistical tests were valid so only treatment means were compiled and used to compare trends over the 12 planting periods and the 3 pruning treatments. Since the effect of low (DUS) and high (LTS) nitrogen was investigated in separate phases, there also were no valid statistical comparisons between N levels. Instead, relationships between nitrogen levels were compared with means which were used to evaluate trends over time. These relationships were developed by formulating linear regression equations which took into account variations in the biweekly data and extracted meaningful trends.

RESULTS AND DISCUSSION

Due to budget restrictions and personnel limitations, the DUS seedlings were never excavated as scheduled at the Savannah River Plant site. The plantation was not visited again until the seedlings had completed their third growing season in 1992. At that time, the DUS seedlings were experiencing competition between rows as well as within rows. Seedling development had not yet been hampered by the close spacing but any future data would be highly suspect due to developing lateral root competition. The LTS seedlings were not experiencing any stem or root competition and long-term measurement and observations are continuing. Early results have been recently reported (Kormanik and others 1998).

Most reports regarding top-pruned seedlings contrast seedling development under a single uniform nutritional treatment which uses various mechanical means for regulating a seedling's morphological characteristics. Usually one fertility treatment is not optimal for all mechanical seedling regulatory regimes for seedlings since the larger, unpruned seedlings would normally have the least desirable top/root ratio. This can result in lower survival after outplanting. The research reported here differed in that it used uniform mechanical treatments to regulate seedling development but varied the nutritional protocol in order to

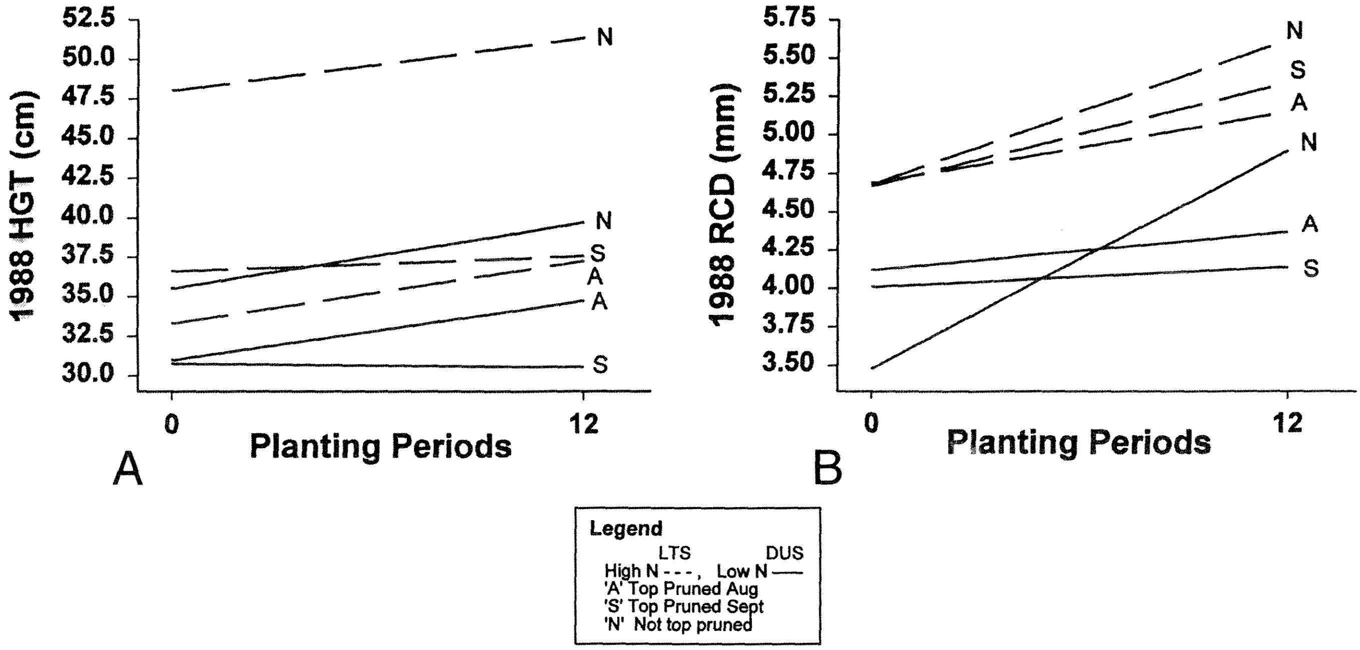
compare how nursery practices affect early plantation performance. Most nurseries in the South depend heavily on mechanical means to regulate loblolly seedling sizes (South 1994). However, it is generally accepted, and this research substantiates, that top and root pruning is used in excess to correct growth imbalances of loblolly pine caused by suboptimal nursery management practices (Mexal and Fisher 1984).

Nursery Development

It is well known that loblolly pine seedlings follow a rather precise ontogenetical development sequence between root and stem activity (Wakeley 1954). Both nursery N treatments followed this reported pattern even though actual seedling sizes varied. The DUS seedlings produced with our nursery protocol reached the desired height of 6 to 8 inches (15 to 20 cm) by the middle of July, when secondary needle development commences. The LTS seedlings attained this size several weeks earlier. This size can occur as early as mid-June as a result of over zealous fertilization and irrigation. Thus, seedling size and secondary needle formation are a function of fertility more than an age response (Kormanik and others 1992). However, early development of secondary needles has little effect on root system activity. As Wakeley (1954) demonstrated, it is mid-August before root activity and root growth begins to be a major sink for carbohydrates (Sung and others 1993a,1994).

This research demonstrates that high application rates of nitrogen early in the growing season results in excessive stem elongation, which results in unbalanced top/root ratios that require top pruning to rectify. Figure 1 presents nursery data for the DUS and LTS seedlings, showing the effects of seedling nutritional protocols and top pruning on seedling development for the 12 outplanting dates. The LTS unpruned seedling stem heights were much taller than all other treatments regardless of N level. RCD was similar among the high N treatments (figs. 1a and 1b). This has been reported elsewhere and is the underlying reason for employing top pruning to readjust top/root ratios to achieve improvement in seedling survival and early field performance (Kormanik and others 1994, Mexal and Fisher 1984). Note in figure 1a that except for the unpruned LTS individuals, all other seedlings are well clustered within a few centimeters of the 30 to 32 cm upper target height commonly desired for artificial regeneration. The same response has been reported among half-sib progeny from specific mother trees that had been grown under different N regimes (Kormanik and others 1994). The RCD's are consistently larger in LTS seedlings regardless of pruning treatment. This would presumably have positive effects on early survival and height growth (fig. 1b).

Interestingly, when nutritional analyses are reported for seedling components, especially nitrogen, the analyses are reported for the seedling at harvest. It is thus assumed that high levels of nitrogen are required throughout the summer to attain and maintain these levels. In fact, this experiment suggests that much N input is directed to wound recovery resulting from mechanical regulation of seedlings. Such input is not required to maintain a specific elevated N level. This latter conclusion is substantiated by a recent report by Sung and others (1997). They report that when only 96 lb per acre N (108 kg per ha N) are applied to loblolly pine seedlings from May to September, N content of loblolly seedlings were within desirable N levels at harvest (May 1984a).



Figures 1a and 1b—Initial heights (HGT) and root-collar diameters (RCD), respectively, of loblolly pine seedlings produced in nursery with and without top pruning at 2 nitrogen levels and lifted on 12 different dates.

The nursery philosophy espoused by this protocol is not to waste nitrogen and contribute excessively to ground water nitrate contamination (Kormanik and others 1992). The goal is to produce a seedling that is balanced nutritionally and morphologically, taking advantage of a species' natural ontogenetic development. We direct management inputs into growing the best naturally balanced seedlings that are economic to grow and plant, have good survival, and exhibit good field performance. This approach may prevent unwarranted levels of N application that are leading many to advocate severe nitrogen use restrictions. These restrictions may complicate N use in many cropping systems including forest seedling nurseries (Johnson 1991).

Field Observations

While the nursery research produced no unexpected results, the field performance for both survival and growth contradicted what commonly has been accepted as factual. This has significantly and positively impacted further development of the nursery protocol with the cooperation of the Georgia Forestry Commission.

Survival

Perhaps the most unexpected field response was that obtained for survival (fig. 2). Here, the larger LTS seedlings, regardless of pruning treatment, did not exhibit acceptable survival percentages until the 6th or 7th planting period, which occurred in January. The nonpruned LTS seedling survival percentages ranged from 36 and 62 percent throughout the first six planting dates. The pruned LTS seedlings had comparable survival rates among planting periods and varied between 56 to 80 percent (fig. 2). The survival percentage for the DUS individuals grown under our nursery protocol was 100 percent regardless of nursery pruning regime (fig. 2). This 100-percent survival of the DUS seedlings was unexpected because in many previous trials survival has consistently fallen between 75 to 90 percent, depending upon environmental and edaphic conditions on the plantation sites. This may have just been an outstanding year for establishing plantations. On the other hand, both groups of seedlings were exposed to identical field conditions.

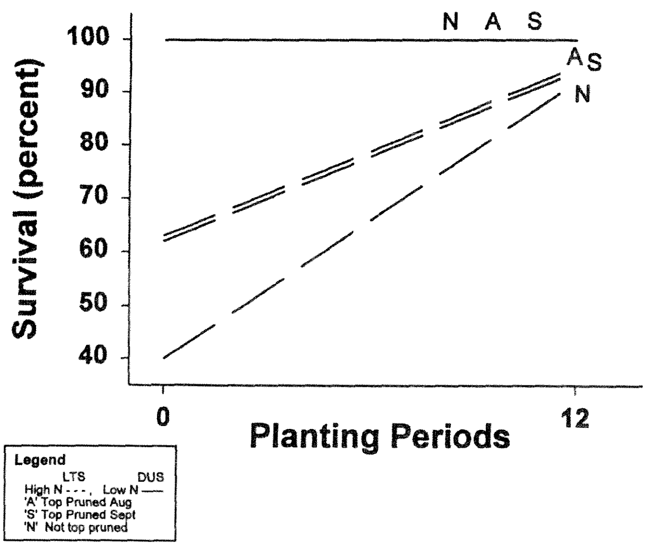


Figure 2—Third-year survival of loblolly pine seedling with and without top pruning grown at different nitrogen levels and outplanted at 12 different lifting dates.

Initially, the low survival of the LTS seedlings was of considerable concern to us but a review of the literature indicates that the survival rates we observed are typical. In a southwide study, including 20 nursery locations where foliar nitrogen content was investigated, Larsen and others (1988) reported first-year survival of 65 percent. The seedlings were from a single sampling period from early to mid-December, which is considered to be near optimal for plantation establishment in many areas, and is comparable to our 6th and 7th planting periods. Comparable survival percentages of 60 to 75 percent have been reported in Texas for 1987-95 (Barber 1996).

In the 1987 Conservation Review Plan for the Southern Region, the survival for the 1986-87 planting season ranged from 60 to 76 percent with an overall average of 71 percent. In Matney and Hodges (1991) review, they report a survival percentage of 55 to 90 percent over a 16-year period with an average survival of 73 percent. Interestingly in only 3 of these 16 years did survival exceed 80 percent. Thus, the overall survival of the LTS seedlings obtained here might not be uncommon since data from many reports may represent seedlings lifted during one optimal period. Sung and others' (1994) research clearly demonstrates how clipping may alter carbon allocation from a developing root system to wound response and affect seedling survival.

Growth Observations

Survival is but one important factor that must be considered in judging a seedling's competitive potential. Survival and subsequent growth are not always comparable. Frequently, smaller seedlings survive better but larger seedlings normally grow better (Thompson 1985). This did not occur here as the smaller, well-balanced seedlings both survived and grew better than the larger and presumable morphological improved seedling obtained through high fertilization and top pruning.

It is apparent (figs. 3a and 3b) that the initially smaller but better balanced DUS seedlings were consistently better field performers for height growth regardless of nursery pruning treatments or nitrogen application schedules. It is unfortunate that the close spacing of the DUS seedlings prevented long-term comparisons with the LTS seedlings. We installed the study with the wrong assumption, i.e., that large, heavily fertilized seedlings are best for maximum competition potential.

The LTS seedlings were most difficult to plant properly even with shovel planting. It is unlikely that such large pine seedlings would consistently be planted properly and, thus, their long-term performance might be questionable (Gruschow 1959). Many of the first-order-lateral roots (FOLR) were in excess of 2 mm in diameter and were difficult to properly place in the planting hole. For both DUS and LTS treatments, there was a reduction in height and diameter at breast height after three field growing seasons as one progressed from October to March. This is expected

since it is well known that late season transplanting has adverse effects on loblolly pine seedlings. Regarding the diameter at breast height development, the late season planting periods were undesirable for all nursery treatments. Recently Sung and others (1994) reported the biological basis of late season growth depression is due to a post transplant shock that severely restricts root function. This shock may extend for 60 to 90 days. The extended post transplant shock extends well into late spring and exposes the late season planted seedling to excessive stress due to unfavorable weather conditions before the roots are fully functional.

CONCLUSIONS

(1) Once target seedling size is determined, it may be better to take advantage of natural ontogenetic development than to rely upon mechanical regulation to control seedling sizes which have been fertilized to excess. Seedlings must be of appropriate sizes to be planted properly with planting techniques currently being used.

(2) Depending upon environmental conditions during the growing season, root wrenching may be occasionally required to prevent excessive stem elongation after secondary needles begin maturing.

(3) Mid-September N applied when loblolly pine root systems begin rapid expansion is beneficial and rarely causes buds to elongate on nonpruned seedlings. However, pruned trees lacking adequate terminal maturation may begin elongation more readily than the nonpruned seedlings.

(4) Although early season lifting research on storage of seedlings has not been completed, lifting and immediately planting loblolly pine seedlings under proper conditions is highly desirable and greatly expands the growing season. This early planting, however, may not be practical with excessively large morphologically improved seedlings because survival is decreased as a result of the long transplant shock period of loblolly pine.

(5) When practical, early season planting should be favored over late spring planting.

ACKNOWLEDGMENTS

This research was funded by U.S. Department of Energy Grant DE-AI09-76SR00870 and by Georgia Forestry Commission.

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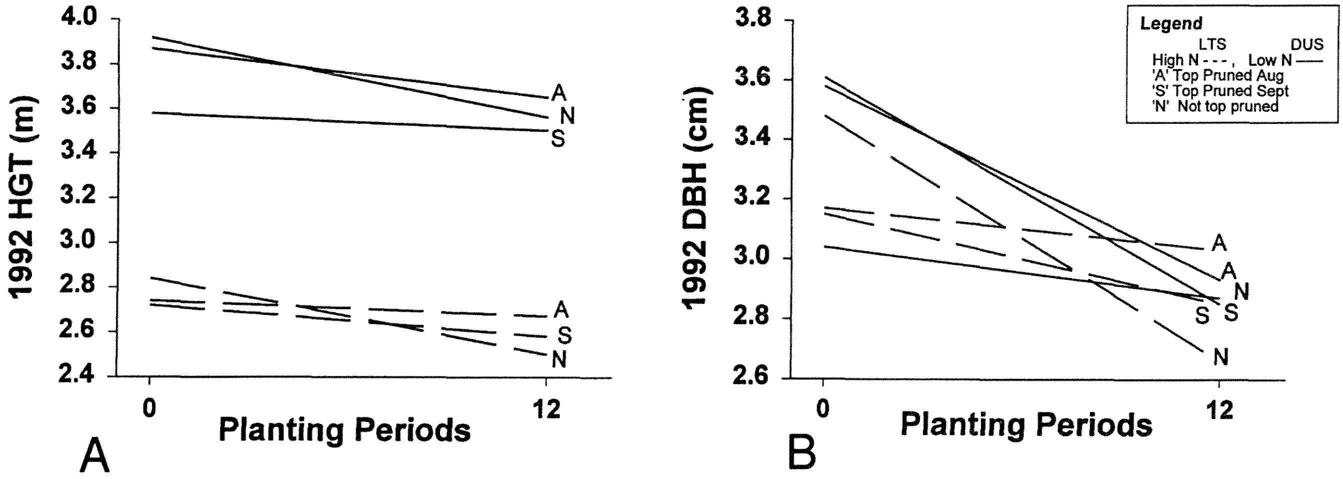

Figures 3a and 3b—Third-year heights (m) and diameter at breast height (cm), respectively, of loblolly pine produced in nursery with and without top pruning at 2 nitrogen levels and lifted on 12 different dates.

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EXCESSIVE RAINFALL PRIOR TO LIFTING ADVERSELY AFFECTS SEEDLING PHYSIOLOGY[1]

David B. South and William A. Carey[2]

ABSTRACT—Observations over the past two decades indicate that waterlogged conditions in the nursery during the fall can adversely affect the transplantability of loblolly pine (*Pinus taeda*) seedlings. Waterlogged seedbeds can occur when frequent rain falls over an extended period of time. Anaerobic conditions can result when warm soils remain saturated for just a few days in November. At some nurseries, rainfall exceeded 50 mm/week for a period of three weeks or more. Fertilization in October might exacerbate the problem due to an increase in respiration of soil microbes. An extended period of anaerobic conditions can alter both the physiology and structure of pine roots. When seedlings are lifted just after a period of anaerobic soil and transplanted in December or early January, a quick death can result due to a lack of new root growth (death often occurs from the roots up as opposed to from the tops down).

Over the last several years, the Auburn University Southern Forest Nursery Management Cooperative has inspected several plantation failures that were not caused by poor planting practices. Failures in Alabama and Georgia appeared to be related to reduced seedling physiology since no pest related symptoms were detected and morphology was acceptable (root mass was adequate and shoot length was not excessive). Symptoms included blackened root surfaces, over development of lenticiles, no new root growth, rapid mortality, and seedlings dying from the roots up. Root systems deteriorated quickly when seedlings were stored under refrigerated conditions for three weeks or less. These symptoms were similar to those described by Oak (1983) for seedlings out planted in South Carolina.

A common factor for these seedlings was unusually high rainfall during the month prior to lifting (e.g. November). Typically, more than normal rainfall occurred over a three or four- week period and as a result, the soil remained "waterlogged" for an extended length of time. The resulting anaerobic soil conditions would have a negative pact on root physiology. In some cases, lenticiles were observed on stems and roots. In addition, aerenchyma can form in the roots (McKevlin and others l987). Under laboratory conditions, aerenchyma can develop in just 15 days (Topa and McLeod 1986). Waterlogged soils not only affects root anatomy, but low soil oxygen reduces the rate of nutrient uptake (Gadgil 1972) and lowers the transport of photosynthate to the roots (Kozlowski 1984).

At many locations in the South, average rainfall for the month of November is less than 25 mm per week. In some years, November rainfall exceeds twice this amount and subsequent survival after transplanting is sometimes lower than expected. For example in 1982, rainfall at one Mississippi Nursery averaged more than 90 mm per week (from November 16 until December 10). Lifting began on December 9th with subsequent widespread mortality. Mortality increased when seedlings were kept in refrigerated storage for longer than a week (Oak 1983). As the lifting season progressed, seedling gradually improved. By mid-February, seedlings appeared to be fully recovered.

Two incidences occurred in 1994 in Alabama and Georgia. Rainfall at a Georgia Nursery during the month of October averaged 59 mm per week. From November 11th until December 5th, rainfall averaged 65 mm per week. Lifting began on November 23rd and by January 20 all seedlings on some sites were dead. By that time seedlings remaining in K-P bags had black and mushy roots. In 1997, above average rainfall occurred at a nursery in Alabama and seedlings lifted from December 3rd to December 15th exhibited poor survival. During the previous month, rainfall averaged 45 mm per week. Although the low performance of seedlings lifted during this period might be attributed solely to the "December Dip," we believe the above average rainfall in November exacerbated the problem.

In addition to the excessive rain, two other factors might contribute to lowering oxygen levels in nursery soil: above average temperatures and fertilization in October or November. It is well known that injury from flooding is greater when soil temperatures are higher (Kozlowski 1984, 1986). Warm water contains less oxygen and soil microbes are more active (microbial respiration is at a higher rate). Therefore, excessive rains in a warm November would be more harmful than the same amount of rainfall in January. Problems associated with excessive rainfall are not new. Wakeley (1954) stated "In a year of extraordinary weather conditions, severe late fall or early winter drought might reduce survival; or excessive fall rain might reduce it by lowering the physiological quality of the nursery stock." Henry (1953) reported on a root rot in Mississippi where the cause of the problem was unknown (possibly nematodes). However, the problem was most severe in low areas of relatively poor drainage and lenticels on diseased seedlings were sometimes enlarged (Henry 1953).

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When nursery managers record above average rainfall in November and early December, they may want to check their seedlings for signs of root injury before lifting. Lenticels on the taproot is one indicator of waterlogged conditions. It may be advisable to delay lifting seedlings until February (to allow the roots time to recover). Managers should first consider lifting from well-drained areas where seedlings have healthy mycorrhizal roots. Anaerobic soil conditions can kill white root tips as well as mycorrhizal roots (Gadgil 1972).

Although studies have been conducted on the effects of flooding or waterlogging on roots in situ, few studies have transplanted seedlings soon after a waterlogging treatment. In one study, Wakeley (1954) reported a 15 percent decrease in survival after just one day of storing pine seedlings in tubs of water. Our assumptions regarding survivability have been based only on observations from plantation failures. Therefore, research is needed to determine the length of time required before anaerobic conditions cause problems with transplanting. In addition, nursery managers need a simple test (such as electrolyte leakage) that could be used prior to lifting to evaluate the health of roots.

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HERBICIDE LABELING[1]

Ken McNabb[2]

ABSTRACT— Knowledge of pesticide law and regulation is necessary for the proper use of crop protection chemicals and to remain vigilant against the potential loss of useful compounds.The principle legal framework for pesticide use is the Federal Insecticide, Fungicide, and Rodenticide Act. There are a number of ways this legislation directly impacts the labelling and use of herbicides and other pesticides in forest tree nurseries.The legislation was modified by the Food Quality Protection Act of 1996. This new law may have serious negative effects on the availability of crop protection chemicals in all areas of agriculture, including nurseries. It is expected this legislation will make pesticides more expensive and less available. Examples are provided of strategies and activities aimed at securing crop protection chemical labels for use in forest tree nurseries.

INTRODUCTION

The use of pesticides is an integral and necessary component in the production of quality seedlings for afforestation. Without crop protection chemicals production costs would increase and seedling quality would decrease. The use of herbicides in particular has had a tremendous impact on seedling cost by reducing the necessity for hand weeding and the improvement of seedling quality through competition control. The availability of herbicides and other crop protection chemicals is controlled by federal and state legislation. Not only is understanding the basics of pesticide law necessary to properly and legally use pesticides, nursery managers also need to follow and keep abreast of trends or changes in the law. Since forest tree nurseries are a very minor use in terms of acreage, they are not given a high priority by pesticide manufacturers or regulatory agencies. Looking out for our own best interest requires a basic knowledge of the legal framework of pesticide registration and regulation.

THE FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

FIFRA is the principle legislation controlling the manufacture, registration, distribution, sale, and application of pesticides in the United States. This law requires pesticides to be registered (i.e. "labelled") before they can be manufactured and distributed in the U.S. FIFRA also sets up the concept of "restricted use" pesticides whereby the purchase or use of these compounds require training and certification. This law also establishes fines and penalties for using a pesticide in "a manner inconsistent with its labelling". FIFRA is enforced by the Environmental Protection Agency in collaboration with state pesticide regulatory authorities. Originally passed in 1949, the law has been amended several times, most recently by the Food Quality Protection Act of 1996.

There are two sections of FIFRA that most directly pertain to the labelling of herbicides and other pesticides. The main labelling provision of FIFRA falls within Section 3 which is considered the full national EPA approved pesticide label.

In order for pesticides to be sold or used in the U.S., the product is required to obtain a Section 3 label. To issue a Section 3 label the EPA must conclude:

1. The composition of the product is such as to warrant the proposed claims for it.
2. Its labelling and other material required to be submitted comply with the requirements of FIFRA.
3. It will perform its intended function *without unreasonable adverse effects on the environment* (*parentheses* added).
4. When used in accordance with widespread and commonly recognized practice it *will not generally cause unreasonable adverse effects on the environment* (*parentheses* added).

To meet these requirements a pesticide manufacturer must submit to the EPA a series of toxicology, environmental fate, and chemical characteristics tests.

The second section of FIFRA which is most directly applicable to the labelling of nursery herbicides is Section 24, or the "special local needs" label. In this case, FIFRA allows that an individual state may provide registration for additional uses of federally registered pesticides. Although the specific requirements for Section 24 labelling will vary between states, there are requirements common to all state procedures: the product must already have a Section 3 national label, the Section 3 registrant must support the special local needs request, a need must be established for the product, crop safety data must be provided, as well as data indicating effective control of the specific pest. All state issued Section 24 labels require EPA approval.

One of the provisions of FIFRA is that the pesticide label is a legally binding document and can be viewed as a contract between the product manufacturer and the user. It is a specific point of the law that a pesticide cannot be used in "a manner which is inconsistent with its labelling". There are six important exceptions to this statement. First, FIFRA

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provides that a pesticide can be used at a lower dosage than what is specifically mentioned on the label. Second, users can apply a chemical to a specific pest that is not mentioned on the label if the application is made to the site approved by the label. While pest control warranties of the manufacturer may be invalid in this case, it is legal to use the product if it is labelled for the site. Third, users may apply the pesticide using methods not included on the label as long as the application method is not specifically prohibited on the label. Fourth, it is legal to mix a pesticide with a fertilizer unless specifically prohibited on the label. Fifth, the law allows for additional use of the product through "experimental use permits" (Section 5), Section 24 labels, and emergency use (Section 18). Emergency use must be declared by state and/or EPA administrators. Finally, EPA reserves the right to approve off-label product usage when it deems necessary.

FIFRA clearly indicates that while the EPA has overall responsibility for administering FIFRA, the states are responsible for enforcing the provisions of the law. Each state has its own legal structure to meet this requirement. Certification of applicators for the use of restricted use pesticides and inspection of applicators to ensure their compliance with FIFRA are regulated by these individual state organizations. Importantly, states can impose further restrictions on pesticide use including the addition of products to the list of restricted use chemicals. For example, the EPA has stated that products labelled for horticultural nurseries are also labelled for forest tree nurseries, in other words, they are considered the same "site". This interpretation can be nullified by the states, however, and nursery managers should check with state authorities before assuming that horticulturally labelled products are legal for use in their nurseries.

THE FOOD QUALITY PROTECTION ACT

The FQPA passed congress unanimously in August 1996. The law was intended to resolve serious conflicts between FIFRA and the Federal Food, Drug and Cosmetic Act (FFDC). The FFDC authorized the EPA to set pesticide tolerances on foods. The Food and Drug Administration is responsible for enforcement of the FFDC through periodic inspections of foods. Unfortunately, a section of the FFDC stated that absolutely no level of any carcinogen could be present in any food. Because analytical capabilities as well as our knowledge about how chemicals produce carcinogenic reactions in the body have improved significantly since this law was passed, the law was often in conflict with EPA and manufacturer data indicating the safe use of many products. The FQPA attempted to resolve this conflict as well as others between these two important laws. Although the FQPA relates primarily to food tolerances, it nevertheless has an important and indirect effect on labelling of nursery pesticides.

One of the fundamental changes the FQPA introduces to FIFRA is that the EPA must use a different standard to determine the safety of pesticide residues on foods. Whereas before, the standard required that a pesticide have no "unreasonable adverse effects", the new FQPA language requires "reasonable certainty of no harm". This effectively sets a higher health safety standard for food tolerances. A second significant change requires the EPA to use a "common mode of toxicity" to assess the danger of individual products. To assess the potential threat to human health regarding Goal® use on Broccoli, for example, the EPA would not just determine the effect of oxyfluorfen (the active ingredient in Goal®), but all the diphenyl-ether compounds currently on the market. Third, the FQPA requires the EPA to assess dietary and non-dietary exposures. This means the use of Goal® in forest tree and horticultural nurseries becomes a part of the equation whereby the EPA tries to assess a reasonable certainty of no harm for Goal® applications to broccoli. Finally, there is an additional safety hurdle imposed by the FQPA whereby there must be special consideration given to children when setting tolerance limits. Any pesticide exposure to children requires an additional 10 fold safety factor when setting tolerances.

To meet the requirements of the FQPA, the EPA uses the "risk cup" concept. The risk cup represents the total allowable theoretical exposure which presents "unreasonable certainty of no harm" to any individual. The size of the risk cup is called the "reference dose". To satisfy the FQPA safety standard, all the pesticides with a common mode of action must fit into the risk cup. The risk cup cannot overflow. Therefore, when adding all the uses of a pesticide, plus all the pesticides with a common mode of action, plus the 10-fold safety factor for children, the result has been that the labelling of entire classes of compounds has been put in jeopardy. A good example is the recent debate regarding the use of all organophosphates (which includes guthion and diazinon). The EPA has determined that based on the FQPA standards, the current use of organophosphate pesticides exceeds the reference dose and overflows the risk cup for this class of compound. The EPA therefore decided that all OPs would be discontinued. Only the complaints of the entire agricultural community and pesticide manufacturers were able to reverse this decision. The issue has not yet been resolved, however.

There are several other changes required by the FQPA. The law mandated all pesticides be reregistered within 10 years of its passage. In addition, endocrine disruptor assessments are to be part of the reregistration process. (This is a test to verify that compounds do not interfere with the human endocrine systems.) Moreover, the FQPA requires reregistration on a 15 year cycle. And finally, the law allows EPA to cover the cost of additional data review through the assessment of fees. In summary, the FQPA results in stricter safety standards, several new tests, and increased costs for pesticide registration. The end result will most likely be the reduced availability and increased price of agricultural chemicals including herbicides.

The impact of these new regulations on nursery herbicide availability is very difficult to predict at this time. The EPA has not yet made it clear how the new endocrine disruptor test is to be conducted or evaluated. Nor have they provided consistent guidelines for the determination of "reasonable certainty of no harm", how "aggregate exposure" is to be calculated, and when will the 10 fold safety factor for children be imposed. The situation is even more complicated given the fact that several companies may

manufacture and distribute different compounds within a class of chemicals. Each company will have their own strategy when evaluating the possibility of dropping a label so as not to overflow the risk cup.

LIABILITY AND COST

The principle hurdles to maintaining current labels and getting new ones for forest tree nursery herbicides will most likely continue to be the same we have faced during the past 20 years. While the new modifications of FIFRA through the FQPA will make things more complicated, it is expected that the two issues of liability and the cost of obtaining field data for a minor use crop will continue to be the most important issues for nursery managers. The economic motivation for manufacturers to label a compound for nurseries is marginal at best. Nurseries represent a small acreage crop of high value. In this situation companies are asked to assume crop damage liability risk for an exceptionally small market. Assuming this risk and paying the costs of obtaining field data and pursuing a Section 3 or Section 24 label is all to often not economically justifiable to manufacturers.

One of the strategies recently developed to overcome the liability and data cost issues for minor crops has been initiated by the Florida Fruit and Vegetable Association. The FFVA formed a separate legal entity called "Third Party Registrations Incorporation" for the express purpose of obtaining Section 24 labels for the fruit and vegetable growers of Florida by becoming the registrant themselves instead of the manufacturer. They require (1) a binding agreement between the manufacturer and TPR Inc. to absolve the manufacturer of liability regarding crop damage, (2) a limitation and waiver of liability between the individual grower and TPR to protect TPR from crop damage lawsuits, and (3) a non-transferable label is issued to an individual grower carefully specifying where and how much product can be used. A fee is assessed to the grower to help defray the costs of obtaining the crop safety and other data that might be necessary to obtain the label.

The Auburn University Southern Forest Nursery Management Cooperative is exploring the possibility of this and other legal arrangements that might facilitate herbicide labelling for forest tree nurseries. The organization of such a Coop is in itself an effective strategy for producing crop safety data that manufacturers might not be interested in paying for. Currently the Coop is obtaining field data for Stinger® (clopyralid) for sicklepod control, Goal® (oxyfluorfen) for use on large seeded hardwoods, and Manage® (halosulfuron-methyl) for nutsedge control. In each of these cases we will pursue a Section 24 label in states where member nurseries request it. Although we are a long way from obtaining a structured methodology such as that of the Florida program, the Coop is also investigating the possibility of removing crop damage liability as an issue through formal agreements with Coop members in collaboration with pesticide manufactures.

THE FUTURE

Certainly the future of herbicide labelling is complicated and difficult to predict at this point in time. There are numerous uncertainties resulting from the FQPA. Perhaps minor use crops will actually receive a boost as this new legislation specifically addresses the difficulties of minor use registrations in some positive ways. On the other hand, the opposite is just as likely as minor use labels may be lost when manufacturers seek to maintain larger markets for their products by eliminating the smaller ones in order to not overflow the "risk cup". In all probability it will be important that minor users maintain a line of communication with manufacturers so their particular label is not lost. University Cooperatives and user associations will be critical in this regard as manufacturers look for partners to assist them work on high value crops with small markets.

METHYL BROMIDE UPDATE[1]

Clarence Lemons[2]

The future availability of methyl bromide is in deep trouble. Not only will the loss of methyl bromide have an effect on the forest nursery industry but will result in a serious economic loss across the board for those who rely on methyl bromide to aid in producing a crop.

At the last United Nations Montreal protocol meeting the agreement reached was for developed nations will have methyl bromide for use until 2005 with a 25 percent reduction in 1999 and additional reductions in 2001 and 2003. Undeveloped nations would have the use of methyl bromide until 2010 with no reductions and no restrictions.

Our troubles go every deep with the U.S. Clean Air Act. When methyl bromide was used as a ozone depleter, it triggered the Clean Air Act which called for it to phase out January 1, 2001.

An effort is being put forward to get Congress and the White House to agree to follow the mandate of the Montreal protocol. House bill 2609 introduced by representative Miller (R-FL) and Condit (DC) to allow use of methyl bromide until alternatives are made available now has 61 co-sponsors. We still need your help. A phone call, letter or visit to a congress person or senator could make the difference. Don't give up.

During this potential phase down of methyl bromide, we have been working in conjunction with Dr. Bill Carey and others at the Auburn Co-op. We have put out plots for the last several years to identify which compounds would come closest to providing control similar to methyl bromide.

We have not identified any product that will replace methyl bromide. Given the broad spectrum control and general effectiveness of methyl bromide, the compounds used in plot work have been 1,3 dichloropropene with chloropicrin and metam sodium with chloropicrin. In some tests herbicide eptam was used to give added control of nutsedge.

The 1,3-d/chloropicrin mixture can be applied with our present methyl bromide applicators with some modifications and would be covered with plastic. This combination has shown to have some promise as a compound to use if we lose methyl bromide,

We have also tested a combination of metam sodium/ chloropicrin without using plastic for several years and are pleased with results we are seeing from this combination of products.

While we see some promise with the combination of compounds we must keep in mind that most of the test sites have been fumigated with methyl bromide for several years. We must consider that disease and weed pressure may have been reduced. We are hoping to be able to test the combinations on fields that have not had fumigation to see what results are produced.

Data generated from these studies were collected by the Auburn Co-op and those interested in copies of data should contact the Auburn Co-op.

Any one interested in having an application of the 1,3d/ chloropicrin or metam sodium/chloropicrin should contact us at our nearest location or call me at 1-800-662-4130 for additional information.

If anyone desires additional information on the methyl bromide contact Doug Curtis at 1-800-637-9466 ext.229.

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ALTERNATIVES TO METHYL BROMIDE IN FOREST TREE NURSERIES[1]

William A. Carey[2]

INTRODUCTION

Methyl bromide (MBr) was listed for withdrawal under the Clean Air Act in 1993. Since then much research has focused on evaluating treatments to replace its use in forest nurseries and other crops. Almost all the techniques were tested before 1960 and then neglected in favor of MBr. Therefore, the real problem was to determine which now fit most effectively into a production scheme that has changed radically since MBr was widely accepted in the late 1960's. With few exceptions good estimates of the effectiveness of available alternatives was possible using published studies. To date, after regulatory losses of pesticides are considered, the most promising alternatives could have been predicted from a review of literature. Considering the probable costs and benefits associated with some retested alternatives, many efforts (money) might be difficult to justify.

Records of disease losses in forest nurseries before MBr may hardly seem credible to us today. Henery (1951), stated that "when the number of seedlings produced per unit area has been calculated, it has not been unusual to find a 40-50 percent reduction resulting from root rot". Problems were similar in Virginia (Morris 1960) where, "the usual loss of from 20 to 30 percent of the germinated seedlings" occurred annually. Root rot "destroyed at least 20 million (20 percent) of Florida's nursery-grown pine seedlings" in 1976 (Seymour 1978). It may seem more surprising to realize that these losses are not far off what seems to have been the average impact of disease in non-fumigated nurseries. Among 157 published comparisons from forest nurseries, there was a 50 percent increase in numbers of seedlings for beds fumigated with MC2 or MC33 compared to controls (Carey 1994).

The following alternatives to methyl bromide are presented in what I consider the reverse order of desirability to the forest nursery industry. That is, Alternative (Move) is least likely to be cost effective based on probable costs and historical benefits. However, each of these alternatives has been used in the past. Most nursery managers would be surprised by what is "reasonable" to those who consider anything but pesticides reasonable.

ALTERNATIVES

Move

Nurseries have been abandoned due to pest problems. Before effective fumigants made eliminating soil borne disease possible moving nurseries was common. "Reasonable commercial control has often been secured in Wisconsin by planting on newly cleared forest soil (Riker and others 1947)." Also, diseases caused the Virginia Division of Forestry's nursery production to be moved to newly cleared land at the New Kent nursery in 1959 (Morris 1960). More recently, referring to MBr fumigation in the northwest, Sutherland (1984) recommended, "sites requiring this level of maintenance might best be abandoned or paved for a container nursery!" Expensive pest avoidance! When two pine crops are grown per fumigation, the cost of pest control is about 4 percent or 0.2 cents of a 3.5 cent bareroot loblolly or slash pine seedling. Similar container-grown seedlings cost about 13.5 cents and although they have other advantages, 10 cents a seedling (75 percent) is expensive pest control. If pest control at bareroot nurseries cost 10 cents per seedling it would be the equivalent of $70,000 per acre. With nursery establishment costs of perhaps $3,000,000 for a bareroot capacity of 50,000,000 seedlings, moving must be put off for about 40 years if it is to be an alternative to fumigation. That is not likely to be cost effective, and within a few years the new nursery could have similar problems.

Sow More Seed

Howe and Clifford (1962) wrote that "the standard nursery practice when sowing conifer seeds is to over-plant in order to compensate for losses from damping-off and other factors that affect germination and survival of seedlings." Over sowing could be a logical consideration if soil-borne diseases were normally distributed. Both the efficacy of fumigation and problems associated with over sowing can be appreciated from an early fumigation study (Hill 1955) where MBr increased bed densities from the expected $48/ft^2$ to the unmanageable $229/ft^2$ which itself would suppress seedling development.

The economic threshold for an effective treatment is relatively easy to calculate. For example, if a seed cost 0.5 cents ($60/lb), then to sow 25 $/ft^2$ the economic threshold for a $1,000 treatment is an expected 28 percent loss. It is difficult or impossible to calculate the economic threshold for non-effective treatments, such as over sowing. If seedling quality is considered, production might be worse in years where too many seedlings survive. In addition, costs associated with morphological or genetic improvement, such as more expensive seed and more space per seedling, are magnified by the risks associated with production. For example, if a seed cost 1.0 cent (control pollination) not only is the extra 28 percent sown to replace disease twice as expensive so are the culls in areas without disease.

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Disease Suppressive Soils—Biological Control

Since at least the turn of the century the importance of soil characteristics to root disease has been recognized and since mid-century it has been known that the fungi responsible for damping-off were relatively rare in natural forests (Riker and others 1947). This has been observed with soils and plants moved from nurseries to forests and from forests to nurseries (Smith 1967). This was part of the reason for moving seedling production as cited in Alternatives. If pathogens do not survive in forest soils then perhaps nursery soils can be made suppressive. The suppressive factor appears to be related to soil organic matter, pH, or biological control agents. These factors were considered as early as 1921 (Taylor) and an extensive review was made 35 years ago (Vaartaja 1964). Unfortunately, it has been a difficult research area and optimal conditions remain unknown. Till recently, "because of frustrations, discouragement, and failures, many scientists have not continued their investigations with amendments. The lack of papers on the subject during the past several years has made this attitude apparent" (Papavizas 1974). Given the extensive history and slow progress of trials with organic amendments and pH modification, the optimism emerging after 1993 may be difficult to understand (at least in terms of the probabilities associated with grower costs).

Physical Suppression

Physical suppression can overlap with techniques to create suppressive soils. For example, if 300 gallons of H_2SO_4 is pH modification then 1,000 (or more) gallons could be thought of as an attempt to directly destroy fungi. Recently, physical suppression has usually involved heat, either by solarization or inputs of hot water or steam. Solarization has the advantage of being relatively cheap. However, it fits poorly into the production cycle and it has not been reliable in forest nurseries.

Unlike most other techniques reevaluated since 1993, the ability to heat soil on a scale to treat fields is new. Advances in mechanical technology make it possible but problems remain. First, lethal temperature must be dispersed through 2,000,000 lbs of soil per acre furrow slice and we would like to treat more than just the top six inches. Even though treatment was effective (Carey 1997) and the technology is getting better, hot water applicators are, at present, too slow. Steam applicators are slower still. The potential to physically change the soil structure and the amount of water (35,000 gal/ac) and fuel needed may make these technologies impractical in some nurseries.

Pesticides

By paying close attention to the literature we could have made our task between 1993 and 1998 easier. A 1994 search of information on fumigation in forest nurseries produced 354 comparisons that included data on seedling numbers for both treatments and controls (Carey 1994). Here are the nine most frequently tested fumigants before 1993 with the percent increase compared to controls in parentheses: MC2 (49), MC33 (49), metham-sodium (37), ethylene dibromide or EDB (28), allyl alcohol (27), MITC generators such as dazomet (18), formaldehyde (16), chloropicrin, (16) and DD (6). Although there were many fewer comparisons with data for seedling size, chloropicrin most enhanced seedling growth. The only available fumigant not extensively covered in the surveyed literature was dichloropropene (1,3-D) which is one of the components of the old DD formulation. Although 1,3-D had good efficacy in our trials, it appears likely to have regulatory problems with air quality. After removing from consideration those compounds which now have regulatory restrictions or are likely to be restricted (that is EDB, formaldehyde, DD, some MITC generators such as Vorlex, and 1,3-D) we could probably have restricted our evaluations to combinations of chloropicrin and metham-sodium along with herbicides to increase nutsedge control. Is it surprising that no new, magic, techniques were developed for forest nurseries from all the money and effort expended? Expected reward for activities as diverse as purchasing lottery tickets or research on methyl bromide alternatives is a function of the cost times the probability of success. More can be done by concentrating on the most likely alternatives. In my opinion, the probability of success was sometimes ignored in favor of options without pesticides. Attempts to mulch, compost, acidify and employ beneficial microorganisms may seem more reasonable to those who don't have to produce seedlings on a budget, but whose money is spent?

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IR-4 CROP PEST MANAGEMENT PROGRAM[1]

J. Ray Frank[2]

INTRODUCTION

In 1962, the State Agricultural Experiment Station Directors recognized the needs of growers in obtaining pesticide registrations for minor use and or speciality crops. They asked the U.S. Department of Agriculture's Cooperative State Research Service (CSRS) to initiate and coordinate a program to unite the agriculture community in an effort to obtain these needs.

The project which is known as IR-4 was established in 1963 to obtain national pesticide registrations for use on food and fiber minor crops.

This national program now involves USDA/ARS and USDA/CSREES, the Environmental Protection Agency (EPA), State Agricultural Experiment Stations (SAES), agricultural chemical companies, commodity organizations, and individual growers.

The IR-4 Program was expanded in 1975 when SAES established regional laboratories to provide regional coordination and analytical services. In 1976, USDA/Agricultural Research Service (ARS) established a minor use program to provide further support for IR-4. The IR-4 program was expanded in 1977 to include ornamentals research on nursery and floral crops. This research now also includes label expansion for the commercial landscape, interior plantscapes, forestry production, turf, tissue culture, and Christmas tree production. In 1982, national label registration research was initiated to include biological pest control agents such as microbials and biochemicals.

Table 1—IR-4 ornamental research 1977-1997

	Total projects	Total registrations
Fungicides	3,930	1,881
Herbicides	4,348	1,311
Insecticides	4.616	1,708
Nematicides	237	80
PGRS	90	48
Others	13	3
Total	13,234	5,031

Table 2—IR-4 ornamental research

	1995	1996	1997
Research trials	443	445	539
New registrations	377	891	135

An IR-4 national headquarters staff based at the New Jersey Agricultural Experiment Station (NJAES) at Rutgers University provides the leadership and coordination for this diverse program.

Each region includes a Regional Coordinator and each state has a representative to provide input for future research needs. A companion minor use program is administered by ARS. The ARS minor use program operates in concert with the IR-4 project in the clearance of minor uses. The major difference between the two programs is that funding comes from separate sources within USDA.

Since the IR-4 Ornamental Pesticide Research Program was initiated in 1977, we have had over 13,000 research projects (see table 1). During this time frame, ornamental research conducted by IR-4 has led to over 5,000 national label registrations (table 1). The number of research trials averaged about 475 for the last three years (table 2). The number of registrations for the period 1995-1997 exceeded 1400 or about 28 percent of the total registrations for the program (table 2).

During 1997, data were collected from 9 fungicides, 14 herbicides and 14 insecticides (Appendix One). During 1997, 135 new registrations were obtained (Appendix Two).

The data collected during the entire program has included research by over 200 different researchers. In 1997, 26 researchers at 20 locations in 16 different states were involved in the program.

The future of the program relies on the input from all research and extension personnel and growers who have pest control problems.

[1]Frank, J.R. 1999. IR-4 crop pest management program. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 75-77.
[2]Research Horticulturalist, IR-4, 6916 Boyers Mills Road, New Market, MD 24431; TEL: 301/898-5332.

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Appendix One

During 1997, data were collected for these 9 fungicides:

- *Ampelomyces quisqualis* (AQ-10 Biofungicide)
- Bordeaux mixture (13.3 percent)
- chlorothalonil (Daconil Ultrex 82.5 percent)
- etridazole (Ethazole) (Truban 5G)
- flutolanil (Prostar 50 WP)
- fosetyl-Al (Chipco Aliette WDG 80)
- Physan 20
- tebuconazole (Lynx 25)
- thiophanate methyl (Clearys 3336 4.5F)

Fourteen herbicides were also evaluated during 1997 including:

- bentazon (Basagran T/O)
- clethodim (Envoy 12.6 percent)
- 2,4-D LV Ester (Weedone LV4)
- oxyfluorfen (Goal T/O 2XL) diuron (Direx 80 DF)
- halosulfuron (Permit)
- isoxaben (Gallery 75DF)
- napropamide (Devrinol 5G or Devrinol 50DF)
- Oryzalin (Surflan AS 40.4 percent, XL 2G)
- oxadiazon (Chipco Ronstar G or Chipco Ronstar 50WP)
- dithiopyr (Dimension 1EC)
- oxyfluorfen +oryzalin (Rout 2G)
- pendimethalin (Pendulum 60 WDG,
- Ornamental Weed Grass Control G 2.8 percent)
- prodiamine (Barricade 65 WG,Factor 65)

Research was also conducted on 14 insecticides including:

- acephate (Orthene Turf, Tree and Ornamental Spray)
- bendiocarb (Dycarb 76WP, Turcam 2.5G, Turcam 76)
- bifenthrin (Talstar Nursery Flowable,
- Talstar Nursery Granular)
- capsaicin (Champons 100 percent Natural)
- chlorpyrifos (Dursban 50 W, 4EN)
- fenitrothion (Pestroy 4EC)
- formetanate hydrochloride (Carzol SP)
- hexythiazox (Hexagon, Savey 50WP)
- horticulture oil (Sun Spray Ultra-Fine Spray Oil)
- malathion (Malathion 5EC, Gowan Malathion 8)
- trichlorfon (Dylox 80)
- pyridaben (Sanmite 75)
- pirimicarb (Pirimor 50 DF) diazinon (Knox Out 2FM)

bendiocarb (Turcam 2.5G 76, Dyvarb 76WP)
Andromeda (Pieris)
Apple (non-bearing)
Arborvitae
Azalea
Crabapple
Geranium
Juniper
Privet
Rhododendron

chlormequat chloride (Cycocel 11.8 percent)
Columbine
False Spirea
Geranium
Hibiscus

chlorothalonil (Daconil 2787)
Aster
Baby's Breath
Balsam
Cactus
Croton
Flowering Dogwood
Good Luck Plant,
Ti Plant
Jade Plant
Pine, Air
Pine, Norfolk Island
Plum (non-bearing)
Redwood

clethodim (Envoy)
Daylily
Stonecrop
Sedum X spectabile

Daminozide (B-Nine)
Larkspur

DCPA (Dacthal)
Kentucky Blue Grass
diquat dibromide (Reward)
Easter Lily

dithiopyr (Dimension IEC)
Geramum
Hawthorn
Juniper
Sugar Maple
Red Oak

fluazifop-butyl (Fusilade TO Herbicide)
Ajuga
Ice plant

fosetyl-Al (Chipco Aliette WDG)
Azalea
Rose

isofenphos (Oftanol 2)
Andromeda (Pieris)
Arborvitae
Ash
Azalea
Birch
Crabapple (non-bearing)
Geranium
Hemlock
Japanese Holly
Japanese Maple
Juniper
Kentucky Bluegrass
Laurel (Kalmia)
Linden
Black Locust
Maple
Oak
Plane
Tree
Privet
Rhododendron
Yellowwood
Yew

isoxaben (Gallery 75DF)
Flowering Dogwood
Fosters Holly
Holly

Malathion (Malathion 5EC, Gowan Malathion)
Chrysanthemum

mancozeb (Penncozeb 75DF Protect T & O)
Gloxinia

methiocarb (Mesurol 75-W)
Afican Violet
Chrysanthemum

oxydemeton-methyl (Metasystox-R)
Spruce

oxytetracycline(Mycoject 4.2 percent)
Pear (non-bearing)

paraquat (Gramoxone Extra)
Easter Lily

PCNB (Terraclor 75 WP,400)
Pansy
Snapdragon
horticulture oil (Sun Spray Ultra-Fine Spray Oil)
Ageratum
Ash
Azalea
Balsam
Camellia
Carnation
Cocunut
Palm
Crown of Thorns
Hydrangea
Leatherleaf Fig
Maidenhair Fern
Marigold
Moth Orchid
Petunia
Philodendron
Rose
Shasta Daisy
Transvaal Daisy
Zinnia

Triadimefon (Bayleton 25, 50, Strike 25WDG)
Purple Wintercreeper

Trifluralin (TreflanE.C,5G, Gowan Trifluralin E.C., 10G)
Bellflower
Cone Flower
Pincushion Flower
Sage
Speedwell

vinclozolin (Curalan D.F.,E.G., Ornalin FL)
Balsam
Begonia
Carnation
Cherry (non-bearing)
Chrysanthemum
English Ivy
Geranium
Hydrangea
Madwort
Marigold
Petunia
Plum (non-bearing)
Poinsettia
Snapdragon
Zinnia

FOREST AND CONSERVATION NURSERY TRENDS IN THE NORTHWESTERN UNITED STATES[1]

Thomas D. Landis[2]

ABSTRACT—There are many changes happening in forest and conservation nurseries in the Northwestern United States. I will be focusing on three trends that I have been watching over the past decade: 1) Changes in federal government nurseries, 2) Demand for larger stock types, and 3) Increased interest in native plants.

CHANGES IN FEDERAL GOVERNMENT NURSERIES

Federal government nurseries, especially those of the USDA Forest Service, continue to decrease in production and some are even being closed. The Forest Service is the largest government nursery operator in the Northwest and the majority of seedlings grown in their nurseries are for reforestation after timber harvest and for fire rehabilitation. Since the early 1950's, the Forest Service was operating under the traditional perception that one of their primary roles was to supply wood and wood fiber from their lands that had been designated for timber production. In the late 1970's, congress mandated that all Forest Service lands be brought up to full production and so a survey of timber lands was conducted. This "reforestation backlog" of lands that were non-stocked or understocked created an increased demand for seedlings (fig. 1). To meet this demand, Congress provided additional funding to bring existing Forest Service nurseries up to full capacity and even build new nurseries, such as the J. Herbert Stone nursery in Oregon. In 1983, however, poor economic conditions and high stumpage prices in the Northwest caused economic hardship to many timber companies that had bought Forest Service timber sales. Congress provided relief through the "timber buyback" program causing a decrease in the demand for reforestation stock for several years (fig. 1). Recently, harvesting has been restricted on timber lands where threatened or endangered species, such as the northern spotted owl, would be adversely impacted. In Region 6 of the Forest Service (Oregon and Washington), timber harvesting on National Forest lands decreased from 5.2 billion bd. ft. in 1987 to 401 million bd. ft. in 1995. This has caused a severe reduction of the reforestation program on some National Forests such as the Umpqua NF in southwestern Oregon where timber harvest decreased from 282 MM bd. ft. in 1989 to just 13 MM in the last 6 years - a decrease of over 95 percent (table 1).

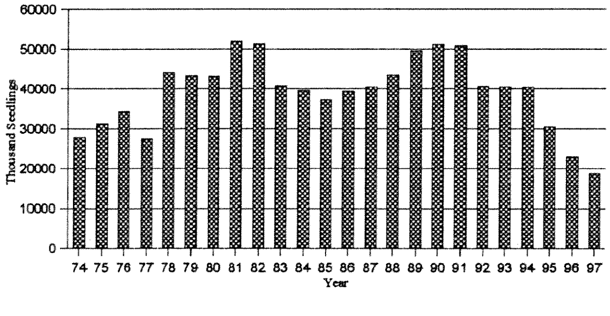

Figure 1—USDA Forest Service nursery production trends in Region 6 (WA & OR) for 1974 to 1997.

This reduction in timber harvest has translated directly into less demand for seedlings. Forest Service nurseries produced over 50 million seedlings in 1990-1991 but this has steadily decreased. In fiscal year 1997, Forest Service nurseries produced less than 20 million seedlings - a greater than 60 percent decrease in only six years (fig. 1). And, it doesn't look like we're at the bottom of the trend yet.

Because of this reduced seedling demand, the Forest Service completed a management review of their Western nursery program which recommended closing nurseries. The Wind River Nursery in western Washington, which was the first forest nursery in the West and had produced over 30 million seedlings per year, was closed in the summer of 1997. The Bend Pine Nursery in Oregon and the Humboldt nursery in California are slated to be closed this coming year. By the turn of the century, there will be only three Forest Service nurseries in the Northwest: the J. Herbert Stone nursery in Medford, Oregon; the Coeur d' Alene nursery in Northern Idaho; and the Lucky Peak Nursery in Southern Idaho.

The future of timber harvesting and therefore reforestation on federal lands is uncertain. Just this year, environmental groups like the Sierra Club and the Native Forest Network have revealed their true intent - zero cut which would mean no more timber harvesting on federal lands. Environmental groups such as the Sierra Club, the Oregon National Resources Council and the Native Forest Network have staged a recent series of protests in Oregon and Washington designed to disrupt logging (Bernton 1997). Just how this will affect the demand for federal seedlings remains to be seen.

Demand for Larger Stock Types

Another trend that we're seeing in the Pacific Northwest is that foresters are asking for larger and larger seedlings. Bareroot transplants are becoming increasingly popular,

[1]Landis, T.D. 1999. Forest and conservation nursery trends in the Northwestern United States. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 78-80.
[2]National Nursery Specialist, USDA Forest Service, Portland, OR 97208-3623; TEL: 503/808-2344.

Table 1—Protection of endangered species, such as the Northern Spotted Owl, has severely restricted timber harvest and thereby reduced demand for seedlings in Region 6 of the USDA Forest Service

Northern Spotted Owl	Administrative unit	Year	Timber harvest	Reduction
			MM bd. ft.	Percent
	Region 6 (OR & WA)	1987	5,200	92
		1995	401	
	Umpqua National Forest (OR)	1989	282	95
		1995	13	

especially the 1+1 stock type, and container transplants are in demand for reforestation as well as for specialty crops like Christmas trees. Foresters are requesting large transplants, from 30 to 50 cm in height (12 to 18 in.) and 5 to 10 mm in caliper (0.2 to 0.4 in.), for outplanting sites in the Coast Range of Washington and Oregon where brush competition is intense. In the 1986-1987 season, the Webster Nursery of the Washington Department of Natural Resources sold 90 percent 2+0 seedlings and only 10 percent transplants. Ten years later, in 1996-1997, the ratio had changed dramatically to only 48 percent 2+0 seedlings and 52 percent transplants (Ramirez 1997).

Several things have contributed to this trend. New "Free-to-Grow" reforestation standards have made foresters demand larger and larger stock that not only survive but will get up and grow quickly. For example, reforestation laws in the State of Oregon require that cutover lands must be "free-to-grow" in only 5 years. In addition, fewer mechanical and chemical site preparation options are available nowadays and larger seedlings with more buds seem to be able to tolerate browsing better. Burning restrictions have left more slash on the outplanting sites, and so foresters like larger trees that can get up above this competition. Fewer and fewer herbicides are available and many foresters are using less chemicals because of environmental restrictions and this trend is expected to get even worse. Because of concerns over dioxin in 2,4,5-T herbicides, a US Federal court in Portland banned the use of all herbicides on federal lands in the early 1984 and this herbicide ban lasted until a mediated agreement in 1989. During this time, foresters experienced what the loss of herbicides would mean and came to realize the benefit of larger stock.

This switch to larger stock types has had several effects on nurseries but lower growing capacity is the primary impact in both bareroot and container nurseries. Bareroot seedlings can be grown at 160 to 270/m^2 (15 to 25/ft^2) whereas transplants are much less dense - 53 to 64 seedlings/m^2 (5 to 6 seedlings/ft^2). Container nurseries have adjusted to the larger volume containers with fewer cells by starting the seedlings in greenhouses and then moving them to open growing compounds, growing them outside for the entire season, or transplanting from miniplugs to large containers. Container-to-container transplants are a relatively new stock type where seedlings are started in very small volume containers in the greenhouse and then transplanted to larger volume, lower density containers that are grown in open compounds. Nurseries also are restoring their old transplanting machines or are buying new ones. The cost per seedling has increased, of course, but it appears that there is little price resistance to these larger seedlings.

Increased Interest in Native Plants

Finally, let's look at another trend that continues to increase in the northwestern US - propagation of native plants. With the change in emphasis from timber production to ecosystem management, there is an increased demand for native plants for a wide variety of uses, especially habitat restoration and diversity plantings.

Of particular interest in the Northwest is the "salmon crisis" (fig. 2). Restoration of salmon habitat is fueling the need for a variety of plant materials such as willows and other riparian trees and shrubs. Most of these plants are being grown in containers and a variety of different container stock types are being used. Large container stock is being used to stop soil erosion and provide instant shade for cooling the water temperature in salmon spawning areas. Other riparian shrubs such as red-osier dogwood are also being grown in containers both by seed and from cuttings. Several Northwest nurseries are growing wetland plants in containers such as sedges and native grass plugs that are being used to restore wetland habitats in meadows.

Since little is known about how to propagate these native species, government nurseries are working to develop the propagation protocols. In Northern Idaho, the USDA Forest Service Coeur d' Alene nursery has been asked to grow whitebark pine (*Pinus albicaulis*) seedlings for grizzly bear habitat. The large seeds are favored food because their high fat content helps the bears store energy for hibernating. Whitebark pine seeds also are available when many other food sources are scarce. X-ray examination when the seeds arrived at the nursery showed that many

Figure 2—The "salmon crisis" should generate a demand for a variety of native plants for riparian restoration projects.

have immature embryos and so needed warm, moist stratification to allow the embryo to finish development. The first step was to sterilize the seedcoat with a 10-minute soak in dilute household bleach (1 part bleach:10 parts water) followed by a running water rinse for 48 hours. Then, the seeds were put into mesh bags within plastic bags and placed into a germination chamber at 24° C (75° F). Three warm, moist stratification periods of 7, 14, and 21 days followed by a 60-day cold, moist stratification period at 4° C (40°F) were tested. The mesh bags are removed weekly for 1-hour running water rinses which help reduce surface mold development during the long stratification period. The 21-day warm/60-day cold stratification appeared to be the best with germination of one lot reaching the high 80 percent range, although others reached only 20 to 30 percent.

Using the warm-moist/cold-moist stratification treatment, the following propagation protocol was developed. At the end of the cold, moist stratification period, the seeds are hand scarified and placed in germination trays with the cut side down to reduce moisture loss. The germinants are then hand-sowed into Ray Leach Super Cell containers [164 cm^3 (10 in^3)] and are grown for two years. After planting in the spring of the first season, they are allowed to grow in a fully-controlled greenhouse until fall when they are moved to a shelterhouse for natural hardening and overwinter storage. At the start of the second year, the seedlings are brought back into the greenhouse where they resume growing until they are hardened-off for late summer-early Fall outplanting (Burr 1997).

CONCLUSIONS

Forest and conservation nurseries in the northwestern US are undergoing many changes, with government nurseries being the most severely affected. USDA-Forest Service nurseries are growing fewer seedlings and some are even being closed due to decreasing demand for reforestation stock. Foresters and other seedling customers are ordering larger stock types, especially large containers and transplants. Many Northwest nurseries, and especially government facilities, are growing more non-commercial native trees, shrubs, forbs, and grasses for a wide variety of restoration and biodiversity projects.

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Combined Forest Nursery Association of British Columbia/Western Forest and Conservation Nursery Association Meeting

Victoria, British Columbia
August 10-13, 1998

Host:
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BRITISH COLUMBIA'S COASTAL FOREST SECTOR - CHALLENGES AHEAD[1]

Bill Dumont[2]

Good morning. I am pleased to be here today in such good company, especially with our American friends and a very important sector of the forest industry. Nurseymen (people, nurseryers, growers?) are essential to our sustainable forestry program and play a critical role in sustaining one of the world's great forestry jurisdictions.

When your president, Ev Van Eerden, approached me several months ago to speak at your meeting today it brought to mind a similar presentation in the fall of 1989 when I also addressed your association. I was a practicing field forester then, rather than the bureaucrat I now am as Chief Forester for WFP. Some of you may well recall my politically incorrect slide presentation urging your nursery industry to provide more excitement in a field foresters life through surprises in the planting box. Of course I was a field oriented person, had a beard and looked something like Grizzly Adams.

Today I've been asked to speak on the future of your industry as you relate to the current and future state of the forest industry. My comments will focus primarily on coastal B.C. because that is where my company, Western Forest Products, operates on 850,000 hectares of productive forest land.

I'm also going to talk about the Greenpeace boycott campaign in the European market and review two recent major announcements by B.C. coastal companies, speak a little about treaties and provide a few comments on your industry and its future. Today, my thoughts are really about the challenges we face as we approach the millennium.

Those of you who know me won't be surprised that I'll express some strong opinions in this area from my experience as an operations forester over the last 25 years. But as James Conant once remarked "Behold the turtle, he makes progress only when he sticks his neck out".

First, let's remind ourselves how important the forest sector is to the B.C. economy and review how dismal things are at the current time. Before I do that I want to be very clear that I believe the coastal industry will recover with our special knowledge and abilities here in B.C. Already we are seeing some slight improvement in pricing and high log and product inventories are slowly coming down.

As Jack Munro, Chairman of the B.C. Forest Alliance, reminds us constantly, there is no number two in British Columbia. While tourism and other sectors have expanded significantly in terms of economic importance B.C.'s forest sector is still the dominant generator of economic wealth in the province and is critical to the survival of over 100 rural communities.

In 1997, the forest industry in B.C. logged 69 million m^3, of which 22 million m^3 was cut on the coast. That's the equivalent of 14 billion board feet of timber. That sustained more than 290,000 jobs and almost $5 billion in personal employment income. More than half the B.C. exports are forest based and we still supply up to 1/3 of the world's export softwood market.

The government take was $88 per cubic metre while personal income was $170/$m^3$. Sales value of the coastal harvest were $6.2 billion of which $2.2 billion went to government. Industry losses were $170 million on the coast last year. Losses will be worse in 1998.

Certainly the Asian financial crisis is part of the problem but there are other factors gnawing at profits and employment in our sector. The Asian problem is very serious. B.C. ships more than a third of its exports to Asia, mostly forest products. Their problems are depressing global commodity prices and will cost B.C. at least 1 percent of its GDP growth this and next year. However, in the long term, our strength in the Asian market is positive.

After outpacing the rest of Canada during 1991 to 1994, B.C. has now significantly lagged in economic growth in the past four years. In fact, the usual "basket case" of Canada, Newfoundland, has been replaced by B.C. in the bottom of the GDP growth heap.

One of our leading economic think tanks, the Fraser Institute, recently asked international investment managers of pension funds and other blocks of funds totaling $200 billion, what they thought of the economic and social

[1]Dumont, B. 1999. British Columbia's coastal forest sector—challenges ahead. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 83-86.
[2]Western Forest Products Ltd., 2300 - 1111 W Georgia Street, Vancouver, BC V6E 4M3, Canada TEL: 604/665-6200; FAX 604/665-6268.

policies in the ten Canadian provinces. Once again, B.C. came out dead last with fully 49 percent saying they had a negative attitude towards the province and only 3 percent indicated a positive outlook.

While Alberta and Ontario vie for the top economic freedom spot among the provinces, B.C. has slowly, deliberately fallen as a direct result of changes in government policy. The economic freedom index uses factors such as tax rates, spending, ownership of business by government, regulatory spending, trade restrictions, etc. These worrisome trends need to be a major wake-up call for our province because without significant change our problems will continue to mount up.

B.C. labour productivity representing percent change and real output per person has been decreasing since the start of this decade with only a slight improvement in 1997.

Coming back to the forest industry specifically, the most revealing negative data are for logging in the first half of this year and the two previous years. From January to June 1996, B.C. logging totaled 32 million cubic metres and $818 million in stumpage payments. For the same period in 1997, production fell to 29 million m^3 with stumpage of $908 million. This year, production was only 27 million m^3 but industry paid $850 million in stumpage. The significant drop was in logging on the coast – 33 percent. This very serious reduction has caused government to finally announce a few tough measures to reduce their costs.

Note that in spite of a significant reduction in volume cut on the coast, stumpage revenue per cubic metre remains high at $28.50/$m^3$ or $142/FBM. Government continues to take more than a fair share of the pie.

The declining commodity prices combined with record stumpage and high logging costs on the coast are very troubling. American objections to stumpage relief were expected and also represent further worries.

How will all this doom and gloom affect your sector? Obviously, reduced harvest levels mean fewer seedlings needed and a reduction in planting. However, the data don't indicate a dramatic reduction yet. In fact, 1996 was the largest tree planting year ever in B.C. with over 259 million trees planted on public lands. It declined in 1997 to 234 million and I expect a significant drop in 1998 in planting and sowing.

Because B.C.'s foresters have been very prompt in regenerating logging areas due to regulation and a concern for maintaining productivity, it is expected that there will be some significant seedling turnbacks in the spring of 1999. Industry and your sector must sit down together and resolve this issue as soon as possible.

I recently completed four trips, including trade missions, to Europe to deal with another significant Greenpeace attack on the B.C. forest sector in our market. While Greenpeace cloaks its campaign as anti-clearcut and opposes logging on the Central Coast, they really have an agenda to stop all old growth, primary forest logging in B.C. The primary forest moniker can also mean natural second growth is in their sights for preservation as well. The attack is continuing and expanding in the United States. Other ENGOs are also involved in the US and are having some effect and are a serious, though manageable, market threat.

The campaign is interesting in that it continually metamorphoses from attacks on WFP, Interfor, MB and gets species specific against western red cedar and western hemlock. Our industry now has a senior action group addressing this and other market access issues. I have found our customers to be loyal and supportive in the face of very intimidating tactics. B.C. needs the higher value, sophisticated European market to support our higher environmental standards.

Because of historic developments and the nature of our resource, we have few alternatives to harvesting in primary forest. Primary forests still cover well over half of our operable forest lands. Of the 94 million hectares of land in B.C., 60 million is forested and 23 million are currently in the working forest.

The coastal rainforest, which coincides roughly with the western hemlock biogeoclimatic zone, covers about 10.6 million hectares.

More than 54 percent of this rainforest is in a mature, old growth condition and 31 percent are forests less than 120 years old. But most importantly, almost a million hectares of the temperate rainforest are protected from development of any kind. This level of protection exceeds most other jurisdictions in the world. As well, new land use planning processes are underway that will result in further significant protection of old growth. A significant and costly B.C. strategy to protect biological diversity in the working forest is dismissed by Greenpeace even through no other jurisdiction is doing as much to address maintenance of biological diversity in its forests.

The Central Coast region, the current target area of Greenpeace's campaign for preservation, also has a low amount of operable timber. The region covers nearly 5 million hectares with 18 percent presently protected from logging in existing parks and deferrals. Less than 10 percent of the central coast area is available for timber harvesting and forest management. In other words, 90 percent of the central coast is not part of any forest development proposal and will remain as intact wilderness. Yet, forest companies working in the region continue to be attacked and vilified in a rather dirty boycott campaign.

It shouldn't be missed by anyone that we are attacked just because B.C. has such huge reserves of old growth forest after 150 years of development in this province. This is, in my mind, testament to strong and responsible conservation commitment and concern for sustainable forest management.

Our company and its predecessors have been in existence since 1857 and mature timber still covers more than half of our forest land. While the public perception is there is little

old growth left in B.C., the reality is the majority of our population looks out at mountains which are still cloaked in old growth timber. We expect to be harvesting in these older forests for at least half a century.

While conservation of old growth will increasingly be a priority of our forest management in coastal B.C., there continues to be good opportunity to harvest quality forests to meet world demand for specialized timber. In coastal B.C. we harvest for solid wood products with raw materials for pulp mills being a by-product of logging and sawmills.

Recently some significant new commitments were made by two coastal forest companies. Our company has announced we are seeking Forest Stewardship Council certification of our forest management. This dramatic move, the first by a forestry company in western Canada and one of the largest single applications for certification in the world, was made after careful study of the Mexico-based Forest Stewardship Council, its aims and objectives and principles.

In response to market demand and customer interest, WFP engaged SGS UK to undertake a Qualifor accreditation. A draft check list for the audit has been developed using B.C. specialists and the international set of FSC principles and criteria. We expect the audit to proceed this fall. While there will be significant challenges in securing forest certification, we believe we will be successful.

Third party verification of sustainable forest management is a worldwide trend and will accelerate in the next decade. While this is not a consumer driven issue, there is a concern by buyers of forest products that customers will eventually increasingly demand products from forests that are verified sustainable. We expect there will be a slight premium for certified products but in the end this will become a requirement of the market rather than something which gives us a market advantage. We are also proceeding with ISO 14001 and the CSA SFM certification. We welcome certification as a validation of our management on a fair and reasonable basis in comparison with other jurisdictions. We believe it will lead to higher public confidence in our forestry programs.

One concern to you in the FSC certification process is the denigration of the role of plantations as socially and ecologically acceptable methods of regeneration in natural forests. There is and will continue to be some shift to greater natural regeneration reliance in B.C.'s forests, but the demands of the Forest Practices Code and concern for prompt reforestation will continue to keep demand for quality seedlings high, even with new and innovative harvesting being proposed. Under FSC rules exotic species must be minimized as is the use of genetically manipulated seedlings.

As part of the establishment of environmental management programs under ISO 14000 certification, you may also expect the forest industry to request nursery stock suppliers establish a similar EMAS system in your operations.

The other dramatic forestry announcement in B.C. in the past few months was from MacMillan Bloedel, Canada's largest forest firm. They announced an end to clearcutting within the next five years, moving to a variable retention harvest system in a combination of three land zones of varying logging intensity.

While I don't intend to go into details on MB's new approach, you should clearly understand each company must develop its own business strategy. MB decided to change its forestry practices after a review of their declining AAC and a belief they had lost the social licence to clearcut in old growth. They made a direction change based on their own unique mix of private and public lands and second growth forests.

As part of the MB plan to operate differently at both the stand and landscape level, a Timber zone will be established and managed intensively for fibre. This zone will cover 65 percent of their lands and natural regeneration reliance will continue to be about 25 percent of the logged area, little change from the current situation.

In the Old Growth zone, which will have a high biodiversity conservation emphasis, natural regeneration is the norm and planting is expected to be minimal. However, this zone is restricted to 7 percent of the old growth and 3 percent of second growth areas that MB manages.

Part of MB's strategy for maintaining forest health is to retain sufficient quantity of superior seed trees and conduct fill planting with quality stock for maintenance of tree species diversity and genetic quality. These bode well for seedling demand.

In discussions with MB on the impact of their forest plan on seedling demand, it's clear that they do not expect a dramatic reduction in planting. Along with the forest practice changes, MB also closed its own seedling nursery. Many of you will now benefit from being new suppliers for MB.

One thing that characterizes forestry in B.C. is change and adaptation to new challenges. Today that rate of change is even greater than many of us expect. It was only 1992 when I attended the World Environment Conference in Rio where conservation of biological diversity was promulgated as a noble goal for the world.

While most of the countries in the world are still talking about protecting biodiversity we are dealing with it practically on the ground. I'd like to take a few minutes to highlight some of the planning at a landscape level we are carrying out now in some parts of our tenures.

The Ingram Lake area is about 500 km north of Vancouver on the central Coast. We are building road right now after years of planning and consultation with First Nations. Operations are guided by a Total Resource Plan for this relatively undisturbed 14,000 hectare watershed. The TRP has many purposes and fits into B.C.'s planning hierarchy but it is not a requirement of the Forest Practices Code.

We inventory and assess all resource values and develop management strategies for each of 5 important resources. Less than 30 percent is operable forest with an equal amount of inoperable forest due to environmental and economic restrictions. The harvest plan and schedule identifies all roads and cut blocks for all the operable timber to be harvested over the next 40 – 60 years. Only 18 percent of the total forest will be harvested over the next 30 years.

The biodiversity analysis includes a careful assessment of the various stages of the forest over time. Of course we predicate the protection of species on the basis of their preferred habitat. This type of planning is world class and uses very sophisticated modeling supported by leading edge GIS systems and skilled planning foresters.

The forest industry operates mostly on crown land in B.C. and any policies that affect public lands will affect us. The recent Nisga'a treaty settlement and treaties in general will have an impact on our access to timber. However WFP and most of industry support the treaty process and the certainty it will bring to land use and ownership.

WFP operates in 30 traditional First Nations territories along the coast and we are working hard to maintain good relations with all Bands. Under existing legislation, policy and emerging local cases we and government must consult before development occurs. First Nations have the right to object but not approve our forestry programs.

We are proceeding with capacity building with Bands who wish to become involved in all aspects of forestry. We have a number of cooperative ventures and these will expand. We currently reserve up to 25 percent of our silvicultural contracting for First Nations contractors.

The Nisga'a agreement has a few shortcomings for industry, specifically the compensation issue related to licenses that will be canceled over the next decade. However, the main elements of the agreement make sense and do not cause us undue concern.

We can only dream, however, to see a few more clauses added which would comfort all of us in British Columbia. Giving up our current crop of local politicians would make a lot of us very happy.

More changes I foresee that will affect you in terms of stock needs related to the Forest Practices Code, quicker greenup including the use of vegetative propagules, cuttings and somatic specialty stock. There will be no reduction for improved genetic material. Currently a relatively high percentage of cut blocks on the coast are replanted with several species and I do not see any reduction in that need as prescriptions become even more sophisticated than now. The last few years of sowing requests in the Vancouver Region show a high degree of stability in terms of species mixes with an emphasis on red cedar, Douglas fir and western hemlock.

The expectations of the forest industry have not changed in the past 20 years with respect to your performance. We need quality and we need it at a reasonable price. While planting costs continue to escalate, seedling costs have been reasonably stable and the efficiencies of large scale production are benefitting both of us.

I want to compliment all of you for the continued improvement in the quality of planting stock we are receiving today compared to a decade ago. It's clear that the quality control you put in place along with our careful stock assessments are really positive. I suspect some of these kudos must also go to your Association which provides an excellent forum for sharing ideas for improvement.

Before I finish, a few words of congratulations are in order to one of your long time members who is retiring this month. Seen here on one of many enjoyable fishing trips, Charlie Johnson has been a major player in your association and the reforestation industry across western Canada. Charlie and his company, Pacific Regeneration, developed the privatized B.C. Government nurseries into an efficient, effective organization, leading in seedling production in B.C. Earlier in his career with the government as a Professional Forester in charge of B.C. Silviculture, Charlie has left a legacy in making silviculture a government and public priority. We wish Charlie and Sue a well deserved retirement.

FOREST NURSERY INDUSTRY: NOW AND THE FUTURE[1]

James A. Bryan[2]

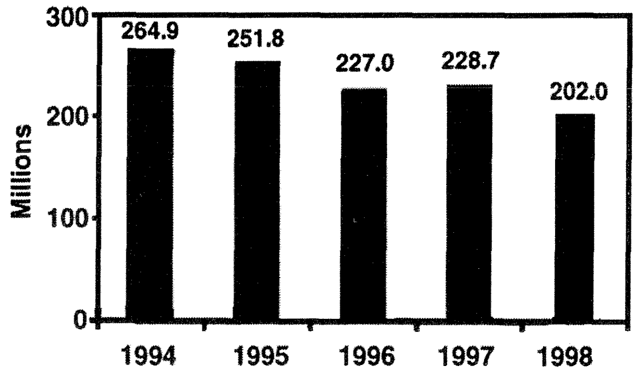
ABSTRACT—*British Columbia, Oregon and Washington have all experienced a similar decline in the seedling market in recent years. This decline has led to stiffening of competition throughout the whole region. This decline in the market will likely stabilize at current levels with only short-term cyclic changes. During this same period, nursery managers throughout the region have experienced an increasing emphasis on seedling quality and customer service.*

The future will bring about numerous changes as we move toward increased deployment of genetically improved material in the region. As this deployment increases, we will also see increased use of advanced technologies in vegetative propagation as we strive to bulk up high-value family and clonal material. The future may also bring an increased use of large container seedlings in the Pacific Northwest as we are challenged to shorten the time required to achieve plantation establishment and improved utilization of genetically improved seed.

RECENT HISTORY

For many years, the nursery industry had remained relatively stable. The annual volumes and stock types seemed to change very little. In the coastal areas of Washington and Oregon bareroot seedlings were the primary planting stock. The competition from brush and browse from wildlife required a large sturdy seedling to withstand the environment following outplanting.

In British Columbia, the bareroot seedling classes had nearly been eliminated in favor of container grown seedlings. The container seedlings survived and performed better under their conditions. The foresters and nurserymen north and south of the border have had difficulty understanding why each chose the seedlings they did. A lack of understanding of planting site environments and the economics behind the different choices most likely were never fully understood.



(Source: Drew Blazier, BC Ministry of Forests)

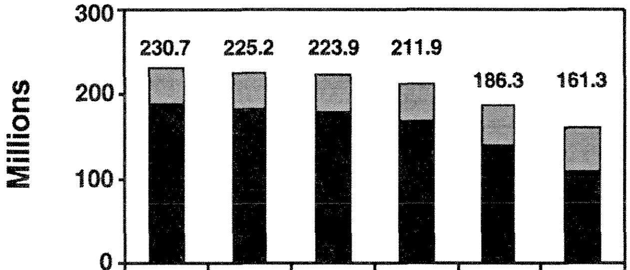
Figure 1—Seedling production in British Columbia.

In recent years, both of our industries underwent major changes. The changes In British Columbia when the nurseries were privatized and the changes in the U.S. Pacific Northwest when the annual harvest levels sharply declined due to changes in the environmental regulations. The spotted owl single handedly (single winged), took on the land managers in both the public and private sectors and I must say the little creature brought about a significant change. The reduction in annual harvest in the Northwest has led to the closure of three large U.S. Forest Service nurseries in the West.

In British Columbia, a decline in demand for nursery stock also occurred during this time frame. A reduction in government funded planting and the down turn in the forest industry have been identified as significant contributing factors. In the last four to five years we experienced a 24 percent reduction in the volume grown for planting in British Columbia, Oregon and Washington. It is interesting that a similar decline occurred on both sides of the border even though different causes have been identified.

Figures 1 and 2 graphically present these trends experienced over the past several years. In figure 1, the data represents the volumes of seedlings sown for planting in BC. The data in figure 2, for the Northwest U.S., covers a slightly longer period going back seven years. Production declined 30 percent over this entire period. In this graph, also note the distribution between bareroot and container seedlings produced in the U.S. Pacific Northwest. Container seedling volumes have increased 10 million while bareroot volumes have declined nearly 80 million.

[1]Bryan, J.A. 1999. Forest nursery industry: now and the future. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 87-90.
[2]Weyerhaeuser Company, 7935 Highway 12 SW, Rochester, WA 98579; TEL: 360/273-5537; FAX: 360/273-6048.



	1990	1991	1992	1993	1995	1997
Container	42.4	43.5	44.7	43.7	46.6	52.5
Bareroot	188.33	181.7	179.2	168.2	139.7	108.8

■ Bareroot ▨ Container

(Source: USDA 1997 Pacific Northwest Directory and Report)

Figure 2—Seedling production in the U.S. Pacific Northwest.

CURRENT SITUATION

With this brief review of the recent past, we are now ready to look at the current status of nurseries in British Columbia, Oregon and Washington.

Customers and Markets

It was interesting to find that our customers; both in Canada and the United States are more alike than different. Our customers on both sides of the border demand high quality seedlings supported by strong customer service that helps them achieve their reforestation goals. While the prices charged for these products and services are still a concern, the price is secondary to seedling survival and performance.

We are all faced with an increasing market for a mixture of diverse species. The industry is no longer growing only the typical reforestation species found in our nurseries just a few years ago. Regulations governing reforestation and the general concern for preserving native plants have greatly expanded the numbers of species we are called on to grow. The species are varied. They range from non-commercial native trees and shrubs to many herbaceous plants and grasses.

Our market demand has likely stabilized for both bareroot and container seedlings in both regions. However, the demand for larger seedlings is increasing in both geographies. Many in western Oregon and Washington have been transitioning to larger stock, especially transplants.

Early in the 1980's, Weyerhaeuser began moving toward 1+1 Douglas-fir as the primary planting stock for our lands. The improved survival and performance we experienced over small 2+0 or container seedlings justified this move. 2+0, the main stock type for many years, was used only in limited quantities by the late 1980's. 2+0's are now a minor seedling type in our system and becoming so in other Northwest nurseries.

Recently, larger container grown stock is gaining favor in Oregon and Washington. Even though the survival of this stock is not significantly improved over transplant bareroot seedlings, there appears to be the potential for improved first year seedling growth due to reduced transplanting shock. The improved first year growth may be a critical factor in helping to meet the Green-Up issues in Western Washington and Oregon. The Green-Up regulations govern the harvest of timber stands adjacent to plantations. Harvest cannot occur until adjoining plantations reach prescribed heights at a specified stocking level. The incentive to reach these target heights quickly can be great. With the many regulations now imposed on landowners, removing this harvest limitation, by achieving the height target quickly, aids in the management of commercial forestlands.

The larger container seedlings, however, add substantially to reforestation costs. In many cases the seedling cost per acre is nearly doubled over large bareroot transplants or other container types. The move toward increasingly larger container sizes has likely peaked due to the economic impact the increased seedling costs have on reforestation costs.

Genetics

We are all seeing rapid increases in the use of genetically improved seed. The seed orchards established in the 1960's and 70's are now fully meeting reforestation requirements for many of the larger organizations. As this seed reaches the nurseries, new challenges are being encountered. The cost of orchard seed is much higher that the field collected seed it replaces. We can no longer afford to solve problems in our growing processes by using large amounts of extra seed to cover losses from disease or lack of growth. Seed to seedling ratios have to be improved. We will never have enough seed or seedlings of the highest value material. Every seed we waste in our nursery growing processes, is one less genetically improved seedling that can be planted in the forest. Another challenge we are finding is individual families may grow differently in the nurseries. These differences will likely require family specific growing practices to optimize quality and yields. Weyerhaeuser and a number of other companies in the U.S. have made the commitment to manage their improved material as single families in order to capture the unique values of different families from the orchard through the nursery and operational stand. In the southeastern U.S. where family management has been a mainstay since the early 1980's, one of the biggest learnings has been the yield efficiency improvement that can come from understanding and managing families in the nursery.

With the many things we currently have in common in the two geographies, there is one major difference, the ownership of the land base. The private sector I represent in the U.S. likely has a different set of economic drivers influencing our decisions. It is interesting to note however; good sound forest management is good business no matter where you are. Renewing our forests is the right thing to do.

FOREST NURSERY IN THE FUTURE
What's coming? Change, Change and More Change!

The customer—We can expect our customers will continue to demand excellent quality and a high level of service for a competitive price. They will be requesting more individualized service to help them achieve their regeneration targets. They will expect continued improvement in seedling quality and early vigorous growth following outplanting. We will need to act more like partners with our seedling customers to jointly work with them to solve reforestation problems.

The market—If we do not experience serious setbacks in our ability to manage our forestlands in the U.S., the market appears to be relatively stable for the future. I anticipate we will experience temporary down cycles throughout the region associated with normal fluctuations in the wood product markets. In the past, to enlarge our businesses, we just expanded to keep pace with an expanding market. This era may have come to an end. In the future, to expand a nursery business will require capturing increased market share by acquiring other facilities along with their customer base or enticing customers away from the competition with better products, services and prices. I expect the competition in the market will encourage innovation in production efficiencies through increased mechanization in handling and processing in an attempt to gain cost competitiveness. In the future, the nursery that can supply the customer's needs will likely prosper. Those that can't adjust to changing customer needs and demands will likely find difficult times ahead. One market segment that appears to have growth potential is the true fir Christmas tree market. Noble fir always seems to be in short supply.

Genetics—In my estimation, the most significant changes we have ahead in the next few years are in the implementation of forest genetics into the nurseries. The deployment of first generation genetically improved seed will become very wide spread. I also anticipate an increase in the nursery growing and possibly planting of individual families. This practice will further enhance the value of forest genetics programs. As you look around the world, you find the most advanced applications of forest genetics are through family or clonal deployment of improved material. You can never fully capture genetic gains unless this step is taken.

Weyerhaeuser's 1st generation seed orchards began producing seed in significant quantities approximately 15 years ago. Nearly 100 percent of our planting stock is from genetically improved seed. In the early 1990's when we began growing and planting by family, we were able to begin identifying family characteristics that were unique. In the future, as these differences are more fully understood, I am sure we will find some of our families will require modifications to the standard growing processes. It is unlikely many families will require special attention, but to maximize the genetic gains from our genetics programs, we will have to understand these differences and be willing to modify our growing processes accordingly.

The introduction of second generation Douglas-fir genetic material will appear shortly. As organizations operating these programs begin to use this seed in their regeneration programs, the amount of 1st generation seed available on the market will increase. Genetically improved seed will then be available to a wider range of land managers in the U.S. Northwest.

To best capture the value potential of genetic programs, vegetative propagation must occur. The highest value family or clonal material will likely be produced with vegetative propagation systems in order to bulk up the volumes available. I anticipate seeing large quantities of seedlings produced using vegetative systems not too distant into the future.

The seedlings—In the future, we will continue to be requested to grow an ever-increasing number of diverse species to meet environmental, regulatory and economic needs. This will be especially true in the government operated nurseries. Container systems may likely prove to be best suited for the production of the numerous native species generally ordered in small quantities and requiring unique cultural practices.

The trend toward large seedlings for reforestation will likely continue in Oregon and Washington due to site preparation restrictions and other planting site considerations. For a number of years into the future, good quality 1+1 seedlings will remain the primary seedling type being planted. With the excellent survival, growth and relatively low cost of this seedling, other stock types will find it hard to displace this seedling class in the market.

Even though 1+1 Douglas-fir will remain the primary seedling type planted, I believe we will see more large container seedlings used in the Pacific Northwest. Where the increased seedling cost can be justified, the larger container seedling will gain popularity. When early outplant vigor, expanded planting windows, better delivery on demand and improved seed efficiency is important; this stock type will increase in use.

SUMMARY
To summarize, we will be facing interesting changes just ahead. The competition for market share will bring about innovation in our nursery processes as we strive to improve quality and service. The production of genetically improved seedlings will require us to be willing to change and customize how we grow our crops in the future. We will likely see new methods for producing trees for planting. The highest value family or clonal material will likely be produced with vegetative propagation systems that have the ability to bulk up small quantities of seed into large numbers of young trees.

For those who like change, the future will hold many exciting adventures.

ACKNOWLEDGEMENTS

I wish to thank the following individuals for providing information used in the preparation of this paper:

Drew Brazier, BC Ministry of Forests
Steve Hutchison, Georgia Pacific
Janet Lane, Weyerhaeuser Co.
Dick Piesch, Weyerhaeuser Co.
Tony Ramirez, Washington State Department of Natural Resources
John Scholtes, USDA Forest Service, J. Herbert Stone Nursery
Mark Thompson, Silver Mountain Nursery
Ev Van Eerden, PRT
Rod Willis, Weyerhaeuser Co.

REFERENCE

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STATUS REPORT OF THE MEXICO CITY METROPOLITAN AREA REFORESTATION PROJECT[1]

Tom Starkey,[2] Peter Germishuizen,[3] and Ignacio Espinosa de los Reyes[4]

INTRODUCTION

Mexico City undeniably ranks as one of the world's largest cities, with a population of at least 19 million (1990 est.). The rapid urbanization coupled with a unique topography of mountains surrounding the metropolitan area has resulted in frequent stagnated polluted air masses over the city. The ring of mountains (two of which exceed 5,000 m) reduces the flow of winds that would otherwise disperse the atmospheric pollution. At an altitude of approximately 2,240 m, the atmosphere of Mexico City contains 23 percent less oxygen than at sea level. This intensifies the pollution problem due to the incomplete combustion of fossil fuels from motor vehicles and industrial activity. Over the last 20 to 30 years, Mexico City has experienced a significant and rapid increase in both population growth and motor vehicle usage.

The impetus for this project began in Mexico with the concern for the air pollution problem. International support to tackle this problem was solicited. The Japanese and Mexican governments finalized a course of action during the early 1990's. During 1996, Sumitomo Corporation, a Japanese corporation, was awarded the bid for the Mexico City Metropolitan Area Reforestation Project. International Forest Company (IFCO), headquartered in Alabama, is part of the team Sumitomo put together to participate in this project. The purpose of this project is to recuperate and restore eroded and deforested areas, as well as establish new green areas, with the purpose of controlling the suspension of dust particles that affect the population of Mexico City, and in general, improve the air quality.

This multifaceted project contracted with the government of Mexico City, and is specifically under the direction of the Comisión de Recursos Naturales (CORENA). This project includes the following facets:

1. establishment of a Forest Operations Center which will include a technical training center, a center for prevention and control of forest fires and a laboratory;
2. repair of existing and construction of new look-out towers for forest protection;
3. repair and construction of forest roads;
4. expansion of a radio communication system
5. and establishment of a tree seed processing center, laboratory, and containerized nursery complex.

The project area is south of Mexico City and north of Cuernavaca, covering more than 132,000 ha. The project area falls within 3 governmental jurisdictions: Federal District, State of Mexico, and State of Morelos. These jurisdictions jointly agreed that this project area was in urgent need of tree cover. The eastern edge of the project area is bordered by two well-known volcanoes, Iztaccíhuatl (Sleeping Lady) and Popocatépetl (Popo). These volcanoes exceed 5,200 meters in elevation. The topography of the project area as a whole is very mountainous. The average annual rainfall is above 1000 mm per year, with most of the rain coming in the months of June through September. At the nursery site, which is located on the northern edge of the project area, the average annual rainfall is about 725 mm per year.

Sumitomo Corporation subcontracted the responsibility to provide the technology necessary for the administration, operation and maintenance of the Seed Processing Facility and Container Nursery Complex to International Forest Company, it's subsidiary, International Forest Seed Company de México, in conjunction with Especies Forestales SA de CV. The production area of the nursery is designed for an annual production of 30 million trees. During IFCO's contract period, nine million seedlings will be grown and shipped during the first year of operation, 1997-1998. During the second year of operation, 1998-1999, 13.5 million seedlings will be grown and shipped. IFCO's contractual responsibility for the seedlings ends at the nursery gate. At the end of the project 5000 kg of seed must be left in storage for future use. A theoretical and practical training program must be implemented to train the professional and technical personnel of CORENA to enable them to take over operation of the nursery complex at end of the contract period. Seedling trials are established on a regular basis, in an effort to increase knowledge about the species being grown in the nursery.

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[1]Starkey, T.; Germishuizen, P.; de los Reyes, I.E. 1999. Status report of the Mexico City metropolitan area reforestation project. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 91-95.

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Especies Forestales, is a subcontractor to IFCO and also their Mexican partner. Their responsibility is the daily operation of the seed plant and nursery, providing and managing the necessary labor and the purchase of all materials.

FACILITIES

Cone and Seed Processing Facility

A 48 tray recirculating dry kiln was built and provided for the project by International Forest Company. In addition, the cone processing area also has a cone tumbler for separating the seed from the cones, storage hoppers, conveyor belts, a hammermill and a circulating head forklift. In the seed processing area, BCC, Sweden has provided a Rotating Drum dewinger, seed cleaning and sizing equipment and gravity separators. Seed is dried in a specially constructed room in which the air is recirculated and dried. Processed seed is stored in refrigeration units at below freezing temperatures.

Seed Laboratory Facility

The seed laboratory is connected to the seed processing facilities. All the necessary equipment to conduct standard tree seed test such as purity, moisture, seeds per kilogram, x-ray, and germination tests have been provided. Two large walk-in Convirons growth chambers are part of the laboratory facilities. One is used for stratification, the other for seed germination tests.

Water Treatment Facility

This facility located adjacent to the nursery complex provides irrigation water for the trees. Sumitomo Corp. is responsible for the operation and maintenance of this complex. Treated water is received from the government operated water/sewage treatment plant. This water is filtered, retreated and passed through a reverse osmosis process before it is stored in one two large covered cement cisterns (each 1920 m^3) for use in the nursery. The plant has a capacity to process up to 500 m^3 per day of treated water.

Media Mixing and Filling Facilities

A 2000 m^2 open sided building adjacent to the substrate building is provided for the storage of bulk raw materials required for sowing. The substrate building which houses the media mixing equipment, filling lines and container washers has approximately 1900 m^2. A four storage hopper continuous feed, on-demand, media mixer supplied by Bouldin & Lawson, McMinnville, TN. feeds a dual line container filling unit, automatic seeder and capper supplied by BCC, Sweden.

A peat-based media is being used in this project. The exact composition of the growing media is proprietary.

The containers being used in this project were supplied by BCC. The HIKO trays being used are non side-slit 93cc capacity cavity (40 cavities per tray), 310 cc capacity cavity (15 cavities per tray) and 530 cc capacity cavity (15 cavities per tray). By contract agreement, up to 80 percent of all seedlings produced are being grown in the 93 cc containers.

Containers are placed on plastic pallets on the production pads. Each pallet holds ten containers and can efficiently be moved by two individuals. The pallets are supplied by BCC.

Nursery Production Areas

The nursery is divided into 8 uncovered production units. One production supervisor can manage each unit. Each production unit has 6 container pads for growing. These container pads are each approximately 2000 m^2. Each production unit is grouped around a work shed and packing area with 3 container pads on either side. In total, there is 96,000 m^2 of growing space available for production, excluding the greenhouse.

Each container pad is irrigated with a traveling irrigation boom that rolls on rails on the ground. The irrigation boom system was supplied by BCC. The irrigation nozzles being used are TeeJet standard flat spray tip. Each production unit has two, two-headed Smith 1:200 R8 Measuremix Injectors located in the unit's work shed.

Shade cloth supports, locally designed for the project, are compatible with the BCC plastic pallets. The shade cloth used is a white 30 percent Ludvig Svensson thermo screen. This shade cloth is designed for use during the sensitive period of germination and can also be used to provide protection at times of high frost risk.

Additional Facilities

The nursery complex also includes a set of offices with a connecting laboratory. The laboratory is equipped with microscopes, centrifuge, distilled water unit, oven, autoclave and basic laboratory supplies.

A 360 m^2 building is provided for the storage of fertilizers and chemicals.

A greenhouse, with approximately 1,400 m^2 utilizable area, was supplied through BCC. The polycarbonate-covered greenhouse is equipped with cooling pads, floor heating, automatic vented roof and automatic shade cloth covering. Three booms provide irrigation within the greenhouse.

ACTIVITIES

Cone Prospection, Collection and Species Selection Activities

Mexico has the greatest number of pine species (including varieties and forms) of any country in the world. Pines are the most economically important timber species in Mexico and Central America. The large number of species has made the field identification of some species confusing, academic and at times mystical.

Cone prospection begins in the in late spring and the summer months. The species selected for the nursery are those requested by CORENA (table 1). The guidelines for the project dictate that the species grown in the nursery should, if at all possible, be those species indigenous to the project area. Personnel from the Seed Operation visit numerous natural stands of trees and make an evaluation of the stands cone bearing potential. At each site that shows good potential, data on the site is collected and placed in a computerized database for future reference. Also, on private land, prior agreements must be obtained for collection of cones.

Project personnel conduct cone collection for the majority of the species. Cones are collected from September until March. The cone harvest crews climb previously selected trees using spikes and ropes. Most cones are removed using pole hooks/ pruning heads. Tree climbing bicycles and sectional ladders are available if needed. Cones are collected in polypropylene bags. These bags are tagged and identified with a ten-digit number unique to the specific collection site, altitude, aspect, season and species. This identification number follows the seed and seedlings throughout the nursery period to outplanting.

For one species, *Pinus ayacahuite*, contracts for collection by local community groups, (ejidos) have been used. In several other cases, contracts with other national seed companies have been used to provide seed that is either outside the project area or not economically feasible for collection by the nursery personnel.

Cone, seed and laboratory activities—Cones and seeds are processed from early October until March. The cones are stored outside in polypropylene bags until ready for processing. The identification code is attached to each bag.

The seed lab conducts routine tests of the seed as part of the overall processing activities. International rules of testing are followed.

Seed required by the nursery for sowing is treated and stratified in the seed processing facilities.

Seedling production and development—For the first season, sowing began in August 1997. With experience, we feel that for most species an additional month of growing time is required. This extra time was needed not only to bring the seedlings to the necessary quality standards, but also to provide sufficient time to harden off the seedlings prior to shipping. Shipping season occurs during the rainy season. It is, therefore, very difficult to harden off seedlings by withholding water once the rainy season arrives.

The first growing season contributed a lot to our general knowledge of the species. Relatively little was known about the seed and seedlings of some of these species, for example *P.hartwegii* and *P.rudis.* Even less was known about the necessary growing requirements of the species, especially in a peat-based media and growing containers. The majority of the seedlings being grown in Mexican nurseries are grown in black plastic bags using a growing media predominately composed of forest soil.

The winter months gave us a set of unusual, but typical conditions for the valley of Mexico. The average minimum temperature from December through the middle of February was 1° C and the average maximum temperature was 25° C.

Table 1—Requested species for the Mexico City metropolitan area reforestation project and proportion of seedlings by species for the first growing season (1998), second growing season (1999) and the seed to be left in storage with the project in August 1999

	Seedlings 1998	Cavities to be sown for 1999 seedlings[a]	Proposed seed remaining at end of project[b]
			kg
Pinus ayacahuite	1,542,000	2,380,000	2,400
Pinus cembroides	0	300,000	1,000
Pinus greggii	0	463,094	80
Pinus hartwegii	1,230,000	1,985,198	225
Pinus leiophylla	437,000	841,720	35
Pinus michoacana	114,000	358,440	300
Pinus montezumae	1,855,000	2,386,726	250
Pinus patula	1,468,000	1,732,280	180
Pinus pseudostrobus	722,000	1,371,000	150
Pinus rudis	0	733,758	20
Pinus teocote	115,000	220,600	35
Abies religiosa	82,000	350,000	200
Cupressus lindleyii	1,193,000	1,441,204	75
Quercus spp.	200,000	300,000	0
Alnus firmifolia	225,000	451,945	20
Liquidambar styraciflua	0	33,750	0
Salix bompladiana	0	60,000	0
Total	9,183,000	15,409,715	5,000

[a]Seedling requirement for 1999 is 13.5 million.
[b] These amount of seeds represents a potential of 75-100 million seedlings singly sown. The actual number, of course, will depend upon the percentage seed germination and number of seeds sown per cavity.

The extremes during this time were -7° C to 30° C. The warm temperature were very well suited for growth, however, the cold evening temperatures were potentially damaging. We had a difficult time trying to maintain the growth of the seedling, avoiding succulent growth and stopping the plant from going dormant.

Additionally, during the spring when you expect rapid growth, the seedlings did not respond as we expected. For almost 6 weeks, extensive burning of agricultural lands and forests provided the nursery with an almost daily layer of smoke that precluded the sun from clear view for quite a number of hours each day. This had the effect of decreasing the quantity of radiant energy.

For the second season, we began sowing the first of July 1998. The goal during the second season is to have the seedlings to the quality height and root collar diameter (RCD) standards early enough to allow sufficient time to harden off the seedlings before the rainy season begins.

A significant problem experienced during the first growing season was an abnormal growth of moss on the surface of the seedlings. During this season, fine vermiculite was used as a seed covering after sowing. Since most of our sowing took place during the rainy season, it was virtually impossible to control the amount of moisture in the plug. Very early in the sowing process, we noticed a film of algae on the surface of the media. By the end of the rainy season, moss had begun to form and its growth went unchecked.

One of the production experiments in the area of seedling trials was to evaluate the covering material (capping material) and moss growth. Materials such as vermiculite, fine sand, two grades of fine pebbles and tezontle (crushed and screened volcanic rock) were evaluated. As a result of this study, tezontle is being used during the second season. In addition, an algaecide is also being applied.

We also experienced difficulties with seedling density. Although the 93 cc container was ideal for most species (526 seedlings per m^2), we experienced problems with *P.leiophylla, P.pseudostrobus, P.patula, Alnus firmifolia* and *Quercus.* The growth habits of these species presented difficulty in allowing sufficient irrigation water to penetrate the foliage and reach the cavity. These species might have performed better at a lower population density using the HIKO cavity size of 150 cc (316 seedlings per m^2).

It was necessary to top prune all the non-grass stage species of conifers and the hardwoods. This was done to control the height growth, help in lignificiation and prepare the seedlings for shipment to the field. Excellent plant response was obtained when the trees were pruned with sufficient time before shipping.

Table 1 shows the distribution of seedlings by species for the first growing season and estimates of the distribution for the second season. In addition, it also presents a proposed distribution of seed in the 5000 kg of seed that will be left in storage at the end of the contract period of two years.

The shipping of the seedlings coincide with the limited rainy season. The project was originally designed to extract the seedlings from the containers and package them in a box for shipment to the field. However, CORENA requested that the seedlings be shipped to the planting sites in containers. Orders for seedlings are placed one week prior to shipment. CORENA provides the trucks that are loaded with individual containers, generally in three layers. A typical truck will hold about 18,000 seedlings in 93 cc containers and 7,000 seedlings in 310 cc containers.

Once delivered to a central area, the seedlings are either extracted and placed in planting bags or more commonly, the container are taken directly to the field by the community group which has been contracted to do the planting in that area. Planting tools consist of hoes, and round and square tipped shovels.

The authors visited a mountainous area site three weeks after planting. The seedlings were in excellent condition with new active white roots growing out of the root ball of both *P. montezumae* and *C. lindleyii.* New top growth was present in the *C. lindleyii.*

Seedling trials—In an effort to expand the available database of information for this nursery, seedling trials are conducted on a regular basis during the course of the contract period. These projects are designed to provide information that can be utilized within the nursery.

Technology transfer—CORENA considers the training program to be of prime importance. The goal of this program is to train the professional and technical nursery staff of CORENA to assume full responsibility of the nursery and seed plant at the close of the contract period in August of 1999.

The training program is a combination of both theoretical classroom training and hands-on practical training. Initially, the theoretical and practical were divided approximately equally. During the first six months of training, a total of 32 days of actual training was conducted. Recently, a switch has been made to have 20 percent of the session theoretical and 80 percent hands-on training.

The training covers all aspects of IFCO's project responsibilities. The theoretical sessions are arranged to coincide with an on going activity in the seed section or the nursery. The classroom sessions can last up to five hours. Extensive handouts are provided to the students and must be submitted in both Spanish and English.

The practical sessions are designed to provide actual on-the-job training to the students. IFCO requested that the students actually participate in all activities rather than observe and take notes.

Tests and other forms of evaluation are used to monitor the progress of the students.

SUMMARY

This project is a bold step for the Mexican government, Sumitomo Corporation, International Forest Company and Especies Forestales. To our knowledge, this is the largest nursery (potentially 30 million trees) of its type in the world where 100 percent of the trees produced are directed to an environmental effort of this type.

Certain aspects of the project, has been a learning experience for all participating parties. There are significant differences between black-plastic bag nurseries, which are very typical in Mexico, and this nursery, utilizing a different container and a peat-based media. A great deal of the published information on Mexican species has not been as useful as needed. This project will hopefully provide information, technology and models for future nurseries of this type in Mexico and Central America.

We have nearly completed the cycle of the first growing season. In general the seedling quality is very good. There are a number of items that have been and will be modified in the second growing season to insure quality improvements in all facets of production.

GREENHOUSE GAS EMISSION REDUCTION TRADING PILOT[1]

Warren Bell[2]

INTRODUCTION

Climate change is one of the most challenging environmental, economic and social issues facing the world today. In an effort to reduce the risk of future climate change, Canada and more than 150 countries reached agreement in December of 1997, on the Kyoto Protocol, which sets binding limits on greenhouse gas (GHG) emissions from industrialized countries.

Canada's target is to achieve, by 2008-2012, a reduction in average annual GHG emissions to 6 percent below 1990 levels. Canadian governments, industry, and environmental groups are searching for flexible and innovative ways to cut greenhouse gas emissions while maintaining a healthy economy and standard of living.

Emission reduction trading is one possible approach. An emission reduction trading system provides industry, governments and other organizations with the opportunity to buy and sell emission reductions. By encouraging investment in lower-cost reductions, this approach has the potential to help Canada meet GHG reduction targets at a reduced overall cost. Whether or not this concept can help solve the climate change dilemma will depend in part on the success of an innovative Canadian experiment launched in June of this year.

The Greenhouse Gas Emission Reduction Trading Pilot (GERT) is a partnership of the federal government, several provinces, industry, environmental organizations and labour groups. It is designed to test the mechanics of a trading system where organizations can buy and sell credits for emission reductions, potentially laying the groundwork for a future full-scale trading regime.

WHAT IS GREENHOUSE GAS EMISSION REDUCTION TRADING?

Emission reduction trading (ERT) is one of two basic approaches to emission trading, the other being allowance-based.

In an allowance or permit-based system, regulatory authorities issue permits to emit pollutants. Sources needing permits can buy them from other sources who are able to reduce their emissions at a cost less than the market price for permits.

In an emission reduction trading system (sometimes called a "baseline and credit" system), tradable credits are created by:

- defining a project- or site-specific baseline
- implementing a specific emission reduction activity,
- monitoring, documenting and verifying results

These credits can then be sold, banked or used to comply with regulatory requirements.

Consider the following example involving a cement plant and a municipal government:

The cement manufacturing process generates large quantities of greenhouse gas emissions that would be very expensive to reduce. The municipality, on the other hand, has an opportunity to capture methane emissions from its landfill and use this greenhouse gas to generate electricity. However, the municipality can't provide the up-front investment that this environmentally-friendly initiative would require. So the two organizations strike a deal: the cement company agrees to finance the landfill project in return for receiving the credit for the municipality's emission reduction.

The Kyoto Protocol contains both kinds of emission trading: allowance trading between Annex 1 Parties, and emission reduction credit- or project-based trading between Annex 1 (Joint Implementation) and non-Annex 1 Parties (Clean Development Mechanism).

While there are differences between emission trading systems, they all share a common trait - they make it profitable for firms to invest in and sell low-cost emission reductions. Organizations that have lower cost options for reducing emissions gain a financial incentive to take action while companies that would otherwise pay a high price for reducing their own emissions can take the credit. Our atmosphere benefits regardless of where or how the reduction occurs. By putting a market value on emission reduction, ERT and other forms of trading offer the potential to significantly reduce the overall cost of meeting reduction targets.

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[1]Bell, W. 1999. Greenhouse gas emission reduction trading pilot. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 96-98.
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THE GERT PILOT

This pilot has been under development for several years. A key element of BC's 1995 Greenhouse Gas Action Plan was the development, in cooperation with industry, of a GHG offset trading pilot. In 1996 the BC government, Environment Canada and the Greater Vancouver Regional District funded a design study for the pilot - released in March 1997. In November 1997, BC Environment Minister Cathy McGregor announced the pilot at a meeting on climate change with her energy and environment colleagues from across Canada.

A number of government and nongovernment partners have joined us in the development of the pilot. By the time the pilot was formally launched on June 3, the partners in this multi-stakeholder initiative included:

Government Partners

Alberta Department of Energy/Alberta Department of Environmental Protection
BC Ministry of Energy and Mines
BC Ministry of Environment, Lands and Parks
Environment Canada
Greater Vancouver Regional District
Natural Resources Canada
Nova Scotia Natural Resources
Quebec Ministry of Natural Resources
Saskatchewan Energy and Mines

Non Government Partners

BC Federation of Labour/Canadian Labour Congress
Canadian Association of Petroleum Producers
Canadian Electricity Association
Canadian Gas Association
Canadian Energy Pipeline Association
Canada's Climate Change Voluntary Challenge and Registry Inc.
Canadian Pulp and Paper Association
Canadian Wind Energy Association
Greenhouse Gas Emissions Management Consortium
Pembina Institute for Appropriate Development
West Coast Environmental Law Association

Objectives of the Pilot

The objectives of the Pilot include the following:

- Understand, evaluate and communicate the potential role of emission reduction trading.
- Develop approaches, tools, methodologies that would be required to support a functioning market for emission reduction credits.
- Provide practical experience with trading for all participants: partners, buyers, sellers.

Structure of the Pilot

There are 5 key elements of the pilot:

1. The development of rules for: determining the eligibility of trades for acceptance by the pilot, evaluation criteria standard methodologies and approaches for defining and measuring emission reductions.
2. The evaluation of trades and projects by a multi-stakeholder Technical Committee comprised of representatives of the pilot partners.
3. The registration on a public web site of trades and emission reductions reviewed by the pilot.
4. Recognition of reductions achieved through trades registered in the pilot as early progress towards the requirements of possible future trading regimes.
5. Evaluation of lessons learned from the pilot about the potential role of emission reduction trading.

Recognition is a key element of the Pilot. At the present time, there are no regulatory limits on greenhouse gas emissions nor a market in which to trade reductions or credits. At the outset of the Pilot we recognized that there would have to be some incentive for buyers and sellers to participate, beyond the opportunity to gain practical experience. Consequently, the government partners in the Pilot have signed an MOU agreeing "recognize emission reductions from trades registered under the Pilot as progress toward possible compliance obligations in the context of any future greenhouse gas trading regime." In other words, reductions made now may be counted towards future regulatory requirements, making them a potentially profitable investment and an incentive to participate in the Pilot.

Eligibility Requirements

Emission reduction projects eligible for the pilot can be located anywhere, but either the buyer or the seller must be Canadian. If the project is located outside of Canada, the buyer must report the reduction only in Canada. As well, if either the buyer or seller is outside the country, use of the emission reduction for compliance purposes will depend on future international trading agreements signed by Canada.

Projects must also have started generating emission reductions after January 1, 1997.

Emission reductions can be generated by projects that:

- reduce emissions (e.g. through fuel-switching or upgrading energy efficiency of equipment)
- avoid increases in emissions that would otherwise have occurred (e.g. by using renewable energy or less carbon-intensive technologies); or
- absorb or sequester emissions (e.g. by managed forests or underground reservoirs)

REVIEW CRITERIA

The multi-stakeholder Technical Committee reviews projects and trades to evaluate whether:

- the project results in actual emission reductions from a baseline,
- the emission reductions are measurable and verifiable, and
- the reductions are over and above what is required by law.

Trades and projects will also be assessed in terms of the extent to which they can show that reductions are in

addition to what would otherwise occur. The principle of additionality is important - we all want to ensure that we are getting emission reductions that would otherwise not have occurred, but it is also clearly very difficult to demonstrate additionality. Consequently, while the Technical Committee will be reviewing additionality, projects will not be rejected if they are unable to demonstrate additionality.

POTENTIAL BENEFITS

The GERT Pilot offers a number of potential environmental, economic and social benefits for Canada.

The GERT Pilot will provide practical experience with all aspects of GHG emission reduction trading. This will better position participants to contribute to the development of possible full scale GHG trading programs in the future.

Emission trading offers, at least in principle, the potential benefit of lowering the economic and social costs of meeting Canada's GHG targets. The reality of course will depend on many factors, including system design. The experience gained through the Pilot will help in the design of future trading programs.

For sellers of emission reductions, the Pilot provides a forum for showcasing innovative GHG reduction technologies, as well as providing investors with an additional source of funding for projects.

For the immediate future, buyers can use emission reductions to meet their own voluntary GHG reduction targets at lower cost. For example, companies and municipalities can include Pilot trades as part of their action plans registered with the national Voluntary Challenge and Registry Program (VCR Program).

In the longer term, the government partners will recognize emission reductions from trades registered under the Pilot as progress towards possible compliance obligations in the context of any future greenhouse gas trading regime.

CURRENT STATUS/PROJECTS UNDER REVIEW

As of August 31, the GERT Pilot has posted one offer to sell and one trade-matched application. The emission reductions offered for sale are from a fuel-switching project at a BC sawmill. The mill's wood drying kilns are being converted from propane to gasified wood residue. The trade-matched application involves the purchase by the federal government of electricity generated by wind power in Alberta, and the associated emission reductions. The trade-matched application is currently under review by the Pilot Technical Committee.

Other trades/projects that we expect to be submitted to the Pilot in the next few months involve:

- landfill gas utilization
- replacement of oil-fired electricity generation with small hydro, and
- super-energy efficient buildings.

We would also welcome the opportunity to review a forest carbon sequestration project.

The Pilot is currently scheduled to run for 18 months and will accept trades/projects until December 31, 1999.

ADDITIONAL INFORMATION

Additional information is available at the GERT Pilot Web site at http://www.gert.org

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"SISTER" NURSERIES: A PERSON-TO-PERSON APPROACH TO TECHNOLOGY TRANSFER[1]

Raúl Moreno,[2] Thomas D. Landis,[3] and Patricia Negreros-Castillo[4]

Most people have heard of the Sister City program where cities in two different countries agree to a cultural exchange to promote mutual understanding. But, how about a Sister Nursery? Tom and Raúl have worked on several nursery projects in Mexico over the past several years but became increasingly discouraged by the steadily decreasing governmental funding and layers of bureaucracy. So, they came up with the idea of a more direct one-on-one program in which nurseries in the USA or Canada could give technical and financial assistance to nurseries in other parts of the world.

Figure 1—The Sister Nursery concept was born during visits to the Yucatan Peninsula of Mexico.

HOW WE GOT INVOLVED

Back in 1992, the USDA Forest Service and the Secretaria de Recursos Hidraulicos (SARH) of the Mexican government signed a Memorandum of Understanding (MOU). Under the MOU, Working Groups (WG) consisting of teams of US and Mexican foresters worked together on projects in Mexico. Tom and Raúl were part of the Forest Plantations WG and they spent several weeks in the spring of 1994 visiting nurseries and plantations across Mexico (fig. 1).

The WG also agreed upon long-range and short-range objectives. One of the long-range objectives was to teach a series of nursery and reforestation training sessions at five locations across the different forest regions of Mexico. The first of these training sessions was held in the summer of 1994 when a 3-week Nursery and Reforestation Training Course was taught by the Center for the Reforestation of the Americas (CEFORA). We didn't know it at the time but this was the financial high point because, unfortunately, WG funding began to decline precipitously in subsequent years. As a result, the remaining training sessions were never scheduled although some field work was done from 1995 to 1998 (table 1).

THE BIRTH OF THE SISTER NURSERY CONCEPT

During a tour of nurseries in the Yucatan peninsula, Tom and Raúl met Patricia, who had been doing forestry research in the area for many years. One of her studies was with some local nurseries and she did a survey of reforestation survival. To her dismay, she found seedling survival rates of as low as 18 percent and so she wanted to learn how to help improve outplanting performance.

One of the groups that Patricia was working with was the Organization of the Forest Ejidos of the Mayan Zone (OEPFZM) which manages over 250,000 ha. (620,000 acres) of dry tropical forests in the Yucatan region. "Ejidos" are communal organizations which own most of the forest land in Mexico and many are composed of indigenous people working to improve their economic self sufficiency. The semi-tropical forests of the OEPFZM contain several native trees such as Honduras mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata*) which are highly prized for their beautiful high-quality wood. Unfortunately, these species have historically been severely overcut and very few large trees survive in the forest. The OEPFZM is working to establish sustainable harvests of these two valuable timber species and, at the same time, enhance the biodiversity of the remaining tropical forest. When we began working with them, the OEPFZM had just established the Chulul nursery in the town of Felipe Carrillo Puerto where mahogany and Spanish cedar seedlings are grown to implement their enrichment planting programs in the jungle of the surrounding communities.

One of the results of the Nursery and Reforestation Training Session was that we found out that Mexico did not have a established system for monitoring outplanting success. So, using funds from the Forest Plantations WG, CEFORA

[1]Moreno, R.; Landis, T.D.; Negreros-Castillo, P. 1999. "Sister" nurseries: a person-to-person approach to technology transfer. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 99-101.
[2]Microseed Nursery, P.O. Box 35, Ridgefield, WA 98642 TEL: 360/887-4477, FAX: 360/887-3721, E-MAIL: microseed@aol.com.
[3]USDA Forest Service, CP, PO Box 3623, Portland, OR 97208-3623 TEL: 503/808-2344, FAX: 503/808-2344, E-MAIL: nurseries@aol.com.
[4]Iowa State University, Dept. of Forestry, 253 Bessey Hall, Ames, IA 50011-1021 TEL: 515/294-1458, FAX: 515/294-2995, E-MAIL: pnc@iastate.edu.

Table 1—Funding for The Forest Plantations Working Group was supplied by the International Forestry Branch of the USDA Forest Service

Fiscal year	Funding	Purpose and location of projects
1994	$140,000	Teach nursery and reforestation training course in Morelia, Michoacan
1995	40,000	Establish outplanting trials in Federal District, the State of Mexico, and the State of Quintana Roo
1996	15,000	Monitor outplanting trials and establish nursery trials in Quintana Roo
1998	7,500	Continue monitoring nursery and outplanting trials

foresters began a series of nursery and outplanting trials in 1995 including some on OEPFZM lands (table 1). Crops of mahogany and Spanish cedar seedlings were grown at the local Instituto Nacional de Investigaciones Forestales y Agropecuria (INIFAP) nursery to test the effects of fertilization and outplanting technique. Height and root collar diameter measurements taken at the time of harvest showed little positive effect on either species. Of course, the true test of seedling performance is after outplanting so samples of these seedlings were outplanted to test survival and growth. The outplantings were measured at 8 and 28 months of age and results are very encouraging for the Mahogany seedlings grown under improved polybag culture. The results Spanish cedar bareroot stock were disappointing, however, and it may be best to grow this species in containers in the future. Survival of the fertilized mahogany seedlings averaged around 80 percent which is a four-fold increase over those of Patricia's initial survey. Subsequent seedling growth has been phenomenal with the fertilized mahogany seedlings averaging over 8 feet and almost 20 mm in diameter after only 2 years (table 2). These results vividly demonstrate the tremendous growth potential of the ejido forest lands.

The ejido workers have traditionally used long sharpened poles to dig holes to plant their seedlings in the jungle. Another trial involved testing several outplanting tools from the US as well as a modified metal blade (a "talacho") that fit on the end of a pole. The results of these tests showed that the talacho was the best and also the most inexpensive. The talacho made it easy to cut through the mesh of roots and remove the numerous rocks in the jungle soil while digging a hole deep enough to avoid root deformation.

But, US government funding continued to decrease in spite of these positive results (table 1). Because they wanted to continue working with the Chulul nursery, Tom and Raúl came up with the idea of an informal person-to-person relationship that would not rely on government sponsorship

Table 2—Preliminary results of nursery and outplanting experiments with mahogany and Spanish cedar seedlings in southern Quintana Roo, Mexico (Mexal 1998)

			Survival		Height			Diameter		
Species	Stock type	Treatment	8 mo	28 mo	Initial	8 mo	28 mo	Initial	8 mo	28 mo
			- - - % - - -		- - - - - cm (ft) - - - -			- - - - - mm - - - - - -		
Mahogany	Polybag	Fertilized	80	75	43 (1.4)	75 (2.5)	246 (8.1)	5	16	19
Mahogany	Polybag	Unfertilized	85	85	41 (1.3)	56 (1.8)	192 (6.3)	5	11	12
Cedar	Bareroot	Fertilized	55	10	19 (0.6)	14 (0.5)	43 (1.4)	3	6	6
Cedar	Bareroot	Unfertilized	25	10	22 (0.7)	18 (0.6)	37 (1.2)	3	7	9

Table 3—An initial donation of $1,000 from Microseed nursery helped accomplish a considerable amount of work at the nursery and on the outplanting sites

Amount of "seed money" US	NP	Expenditures at the Chulul Sister Nursery, QR MEXICO
$437.50	$3500.00	Purchase of water for the 1998 growing season (the well pump was broken)
$237.50	$1900.00	Labor for nursery work, outplanting, and installation of test plots
$125.53	$1004.30	Transportation (gasoline and bus tickets) to the nursery and outplanting sites
$100.00	$800.00	Meals for students while doing research work
$47.09	$376.75	Tools and supplies

or funding. And so, the Sister Nursery concept was born. Interestingly enough, "sister nursery" translates to vivero hermano ("brother nursery") in Spanish because the gender of the modifier must agree with the noun.

Sister Nursery Projects

There was no shortage of ideas for technical assistance. Copper-coated polybags have improved root morphology with other species in Mexico and so some operational trials were set-up in the Chulul nursery in 1998. Another exciting possibility was using copper landscape cloth as a root growth barrier under polybags and under the traditional raised bareroot seedbeds. Other ideas include developing a compost-based growing media, and improving the method of harvesting and transporting of seedlings to the field. As you can see, there are plenty of possibilities.

In addition to technical assistance, we wanted to provide financial help to the Chulul nursery which could be used for both practical research as well as day-to-day nursery production. To give you an idea of how far a small contribution can go, consider that a day's wages for a nursery worker is about 25 pesos (US$3.00), and a kilo of poly bags costs 17 pesos ($ 2.09). Raúl provided the seed money for the sister nursery project by donating $1,000 from his Microseed nursery (table 3).

We are currently looking for other ways to provide financial support other than direct donations, and are also investigating getting nonprofit status for tax purposes. Raúl and Tom are doing some consulting work and plan to donate any profits to the sister nursery fund. Following this presentation at the joint meeting of the Forest Nursery Association of British Columbia (FNABC) and Western Forest and Conservation Nursery Association meeting, the sister nursery project was discussed at the FNABC business meeting and the group voted to donate $1,000 to the Chulul nursery project. This money will allows us to make further improvement in the nursery irrigation system such as repairing the pump and buying pipe.

THE FUTURE

There has been considerable interest in the sister nursery concept from people in both the US and Canada. The J.H. Stone Nursery in Medford, OR has sponsored a foreign intern program for several years and are considering establishing a sister nursery relationship with the indigenous ejidos in the states of Michoacan and Chihuahua in Mexico. There are many possibilities for sister nursery relationships around the world. While conducting nursery training on the island of Pohnpei in Micronesia, Marla Schwartz of Northwoods Nursery came up with the idea of becoming their sister nursery.

In conclusion, we feel that the Sister Nursery concept has application for technical assistance and cultural exchange in many places around the world. All that is needed is the desire to share some of your technical knowledge about growing plants.

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POSSIBILITIES FOR A NATIONAL FOREST NURSERY ASSOCIATION IN CANADA[1]

Irwin Smith[2] and Jolyon Hodgson[3]

INTRODUCTION

In January 1999, Hodgson presented a discussion paper on the need for a national forest nursery association to the first ever meeting of group of provincial representatives engaged in the business of growing and using tree seedlings for the purpose of forest renewal. Delegates agreed that there was a need for such an organization and that a survey should be carried out to assess the interest of the community at large.

This paper outlines some of the issues raised by Hodgson and summarises some of the information gathered at the Thunder Bay meeting.

SIZE OF THE INDUSTRY

It was estimated that the total value of the industry Canada wide was $462 million, taken to include a greenhouse value of $128 million (approx. 100 ha), input costs of $17 million, a labor value of $42 million, tree plant value of $158 million, and tree seedling value of $117 million.

The total numbers of tree seedlings grown and planted in the different provinces added up to 624 million Canada wide, for a planted value of approximately $0.75 per seedling, not taking into account the value of land preparation and post plant release or other management treatments required to ensure the establishment of a healthy forest. Provincially it was estimated that Alberta plants 70 million seedlings, the Atlantic provinces 35, British Columbia 229, Manitoba 20, Ontario 120 and Quebec 150 million seedlings. These numbers are down from past years due to government cutbacks and economic forces controlling the amount of timber harvested.

Provincial Organization to Date

Different forms of Association or Co-operative have existed in the provinces for many years, mainly to address a need for technology transfer, although OTSGA (Ontario Tree Seedling Growers Association) and the BC Growers Association were formed in response to a united front being required to deal with political issues surrounding privatisation of the industries in those provinces. At present two of the associations have changed their mandate to become Not-for Profit Co-operatives (Ontario and Atlantic provinces), and all address a need for technology transfer due to government cutbacks in research and extension services. Smaller growers now buy these services independently through their Co-ops, which pursue outside sources of funding for their research business. Large companies employ their own research personnel and keep the information in house as free enterprise takes a stronghold on the industry.

A private nursery size in excess of 30 million seedlings may be necessary for the budget to be large enough to employ in house research expertise. Few companies in Canada have this capacity, and one of the few has recently become a public company.

FORCES OF CHANGE

The following economic and political pressures were recognized as driving change in the industry.

Privatization of Government Nurseries

In most provinces there has been a complete change from government owned and run nurseries producing bareroot seedlings to a private containerised seedling industry. This first happened in 1989 with the birth of PRT Inc. in BC, and was followed in 1996 with Pineland in Manitoba, a consortium buyout of Pine Ridge in Alberta in 1997, and several privatisation contracts in Ontario in 1998. The same issues are being addressed in Quebec at present. In the Atlantic provinces there are historical reasons why the government continues to own and operate forest seedling nurseries.

The change in ownership has always resulted in an increase in the proportion of containerised seedlings in relation to bare root, such that the latter form a small percentage of the total number of seedlings grown country wide.

Growth, Takeovers and Withdrawals

Free market forces have resulted in take overs, and the formation of consortiums to address the effects of competition in the market place, especially in light of a reducing market due to world economy changes which affect the amount of land required to be reforested. The privatisation of forest management through Sustainable Forest licence agreements has also played a role.

Dismantling of Provincial Boundaries

The marketing of seedlings Canada wide has become possible as provincial trade barriers have changed and BC

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companies now market seedlings in Alberta, Saskatchewan, Manitoba and Ontario, as well as export to the USA. Similarly Quebec and Manitoba companies sell into Ontario and vice versa, and also export to the USA. The buying of seedlings out of province has also been used to create change in the type of service delivered, and the product being delivered.

NEW DIRECTIONS

Environmental Pressures

The forces of change, environmental pressures, and the development of new technology has resulted in new products. On average larger seedlings are being grown today as they address the need for less use of weedicides on competitive sites, and faster growth to 'free to grow'. In many cases these are client driven due to conservation and environmental needs, or a need to grow more fibre on a shrinking land base.

New Products

The nursery industry has an increased range of products including conservation species for special habitat restoration (wetlands, stream banks and windbreaks). Recently a change in name was required for the long time journal which met tree seedling technology needs (Tree Planters' Notes) in order to incorporate a wider audience.

Global Change

Climate change and global emissions may affect the health of the forest, as well as population pressures in third world countries. There are opportunities for tree seedling growers to exploit carbon emission credit trading which has already been floated on the futures market in Canada. Carbon dioxide emitters (the oil and energy business) will have to invest in credits which will translate into more reforestation worldwide. New nursery projects with international investment and management in Mexico City, Chile and other countries are evidence of this.

Private Research Companies

New opportunities have been created for research in the private sector due to government cutbacks and downsizing. Analytical laboratories, product development testing, and quality control services are all available as a result of less government activity in this sector. Many consultants, operating with low overheads, offer services on a contractual basis to growers and forest companies.

Changes in Research Funding

Federal and provincial governments encourage business development and employment creation by providing funds on the open market which can be accessed for research, product development and marketing. Co-operatives are efficient vehicles which monitor availability and provide access and services for these funds to their grower members. New companies monitor new funds for clients.

Other organizations (Flowers Canada) have set up trusts to fund long term research in partnership with government and Universities as they embrace change.

National Forum

Participants at the Thunder Bay meeting identified the need for a national organisation as being:

Education

Influence—Of government, industry and the populaton at large.

Research and technology transfer—To maintain or improve market position, develop new products.

- Create national data base
- Project Canadian industry into the global market place
- Foster national meetings and trade shows
- Develop a national certification programme
- Address emission offset issues
- Register a national research trust/foundation
- National lobby forum
- Digital technology transfer
- Research data base

The meeting voted to establish the name of the organisation as being: The Forest Nursery Alliance of Canada/Alliance Canadienne dePepiniere Forestiere.

This could only be formalized at a first national meeting which was recommended to take place as soon as possible.

The aims and objectives of the new organization would be to :

- provide a co-ordinating function for growers and forest managers,
- research seedling production systems,
- research the use of seedlings in forest renewal,
- determine research priorities,
- raise and allocate funding,
- encourage the use of research technology, and
- provide technology transfer.

There are at present 122 forest seedling nurseries in Canada. How many can be persuaded to buy in, together with their customers and supply companies to achieve these objectives for the long term health of the industry? The seedling industry should be in control of its own destiny going into the 21st century.

FOREST SEEDLING NUTRITION TRENDS[1]

Eric van Steenis[2]

INTRODUCTION

Trends don't just happen. They are driven by change, which in turn has its own motivating forces. In our industry change is driven in large part by the product end user or customer. Change in this case is often positive since it involves a healthy degree of economic and biologic analysis as well as consultation between affected parties. Change brought about as a result of implementation of research findings also impact positively. It generally requires the ability to translate research from the laboratory to an operational setting. Change imposed by government can be a major driving force of trends we observe. Actual objectives set out in legislation are generally positive but unless rules and regulations are carefully drafted so as to achieve them results can be anything but... positive.

This presentation delineates some client driven trends in the BC reforestation industry. It then focuses on one particular aspect of mineral nutrition of forest seedlings that growers can use to help meet customer expectations.

FOREST SEEDLING PRODUCTION TRENDS IN BRITISH COLUMBIA (CLIENT DRIVEN)

In accordance with an increased emphasis on field performance of nursery stock, there have been general trends in favor of:

- Copper treated containers for regulation of root growth.
- Larger stock-types to overcome site limiting factors.
- Summer delivery or "hot" planted stock-types to take advantage of the summer planting season.
- Earlier delivery dates of summer planted 1-0 stock (shorter crop rotations) which facilitates its substitution for summer delivery 2-0 and cold-stored 1-0 products.
- A-class seed sources to take advantage of genetic gain.
- Hardwoods and other native plants for site rehabilitation and alternate wood products.

In order to live up to client expectations, the use of all available resources at the nursery has to be optimized. This requires an intimate knowledge of resource availability and how each contributes to final product quality. Aspects of nursery culture which can be limiting are light, temperature, water, mineral nutrition, pests and time. A basic trend is to acquire this intimate knowledge or greater understanding which will ultimately lead to optimized use and increased product quality.

For the mineral nutrition component the following are concepts studied:

- Individual nutrient function within plants.
- Functional relationships between nutrients within plants.
- Functional relationships between nutrients outside plants.
- Relative proportion requirements based on the above.
- Timing and optimization of availability.
- Timing and rate of application.
- Nutrition and stress.
- Interactions with water, growing media and atmospheric environment.
- Monitoring.
- Custom blends.

EMPHASIS ON FIELD PERFORMANCE

Imparting appropriate levels of hardiness, stress and pest resistance, and growth/differentiation balance to seedlings is important. In conjunction with field personnel, work continues to bridge the knowledge gap between nursery culture and its impacts on field performance. Seedling quality and stress tests are available to help predict seedling performance. Knowing how to alter nursery culture so as to effect a positive change on the aforementioned test results can be a challenge. Nutrition is integral to the final anatomy, morphology, physiology, and phenology we package and call a seedling.

K/N Ratio as an Example

The importance of the K/N (Potassium/Nitrogen) ratio within plants is well documented in the literature, thus making a good example for this presentation. The relative amounts of these two nutrients within a seedling have a profound impact on its growth/differentiation balance, affecting the level of hardiness it is able to acquire, its disease and insect resistance, degree of succulence, and timing and degree of dormancy. It basically impacts on the overall performance of a plant's metabolic machinery.

Optimum K/N ratios for seedlings will vary somewhat between species, growth stage, cultural context at the nursery and the K status of the planting site. Careful monitoring and keen observation of stock performance will allow us to start focusing in on appropriate ratios. Moore and Mika (1997) listed foliar status as poor when foliar $K<6000$ PPM or 0.6 percent and $K/N<0.5$.

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[1]van Steenis, E. 1999. Forest seedling nutrition trends. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 104-107.
[2]Extension Services, BC Forest Service, 14275-96th Ave. Surrey, BC, V3V 7Z2, Canada; TEL:604/930-3303; FAX: 604/775-1288.

In order to understand why a particular nutrient element ratio is important and how it impacts on seedling quality one must look at the function of each of the elements, paying particular attention to any biochemical relationship between them, as well as particular functions that might impact on final product traits (qualities) of interest.

Nitrogen—

- Constituent of proteins, nucleic acids, chlorophyll.
- Mineral nutrient element required in highest amount.
- Often used to control growth rate.
- Supplied as ammonium and/or nitrate ions.
- Ammonium drives growth, and requires carbohydrate resources in roots to detoxify it at uptake.
  (Carbohydrate depletion in roots may attract low sugar pathogens.)
- Nitrate is not toxic and can be stored in vacuoles until needed
- High N induced succulence reduces overall stress resistance and physical barriers to penetration by fungal and insect pests.
- Affects growth~ differentiation balance, excess favoring growth.

Nitrogen is obviously very important. Being a constituent of proteins in general makes it an integral component of all enzyme systems and plant structure. In addition it is also a component of nucleic acids, hence integral to cell division and reproduction. Then, as part of the chlorophyll molecule it basically asserts itself as a kingpin within all creation.

Potassium—

- Highly mobile in plants at all levels.
- Involved in osmotic regulation and water movement
  - maintenance of turgor
  - cell extension
  - stomatal control.
- Stabilizes internal pH (7 - 8).
- Enzyme activation
  - protein synthesis.
  - Starch synthesis.
  - Photosynthesis/ATP production/energy relations.
- Membrane transport and ionic balance
  - Translocation of carbohydrates.
- Promotes thickening of cell walls
  - involved in synthesis of complex carbohydrates, lignin
  - promotes "structural" vs. "cytoplasmic" nutrition.
- Increases resistance to stress in general.

Why a K/N ratio?—Potassium, although not a constituent of any physical plant parts, is involved in virtually all plant processes, being a facilitator of most. What is interesting to note is how the two interrelate or depend on each other. The relative levels of each basically determine the efficiency or usefulness of the other.

Potassium deficiency—In this case what we are really interested in is Potassium deficiency symptoms. Potassium toxicity as such does not occur although excessive levels of potassium can induce deficiencies of other elements, namely magnesium. Deficiency symptoms appear when potassium is low or the K/N ratio is too high resulting in a N induced K deficiency. From the list of functions above it can be seen that a K deficiency basically results in an inability to process/utilize nitrogen properly. The difference in symptom expression if any, reflects on whether the seedling is operating in the deficiency, sufficiency or luxury range of nutritional status. Yellowing of foliage from the bottom up occurs if operating in the deficient to sufficient range.

Without adequate potassium, overall plant metabolism slows and building blocks for various biosynthesis reactions start to accumulate. An absence of potassium is akin to inserting a bottleneck into virtually every biochemical and physical process occurring within the plant.

Soluble carbohydrates and nitrogen compounds accumulate because their K facilitated incorporation into macromolecules such as starch, proteins, DNA and chlorophyll is impaired. This reduces or eliminates their subsequent functions, e.g. photosynthesis, protein synthesis, etc. Source to sink transport diminishes leading to localized deficiencies of metabolic products (usually roots loose out with respect to carbohydrates). New cell expansion (plant growth) is reduced due to an inability to generate and maintain adequate turgor pressure. Even though accumulating soluble carbohydrates and nitrogen compounds help with osmo-regulation in the absence of K they are unable to fulfill this function completely.

All in all, the plant has to respire or expend extra energy to grow and maintain itself, reducing its rate of net photosynthesis or overall efficiency as a converter of light energy to chemical energy. For the grower this means lower production and/or longer production, in addition to the possibility of producing lower quality stock.

Concepts—Reduced stress resistance occurs due to a general decrease in biochemical function at all levels. When potassium levels are depressed, plant tissues mature more slowly hence are unable to prepare or repair themselves as quickly as might otherwise be possible. One result is that wilting (loss of turgor) occurs more easily when the soil water supply is limiting, i.e. the plant has a lower tolerance to drought. Susceptibility to frost is also increased for similar reasons as well as the fact that crop maturity in general is delayed.

Potassium is involved in the further metabolism/utilization of sugars into starches and plant structure, etc. An accumulation of these basic building blocks due to depressed levels of potassium can increase susceptibility to high sugar pathogens. *Botrytis cinerea* is an example of a high sugar pathogen, bark beetles are an example of a high sugar parasite. These two take advantage of high levels of available simple sugars and free nitrogen compounds (amino acids and amides) in foliage and phloem tissues.

A high ammonium (NH_4+) nitrogen feed can, especially under conditions of low photosynthetic rates such as occur during winter growing where nights are long and available light is of poor quality, lead to a depletion of carbohydrates in the roots. This can result in a low sugar pathogen attack

Table 1— Foliar analysis "adequate levels" for Sx - young stands - Ballard and Carter (1986)

Nutrient	PPM	mmoles	Presence/100 N atoms
N	14500.	1035.	100.
P	1600.	52.	5.
K	4500.	115.	11.
Ca	2000.	50.	5.
Mg	1200.	49.	5.
S	1600.	50.	5.
SO4-S	600.	19.	2.
Fe	45.	.81	.08
Fe (active)	30.	.54	.05
Mn	25.	.46	.04
Zn	12.	.18	.02
Cu	3.	.05	.0005
B	12.	1.11	.11
Mo	.30	.003	.0003
Al	400.	14.83	1.43

Table 2—Foliar nutrient ratios for Sx - young stands - Ballard and Carter (1986)

Macro/Macro	Concentration based	Weight based ppm/ppm
N/P	20.0	9.1
N/K	9.0	3.2
K/N	.01	0.3
N/S	20.7	9.1
K/Ca	2.3	2.3
K/Mg	2.3	3.8
Ca/Mg	1.0	1.7
Mg/Ca	1.0	0.6
P/Ca	1.0	0.8
Macro/Micro		
Ca/B	45	166.7
P/Fe	64	35.6
P/Cu	1094	533.3
P/Zn	281	133.3
N/Zn	5640	1208.3
P/Al	3.5	4.0
Micro/Micro		
Fe/Mn	1.8	1.8
Mn/Fe	0.6	0.6
Fe/Cu	17.1	15.0
Cu/Fe	0.1	0.1
Zn/Cu	3.9	4.0
Cu/Zn	0.3	0.3

on roots. *Fusarium oxysporum* is an example of a low sugar pathogen.

Because potassium is also involved in transporting of products between sources (photosynthetic products in needles/leaves) and sinks (roots requiring carbohydrates as an energy source to fuel growth and nutrient uptake), low K can also induce susceptibility to low sugar pathogens in the root zone.

Obviously the worst combination is high nitrogen (especially NH_4+) coupled with low potassium in terms of whole plant status. This can result in an accumulation of soluble N compounds such as amino acids, amides, NO_3-, as well as simple sugars such as glucose in the foliage and bark, encouraging high sugar pathogen attacks on the shoot (*Botrytis cinerea* /aphids). In addition, due to reduced source/sink transport it can also result in increased susceptibility of sinks (roots) to low sugar pathogen attacks such as *Fusarium oxysporum*.

K and N levels—Below are 4 tables (tables 1-4) depicting average foliar nutrient levels and ratios. One and two represent data from young *Picea glauca* (White Spruce) stands from Ballard and Carter (1986). Three and four represent average data from 1990 - 1996 for BC nursery grown *Picea glauca* seedlings. Note the differences between seedlings in the nursery and young forest plantations with respect to absolute levels as well as the nutrient ratios.

CONCLUSIONS

Obviously mineral nutrition is a key component of seedling quality and performance potential. However, the interactions with other cultural factors cannot be ignored. The K/N relationship is only one of many important in plant production.

Understanding how mineral nutrients function and interrelate with each other allows better utilization of the contribution each can make to the overall quality and performance potential of seedlings being produced. As a business, it is important to become better before getting bigger. Paying attention to details that allow maximization of benefits from resources at hand will help achieve the former.

The ultimate goal is to accurately define, based on requirements imposed by the plantation environment, seedling quality in terms of morphology, anatomy, and physiology. Then, coupled with an understanding of how mineral nutrition can be used to alter the aforementioned, progress can be made.

Table 3—Foliar analysis "averages" for Sx seedlings- 1990-1996

Nutrient	PPM	mmoles	Presence/ 100 N atoms
N	20400	1456	100
P	3300	107	7
K	11200	286	20
Ca	5100	127	9
Mg	1500	62	4
S	1400	44	3
SO4-S	241	8	1
Fe	162	2.9	.2
Fe (active)	98	1.75	.12
Mn	326	5.93	.41
Zn	63	.96	.07
Cu	7	.11	.008
B	26	2.41	.17
Mo	1.42	.015	.001
Al	149	5.52	.38

Table 4—Average foliar nutrient ratios for Sx seedlings 1990-1996

Macro/macro	Concentration based	Weight based ppm/ppm
N/P	13.7	6.2
N/K	5.1	1.8
K/N	0.2	0.5
N/S	33.4	14.6
K/Ca	2.3	2.2
K/Mg	4.6	7.5
Ca/Mg	2.1	3.4
Mg/Ca	0.5	0.3
P/Ca	0.8	0.6
Macro/Micro		
Ca/B	52.9	196.2
P/Fe	36.7	20.4
P/Cu	967.2	471.4
P/Zn	110.6	52.4
N/Zn	1511.5	323.8
P/Al	19.3	22.1
Micro/Micro		
Fe/Mn	0.5	0.5
Mn/Fe	2.0	2.0
Fe/Cu	26.3	23.1
Cu/Fe	0.04	0.04
Zn/Cu	8.7	9.0
Cu/Zn	0.1	0.1

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FERTILIZER TECHNOLOGY[1]

Richard R. Benson[2]

INTRODUCTION

It's only recently that a conifer forest seedling in a production phase is being outplanted with initial fertilization. Standard practice has been to allow the seedling to develop on its own. First scheduled fertilization is often not until several years into the cycle. Under this scheme, any nutritive help must be given at the nursery stage. Yet the need for accelerated growth is required. Why do growers of the majority of other crops have an initial nutrient program while the forestry industry doesn't? One answer involves the safety aspect of an early fertility program under the limited Pacific Northwest summer precipitation regimes. Too often salinity builds up and causes plant injury. Current fertilizer technology does offer useful alternatives that can both be safe and growth enhancing. In fact, perhaps a very long-term source can be used at the nursery stage that continues to release and provide nutrients well after outplanting.

TYPES OF FERTILIZER

There are four classes or types of fertilizers. Dry solubles such as ammonium sulfate or potassium sulfate are applied right out of the bag. Being soluble, they have a short period of nutrient availability, not much more than 30 days under a typical irrigation program. Blends using dry solubles often segregate due to particle size differences. Multiple applications can increase the chance of usage error (rate).

Liquid solubles are available in either liquid—bulk fertilizer tanks from blenders, for example—or dry form such as Miracle-Gro® or Peters®. They too have a short availability before leaching or absorption and chances of usage error increase with the number of applications over a crop cycle.

Slow release fertilizers are typically three-month fertilizers such as ureaformaldehyde (UF), isobutylidenediurea (IBDU®), or sulfur-coated urea (SCU), all materials originating in the 1960s and 70s. They are excellent components of some current post-outplanting forestry fertilizer formulations.

Controlled release fertilizers (CRFs) are the fourth type and have a release pattern well in excess of 3-4 months. They are characterized by a polymer or resin coating, examples of which are Osmocote® and Nutricote®. They are expensive, efficient (rates generally are 75 percent of normal grower practice and resulting yields are typically increased 10 percent or more), and used in numerous high value markets. Are they really expensive? Changing the perception from cost per ton to cost per plant per unit time is a measure of true value. If a $600 per ton fertilizer is applied 6x per year at a 1x rate isn't it logical that a $1200 per ton fertilizer that needs to be applied only once at a 2x rate is more economical?

FERTILIZER CONSIDERATIONS

There are limits to which nutrient content can be pushed into available formulations. Nitrogen, phosphorus (as P_2O_5), and potassium (as K_2O) each reach maximums of about 45-50 percent. Urea contains 46 percent nitrogen. P_2O_5 is available in several useable forms—triple superphosphate (0-50-0), monoammonium phosphate (11-52-0) or diammonium phosphate (18-46-0). K_2O can be found in the chloride form at 0-0-60, but a more "plant-friendly" source containing sulfur and a lower salt index is potassium sulfate (0-0-50). A blend of NPK using 46-0-0, 0-50-0, and 0-0-50 at one-third each gives us a formulation of 15-16-16. As

Table 1—Fertilizer characteristics by type

Characteristic	Solubles	Slow release	Controlled release
Longevity	Short	Medium	Long
Ease of use	Many applications	Several applications	Single application
Cost	Low	Medium	High
Cost of use	High	Medium	Low

[1]Benson, R.R. 1999. Fertilizer technology. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 108-110.
[2]The Scotts Co., 2895 Etomina Lane S., Salem, OR 97306; TEL: 503/315-7171; FAX: 503/315-7077.

other nutrients are added to this blend, such as magnesium or micronutrients, the NPK analysis is further reduced. State regulatory agencies can sample the product at manufacturing, distribution, and user sites and can issue fines to the manufacturer for being under-analysis. The nationwide trend is to also regulate "overformulation" and penalize producers for putting too much nutrition in the product.

Nutrition sources can be important criteria for selecting a proper fertilizer. While urea is the economic nitrogen choice, many plants prefer other sources such as ammoniacal or nitrate nitrogen. Generally, the more important the flower stage is to the grower, the more the nitrate form is required. Chrysanthemum producers, for instance, rely on ammoniacal nitrogen for the first half of the crop cycle and finish with nitrate nitrogen during the second half to enhance flowering. "Green" plant production—foliage, woody ornamental, and conifer growers—can rely on the more economical urea and ammoniacal forms of nitrogen.

Phosphorus and potassium sources are easier choices—the materials mentioned above are commonly available and in forms useable to the plant. Potassium nitrate is an excellent alternative to potassium sulfate but is expensive and usually selected for use on high-value crops due to its nitrate content rather than potassium. Sulfur is generally found in most fertilizers and additions are rare unless high soil pH conditions are prevalent. Calcium and magnesium are popular additions but the choice depends more on irrigation water quality, soil fertility, and pH status. Micronutrients are also a common component either as single element additions, such as iron, or a full complement. Many soil types contain ample levels of some or all micronutrients and make additions unnecessary.

A general rule-of-thumb for NPK ratios is to use a 1-1-1 type for flowering plants, and a 3-1-2 type for development of green or foliage plants. Add micronutrients if chlorotic new foliage or growth is a problem.

Finding where to obtain the different types of fertilizers can be awkward. As we move from the least expensive solubles to the most expensive CRFs, availability decreases. Everyone sells dry solubles, many sell liquids, few sell slow release fertilizers and fewer yet sell controlled release materials. It's a function of the time and training required by the seller to explain to the customer the benefits of the more expensive fertilizers. Therefore, most retail stores have dry solubles and many have liquids. Blenders, turfgrass, and farm suppliers have slow release fertilizers. CRFs can be found only at horticulture suppliers, those that service the nursery and greenhouse growers. CRF blends for nursery and greenhouse crops are readily available; special custom blends are available in batch amounts (usually 3+ tons) from the manufacturer.

CRFS

Most controlled release fertilizers are temperature dependent—nutrient release increases as temperature increases. Product lifespan, or longevity, can be controlled by changing the physical characteristics of the coating, either the thickness or the nature of the polymer itself.

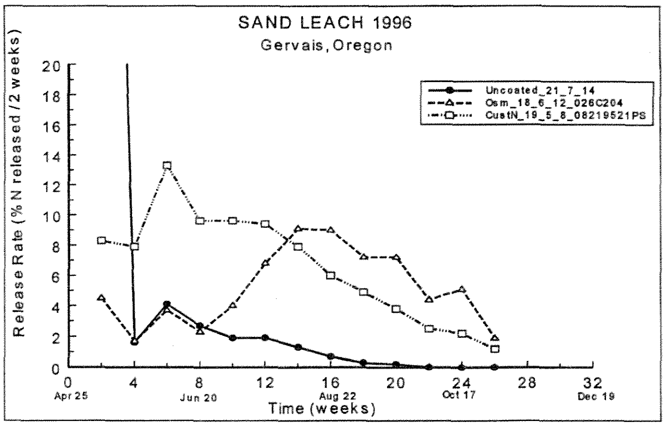

Figure 1—Release curves.

Normally, the effective range of longevities a manufacturer offers is from three to sixteen months. Any requirement or crop cycle shorter than three months can utilize solubles or slow release materials. Crop cycles longer than sixteen months certainly exist, just look at the forestry market, but the manufacturer loses control over precise longevity and a "24 month" product actually becomes an "18-30 month" material.

We use a single coating thickness for the shorter longevities. However, relying on a single, thicker coating for longer periods of time builds an initial delay into the product and results in a nutrient void the first few weeks of the crop cycle. This delay increases as the coating thickness increases. Therefore, blends of short and long-term, or light and more heavily coated fractions are necessary to provide a balanced release curve over the claimed longevity.

Here are release curves for an 1) uncoated soluble 21-7-14, 2) that same 21-7-14 material coated for a six-month longevity (18-6-12), and 3) an example of how that 18-6-12 curve can be given an upfront "kick" by adding a second coated material (becoming a material with a final analysis of 19-5-8)(fig. 1). Both CRFs have six-month longevities but different release patterns.

Table 2—CRF characteristics

Change	Rate increases	Rate decreases
Low to high irrigation/rainfall	X	
Clay to sandy soil	X	
Slow to fast growing plants	X	
Salt tolerant to salt sensitive plants		X
Seedlings to established plants	X	
Container to field plants		X
Grower objective from "push" to		X
"hold"		X
Spring to fall feeding		X
Short term to long term CRF	X	
Small to large pot	X	

CRF RATES

In order to describe some practical CRF characteristics here are several cultural practice situations that can occur in nurseries. These concepts are applicable also to field use. Try to explain in each instance how CRF rates are affected by the following changes.

ECONOMICS OF CRF USE

Determining if CRF makes sense to use depends in part on the cash value of the crop and the yield increases that CRF provides. Let's compare CRF use on two crops—corn and strawberry—and try to pull in forestry.

Corn (economic yield = $122 per acre)

If the cost of the current grower fertilizer practice is $52 per acre and the cost of CRF on an equivalent N/acre basis is $386 per acre, the incremental fertilizer cost per acre is $334. A 25 percent yield boost that CRF can provide is equal to $31 per acre. The grower invests an extra $334 per acre for only a $31 per acre return!

California Strawberry (economic yield = $32,000 per acre)

Here the cost of grower practice is $176 per acre. The cost of the CRF is $270, again on an equivalent N basis, for an incremental cost of $94 per acre. A 15 percent CRF yield increase results in $4,800 per acre for only an increased fertilizer cost of $94 per acre!

Forestry Nurseries (economic yield = ?)

Here the costs of grower practice and CRF might be close to that in the strawberry example above. A 10-15 percent yield or growth increase could very well justify the incremental cost of $94 per acre.

LOOKING AHEAD

The challenges for continued CRF use in forestry involve the research of proper rate, placement, fertilizer component, ratio, and longevity. As you know, many projects are underway in many locations that involve these challenges. The Scotts Company is participating at several university and industry sites to help determine solutions.

Fertilizer formulations are becoming more crop specific, that is to say, designed for a given application. We already are seeing forestry CRFs that are used only at the greenhouse seedling stage, in nursery beds, at initial outplanting, and post-outplanting. It won't be long before requests for a fertilizer having separate and yet different N, P, and K releases can be satisfied. Consider a nitrogen that has a sustained season-long release blended with a phosphorus and potassium that each have a unique but necessary release pattern, say, for example, that the P release is two months and the release for K is 12 months. All that remains is really the research that provides the release characteristics needed—perhaps we already have it.

SEEDLING STANDARDS AND THE NEED FOR THEM[1]

Clare Kooistra[2] and Drew Brazier[3]

CLASSIFIERS, ORGANIZERS, STANDARD SETTERS

Human beings are creatures of order, at least creatures that attempt to understand their world by establishing an order to things. In this attempt at understanding; humans classify, organize, and set standards. The second law of thermodynamics states that "entropy (disorder) always increases in the universe." Human beings, it can be argued, in the understanding and shaping of their world, work against this law.

This order, as perceived in the natural world, leads to varied response on our part. Let me use an analogy to illustrate how I see these respond and how they will help us in the understanding of standards we use in forest seedlings.

Let's consider a child on the seashore - one of our beautiful Vancouver Island beaches - the child is doing what all children do on beaches - collecting sea shells. The child notices that all the shells are not the same and begins to organize the shells into groupings such as mollusks and bivalves. Then the child recognizes that the shells are not all the same size. The horseclams are much larger than the cockles and even within these there are many size classes. The child further values some shells more than others and decides that the biggest shell is also the best.

Our approach to seedlings is not significantly different from the child with shells on the beach. We organize, classify, and set standards for seedlings.

Today's talk is concerned with a look at this last area, ie. the standards we set for forest tree seedlings in British Columbia. These standards are values we place on the seedlings we grow.

Let's for a Moment Consider Some Other Products

In businesses the customer is all powerful. If the customer doesn't like your product there is little hope in attempting to convince the customer that they are wrong and don't really know what they want. As a example, let's look at apples. I have here a green apple. It happens to be a rather small green apple. I can vouch for the flavour - excellent. I also have a red apple - a rather large red apple. There is little hope of selling a customer a little green apples if they want a big red one. Or, let's look at possibly a better example. I have here two cucumbers - one straight and perfect - the other twisted and rather lumpy; by most customer standards just plain ugly. Now for the purpose of nutrition, there is no difference in these products, but one commands a high price and the other ends up on the waste heap.

What then of seedlings?—Certainly we organize our seedlings by species. Certainly we classify our seedlings within species by stock types and age. We also apply standards to our seedlings as to acceptable and target sizes; a value judgment.

Do we need standards?—In the strict biological sense we do not. The seedlings that germinate all have the potential to develop into trees, but not necessarily the trees that suit man's purposes. Conifers tend to produce large quantities of seed, however, and in the natural environment there is heavy attrition of seedlings and only a few grow into trees.

When culturing seedlings in a nursery, the bulk of the seeds do develop into seedlings. In the container culture different size plants are achieved primarily by selection of different container sizes. Within a stock type there is a distribution of seedling sizes. This distribution is generally a normal bell shaped distribution on the seedling characteristics of height and root collar diameter (RCD) (figs. 1, 2, 3, 4).

When setting standards the normal distribution must always be considered. If the range from the minimum to the maximum height is too narrow the result will not be to eliminate the tails of the population distribution, but a much larger part. When looking at the normal distribution and viewing the small plants in the left tail of the curve these plants are considered of poorer performance quality. This is true for each particular stock type. This is also true for forest seedlings as well and in a natural setting, these plants are likely to be out competed by their more vigorous neighbors. In a nursery environment they persist and form part of the population. There is always the argument that we are selecting the fastest growing seedlings in the nursery over a one or two year period and this does not necessarily select the fastest growing trees over a rotation. The depth of the

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[2]South Zone Nursery Services, Ministry of Forests, 106-1340 Kalamalka Lake Rd., Vernon, BC, V1T6V4, Canada.
[3]MOF Nursery and Seed Operations, PO Box 9501, Victoria, BC, V8W 9C1,Canada; TEL: 250/387-8955; FAX: 250/356-0472.

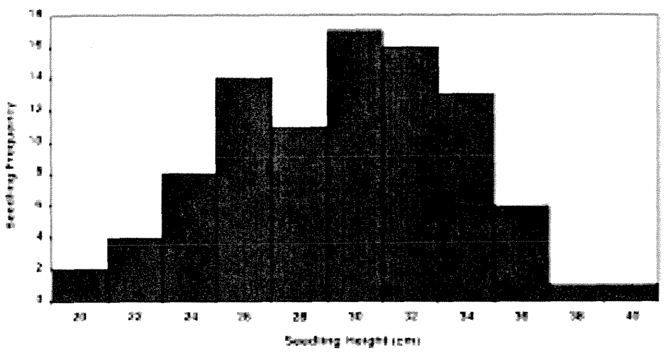

Figure 1—Height versus Frequency (Sx PSB 415D)

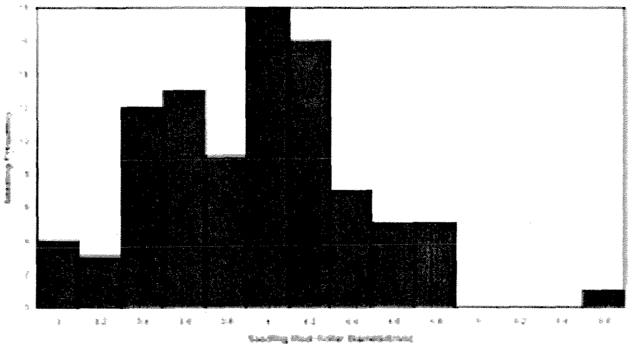

Figure 2—Root Collar Diameter versus Frequency (Sx PSB 415D).

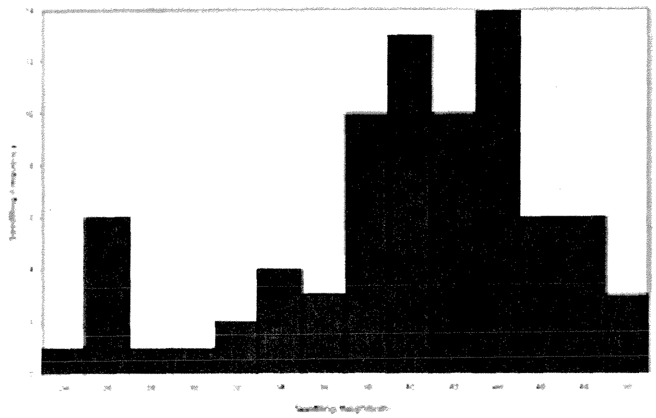

Figure 3—Height/Frequency (CW PSB 410).

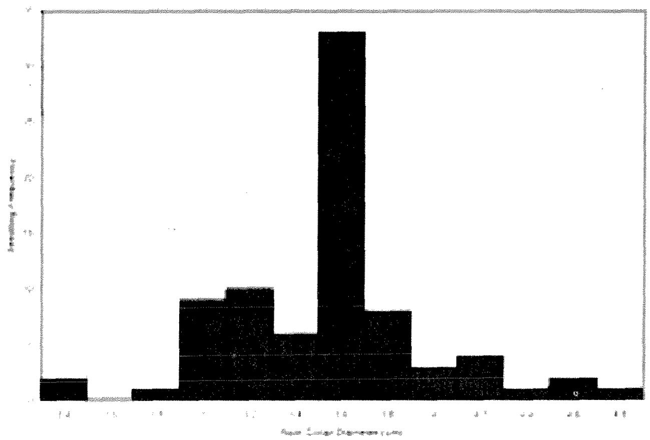

Figure 4—Root Collar Diameter versus Frequency (Cw PSB 415D).

breeding program, however, allows the selection of the fastest growing seedlings in the nursery and in the field. My expectation is that in future most nursery production will be grown by families. This will eliminate the culling of slightly slower growing families, but culling will still happen within the family population.

While it is true larger stock types tend to perform better, this is not primarily a standards issue. Larger stock types resulting from larger containers provide the plant with more soil media to grow in and with greater spacing for each plant, thus allowing for a larger amount of active foliage and a greater amount of products of photosynthesis, thus greater biomass.

WHY SET STANDARDS?

If biologically not strictly required, why make value judgments on a group of seedlings? The reason is that we place value on high survival and rapid and reliable growth. In the forest environment great quality seedlings result in enhanced survival and performance. In the nursery high quality seedlings result in satisfied return customers and in better utilization of space as over sowing can be reduced. Standards can only be set by understanding both the limitations of the field performance and the nursery's capability to produce such a standard in a given stock type.

It should be noted that if the field requires a large size seedling to meet it's performance objectives, this can not be ordered in a small stock type with the hopes of achieving this end. The ordering of appropriate stock types is of major importance to success and requires continual extension activity to support field staff in the ordering stock.

We make value judgments in establishing standards for seedlings because we wish to obtain good performance of these seedlings in the field. Through trials and research it has been observed that out of a given population, larger balanced seedlings perform best. The recent remeasurement of a long term trial has again shown that even after 15 to 17 years the initial differences of size in interior spruce are still evident and significant.

We also establish these standards to encourage the nursery community to achieve a goal. This is the reason why in BC we have not only set the minimum standard for a

species/stock type, but also have set target standards. The goal is to focus nursery managers and growers on producing stock that not only meets the minimum standard, but also meets or exceeds the target standard. Keeping these standards high, but attainable has helped the nursery industry in BC produce seedlings of high quality while removing those of lower performance potential.

MORPHOLOGICAL STANDARDS

The primary morphological standards are height and root collar diameter. These are published by the Ministry of Forests every year for each species, stock type and age. They are based on what is needed in a stock type for it to perform well in the field and what is realistic to expect that particular container to produce in the nursery for that species and age. In this, the work by Eric Van Steenis of the

Species	Stock Type	Height (cm)			RCD (mm)	
		Cull	Target	Maximum	Cull	Target
Pine, Lodgepole (Pll)(Plc)	PSB/PCT211A	6	11	16	2.0/2.2*	2.3/2.5*
	PSB/PCT 310B/313B	6	12	19	2.2/2.4*	2.6/2.8*
	PSB/PCT 410	7	13	20	2.4/2.6*	3.0/3.2*
	PSB/PCT 415B	8	14	21	2.5/2.7*	3.1/3.3*
	PSB/PCT 412A	8	15	22	2.6/2.8*	3.2/3.4*
	PSB/PCT 415D (E)	8	15	23	2.8/3.0*	3.4/3.6*
	PSB/PCT 615A	10	18	26	3.2/3.4*	3.8/4.0*
Pine, Ponderosa (Py)	PSB211A(E)	7	11	–	2.2	2.5
	PSB313B	8	13	–	2.4	3.0
	PSB410	8	14	–	2.6	3.2
	PSB415B	9	15	–	2.8	3.5
	PSB412A	9	16	–	2.9	3.6
	PSB415D	10	17	–	3.0	3.8
Pine, White (Pw)	PSB313B	6	13	20	2.4	3.0
	PSB410	8	14	23	2.6	3.2
	PSB415B	8	15	25	2.8	3.4
	PSB412A	9	15	25	3.0	3.6
	PSB415D	10	17	28	3.2	3.8
Spruce, Sitka and Crosses (Ss, Sxs)	PSB211A(E)	12	17	22	2.0	2.4
	PSB310B (E)	12	18	24	2.1	2.5
	PSB313B	14	22	30	2.2	2.6
	PSB410	16	25	35	2.4	3.0
	PSB415B	17	26	35	2.6	3.2
	PSB415D	18	30	40	3.0	3.8
	PSB615A	30	45	60	3.8	4.8
Spruce, White/Engelmann & Crosses (Sw,Se,Sx,Sxw)	PSB/PCT211A (E)	10	15	20	2.2	2.6
	PSB/PCT310/313B	11	18	25	2.2/2.4*	2.8/3.0*
	PSB/PCT410	12/10(PR)	19/17(PR)	27	2.4/2.6*	3.0/3.2*
	PSB/PCT415B	13/11(PR)	22/20(PR)	28	2.6/2.8*	3.3/3.5*
	PSB/PCT412A	14/12(PR)	24/22(PR)	35	2.8/3.0*	3.6/3.8*
	PSB/PCT415D	14/12(PR)	26/24(PR)	40	3.0/3.2*	3.8/4.0*
	PSB/PCT512A	15	27	40	3.3	4.0/4.2
	PSB/PCT515A	16/14(PR)	28/26(PR)	42	3.2/3.4*	4.3/4.5
	PSB/PCT615A	20	40	50	4.0	5.0

Figure 5—Morphological standards for Lodgepole pine and White/Engelmann spruce.

BC Ministry of Forests has been very useful in relating stem basal area to the cavity spacing on the container and cavity diameter. An example of a current set of standards for Lodgepole pine and white/Englemann spruce are given in figure 5.

These types of morphological standards were successful in pushing the BC forest nursery industry to improve the size and uniformity of the seedling crops. These Height/RCD scattergrams show the type of crops that can be grown (figs. 6 and 7). The tightly clustered population around the targets and within the minimum/maximum specifications indicates a high quality crop. These scattergrams are also very helpful in determining the impact of any change in the culling standards.

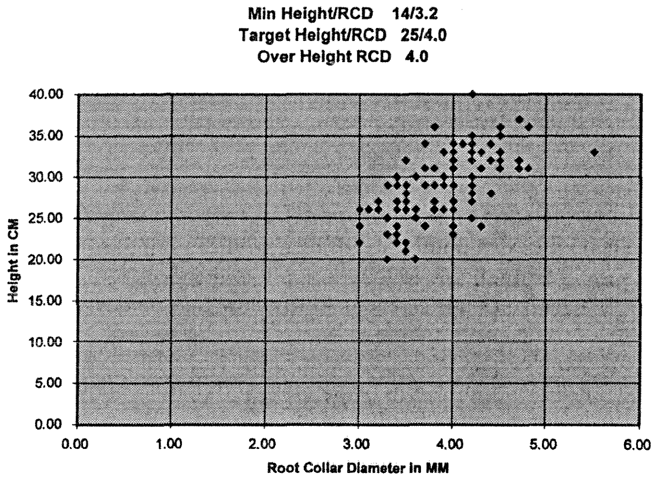

Figure 6—Scattergram Interior Spruce PSB 415D.

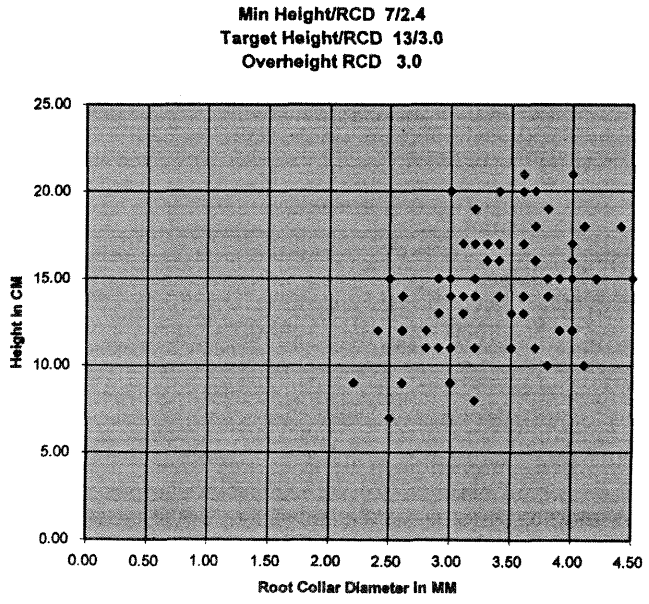

Figure 7—Scattergram Lodgepole Pine PCT 410.

While shoot root ratios have been used in the past, less attention is paid to these today. Rather we have seen an increasing interest in the height - root collar diameter ratio as a measure of a seedling's sturdiness. This ratio, sometimes called Sturdiness Ratio, is important when considering resistance to the physical impacts of vegetation or snow press.

The values of setting a morphological standard(s) for the production of a seedling are as follows:

1. The standard is set in part to ensure the seedling has enough biomass and in the correct balance to meet the site conditions of the forest planting environment.
2. The standards, as published, are a useful guide to field staff when selecting a type of seedling that is required to meet specific planting site conditions. Effectively field staff can select the seedling size that is desired and then order the corresponding container size.
3. The standards are also useful as a contractual tool to determine what seedlings meet conditions for payment. For this reason, height and RCD usually form part of contract specifications in BC. Field staff can count on a uniform product since all seedlings must fall within the minimum and maximum morphological parameters. These measurements are also quick and non-destructive.

PHYSIOLOGICAL STANDARDS

To determine an acceptable state of seedling it is also important to look at its physiology. In BC we have a number of tests to determine this and help guide in the acceptance of seedlings for planting stock.

Root Growth Capacity

The prime physiological test is the root growth capacity test. A sample of the seedlings is placed in an ideal growing environment for seven days before the new root growth is evaluated. The standard we use here relates to the scale developed by N. Burdett and on a scale from 0 to 5 with 5 being excellent and 0 meaning no root growth. On seedling samples that have 0's in them or are less than 2 on the scale, re-testing is recommended. If it remains low in the second test, advice is given to plant seedlings at a higher density, anticipating some mortality, or it may be recommended that the seedlings be discarded.

Prestorage Storability Determination

The standard we use to determine the seedling readiness for storage is the Storability Test developed by D. Simpson and W. Binder of our Research Branch. This test can have a major positive impact on the success of long-term over winter storage because it determines the state of dormancy and frost hardiness of a seedling in relation to fall lift and the placement of seedlings into storage. It is recommended that representatives of all seedlings by species, elevation, and latitude be passed through this test. The standard set is such that seedlings are lifted and stored only once the seedlings passes the storability criteria of the test.

Variable Fluorescence

During the growth phase of seedlings, few tests have been developed to determine seedling health. One method that has recently become available is a variable fluorescence determination. If it is suspected that seedlings have been damaged or appear in poor condition, this test can provide data on the vigor of the photosynthetic system of the plant. Standards for this test show those seedlings that are healthy, stressed and/or dying.

Operationally the EARS (Institute of Environmental and Remote Sensing) PPM (Plant Photosynthetic Meter) is used. This instrument is lightweight, portable, and able to do a larger number of samples on a battery charge. This meter is extremely effective at quickly identifying damaged or dead tissue. The readings are simple numbers and thus can be interpreted directly without the use of charts or formulas.

Others have incorporated more differing physiological tests that involve the use of stress and monitor the seedling response. BC Research has pioneered this area, but they are not widely used in the province to date.

CONCLUSION

The setting of standards is a human activity of applying a value judgment to the natural world. In seedlings these standards have helped us achieve reforestation success in survival and field performance. It has also been beneficial in providing nurseries with goals that through utilizing innovation, are being achieved and high quality forest seedlings are being produced.

Finally, let us return to the seashore. The child on the beach has made value judgments on the groups of shells collected. The biggest clam shell is best, but all of the collection are OK if the shells are not chipped or broken, or too small. Even the mid size shell holds appeal. We use scientific measures to provide the judgment criteria we use in morphological and physiological standards. We recognize the best shells, we accept the large part of the collection, but reject the broken, chipped and smaller stock as unacceptable to our goals.

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USE OF VEGETATIVE PROPAGULES IN REFORESTATION IN B.C.[1]

B.G. Wigmore[2] and J.H. Russell[3]

ABSTRACT—Vegetative propagation is a silviculturist's reforestation tool which can be used for various purposes including: bulking-up a scarce seed supply; delivering genetic gains from selected families for improved traits such as pest resistance; and for clonal forestry. The focus of this talk will be to describe the above, using specific species as case studies. As well, recent innovations in vegetative propagation and future directions will be discussed.

INTRODUCTION

As interest in vegetative propagation for reforestation increases, nursery growers are faced with the task of learning to manage new and often challenging stock types, including cuttings, emblings, seedling donor plants and hedge orchards. What is driving this trend, and will it continue? Is vegetative propagation really necessary? There are several reasons why these programs are implemented, including: bulking-up a scarce seed supply, bulking-up elite families, ease of propagation, and clonal forestry. Not all forest tree species are amenable to vegetative propagation. As well, the reasons for implementing a program are usually quite species-specific.

YELLOW-CEDAR—BULKING-UP SCARCE SEED; CLONAL FORESTRY

The yellow-cedar (*Chamaecyparis nootkatensis*) cutting program is the largest and oldest operational vegetative program in B.C. It was implemented in the 1970's to bulk-up a scarce seed supply, and is now becoming the vehicle for clonal forestry.

Historically, there has not been enough yellow-cedar seed available to meet demand. Cone crops in the wild are erratic, and the number of filled seed per cone is low. Yellow-cedar seed orchards have never really produced; there are a number of problems associated with them. Also, seed germination has been poor in the past. However, yellow-cedar roots naturally through layering, thus rooted cuttings were an obvious alternative.

Seedling production is better now, due to improved cone collections and learning how to overcome seed dormancy. Over one million yellow-cedar seedlings are now produced annually in B.C. Even so, there is still a shortfall, and up to one million cuttings are grown annually to help meet the demand.

Most of the yellow-cedar cuttings come from hedge orchards, which may be field-grown or containerized. It is important to maintain juvenility and health of hedges to achieve a good quality cutting crop (figs. 1a, 1b). An alternate method of obtaining juvenile cutting material is through serial propagation, which at least one B.C. nursery is doing.

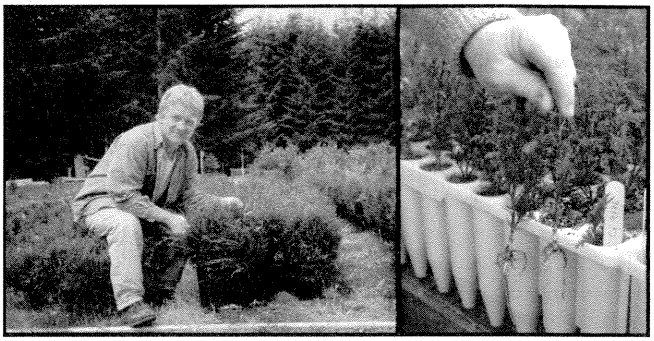

Figure 1—a) A juvenile containerized yellow-cedar hedge orchard, b) a newly rooted yellow-cedar cutting.

Quality is an issue, and one effective way of improving the cutting crop is to rogue donor plants based on nursery performance. Individual seedlings within a family can vary widely in characteristics such as stem form and rooting percentage. By identifying and clonally bulking-up the good seedlings in a hedge orchard, and removing the poor seedlings, the cutting crop quality can be greatly improved. MacMillan Bloedel has done this with very good results.

Clonal selection for nursery performance is only the beginning. A clonal breeding program for field performance is in place, led by the Ministry of Forests and Western Forest Products. Seedlings from the breeding program were cloned using cuttings, and the clones were put out into field tests. The results are forthcoming; selections have been made and are being bulked now. A volume gain of 10-20 percent at rotation is anticipated from orchards composed of this elite clonal material (J. Russell, unpub. data).

HYBRID POPLAR—CLONAL FORESTRY; EASE OF PROPAGATION

The hybrid poplar vegetative propagation program was implemented specifically for clonal forestry, and takes advantage of the relative ease of propagation of poplar. Poplar culture is relatively new in B.C. compared to the U.S. There are mainly two companies involved, Scott Paper and Pacifica Paper (formerly part of MacMillan Bloedel).

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[1]Wigmore, B.G.; Russell, J.H. 1999. Use of vegetative propagules in reforestation in B.C. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 116-118.
[2]5909 Deuchars Drive, Duncan, BC V9L 1L5, Canada;TEL: 250/748-0357.
[3] Research Branch, BC Forest Service, Cowichan Lake Research Station, Box 335, Mesuchie Lake, BC V0R 2N0, Canada.

So why hybrids? and why clones? The hybrid poplars used are crosses between the native *Populus trichocarpa* and the non-native *P. deltoides* (or occasionally another non-native species). Hybrids between related species are not usually successful, but occasionally there is a phenomenon called hybrid vigour, wherein a hybrid offspring has a much faster growth rate than either of its parents. This hybrid vigour occurs in a few clones within some families of *P. trichocarpa x deltoides.* Many clones are screened to find these elite ones. Both Scott and Pacifica have selected approximately 20 clones that they use for most of their plantations.

Poplar cuttings are produced in stoolbeds. Whips are harvested while dormant by cutting the stools back to the ground. The whips are then cut into the desired lengths, and planted directly in the field. Poplar roots very easily in the field, they can even be planted upside-down and still root.

Scott Paper plants 200-600K cuttings per year. Pacifica Paper plants 1.2 million cuttings a year, but only 40 percent of that is in B.C. and the rest is in Washington. There is little available good land for poplar plantations left in B.C., hence the expansion to the U.S. Hybrid poplar plantations are highly productive, with a rotation age of 10-12 years, and an average yield of 300-350 m^3/ha at age 10 (D. Pigott, pers. comm.).

WEEVIL-RESISTANT SPRUCE—BULKING-UP ELITE FAMILIES; CLONAL FORESTRY

Yellow-cedar and hybrid poplar are well-established vegetative propagation programs in B.C., but propagation of weevil-resistant spruce has only recently become operational. The white pine weevil (*Pissodes strobi*) causes significant damage to both interior spruce (*Picea glauca x englmannii*) and Sitka spruce (*P. sitchensis*). Two propagation systems for weevil-resistant spruce are under development, rooted cuttings and somatic embryogenesis. Sitka spruce rooted cuttings will be discussed as an example of bulking-up elite families, while somatic seedlings (emblings) will be addressed for their potential value in clonal forestry.

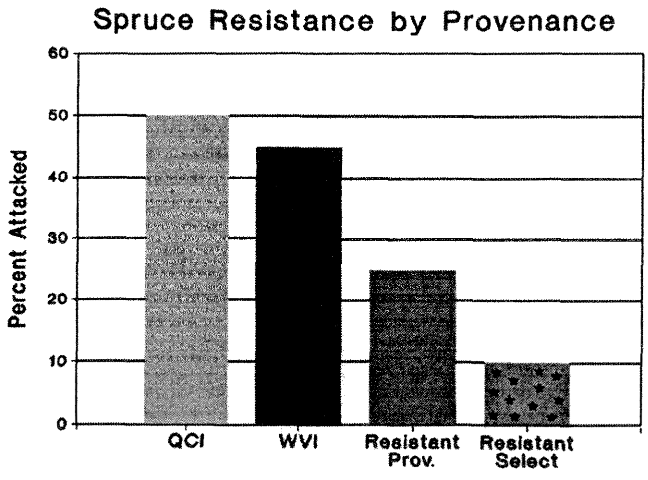

Figure 2—Percentage of Sitka spruce trees attacked by white pine weevil at a test site near Jordan River, B.C., by provenances and select families.

Planting of Sitka spruce on the coast of B.C. has been reduced from 10 million trees annually to about 0.5 million because of the weevil. Only the Queen Charlotte Islands are free of the weevil and can be planted successfully with Sitka. Two provenances, Qualicum and Haney, have been identified as having some resistance to the weevil. Wild stand collections from the Qualicum provenance show about 50 percent resistance compared to the Queen Charlotte and West Vancouver Island provenances (fig. 2). Qualicum seedlots are recommended for use in low weevil-hazard areas.

A selection program has identified particular families within the Qualicum provenance that show superior resistance (fig. 2). By using these selected families, planting of Sitka can be expanded to the medium weevil-hazard areas, which could result in a demand for around 5 million trees annually (J. King, pers. comm.). Seed from these families, however, will be in chronically short supply for some time; thus vegetative propagation is used as a tool to help meet the demand. Rooted cuttings are currently the best way to bulk up these resistant families, and after an initial research period are now being produced operationally.

It is important to use juvenile donor material for spruce, and neither long-term hedging nor serial propagation are particularly successful for this species. Therefore one-year-old seedling donor plants are used, which, when potted and grown aggressively, yield an average of about 50 cuttings per plant (fig. 3a). New crops of donor stock plants are sown each year. This system is similar to that employed by Weyerhaeuser for Douglas-fir (Ritchie 1994), and as developed for interior spruce in B.C. (Russell and Ferguson 1990).

Sitka spruce cuttings root relatively easily and generally have good form. All three nurseries growing them achieved over 90 percent rooting in 1998. Rooted cuttings of this species cost only 60-75 percent more than seedlings, and the program is expanding from 50K in 1998 to over 100K in 1999, with further increases expected as more companies become involved. Sitka spruce cuttings from juvenile donors perform as well as seedlings in the field, and they have been in use for about twenty years in the U.K. (Morgan and Mason 1992).

The alternative propagation method for resistant spruce is somatic embryogenesis (s.e.). This technology is capable of producing an infinite number of copies of particular clones. Also, tissue can be cryo-preserved for many years, thereby maintaining juvenility of the clone while waiting for field test results. However, until individual clones have been tested for weevil-resistance, s.e. provides no additional gain over capturing an elite family's breeding value, which is achievable through rooted cuttings at a lesser cost. In fact, due to the large number of recalcitrant families and clones in s.e. technology, it is possible that the clones being bulked now are not representative of the parental breeding values. However, when superior clones are identified through field tests, and cost is reduced, then s.e. will be a valuable tool.

DOUGLAS-FIR AND WESTERN HEMLOCK—BULKING-UP ELITE FAMILIES

As with rooted cuttings of Sitka spruce, cuttings of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) are also used for bulking-up elite families. The only difference is that the families are selected for growth and/or wood quality, rather than pest-resistance.

Weyerhaeuser Co. in the U.S. has a successful Douglas-fir cutting program, and it was hoped that a similar one could be developed in B.C. One-year-old stock plants have been grown here successfully, but there are problems with plagiotropism in the cuttings. Weyerhaeuser grows Douglas-fir cuttings as a 1+1 stocktype, and the cuttings make a transition from plagiotropic to upright growth in the nurserybed in their second year. In BC, however, a 1+0 container stocktype is required. Some progress has been made in overcoming plagiotropism - there are cultural techniqes and genetic factors that help, but container Douglas-fir cuttings are still too unreliable and costly for operational use.

Western hemlock rooted cuttings are more successful. The Ministry's realized gain trials show that greater than 20 percent volume gains at rotation are attainable using top families (J. King, pers. comm.). Canadian Forest Products has some of these elite trees in their seed orchard. Through controlled crossing, elite seedlots are produced, which can then be bulked up through rooted cuttings. Again, one-year-old seedling donor plants are used (fig. 3b). Several private nurseries are involved with growing hemlock cuttings for CFP, and high rooting rates and good crop quality have been achieved. Trials have been established to compare performance of cuttings and seedlings in the field.

a b

Figure 3—a) Sitka spruce donor plant, less than one year old, yielding about 50 cuttings; b) western hemlock donor plant, less than one year old, yielding about 70 cuttings.

CONCLUSION—VEGETATIVE PROPAGATION IN THE NEXT MILLENNIUM

Vegetative propagules will become increasingly common in the next millennium. In just a few years, yellow-cedar cuttings will be used for clonal forestry. Clonal forestry with hybrid poplar is already well established. Somatic embryogenesis will become operational for spruce and possibly other species. Also, genetic engineering is not far-fetched, and s.e. will be the vehicle for that technology. There will be continual increase in the use of rooted cuttings to bulk-up elite families, as there is always a lag of several years between the time when tree improvement selections are made, and when fully-producing seed orchards can be established.

ACKNOWLEDGEMENTS

Funding for B. Wigmore's research and development of rooted cuttings of Douglas-fir, western hemlock and Sitka spruce is provided by Forest Renewal B.C. The authors would like to acknowledge all of the talented and enthusiastic growers in B.C. who have made the vegetative propagation programs successful.

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GROWING INTERIOR SPRUCE (Sx) SOMATIC SEEDLINGS IN THE NURSERY[1]

Don Summers and Cheryl Calam[2]

INTRODUCTION

Since the late 1980s in British Columbia, there has been a growing interest in the idea of replicating conifers through embryogenesis. Theoretically this procedure allows the production of unlimited numbers of trees with the same genetic make up (i.e. for insect resistance, better growth, desirable wood quality). In practice and with due diligence with respect to testing and biodiversity issues, this technique could be used to produce custom clonal lots tailored to specific site needs in the field. While this technique may not be acceptable in some situations, it could offer advantages in areas where timber production is the primary land use.

The actual production of the somatic propagules takes place in the laboratory and is beyond the scope of this paper. Suffice to say that seed embryos from superior provenances are dissected out of the seed and passed through a variety of processes to develop an undifferentiated callus-like material. Portions of the callus can then be differentiated into many small somatic propagules resembling germinating seedlings. Those propagules can then be raised in a nursery using normal cultural practices. At various times, the common name for this kind of tree has been either somatic seedling or embling.

At the suggestion of Drew Brazier, Director of Nursery and Seed Operations Branch, our Extension Services (ES) nursery started growing interior spruce (Sx) somatic seedlings in 1994. This was part of a larger program that would grow and test various clones in the nursery and out in the field. To-date, with the cooperation of Kendal Thomas (Woodmere Nursery, Fairview, Alberta), Chris Hawkins (UNBC, Prince George, B.C.) and a number of other ministry and industry partners, there are in the order of 30 demonstration sites and 33 research sites planted in the Prince George and Cariboo Forest Regions. The field goals of this project are to test and demonstrate the performance of the various clones produced over the range of bio-geoclimatic zones they may be planted in. There have been a number of other nurseries involved from time to time, but we will only report on what we have found at Extension Services.

SCALING UP

Table 1 illustrates the gradual increase in numbers of somatic seedlings grown in our nursery between 1994 and 1997. For comparison, in 1998, Green Timbers Nursery began an operational crop of 190,000.

Table 1—Production of somatic seedlings at Extension Services 1994-1997

Year	Age	# Lines (cones)	# Arriving	# Lifted	Percent[a]
1994	1+0	10	4,704	2,881	61.2
	2+0	4	1,792	1,200	67.0
1995	1+0	21	22,396	13,688	61.1
1996	1+0	34	23,987	19,487	81.2
1997	1+0	38	93,502	64,450	68.9
	1+0	776	41,587	35,369	85.0

[a] Culls often include entire clones, testing should reduce this in time.

In 1997, we had 38 lines or clones that were destined for clonal block demonstration sites and 776 lines destined for research trials. To put this in perspective, each clone has the specific genetic traits of one seed. In essence, the individuals in each block of the same clone or each pallet of the same clone exhibit very similar growing characteristics. To put this in perspective further, the natural variation you might find within a seedlot is now separated into batches within the greenhouse. In 1994, there were some styroblocks that held 2 or 3 clones each and as you can imagine, that affected crop management. In 1997, production was scaled up for part of this work and we were able to produce 2 or more pallets of each of the 38 clones above. That significantly improved our ability to manage the crop. Some of the issues this raises will be discussed later.

THE GROWING REGIME

Somatic seedlings arrive in the nursery as young plantlets (1.5 - 5 cm long including radicle) in their laboratory media containers and bearing varying amounts of root and shoot. In general (as you would expect) we found that more roots on young plantlets improves survival and early growth.

Tender somatic seedlings are removed by hand and individually placed in watered 415B styroblock containers with our regular seedling mix (3:1 Peat/vermiculite; lime and micromax) (table 2). Planting dates ranged from March/April in 1994 to mid-February in 1997. During planting the blocks are misted to keep the media moist, much like with germinating seed. This is critical with somatic seedlings because they initially have a radicle protruding into the media right at the start. They lose some of their turgor quickly after transplanting and are subject to desiccation at this point. We generally use 3 to 5 scheduled mistings a

[1]Summers, D.; Calam, C. 1999. Growing interior spruce (Sx) somatic seedlings in the nursery. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 119-121.

[2]MOF Nursery Extension Services, 4275 96th Street, Surrey, BC, V3V 7Z2, Canada: TEL: 604/930-3301; FAX: 604/775-1288.

Table 2—Growing regime for spruce at Extension Services

Lights	21h through July/August
Soil mix	Peat/vermiculite (3:1) plus lime and micromax
Blocks	PSB 415B
Misting	3-5 times/day; changing to ad lib once germinated
Day/night temps	21 through germination changing to 24/17 during growth. Ambient once outside in July/ August
Lift	December after storability testing

day, depending on weather and may apply one or two manual passes as needed on hot days. Misting occasionally includes a foliar application of fertilizer (at 25 ppm N). Misting continues for up to a month, depending on the condition of the somatic seedlings and how long it takes them to begin regain their turgor.

Our measure for how long to mist has been to watch the foliage. When the turgor increases (i.e. the young tops begin to straighten up just a little), we reduce misting (other than for heat protection) and begin the fertilizer regime (table 2) and wet/dry cycles. Greenhouse temperatures are set about the same as for germinating seeds (24h at 21C) during the misting period. Day/night temps (24/18 C) are instituted once the misting is terminated. A day length of 21h was used for acclimating somatic seedlings in most years. An outline of our culture is provided in table 2.

During the growing season, visual differences in growth appear between clones. Due to a slow transplanting process and different delivery times from the lab, some clones are planted earlier. Some others may recover quicker after transplanting and some seem to grow faster. We have found that sorting the material into 2 or more groups can be beneficial when this occurs. In fact, with some clones this can occur early on and grouping may be beneficial when misting is reduced. We seldom had more than 3 groups of clones for any length of time and it did not result in too much extra management, once we were use to it.

Stock is moved outside as it begins to reach minimum height specifications (13 cm = cull: BCMOF Stock Specifications, 1997, unpublished). Early grouping according to height facilitates this. In general, the bulk of the material was ready to go out within a window of about a month.

Crop management remained much the same outside the greenhouse as in, however there was no supplemental lighting. Irrigation and fertilization were done according to wet/dry cycles of the crop. Reduced rates of fertilizer began at about the end of July or early August and became periodic about the middle of September with the onset of fall rains. Lifting took place after storability testing in December.

Table 3—Example lift data for interior spruce seedlots (SL) and somatic seedlings

Seedlot or somatic line	Height (std. dev.)	Caliper (std. dev.)
SL 29163 (wild seed)	183.63 (21.64)	3.42 (0.48)
SL 6863 (orchard seed)	213.65 (27.17)	3.82 (0.44)
119-2558	154.91 (12.61)	3.70 (0.32)
107-1917	203.71 (18.02)	3.85 (0.41)
1-1446	181.43 (17.01)	3.37 (0.42)
7-2833	300.64 (33.61)	4.10 (0.56)

In the final crop the clonal effects are quite apparent. Individual clones have identifiable height, color, needle shape and tree form. Other than some variation (table 3) due to position in the blocks and location of the blocks on each pallet (i.e. within each clone), the individual clones generally appear quite uniform.

Discussion

Probably the most important thing to note is that only minor modifications to early seedling culture and some bio/spatial issues due to clone are required to grow somatic spruce seedlings.

Somatic seedlings arrive in the nursery as a lab culture with varying degrees of tops and roots. Some resemble young germinants just after the seed coat has fallen off - although they are much smaller and less robust. Others more resemble very small cuttings - all top, a bit of stem and almost no root. As they are planted, there is obviously damage being done to any root hairs and perhaps the root tips. This compounds the existing low root to shoot ratio and their inability to support high transpirational demands.

In essence what you are starting with is an upside-down version of a seedling. With a seedling, the radicle emerges first and becomes established as the shoot and leaves begin to expand. Seedlings draw on the endosperm and gradually shed the seed coat as the roots develop, take hold and begin to supply nutrients and water. With somatic seedlings, you have the reverse: a significant top and due to transplanting, very little root support until the root gets acclimated to it's new medium.

This is probably the most critical stage of production. The difference is that with somatic seedlings at this stage, you have a high rate of evapo-transpiration from the foliage and an impaired root system. Humidity and irrigation patterns are critical to ensure the tops don't dry up and the roots are able to get established. For the most part however, we found that misting and irrigation was much like with regular germination. The key is to keep the humidity around the plants high and avoid prolonged periods with saturated blocks which could induce additional stress and disease. Bottom heat may help in reducing evapo-transpirative stress as compared to the unit heaters, fans and overhead tubes used to heat many greenhouses. It may also help with moisture management in the media.

With a germinating seedlot, individuals may germinate at different rates. The same holds true for somatic seedling establishment, but with an added twist - clones differ as well. Depending on the quality of the material planted, you are presented with the same issue as with seedlings and/or an extra consideration - pallets of different clones that are generally growing faster or slower. In many ways, it's much like having a number of different seedlots in the same house.

One of the biggest challenges is getting all the material planted so that the future crop is uniform. This requires a lot of organization and well trained manpower. Currently, the process is not automated, although companies are working hard to accomplish this through various means.

The organizational skills that are needed are much the same as with any job that requires a crew of people on an assembly line. Materiel must be supplied at the rate and in the order needed. Crew movement should be limited and tasks should be focused.

When planting somatic seedlings, we found 2 things that can speed up a crew's production: pre-gritting the cavities (top dressing with forestry sand) and dibbling planting holes in the media. With pre-gritting, we use somewhat less grit than normal (about 0.5 cm), but still enough to slow down evaporation and inhibit algae and mosses. If this is not done beforehand, gritting must be done afterwards by hand and this can damage the young plants. Dibbling is done after gritting with a home-made dibbler. It consists of a piece of wood about the same dimensions as a styroblock with a handle attached to one of the flat sides. Nails are driven through the wood such that they match up with the cavity layout in the styroblocks. The wood is placed over the block and pressed down to create planting holes. This process seems to reduce the amount of damage done to roots during planting. Blocks are watered after planting to settle the media around the new roots.

Once the material is planted, we mist under lights for a week or two until the crop shows signs of perking up. This is largely a subjective assessment much like estimating when most of the seedcoats have been shed in a seedling crop. In this case, we wait until stems and foliage stand taller and start to elongate a bit. There has been some suggestion that misting or charging the media or mist with phosphorus may promote faster root establishment (Dan Polenenko, Silvagen Inc., personal comm.). We tried this one year, but did not see a difference.

With somatic seedlings you have individual clones representing the range of diversity of a regular seedlot in terms of growth. Seedlots have slow and fast growing seedlings mixed up and they are all treated the same. However, with clonal material, each clone seems to exhibit the same general patterns - some individual clones seem generally fast growing (or more responsive to nursery culture) and some seem slow. As the season progresses, this requires a bit more management of the crop. The fast growers may have to be separated out and treated differently than the slow ones. Typically we have 2 - 3 groups.. For example, we keep the slow ones inside the greenhouse under full fertilization and lights for up to 4 weeks after the faster growers have been moved outside.

If the crop is managed properly, grading also presents a unique experience - for the most part, a clone is either a cull or not. However, even with the obvious visual clonal similarity, there is still variation for individuals within a clone due to such things as lab culture, planting technique or position in the block or on a pallet (table 2). With careful management, some of those differences can be minimized.

In summary, other than a few minor management differences, growing Sx somatic seedlings is much like growing regular seedlings. Misting continues until the plants appear to be established. Once that is accomplished the culture changes over to a regular fertilizer regime and wet dry cycles. Normal culture is used through to the final lift. There is more opportunity to manage diversity within the crop with somatic material and to a certain extent the cull factor can be reduced.

Somatic seedling quality at time of planting is as important as having a good seedlot and it seems that within certain bounds, larger plantlets are better than small, some root is better than none and sturdy is better than lanky due to the tendency to 'wilt' a bit on transplanting.

Planting dates (environment) can be significant. In our case it seems that planting in February provides more assurance of success than planting in March due to the rapid, frequent changes in weather and insolation that occur in the early spring in the Vancouver area. In sunnier climes this may point out the need for stricter control of media moisture, temperature and humidity for the establishment phase.

Knowing something about past nursery performance can help in organizing the crop to minimize the amount of labour expended in moving stock around. In the early stages of testing this is critical so that important genetic gains are not screened out at the nursery stage. This has to be managed carefully until more testing is done. It may be that clonal forestry will demand some custom cultural techniques to ensure that the very best material gets planted out in the field. After all, genetic gain is what the customer if after.

ACKNOWLEDGMENTS

The authors would like to thank Drew Brazier, Director Nursery and Seed Operations Branch for initiating and supporting this project, B.C. Research Ltd./Silvagen Inc. for supplying the somatic material, Bev Wigmore for getting the nursery work off the ground initially and Kendel Thomas and Chris Hawkins for managing the field work and being obliging customers.

EARLY FIELD PERFORMANCE OF INTERIOR SPRUCE EMBLINGS[1]

C.D.B. Hawkins[2]

ABSTRACT—Somatic embryogenesis (SE) is a type of vegetative reproduction. It may offer an effective way of utilizing superior genetic material developed by tree improvement programs. Sixteen clonal tests or candidacy trials (CT) were established in the central interior of British Columbia between 1994 and 1998. The objective was to identify superior (growth and insect tolerance) SE clones from 52 interior spruce (*Picea glauca* (Moench) Voss, *P. engelmannii* Parry ex Engelm., and their naturally occurring hybrids) families. More than 48,000 individuals are in these CT. To date, survival has been excellent, greater than 95 percent, and exceeds 99 percent on the oldest CT. Clonal growth is affected more by environment than by genotype even on the oldest CT sites. This will delay the identification of superior SE clones. Attack by the spruce leader weevil (*Pissodes strobi* Peck) began this year in the older CT. It will be several years yet before weevil tolerant SE clones can be identified. In addition to biological issues, there are economic and social ones that must be addressed before operational scale deployment of SE emblings. The potential of SE technology is great but the validation process is exceedingly slow and costly.

INTRODUCTION

Vegetative reproduction is effective for utilizing superior genetic material developed by tree improvement programs. Significant advances in conifer vegetative propagation systems have been made over the past 25 years (Grossnickle and others 1996). These systems provide a means of bringing new genetic material into forestry programs (Libby and Rauter 1984) and a way to bulk up superior families (Gupta and Grob 1995, Kleinschmit and others 1993). By far the most significant means of vegetative propagation, today, is with rooted cuttings. Annual plantings exceed 65 million (Ritchie 1991, Talbert and others 1993). However there are significant limitations to this technology (Grossnickle 1998, Hackett 1985). Organogenesis is another means of vegetative reproduction but in conifers it has been used only on a limited operational scale (Frampton and Foster 1993, Ritchie and Long 1986, Smith 1997). Another vegetative protocol and the focus of this paper is somatic embryogenesis (SE) and it is described elsewhere (Grossnickle and others 1996, Tautorus and others 1991).

Compared to rooted cuttings technology, SE technology has the advantage that genotypes can be stored for a long time using cryopreservation (Cyr and others 1994) with little affect on genotype (Kartha and others 1988). The interior spruce (*Picea glauca* (Moench) Voss, *P. engelmannii* Parry ex Engelm., and their naturally occurring hybrids) seed orchard program of the BC Forest Service (Kiss 1968) was used as the source of parents with proven superior growth potential to assess the efficacy of SE technology in BC (Sutton and others 1993). Some of this parental material also has increased tolerance to the spruce leader weevil (white pine weevil *Pissodes strobi* Peck) (Alfaro 1996, Kiss and Yanchuk 1991). A large scale SE clonal testing program has evolved and it is expected that clonal selections for superior growth and tolerance to the weevil will occur about 5-7 and 7-10 years, respectively, after planting.

However, three issues must be addressed before SE technology can be successful operationally: 1) identification of clones with desired traits from sufficient superior families to have an effective population size of 10, 2) economic or cost benefit of SE embling clones compared to full sib or open pollinated seedlings of the same family, and 3) public acceptance of clonal forestry in BC. The paper will describe field testing of SE clones in candidacy or clonal test (CT) sites established between 1994 and 1998 in the central interior of BC, Canada, and briefly look at social and economic issues.

THEORETICAL

Why field test if all the parents other than some from the BIOTIA series been chosen for the program based on superior growth and weevil tolerance? There are several reasons: a) a very small number of genotypes from each family has successfully progressed from the laboratory on to

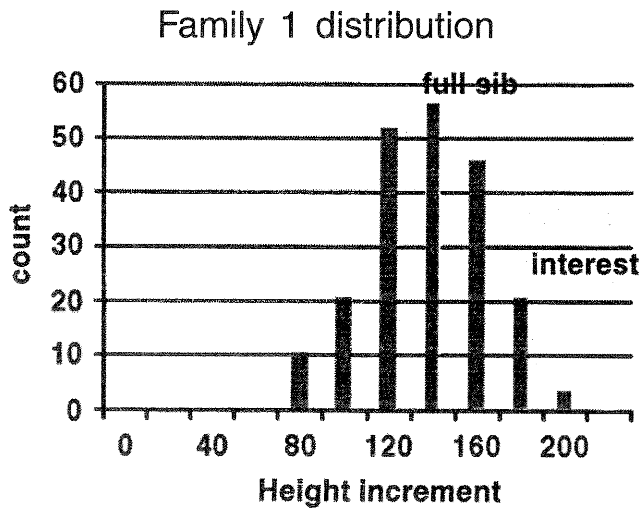

Figure 1—Count of the first year height increments for Family 1 (PG001 X PG021).

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[1]Hawkins, C.D.B. 1999. Early field performance of interior spruce emblings. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 122-128.
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the nursery and out to the field; b) it is necessary to determine if family clonal means, for any trait, approximate a normal distribution (fig. 1); c) full sib or seedling controls are expected to be near the centre of the normal distribution for a family and this must be determined through testing; d) clones selected for operational deployment should be at the extreme right of the normal distribution; and e) need to ascertain clonal weevil tolerance under field rather than laboratory conditions. The only way to meet these objectives with any degree of certainty is through field testing.

The goal of the SE, CT program is to identify the superior clone for growth and for weevil tolerance from each of the families plus those clones that display desirable silvicultural characteristics such as tolerance to low air temperatures, cold wet soils, or competing vegetation. Ideally after growth and weevil results are determined from the described CT series about 70 clones (five percent selection intensity) would be selected to form the base population. Seedlots with a minimum of 30 clones and an effective population size of 10 (Anonymous 1998) would be constructed from the base population for operational deployment. A more likely scenario is a second phase of CT where the top 15-20 percent of the clones from the present CT are tested on a wider range of sites. The base population of 50-70 clones would then be chosen from this smaller phase two test population.

Regardless of test scenario, it will take a minimum of 5-8 years from plantation establishment to attain reliable growth estimates. Estimates of weevil tolerance will take longer, probably a minimum of 8-10 years. Therefore while the

Table 1—Candidacy test sites: year of establishment, stocktype planted, locale, biogeoclimatic (BEC) subzone, parental origins, number of families and total number of clones planted per familv including full sib seedlings

Year planted	Stocktype	Sitename	Site BEC	Parental source	Number families[a]	Number clones
1994	1+0 313B	Hungary Creek 4	ICHvk	BIOTIA	12	113
1995	1+1 PBR	Hungary Creek I	ICHvk	BIOTIA	12	158
1995	1+1 PBR	Huble Road	SBSwk1	BIOTIA	12	206
1996	1+0 415B	Aleza Lake	SBSwk1	PG95[b]	15 (24)	268 (290)
1996	1+0 415B	Tumuch	ICHvk	PG95	15 (24)	306 (329)
1996	1+0 415B	Indian Point	SBSwk1	PG95	15 (23)	312 (334)
1997	1+0 415B	Aleza Lake	SBSwk1	PG-ENA	7 (29)	109 (278)
1997	1+0 415B	Hungary Creek 1.5	IVHvk	PG-ENA	6 (30)	97 (263)
1997	1+0 415B	Arctic Lake	SBSwk	PG-ENA	7 (28)	94 (268)
1997	1+0 415B	2700 Road Quesnel	SBSmw	PG-ENA	7 (30)	64 (166)
1997	1+0 415B	Marie North	SBSmc2	PG-ENA	4 (14)	49 (87)
1998	1+0 415B	Weldwood 6000	ICHdk	QL[c]	18 (34)	452 (497)
1998	1+0 415B	Riverside Likely	ICHmk3	QL	18 (37)	654 (705)
1998	1+0 415B	Weldwood TFL 5	SBSdw	QL	18 (34)	513 (558)
1998	1+0 415B	Catfish Creek	ICHwk3	QL	18 (34)	436 (477)
1998	1+0 415B	Missinka	SBSvk	QL	18 (33)	485 (528)

[a] Number of families and clones are new for that year while the numbers in parentheses indicates the total number of families and clones planted.
[b] All sites planted after 1995 have clones from previous years to serve as benchmarks among the years.
[c] Quesnel Lakes, no clones were produced from families 3 1 and 32 (see table 2).

Table 2—Embling family, parents used in cross and parental rank for growth and weevil tolerance if known. Rank for BIOTIA and PG material is based on 15 years of 173 parents and for Quesnel Lakes (QL) it is 10 year data from 142 parents

Source	Family	Female	Rank growth	Rank weevil	Male	Rank growth	Rank weevil
BIOTIA	G	PG001	29	14	PG144	19	34
BIOTIA	H	PG001	29	14	PG127	67	118
BIOTIA	I	PG002	4	20	PG096	78	97
BIOTIA	J	PG002	4	20	PG094	102	130
BIOTIA	L	PG010	46	32	PG146	45	82
BIOTIA	M	PG059	165	146	PG021	11	3
BIOTIA	N	PG059	165	146	PG073	167	138
BIOTIA	Q	PG084	21	57	PG088	68	18
BIOTIA	R	PG090	158	132	PG041	168	142
BIOTIA	T	PG113	60	83	PG143	3	36
BIOTIA	U	PG113	60	83	PG140	36	15
BIOTIA	W	PG171	170	91	PG173	173	145
PG95	1	PG001	29	14	PG021	11	3
PG95	2	PG001	29	14	PG029	8	1
PG95	5	PG001	29	14	PG087	1	10
PG95	10	PG001	29	14	PG167	9	9
PG95	23	PG167	9	9	PG161	2	7
PG95	65	PG087	1	10	PG021	11	3
PG95	73	PG087	1	10	PG161	2	7
PG95	75	PG087	1	10	PG167	9	9
PG95	107	PGO87	1	10	PG138	5	2
PG95	119	PG021	11	3	PG029	8	1
PG95	125	PG021	11	3	PG161	2	7
PG95	127	PG021	11	3	PG167	9	9
PG95	142	PG029	8	1	PG161	2	7
PG95	143	PG029	8	1	PG167	9	9
PG95	186	PG161	2	7	PG029	8	1
PG-ENA	3	ENA0663	-	-	ENA0866	-	-
PG-ENA	4	EBA0872	-	-	PG145	6	-
PG-ENA	6	ENA0866	-	-	PR0063	-	-
PG-ENA	7	ENA1659	-	-	ENA1649	-	-
PG-ENA	8	PR0063	-	-	ENA0866	-	-
PG-ENA	13	ENA1659	-	-	ENA1645	-	-
PG-ENA	77	PG087	1	10	ENA1645	-	-
QL[a]	14	QL4731	14	1	-	-	-
QL	15	QL1846	26	1.5	-	-	-
QL	16	QL1665	52	4	-	-	-
QL	17	QL1856	1	4.5	-	-	-
QL	18	QL1816	62	9.5	-	-	-
QL	19	QL1848	28	11	-	-	-
QL	20	QL1819	59	11.5	-	-	-
QL	21	QL1857	16	11.5	-	-	-
QL	22	QL4781	2	12.5	-	-	-
QL	24	QL1871	24	13	-	-	-
QL	25	QL1951	8	14	-	-	-
QL	26	QL4729	42	17	-	-	-
QL	27	QL1843	5	17.5	-	-	-
QL	28	QL1870	10	17.5	-	-	-
QL	29	QL1837	25	18.5	-	-	-
QL	30	QL4728	3	19	-	-	-
QL	31	QL4757	56	19	-	-	-
QL	32	QL4790	9	20	-	-	-

[a] No clones made it to the field from QL families 31 and 32 in 1998.

potential of SE technology is great, the validation process is costly and exceedingly slow.

ESTABLISHMENT

Generally all CT have been established on mesic sites in the various biogeoclimatic ecosystem classification (BEC) units utilized. The appropriate seedling control material (full sib or open pollinated) was planted for each family on all the CT.

1994 and 1995

The first CT was established in the spring of 1994 (table 1) with 12 families from the BIOTIA series of crosses (table 2). The parents of these families were high, mid and low ranked. Due to the poor nursery quality of the material scheduled for planting in 1994, much of it was grown as a bareroot transplant in 1994. In the spring of 1995, two more CT were established using the BIOTIA transplant material (table 1). The above CT were all single tree plot design with 10 randomly allocated ramets per genetic entry. All future CT were also single tree plot design with random allocation of ramets.

1996

The PG95 (Prince George 1995 nursery culture) material was established on three sites in the spring of 1996 (table 1). The parents of this series of crosses were chosen for their superior growth and tolerance to the spruce leader weevil (table 2). The quality of the SE material in some families was as good as that of the seedling controls. However, in others quality was still lacking as it had been for the earlier BIOTIA material. The three sites were subjected to a growing season frost in early July 1996 and again in early June 1998. Subsequently they have gone into severe planting check. Selection for growth will be delayed by at least three years for the PG95 material.

1997

In the spring of 1997, the PG-ENA (Prince George - Eastern North America parents) clones were planted on five sites (table 1). All parents in this series of crosses had demonstrated good growth and tolerance to the spruce leader weevil (Kiss 97/01, retired spruce breader, BC Forest Service, Vernon, BC) (table 2). For the first time, the quality of the SE material at planting was equal or superior to that of the seedling controls. These plantations did not appear to be affected by the early June 1998 frost.

1998

Five CT were established across the central interior of BC with material from the former Quesnel Lakes (QL) seed planning zone in the spring of 1998 (table 1). These parents were selected primarily for tolerance to the spruce leader weevil and secondarily for growth potential (table 2). Again the quality of the SE material was equal or superior to that of the seedling controls. It is too soon to assess the impact of the June 1998 frost on these sites.

Overview

A total of 16 CT were established between 1994 and 1998. There are more than 48,000 single tree plots from 1400+ clones within 52 families in test. The size of the CT are variable. They range in size from about 1000 to 7000 emblings and seedlings per CT. Immediately after planting for each CT, groundline stem diameter (GSD) was determined. In the fall of the year of planting, height at planting and fall height and fall GSD are measured. This is the base data for all CT on all sites. CT sites are visited in the spring and fall of the first three years and annually in the fall thereafter to assign a health or vigor score to each individual in the CT.

Stock quality differences observed between clones and seedlings on the CT established in 1994-1996 may be due to nursery culture or genetics. This has two ramifications. It slows down the testing (takes longer for stock to equilibrate) and it may result in early over estimates of seedling growth potential when compared to appropriate SE clones. This should not be a concern for the CT established in 1997-1998.

At the same time as the CT were established, demonstration plantations called clonal block (CB) sites were also planted. The base unit of a CB contains about 200-300 ramets of a single clone planted at operational spacing. Generally at each site, a minimum of 10 SE clones and an operational and a wild seedlot were planted, a dozen base units. There are more than 25 CB in the central interior of BC containing more than 100,000 emblings and seedlings. Survival plots were established in each base unit of a CB. The CB will be discussed elsewhere (report in preparation, D Summers and C Hawkins unpublished data).

RESULTS AND DISCUSSION (PRELIMINARY)

Surprisingly on all CT sites, regardless of when established or quality of planting stock, survival was excellent. It exceeded 95 percent on all sites and on some sites it still exceeds 99 percent. The oldest site, Hungary Creek 4 planted with the poorest quality stock, is in the latter category. These results may be due, in part, to the aggressive control of competing vegetation on the CT sites.

Table 3—ANOVA model for comparison among sites after the same number of growth periods. All sources in the model are significant, aŏ = 0.05

	HR vs HC1 2 years		HR vs HC4 3 years		HR vs HC1 vs HC4 2 years	
Source	df	F	df	F	df	F
Site	1	1595.5	1	2939.2	2	2156.4
Family	11	29.0	11	15.4	11	20.5
Clone (family)	136	14.0	85	13.7	78	20.1
Site X family	11	5.3	11	4.5	22	3.0
Site X clone (family)	136	2.9	85	2.9	155	2.9
Error	4900		3594		4372	

On at least two sites, vegetation control was done in the summer of the year of planting. Stock vigor, health or quality was good for both seedlings and SE emblings and not different between them but differences among sites were considerable. The range among sites for stock that was healthy is 70 - 86 percent. Survival and quality were not different between SE emblings and representative seedlings on a given CT site.

Analysis of variance for the BIOTIA sites, when compared after an equivalent number of growth periods on site, indicates model main effects were significant (table 3). More importantly, all interactions were significant. The interaction between genotype and environment (Site X Clone(Family)) is of particular interest. For example, after 3 growing seasons clone T689 ranked 162 at Huble Road but was ranked in the top 10 (9th) clones at Hungary Creek 4. This indicates some clones are not spatially stable and they will not be selected if the difference remains.

When comparing Huble Road and Hungary Creek 4, after 3 years growth on site for both, broad sense heritabilites were low 0.05 and 0.24 respectively. Pooled H^2 for these two sites was 0.13. This suggests that 10-15 percent of any clone mean for height is due to true genetic differences among clones. Conversely, 85-90 percent of the variation in clone mean is due to environment. Therefore at this point in time, BIOTIA clone means are not reliable for the selection of superior clones. The younger CT plantations have not had sufficient time or growth for any selection to be considered.

Generally full sib seedling grew faster than their BIOTIA clonal counterparts. This may reflect the seedlings better quality and larger size at planting. The larger stock at planting usually was still larger after three growth periods at the Huble Road site (fig. 2). Removing seedlings from the plot does not change the relationship, the taller emblings at planting are generally still taller after three seasons. This relationship was not as good at Hungary Creek 4 or 1, some of the smaller individuals at planting performed as well as the taller ones and vice versa (poorer). This probably reflects differences among sites; that is clone by site interactions. Again, this reinforces the observation it is too soon for clonal selections.

The susceptibility of interior spruce to the leader or white pine weevil (*Pissodes strobi* Peck) depends on several factors in addition to spruce genotype (SE clone): local weevil population dynamics, site elevation and aspect, and BEC subzone (for example weevil hazard is generally low in the SBSmc2 but can range from low to extreme in the SBSwk1). The weevil requires 785 degree days above 7.2°C to complete its life cycle in an interior spruce plantation (Alfaro 1996). In some BEC subzones, such as the SBSvk this requirement will be met some years and not in others. The spruce seedling (embling) probably needs to be taller than 1.5 m to be susceptible to weevil attack (Turnquist and Alfaro 1996). To date, summer 1998, weevil attack has just started in the BIOTIA CT. However, the attack levels are still too low to identify tolerant or susceptible clones. This information will be forthcoming as the plantations grow in size and local weevil populations

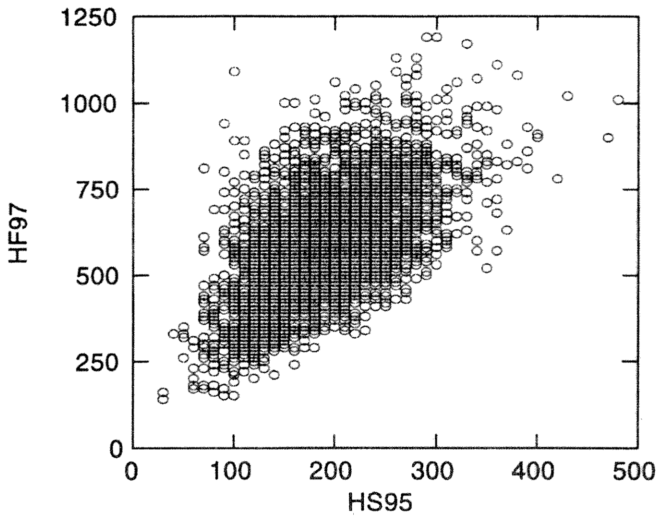

Figure 2—Height after 3 growing seasons (HF97) versus height at planting (HS95) for 12 BIOTIA families at Huble Road.

increase. Again, as with height growth, more time is required before superior clones will be identified.

ADMINISTRATIVE CONCERNS

The basic or first comparison for SE emblings is how much better is the SE embling clone than the full sib seedling from the same family. Based on a 415B stocktype which appears to be adequate for spring plant deployment on most sites in the central interior, the incremental increase in cost for full sib material is about 5-10 cents. This is considerably less than the present incremental cost of SE emblings at the nursery gate of 60-80 cents. Clearly, if incremental costs for SE emblings do not decrease, to justify a large operational SE program, there has to be SE benefits to which economic worth can be assigned beyond enhanced growth. Earlier free to grow, green up and adjacency considerations are three factors which could increase the relative worth of the SE propagule. Tolerance to the spruce leader weevil will increase the economic value of SE material. However, seed orchard full sib seedlings will also have some degree of tolerance to the weevil, and again, it comes down to the difference between seedlings and emblings from the same family.

Until the testing program is well underway, at least five more field seasons, the growth potential value that can be assigned to any SE clone is the same as that of full sib seedlings from the same family. Therefore in the short term, on an operational scale, SE technology cannot compete economically with full sib seedling lots from the same family or even with orchard select families. However, once the superior SE clones have been identified and the incremental SE costs have decreased (similar to that of rooted cuttings), there is a good probability that a small SE operational program for interior spruce in the BC central interior will be justified.

SE deployment is a form of clonal forestry. Public concerns have been expressed about forest health, ecosystem function and reduced genetic diversity certainly with regards to clonal forestry. In British Columbia, the Forest

Practice Code ensures that technical standards are in place to ensure adequate genetic diversity is maintained in seed and vegetative lots derived from seed orchards. The basis for these standards resides in many publications, for example Roberds and Bishir (1997). Further, Carson (1997) refutes the claim that forest health problems are more likely in a clonal forest. Rather, he (Carson 1997) suggests more forest health problems will arise from poor forest management than from atypical genotype representation in a clonal forest. Concerns about ecosystem function for a clonal forest with adequate genetic diversity is no different from concerns about ecosystem function for any plantation regardless of its seed origin. The public likely will have to be convinced of the safety of an operational SE program before operational deployment on any scale will be accepted in BC. This can be achieved through a concentrated, well focused extension program.

SUMMARY AND CONCLUSIONS

The CT for all interior spruce parental sources are established with about 48,000 individuals identified in the field. Environment still contributes significantly to observed clonal variation in the oldest CT site. This may result in a longer time frame, than projected at the beginning, for testing. In the older CT, few clones are performing better than the full sib seedlings from the same family. This may reflect SE stock quality issues at planting. It could result in fewer clones to select from for operational deployment. The full sib seedling - SE embling concern does not appear to be a factor in the more recent CT.

Weevil attacks were observed for the first time in BIOTIA CT in 1998. This should result in preliminary BIOTIA clonal weevil ratings by about 2000 or 2001. Unfortunately the 1996 CT have been hit with growing season frosts and it may be 2003 - 2005 before useful weevil ratings come from these CT. It is too soon to predict when weevil ratings will be available from the 1997 and 1998 CT.

Today, the economics associated with SE technology does not justify operational deployment. However there are some very good SE clones in the CT. As these clones are confirmed and selected, economic worth will be assigned to other traits or characteristics, such as weevil tolerance or green up. The economics then will probably justify a small SE operational program in the central BC interior.

Public concerns about clonal forestry need to be addressed through a coordinated extension program to ensure the opportunity to deploy SE material operationally.

ACKNOWLEDGMENTS

Field testing has been funded by Nursery Services (Drew Brazier) and Research Branches of the BC Forest Service, Operational Tree Improvement, and industrial cooperators. The work and cooperation of the following helped to make this possible and is greatly appreciated: B Hooge, K Thomas, D Summers, B Richards of the BC Forest Service; P Forsythe, S Thorpe, S Switzer, G White of the forest industry; 31 Coop students from UVIC, SFU and UNBC since 1994; Forest Biotechnology Group at BC Research (D Cyr); and Pelton Reforestation and Green Timbers Test Nursery. The comments of A Yanchuk and D Summers on the paper were appreciated.

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VEGETATIVE PROPAGATION OF ASPEN, NARROWLEAF COTTONWOOD, AND RIPARIAN TREES AND SHRUBS[1]

David R. Dreesen[2] and John T. Harrington[3]

ABSTRACT—Vegetative propagation of planting stock for revegetation projects may be required if unique genotypes are desired, viable seed is unavailable, or unconventional establishment methods are used. Aspen (*Populus tremuloides*) propagation studies using root cuttings from pot-in-pot stock plants showed appreciable growth and survival differences among clones and among stock plants of the same clone. Long root cuttings (10 cm) had generally superior survival and growth. Small caliper root cuttings (3-4 mm) were not detrimental to survival and growth and for some clones are preferable. The effect of source plant physiology, timing of collection, post cutting treatments, and rooting environment on the rooting and growth of *Populus angustifolia* cuttings was evaluated. Stock plant vigor exhibited the greatest influence on rooting and growth. Timing of collections contributed to rooting success but had only a marginal effect on shoot growth. Incorporation of controlled release fertilizer had significantly improved growth, but had no effect on rooting. Geographical location had a significant effect on the rooting and growth of cuttings. The success of riparian forest regeneration using large dormant cuttings of willows and cottonwoods as planting stock ("pole planting") is dependent on cutting characteristics, cutting handling, planting site characteristics, and post-planting care. Preliminary studies investigating pole planting of woody riparian species outside the Salicaceae family have shown some success with seepwillow (*Baccharis* sp.), false indigo (*Amorpha fruticosa*), and New Mexico olive (*Forestiera neomexicana*).

INTRODUCTION

The restoration of lands disturbed by the extraction of mineral resources or by the poor management of sustainable natural resources often involves the re-establishment of woody species. The use of seed or vegetative propagules from local sources is preferable to maintain genotypes that evolved by natural selection pressures at the site. Vegetative propagation of these plant materials is often required because seed of the local ecotypes is not available. In other instances, vegetative propagation provides stock types with characteristics advantageous to establishment on certain planting sites.

Our revegetation research at a high elevation mine in north-central New Mexico has concentrated on two deciduous tree species, aspen (*Populus tremuloides*) and narrowleaf cottonwood (*Populus angustifolia*), in addition to the dominant conifers at the mine site (e.g., *Pinus ponderosa, Pinus flexilis, Pseudotsuga menziesii,* and *Abies concolor*). Both of these deciduous species have naturally invaded mine overburden piles to a greater extent than any other tree species probably because of the extent of wind dissemination of aspen and cottonwood seed. A number of studies have been conducted to determine the most important factors influencing the propagation of aspen from stock plant root cuttings and the propagation of narrowleaf cottonwood from hardwood cuttings. The ultimate goal is to develop cost effective propagation methods for these mine site ecotypes to enable large-scale revegetation.

In addition to high elevation mined land revegetation, we have been investigating restoration of riparian areas perturbed by the lack of natural flood events or disturbed by excessive browsing pressure by both domestic and wild ungulates. A revegetation technology relying on vegetative propagation has been developed to reestablish woody riparian species using large dormant cuttings ("poles") up to 5 m in length. This technology has been used for many decades but large-scale plantings in the past decade have provided information which enables successful re-establishment of cottonwood and willow species on some sites where they can no longer naturally regenerate. Applications of this technique to woody species outside the Salicaceae family are also described.

PROPAGATION OF ASPEN FROM ROOT CUTTINGS

Preface

Although aspen has invaded many sites on the mine overburden piles, we have been unable to find seed-bearing clones in the vicinity of the mine. Therefore, we had to resort to vegetative propagation from root cuttings, a procedure with a long history in forestry literature (Hall and others 1990, Starr 1971). For this propagation methodology to be employed on a large-scale, a number of considerations would have to be investigated. Stock plants would have to be grown in a nursery because the native stands could not provide sufficient root cuttings and these stands are inaccessible during the winter months. The size of root cutting (caliper and length) with superior performance would dictate the number of propagules that could be obtained from each stock plant. The influence of clonal genotype on the survival and growth rate would determine the cost effectiveness of propagating each clone. Another production complication would be introduced if different stock plants of the same clone yielded root cuttings with different survival or growth rates.

Methods

Root cuttings were collected from aspen clones growing in natural stands adjacent to overburden piles; the elevation of these stands ranged from 2400 to 2900 m. Several stands were adjacent to each other (Clones No. 1 and 4; Clones

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No. 3, 5 and 7) and could be the same clone; only root cuttings from Clones No. 3 and No. 7 had similar survival and growth. The individual plants obtained from these cuttings were transplanted from flats to 1.3 liter tree bands (81 cubic inch) and finally to 13.7 liter nursery cans (5 gallon egg cans) over one year. These stock plants were grown for an additional growing season in a pot-in-pot system buried in the ground to moderate media temperature. The first experiment was initiated 2.5 years after initial cutting collection; cuttings were collected from each stock plant between March 20 and 26, 1997. The cuttings were harvested within 2 cm of the periphery of the root ball; from 22 to 36 cuttings were harvested from each pot. Each cutting was harvested so that the distal end had a slant cut and the proximal end had a perpendicular cut. The root cuttings were soaked in a Captan suspension (1:125 volumetric ratio, i.e., 2 tbs/gal) immediately after harvesting. The root cuttings were removed from the suspension after 15 to 30 minutes and placed in polyethylene bags containing moist spaghnum peat moss. The bags were stored at 4°C for six weeks before planting. On May 7, 1997, the cuttings were stuck vertically in 160 ml Super Cell Conetainers containing media (2 parts Sunshine #1 pent mix to 1 part perlite). Before sticking, the length and caliper of each cutting was recorded. The cuttings were inserted into dibbled holes until the proximal end was just below the media surface. Eight weeks after sticking, the length and number of shoots and branches were determined. Second experiment was commenced on March 2, 1998 when cuttings were harvested from the same group of stock plants. In this experiment, the cuttings were harvested from most of the root ball, not just the periphery, as in the first experiment. Cuttings from 3 stock plants of each clone were kept separate to investigate stock plant effects. One set of cuttings was measured and stuck immediately. The remaining cuttings were immersed in a Captan suspension and stored for 12 weeks in moist spaghnum peat moss at 4°C. Significant temperature deviations occurred during storage as a result of refrigeration malfunction. Before sticking, the cuttings from each stock plant were grouped into sets of 4 having similar caliper and length. One cutting of each set was immersed for 15 minutes in one of the following treatments: tap water, Cleary 3336 (thiophanate methyl) at 1:250 vol., Captan at 1:125 vol., and Banrot (thiophanate methyl, ethazol) at 1:250 vol. Cuttings were measured and stuck as in the first experiment.

Table 1—Mean caliper, mean length, mean calculated volume, number of root cuttings, and number of stock plants for 6 *Populus tremuloides* clones.

Clone	Mean	Mean	Mean	Cuttings	Stock plants
	mm	cm	cm³	No.	No.
1	5.4 (2.3)	8.4 (2.0)	8.4 (2.0)	432	21
3	5.2 (1.7)	7.9 (2.1)	7.9 (2.1)	231	9
4	5.4 (1.8)	8.3 (1.7)	8.3 (1.7)	170	6
5	5.1 (1.5)	8.3 (1.7)	8.3 (1.7)	88	3
6	5.1 (1.2)	8.9 (1.4)	8.9 (1.4)	109	3
7	4.5 (1.2)	8.9 (1.5)	8.9 (1.5)	101	3
Mean	5.1 (1.6)	8.5 (1.7)	8.5 (1.7)		

Standard errors presented in parentheses.

Results

The mean caliper, length, calculated cylindrical volume, number of cuttings, and number of stock plants are presented in table 1 for the 6 aspen clones. The mean calipers ranged from 4.5 to 5.4 mm, the mean lengths ranged from 7.9 to 8.9 cm, and the volumes ranged from 1.5 to 2.1 cm^3. The percentages of ramets present in 6 vigor classes are given in table 2 for each clone. Two clones (No. 4 and No. 6) showed high survival and growth with 63 to 73 percent of the ramets having good vigor (>8 cm total shoot and branch length 8 weeks after planting). An intermediate group (No. 7 and No. 3) had 39 to 42 percent with good vigor. A low survival group (Clones No. 1 and No. 5) had 41 to 52 percent mortality (including those which died soon after shoot emergence) versus 6 to 23 percent for the other 4 clones.

Total stem and branch length was correlated with root cutting caliper, length, calculated volume, and length:caliper ratio to determine which root cutting characteristics were related to ramet growth. The correlation coefficients and significance levels are presented in table 3. The limited number of cuttings available for 3 clones (No. 5, No. 6, and No. 7) resulted in no significant correlations. However, trends indicate that growth was negatively correlated with caliper (3 out of 6 clones), positively correlated with length (5 out of 6 clones), and positively correlated with length:caliper ratio (4 out of 6 clones). The poorest performing clone, No. 5, had correlation trends which were the opposite of the majority of the other clones. The overall correlation trends suggested an analysis to investigate the performance of large caliper short cuttings versus small caliper long cuttings. Therefore, the root cutting data was divided into four groups each representing one of the 4 permutations of caliper (large, small) and length (short, long) classes. The mean cutting dimensions of the 4 groups are presented in table 4 along with the group mean stem length (based on live plants only) and group survival. The mean of caliper-length classes for all clones are as follows: small-long 3.8 mm and 10.3 cm; large-long 6.2 mm and 9.3 cm; small-short 3.9 mm and 7.7 cm; and, large-short 6.5 mm and 6.7 cm. The small-long root cuttings provided appreciably greater growth for Clones No. 4 and No. 7. The large-short root cuttings yielded substantially less growth for Clones No. 3, No. 4, and No. 6. The large-long root cuttings provided superior growth in the poorest growing clone, No. 5. The mean growth of all clones shows an overall trend with small-long cuttings having the best growth and thick-short cuttings having the poorest growth. The overall survival trend for all clones indicates that the longer cuttings were superior; this trend was most evident for Clones No. 3 and No. 7. The lowest survival was found in the small-short cuttings of Clone No. 5 and the large-short cuttings of Clone No. 1.

Table 2—Percentages of *Populus tremuloides* ramets in vigor classes based on total shoot and branch length evaluated 8 weeks after sticking

Clone	Total Shoot and Branch Length Class				Shoots emerged then died	No shoot emergence
	>22cm	9 to 22 cm	4 to 8 cm	<4		
1	15	18	12	14	05	36
3	13	26	22	19	04	16
4	54	19	16	05	02	04
5	07	13	14	16	05	47
6	44	19	10	07	03	18
7	15	27	20	16	10	13

The root cuttings stuck immediately after harvest in early March 1998, exhibited universal delayed shoot emergence and substantial mortality soon after emergence. This set of cuttings was not investigated further because of these anomalies. These results suggested that the cuttings might not have received a sufficiently long cold period to overcome dormancy. The high mortality suggested possible pathogen presence; therefore, pre-planting fungicide soaks were investigated in the next phase of the experiment.

The root cuttings in the second phase of the second experiment had severely depressed survival versus the first experiment. These cuttings had received a Captan soak at harvest, were cold stored for 12 weeks, and then treated with fungicide or water at sticking. If the control treatment (water) of the second experiment (see table 5) is compared with the results of the first experiment, the survival percentages are depressed from 40 to 48 percent except for Clone 6 (24 percent depression). These results suggest that the refrigeration problems resulting in cold storage temperatures reaching approximately 10° C for long periods had a substantial deleterious effect on survival. Banrot had a definite negative influence on both survival and growth (see table 5) compared with the control and other fungicide treatments. The growth depression with Banrot is at least partially a result of the large delay in emergence for those few cuttings which were viable; the first shoot emergence from the Banrot treatments was noted 4 weeks after the other treatments. For Clones No. 1 and No. 7, the control and Cleary 3336 treatment had significantly higher survival than the Captan treatment. For the other clones, the control, Cleary 3336, and Captan treatments did not have significantly different survival percentages. Large variances among ramets from different stock plants resulted in no significant growth differences among clones. These large variances were also apparent in the survival results and indicate a substantial stock plant effect. The superior clones in the second experiment (No. 3, No. 4, and No. 6) had smaller mean coefficients of variation for survival and growth data (0.19 to 0.41) than the inferior clones with coefficients of variation of 0.52 to 1.18. Therefore, differences between stock plants are more apparent among poorer performing clones.

Table 3—Correlation coefficients of total stem and branch length of Populus tremuloides ramets with root cutting caliper, length, calculated volume, and length:caliper ratio.

Clone	Caliper	Length	Volume	Length: caliper ratio
1	-.13**	0.20***	-0.07	0.17***
3	-0.04	0.27***	0.09	0.17*
4	-0.24**	0.23**	-0.16*	0.28***
5	0.12	-0.09	0.14	-0.19
6	-0.03	0.14	0.03	0.07
7	-0.15	0.15	-0.12	0.18

Significance at $P<0.05$, $P<0.01$, and $P<0.001$ noted with *, **, or ***, respectively.

Conclusions

Clonal and stock plant differences can have appreciable effect on the survival and growth of aspen root cuttings. A Captan soak after harvest and before cold storage appears to be sufficient pathogen protection. Long cuttings averaging 10 cm in length are preferable. Cutting caliper as small as 3 to 4 mm is not detrimental and in some cases may be beneficial. Pot-in-pot systems for aspen stock plants appear feasible; small stock plants (5 gallon) can provide about 20 to 30 cuttings from the outer portion of the root ball at an early age. Annual root cutting harvest from the periphery of the root ball grown in large pot-in-pot systems (15 gallon) is currently under investigation.

Table 4—Root cutting length, root cutting caliper, ramet growth, and survival of *Populus tremuloides* clones classified into 4 classes (caliper-length). Mean stem length based on the number of live plants

Class	Clone 1	Clone 3	Clone 4	Clone 5	Clone 6	Clone 7	Mean
			Mean root cutting length (cm)				
Small-long	10.7	10.3	10.1	9.7	10.3	10.4	10.3
Large-long	9.2	8.6	8.9	9.3	9.6	9.9	9.3
Small-short	7.8	7.2	7.4	7.5	8.1	8.0	7.7
Large-short	6.1	5.7	6.6	6.6	7.6	7.5	6.7
			Mean root cutting caliper (mm)				
Small-long	3.6	3.8	4.0	3.9	4.2	3.5	3.8
Large-long	6.8	6.6	6.9	5.8	5.7	5.6	6.2
Small-short	3.9	3.9	3.8	4.1	4.1	3.6	3.9
Large-short	7.5	6.6	6.8	6.4	6.3	5.3	6.5
			Mean stem and branch length (cm)				
Small-long	15	14	32	6	25	19	18
Large-long	14	13	25	11	25	8	16
Small-short	13	11	21	7	21	10	14
Large-short	12	6	17	9	15	8	11
			Survival percentage (percent)				
Small-long	69	90	98	68	74	92	82
Large-long	59	95	93	59	89	100	83
Small-short	61	69	90	32	79	76	68
Large-short	46	71	93	55	81	81	71

Table 5—Percentage survival and total stem and branch length for *Populus tremuloides* root cuttings treated with water (control), Cleary 3336, Captan, or Banrot at sticking

Fungicide	Clone 1	Clone 3	Clone 4	Clone 5	Clone 6	Clone 7	Mean
			Survival percentage (percent)				
Control	19	36	52	2	55	29	32
Cleary	26	64	62	5	38	38	39
Captan	10	48	38	5	43	19	27
Banrot	0	10	2	0	12	12	6
			Mean shoot length (cm)				
Control	6.0	10.2	11.3	3.0	13.5	7.0	8.5
Cleary	7.5	10.5	8.5	2.3	8.8	6.5	7.3
Captan	4.1	6.0	12.3	8.5	13.7	5.8	7.6
Banrot	0.0	1.4	1.0	0.0	0.9	1.3	0.8

Table 6—Narrowleaf cottonwood ecotype locations and elevations

Ecotype	Elevation
	m
Capulin	2,990
Raspberry Ridge	3,000
Pinon Knob	2,830
Neutral	2,620
River	2,470

FACTORS INFLUENCING THE ROOTING AND GROWTH OF NARROWLEAF COTTONWOOD PROPAGATED FROM HARDWOOD CUTTINGS

Preface

Narrowleaf cottonwood (*Populus angustifolia*) commonly occurs at elevations of 1,520 m to 2,440 m in riparian areas of the Rocky Mountains (Elmore and Janish 1987). Narrowleaf cottonwood has been found in drastically disturbed upland mine sites and undisturbed upland sites at elevations up to 3,000 m (Harrington and Dreesen, personal observations). The ability to naturally colonize such sites indicates members of this species may be suitable for high elevation revegetation projects.

Many species in the genus *Populus* are considered easy to root from dormant hardwood cuttings. Traditionally, Populus species are propagated in outdoor nursery beds using 15 to 22.5 centimeter cuttings (Morin and Demeritt 1984). Under certain circumstances, primarily riparian plantings, cuttings or whips can be successfully used in lieu of rooted cuttings. However when using cottonwood in drier or upland plantings, superior survival and early growth are obtained when rooted cuttings are utilized (Phipps and others 1977). Little published work exists on the performance of bare-root rooted cuttings versus container grown rooted cuttings of cottonwood.

Published research on container production of narrowleaf cottonwood is sparse regarding the most basic information including media composition, fertility, timing of collections, and utility of exogenous auxin applications. Phipps and others (1977) report that for other species of *Populus*, a 3:1:1 ratio of peat:perlite:vermiculite is typically used. Previous work on other cottonwood species indicate a lighter, more porous media may be better (Harrington, unpublished data). Fertilizing is considered not necessary or effective prior to root initiation (Dirr and Heuser 1987). After root initiation, a well balanced fertilization regime is required to produce vigorous containerized plants. A common approach to fertilizing container plants in the southwest is to incorporate controlled release fertilizer into the growing media and supplementing with liquid based fertilizer applications after shoot growth begins (Harrington 1995). Rooting hormones are not commonly used in *Populus* propagation and in some cases have been inhibitory to root production (Phipps and others 1977).

Stock plant physiology and vigor, strongly impact rooting success and cutting growth (Dirr and Heuser 1987). In Populus, 3-10 year old stock plants produce the most vigorous cuttings and the highest rooting percentages (Phipps and others 1977). Frequently, nurseries establish stooling blocks of desirable clones to maximize stock plant vigor through irrigation, fertilization, and pest management. In some situations, establishment of stooling blocks is not feasible and post harvest treatment of cuttings must be employed to obtain satisfactory rooting and growth.

The objectives of this study were to evaluate the effects of timing of collection, auxin formulation and concentration, media density, incorporation of controlled release fertilizer and stock plant location (vigor) on the rooting response and shoot growth of narrowleaf cottonwood.

Methods

To examine the influence of several factors on rooting success of narrowleaf cottonwood stem (branch) cuttings and the subsequent shoot growth of rooted cuttings four factorial experiments were conducted. Factors examined were source, stock plant vigor, exogenous auxin formulation, exogenous auxin concentration, density of rooting media, fertility and collection date. The first three experiments were initiated in February 1996. The fourth experiment which examined timing of collection was performed during the following dormant period and was conducted from November 1996 through February 1997.

Stem cuttings used in these experiments originated from five distinct stands (sources) of narrowleaf cottonwood growing in the Red River canyon approximately five miles east of Questa, New Mexico. Stands were separated by no less than 1,000 meters with four stands in upland situations and the fifth stand adjacent to the Red River (table 6). Stem cuttings originally taken from these stands in 1992, were used to establish stooling blocks at the Plant Materials Center in Los Lunas, New Mexico in 1993. The stooling blocks were kept under a cultural regime to promote rapid growth. Source identification of the stooling block material was maintained to the stand level.

The stem cuttings used in these experiments were harvested from both the original stands at the mine as well as from the 3-year-old stooling block material. The source plants at the mine site ranged in age from 3 years to 15 years. When possible, branches were harvested from young trees or younger materials from older trees. Branches were transported to the nursery facilities at the Mora Research Center and stored at 2° to 4° C until utilized (less than two weeks). Individual branches were subdivided into stem cuttings immediately prior to use. Stem cutting length ranged from 10 cm to 15 cm and contained a minimum of three vegetative buds.

When used, rooting hormones included in this study were indole-3-butyric acid (IBA) and naphthalenacetic acid (NAA). Stock solutions of 1,000 ppm were prepared for each hormone and through dilutions the various treatment levels were obtained. A distilled, deionized water control was also used. Rooting hormone application was a 5 second dip into the appropriate treatment immediately followed by sticking the cuttings into 105 ml copper coated styroblock cells (Beaver Plastics LTD).

Media components for all facets of this study were mixed using a large paddle mortar mixer. The media formulations utilized for these experiments were either 1:1:1, 1:2:1, 1:1:2, 2:1:1 and 1:3:1 ratios of peat:perlite:vermiculite (v:v:v). Fertilizers, when incorporated into the media, were encapsulated controlled release (Osmocote 14:14:14; 3 month) and triple super phosphate at rates of 4 kg/m^3 and 600 g/m^3, respectively.

After treatment, stem cuttings were placed in a greenhouse on a propagation bench with bottom head which kept root zone temperature at 24°C. Greenhouse temperature were 20° – 22°C days and 16° – 18°C nights. Photoperiod was a 10 hour light 14 hour dark with the dark cycle interrupted twice at 5 and 10 hours with 30 minute light periods. Artificial light used to extend the ambient light period and provide light interruptions was supplied by 1,000 watt high pressure sodium vapor lamps suspended 3 meters above the stem cuttings.

Cuttings were misted 4 times daily until the majority of cuttings had significant bud break. Following bud break, cuttings were irrigated as necessary, increasing from once every 3 days at the beginning to once every day at week 20. Foliar applications of a 25 ppm nitrogen solution of Peter's Foliar Feed (27:15:12) were made following every second irrigation from week 4 through week 12. At week 13, fertilization was increased to applications of 100 ppm nitrogen of Peter's Conifer Grower (20:7:19) every other irrigation.

After 20 weeks, cuttings were destructively sampled to evaluate rooting success and shoot growth. Shoot growth was measured from the origin of the longest shoot to its growing apex. All successful rooted cuttings had well developed root systems so rooting success was simply a measure of presence or absence of roots.

In the first experiment, stock plant source, stock plant vigor and exogenous auxin formulation were evaluated in a factorial experiment. All five sources from both the native stand and the stooling blocks were evaluated. Auxin formulations examined were: 1) 250 ppm IBA; 2) 250 ppm NAA; 3) 125 ppm IBA + 125 ppm NAA; and, 4) 0 ppm control. The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

Table 7—Location and timing of narrowleaf cottonwood source material collections

Site	Collection date
Native Stand	11/13/1996, 12/11/1996, 01/04/1997
Los Lunas PMC	11/20/1996, 12/13/1996, 01/17/1997, 02/19/1997

In the second experiment, stock plant source, stock plant vigor, rooting media density and exogenous auxin concentration (dosage) were evaluated in a factorial experiment. All five sources from both the native stand and the stooling blocks were evaluated. Auxin concentrations evaluated were: 1) 500 ppm IBA; 2) 250 ppm IBA; 3) 125 ppm IBA; and 4) 0 ppm control. Media densities evaluated were: 1) 2:1:1; 2) 1:1:1; 3) 1:2:1; and, 4) 1:3:1 mixtures of peat:perlite:vermiculite (v:v:v). The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

In the third experiment, stock plant source, rooting media, and fertility were evaluated in a factorial experiment. All cuttings originated from stooling blocks growing at the Los Lunas Plant Materials Center. The three sources evaluated were Capulin, Raspberry Ridge, and Pinon Knob. Media densities evaluated were: 1) 2:1:1; 2) 1:1:1; and, 3) 1:1:2 mixtures of peat:perlite:vermiculite (v:v:v). The four fertility treatments were: 1) Osmocote and triple super phosphate; 2) Osmocote only; 3) triple super phosphate; and 4) no fertilizer incorporated into the media. No exogenous hormones were applied. The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

In the fourth experiment, collection date, stock plant source, and stock plant vigor were evaluated. The locations and dates for the timing of collection are provided in table 7. The rooting media was a 2:1:1 ratio of peat:perlite:vermiculite (v:v:v). Cuttings were monitored daily and tagged when bud break occurred. No exogenous auxin applications were used. Each treatment combination was replicated by 14 cuttings. Chi-square tests of homogeneity were used to detect differences in rooting response. Heavy snowfall in the native stand precluded collections for the final sample period (February 1997).

Results

All sources evaluated appear to be suitable for cutting propagation. Source and stock plant vigor significantly impacted rooting percentage. Overall, cuttings from the 3 year-old stooling blocks had an average rooting success in excess of 90 percent while cuttings from the native stands ranged from 62 percent to 85 percent (fig. 1). Collection date also impacted rooting success with rooting peaking in the latter three collection dates (fig. 2). However, sources differed at the two earliest collection dates in the rooting response. All sources had at least three collection dates with greater than 90 percent rooting success.

The influence of auxin formulation and concentration was dependent on source and plant stock vigor. In both cases, the addition of exogenous auxins only slightly (less than 5 percent) improved the rooting response. Media density and fertility treatments did not influence rooting success.

Final shoot size was satisfactory in all treatment combinations examined. Cuttings from the more vigorous stooling blocks were faster growing; however, this trend was dependent on the original source (stand) (see fig. 3). There was some sensitivity to media density with the cuttings

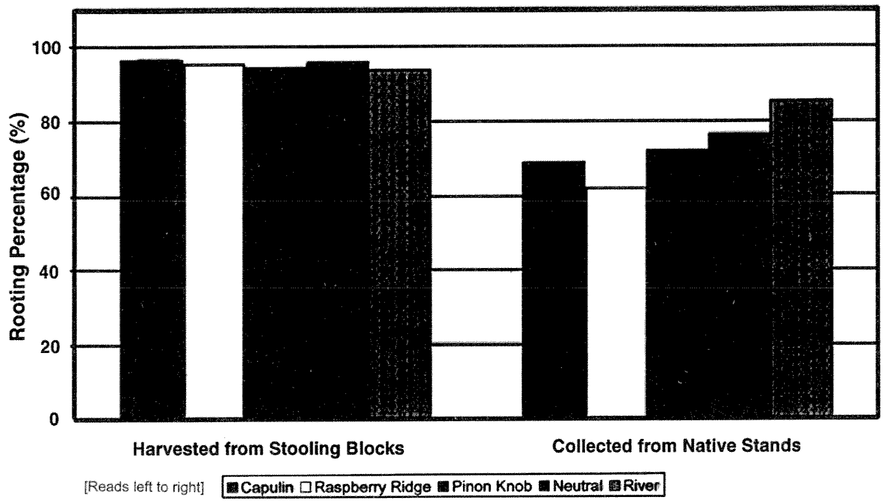

Figure 1—Effect of stock plant vigor and source on rooting of *Populus angustifolia* cuttings.

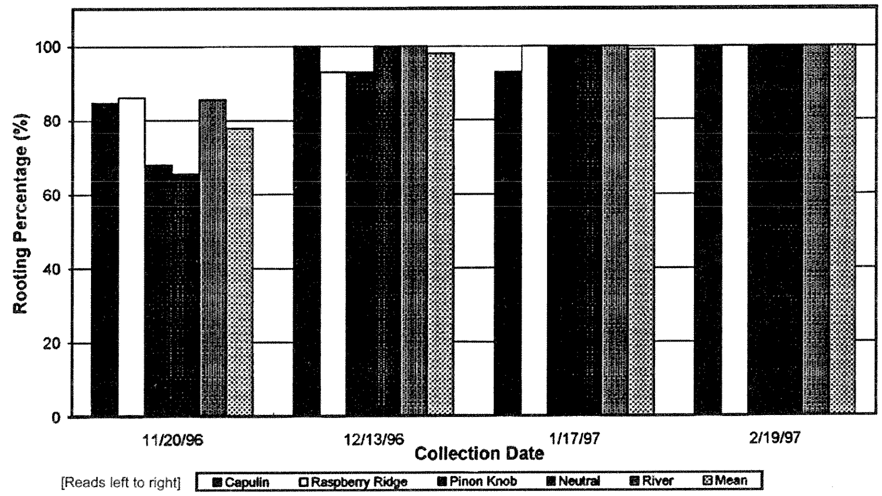

Figure 2—Effect of collection date on the rooting of *Populus angustifolia* cuttings from stooling blocks.

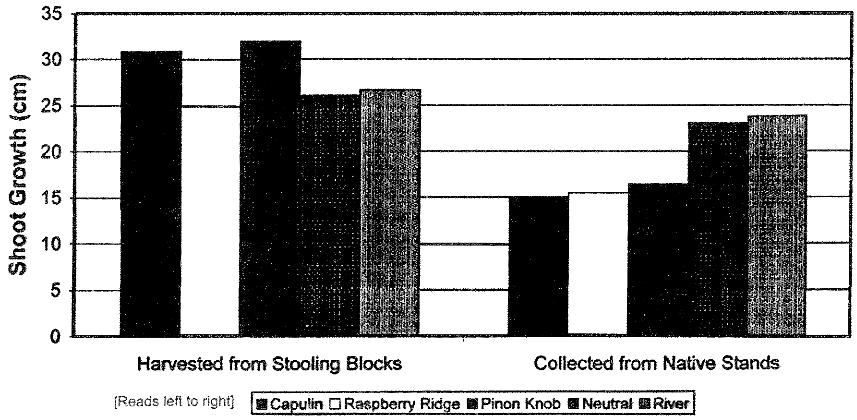

Figure 3—Influence of ecotype on shoot growth of rooted *Populus angustifolia* cuttings.

growing better in the slightly heavier (2:1:1 and 1:1:1 peat:perlite:vermiculite) media. However, the magnitude of the media affect was also dependent on the source (stand) of the cutting material. The triple super phosphate treatment had minor impact on the subsequent growth of shoots. The presence of Osmocote in the rooting media also significantly promoted shoot growth. Again, the magnitude of this response was dependent on the source (stand) of the cutting material.

Conclusions

While all treatments generated relatively high percentages of viable cuttings after 20 weeks, some treatments were more effective. Source of the stock plant impacted the effectiveness of other cultural treatments in promoting rooting and subsequent shoot growth. Cuttings from the stooling blocks consistently had better success than cuttings from the original stands. Use of exogenous auxin applications does not greatly improve the rooting response. To sustain the rapid growth of cuttings, the incorporation of controlled release fertilizers appears to be a cost effective technique. While all media mixtures generated suitable cuttings after 20 weeks, the heavier media treatments required less frequent irrigation.

POLE PLANTING OF RIPARIAN TREES AND SHRUB

Preface

The cottonwood gallery riparian forests of the southwest U.S. are one of the most endangered forest types in North America. The conversion of forest to agricultural and urban land uses, the lack of natural regeneration of the dominant native tree species with the cessation of natural flooding, and the invasion of invasive exotic woody species (saltcedar and Russian olive) have resulted in a drastic reduction in the extent and health of these riparian forests. Several regeneration techniques are being investigated to reestablish the native tree and shrub species: 1) artificial flooding of former flood plain areas to simulate spring flood events and allow natural regeneration (Crawford and others 1996); 2) micro-irrigation of former flood plain sites to allow regeneration from naturally disseminated cottonwood seed (Dreesen and others 1998); and, 3) the planting of large dormant cuttings or poles (Carlson and others 1992). The principal concept of pole planting is to plant a dormant cutting of sufficient length to reach the water table which allows establishment with no supplemental watering. Over a decade of pole planting experience allows the development of some generalizations and recommendations which will maximize pole planting success

Pole Characteristics

Pole cuttings are grown in large production blocks containing either superior selections or particular ecotypes. The production block rows are 90 m long with plants on one meter centers and rows 3 m apart. Large dormant cuttings (>50 cm long, >1 cm caliper) are inserted into collapsed trenches created with a large single ripper and are flood irrigated immediately after sticking. During the first growing season, frequent flood irrigation (weekly) is required until roots are well established; at maturity the production blocks are flood irrigated on a monthly basis unless substantial rains have occurred. Mechanical and manual cultivation is required to control weeds primarily during the first growing season. Some cuttings will produce multiple shoots, others will form a dominant leader which when harvested will generally result in the emergence of multiple shoots. Under ideal conditions, large poles (3m) can be harvested after 3 growing seasons. Only the large stems on each plant are removed during the winter harvest (January through March) releasing the smaller stems to grow for future harvest. After the large poles are removed with a chain saw, all the lateral branches are pruned off. The butt end of the pole is submerged in water until transport to assure the pole is well hydrated before planting. As long as the weather is cold and bud break is far off, the poles can be stored for several weeks or more in water. Transporting and planting must take place before bud break for best results. The hydrated poles are often transported on flat bed trailers with tarp coverings to limit desiccation.

Site Characteristics

A site characteristic which needs early definition is the depth to the water table and the variation in water table depth over an annual hydrologic cycle. Monitoring wells should be drilled at least a year before planting to determine water table depth fluctuations. This knowledge will determine the length of pole necessary so that the butt end of the pole is always in contact with moisture in the capillary fringe above the water table. The drilling of monitoring wells can also provide knowledge on the type of alluvium present at the site. Clay rich soils are generally detrimental to pole planting success possibly as a result of poor soil aeration. At the opposite extreme, augering holes in cobbly soils is very difficult. Two alternatives to augering have been successful on occasion: 1) a sharpened steel rod mounted on a backhoe bucket which can poke and wiggle a hole between cobbles, "a stinger", or 2) a high pressure water jet to wash out sediments between cobbles allowing the insertion of a pole. Drilling techniques include one-person gasoline powered augers, manual bucket augers with long shafts, and tractor-mounted augers. For small pole or whip sized material such as coyote willow (*Salix exigua*), shallow holes can be dug with electric hammer drills powered by portable generators; this technique can be helpful for winter plantings where the surface soil is frozen. Accessibility of the site to heavy equipment is an important consideration especially when deep holes must be augered.

Shallow water tables are one site characteristic often encountered in montane riparian areas and produce wetland conditions not appropriate for planting cottonwoods and often even willows. Thus, extreme water tables either too shallow or too deep are often limiting site characteristics. The salinity and sodicity of the alluvium are other critical factors in determining pole planting success. Many pole planting failures have occurred from planting in high salinity sites. Sites supporting a halophyte like saltcedar (*Tamarix* sp.) can be too saline or sodic for cottonwoods and willows.

Care after Planting Poles

Large herbivore control is often a required step before pole planting and usually involves fencing. Among small herbivores, beaver are the major problem and can easily gnaw down poles and even steal poles stored on the shore of a river or pond. Planted poles can be protected with tree guard tubes constructed from 1.5 m tall poultry wire. These guards will protect poles from all but the smallest herbivores, e.g., mice. One of the most costly endeavors is to protect the poles during first several years of establishment from defoliation by insects; the cottonwood leaf beetle (*Chrysomela scripta*) is a significant problem at lower elevation sites in the Southwest. Several readily available insecticides are currently effective in controlling this pest, but several applications per growing season are required for the first few years.

Non-Traditional Species for Pole Plantings

Pole plantings have focused on cottonwoods and willows known to be easily rooted from hardwood cuttings. Several shrub and small tree species are important components of cottonwood gallery forests. Some preliminary studies have shown some promising results with pole planting species outside the Salicaceae family. False indigo or indigobush (*Amorpha fruticosa*), New Mexico olive (*Forestiera neomexicana*), seepwillow (*Baccharis spp.*), and desert willow (*Chilopsis linearis*) are species which have shown some reasonable survival percentages in trial pole plantings. Further work is required to better define pole cutting characteristics which will maximize success for these species. Although some of these species are not as fast growing as willows and cottonwoods, it appears that conventional pole production blocks are feasible. It is probable that high success rates with these species may require selection of genotypes with favorable rooting characteristics.

Conclusion

Pole plantings are particularly advantageous in riparian situations with deep water tables because no watering is required; containerized stock would require substantial watering until the roots could reach the capillary fringe. In addition, pole plantings are not effected by herbaceous weed competition because of their large initial size and deep roots. Potential disadvantages of pole planting would result from the planting of selected clones with limited genetic diversity. If pole production blocks were planted with diverse stock from many seedling trees, these concerns of the lack of genetic diversity could be reduced. Pole planting is an expensive planting method because of the cost of the pole planting stock, the equipment needed to plant the pole, and the aftercare required. However, there may be situations where this planting technology is the only feasible method of reestablishing these riparian forests.

ACKNOWLEDGEMENTS

The propagation studies on aspen and narrowleaf cottonwood were made possible by funding support by Molycorp Inc. (Questa, NM). Riparian studies were funded by U.S. Forest Service, Army Corps of Engineers, Bureau of Reclamation, Bureau of Land Management, and U.S. Fish and Wildlife Service.

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CURRENT ISSUES IN NURSERY PEST MANAGEMENT IN BRITISH COLUMBIA[1]

David Trotter[2]

INTRODUCTION

In recent years, there has been a number of improvements to the management of reforestation container nursery insect pests and pathogens in BC. These have centered on three main themes; 1) better monitoring and timing systems, 2) a more comprehensive understanding of their impact on seedling outplanting performance and 3) a reduction in pesticide use. As with all things, nursery production systems are in constant change to meet shifting client priorities and demands. As such, some of these destructive agents are now having an impact on seedling quality because of their adaptation to changes in nursery production. In addition, there is the introduction of new insect pests or pathogens that adapt to our conifer seedling production systems. This paper will briefly summarize current developments in reforestation container nursery pest management in the areas of insect and pathogen control.

NURSERY INSECTS

Lygus Bug Trapping Program

The pest status of the *Lygus* spp. complex has been recognized for many decades in North America. Though considered a pest of agricultural crops, in the last fifteen years *Lygus* bugs have gained recognition as important pests in bare-root and container conifer nurseries. Feeding by the adults causes deformation of seedling terminal shoots, which later become undesirable multiple leaders or crooked terminals. All conifer species grown in BC reforestation nurseries are susceptible to feeding damage but *Lygus* bugs appear to prefer 1+0 pine seedlings particularly lodgepole pine. To date there had been no effective monitoring system for *Lygus* bugs and control of this pest has depended entirely on repetitive applications of one insecticide. In 1995, a small scale monitoring program and a caging study was initiated at one BC reforestation nursery. Results from this preliminary study showed that yellow sticky traps could be used to monitor *Lygus* bugs. The caging study, which introduced *Lygus* at biweekly intervals, found that lodgepole pine seedlings were most susceptible during the first 11 weeks after germination. In addition, outplantings of these seedlings based on the biweekly *Lygus* introductions found no terminal leader or flushing problems with seedlings 11 weeks or older from germination. In 1996-97, studies were conducted to; 1) determine the *Lygus* spp. complex at coastal and interior reforestation nurseries, 2) construct a life history profile of the most common *Lygus* species, 3) develop an efficient trapping system, 4) review the efficacy of the current control program and 5) assess the effect and timing of *Lygus* damage on the outplant performance of 1+0 lodgepole pine seedlings.

In 1997, five *Lygus* species were positively identified from lodgepole pine seedlings in 3 coastal (Fraser Valley) and 2 interior (Okanagan) nurseries. *Lygus elisus* Van Duzee was found in all surveyed nurseries indicating that this species is broadly distributed in southern BC. *L. shullii* Knight was located at 1 interior and at all 3 coastal facilities where it was most abundant. *L. hesperus* Knight was collected at 1 coastal and interior nursery respectively. The remaining two species, *L. robustus* Uhler and *L. lineolaris* P. de Beauvois, were found only in the interior. Life history studies on the two predominant *Lygus* species found that *L. shullii* developed from egg to adult in 93 days at 12.5°C and 24 days at 25°C. *L. elisus* matured in 67 days at 15°C and 23 days at 25°C. Timed caging studies of both species found that the expression of feeding damage on 1+0 lodgepole pine occurred only after 72 hours. This would suggest that there is a lag between the time a *Lygus* bug enters a susceptible crop and when it begins to feed.

Results from the 96/97 studies showed that yellow sticky traps (#611, PheroTech Inc.) can effectively monitor populations of *Lygus* species. The visual response of *Lygus* species to traps of various sizes and heights found that 1+0 lodgepole pine container seedlings could be monitored by placing one small (15.5 x 19 cm) trap every 300-500 m^2 of seedling area approximately 5 cm above the crop canopy. Also, vegetation surrounding the susceptible crop could be monitored by placing one large (31 x 19 cm) trap every 500-700 m^2 of area about 30 cm above the ground vegetation. In all cases, monitoring should start soon after germination and continue weekly throughout the susceptible growth period of 11 weeks. A preliminary weekly threshold of a mean of 0.5 *Lygus*/trap across all in-crop traps is currently being tested as an operational decision criterion.

Reforestation nurseries in BC use a preventative insecticide program for control of *Lygus* spp. Under this program 2-4

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applications of cypermethrin (Cymbush) are made each season to prevent *Lygus* bug damage particularly on 1+0 container lodgepole pine. Control with cypermethrin appears to be effective but over the years there have been efficacy inconsistencies at some nursery facilities. In 1996, a study was conducted to review the residual efficacy of cypermethrin in comparison to another *Lygus* insecticide, dimethoate (Cygon). The effectiveness of the two insecticides was compared at four seedling ages (8, 13, 16, & 22 weeks) with *Lygus* bugs being introduced to caged 1+0 lodgepole pine container seedlings at 4 post-spray intervals (3, 7, 11 & 15 days). Cypermethrin was significantly more effective than dimethoate in preventing *Lygus* damage but both residues only provided adequate protection for 2 - 3 weeks. Overall, only the 8 week old seedlings sustained the highest proportion of damage. By 13 weeks, the damage was negligible regardless of insecticide efficacy. These results were very similar to the 1995 caging study

The results of these studies along with our experience with *Lygus* bug indicate that an effective control program can be implemented at most facilities. This will involve a commitment to a trapping program coupled with the understanding of the susceptibility window of the seedlings. Life history information can be used to develop degree-day counts to help predict the appearance of adults. Unfortunately, it would appear that the efficacy period of cypermethrin is reduced but our ability to better target these sprays has been enhanced.

Cyclamen Tortrix

A new insect pest to BC reforestation nurseries is the *Cyclamen tortrix* or *Clepsis spectrana*. It has been introduced to BC from Eurasia where it is a problem on a variety of horticultural and berry crops. In 1993, *C. spectrana* was reported in the Lower Fraser Valley as an incidental pest of raspberry. Since then it has become a major pest of currants and strawberry, and has been reported on blueberry and cranberry. Under natural conditions, it has 2 generations per year with the adults flying from May-June and August-September. A female can lay up to 350-400 eggs. The eggs hatch in June/August and the larvae can pass through 4-8 instars depending on food source and environmental conditions. It overwinters as a larva. A mature larva can be up to 1.8 cm length, brown with white spots similar to a spruce budworm and has a black head.

The problem has been further amplified when this insect has been introduced to greenhouse situations. Under these conditions, *C. spectrana* has been found to no longer enter a diapause phase. The result is 8-10 generations within a single field season at 20°C. In the Netherlands, this has resulted in tremendous infestations in horticultural and floriculture greenhouse crops. Studies have shown that insect lights and pheromones within a greenhouse setting are ineffective in controlling the insect. Permethrins have been reported to be effective but only on the early instar larval stage. There is no effect on the eggs or pupae. The larvae actively move from old feeding sites to new ones thus increasing the damage potential of each larva.

In BC, our first encounter with this insect pest started at one coastal facility in 1996. Larvae were found on a 2+0 container *Abies grandis* crop that had been brought into a greenhouse for the winter. The small infestation was not controlled and resulted in the infestation taking hold within the greenhouse complex. In early 1997, with the start of the new growing season, the larvae were found throughout the entire nursery greenhouse complex. They were observed feeding on both container spruce and coastal Douglas-fir. Feeding damage by this insect is similar to most needle tiers as the larvae web the terminal needles of seedlings. The population exploded within these optimal plant conditions resulting in multiple generations in numerous crops. Attempts to control the infestation with dimethoate, diazinon and pyrethrins were unsuccessful. The result was numerous damaged seedlings and a fully infested crop at the time of seedling lift. Subsequently, the infested stock was frozen shipped and stored at -2 to -4°C at a northern BC facility. A re-sort on the seedling crop was recommended due to stock quality problems. When the seedling were thawed and the boxes opened, tremendous numbers of *C. spectrana* larvae were found in every box. It was recommended to this facility that they spray all seedling crops adjacent to the sorting facility with an insecticide and fumigate the sorting building. This past summer, pheromone trapping at this site has found numerous adults in traps placed adjacent to the cull pile area. This facility will continue to monitor its location with pheromone traps for 1999. Nursery facilities, especially in the Fraser Valley, should closely monitor and inspect all greenhouse or overwintering stock for this potentially devastating insect.

NURSERY PATHOGENS

Meria Needle Cast

Meria laricis Vuill. is the fungus responsible for *Meria* needle cast on larch. In BC, most damage is to containerized 1+0 western larch stock. In the United States, occurrence of larch needle cast is most severe on 2+0 bareroot stock. In container production, diseased seedlings can be detected with the appearance of yellowing and wilting of needles near the base of the plant. The needle tips then begin to turn brown and the disease progresses to the base of the needle. The needles the turn reddish-brown, and fall off within six weeks of initial disease expression. Infection is promoted by cool moist conditions. Frequent watering promotes development of the disease both by maintaining high humidity and splashing spores to nearby seedlings. Optimal growth of the fungus in culture is obtained at 17.5°C, while growth is stopped completely at 25°C. Major losses in three of the past five crop years at nurseries in BC has prompted interest in developing a better understanding and more effective management program. Very little information about the effects and control of *Meria* needle cast has been published in the scientific literature.

Two recent studies have looked at the efficacy of fungicides readily available to reforestation nurseries in BC for control of *Meria*. An initial screening of *Meria* isolates *in vitro* was conducted using the following fungicides: benomyl, captan, chlorothalonil, iprodione, mancozeb and propiconazole. Evaluation of fungicide efficacy found only 3 of the fungicides effective in reducing fungal growth; benomyl,

propiconizole and mancozeb. In a subsequent container assay, only propiconizole was ranked the most effective in reducing the level of disease. Preliminary results from outplantings studies in 1996/97 demonstarted that *Meria* can severely reduce the outplant success of western larch seedlings. Results indicate that even among seedlings that meet height and caliper specifications, moderate to severe defoliation assessed in the nursery in October could impair root dry weight, stem growth, and height and root collar diameter of outplanted seedlings the following year. In addition, the survival and health of fully defoliated seedlings was significantly reduced at both field assessments. For nursery managers, management of *Meria* needle cast is contingent on reducing seedling canopy humidity and increasing airflow. Every effort must be made to reduce outside inoculum source and to maintain an effective sanitation program to eliminate discarded senescent needles from previous crops. Finally, if disease symptoms are recognized, it is important to use an effective fungicide to reduce both the damage and inoculum build-up in the nursery.

ACKNOWLEDGMENTS

The author would like to thank the following for their contributions both technically and financially in the development of nursery pest management programs in British Columbia: Drew Brazier, BC Forest Service; Mike Peterson, Renata Outerbridge, Terry Holmes, Applied Forest Science Ltd.: Reed Radley, Paige Axelrood, Monica Lam, BC Research Inc: John Dennis, Bob Duncan, Canadian Forest Service; Anna Luczynski, Mike Short, ES Cropconsult Ltd.

BIOLOGICAL CONTROL OF PESTS IN FOREST NURSERIES[1]

Don Elliott[2]

Most major insect pests have developed resistance to the pesticides now available and new pesticides are facing increased costs and legislated restrictions. These, coupled with increased worker and consumer health concerns and possibilities of environmental contamination, have resulted in increased interest in biological pest control applications. The term biological control as used here refers to the use of living organisms to control plant pests. This is a very active and growing area and is being applied in increasing numbers of commercial applications in North America and Europe. The following programs have been developed in North America and Europe to use biological control agents to limit many common pests found in nurseries. Integrated pest management using biological control requires knowledge of the pest life cycle, careful monitoring to determine pest threshold levels, modification of spray programs to avoid harm to the biocontrol agent and a slightly different way of thinking about insect pests, parasites and predators. The rewards are better pest control, healthier plants, lower pesticide inventories, reduced health and environmental hazards and happier employees.

IMP PROGRAMS USING BIOLOGICAL CONTROL FOR NURSERY PESTS.

The programs that follow are only general guidelines that have been used with success in Canada. An IPM program must be custom designed for each different crop and greenhouse or farm situation. This should be done initially before purchasing the biocontrol products and then in ongoing consultation with the biocontrol producer, supplier or IPM advisor.

Fungus Gnats (*Bradysia sp.*)

Root damage by fungus gnats can spread disease to healthy roots and if common can cause losses of 20-40 percent of plants in early propagation stages. Excellent preventive control of fungus gnats can be obtained with early applications of the predatory mite *Hypoaspis miles*. This predator also feeds on spring tails, thrips and other small soil organisms. If fungus gnats are established on the crop and appearing in high numbers, beneficial nematodes or the new fungus gnat (Bt) may be also applied for control of the larval stages. Improve drainage and avoid over watering to limit algal growth and sites for fungus gnat and shore fly breeding. Algae may also be controlled with algaecides such as Agribrom.

1. Apply *Hypoaspis* predatory mites onto all plants during early propagation. Use a general preventive rate of 30 predators per square meter of planted area. Apply weekly in the propagation area and other areas where fungus gnats are a problem.

2. Monitor plants for adult fungus gnats weekly using 1 yellow sticky trap per every 500 square meters. If adult fungus gnat counts are above 20/trap/week, treat area with parasitic nematodes or fungus gnat Bt formulations using the recommended rates. Repeat these treatments weekly until the adult fungus gnat numbers are below 20/plant. This treatment will not harm other biocontrol agents.

Spider Mite

Very good control of mites has been achieved on many species of woody ornamental shrubs in British Columbia using the predatory mite *Amblyseius fallacis*. Two new predators, the beetle *Stethorus punctillum* and midge, *Feltiella acarisuga* are also now available and are being used experimentally.

1. Apply *Amblyseius fallacis* onto all spider mite sensitive ornamental plants during propagation or when setting them out in cold frames or the field. Use a general rate of 3 predators per square meter of infested plant area repeated weekly for 3 weeks if spider mite are present.

2. Monitor these plants weekly to check spider mite levels. If mites are building up or causing webbing apply fenbutatin-oxide (Vendex™, Torque™) through a high volume sprayer. This will not harm predatory mites. Avoid the use of any other miticide or pesticide unless known to be safe for biological control agents.

3. Where there are species of plants that are very attractive to mites the new predatory beetle, *Stethorus punctillum* and the predatory midge, *Feltiella acarisuga* may be released. Release 100 adult beetles or 100 midges into each infested plant site. Make weekly introductions for 3 weeks. These biological controls can fly and feed on all stages of spider mite and will reproduce and remain in the area for more than one season. *Feltiella* will only establish if humidities are 65 percent or higher.

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[1]Elliott, D. 1999. Biological control of pests in forest nurseries. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 141-143.
[2]Applied Bio-Nomics Ltd., Sidney B.C. Canada; TEL: 250/656-7123; FAX: 250/656-3844; E-MAIL:bug@islandnet.com.

Aphids (Many Species)

There has been excellent success treating aphid infestations in nurseries with biological control agents. In fact, if biological control agents are introduced in open screen houses and field settings, it is usually unnecessary to apply pesticides for most species of aphids. Unfortunately, protected or gall forming aphids are not controlled by biological control agents that are presently available from commercial suppliers.

1. At the first sign of aphids, apply the *Aphidoletes* aphid predatory midge at the rate of 2 predators per square meter of infested area, repeated weekly for 3 weeks. These biocontrols can fly and feed on all stages of most species of aphids and will reproduce and often over-winter and remain in the area providing control for more than one season.

2. At the first sign of aphids, apply the aphid parasite, *Aphidius* at a rate of 1 parasite for every 2 square metes of infested area, repeated weekly for 3 weeks. Three weeks after release look for signs of parasites in the form of parasitized aphid mummies attached to the leaves.
3. If aphid hot spots are building up apply the Ladybeetle, *Harmonia axyridis* at the rate of 1 per plant in the infested area repeat this treatment in 2 weeks.
4. Monitor plants weekly, if aphid hot spots continue to develop and there is plant damage, spot spray with pirimocarb (Pirimore™) or Insecticidal Soap. This will cause minimal harm to the biologicals. Avoid the use of other pesticides unless determined to be safe for biological control agents.

Caterpillars (Lepidopteran larvae)

Caterpillar damage may be controlled by releasing the commercially available moth egg parasite *Trichogramma* spp. or sprays containing the spores and insecticidal crystals of strains of *Bacillus thuringiensis* (Bt). A new larval parasite, *Cotesia marginiventris*, is also available for experimental use. *Cotesia* attacks a wide range of hosts and is a natural enemy of 21 different Lepidopteran species.

1. Monitor planted area for adult moths using pheromone traps or ultra violet light traps.

2. Release *Trichogramma* egg parasites as soon as adult pest moths are detected at rates of 50,000-100,000/acre or as advised by the supplier.

3. Release *Cotesia* parasites as soon as larvae are found on plants at weekly rates of 1 parasites per square meter of infested area. If there is more than 1 caterpillar for every 10 plants apply Bt sprays as well.

4. Bt is usually applied as a high volume spray at first sign of larval damage. Follow the formulators recommendations for rates.

Vine Weevil (*Otlorhynchus sulcatus*)

The vine weevil can cause serious harm to nursery plant roots and the adult also feeds on leaves. Unfortunately root weevils are all female do not require mating and can lay up to 1000 eggs each! Adults are also flightless, are most active at night and they can walk as far as 1000 metres per day. Adults lay eggs in the root ball and both larvae and adults continue feeding at temperatures as low as 2°C As many as 400 weevils have been found in a single 2 gal. container root ball. A nematode is available as a bilogical control agent of this pest. Nematodes are most effective when applied into potted plants under warmer growing conditions in greenhouses or when soil temperatures are greater than 12°C. Nematodes are mixed with water and applied as a drench. Nematodes in the Heterorhabditis group have been found more effective than other types against vine weevil.

1. Monitor plants weekly for damaged leaves and check the root ball of wilting plants for weevil larvae causing root damage.

2. Apply nematodes to the root zone following label recommendations. Apply 2-3 treatments at weekly intervals. Spring and Fall applications are best as most adult weevils are in the soil at this time. Treated plants should be watered before treatment and kept moist as the nematodes can only move through moist substrates. Do not overwater treated plants as this will wash away nematode larvae. Nematode biocontrols are resistant to Orthene and it may be applied as well where necessary.

Biocontrol of *Lygus* Bug?

At the moment there is no commercially available biocontrol for *Lygus* Bug and the only control method is excluding by screening vent openings or use of pesticides. Entomologists at Agriculture Canada are investigating the use of parasites for biological control of *Lygus*. Cornell University is experimenting with the fungus, *Beauvaria bassiana*, a microbial biocontrol that is now available in the USA. Work is also being done at Simon Fraser University on *Lygus* attraction or mating disruption pheromones and this may have direct application to nursery IPM.

IPM SUMMARY FOR NURSERY PESTS

Fungus Gnats	Yellow sticky traps	Use 1 trap/500m^2 for monitoring adults
	Hypoaspis miles	Apply once at planting or transplanting or if fly trap counts are below 20/trap/week 15,000/ 100m2 or 30/pot (1tsp)
	Steirnernema feltiae (Microkil™)	Apply at least 2X at 2 week intervals if fly trap counts are above 20/ trap/week rate- 50,000,000/250m^2 or as recommended
	Bacillus thuringiensis israelensis (Vectobac™)	Apply weekly if fly trap counts are above 20/ trap/week rate- 4-8 litres/1000 litres of water
	Bromide(Agribrom™)	Apply with irrigation to control algae 10-15 ppm bromine or as directed
Spider Mite (*T.urticae*)	*Amblyseius fallacis*	Preventative and low curative 3 predators/m^2 repeated weekly for three weeks when mites are detected
	Stethorus Punctillum	Preventative and low curative 100/infested site/weekly for 3 weeks
	Feltiella acarisuga	Preventative and low curative (requires Rh+65) 100/infested site/weekly for 3 weeks
	fenbutatin oxide (Vendex 50W™)	500g-1Kg Vendex 50W/ 1000 litres water
Vine Weevil	*Heterorhabditis megidis* (Nemasys™)	Soil temperature must be 12°C or greater most effective in pot or container culture apply as a soil drench as directed (eg.) 50,000,000/250m^2
Caterpillers (many species)	Pheromone traps Ultraviolet light traps	Use 1 trap/50000m^2 for monitoring adults
	Trichogrammma brassiere	Egg parasites should be released as soon as pest adult moths are detected, release 50,000-100,000 parasites/acre weekly for 3 weeks or as advised by supplier
	Bacillus thuringiensis var.kurstaki (Dipel™)	Apply as a high volume spray at first sign of larval damage at recommended rates (eg.) 1.2Kg. Dipel/1000 liters of water.
Aphids (many species)	*Aphidoletes aphidimiza*	Preventative and curative 2 predators/m^2 of infested area repeated weekly for 3 weeks
	Aphidius spp.	Preventative and curative 1 parasite/2m^2 of ingested area repeated weekly for 3 weeks
	Harmonia axyridis	1/plant in infested are repeated in 2 weeks
	Pirimicarb (Pirliss™ 50DF)	500g Pirliss 50DF/1000 litres water or as directed moderately harmful to biologicals so apply at low rate to tops of plants only or use only in hot spots
	Insecticidal soap (Safer's Soap™)	1part soap/100 parts water of use low rate moderately harmful to biologicals so apply to tops of plants only or use only in hot spots

SOURCES OF BIOLOGICAL CONTROL PRODUCTS:

The following is a partial list of biological control and IPM product suppliers. There are now more than 130 different species of beneficial organisms for sale in North America. An electronic data base of suppliers with information on IPM may be accessed through the internet at: http://www.cdpr.ca.gov/docs/dprdocs/goodbug/organism.htm

Canada

Westgro Sales Inc.
7333 Progress Way, Delta, B.C.
(604) 940-0290

Plant Products Co. Ltd.
314 Orenda Road, Brampton,On.
(905) 793-7000

Plant Product Quebec
3370 Le Corbusier, Laval, Que.
(450) 682-6110

U.S.A.

The Green Spot Ltd.
93 Priest Road, Nottingham, N.H.
(603) 942-8925

Rincon Vitova Inc.
3891 North Ventura Ave.,Ventura, Ca.
(805) 643-5407

I.P.M. Laboratories Inc.
Main Street, Locke, N.Y.
(315) 497-2063

Evergreen Growers Supply
17492 S. Eaden Rd., Oregon City, Or.
(503) 631-7954

INNOVATION IN THE HORTICULTURE NURSERY INDUSTRY[1]

David Woodske[2]

INTRODUCTION

Over the years, growers of forest seedlings have adopted innovative technologies that were pioneered by producers of horticultural crops, and vice versa. This sharing of technology has improved the quality of crops and production efficiency in both sectors. Today, the major innovative ideas that are being developed by the horticultural nursery industry are in use by forest nurseries. These include the use of copper compounds to control root growth in containers; somatic embryogenesis; environmental-control computer systems; and the use of ergonomically designed equipment to reduce worker arm and back injuries.

In order to identify future technological advancements in the nursery industries, it is best to look at developments in the greenhouse sector. It has been said that the greenhouse sector is 10 years ahead of the nursery sector in the adoption of technology. If this is true, one future trend will be greater adoption of production practices that reduce or prevent the discharge of chemicals into the environment. These practices are commonly referred to as Best Management Practices (BMP), and include both structural systems and cultural practices.

WAYS TO REDUCE THE LEVEL OF CHEMICALS LEACHED FROM NURSERY STOCK

How does a nursery reduce the release of liquid wastes from their operation? The approaches available range from reducing the volume of irrigation and chemicals fed to the crop, to collecting and 'dealing with' the runoff. Some examples of BMP used to reduce irrigation inputs are drip or subirrigation systems, using information on the crop's water status and weather conditions to determine crop irrigation requirements, pulse irrigation, and collection and re-use of irrigation runoff.

Soilless media have a very low nutrient holding capacity, on a volume basis, and therefore leach fertilizer readily when irrigated. To reduce this risk, growers are replacing soluble fertilizers with slow and controlled-release fertilizers. Controlled-release fertilizers have tremendous potential to reduce nutrient leaching since their release profiles closely approximate a crop's fertilizer demand. This occurs because fertilizer release and plant growth are both correlated with temperature. There is also work being done to increase the nutrient holding capacity of soilless media. One direction this work is taking is the pre-loading of media with alumina or aluminum sulphate, which are responsible for forming insoluble complexes with phosphorus in soil. The results of this research have proven that the system does reduce phosphate leaching without negatively impacting crop production (Williams 1995). In fact, pre-loaded media produced equivalent crop growth despite using 65 percent less triple superphosphate (Williams 1995).

A step used to reduce pesticide inputs is Integrated Pest Management (IPM). IPM systems generally result in the use of less pesticides, and often use new, biorational pesticides. Biorational pesticides have relatively low toxicity levels and do not have long residual activity.

COLLECTION AND RE-USE OF NURSERY RUNOFF

To prevent raw wastewater from entering the environment, on-farm runoff collection systems are required. This technology is rapidly being adopted by the greenhouse industry to deal with the large volumes of nutrient-rich irrigation leachate they generate. For instance, greenhouse vegetable operations generate up to 45,000 L/ha/day of leachate (Prystay 1997). The Netherlands, a World leader in greenhouse crop production, had aimed to employ 100 percent nutrient collection and re-use by the year 2000. This target will not be met, but the greenhouse industry is still moving in this direction. In B.C., the greenhouse vegetable and floriculture industries are gradually adopting recirculation technology, too. Today, 13 percent of greenhouse vegetable operations collect and recycle all of their fertilizer leachate. B.C.'s nursery industry has not embraced this technology. However, Byland's Nurseries in Kelowna collects and recycles all of the runoff from their 40-acre container production site. The nursery industry in other regions of North America is adopting the technology. Oregon, which is the third largest producer of nursery stock in the U.S., is quickly seeing the implementation of recirculation systems.

There are several reasons why recirculation technology is being adopted.

- To conserve water in regions where fresh water supplies may be too expensive, or limited in quantity and/or quality during periods of peak demand. Byland's Nurseries has found their runoff collection system to reduce water consumption by 25 percent. With continued population growth, nurseries near high density urban areas may find it more difficult to secure a reliable source of good quality water. This is already occurring. In some regions along the west coast of Oregon, due to excessive withdrawal of water from wells, saltwater infiltration has polluted some freshwater aquifers.

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[1]Woodske, D. 1999. Innovation in the horticulture nursery industry. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture. Forest Service, Southern Research Station: 144-146.
[2]Ministry of Agriculture, 1767 Angus Campbell Road, Abbotsford, BC V3G 2M3, Canada; TEL: 604/556-3044; FAX: 604/556-3117.

- To reduce fertilizer use. Although fertilizer costs are only a small fraction of crop expenses, the potential savings can still be significant.

- Maintain the productivity and value of the land resource. The environmental quality of land is becoming a more important consideration in real estate transactions. Purchasers are beginning to perform environmental site assessments prior to property transfer, because the property owner must bare any costs for environmental remediation, which, depending on the wastes involved, can be significant. Some common contaminants are solid wastes in on-site disposal areas, and fertilizer, pesticide, and fossil fuel residues in the soil and water supply.

- To meet local regulations.

Most operations use collected irrigation runoff to irrigate their crops. The runoff can also be used to fertigate adjacent field-grown crops or it can be scrubbed in a manmade wetland prior to being discarded. Fertigating field-grown crops is permitted in B.C., however the "Code of Agriculture Practice for Waste Management" restricts when fertigation can occur. The Code states that the application rate must not exceed the amount required for crop growth; it must not be applied if runoff causes pollution of a watercourse or groundwater, or goes beyond the farm boundary; and it cannot be applied to frozen or saturated soils.

Several wetland designs were tested over a two-year period at Houweling Nurseries Ltd. in B.C. These manmade wetlands consumed up to 65 percent of phosphate, 74 percent of ammonia, and 54 percent of nitrate-N in greenhouse leachate (Prystay 1997). However, a very large land base would be required to generate sufficient carbon to denitrify all of the nitrate-N in the leachate: the ratio of wetland to greenhouse area would be in the order of 1:2 (Prystay 1997). Other drawbacks are self-contained wetlands are expensive to construct, require periodic vegetation thinning to maintain adequate flow, and do not remove phosphates quick enough (Prystay 1997). For these reasons, the wetland system has been abandoned as an option by the greenhouse vegetable industry.

Table 1—Fixed and operating costs of water disinfection systems used in The Netherlands (Runia 1994)

Disinfection system	Fixed cost	Operating cost (per m^3)	# in use
Heat pasteurization	$30,700	$1.44	~300
Ozone	$35,000	$1.54	~150
UV light	$29,000	$1.27	~50
Slow sand filtration	$11,000	$0.47	5-10

THREAT OF DISEASE SPREAD WITH RECIRCULATION

The major concern with recirculating runoff is the potential for the spread of pathogens. Lesser concerns include the accumulation of pesticides, growth regulators, and toxic levels of nutrients. Byland's Nurseries dilutes the irrigation runoff with fresh water before use, but does not treat it in any other way prior to re-use. In the 6 years the system has been in operation, no crop damage has occurred due to re-using runoff water. Every incident of root rot has been attributed to another cultural practice.

There are several possible explanations why root rot diseases have not been spread with recirculation at Byland's Nurseries. First, many of the crops grown are resistant to the common root rot organisms, namely *Pythium, Phytophthora, Fusarium,* and *Verticillium.* Second, the nursery has a large, one million gallon holding pond, which would provide a long retention period for chemical, physical, and biological processes to reduce pathogen levels. For instance, spores of *Fusarium* spp. and other fungi are known to settle-out in standing water within 24 hours (Anon. 1992). Third, there is a high background level of free chlorine in their water source. It has been found that a 5 minute exposure to at least 0.2 ppm free chlorine is adequate to completely eliminate *Phytophthora* zoospores in water (Reeser 1997). However, the actual dose required will depend on the quality of the water, since the effectiveness of chlorine is impacted by several impurities in water. Fourth, good cultural practices and a free-draining medium will play a major role in root rot prevention. Fifth, beneficial microbes, or the crop, may be releasing chemicals into the irrigation solution that are antagonists of the disease-causing organisms (McPherson 1994).

Both the greenhouse vegetable and floriculture industries have installed recirculation systems. Not all of these greenhouses use a disinfection system. Greenhouses that grow crops susceptible to water-borne pathogens, such as tomatoes or gerbera daisies, have incorporated a water disinfection system. There are numerous systems available, including heat pasteurization, ozonation, UV light, membrane filtration, iodination, and slow sand filtration. In The Netherlands, the preferred system is heat pasteurization (table 1). Not enough greenhouses are using a disinfection system in B.C. to determine a preference, although slow sand filtration is very popular due to economics. Slow sand filtration is the least expensive disinfection system to purchase and to operate (table 1). In addition, the system is effective against several fungi, including *Fusarium, Thieaviopsis, Verticillium,* and *Phytophthora* (Wohanka 1992).

SLOW SAND FILTRATION

Slow sand filters, as their name implies, contain a series of layers of sand, gravel, and drainage rock. The system removes microorganisms by physical and biological means. A layer of organic matter forms on and in the fine-textured layer of sand at the top of the filter. A unique collection of microorganisms colonize this zone and breakdown the organic layer, including any pathogens present. The effectiveness of the filter is determined by the flow rate of

the solution, and the thickness and particle size of the sand layers. The system is very effective at eliminating water turbidity, which makes it an ideal pre-treatment for UV light. UV light is a very effective disinfectant, but its usefulness is limited due to water quality. Organic matter and other particulates shield microbes and lead to poor performance by UV systems. Combining slow sand filtration and UV light would be a very effective disinfection treatment. The slow sand filter developed by Wohanka (1992) is currently being tested and refined at the Pacific Agriculture Research Centre, Agassiz, B.C.

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CONTAINER MECHANIZATION AT RIVERSIDE'S EAGLE ROCK NURSERY[1]

Garry DeBoer[2] and Jim Kusisto[3]

Over the years we have focused on mechanization as a major part of our approach to control labour costs, maintain productivity and reduce the potential for injury. This has been especially important during seedling extraction and grading, which accounts for a major portion of annual labour costs as well as injury potential. Initial attempts to mechanize seedling extraction and grading were unsuccessful. They did, however, provide useful information and insight as to what might be feasible. At least we discovered what would not work. Our current system has worked out reasonably well. It is centered around a Vancouver Bio Machines pin extractor. The extractor is a dual outfeed model. It delivers seedlings onto two Byronix counting and bunching lines. Culls are removed by one person on each line, with the remaining seedlings being electronically counted and grouped into bunches for wrapping. The bunches of seedlings are manually gathered and placed vertically into two Byronix seedling wrappers. The wrapped bundles of seedlings drop onto conveyors which transport them to powered carousels, from which the stock is packaged. The pin extractor, outfeed conveyors, and counting / bunching conveyors are variable speed controlled, allowing for a high degree of calibration. Manpower required to operate the line is 10 persons:

1 person loading/hauling stock to operations building
1 person loading extraction line/washing blocks
2 persons grading/culling
2 persons feeding wrappers
2 persons packaging
1 person carton assembly, labelling/palletizing packaged stock
1 person quality control/lead hand

Production is relative to stock quality. With net seedling recovery in the 75-80 percent range we can expect the following:

PSB 160	125-140,000 net seedlings over 7.5 hours
PSB 112	90-100,000
PSB 77	65-75,000

Mechanized extraction has reduced manpower requirements by 40 percent from the manual method, while maintaining similar production levels. Risk of repetitive motion injury has been greatly reduced. All persons are cross-trained and rotate to a different job every 2 hours. The manual line is kept on standby in case of downtime or if hand lifting is required. Pay back on the extraction line was projected at 3 years. In fact it paid for itself in under 2.5 years. Several areas still require additional development. The wrappers work adequately with most stock types, but could be more robust to improve reliability. Packaging is another area that has been considered for mechanization.

The innovations of people in this industry and the technological advances we have witnessed over a relatively short time have combined to get us where we are today. The future of container seedling nursery mechanization is only as distant as the next good idea.

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[2] Eagle Rock Nursery, Riverside Forest Products Ltd., Bag Service 5000, 844 Otter Lake Cross Rd., Armstrong, BC VOE 1BO, Canada; TEL: 250/546-2272; FAX: 250/546-8660.
[3]MOF Skimikin Nursery, RR 1 S13 C11,Tappen, BC V0E 2X0, Canada; TEL: 250/835-4541; FAX: 250/835-8633.

NATIVE PLANT PROPAGATION AT PACIFIC FORESTRY CENTRE[1]

Rob Hagel[2]

Some of the shrubs which have been grown at (PFC) for research purposes, i.e. Biological Control of Forest Weeds, White Pine Blister Rust Investigations, include:

Rubus parviflorus (Thimbleberry)
Rubus spectabilis (Salmonberry)
Rubus idaeus (Red Raspberry)
Ribes sanguineum (Red-Flower Currant)
Ribes bracteosum (Stink Currant)
Gaultheria shallon (Salal)

Shrubs of interest for PFC's native landscape or other local plantings:

Arctostaphylos columbiana (Hairy Manzanita)
Arctostaphylos uva-ursi (Kinnikinnick)
Holodiscus discolor (Ocean Spray)
Philadelphus lewisii (Mock Orange)
Spiraea douglasii (Hardhack)
Symphoricarpos albus (Common Snowberry)

Trees which have been grown extensively at PFC:

Quercus garryana (Garry Oak)
Arbutus menziesii (Arbutus)

STANDARD METHOD OF VEGETATIVE PROPAGATION

Most vegetative propagation is done in Green House 5 which has 3 benches with adjustable bottom heat (usually calibrated to produce 20 degrees Celsius temperature in the flat). Intermittent mist is always supplied to bench 1 in the compartment by means of a "Mist-a-Matic". Mist can be supplied to bench 2 or 3 by opening the 1/4 turn valve to the bench. The mist is delivered with Pate L10 nozzles at 36 inch spacing (3 nozzles over each bench).

The standard media used is 1 peat: 2 perlite with no added fertilizers. Cuttings are usually set in 1 foot by 2 foot by 4 inches deep cedar flats. Flats of cell packs are sometimes used as are individual pots or styroblocks.

The standard hormone treatment is to dip the cutting in the appropriate strength of 'Stimroot' powder by Plant Products Co. Other hormone treatments are occasionally given such as liquid 'Stimroot'.

A PROPAGATION BOX FOR WOODY CUTTINGS

Please refer to figure 1 for drawing and details of this propagation frame.

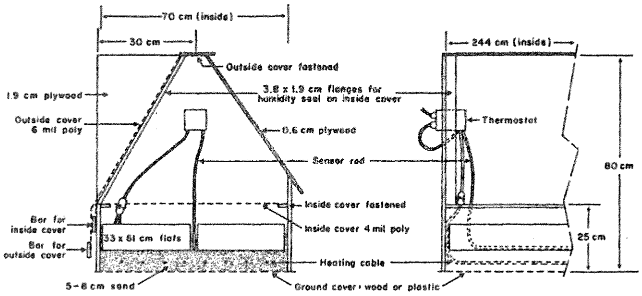

Diagram of outside propagation frames

Figure 1—A propagation box for woody cuttings. Vegetative propagation of woody plants is often promoted when cuttings are maintained in a humid atmosphere with bottom heat. This will help to increase success rates and speed the rooting process. This structure was originally designed at Pacific Forestry Centre by Dr. H. Brix to provide such an environment at minimal cost. It can be easily constructed and uses household electricity. Soil temperature is regulated using a heating cable and controller. The cable is buried in sand and a thermometer is used to monitor temperature. The front of the box is covered with 6 mil. plastic in two layers to create a high humidity environment and minimize water loss from the cuttings. This also reduces watering requirements to approximately once a week.

This propagating box can be used successfully to root a wide range of woody cuttings of native and ornamental shrubs. It requires very little maintenance (once a week watering).

PROPAGATION TREATMENTS FOR FOLLOWING SHRUBS AND TREES

Rubus parviflorus (Thimbleberry)

The traditional propagation method has been to collect root pieces in the fall. These root pieces should be cold stored until spring to ensure that they have been given sufficient cold treatment to sprout and root properly. The root pieces can be cut to 6" long for thick pieces and down to 2" long for thin pieces. They should be covered shallowly in the flats of rooting medium (1/2" covering). Once well developed shoots have formed the root pieces (with vigorous shoots) can be dug from the flats and potted up individually. The problems with this method are:

- Many times other root pieces than the target *Rubus* sp. are supplied.

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[1]Hagel, R. 1999. Native plant propagation at Pacific Forestry Centre. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 148-153.
[2] Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5, Canada; TEL: 250/363-0764; FAX: 250/363-0775.

- Shoot sprouting is sometimes poor if the root pieces are collected from poor plants or are collected too early in the fall.

- The method is somewhat space and labour intensive. The propagation method I use is to root softwood cuttings off of nursery stock plants which are obtained by the above method. This can be done successfully almost any time of the year, providing the stock plants are pruned to produce vigorous new shoots. Cuttings can be standard tip cuttings, second or third cuttings from tip, and leaf-bud cuttings. Stimroot #1 or #2 (or comparable rooting hormone) should be used on the cuttings to help promote rooting. Wounding can be done to the more woody lower shoot cuttings. Large, vigorous 1 gallon stock can be produced in 2-4 months from cuttings.

Rubus spectabilis (Salmonberry)

As per *R. parviflorus* above. The salmonberry cuttings should root near 100 percent and will usually be more vigorous than the thimbleberry cuttings.

Rubus idaeus (Red Raspberry)

As per *R. parviflorus* above. The red raspberry usually roots well from softwood cuttings but is slower to grow than the other *Rubus* species.

Ribes sanguineum (Red-Flower Currant)

The Red-Flower Currant is normally propagated from hardwood cuttings collected in the fall. This method is very successful and will produce large 1 or 2 gallon stock plants in one growing season. I have also been required to produce plants in the early summer. Good success can be achieved with summer softwood cuttings if treated with Stimroot and placed under intermittent mist as outlined under "Standard Method of Vegetative Propagation".

Ribes bracteosum (Stink Currant)

As per *R. sanguineum*.

Gaultheria shallon (Salal)

Salal is usually grown from seed. I have had good success rooting salal from July softwood cuttings (three collections: Bamfield, Shawnigan, and one other). The poorest rooting percentage was > 80 percent with 2 collections > 90 percent. These cuttings were rooted in styroblocks in our main greenhouse using the irrigation boom for misting and the high pressure fog system for increasing humidity and reducing stress on the cuttings.

Arctostaphylos columbiana (Hairy Manzanita)

Hairy Manzanita can be easily grown from cuttings placed under mist as outlined in "Standard Method of Vegetative Propagation". Tip cuttings root well but the next cutting down from the tip often roots quicker and better, especially if given a wounding treatment as shown on my slides. I have rooted cuttings that were taken in November, December, January, and in February with equal success (usually > 80 percent). Cuttings taken from good quality nursery stock plants will root near 100 percent.

The plants grow very vigorously in the first year in the greenhouse or shelterhouses at PFC and can be a little tricky to grow. Fertilizing from pot-up time to the end of August should only be done once a week or once every two weeks with a balanced fertilizer (such as Plant Prod 20-8-20 or 20-20-20) at 100 ppm N. To prevent plants from getting leggy it may be necessary to regularly pinch the new growth to produce a compact bushy plant. At the end of August/beginning of September it is recommended to switch to a low nitrogen fertilizer (such as Plant Prod 8-20-30) to help harden the plants and reduce the potential for a late flush to occur.

All plants produce flowers at 2 years old. At 3 years old the plants are looking much like a mature plant.

Arctostaphylos uva-ursi (Kinnikinnick)

I have only rooted Kinnikinnick from November tip cuttings. They root easily and produce good plants in one season.

Holodiscus discolor (Ocean Spray)

I grew Ocean Spray from seed for the first time last year. I found that 6 weeks cold stratification was not near enough for the seed source I had. However the germinants I did get grew well and more than filled a styroblock 45 plug (PSB615A).

This year I fall sowed my seed which gave the seed approximately 4 months cold stratification. The trays have just been brought to germinating temperature and so far the germination looks very good.

Philadelphus lewisii (Mock Orange)

Mock Orange is easily propagated by hardwood cuttings taken in November. The first year growth is very vigorous and may require stock to eventually be potted-on to 2 gallon pots in the first year. Sturdy, well branched plants 1 meter tall were the average stock produced.

Spiraea douglasii (Hardhack)

Hardhack is easily grown by seed. A fall sowing scattered in a flat with a cover over will provide the necessary cold stratification for the previously dry seed. Seedlings can be transplanted from the flat to appropriate styroblocks (PSB 415D - 77 cav./170 ml or PSB615A - 45 cav./336 ml) in early spring. Seedling stock should reach 30 cm in height with a caliper of 5 mm or greater.

Hardhack is also readily propagated by December hardwood cuttings. On December 20, 1997, I set 1 flat of cuttings with Stimroot #2 powdered rooting hormone. The flat was placed in the rooting box (fig. 1). The rooted cuttings were potted up on February 4, 1998 with a rooting success of 110/112. All rooted cuttings are currently growing very well with no after potting mortality. This stock is extremely vigorous and will easily fill out a one gallon pot in it's first year.

Symphoricarpos albus (Common Snowberry)

Snowberry can be readily propagated by hardwood cuttings taken in November and placed under mist as outlined in "Standard Method of Vegetative Propagation". The cuttings will likely do well in the propagation box as described earlier or in a greenhouse with bottom heat and only occasional mist.

Snowberry grows vigorously and will produce large 1 or 2 gallon stock in one year. The plants will also produce a profusion of flowers and subsequent berries in the first year.

QUERCUS GARRYANA (GARRY OAK)

Seed Selection

Fallen seed is all right to collect but should be done frequently to ensure that the acorns do not dry out too much before collection. Collected seed should be given a float test and any floaters should be discarded (either partially filled seed, too dry with visible cracking, or weevil damaged). Inspect seeds and discard ones with round weevil holes, very small acorns, and acorns with large cracks. Soak remaining good seed for 24 hours. Any sprouting acorns can be planted right away as there is no embryo dormancy in the seed. Place non-sprouted seed in heavy plastic bags and place in cold room that is just above freezing (0 to 1° C is ideal) for one month. Check acorns weekly to allow removal and planting of sprouted ones and removal of molding or damaged ones. The one month cold storage provides for more rapid and complete germination and also spreads out the work load. I have successfully stored and subsequently grown acorns that were stored until March.

Types of Containers

Since oaks naturally form a deep root, narrow deep containers are preferable to short wide ones. Containers must allow roots to air prune themselves at the container bottom to ensure that roots don't circle around and become "pot-bound". Container types I have used successfully are:

- Monarch Plant Band - 2"x2"x8" deep (waxed cardboard much like a milk carton). This container is the one most widely used in California. The cells begin to break down toward the end of the season and subsequently the seedlings are best planted in the fall at 1 year old.

- PSB 615A - 45 cavities per block that are 15 cm deep with a volume of 336 ml per cavity. This container is best for growing the oak seedlings for one season only, although it is possible to grow seedlings for 2 years in this container.

- PSB 623B - 28 cavities per styroblock with 500 ml volume per cavity (~ 23 cm deep). Seedlings can be grown 2 years in this container although it can be very difficult to water thoroughly enough to saturate the bottom of the plugs in the second year (up to 8 passes with wand if hand watering).

Soil Mix

It is important that mixes provide good aeration and drainage. The mix recommended by California researcher Douglas D. McCreary is listed below:

1 5-cubic foot bag of course peat
1 5-cubic foot bag of course vermiculite
4 cubic feet of fir bark (1/8" - 1/4" size)
1 pound of lime
2 pounds of Osmocote slow release fertilizer.

The rates work out to approximately 1.0 kg/m^3 of lime and 2.0 kg/m^3 of Osmocote. I used a mix comparable to this one when first growing oaks in October 1992 but added 2 ft^2 of perlite and used the following fertilizers:

coarse dolomite lime at 3.0 kg/m^3
Micromax at 0.75 kg/m^3
Osmocote 18-7-12 (9 month) at 2.0 kg/m^3

Currently I use a soil mix of 3 peat : 1 vermiculite : 1 perlite with fertilizers approximately as above. Containers should be loaded with low rates of compaction to ensure that a well drained and highly aerated soil is maintained.

Planting Acorns

If radicles on acorns have started to emerge prior to planting, position the acorn such that the radicles is pointing down. Acorns that have not germinated should be placed on their side. All acorns should be covered with 1/2 to 1 inch of potting soil, then 1/3 inch of forestry sand.

Irrigation and Fertilization

Irrigation frequency will depend on soil mix, container size and depth, and growing environment. However, the mixes should be allowed to dry down somewhat between each irrigation and not kept saturated all of the time. Fertilizing should not be required until leaves are visible (February). At that time commence regular fertilizing with a balanced fertilizer i.e. 20-20-20 at 100 ppm. of nitrogen or Plant-Prod 20-8-20 high nitrate at 0.5 g/l. At the end of August it is best to change to a lower nitrogen fertilizer such as Plant-Prod Fall Finisher 8-20-30 at 0.5 g/l.

Growing Facilities

The seeded containers are best protected in a heated greenhouse. The greenhouse can be kept at dormant winter temperatures until the end of February (i.e. 2-3° C night temperature and 10° C day). Grow the oak seedlings at approximately 21° C day temperature and 15 C night temperature from March 1st until the end of May. After that time they may be moved outside to grow the remainder of the season. To prevent scorching of the seedling's leaves move stock out under shade for two weeks prior to the full sun treatment or during a period of prolonged wet weather.

Garry Oak Growth Patterns

The oaks will normally spend several months growing a root system before the shoots emerge. The Garry Oaks will initiate root growth soon after they are collected, even while still in cold storage. By the time the shoots emerge in February or March, a substantial root system will be developed. The tap root will reach the bottom of the 15cm - 23cm containers in 4 to 6 weeks after sowing, even when they are kept at dormant winter conditions.

Shoot growth consists of a series of 2 to 4 "flushes" or growth periods. Care should be taken to prevent a late flush in the fall. Begin to restrict watering and fertilization in the late summer and also switch to a low nitrogen fertilizer at that time.

Planting

Planting guidelines are covered in a "Forestry Facts" (Appendix 1) publication prepared for a fall 1993 planting of 3000 Garry Oak seedlings by individuals in Greater Victoria. Please refer to this publication for detailed instructions.

A fall planting once fall rains have commenced has been very successful. A February/early March planting will also be successful.

ARBUTUS MENZIESII

Mature berries may be collected off the trees from October to December or off the ground at the same time. The seeds should be removed from the flesh of the berry, placed in a moist medium, then given a cold stratification treatment. A 60 to 90 day stratification period may be necessary for some seed lots. Germinants will transplant readily if required. I have found the PSB615A to be an adequate container but would expect better quality seedlings from the PSB615B.

Forestry Facts

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Guidelines for Planting and Establishment of Oak Seedlings

The Garry Oak

The Garry Oak (*Quercus garryana*) is one of the more distinct and certainly one of the most stately trees growing in the Greater Victoria landscape. It is the only oak native to British Columbia, and is confined to the southeast coast of Vancouver Island and the adjacent Gulf Islands, with two isolated locations on the mainland.

Garry Oak normally grows to massive proportions on deep, rich, loam soils, but is usually a smaller, gnarled tree on dry rocky knolls and shallow pockets of soil.

Site Selection and Preparation

The Garry Oak grows best in a bright sunny location having well drained soils. Dry, rocky areas are acceptable, but avoid wet, marshy land. When choosing a location for planting, remember that over two or three generations your tree can grow to be enormous, so leave plenty of room for expansion.

An important factor that often limits growth and survival of the newly-planted oak seedling is dry soil. Vegetation (especially grasses) often competes for available soil moisture, leaving little for the oak seedling. It is therefore recommended that a .5 m-1.5 m diameter circle around each planting site be cleared of other vegetation (fig.1). This can be done by hand weeding, scalping, hoeing, scraping, or removing the grass sod on sites with heavy grass competition. This clear area around the planting spot should be maintained until the seedling is well established. Placing some type of mulch such as bark mulch, composted leaves, straw, compost, or landscape fabric around the planted seedling will help reduce future weed and grass growth as well as conserve moisture by reducing evaporation from the soil surface.

Figure 1 — Planting the seedling

Transplanting

Use a shovel to dig a planting hole approximately 40 cm deep. Backfill the planting hole half way with the loosened soil. Gently set the plug seedling in the hole with the root crown at the level of the soil surface. Fill the hole with soil, firmly tamp the soil down, and soak it. Soaking the transplant will settle the soil and help eliminate air pockets around the seedling roots. Continue to soak the planted seedling weekly until fall rains soak the surrounding soil to a depth of 15 cm.

Watering transplanted oaks

Watering, weeding, and mulching is important until the seedling is well established. For the first growing season, thoroughly soak the seedling so that water deeply penetrates the soil (10 L per seedling) every two weeks or whenever the top 5 cm of soil is dry (fig. 2). Taper off watering as the seedling becomes established—many plantings will be successful with only a few waterings during the first season. If your seedling is

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planted in an area receiving regular irrigation (such as a lawn), plant on a raised mound to ensure the area around the root crown is well drained.

Figure 2 — Watering the transplanted seedling

Seedling Protection.

If browsing by rabbits, deer, or other animals is a problem in your area you can reduce the risk of such injury by placing a protective cage over the seedling. One type of cage that will work consists of a 50x50 cm aluminum screen that is formed into a 13-cm-diameter cylinder and stapled to a 1" x 2" x 60 cm wooden stake. Drive the stake into the ground so that the cage covers the seedling, then fold the cylinder closed at the top. This cage will keep out browsing animals and some insect pests until the seedling is established.

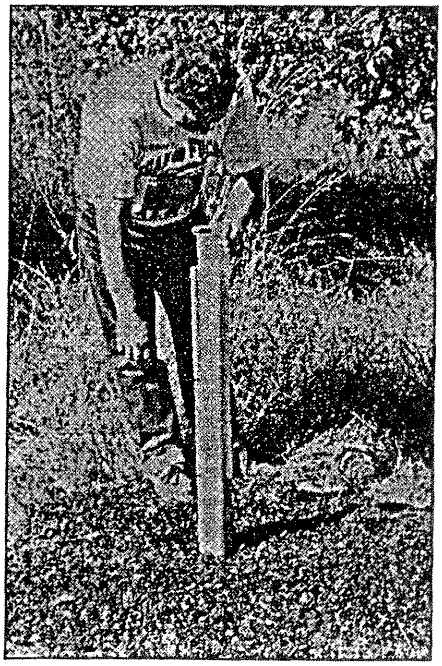

Figure 3 — Seedling protector over oak seedling

Another type of seedling protector is a rigid translucent tube. A 90 cm high tube is recommended for your oak seedling (fig.3). These shelters not only exclude browsers and some insects but also stimulate height growth as well. When the seedling grows to the top of the protector, open up the cage or remove the protector so the seedling can continue to grow. You are now well on your way to establishing a Garry oak tree.

Insect Pests

Two insects, the jumping gall wasp and the oak leaf phylloxeran, are currently causing extensive scorching of the leaves on Garry oaks throughout the Greater Victoria area. Natural biological controls are expected to reduce jumping gall wasp populations to non-damaging levels. However, damaging populations of the oak leaf phylloxeran are expected to develop on about 10% of the seedlings after planting. Seedlings chronically infested with heavy phylloxeran populations are unlikely to survive since natural biological controls have been ineffective. These seedlings should be removed.

Although damage symptoms are similar, the two pests can easily be distinguished by examining the lower surface of effected leaves. The jumping gall wasp produces small 1-1.5 mm round galls resembling mustard seeds (fig.4). The oak leaf phylloxeran is a small (1 mm) orange aphid (fig.5).

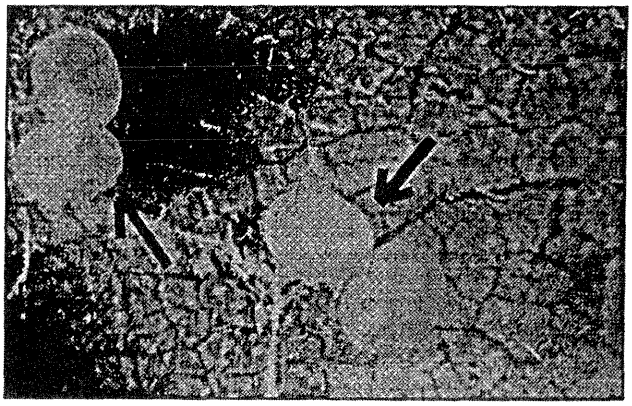

Figure 4 — Jumping gall wasp galls

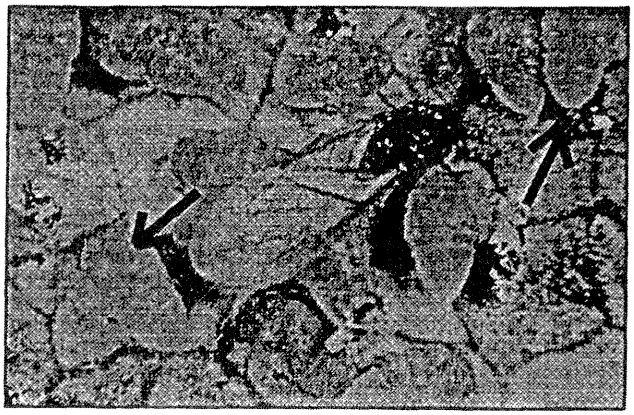

Figure 5 — Oak leaf phylloxeran

Canada

GROWING NATIVE PLANTS FOR MINE RECLAMATION[1]

Carol E. Jones[2]

Mine soils are often coarse textured materials with high coarse fragment content and low nutrient status. The same is often true for forest roads and landslides which require rehabilitation. Application of a fertilizer is typically used to initiate a nutrient pool in these disturbed soils. Legume species, such as clover or alfalfa which have rhizobial associations that fix atmospheric nitrogen are often seeded to improve the nitrogen content. At some sites a cover of these agronomic species may not be compatible with the end use objectives of forestry or wildlife habitat, and on these sites the establishment of woody native species is more desirable. Native species are selected for these sites based on their ability to improve the nutrient status of the soil and on their palatability to wildlife.

NITROGEN FIXATION

Actinorhizal perennial woody trees and shrubs can fix nitrogen and increase the soil nitrogen content. Various species of actinorhizal shrubs and trees are grown in western Canada for use in mine land reclamation. These species include *Alnus rubra* (Red alder), *Alnus crispa* spp. *sinuata* (Sitka alder), *Ceanothus velutinus* (snowbrush), *Elaeagnus commutata* (wolf-willow), and *Shepherdia canadensis* (buffaloberry). While these plants have the capability for association with a bacteria (*Frankia* spp.) and the potential to form root nodules this often does not occur in container grown nursery stock. A survey conducted of seven nurseries located in Alberta and British Columbia indicated that *Elaeagnus commutata* and *Shepherdia canadensis* seedlings did not become nodulated in their first year and that planting stock generally lacked nitrogen fixing ability (Danielson and Visser 1990). The conclusion of this survey supported our observation that container grown nursery stock of *Elaeagnus commutata* and *Shepherdia canadensis* were lacking *Frankia* nodulation. In monitoring programs conducted at various mine sites planted with these two species it was also our observation that the initial growth of these two species planted on reclaimed mine sites was poor. The soils at these mine sites, in addition to having low nutrient conditions, did not contain potential *Frankia* inoculum. Occasionally, a number of years subsequent to planting, the actinorhizal species would begin to grow rapidly and could be shown to have become nodulated. This was particularly noticeable with *Shepherdia canadensis* where the leaf colour would change to a dark green shade. This type of on-site nodulation must be due to inoculum from adjacent forest areas being transferred to the reclaim site.

To effectively use actinorhizal plants in land rehabilitation it is necessary to ensure that the seedlings were inoculated with the appropriate *Frankia* species before they were planted on the site. We experimented with collecting nodules from plants growing in natural forest sites and applying a slurry of the ground nodules to our nursery stock. The results from these initial experiments had limited success. We then contacted Mikro-Tek, a company in Ontario with experience in growing bacterial cultures of *Frankia* for the inoculation of *Alnus*. At that time they had not grown *Frankia* inoculum for either *Shepherdia* or *Elaeagnus* but believed they could provide us with a suitable culture. We collected nodulated roots from these species and sent them in coolers to their laboratory where they processed the nodules and initiated the cultures. The growth of these *Frankia* species were much slower than Mikro-Tek had experienced with other *Frankia* cultures, but with adjustments to their media they were able to successfully culture these bacteria. We also collected nodules from a northwestern British Columbia population of *Alnus crispa* spp. *sinuata* and were provided with a suitable culture for this stock.

We have experimented with the method and timing of application of the *Frankia* to the seedlings. With the first method the bacterial culture is mixed into the soil media at the time of seeding encapsulated in peat moss beads called Mikro-Beads. It is important to mix the appropriate number of Mikro-Beads in to the soil media to ensure that the bacteria are evenly distributed to each cavity and available to the young roots. In the second method the bacterial culture is directly watered onto the seedings. This method is relatively simple, the inoculum can be hand watered or can be introduced onto the overhead watering system. To utilize and overhead watering system it is important to remove and filters in the system which could trap the bacteria. We have applied the inoculum using hand watering in the spring as the seedlings are just starting to root, but plan to try a late summer treatment in 1998.

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[1]Jones, C.E. 1999. Growing native plants for mine reclamation. In: Landis, T.D.; Barnett, P.J., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 154-155.
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The Mikro-Bead method has the advantage of being able to store the product for a longer period of time over a wider range of temperature conditions. The liquid cultures are shipped in a growth media and must be shipped and stored in refrigerated conditions. Additionally, the liquid cultures must be applied quickly after reaching the nursery.

Our experience over the past few years suggests that the application of the inoculum in the liquid culture has been more successful than with Mikro-Beads. This year we want to try application of the inoculum in the late summer to determine if we can achieve a higher nodulation rate when the seedlings are not receiving high application rates of chemical fertilizers. In conditions of high amounts of nitrogen, the rate of nodulation is known to be reduced. Therefore we will try to apply the inoculum just prior to shipping the plants to the reclaim site for planting.

We intend to monitor the nodulation rate and growth characteristics of the actinorhizal shrubs grown in our nursery that have been planted in various mine reclamation projects. We expect that the successful inoculation of these species with appropriate *Frankia* species in the nursery will result in superior growth at the mine sites. In a field trial conducted on oil sands tailings, Visser and others (1991) reported that both *Elaeagnus* and *Shepherdia* had greater height growth, and produced heavier shoots and roots when inoculated with soil containing *Frankia* than did the uninoculated controls.

WILDLIFE HABITAT

Ungulates are the major wildlife resource in the vicinity of several mines in British Columbia. At the Fording River Coal mine in southeastern BC, elk (*Cervus elaphus nelsoni*) are the most abundant, although Big Horn Sheep (*Ovis canadensis canadensis*) are also year round residents. The availability of winter range is the limiting factor for the elk population, therefore research efforts have focused on providing good quality winter range through reclamation. Experiments began in 1985 to develop the technology necessary to rehabilitate suitable waste dump slopes to elk winter range. The physical conditions which are required to provide this habitat include steep high elevation slopes with south or southeast aspects. These sites characteristics result in challenging conditions for establishment of the required vegetation. A major component of elk winter range is the development of areas of woody plant species which provide important browse. Selected species include: *Prunus virginiana* (choke cherry), *Amelanchier alnifolia* (saskatoon), *Symphoricarpos albus* (common snowberry), *Ceanothus velutinus* (redstem ceanothus), *Populus tremuloides* (trembling aspen), *Elaeagnus commutata, Cornus sericea* (red-osier dogwood), *Acer glabrum* (Douglas maple), *Salix scouleriana* (Scouler's willow), *Shepherdia canadensis* (buffalo-berry), *Spiraea betulifolia* (birch-leaved spirea) and *Rosa acicularis* (prickly rose).

Results of initial experiments indicated that survival of browse species planted on these exposed slopes was very low, ranging from 0 to 58 percent, and that the same seedling stock planted on other less exposed areas of the mine site achieved much higher rates of survival. The greatest loss to survival usually occurs in the first year after planting and these losses are presumed to be due to two factors: the site exposure; and wildlife browsing.

Trials have been established to determine if plant protectors installed at the time of planting would improve shrub establishment and survival by providing additional shelter for the seedlings from the adverse climatic conditions and wildlife browsing. Plant protectors have been installed on fifty percent of the seedlings and various types of protectors have been tested.

The results to date indicate that the shrubs and trees in the protectors were generally in better condition than the unprotected ones: protected plants are larger and leafed out earlier in the spring. The majority of the unprotected deciduous shrubs were heavily browsed and some were uprooted by animals. The results of this trial will be used to determine the optimal type of plant protector, the best season for planting, and the appropriate combination of browse species. This trial has illustrated that valuable browse species can be established on these types of exposed sites and that the important native shrub component of the wildlife habitat can be developed.

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Visser, S.; Danielson, R.M.; Parkinson, D. 1991. Field performance of *Elaeagnus* commutata and *Shepherdia canadensis* (*Elaeagnaceae*) inoculated with soil containing Frankia and vesicular-arbuscular mycorrhizal fungi. Can. J. Bot. 69: 1321-1328.

COLLECTION, PROPAGATION AND USE OF NATIVE PLANTS[1]

Paulus Vrijmoed[2]

INTRODUCTION

Before we begin let us decide what we mean by native plants for the purpose of this presentation. By native plants we mean plants found growing naturally in a certain area. They include native perennials, shrubs and trees. These are the plants present in that area before other plants were introduced, intentionally or unintentionally, from elsewhere. These native plants evolved in their natural habitat over time, and they can be assumed to be the most optimum plants for the sites where they are found. Along with the plants evolving in their particular area other life forms have evolved with them, such as mammals, birds and insects, as well as more primitive life forms, including fungi and soil organisms which, together with non-living elements, form complex ecosystems.

Native plants have an important role to play in maintaining the diversity of ecosystems in the less disturbed outlying areas where forestry and agriculture dominate, as well as in the urban areas. In conclusion, we can say that native plants will always be an essential component of the landscape, both urban and non-urban, for reasons of biodiversity, as well for their aesthetic value.

PROPAGATIVE MATERIAL

Native plants have been used for habitat restoration and landscaping purposes in B.C. for at least the past two decades. Initially the common propagation method was to collect plants in their natural habitat and replant them in the desired location. In some instances, e.g. Ferns, the root systems would be divided, and the divisions potted up. This practice has led to the disappearance of a number of species from extensive areas. Some local species that come to mind are: Deer Fern: *Blechnum spicant*; Evergreen Huckleberry: *Vaccinium ovatum*; White Fawn Lily: *Erythronium oregonum*; Western Trillium: *Trillium ovatum.*

For obvious reasons the collection of plants is unacceptable. As a result the collection of native plants has been replaced, to a large extent, by plant propagation, although a substantial number of plants, e.g. Ferns and wetland species (for restoration purposes mainly) are still collected from the wild.

Two Main Methods of Propagation are Currently Being Used

a) seed, and
b) vegetative propagation by way of cuttings.

Additionally, tissue culture is used for some species, e.g. a selection of *Vaccinium ovatum*, i.e. 'Thunderbird'. In the case of native ferns, these can be propagated from spores.

Whether Seed or Cuttings are Used for Propagation Depends on

a) the destination of the resulting plant material, and
b) which one of the two methods is the easiest.

As to the Destination of the Plant Material a Distinction between Two Markets can be Made

a) The ornamental and/or landscape market.
Some of the users of native plants for this purpose attach a value to the uniformity, form, colour or size of the product. As a result selections of several native plant species have been made, which are maintained by way of vegetative propagation. The University of British Columbia Botanical Garden has, through its plant introduction scheme, released a number of native plant selections. Some are: *Arctostaphyllos uva-ursi* 'Vancouver Jade', *Ribes sanguineum* 'White Icicle', *Vaccinium ovatum* 'Thunderbird' and *Penstemon fruticosus* 'Purple Haze'.

b) The restoration or rehabilitation market, e.g. mine sites, utility corridors, forestry sites, wetlands. In this case, factors such as uniformity, size, etc. are not important; in fact plant selections are undesirable. The user will look for proper seed origin, i.e. geographic location, elevation, andbiogeoclimatic zone in an effort to maintain the genetic variation of the species and the suitability of the new crop to the planting site.

VEGETATIVE PROPAGATION

In order to maintain a cultivar or selection, with its "improvements", cuttings are taken from plants of the desired selection either in the landscape or from (stock) plants in the nursery. This is also done for species not easily grown from seed. Some of these are: Falsebox: *Pachistima myrsinites*; Willows: *Salix spp.*; Stonecrop: *Sedum spp.*; Twinflower: *Linnaea borealis*; Wild ginger: *Asarum caudatum*; Strawberries: *Fragaria spp.*; Poplars and Aspen: *Populus spp.*

In most cases softwood cuttings are taken, however, *Populus spp.* and *Salix spp.* are grown from hardwood cuttings. More research for the optimum timing when cuttings are to be to be taken needs to be done.

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[1]Vrijmoed, P. 1999. Collection, propagation and use of native plants. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 156-159.
[2]Corresponding Author: Linnaea Nurseries Limited, 3666 - 224th Street, Langley, British Columbia, Canada V2Z 2G7; TEL: 604/533-8281; FAX: 604/533-8246.

PROPAGATION FROM SEED

The majority of native plants are grown from seed. Seed is not easily available commercially, so seed has to be collected. As seed is not always produced reliably every year, it is a good idea to try to build a seed inventory large enough to cover at least a two year requirement.

Growers may collect their own seeds or they may use seed collectors. At Linnaea Nurseries Limited we collect seed crops that we can reach within one day; longer overnight trips are not economical. For this reason we contract out seed collections to contractors who cover other biogeoclimatic areas. This also allows us to obtain other species not available in our own collection area, and build up a seed inventory that includes the same species from different biogeoclimatic zones.

A Successful Seed Collector

- Knows the collection area well;
- has an inborn interest in plants growing in their natural environment;
- has a basic knowledge of seed and plant biology;
- is able to use field guides and identify plant species;
- has the time and ability to locate adequate seed crops, as well as to monitor seed development and maturity;
- knows when and how to collect seed, ship and store it; and
- properly records and labels any seed collected.

Types of Seed the Collector Encounters

- Seeds in fruits, containing from a single or several to many seeds, e.g. *Rosa spp., Amelanchier spp., Cornus spp., Vaccinium spp.;*
- dry seeds, e.g. in capsules containing a number of seeds like, *Menziesii ferruginea, Rhododendron spp.* or Achenes, a dry fruit containing a single seed, e.g. *the Asteraceae;* and
- in the case of many conifers, seed in cones.

Seed maturity is an important factor, which strongly influences the seed germination rate. Immature seed has a low germination rate or does not germinate at all. On the other hand, if the collector waits too long, the seed will often fall off the plant or will be eaten by birds. In many cases the "collection window" (occurs between the time when seeds reach the required maturity level for collection and when seeds are released and dispersed naturally) can be as short as a couple of days. Crop monitoring therefore is essential.

SEED MATURITY

Seed maturity can be evaluated in different ways and varies per species. Many berries turn from hard and green fruits to soft and to a colour indicating the stage of maturity, e.g. orange/red for rose hips, blue for *Mahonia* species, orange for *Cornus canadensis.* In the case of dry seed, seed heads or capsules will turn from green to brown.

Whenever feasible, before collecting berries, cones, capsules, etc., the seed containing structure should be opened, e.g. cut with a knife to check the presence and the number of seeds. If there is no seed present, or in the case of seed cones, if the seed count is very low a seed collection may not be worthwhile.

Other Criteria in Judging Seed Maturity

- Seed colour, usually brown if mature;
- hardness of seed, milky or soft seeds are immature. Mature seed is hard; cannot be squeezed, indicating a low seed moisture content; and
- embryo development; a mature embryo fills at least 90 percent of the embryo cavity. This requires cutting the seed with a sharp knife or one-sided razor blade. The embryo is usually cream to yellow in colour, while the seed storage tissue (megagametophyte) is white. An empty seed or a discoloured seed (often with a "woody" brown seed interior) indicates seed is not viable.

Mature berries and dry seeds are collected by hand in pails or plastic bags. Tree seeds require different methods. Mature cones can be picked off trees or collected form squirrel caches. In some cases, e.g. *Thuja plicata, Alnus spp.*, the collector can wait till seed is dispersed naturally, by shaking the branches and have the seed drop on a tarp below the tree.

Berries, seeds and cones in transit and temporary storage are to be kept cool, ideally, between 2- 4°C (35 - 39°F).

SEED PROCESSING

Upon arrival at the processing location, seed has to be checked for weight, quality, maturity and, in the case of dry seeds, for moisture content. Most dry seeds benefit from additional drying on trays or racks in a dry, well ventilated space. Often an unused, dry spot in the greenhouse works well. Berries should be processed as soon as possible. For most cases a simple food processor is adequate. Large commercial macerators and separators are available, but expensive (there are several European products costing in excess of CDN $10,000.00 each).

The berries are macerated (ground into a pulp), which takes from 25 seconds to 5 minutes per batch. If processed for too short a time pulp is not removed adequately. If processed too long seed may be damaged. Stop the processor regularly to check. Experience will do the rest. The pulp and the seed are separated in water. A 20 l. (5 gal.) pail works well. As a rule, the good, heavy (filled) seed sinks to the bottom, and the pulp and empty seeds are floated off. To prevent losing valuable seed, the water solution containing seeds and pulp is run through a strainer. Have several strainers with different mesh sizes at hand. Floating seeds must be checked (cut with a knife) regularly to ensure that not too many filled seeds are floated off with the pulp. The pulp has to be checked for the presence of seed and may have to be re-processed. Most of the debris can be floated off, and seed purities of approximately 90 - 95 percent upon completion of processing are quite common.

After processing the seed needs to be dried back. This can be done on fine mesh wire or cloth screens, which are easy to construct. The same screens can be used to screen off most of the remaining debris from the dry seed. Screens with different mesh sizes will be required. Seed that is to be sown or stratified shortly after processing can be dried back to between 10 and 30 percent moisture content. Seed that will go into (long term) storage must be below 10 percent moisture content. Either a dry stove or lots of experience will be needed to determine moisture content. Store seed in air-tight containers, or 4 mil plastic bags at approximately 2°C (35-36°F). For long term storage (2 -10 years) ensure moisture content is below 8 percent for freezer storage at -5/10°C (20°/15°F). Some (often non-hardy coastal) species do not store well at below freezing temperatures.

RECORDS

Records are an essential tool in quality and inventory control. Records are to include the following information: name (and address) of collector, botanical species name, collection location, collection date, seedlot number, weight of seed before processing, weight of seed after processing and drying, filled seed count, seed purity in percentage, number of seeds per dry weight unit (e.g. gram, ounce, etc.), yield of seed per weight or volume unit of collected seed before processing and storage location (e.g. box number, shelf number).

With this information you build up a data base on collectors, collection areas, yield comparisons between collection years and locations, sowing rates, costing, invoicing, etc. A computer is a helpful tool for record keeping!

SEED STRATIFICATION

At Linnaea Nurseries two methods of stratification are used:

- natural stratification; mostly in propagation trays filled with peat moss or some other soil medium; and
- artificial stratification; in cooler at approx. 2°C (35 - 36°F).

Where we have found no advantage in natural stratification we stratify seed in plastic bags in the cooler, e.g. *Arctostaphyllos uva-ursi, Cornus canadensis, Amelanchier alnifolia, Shepherdia canadensis.*

Standard procedure: a 24 - 48 hour soak in running water, drain seed, mix with moist peat moss and store in plastic bag in cooler for the required duration for the species. Stratification development can be monitored by taking e.g. 25 seeds out of the bag followed by a germination test during the final stages of the stratification period.

For natural stratification seed is sown in late summer or early fall for species requiring warm/cold stratification, e.g. *Mahonia spp., Acer spp., Symphoricarpus albus.* Many species are sown in October and November. Many native perennials are sown in early spring.

Seed flats are either left outside without protection (woody species) or in the case of small seeded species with thin seed coats and some perennials, in an unheated shelter house.

Seed scarification, e.g. using acid, crushing, grinding, etc. are rarely used at Linnaea Nurseries.

Seed germination timing can be influenced somewhat by bringing seed flats into a heated greenhouse either earlier or later (e.g. between February and April). If in doubt whether stratification is satisfactory, carry out a germination test before moving seed flats into the warm greenhouse.

Stratified seed can be sown just before germination or seed can be allowed to germinate in seed flats and be transplanted into the desired container type.

Generally, growing media should be well drained, using fairly coarse peat moss in combination with perlite, pumice and sometimes some sand. Being aware of the natural growing conditions of native plants is helpful in selecting the growing media and growing regime, i.e. water, fertilizer and shade requirements.

Once the native plant seedling is established you will find that the growing requirements are similar to the non-native crops, and the same rule applies: the grower's footsteps are the best fertilizer.

USE OF NATIVE PLANTS

We have touched on some of the uses for native plants. One of the oldest uses, and often not thought of as such, is in growing seedlings for reforestation purposes. Almost all seedlings planted in logged areas are native conifer species. More recently, native shrub and non-woody species are used for de-activation of logging roads, landings, etc., as well as slope stabilization, erosion control, streambed restoration, etc.

Public pressure has led to legislated measures and a general preparedness to repair the damage to the landscape from forestry, mining, gas pipelines and urbanization. Although the methods used by some environmental groups may sometimes be questionable, it is largely thanks to their pressure that the public has become aware of environmental issues and a new environmental ethic has come about. This has led to an increased interest in end use of native plants which has provided new opportunities to the nursery industry. Furthermore, initiatives such as Greenways, Naturescape and recently the establishment of the BCNPS, British Columbia Native Plant Society are reinforcing awareness and use of native plants in the (urban) landscape, including their use in the garden.

It is my belief that native plants have a continuing role to play in maintaining a healthy environment, and for that reason we at Linnaea Nurseries are prepared to identify and fill the needs created by this new reality.

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Business Meetings

Southern, Northeastern, and Combined

Southern Forest Nursery Association Conference Agenda
Lafayette Hilton and Towers, 1521 Pinhook Road
Lafayette, Louisiana

July 13, 1998

4:00 PM - 5:30 PM	Nursery Technical Committee Meeting (to plan next conference)
6:00 PM - 7:30 PM	Registration (Portico Foyer - Fourth floor)
7:00 PM - 9:00 PM	Reception (with cash bar) (Salons ABC)

July 14, 1998

6:00 AM	Breakfast Buffet (Salons C&F)
7:00 AM	Registration (Portico Foyer-Fourth floor)
	General Sessions (Salons A&B)
8:00 AM	Orientation to Conference: Paul Frey, State Forester, Louisiana Department of Agriculture and Forestry
8:30 AM	Orientation to Acadiana: Chamber of Commerce
8:45 AM	Use of Digital Recorders During Seedling Storage: Dean McCraw, Rayonier, Glennville, GA
9:15 AM	Current Reforestation Demands on Southern Nurseries: Clark Lantz, Retired Nursery/Tree Improvement Specialist, USFS
9:45 AM	Break (Salons)
10:15 AM	5 Year Overview of WRP Seedling Needs: Jim Emfinger, Ducks Unlimited Project Leader, Jackson, MS
10:45 AM	Hardwood Seed Availability - A Wildlife Biologist Viewpoint: Ray Aycock, US Fish & Wildlife Service
11:15 AM	Pine Seed Production Orchards: Tom Byram, Texas A&M
11:45 AM	Lunch - Recognition of Retirees (Salons C&F)
1:15 PM	**Concurrent Breakout Sessions**
	Session A: Hardwood Discussions (Salon A) Session B: Pine Discussions (Salon B)
3:15 PM	Break (Salons D&E)
3:45 PM	**Concurrent Breakout Sessions**
	Session A: Hardwood Discussions (Salon A) Session B: Pine Discussions (Salon B)

Concurrent Breakout Sessions

Session A (Salon A)

1:15 PM	Hardwood Seed Production: John Delaney
1:45 PM	Hardwood Seedling Production: Randy Rentz
2:15 PM	Southern Appalachian Oak Programs: Tom Tibbs
2:45 PM	The Effects of Stock-type, Mineral Fertilizer, & Mycorrhizal Inoculation Treatments on the Early Field Survival & Growth of Bottomland Hardwood Seedlings: Hans M. Williams
3:15 PM	Break (Salons D & E)
3:45 PM	Hardwood Containerized System: John McRae
4:15 PM	Effect of Chloropicrin & Herbicides on Purple Nut Sedge: Bill Carey
4:45 PM	Containerized Loblolly: Harry Vanderveer
5:15 PM	Adjourn

Session B (Salon B)

1:15 PM	Contamination of Seed by Pitch Canker Fungus: Dave Dwinell
1:45 PM	Longleaf Pine Seed Sowing Treatments - Effect on Nursery Establishment: Jim Barnett/Bill Pickens/Bob Karrfalt
2:15 PM	Effects of Spring vs Fall Sowing of Longleaf on Field Performance: Chuck Fore/Jim Barnett
2:45 PM	Cold Hardiness Evaluation in Southern Nurseries: Mary Ann Sword/Dick Tinus
3:15 PM	Break (Salons D & E)
3:45 PM	Utilization of Jiffy Pellets in the Production of Pine & Eucalypt Seedlings, Pine Rooted Cuttings & Native Species Propagation: Jeff A. Wright
4:15 PM	N Levels & Top Pruning Affect Nursery Development & Early Field Performance in Longleaf Pine Seedlings: Paul Kormanik
4:45 PM	Physiological Quality of Pine Reduced by Heavy Rainfall Just Prior to Lifting: David South
5:15 PM	Adjourn

July 15, 1998

6:00 AM	Breakfast Buffet (Salons C&F)
7:00 AM	Depart by Bus for Beauregard Nursery, DeRidder, LA
9:00 AM	Tour of Beauregard Nursery
10:30 AM	Depart by Bus for Louisiana Forest Seed Company, LeCompte, LA
12:00 PM	Catered Lunch - Louisiana State Forest at Indian Creek
1:30 PM	Tour of Louisiana Forest Seed Company
3:00 PM	Return to Lafayette
5:30 PM	Depart by Bus for Cajun Dinner & Dance (Fais-do-do)

July 16, 1998

6:00 AM	Breakfast Buffet (Vermilion Ballroom)
	General Sessions (Salons B&C)
8:00 AM	Herbicide Labeling: Ken McNabb, AUFTN Coop, Director, Auburn University
8:45 AM	Methyl Bromide Status: Hendrix and Dail
9:30 AM	Alternatives to Methyl Bromide: Bill Cary, AUFTN Coop, Pest Management, Auburn University
10:15 AM	Break (Salons D&E)
10:45 AM	Organic Soil Amendments as a Control for Rhizoctonia: Rod Hendrick, LA Cooperative Extension Service, LA State University
11:15 AM	Business Meeting
12:00 PM	Adjourn

SOUTHERN FOREST NURSERY ASSOCIATION
BUSINESS MINUTES OF THE JULY 16, 1998, MEETING

The annual business meeting of the Southern Forest Nursery Association (SFNA) was called to order at 11:30 on Thursday, July 16, 1998 by Charlie Matherne, host for this year's meeting.

There were three items of new business:

ADOPTION OF NEW BYLAWS

Charlie Matherne took the lead in drafting a new set of bylaws for the SFNA. During the past year, Tom Landis sent a copy of the bylaws for the Western Forest and Conservation Nursery Association to Charlie and Clark Lantz. With the help of the Louisiana Department of Agriculture and Forestry (LDAF) legal department, Charlie had new bylaws drafted. At this meeting, Charlie presented the proposed bylaws to the SFNA technical committee (Jim Barnett, Tom Landis, Clark Lantz, Ken Woody, Charlie Matherne, Ken McNab, and David South). A few changes were made by the committee to establish a Board of Directors, and then the bylaws were unanimously accepted by the committee. Two of the key points were that voting membership will be made up of all conference attendees, and that SFNA meetings will be held biannually on even-numbered years.

The new bylaws were presented to the general membership. A motion was made by Tom Landis to accept the changes in the bylaws, and the motion was seconded by Leonard Bosch. The motion was passed.

ARTICLES OF INCORPORATION

At last year's business meeting, Charlie noted that the SFNA was subject to liability because they were not incorporated. The host nursery could be held liable for any personal injury or property damages during the annual meeting. Again, with the assistance of the LDAF legal department, Charlie had articles of Incorporation drafted to incorporate the SFNA as a nonprofit cooperation for the Parish of East Baton Rouge in the State of Louisiana. Key points are that the Board of Directors and membership will be defined in the bylaws, and membership dues are paid through the registration fee for attending the annual SFNA conference.

At the business meeting, Tom Landis made a motion to incorporate, and the motion was seconded by Jim Barnett. The motion passed.

MEETING FOR THE YEAR 2,000

Charlie Matherne made a motion to nominate John Rice, Alabama Forestry Commission, as the new chairman of the SFNA. Leonard Bosch seconded the motion, and John Rice was elected unanimously as the new chairman, and the host of the 2000 Conference.

There being no addition business, the meeting was adjourned.

Northeastern Forest Nursery Association Conference Agenda
July 27-30, 1998
Annapolis, Maryland

July 27, 1998

2:00 - 6:00 PM	Registration at Wyndham Hotel lobby
6:00 - 8:00 PM	Reception

July 28, 1998

7:00 - 8:00 AM	Registration in lobby
8:00 - 8:15	Welcome and opening remarks James Mallow, State Forester
8:15 - 9:00	Reforestation In Maryland, The Need For Trees Steve Koehn, Associate Director, Forest Service
9:00 - 9:45	Building John S. Ayton State Tree Nursery John S. Ayton, Nursery Manager, Retired
9:45 - 10:15	Using Contract Labor and Prison Labor Dwight Stallard, Virginia Dept. of Forestry
10:15 - 10:30	Break
10:30 - 11:15	Migrant and Seasonal Ag Workers Protection Act Jim Kessler, Wage Hour Investigator, U.S. Department of Labor
11:15 - 12:00	Working with Migrant Labor John Shallman, Immigration and Naturalization Service
12:00 - 1:00	Lunch (provided)
1:00 - 1:30	State Nursery Perspectives Ron Overton, U.S. Forest Service
1:30 - 2:00	National Nursery Perspectives Tom Landis, U.S. Forest Service, National Nursery Specialist
2:00 - 2:45	IR4 Minor Crop Pest Management Program Ray Frank, Research Horticulturist
2:45 - 3:00	Break
3:00 - 3:45	Drip Irrigation for Seedbeds Ray Pisarkiewicz, Plastic Piping Systems
3:45 - 4:30	Nursery Business Meeting
5:30 - 8:00	Crab Feast at Sandy Point State Park Scales and Tales Program: The Good, the Bad and the Ugly

July 29, 1998

8:00 - 9:30	Load Buses, Travel to Ayton State Tree Nursery
9:30 - 12:30	Tour Nursery Equipment demos (combine, seed extraction, etc.) Herbicide plots
12:30 - 1:20	Bag lunch at nursery
1:20 - 2:00	Travel to Environmental Concern, St. Michaels, Md.
2:00 - 3:00	Tour Environmental Concern
3:00 - 4:15	Load Buses, Return to Annapolis
6:00 PM	Banquet at Hotel

July 30, 1998

8:30 - 9:15	Methyl Bromide vs. Basamid Allan Iskra, U.S. Forest Service
9:15 - 9:45	Methyl Bromide Update and Alternatives Hendrix and Dail
9:45 - 10:30	Using Organics in Nursery Production K. Marc Teffeau, Cooperative Ext. Service, Commercial Horticulture
10:30 - 10:45	Break
10:45 - 12:00	Various Packaging Methods Nurserymens Panel

Adjourn

NORTHEASTERN FOREST NURSERY ASSOCIATION CONFERENCE MINUTES OF THE JULY 28, 1998, MEETING

On July 28, 1998, the following persons were present at the Wyndham Garden Hotel in Annapolis, Maryland for the Annual Meeting of the Northeastern State, Federal and Provincial Nursery Association:

Dan DeHart	Martin Cubanski
Chuck Bathrick	Calvin Gatch
Dave McCurdy	Jason Huffman
Dave Lee	Fred Rice
Roger Underchat	John Solan
Jerry Grebasch	Ron Walter
Jim Bailey	Alex Day
Don Westefer	Greg Hoss
Bob Karrfalt	Jim Storandt
Gordy Christians	Willard Dilley
Susan Pontoriero	Mike Carroll
Tom Landis	Ron Overton

The meeting was called to order by Chairman Carroll at 3:45 PM. The minutes of the August 13, 1997, meeting at Bemidji, Minnesota were presented. On a motion by Jerry Grebasch, second by John Solan and approval of all members present, the 1997 minutes were accepted.

Chuck Bathrick was appointed to review the Association's financial records for the past year. Chuck reported the books to be in order. On a motion by Chuck Bathrick, second by Jerry Grebasch and approval of the members present, the Treasurers Report was approved as presented. The balance as of June 30, 1998, was $7,066.12.

OLD BUSINESS

Mike Carroll discussed responses to his letter to all members suggesting we show support for USDA-Forest Service public nursery programs by contacting our State Foresters and using them to convey support through the State Foresters Association. For example Mike, was he was in support of he USDA-Forest Service, State and Private Forestry, continuing to organize and hold Regional Planning Teams. Several members mentioned they had contacted their State Foresters and done such a thing.

There was some limited discussion that our organization should hold our meetings before the State Foresters Association meeting in early July. This would give all members a chance to have input into formulating issues to present the State Foresters Association. Mike's letter was an attempt to have input before this meeting.

Jerry Grebasch suggested we should attempt to invite the Chairman of the Forest Resources subcommittee of the State Foresters Association to our meetings. Mike Carroll stated he would invite this person to our next meeting in Iowa. Greg Hoss, Missouri, was tasked to find out who the Chairman of the Forest Resources subcommittee is and get this information to Mike so be can draft a letter.

Ron Overton expressed concern that USDA-Forest Service, State and Private Forestry will be combined with Forest Stewardship and in the process, funding expressly for State and Private nursery work will be lost. Mike Carroll will draft a letter from the Association to address the Federal funding issue.

Discussion then centered on training needs for Nursery Managers. The group compiled the following list of proposed training relevant to Nursery Management:

- updates and training on riparian species propagation;
- hardwood propagation techniques (Alex Day, Pennsylvania);
- propagation, seed collection and handling of hardwood and riparian species; and
- training on how to do trials for IR4 pesticide certification (Trent Marty, Wisconsin).

John Solan reported that plaques will be presented to Dick Johnson and Bill Yoder. John also stated that he needed more plaques. The current plaque which is black walnut that is laser engraved would cost $32.50 each and that we would need to purchase at least 10. On a motion by Horvath, second by Grebasch, and approval of all members present, John Solan was approved to purchase 10 more plaques to present to individuals that have left the nursery profession. Mike Carroll suggested that Miles Wiggens also deserved a plaque.

John Solan posed the question of changing the name of the Association; removing the "Provincial" from our name as we have had no contact with Canada for past several years. Fred Rice thought this action might close the door to all Canadian input. Dave McCurdy was in favor of leaving name as is. Richard Garrett stated he thought the private sector was turned off by State, Federal and Provincial title. Richard thought the Southern Association had better turnout with private sector involved. Ron Overton mentioned that the NE area was the only sector left with this type of name.

Jim Storandt then made the motion to change the Associations name to the "Northeast Area Forest Nursery Association", Jerry Grebasch seconded this motion. Tom Landis called to amend the motion, to amend the name to the Northeastern Forest and Conservation Nursery Association. Horvath checked the by-laws and a name change would require a mail ballot of all members. Horvath would put this together sometime before the Iowa meeting.

NEW BUSINESS

Mike Carroll asked the question, 'What to do about Canadian counterparts"? Horvath stated he needed current information on names and contacts of Canadian Nursery Specialists. Tom Landis will provide some of this information to Horvath.

Calvin Gatch asked about nursery catalogs from each state. Ron Overton stated if people will send the catalogs to him, he will collate this information and send it out to individuals in the Association who are interested. Ron stated some of this information was on Web Sites and could be accessed through the web. Those nurseries that weren't on the web yet would send a catalog by just giving them a phone call.

Upcoming meetings were discussed. The following schedule for the meetings was approved:

Iowa 1999
Wisconsin 2000
Pennsylvania 2001
Illinois 2002

Discussion then centered around IR4 pesticide certification issue. Jerry Grebasch made a motion that a subcommittee be appointed to investigate hardwood and shrub IR4 pesticide certification. This motion was seconded by Jim Storandt. On this motion, a yes vote was cast by all members present. Mike Carroll appointed the following people to this subcommittee: Richard Garrett-Chairman, Jerry Grebasch, David Horvath, and Marty Cubanski.

Focus Funding was discussed, proposals for Focus Funding projected needed to be coordinated by states and submitted through and supported by State Foresters. Current "themes" for Focus Funding projects was stewardship issues.

Bob Karrfalt asked the question "is the association incorporated"? The answer was no. Bob suggested the Association consider incorporating to limit liability. Dave McCurdy made the motion to allow the executive committee to pursue incorporation. This motion was seconded by Ron Overton and approved by all members present. Dave Horvath was to get information on this issue.

ELECTIONS

The election committee of John Sloan/Jim Storandt nominated the following slate of candidates:

2 year Nursery Manager - Bob Hawkins
1 year Nursery Manager - Alex Day

A motion to close the nominations and cast an unanimous ballot for the above candidates was made by Horvath, seconded by Jim Storandt, and approved by all members present. The following is the list of officers for the next year. Chairman and Vice Chairman are in the second year of a two year term.

Chairman	Mike Carroll Badoura State Nursery R.R 2, Box 210 Akeley, Minnesota 56433 218-652-2385
Vice Chairman	Chuck Bathrick Zanesville State Nursery 5880 Memory Road Zanesville, Ohio 43701 614-453-9472
1 year Nursery Manager	Alex Day PA. Dept. of conservation and Nat. Resources P.O. Box 8552 Harrisburg, Pennsylvania 17105-8552 8l4-787-4777
2 year Nursery Manager	Bob Hawkins Valonia Nursery 2782 W. 540S Valonia, Indiana 47281 812-358-3621

A motion to adjourn the meeting was made by Mike Carroll, seconded by Jim Storandt. With approval of all members present, the meeting was adjourned at 4:55PM.

Combined Forest Nursery Association of British Columbia/ Western Forest and Conservation Nursery Association Agenda Dunsmuir Lodge, Victoria, British Columbia, Canada August 10-13, 1998

August 10, 1998

6:00 - 9:00PM	Registration/ Exhibit Viewing

August 11, 1998

7:00 AM	Breakfast
8:30 AM	Welcome and opening comments Ev van Eerden, FNABC President
8:45 AM	Welcome by Linda Michaluk, Mayor of North Saanich

Today and the Future

Moderator - Ev van Eerden - 9:00- 11:10 AM

9:00 AM	West Coast Forest Industry Perspective Bill Dumont, Chief Forester, Western Forest Products
9:50 AM	Coffee Break
10:20 AM	Forest Nursery Industry, Now and the Future Jim Bryan, Weyerhaeuser Co.
10:45 AM	Status Report of the Mexico City Metropolitan Area Reforestation Project Dr. Tom Starkey, International Forest Company, Alabama, Carbon Sequestation Project Mexico

Moderator - Al McDonald - 11:10- 12:20 PM

11:10 AM	Carbon Sequestation Pilot Projects in BC Warren Bell, Ministry of Environment, BC
11:30 AM	Sister Nurseries Raul Moreno, Microseed, Ridgefield, WA Tom Landis, National Nursery Specialist, Portland, OR
12:00 PM	Forest Nursery Alliance of Canada Dr. Irwin Smith, Ececutive Director, Lustr Co-op, Thunder Bay, ON
12:20 PM	Lunch at Dunsmuir Lodge
1:30 PM	Travel to Arbutus Grove Nursery Tour of nursery
2:45 PM	Visit to Forest Museum
6:00 PM	Barbecue at the Forest Museum

August 12, 1998

6:30 AM	Breakfast at Dunsmuir Lodge

Container Nursery

Moderator - Rob Bowden- Green - 8:00 AM to 9:45 AM

8:00 AM	Current Trends in Nutrition in Container Seedlings Eric van Steenis, Ministry of Forests, BC
8:35 AM	Fertilizer Technology Andrew Schenk, Scotts Company
9:10 AM	Seedling Standards & Need for Them Drew Brazier, Ministry of Forests, BC
9:45 AM	Coffee Break

Vegetative Production

Moderator - Patti Kagawa - 10:15 AM to 12:00 PM

10:15 AM	Use of Vegetative Propagules in Reforestation in BC Bev Wigmore, FRBC Project
10:35 AM	Growing Spruce Somatic Seedlings Don Summers, Ministry of Forests, BC
10:55 AM	Somatic Spruce Seedlings - Field Results Dr. Chris Hawkins, University of Northern BC, Prince George, BC
11:20 AM	Eucalypt Propagation: Nursery Development and Management in Hawaii Jeanine Lum, Forest Solutions, Hawaii
11:40 AM	Vegetative Propagation of Aspen, Narrow Leaf Cottonwood, and Riparian Trees and Shrubs. David R. Dreesen, USDA, New Mexico
12:00 PM	Lunch at Dunsmsuir Lodge

Moderator - Rod Massey - 1:00 PM to 2:45 PM

1:00 PM	Informal Presentations (Presenters have 10 minutes maximum and must register in advance) Limitation, maximum 9 speakers
3:00 PM	Travel to Butchart's Gardens
5:30 PM	Return to Hotel
6:00 PM	No Host Bar
7:00 PM	Banquet at Dunsmuir Lodge Chief Forester's Awards

August 13, 1998

6:30 AM	Breakfast at Dunsmuir Lodge

Seedling Health
Moderator - Barry Kasdorf - 8:00 AM to 9:45 AM

8:00 AM	Forest Nursery Pest Management in BC Dave Trotter, Ministry of Forests, BC
8:30 AM	Biological Control of Pests in Forest Nurseries Con Elliot, Applied Bionomics, Victoria, BC

Innovation in Nursery Operations

9:00 AM	Best Management - Horticulture Nurseries Dave Woodske, Provincial Nursery Specialist, Ministry of Agriculture, Abbotsford, BC
9:20 AM	Container Harvesting Mechanization Jim Kusisto, Manager, Skimikin Nursery, Ministry of Forests, BC Garry DeBoer, Riverside Nursery, Armstrong, BC
9:45 AM	Coffee Break

What's Up with Native Plants
Moderator - John Kitchen - 10:15 AM to 12:00 PM

10:15 AM	Native Plant Propagation at Pacific Forestry Centre Rob Hagel, Pacific Forestry Centre, Victoria, BC
10:35 AM	Growing Native Plants for Mine Reclamation Carole Jones, C.E. Jones & Associates, Victoria, BC
10:55 AM	Native Plants in the Styroblock System Dan Enns, Landing Nursery, Vernon, BC
11:15 AM	Role of Riparian Planting in the Salmon River Watershed Restoration Project Mike Wallis, Biologist, Salmon River Round Table, Salmon Arm, BC
11:35 AM	Native Plant Production at Linnaea Nurseries Paulus Vrijmoed, Linnaea Nurseries Ltd., Langley, BC
11:55 PM	Closing of Joint Conference Ev van Eerden, FNABC President
12:10 PM	FNABC Business Meeting

Combined Forest Nursery Association of British Columbia/ Western Forest and Conservation Nursery Association Business Meeting Minutes August 13, 1998

The 1998 Business Meeting of the Forest Nursery Association of British Columbia (FNABC) was called to order at 12:15 on August 13, 1998, by Meeting Chair Ev van Eerden.

FINANCIAL REPORT

Treasurer Allan McDonald reported that the FNABC has $17,000 on hand with an estimated additional $5,000 still to come for the 1997 meeting. The proceedings of the 1995, 1996, and 1997 meetings will be printed by the 1997 committee. The expected proceeds from the 1998 meeting is expected to net $3-4,000.

Report accepted as presented.

NEW RESOLUTIONS

A call for new resolutions was entertained by Chair Drew Brazier

Resolution:
That the FNABC donate $1,000 in American funds to the sister project of Raul Moreno and Tom Landis from the funds currently on hand in the FNABC account. Moved by Gary Castonguay and Bevin Wigmore. Motion - Carried.

Resolution:
That the organizing committee of the 1999 FNABC meeting be authorized to award a $500 bursary to a student and report the details to the recipient at the 1999 business meeting of the FNABC. Moved by Shon Ostafew and Dave Trotter - Carried.

OTHER NEW BUSINESS

Irwin Smith of Lustre requested that the survey of the Forest Nursery Alliance of Canada be completed by all nurseries.

Anne Johnson-Flanagan indicated the need for research donations and the ability to lever these funds four-fold and more.

Ev van Eerden voiced the concern about the reductions in funding from the provincial government and the need to write a letter to indicate these concerns. He indicated that he would do this as outgoing president.

Dave Trotter will be the 1999 president of the FNABC and the meeting will be held in the lower mainland.

Minutes Submitted by Drew Brazier.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1999-765-018/00003

Landis, T.D.; Barnett, J.P. tech. coords. 1999. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station; 192 p.

This proceedings is a compilation of 43 papers that were presented at the 3 regional nursery meetings in 1998. The Southern Forest Nursery Association Conference was held in Lafayette, LA, on July 13-16; the Northeastern Forest Nursery Association Conference was held in Annapolis, MD, on July 27-30; and the Combined Forest Nursery Association of British Columbia/Western Forest and Conservation Nursery Association meeting was held on August 10-13 in Victoria, BC, Canada. The subject matter ranged from seed collection and processing—through nursery cultural practices—to harvesting, storage, and outplanting.

Keywords: Bareroot seedlings, container seedlings, nursery practices, reforestation.